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Assessing the Utility and Costs of Statewide Travel Demand Models

Requested by:

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Chapter 1. Introduction

The goal of this research is to assess the expected cost and utility that can be expected to accrue from developing or upgrading a statewide travel demand model. Statewide travel models are computer simulations of the transportation system within a state that can be used to forecast the change in traffic conditions that would result from infrastructure or policy changes. Most states operate statewide models. Among those that do, there is a considerable range of model types and uses.

The core audience for this report will be technical or planning staff at state transportation agencies who must make a recommendation on whether and how to engage in statewide modeling at their agency. To make a recommendation, those individuals need to specify a budget request both in terms of external costs (consultants and materials) and in terms of staff time. They also need to be able to, at a minimum, articulate, and preferably quantify, the value they expect to achieve by pursuing the proposed approach.

This research quantifies the costs of statewide models, and both identifies and quantifies the benefits of statewide models in a range of situations. It does so using a novel approach that combines data on the revealed outcomes of existing statewide models, with the collective professional judgment of statewide modelers.

This report serves as a complement to the recently published NCHRP Synthesis 514: Statewide and Megaregional Travel Forecasting Models: Freight and Passenger (Donnelly & Moeckel, 2016). Note that this report is referred to in the appendices as NCHRP 20-05 Topic 47-17 based on its draft title. Readers are referred to NCHRP Synthesis 514 for a more detailed review of the methods and data currently used in practice, as well as new and emerging opportunities. Whereas NCHRP Synthesis 514 goes into the “How?” of statewide modeling, this research focuses on the questions of “Why?” and “How much?” That is, it considers the rationale for when it is or is not a smart decision to invest in developing or upgrading a statewide travel model.

The findings in this report are based on a series of structured interviews with statewide modelers and transportation planners. In total, representatives from 29 state Departments of Transportation (DOTs) and 5 consulting firms participated.

The interviews are structured around a series of 9 hypothetical scenarios, as summarized in Table 1. The scenarios span two dimensions: model development options and policy focus. The model development options recognize that developing a statewide model is not a binary choice, and that states that currently have a relatively simple model are still faced with the choice of whether it is worth upgrading that model. The policy focus dimension recognizes that the value derived from a model is likely to depend on the types of policies that the DOT is interested in. Together, they are intended to span a sufficient range of scenarios such that readers of this report can reasonably identify with one of them. This report is intended to help readers at state DOTs select a model development option based on the policy focus area most closely aligned with their DOT.

Table 1 Interview Scenarios

		Model Development Options		
		M1	M2	M3
		Start from: No Model	*Start from:* Basic 3-step model	*Start from:* Enhanced 4-step model
Policy Focus		*Upgrade to:* Basic 3-step model with transferred model parameters, static truck trip tables.	*Upgrade to:* Enhanced 4-Step Model with estimated parameters, National Long-Distance Model, FAF-based commodity flows model, NHTS add-on sample.	*Upgrade to:* Activity-based model with estimated parameters, custom long-distance travel model, policy-sensitive freight model, custom travel surveys.
P1	Rural highways: Primary need is to evaluate highway projects outside urban areas.	Scenario P1-M1	Scenario P1-M2	Scenario P1-M3
P2	Congestion & multi-modal: Also a need to evaluate projects in urban areas, transit projects, truck projects and/or rail/intermodal projects.	Scenario P2-M1	Scenario P2-M2	Scenario P2-M3
P3	Policy, pricing & environment: A need to test broader policy or global scenarios, such as congestion pricing, demand management, growth scenarios, demographic changes, environment, equity and connected & autonomous vehicles.	Scenario P3-M1	Scenario P3-M2	Scenario P3-M3

The remainder of this report covers the following topics:

- Chapter 2 describes the methodology used in this research in more detail, including how the scenarios were presented to the interviewees, and other data that were collected.

- Chapter 3 presents the results of an effort to categorize existing statewide modeling practice based on the scenarios described above. For a reader identifying with a particular scenario, this categorization provides a list of states in a similar situation—a useful resource for those who wish to call and discuss the matter with their peers.
- Chapter 4 describes the use of statewide models as policy analysis tools, covering the types of policies considered by different states, and the respondents' assessment of the effectiveness of their statewide models for evaluating those policies.
- Chapter 5 examines the cost of statewide models in more detail. The cost assessment considers both what states reported they actually spent, and detailed budget estimates for each model development scenario.
- Chapter 6 presents evidence on the estimated value of statewide models, based on the responses to a willingness-to-pay exercise conducted during the interview.
- As part of this effort, the interviews solicited advice from statewide modelers and planners. Chapter 7 reports several themes that emerged during the interviews, and provides broader discussion around the results as they relate to effective ways of implementing a statewide modeling program.

Several appendices are included with more detailed information. These include a detailed literature review and a "cheat sheet" that were distributed to participants prior to the interviews, the interview questionnaire itself, the list of participants, a worksheet and process for developing customized cost estimates from these data, and advice given by the respondents.

Chapter 2. Methodology

This section describes the key challenges in trying to meet the project objectives, and the methods used to do so.

2.1 Key Challenges

The strongest form of evidence about the costs and utility of statewide models is based on the revealed outcomes of existing models. However, revealed outcome evidence in this situation is inherently limited due to the moderate number of states with relevant experience and high variation in situations across the states. Further, the benefits are qualitative in nature, so there is a challenge in how to quantify qualitative information.

This limitation is highlighted by past attempts to quantify the costs of travel models. The range of costs reported in NCHRP Synthesis 358 (Horowitz, 2006) and NCHRP Synthesis 514 (Donnelly & Moeckel, 2016) indicates that it is difficult to pinpoint an expected cost for developing a statewide model. This outcome is consistent with our Principal Investigator's own experience attempting to specify the costs of advanced travel models for NCHRP Synthesis 406 (Donnelly, Erhardt, Moeckel, & Davidson, 2010). In interviewing agencies who had developed advanced models, we found that some agencies were reluctant or unable to specify the full model development cost, and many cautioned against attempts to generalize their own experience. This was for a few reasons. Consulting and other external costs were typically well documented, but these varied based on the level of staff time dedicated to the project, which was often more difficult to track precisely. Agencies that were at the cutting edge of developing new methods spent more, but the costs were expected to be lower for subsequent projects. In addition, the methods, extent of data collection, size of the agency, and planning needs varied such that for a limited number of agencies it was difficult to identify a "typical" experience. The same can be expected to be true for statewide models.

While it is somewhat easier to ask agencies to list the benefits they have achieved from their statewide models, there is a risk of that process being reduced to a box-checking exercise. More valuable is information about the value or importance of those benefits, and how that importance relates to the specific planning needs of state transportation agencies. For example, a mostly rural state with a strong policy focus on transportation system preservation may face a very different set of planning issues than a fast-growing urban state with major congestion challenges. Likewise, a state with a long history of statewide modeling may have institutional relationships that allow a broader set of benefits than a state looking to develop a new statewide model may be able to achieve. Here again, the issue of a limited number of "similar" states arises.

To meet these challenges, this research used a structured approach for combining revealed outcome evidence with stated evidence on expectation to pay and willingness to pay.

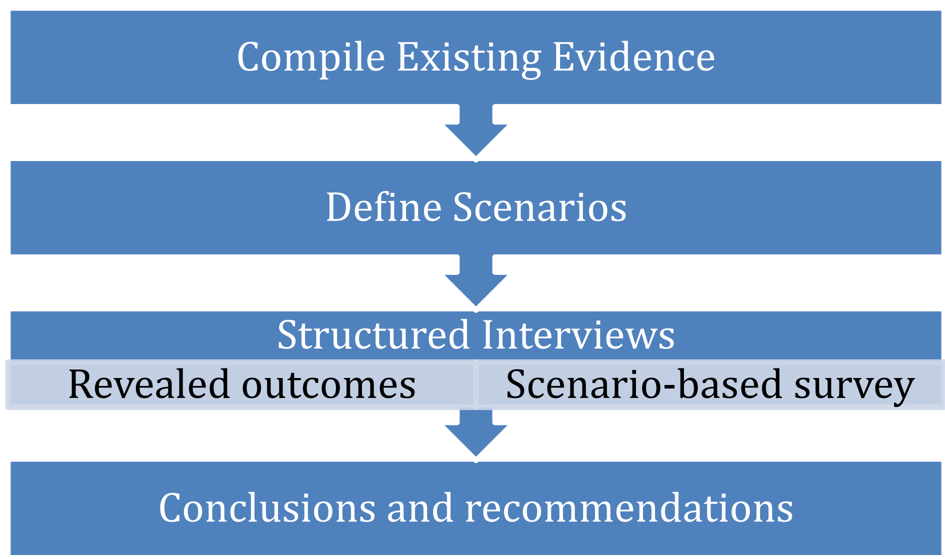
2.2 A Structured Approach for Evidence-Based Decisions

As noted above, the strongest basis for understanding the costs and benefits of an approach is the revealed outcomes of past implementations. However, such evidence may be sparse due to the limited number of implementing agencies and the variation in their situations. Therefore, we propose a structured method for combining revealed outcome evidence with the collective judgment of the statewide modelling community.

This particular challenge is not unique to travel forecasting, with a good analogy existing in health care. Doctors are often faced with a situation where they must make a decision about the appropriate method of treatment for patients in cases where evidence from randomized clinical trials is limited or inconclusive. The standard approach used to provide guidance in such situations is the RAND-UCLA Appropriateness Method (Fitch et al., 2001). The method combines available research with the expert judgment of a panel of doctors. It does this by distributing a literature review of existing evidence to the panelists, along with a definition of all terms, then asking them to rate the appropriateness of treatment methods for different clinical indications. The data are used to classify treatment methods based on their level of appropriateness, with the outcomes qualified as uncertain when there is general disagreement among the panelists, and this information is used to develop guidelines for appropriate treatment methods.

Using the RAND-UCLA Appropriateness Method as inspiration, this research follows the process outlined in Figure 1.

Figure 1 Research Methodology



It begins by compiling existing evidence, focusing on current revealed outcomes. This includes both a broad literature review, and the recent survey of practice that was completed as part of NCHRP Synthesis 514. This existing evidence provides a basis for understanding the range of models currently in use, the range of applications, and the range of costs.

The research team used that compilation to define a set of scenarios based on a qualitative identification of common themes and clusters of practice. These scenarios are intended to cover a reasonable range of practice in three dimensions: policy focus, model type and state size. The scenarios serve to consolidate the results such that they are not viewed as entirely dependent upon the specific situation of each state.

Both the compilation of existing evidence and the scenarios feed into a series of structured interviews with statewide modelers or planners at DOTs, and with selected consultants who have statewide modeling experience. The interviews focused on two areas. First, they served to fill gaps in the revealed outcomes. This was important because the feedback we got from the authors of NCHRP Synthesis 514 was that there was nuance to the responses that was difficult to capture in a written questionnaire, and could be best captured through a telephone or face-to-face conversation. It is based on this feedback that the current study opted for an all-interview approach to fill remaining gaps on our understanding of the revealed outcomes.

The second focus of the interviews was to conduct a scenario-based survey. In this portion of the interview, respondents are not asked what they did, but rather what they would do in the given scenario. This allows for multiple responses for each of the nine scenarios (segmented by two state sizes), providing for a larger sample of responses. It also establishes all costs in the current year, which is important because the level-of-effort required to develop a statewide model is substantially different now than it was 10 years ago given advances in software, methods, and new data sources. Finally, the scenarios allow us to explore the value of statewide models using a willingness-to-pay exercise that is similar to a stated preference survey.

Prior to the interviews, respondents were provided with the compilation of existing evidence, in the form of a literature review (Appendix A), and a "cheat sheet" (Appendix B). This allowed respondents to begin with a common understanding of the state of the practice, and draw from that understanding in answering the questions.

The results of both the revealed outcome questions, and the scenario-based survey were used to develop the conclusions and recommendations presented in this report.

2.3 Compilation of Existing Evidence

The compilation of existing evidence included a literature review and an information for interviewees documented, which is referred to as the "cheat sheet". Both documents are included in the appendices, and are not repeated here. They were distributed to the interviewees when the interview was scheduled, about two weeks ahead of time. This allowed the interviewees to become familiar with the content beforehand, which was especially useful for respondents who were not especially familiar with what other states had been doing, or with some of the types of models considered in the interview. Most reported that they skimmed the material, but did not peruse it.

The literature review (Appendix A) covers past synthesis both from a content perspective and a methods perspective, and also provides a summary of the current state of statewide modeling.

The "cheat sheet" is derived mostly from the data collected as part of NCHRP Synthesis 514. It begins with an overview of what to expect during the interview. It then provides an initial classification of statewide models by model type, policy focus and state size. Part of the interview involved reviewing this classification for each state, with the updated classification reported in Chapter 3. It then presents cost data as reported in the past to syntheses on statewide models, with those costs segmented by the classifications. These costs provided a benchmark that respondents could refer to when estimating costs for the scenarios. Finally, the "cheat sheet" provides fact sheets on four topics referenced during the interviews: activity-based models, transferrable parameters, the national long-distance travel model (NLDTM), and the freight analysis framework (FAF). These cheat sheets help ensure that the respondents are knowledgeable about the topics covered, and can respond appropriately.

2.4 Scenarios

The interviews were composed of three parts:

- Part 1: About You and Your Agency: Respondents were asked a series of questions about the agency that they represent.
- Part 2: Scenarios: Estimating Costs: In this section, respondents were asked to imagine that they have the ability to influence the selection of technical resources for planning. They were given a series of three model upgrade scenarios and asked to develop a budget estimate for doing so.
- Part 3: Scenarios: Go/No-Go Decisions: Again, respondents were asked to imagine that they have influence over the selection of modeling and technical resources. They were given a series of scenarios in which they must recommend a go/no-go decision for whether this new DOT should proceed with a statewide modeling project at the cost specified. This section included a total of nine scenarios, which vary based on the policies to be analyzed and on the type of model considered.

The scenarios associated with parts 2 and three are described below.

2.4.1 Cost Estimating Scenarios

In addition to asking how much they spend on statewide modeling in part 1 of the interview, we changed the framing of the question in part 2 and asked how much the respondent would budget for a specific model development or upgrade. There are a few reasons for this:

1. It gives us a way to get a range of cost estimates for a similar modeling approach, effectively increasing our sample size.

2. It establishes the cost in the present, recognizing that it may be easier to develop a travel model now than it was 10 years ago with access to new data sets, better software, and more developed methods.
3. It is the question we actually want to answer.

We asked respondents to estimate the costs for three scenarios.

1. Starting from no statewide model, and implementing a Basic 3-Step Model.
2. Starting from a Basic 3-Step Model, and upgrading it to an Enhanced 4-Step Model.
3. Starting from an Enhanced 4-Step Model, and upgrading it to an Activity-Based Model.

Table 2 summarizes the features included in each model development scenario. While we label the scenarios as Basic 3-Step Model, Enhanced 4-Step Model and Activity-Based models for convenience, each represents a package of model improvements and data collection that go beyond the basic model structure. For example, the increment from a Basic 3-Step Model to an Enhanced 4-Step Model includes the addition of a freight and long-distance model, which are of greater significance for most statewide models than whether or not it has a mode choice model. The scenarios are broken out into components such that readers of this report can mix-and-match the features in different columns and still obtain a reasonable cost estimate. Further details about the working assumptions for each of the scenarios were provided to the respondents, and discussed in further detail in Chapter 5, such that those descriptions are adjacent to the associated cost estimates.

Table 2 Model Development Scenarios

Attributes\Model scenarios	**Basic 3-Step Model**	**Enhanced 4-Step Model**	**Activity-Based Model**
Networks & TAZs	Highway networks, TAZ system, socio-economic data	Highway networks, TAZ system, socio-economic data, urban transit networks, intercity air, rail & bus networks	Highway networks, TAZ system, socio-economic data, urban transit networks, intercity air, rail & bus networks, freight intermodal network
Baseline Data	Traffic Counts	Traffic Counts, Base IE/EI/EE trip tables from GPS or cell phone data	Traffic Counts, Full base trip tables from GPS or cell phone data
Survey Data	None	NHTS Add-On Sample	Custom Travel Surveys
Passenger Travel	Basic 3-step model (no-mode choice) with parameters from NCHRP 735 and NCHRP 716	4-step model with estimated model parameters	Activity-based model with estimated model parameters. Uses population synthesizer.
Long-Distance Passenger Travel	No explicit long-distance model	Adapted National Long-Distance Model	Develop custom long-distance travel model
Freight Transportation	Static truck trip table	Commodity flows adapted from FAF with truck flows assigned to network	Policy-sensitive freight model with non-Truck freight modes
Overall Classification	Basic 3-Step Model	Enhanced 4-Step Model	Activity-Based Model

The scenarios are incremental, meaning that when the option to develop an Enhanced 4-Step Model is given, the respondents are told to assume that they currently have a Basic 3-Step Model in place. This affects the cost estimates primarily in the effort involved to develop networks and TAZs.

Using the first scenario as an example, the basic setup given to the respondents was as follows.

> Imagine that you have left your current position to start a new job as the manager of planning analysis at a DOT for a <large/small> state. This DOT does not currently have a statewide model, and instead uses time-series methods, such as growth factors, when projecting demand for highway projects. Your supervisor, the Director of Planning, has asked you to consider developing a statewide model. You have been asked to provide costing broken out into several categories, as listed in the tables below.

This new DOT is envisioned at a state that is similar in size to the state they recently left, considered to be a 'peer' agency. The framing of peer agencies allows us to later segment the responses by state size, without requiring the respondents to answer twice as many questions. The setup goes on to describe the specific attributes of the envisioned model and associated data collection.

For each model component, we asked respondents to specify both a dollar amount for the costs of external contractors or consultants and the number of person-hours of in-house staff time you expect to dedicate to the effort. In the results presented later in this report, person-years of in-house staff were converted to a dollar amount assuming a person work 2000 hours per year at a fully-loaded rate of $100 per hour. This assumption was selected as a reasonable average rate for travel model consulting services, thus creating an equivalency between doing the work in-house and contracting it out. The rate for DOT staff is probably less—a lead modeler making $100,000 per year with 50% overhead (benefits, office space, administrative time, etc.) would cost about $75 per hour. Therefore, there is potential for significant cost savings from what is reported here for work done in-house if that work is within the staff's areas of expertise.

The precise details of the scenarios and the associated setup can be found in the interview questionnaire, which is included as Appendix C of this report.

2.4.2 Go/No-Go Decision Scenarios

The second exercise asked respondents for their recommendations on whether it would make sense to proceed with the statewide model development or upgrade projects described, at a given price point. The goal was to quantify their "willingness to pay" for statewide models and implicitly the value they see in these models.

The questions were set up in the form of a contingent valuation question (Bateman, 2001; Mitchell & Carson, 1989), in which respondents were told how much a state DOT would have to pay to develop or upgrade the statewide model, under a given policy focus area and the model development option for a hypothetical state. They are then asked to make go/no-go decisions. We asked them to define their responses as follows:

- Go – they believe that the value of the model capabilities exceeds the cost specified, and the DOT should proceed with the model development/upgrade project.
- No-go – they believe that the value of the model capabilities does not exceed the cost specified, and the DOT should maintain the status quo.

Within each of the scenarios, we varied the cost from the starting estimate to understand the limits of their recommendation. The cost estimates were expressed in terms of "ten-year cost per capita".

In pre-testing these questions, initially we presented the costs in absolute terms (X dollars over ten years) rather than ten-year cost per capita. However, we found that presenting the cost in absolute terms caused respondents to anchor their responses strongly to how much reasonable consultancy fees “should be”, instead of the how much the model capabilities are worth. Thus, we revised the interview protocol to reframe the questions in ten-year cost per capita terms. While during many of the interviews respondents often convert the ten-year cost per capita to absolute terms based on the population of their states, this one level of abstraction served to help to respondents to decouple their willingness to pay with the consultancy fees, and make the focus on value added, better information and informing policymaking more prominent in their considerations.

Since ten-year cost per capita is not a commonly used unit, we made sure to provide some background on what a ten-year cost per capita means in practice, so in the interview script we included a short explanation to put ten-year cost per capita in the context of the total spending on transportation infrastructure, as follows.

> For reference, 10-year spending on transportation infrastructure in the US exceeded $1 trillion from 2001 through 2010, for an average cost of $3,300 per person. Most of that money flowed through the state DOTs. A DOT that spent $0.33 per capita on statewide modeling over that period would have spent about 0.01% of the transportation infrastructure cost.

The per capita framing ensures that the value scales with state size. For example, the exact same model in a large state and a small state should have more benefit in the large state because there are more people served, a larger DOT budget, etc.

This section included nine scenarios, which varied by the model development options, as described above, and the policy focus area.

Table 3 summarizes the policy focus areas, with the rows indicating specific policies that may be of interest to the DOT, and the columns showing the overall classification. The policy focus areas build upon each other, meaning that the Congestion and Multi-Modal also includes an interest in Rural Highways, and the Policy, Pricing and Environment focus includes all policies of interest.

Table 3 Summary of Policy Focus Areas

	Rural Highways	Congestion & Multi-Modal	Policy, Pricing and Environment
Highway forecasts outside urban areas	X	X	X
Highway forecasts in urban areas		X	X
Transit projects		X	X
Evaluating walk and bike mode shares		X	X
Truck-only lanes, truck climbing lanes and truck passing lanes		X	X
Freight rail & intermodal freight projects		X	X
Pricing scenarios (tolls, gas prices, transit fares, congestion pricing)			X
Travel demand management			X
Alternative growth scenarios			X
Effects of changing demographics (aging population, immigration, etc.)			X
Air quality, greenhouse gas and environmental analysis			X
Equity analysis & environmental justice			X
Transportation & health			X

The policy focus areas are described as follows:

- Rural Highways. The DOT is primarily involved in evaluating highway projects outside the states urban areas. It is expected that the MPO models would be used within the urban areas.
- Congestion & Multi-Modal. The state is still interested in evaluating rural highway projects, but is also involved in evaluating projects where congestion is a major issue, or where non-car modes are of particular importance. A statewide model may be used to provide consistent estimates throughout the state, including in the urban areas, or it might be used for specific projects such as evaluating freight inter-modal facilities, truck-only lanes, or bicycle and pedestrian issues.
- Policy, Pricing & Environment. DOT analysts may be involved in all of the above projects (including rural highway projects, congestion related projects and multi-modal projects), but also be asked to evaluate broad policy issues, such as alternative growth scenarios, pricing studies, or the effects of changing demographics.

For the willingness-to-pay exercises, respondents are given a specific policy focus, and a model development option. For example, the state has a rural highways policy focus, and is considering upgrading from a Basic 3-Step Model to an Enhanced 4-Step Model. Is it worth spending X per person over the next 10 years to upgrade the statewide model? The starting cost is based on the average amount spent on statewide modeling over the past 10 years for that type of model. If the respondent makes a Go decision, then the interviewer repeatedly increases the cost until the point that the respondent answers with a No-Go decision. If the respondent makes a No-Go decision to start, then the interviewer repeatedly decreases the cost until the point that the respondent answers with a Go decision. The respondent is given the option to specify a more precise limit between the last two costs.

The maximum willingness-to-pay is taken as the judged value of having the additional modeling capabilities in place. It was sometimes challenging in this exercise to get the respondents to move beyond the anchor point of what they expect it to cost. The logic was along the lines of, "If I expect it to cost $500,000, then I might be willing to go up to $700,000, but beyond that, I'm getting a bad deal from the consultant, and I'm not willing to stomach that." Because the question of the value of the model is different than the question of getting a good price on its development, the interviewers pushed the respondents to consider that it is based on the value of the DOT having the additional modeling capability in terms of its effect on the planning process. Nonetheless, our sense from the interviews is that willingness-to-pay remains somewhat anchored to the expected costs, and therefore may represent more of a lower bound on the value of a model than a mean estimate.

The interview questionnaire in Appendix C documents the details of the scenarios as presented in the interviews.

2.5 Structured Interviews

Interviews were conducted with representatives of 29 DOTs and 5 consultants. Respondents were selected as individuals with experience in statewide modeling. For DOTs that do not operate a statewide model, the most relevant individual in planning or technical analysis in the DOT was interviewed. If the state does not have a statewide model, respondents were asked an abbreviated set of questions from Part 1 of the interview. The consultants were also asked an abbreviated set of questions from Part 1, because they were not in a position to answer on behalf of a DOT. All individuals could answer the scenarios, though. Appendix D shows the full list of participants, whom we thank for their generosity with their time.

The interviews followed the questionnaire included in Appendix C. They were conducted via a web conference, such that the interviewers and interviewees were connected via audio and video (at least when the respondent had a webcam). The web conferencing software allowed us to display the questionnaire on a shared screen such that the respondents could see the questions in writing. They could also see our notetaking in real time, providing them an opportunity to correct as we typed.

With only a few exceptions, each interview included two members of the research team. One served as the lead interviewer, and a second served as the notetaker. This structure allowed the lead interviewer to more actively engage with the respondents.

Interviews were scheduled for two hours, although they sometimes ran longer. It tended to take more time if there was more than one respondent from the same organization involved. In those cases, the respondents tended to discuss among themselves to reach consensus before answering. A single answer was recorded per organization.

One DOT chose to respond in writing. In that instance, we held a short conference call to explain the process and the scenarios before the DOT responded.

The interviewer notes were used to compile the data presented in this report. These included both quantitative responses (costs, willingness-to-pay, etc.) and qualitative responses to broader questions. The interviews were also recorded through the web conference software, but we found the written notes to be sufficiently detailed such that it was not necessary to refer back to the audio recordings. Both the notes and the audio recordings are being held in archive by the researchers. They will continue to be archived for at least 6 months beyond the publication of the final report, but will not be published.

Chapter 3. Classification of Existing Statewide Modeling Practice

The variation in policy applications and modeling approaches for different states poses a challenge to this research. If our findings are too specific to individual circumstances, they may not apply to other states. However, if our findings are so general as to apply universally, we may lose important distinctions. Therefore, we are aiming to achieve some balance between these two objectives by grouping statewide modeling practice in three dimensions:

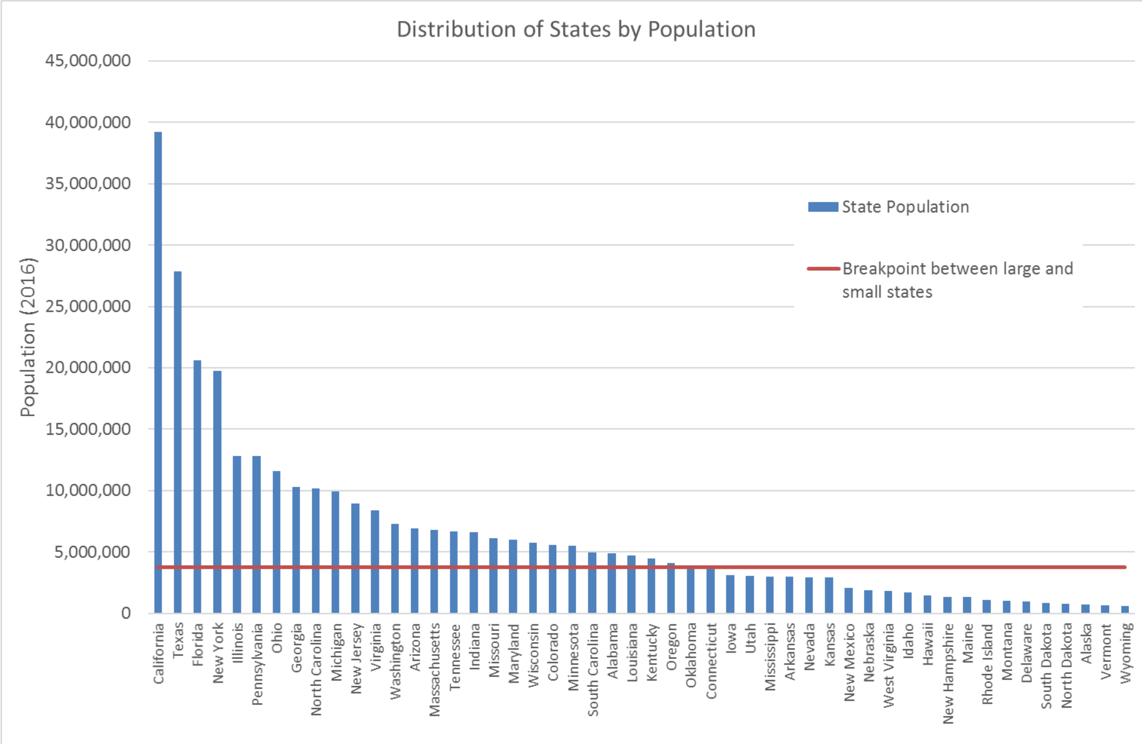
1. State Size
    a. Small state
    b. Large state
2. Model Type
    a. Basic 3-step model
    b. Enhanced 4-step model
    c. Activity-based model
3. Policy Focus
    a. Rural highways theme
    b. Congestion & multi-modal theme
    c. Policy, pricing & environment theme

The remainder of this section defines these categories in more detail, and shows how the states fit within each category. The classification was initially developed by the research team based on the responses to NCHRP Synthesis 514. These draft classifications were included in the cheat sheet (Appendix B), and updated by each state during the interviews. For states that were not interviewed, the tables below show values from the initial assessment.

3.1 State Size

For this exercise, a large state is defined as one with a population of 3.75 million or more. This definition gives 28 large states, with Oklahoma being the smallest large state, and 22 small states with Connecticut being the largest. Figure 2 shows the breakpoint and the allocation of states into large and small categories by population. Respondents did not answer questions for both small and large states—they were directed to assume that the scenarios apply to a state that is similar in size to their own, with the DOT considered to be a "peer agency". Consultants were directed to assume that the scenarios applied to a medium sized state.

Figure 2 Classification of States by Size



3.2 Model Type

We expected that both the cost and utility of a statewide model would depend on the specific features of that model. Therefore, we grouped each statewide model into one of three categories, labeled as: a Basic 3-Step Model; an Enhanced 4-Step Model; or an Activity-Based Model (ABM). Because the possible variation in features is more complex than the names implies, additional features of each group were considered.

Table 2 (in Chapter 2) summarizes the key features of each model type.

What we have titled a Basic 3-Step Model could be considered an 'entry-level' statewide model. It has basic functionality, and it is responsive to changes in TAZ data and highway networks. It does not include any custom data collection, other than some traffic counts. It does not have any special purpose models, such as an explicit long-distance travel model. The parameters are transferred based on recommendations in NCHRP 735: Long Distance and Rural Travel Transferable Parameters for Statewide Travel Forecasting Models (Schiffer, 2012) and NCHRP 716: Travel Demand Forecasting: Parameters and Techniques (Cambridge Systematics, Inc. et al., 2012).

The second group, titled Enhanced 4-Step Model, is a trip-based model with a greater degree of customization. We assume it to include urban transit networks and a mode choice model, and have an internal-external and external-external trip table as input that could be derived from an OD survey, or from mobile phone data. The coefficients may be estimated from an NHTS add-on sample or from another travel survey. It may have an explicit long-distance travel model and a commodity flow model that assigns trucks to the highway network.

The third group is an Activity-Based Travel Model (ABM), and broadly reflects a high degree of customization. It would operate using a using a synthetic population (rather than providing the number of households in a zone, segmented by socioeconomic characteristics, a synthetic population provides information for every household separately), and reflect trip-chaining behavior. Model parameters are estimated from travel surveys. It includes an explicit long-distance travel model, and a detailed freight model that considers intermodal freight movements.

During the interview, respondents were asked to select which of the three columns in

Table 2 is closest to their actual practice for each row. There was usually some mixing between columns indicting that the choice of model is not a trinary choice, but more customizable. Respondents were also asked to select which overall classification they think best fits their model, and to consider the overall range of features in doing so. Therefore, the results show cases such as an Enhanced 4-Step Model that does not have a mode-choice step, but holistically is aligned with the level of sophistication indicated by the features in the Enhanced 4-Step Model column.

In several cases, a state was operating a statewide model in one form, and developing an updated model. In these cases, the respondents were given the choice to answer for one model or the other. Respondents based this decision on how far along the development process they were. If the updated model was almost done, the costs and associated features were fresh in their minds and they could effectively answer the questions. If the development project was in its early stages, they generally answered based on their existing model.

Table 4 shows the responses to this model classification exercise. The results show that 8 Basic 3-Step Models, 17 Enhanced 4-Step Models, 6 Activity-Based Models, and 4 models that are somewhere between the Basic 3-Step and Enhanced 4-Step model. There was significant variation the specific components that are included, as shown in the table.

Table 4 Model Type Classification

State	Model Attributes: Networks & TAZs	Baseline Data	Survey Data	Passenger Travel	Long-Distance Passenger Travel	Freight Transport.	Overall Classification
Alabama	1	1	1	1	1	2	**1**
Alaska*	No Survey Response						
Arizona	1	1	2	1	2	2	**1**
Arkansas	1	1	1	1	2	2	**2**
California*	2	2	3	3	1	3	**3**
Colorado	2	2	3	3	1	3	**3**
Connecticut	2	1	3	2	1	1	**2**
Delaware*	No Survey Response						
Florida	2	3	3	2	1	2	**2**
Georgia	2	2	2	2	2	2	**2**
Hawaii*	No Model						
Idaho*	2	1	3	3	3	3	**3**
Illinois*	No Model						
Indiana*	2	1	2	2	1	2	**2**
Iowa	2	2	2	2	2	2	**2**
Kansas	2	2	1	2	3	2	**2**
Kentucky	1	2	2	1	2	2	**2**
Louisiana*	2	1	2	1	1	3	**2**
Maine	1	2	1	2	2	2	**2**
Maryland*	1	1	2	3	3	3	**3**
Massachusetts*	2	2	3	2	1	1	**2**
Michigan	1	1	3	1	1	2	**2**
Minnesota	No Model						
Mississippi	1	2	1	1	3	2	**1**
Missouri*	No Model						
Montana*	No Model						
Nebraska	1	1	1	2	1	1	**1**
Nevada	1	1	1	1	1	2	**1**
New Hampshire*	2	1	3	2	1	1	**2**
New Jersey*	No Survey Response						
New Mexico	1	1	1	1	1	2	**1**
New York*	No Model						
North Carolina	1	1	2	2	3	2	**2**
North Dakota	1	1	3	1	1	2	**2**
Ohio	2	1	3	3	3	3	**3**
Oklahoma*	No Model						
Oregon	2	1	3	3	3	3	**3**
Pennsylvania*	No Survey Response						
Rhode Island	2	2	2	2	1	1	**2**
South Carolina	1	1	2	1	1	3	**1**
South Dakota	No Model						
Tennessee*	No Survey Response						
Texas	2	1	2	2	3	3	**2**
Utah*	2	1	3	2	3	3	**2**
Vermont	1	1	2	2	3	1	**1**
Virginia	2	2	2	2	2	2	**2**
Washington	No Model						
West Virginia*	No Model						
Wisconsin*	2	1	2	2	3	3	**2**
Wyoming	1	1	3	1	1	3	1
Classification Codes	1-Hwy only	1-Counts only	1-None	1-3 step with transferred parameters	1-None	1-Static trip table	**1-Basic trip based model**
	2-Hwy & transit	2-Counts & GPS or cell phone data	2-NHTS add-on	2-4 step with estimated parameters	2-Adapted national LDT model	2-Commodity flows from FAF	**2-Enhanced 4 step model**
			3-Custom survey	3-Activity based	3-Custom LDT model	3-Policy sensitive freight model	**3-Activity based model**

* State was not interviewed. Category based on previous data.

3.3 Policy Focus

The types of policies analyzed affect the value of a statewide model. To better understand the issues of importance to DOTs, whether they use a model to analyze those issues or not, respondents were asked whether each policy topic listed in

Table 3 (included in Chapter 2) was of interest to the agency. Further, they were asked if the policy was a priority to the agency.

Table 5 shows the responses to these questions. A 0 indicates that the policy is not of interest. A 1 indicates that it is of interest, but not a priority, and a 2 indicates that it is a priority. The results indicate that testing rural highway scenarios is a priority for almost all DOTs, that testing urban highway scenarios is a priority for most DOTs, and that the level of interest is more variable for many of the remaining policies. Table 5 also shows the overall policy focus classification, as judged by the respondents. For states that were not interviewed, this reflects the authors' assessment based on the responses to previous surveys.

Table 5 Policy Focus Classification

State	Type of Scenario (0-Not used; 1-Used; 2-Priority)													Overall Classification
	Rural Highways	Urban Highways	Transit	Walk & Bike	Trucks	Freight & Inter-modal	Pricing	Travel Demand Mgmt	Growth scenarios	Changing Demo-graphics	Air & Environ-ment	Equity	Connected & autono-mous vehicles	
Alabama	2	1	0	0	1	1	1	0	0	0	0	0	0	1-Rural Highways
Alaska	No Survey Response													
Arizona	2	1	2	0	1	2	2	2	1	2	2	2	1	3-Policy, Pricing & Environment
Arkansas	2	2	0	0	2	1	2	0	2	1	0	0	1	1-Rural Highways
California	2	2	1	0	1	1	2	0	1	0	0	0	0	2-Congestion & Multi-modal
Colorado	1	2	1	1	1	1	1	1	1	1	2	1	2	3-Policy, Pricing & Environment
Connecticut	1	2	2	1	0	2	2	1	1	0	2	2	1	2-Congestion & Multi-modal
Delaware	No Survey Response													
Florida	2	2	2	2	1	2	2	1	2	2	1	2	2	3-Policy, Pricing & Environment
Georgia	2	0	0	1	2	2	2	1	2	1	2	1	1	3-Policy, Pricing & Environment
Hawaii	No Model													
Idaho	2	2	0	0	0	0	0	0	0	0	0	0	0	1-Rural Highways
Illinois	No Model													
Indiana	2	2	0	0	1	0	1	0	1	0	0	0	0	3-Policy, Pricing & Environment
Iowa	2	1	1	0	2	2	2	1	1	1	0	1	2	3-Policy, Pricing & Environment
Kansas	1	2	1	1	1	2	2	1	1	1	1	1	1	2-Congestion & Multi-modal
Kentucky	2	1	0	2	2	1	1	0	1	0	1	1	1	2-Congestion & Multi-modal
Louisiana	2	2	0	0	0	0	0	0	0	0	0	0	0	1-Rural Highways
Maine	2	1	1	1	1	1	1	1	1	1	1	1	1	1-Rural Highways
Maryland	2	2	1	0	1	0	1	0	2	0	0	0	0	3-Policy, Pricing & Environment
Massachusetts	0	0	0	0	0	0	0	0	0	0	0	0	0	1-Rural Highways
Michigan	2	2	2	2	0	2	2	1	2	2	2	2	2	3-Policy, Pricing & Environment
Minnesota	2	2	1	1	0	1	2	1	0	1	1	1	1	1-Rural Highways
Mississippi	2	2	1	1	1	1	1	0	2	1	1	2	2	3-Policy, Pricing & Environment
Missouri	No Model													
Montana	No Model													
Nebraska	2	1	0	0	0	0	0	0	0	0	1	0	0	1-Rural Highways
Nevada	1	2	1	1	1	1	1	2	2	1	2	1	1	3-Policy, Pricing & Environment
New Hampshire	0	0	0	0	0	0	0	0	0	0	0	0	0	1-Rural Highways
New Jersey	No Survey Response													
New Mexico	2	1	1	1	2	1	1	1	2	2	1	0	1	1-Rural Highways
New York	No Model													
North Carolina	2	2	2	1	1	2	2	2	2	1	2	2	1	3-Policy, Pricing & Environment
North Dakota	2	1	1	0	1	1	0	0	1	1	0	0	0	1-Rural Highways
Ohio	2	0	1	0	1	1	2	0	0	0	0	1	0	3-Policy, Pricing & Environment
Oklahoma	No Model													
Oregon	1	2	1	1	1	2	2	1	1	1	2	1	1	3-Policy, Pricing & Environment
Pennsylvania	No Survey Response													
Rhode Island	1	2	2	2	2	2	2	1	2	2	2	2	2	3-Policy, Pricing & Environment
South Carolina	2	2	0	1	1	2	0	1	0	0	1	1	0	2-Congestion & Multi-modal
South Dakota	2	1	1	0	0	1	0	1	1	1	0	1	1	1-Rural Highways
Tennessee	No Survey Response													
Texas	1	1	0	0	0	1	1	0	1	0	0	0	0	3-Policy, Pricing & Environment
Utah	2	2	0	0	0	0	0	0	1	0	0	0	0	3-Policy, Pricing & Environment
Vermont	2	2	1	1	1	1	0	1	1	1	2	1	0	1-Rural Highways
Virginia	2	0	0	0	2	2	1	0	0	0	0	0	0	2-Congestion & Multi-modal
Washington	1	2	2	2	1	1	2	2	2	2	2	1	1	3-Policy, Pricing & Environment
West Virginia	No Model													
Wisconsin	0	0	0	0	0	0	0	0	0	0	0	0	0	1-Rural Highways
Wyoming	2	1	0	1	1	1	0	0	2	0	1	0	0	1-Rural Highways

* State was not interviewed. Values based on past data or inference.

3.4 Overall Classification

Table 6 shows a combined view of how the states, their policy focus areas, and their models are grouped. This classification allows a means of identifying the closest peer agencies as they relate to specific scenarios. Respondents were asked to review this information during the interviews.

Table 6 Overall Classification

State Size	Policy Focus Area	Model Classification			
		No Model or No Response	Basic 3-Step Model	Enhanced 4-Step Model	Activity-Based Model
Population < 3,750,000	Rural Highways	*Alaska, Delaware, Hawaii, Montana*, South Dakota, *West Virginia,*	Maine, Nebraska, New Mexico, North Dakota, Vermont, Wyoming	Maine, North Dakota, Vermont, *New Hampshire*, Vermont	*Idaho*
	Congestion & Multi-Modal		Connecticut	Connecticut, Kansas	
	Policy, Pricing & Environment		Mississippi, Nevada	Iowa, Rhode Island, *Utah*	
Population >= 3,750,000	Rural Highways	*Illinois*, Minnesota, *Missouri, New York, New Jersey, Oklahoma, Pennsylvania, Tennessee,* Washington	Alabama	Arkansas, *Louisiana*, *Massachusetts*, Texas, *Wisconsin*	
	Congestion & Multi-Modal		South Carolina	Kentucky, Texas, Virginia	*California*
	Policy, Pricing & Environment		Arizona	Florida, *Indiana*, Georgia, Michigan, North Carolina, Texas	Colorado, *Maryland*, Ohio, Oregon

* States in *italics* were not interviewed directly for this project. States in *gray italics* also did not respond to the NCHRP Synthesis 514 survey.

Chapter 4. Statewide Models as Policy Analysis Tools

Statewide models are applied to evaluate whether an infrastructure or policy change would be effective if it were to be implemented in the real world. An important advantage to such evaluations is that they are cheap to conduct, relative to the cost of building infrastructure.

While evaluating road capacity projects is a classic use of travel models, and a classic focus of DOTs, modern DOTs often consider a broader range of policy alternatives. Applying a statewide model is one way to evaluate relevant policies, it is often not the only way. For example, it is possible to forecast road traffic by applying a statewide model, but it is also possible to do so by extrapolating historic traffic counts. Similarly, it might be possible to evaluate policies designed to serve pedestrians and bicyclists by applying an appropriately featured statewide model, or alternatively by conducting a literature review on the topic to consider research papers that have empirically evaluated similar projects elsewhere. Highway safety is one field where relatively robust before-and-after analyses are commonly used to inform the cost effectiveness of similar improvements in different areas.

It is useful to consider the range of uses for statewide models, how effective statewide models are at evaluating different types of policies, and how effective non-model alternatives may be at evaluating those same types of policies. This chapter presents the results of a series of interview questions aimed at addressing these topics.

4.1 Statewide Model Use

As reported in Chapter 3, this research asked respondents to consider a list of policies, and indicate whether those policies are of interest to the DOT, and if so, whether they are a priority. The results of that exercise were presented in Table 5.

For the same set of policies, the researchers also asked whether the DOT uses a statewide model to evaluate and inform policies of that type. This question was only asked of DOTs that indicated the policy is of interest. Table 7 presents the results of this line of inquiry. The table shows the percent of respondents who indicated each level of policy interest, and the right-most column shows the percentage of DOTs who indicated that the policy is of interest that use a statewide model to analyze that policy.

Table 7 Policy Interest and Statewide Model Use

	Policy Interest			**Percent Using a Statewide Model**
All Focuses	**0 - Not of interest**	**1-Of interest**	**2-A priority**	
Highway Forecasts Outside Urban Areas	0%	25%	75%	80%
Highway Forecasts in Urban Areas	11%	36%	54%	42%
Transit Projects	29%	46%	25%	20%
Evaluating Walk and Bike Mode Shares	32%	50%	18%	9%
Truck-Only Lanes, Truck Climbing Lanes, etc.	18%	57%	25%	36%
Freight Rail & Intermodal Freight Projects	4%	54%	43%	32%
Pricing Scenarios	21%	29%	50%	54%
Travel Demand Management	32%	54%	14%	26%
Alternative Growth Scenarios	21%	39%	39%	67%
Effects of Changing Demographics	29%	50%	21%	29%
Air, Greenhouse, & Environmental Analysis*	25%	38%	38%	45%
Equity Analysis & Environmental Justice	25%	50%	25%	17%
Connected & Autonomous Vehicles	29%	50%	21%	14%

* Includes one state that could not decide between 1 and 2, so is split between both.

For example, highway forecasts outside urban areas is a priority for 75% of states, and 80% of states that are interested in the topic use a statewide model to analyze it. Those who do not use a statewide model include states that do not have a statewide model. Conversely, highway forecasts in urban areas also scored high on the interest score, but only 42% of DOTs use a statewide model to evaluate such projects, with the remainder deferring to the MPO models for projects in the urban areas. The remaining policies can be observed directly in the table.

Table 8 shows these same data segmented by the policy focus of the DOT. It is observed that states with a broader set of policy interests are more likely to use a statewide model to evaluate those policies.

Table 8 Percent of States using a Statewide Model to Analyze Each Policy, by Policy Focus

Model Attributes	Rural Highway Focus	Congestion & Multi-Modal Focus	Policy, Pricing & Environment Focus
Highway Forecasts Outside Urban Areas	70%	80%	82%
Highway Forecasts in Urban Areas	40%	40%	36%
Transit Projects	0%	20%	36%
Evaluating Walk and Bike Mode Shares	0%	20%	9%
Truck-Only Lanes, Truck Climbing Lanes, etc.	20%	40%	45%
Freight Rail & Intermodal Freight Projects	10%	40%	45%
Pricing Scenarios	30%	60%	64%
Travel Demand Management	10%	0%	45%
Alternative Growth Scenarios	50%	40%	82%
Effects of Changing Demographics	20%	0%	45%
Air, Greenhouse, & Environmental Analysis	30%	40%	45%
Equity Analysis & Environmental Justice	0%	20%	27%
Connected & Autonomous Vehicles	0%	0%	27%

4.2 Value over Alternative

Next, we sought to consider how effective models were when they were applied to analyze different types of policies, relative to how effective other alternatives might be. To address this question, we asked DOTs that use a statewide model to evaluate a type of policy to rate how effective the model is at addressing that policy, on a scale of 1 to 5, with 1 being poor, and 5 being excellent. The ratings are defined as shown in the survey questionnaire.

In addition, we asked all DOTs who expressed interest in a policy how effective they thought the best non-statewide model alternative would be at evaluating those same policies. For example, with the highway forecasts outside urban areas, the best non-statewide model alternative might be to project traffic counts using time-series methods. For highway forecasts in urban areas, the best alternative might be to apply an MPO model. For equity analysis and environmental justice, these policies are often evaluated through an analysis of Census data relative to the project location.

Table 9 presents the results of these assessments. The non-statewide model rating was answered by all agencies with an interest in the topic. The model ratings were only answered by agencies with that type of model, so the sample sizes can be small in some cases. Nonetheless, it is observed that agencies with more sophisticated models tended to rate their models as more effective at analyzing a broader set of policies. One notable exception to this trend is for highway forecasts outside urban areas, where there is a lower rating for the Activity-Based Model. Several respondents told us that they thought an Activity-Based Model was overkill for highway forecasts outside urban areas, and noted that the added complexity and runtime were disadvantages. The scores reflect this assessment from those respondents.

Table 9 Effectiveness Rating of Each Type of Model for Different Policies

Policy Topic	Model Type	Rating* 1 - Poor	2- Limited	3- Useful	4- Important	5- Excellent	Total
Highway Forecasts Outside Urban Areas	No Model	4%	38%	24%	26%	8%	100%
	Basic 3-Step Model	0%	0%	38%	38%	25%	100%
	Enhanced 4-Step Model	0%	9%	9%	82%	0%	100%
	Activity-Based Model	25%	25%	0%	50%	0%	100%
Highway Forecasts in Urban Areas	No Model	4%	20%	26%	33%	17%	100%
	Basic 3-Step Model	0%	33%	33%	33%	0%	100%
	Enhanced 4-Step Model	0%	0%	42%	58%	0%	100%
	Activity-Based Model	N/A	N/A	N/A	N/A	N/A	N/A
Transit Projects	No Model	27%	23%	27%	17%	7%	100%
	Basic 3-Step Model	N/A	N/A	N/A	N/A	N/A	N/A
	Enhanced 4-Step Model	0%	0%	83%	17%	0%	100%
	Activity-Based Model	0%	0%	100%	0%	0%	100%
Evaluating Walk and Bike Mode Shares	No Model	17%	57%	20%	7%	0%	100%
	Basic 3-Step Model	100%	0%	0%	0%	0%	100%
	Enhanced 4-Step Model	0%	100%	0%	0%	0%	100%
	Activity-Based Model	N/A	N/A	N/A	N/A	N/A	N/A
Truck-Only Lanes, Truck Climbing Lanes, etc.	No Model	5%	37%	37%	21%	0%	100%
	Basic 3-Step Model	33%	0%	67%	0%	0%	100%
	Enhanced 4-Step Model	0%	0%	40%	40%	20%	100%
	Activity-Based Model	0%	0%	100%	0%	0%	100%
Freight Rail & Intermodal Freight Projects	No Model	14%	29%	48%	10%	0%	100%
	Basic 3-Step Model	50%	0%	50%	0%	0%	100%
	Enhanced 4-Step Model	0%	0%	20%	60%	20%	100%
	Activity-Based Model	0%	0%	100%	0%	0%	100%
Pricing Scenarios	No Model	24%	41%	24%	6%	6%	100%
	Basic 3-Step Model	67%	0%	0%	33%	0%	100%
	Enhanced 4-Step Model	13%	13%	31%	44%	0%	100%
	Activity-Based Model	0%	0%	0%	100%	0%	100%
Travel Demand Management	No Model	7%	29%	43%	21%	0%	100%
	Basic 3-Step Model	33%	33%	33%	0%	0%	100%
	Enhanced 4-Step Model	0%	0%	33%	67%	0%	100%
	Activity-Based Model	N/A	N/A	N/A	N/A	N/A	N/A

Alternative Growth Scenarios	No Model	26%	26%	32%	16%	0%	100%
	Basic 3-Step Model	17%	17%	17%	50%	0%	100%
	Enhanced 4-Step Model	0%	0%	56%	33%	11%	100%
	Activity-Based Model	0%	0%	0%	0%	100%	100%
Effects of Changing Demographics	No Model	13%	19%	50%	19%	0%	100%
	Basic 3-Step Model	50%	0%	0%	50%	0%	100%
	Enhanced 4-Step Model	0%	0%	100%	0%	0%	100%
	Activity-Based Model	0%	0%	0%	0%	100%	100%
Air Quality, Greenhouse Gas, etc.	No Model	23%	35%	26%	8%	8%	100%
	Basic 3-Step Model	33%	33%	33%	0%	0%	100%
	Enhanced 4-Step Model	0%	0%	33%	50%	17%	100%
	Activity-Based Model	N/A	N/A	N/A	N/A	N/A	N/A
Equity Analysis & Environmental Justice	No Model	6%	19%	44%	13%	19%	100%
	Basic 3-Step Model	100%	0%	0%	0%	0%	100%
	Enhanced 4-Step Model	50%	0%	0%	50%	0%	100%
	Activity-Based Model	0%	0%	100%	0%	0%	100%
Connected & Autonomous Vehicles	No Model	36%	55%	9%	0%	0%	100%
	Basic 3-Step Model	100%	0%	0%	0%	0%	100%
	Enhanced 4-Step Model	50%	0%	50%	0%	0%	100%
	Activity-Based Model	0%	0%	100%	0%	0%	100%

* Responses that provided a half score are marked as half a response in each of the neighboring scores.

4.3 Discussion of Additional Policies

During the interviews, respondents were given the opportunity to identify additional policies of interest to them, and perform the same rating exercise for those topics. Several themes emerged from this and related discussions. These are discussed in further detail in Chapter 6, but a few are worth mentioning here.

Several respondents indicated that their agencies are increasingly interested in understanding the economic impacts of transportation projects. Evaluating economic impacts requires a travel model, in addition to an economic model that is either integrated with or appended to the travel model. The latter goes beyond the scope of this report, but should be considered as an important direction if the agency is interested in understanding economic impacts.

A number of states also mentioned the value of having a statewide model as a consistent basis for project prioritization throughout the state. This could be with or without economic impacts as part of that prioritization.

Several respondents noted that forecasting traffic on an existing road is relatively straight-forward, but a new road, a bridge, or any other project that can be expected to cause diversion is much harder. They noted that if you care about projects where diversion is an issue, the only effective way to capture that is by applying a statewide model that includes a proper network model.

It should be noted as well that none of the respondents felt they had an adequate means to evaluate the potential effects of connected and autonomous vehicles, and that they were only starting to be asked such questions. It has been the authors' observation that there seems to be a greater sense of urgency on the topic among the cities and MPOs, especially in the largest cities. It is reasonable to expect that this will become a much bigger priority at DOTs over the next few years, so it may be worth proactively considering what tools may be required to make smart decisions in this domain.

4.4 Maintenance and Funding: A Dominant Priority for DOTs

In addition to these specific topics, respondents were asked the question:

> "Can you tell us about the most important issues facing <state DOT>? Can you provide the necessary information to decision makers about these priority issues (with or without a model)? Explain."

And if they hesitated or asked for clarification, the interviewer would follow up with the clarifying question:

> "If I were to talk to the executive director of <state DOT> and asked what issue keeps her up at night, what would she say?"

By far, the most commonly identified topics were maintenance and funding. These are directly related, with the issue coming from two sides. On the maintenance side, a huge portion of infrastructure build in the post-World War II boom is reaching the end of its design life and needs to be re-constructed at a high cost.

At the same time, gas tax revenues have generally been flat or declining, and is projected to decline much further over the coming decades. Like the federal government, most states have not indexed their gas taxes to inflation. Thus, there is a steady decline in purchasing power.

At the same time, vehicles are projected to become much more fuel efficient. After remaining flat for about two decades, the current standards call for an increase in the fleetwide average efficiency to 54.5 mpg for cars built in the 2025 model year, nearly double the starting point. While more efficient vehicles can be viewed as a positive, it would mean much lower revenue for transportation.

The combination of these factors presents a stark view for transportation budgets in the coming decades, unless some change is made. It also means that many DOTs are spending 90% or more of their budget on maintenance, with capacity expansion often de-prioritized.

The question of relevance to this report is what it means for the utility of statewide travel models. It is reasonable to expect that a statewide model is less relevant to maintenance projects than capacity expansion projects, although several respondents contradicted this notion, pointing out that rebuilding a major highway is a highly complex project that requires modeling analysis both of the final project and of the construction effects. In addition, statewide models are used in several states to develop design-traffic forecasts for repaving projects. Truck models are of particular relevance to such applications due to the effect of heavy vehicles on pavement conditions.

Limited funding may also mean that toll projects, congestion pricing, or public-private partnerships become more common, even in states that currently lack tolling. Therefore, it may be important to have the tools in place to analyze those issues.

Chapter 5. Statewide Modeling Costs

Whether a statewide model is worth developing or upgrading will depend upon the cost to do so. This chapter presents evidence on the cost of statewide model projects. There are several considerations when examining the costs of statewide models:

- The costs are not a one-time expense. There is a need for staff to operate and maintain a statewide model. This may include updating the networks as new projects are built, keeping household and employment data up-to-date, and various other tasks.
- Many of the states interviewed are on their second or third generation statewide model. Various updates described include adding functionality, streamlining software, and re-calibrating as the base year is updated every 5 or 10 years.
- Statewide models rely on data in various forms, including networks and socioeconomic data as inputs and survey data to estimate coefficients. Many statewide also use trip matrices or travel time data derived from passively collected sources. These data are often a major cost component of statewide models, but their use is not limited to the statewide model. A major factor in the cost of statewide models is different judgments about how much data collection is necessary, and from which budget that comes.
- The cost can be expected to vary based on the size and complexity of the state being modeled.
- The cost will also vary based on the type of model and the scope of the project. While the models are grouped into three types, each type is not homogeneous, and it is possible to mix-and-match different features from different types of models. For example, a state may build a relatively simple 3-Step or 4-Step model, but also develop a fully-featured freight model. To understand the effects of such decisions, the cost estimates provided here are broken out by task.
- States make different decisions about how much of the work to do them in-house, and how much to contract out. The data collection process allowed respondents to specify either or both, with contractor costs (and the cost of purchasing data) estimated in dollars, and in-house time estimated in hours, weeks or months. This split in the data makes it more difficult to compare across states. Therefore, for the tables included in this report, in-house staff time was converted to a dollar value assuming a person works 2000 hours per year at a fully-loaded rate of $100 dollars per hour.

Finally, the cost estimates presented here are educated guesses on the part of the respondents, based on a limited number of observations. Readers should bear this in mind when considering these results.

The evidence presented here takes three forms:

1. The total reported spending over the past 10 years, as reported in the survey for NCHRP Synthesis 514.
2. The reported spending on past statewide modeling projects, broken out by task.
3. The results of the cost estimating scenario exercises.

Together, these data provide a starting point for DOT's interested in understanding the costs of their own project. Building upon these data, a worksheet and associated process are presented to allow DOTs to develop their own cost estimates based on where a proposed project falls within the context of these data.

5.1 Reported Total Spending over the Past 10 Years

Two previous synthesis reports have collected data on the cost of statewide models, so we start from those. In 2005, NCHRP Synthesis 358 asked:

> "How much did/will it cost to develop the model?"

In 2016, the survey for NCHRP Synthesis 514 asked:

> "How much money did your State invest into statewide modeling over the last few years (including data purchase, surveys, hard- and software, consultant fees, but excluding costs for staff). Please provide data for several lines if readily accessible to you.
>
> > Over the last year, we spent about:
> >
> > Over the last 2 years, we spent about:
> >
> > Over the last 3 years, we spent about:
> >
> > Over the last 5 years, we spent about:
> >
> > Over the last 10 years, we spent about:"

It also asked:

> "How many employees (full-time equivalent) at your agency work predominately in statewide modeling?"

The responses to these questions are documented in the "cheat sheet" in Appendix B, but two relevant aspects of those data are summarized here.

The responses show a high variation in the reported cost for states that have a statewide model. At least part of this variation is related to the population of the state, with bigger states tending to spend more. Figure 3 illustrates this effect, showing the population against spending. Due to the high variation in both, it is plotted on a log-log scale, and shows a correlation. For example, the $21,000,000 California reports spending on statewide modeling over the past 10 years is in line with other states, relative to their size.

This may reflect a combination of either a greater challenge of modeling a more complex state, or a larger DOT budget. Other factors, as will be discussed throughout this chapter, matter to the cost as well.

Among the outliers, Texas had a $1,700,000 cost reported in the 2005 survey, and New Hampshire had a $2,000,000 cost reported in the 2005 survey. Counting these costs would mean spending in these states is closer to spending in other, similar sized, states.

Figure 3 State Population vs 10-Year Spending on Statewide Modeling

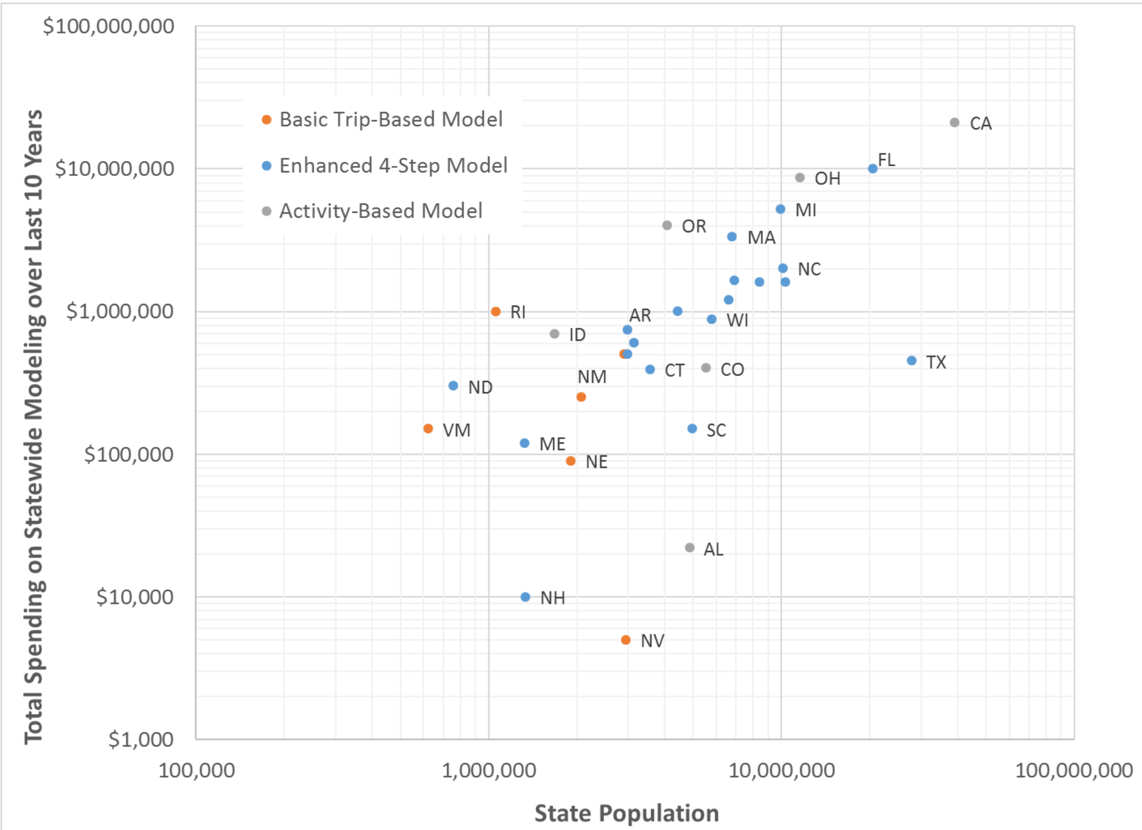


Table **10** presents the same information summarized by the type of model and the size of the state. The average per capita spending is higher for the larger states, and higher for the more complicated model types. These data are used to provide the starting point for the willingness-to-pay exercises, reported in Chapter 6.

Table 10 Total per-capita Spending on Statewide Modeling over Past 10 Years

Average (Lower Quartile – Upper Quartile)

State Size	Basic 3-Step Model	Enhanced 4-Step Model	Activity-Based Model
Population < 3,750,000	\$0.08 (\$0.04-\$0.10)	\$0.08 (\$0.03-\$0.09)	
Population >= 3,750,000	\$0.13 (\$0.08-\$0.18)	\$0.22 (\$0.11-\$0.27)	\$0.48 (\$0.33-\$0.59)

5.2 Reported Spending by Task

Respondents were asked to report how much their agency spent to develop their statewide model, and to break that cost down by task.

Respondents were varied in their ability to provide details. A number of respondents came to the interview with budgets or consultant contracts in hand, and were able to provide very reliable cost estimates. In some cases, only a total cost was available, and the respondent used his or her judgment to allocate that total cost among tasks. Sometimes, though, this level of detail was not possible, and the estimates reflect a best guess. This was more common for models that were developed, with few staff able to effectively estimate the costs of models developed more than about 10 years ago[1]. None of the DOTs were able to provide a detailed accounting (such as from timesheets) of in-house costs.

In some cases, a DOT may have built a statewide model in the past, but updated it more recently, or currently be in the process of updating it. In those cases, the respondent was given the choice for which project they felt most comfortable estimating. In each of these cases, the respondent chose to answer for the most recent model overhaul for which they had cost information. The data are intended to represent a single project—focused on what it takes to develop or upgrade a full model—rather than a cumulative sum of every modeling project in their history.

Figure 4 and Figure 5 are box-and-whisker plots that show the distribution of costs by task. The upper plot in each figure shows the cost of modeling tasks, while the lower plot shows the cost of data collection tasks. Each dot represents one reported value. The dark gray box goes from the first quartile to the median, and the light gray box goes from the median to the third quartile. The lines, or “whiskers”, show the range of values, excluding extreme outliers. The data are segmented by task and by model type. Readers

[1] As an interesting aside, Kentucky is believed to have the first statewide model, developed in 1975 by Alan Voorhees, the inventor of the gravity model of trip distribution. To support the model, they conducted large-scale manual origin-destination surveys, at a cost of between \$5-6 million in 1970s dollars.

interested in details about the box-and-whisker plots, or about the calculation of quartiles, are referred to the blog post by (Capitula, 2014).

The box-and-whisker plots are segmented into model and data costs due to the large role data collection costs can play in driving the total cost. This is particularly true for states that conduct household travel surveys, with the most expensive reported survey costing $6.5 million, dominating all other costs.

The average total reported spending ranges from about $500,000 for a small state developing a 3-step model, to about $5,000,000 for a large state developing an activity-based model. A large portion of those costs are associated with data collection, with the model development component closer to $250,000 and $2,000,000.

Table 11 shows the reported statewide model spending by small states and Table 12 shows the reported spending by large states. The different columns show segmentation by the different types of models. Each cell shows the average cost. Reported below the average cost, in parentheses, are the lower quartile and the upper quartile. The quartiles are reported as a means of providing a range of estimates while excluding the biggest outliers. Note that the total column is an average of the reported totals, and can be different than the sum of the averages.

All costs represent a single outlay, except for the annual maintenance and troubleshooting line item, which is a cost per year. This cost is reported in dollars, but is most often a cost associated with paying staff.

Table 11 Reported Spending by Small States

Category	Tasks	Average Cost (Lower Quartile – Upper Quartile)		
		3-Step Model	Enhanced 4-Step Model	Activity-Based Model
Networks & TAZs	Code highway networks, urban transit networks, intercity networks, freight intermodal networks, TAZ system, develop socio-economic data.	$93,000 ($36,000-$100,000)	$154,000 ($48,000-$260,000)	N/A
Baseline Data	Collect traffic counts or speed data, purchase GPS or mobile phone data.	$187,000 ($168,000-$213,000)	$130,000 ($70,000-$184,000)	N/A
Survey Data	Conduct household travel surveys or other surveys, purchase NHTS add-on samples.	$187,000 ($36,000-$338,000)	$940,000 ($380,000-$1,500,000)	N/A
Passenger Travel	Develop passenger travel models, estimate coefficients, software implementation.	$123,000 ($63,000-$160,000)	$141,000 ($44,000-$238,000)	N/A
Long-Distance Passenger Travel	Develop long-distance passenger travel models, estimate coefficients, software implementation.	$38,000 ($21,000-$55,000)	$102,000 ($102,000)	N/A
Freight Transportation	Develop freight & commercial vehicle models, estimate coefficients, software implementation.	$166,000 ($99,000-$218,000)	$84,000 ($40,000-$128,000)	N/A
Calibration and Validation	Calibrate and validate model, conduct sensitivity testing.	$125,000 ($28,000-$175,000)	$130,000 ($40,000-$220,000)	N/A
Total	(Excluding annual maintenance)	$577,000 ($320,000-$638,000)	$1,101,000 ($344,000-$1,858,000)	N/A
Annual Maintenance & Troubleshooting (cost per year)	Maintain networks, update socio-economic data, troubleshoot problematic model results/errors.	$119,000 ($78,000-$175,000)	$50,500 ($5,000-$96,000)	N/A

Figure 4 Reported Spending Distribution by Small States

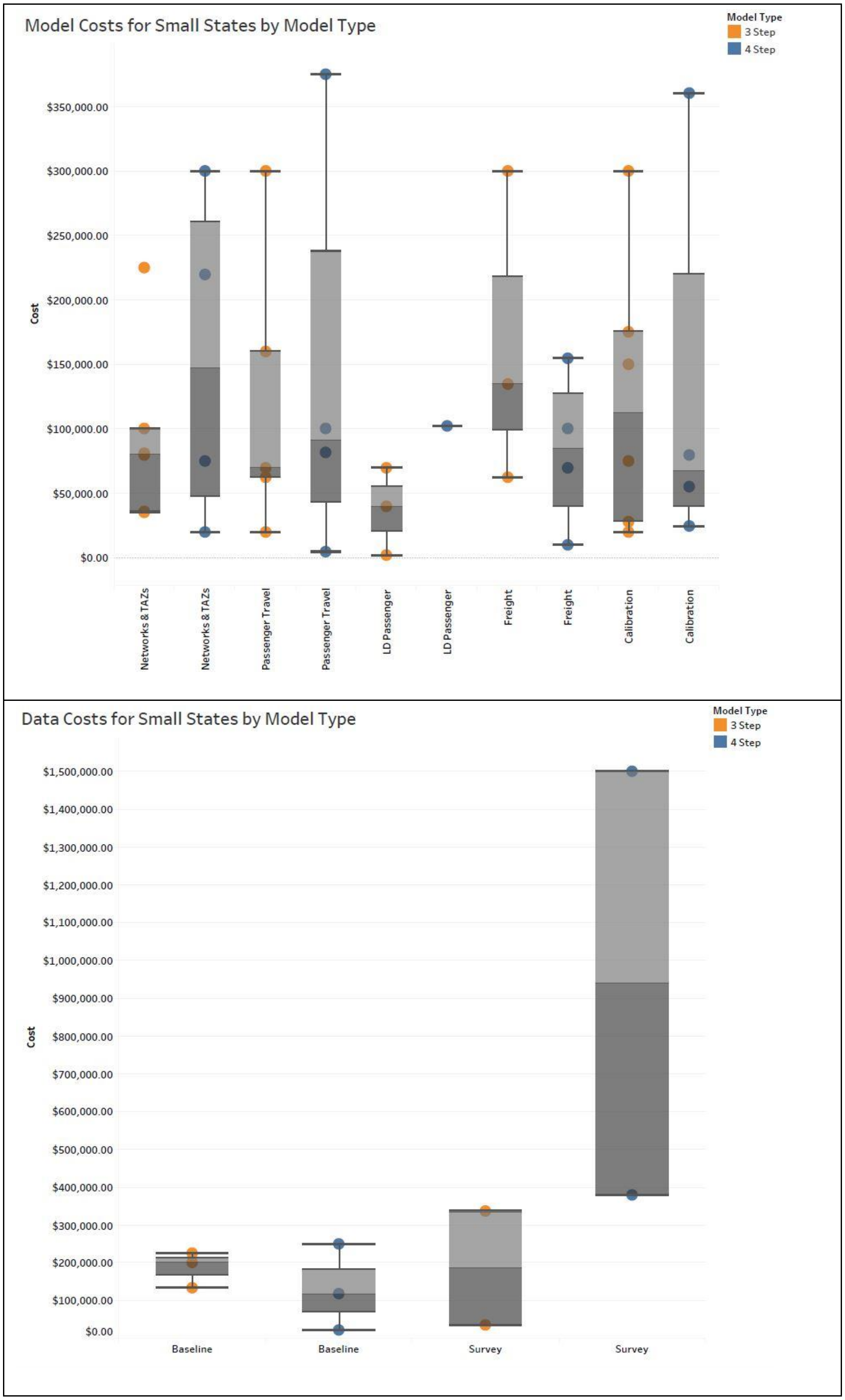
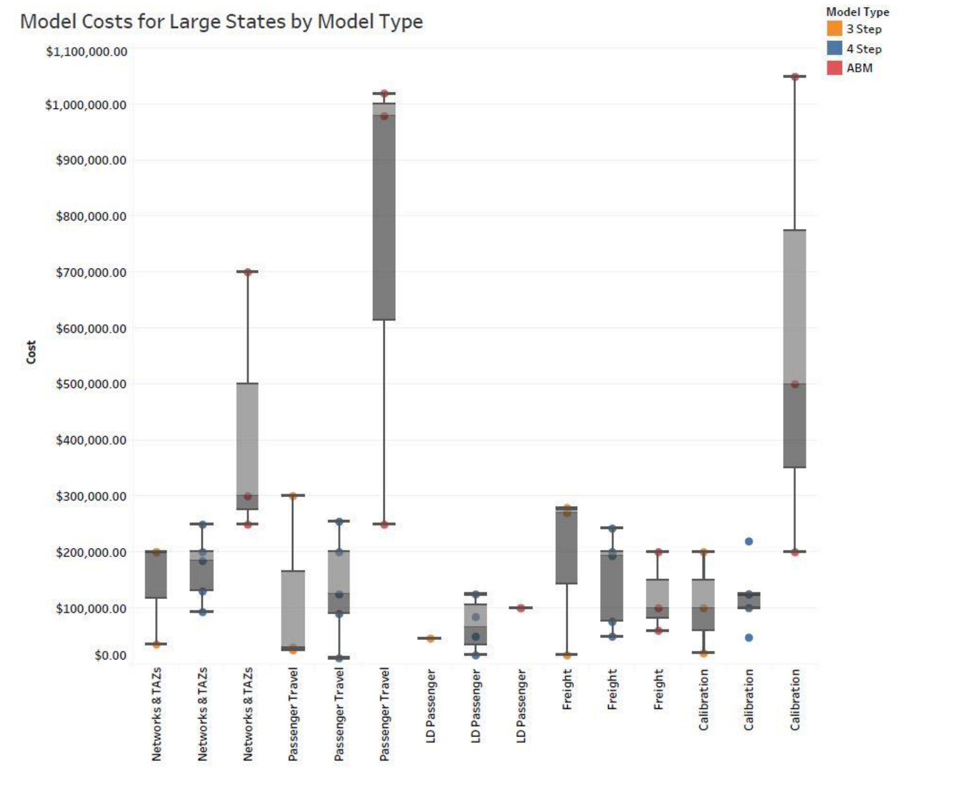
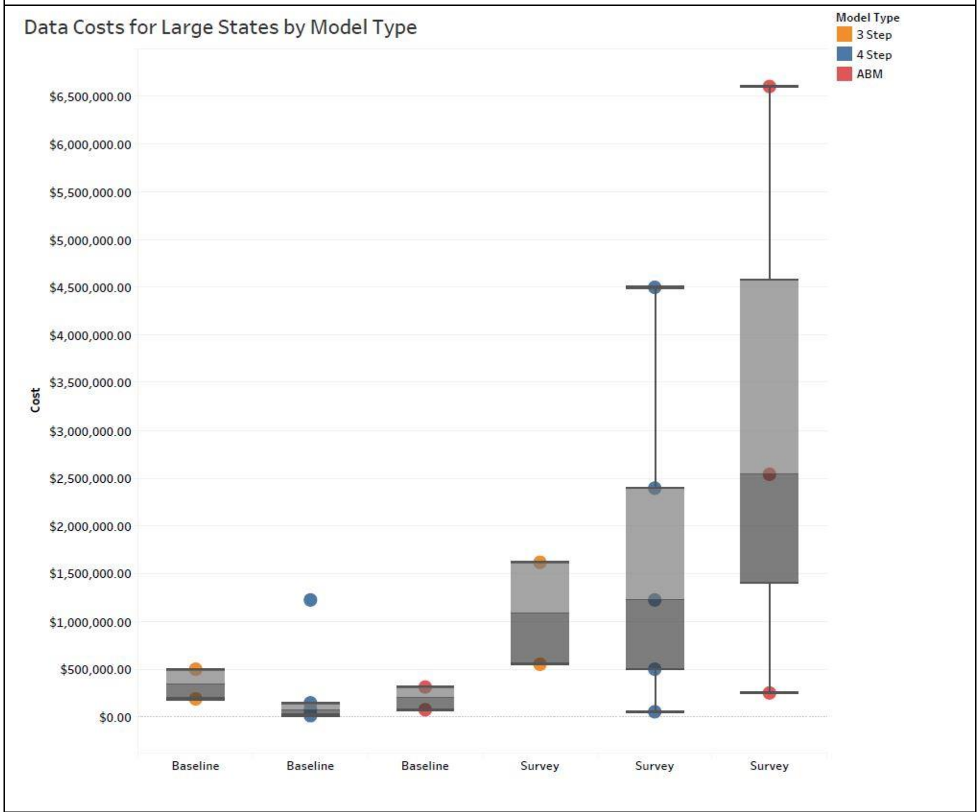


Table 12 Reported Spending by Large States

Category	Tasks	Average Cost (Lower Quartile – Upper Quartile)		
		3-Step Model	Enhanced 4-Step Model	Activity-Based Model
Networks & TAZs	Code highway networks, urban transit networks, intercity networks, freight intermodal networks, TAZ system, develop socio-economic data.	$145,000 ($118,000-$200,000)	$172,000 ($130,000-$200,000)	$417,000 ($275,000-$500,000)
Baseline Data	Collect traffic counts or speed data, purchase GPS or mobile phone data.	$345,000 ($190,000-$500,000)	$298,000 ($25,000-$150,000)	$193,000 ($75,000-$310,000)
Survey Data	Conduct household travel surveys or other surveys, purchase NHTS add-on samples.	$1,085,000 ($550,000-$1,620,000)	$1,735,000 ($500,000-$2,400,000)	$3,130,000 ($1,395,000-$4,570,000)
Passenger Travel	Develop passenger travel models, estimate coefficients, software implementation.	$118,000 ($28,000-$165,000)	$136,000 ($90,000-$200,000)	$750,000 ($615,000-$1,000,000)
Long-Distance Passenger Travel	Develop long-distance passenger travel models, estimate coefficients, software implementation.	$45,000 ($45,000)	$69,000 ($33,000-$105,000)	$100,000 ($100,000)
Freight Transportation	Develop freight & commercial vehicle models, estimate coefficients, software implementation.	$188,000 ($143,000-$275,000)	$152,000 ($75,000-$200,000)	$120,000 ($80,000-$150,000)
Calibration and Validation	Calibrate and validate model, conduct sensitivity testing.	$107,000 ($60,000-$150,000)	$123,000 ($100,000-$125,000)	$583,000 ($350,000-$775,000)
Total	(Excluding annual maintenance)	$1,527,000 ($1,083,000-$2,240,000)	$2,187,000 ($1,083,000-$2,734,000)	$5,195,000 ($3,843,000-$6,145,000)
Annual Maintenance & Troubleshooting (cost per year)	Maintain networks, update socio-economic data, troubleshoot problematic model results/errors.	$38,000 ($25,000-$50,000)	$35,000 ($35,000)	$1,030,000 ($60,000-$2,000,000)

Figure 5 Reported Spending Distribution by Large States





5.3 Cost Estimates of 3-Step Models

In the previous section, we discussed the results on respondents how much the states spent on statewide modelling. In this and the following two sections, we changed the framing of the question and asked how much the respondent would budget for a specific model development or upgrade. This provide a means to get many estimates for the same modeling approach, and to establish the costs based on present conditions and technology.

In the first cost estimation scenario, we asked respondents to imagine they have started a new job at a DOT that does not currently have a statewide model. Instead of using a statewide model, the DOT uses time-series methods, such as growth factors, when projecting demand for highway projects. Their supervisor, the Director of Planning, has asked them to consider developing a basic 3-step statewide model. Their task was to provide costing broken out into several model components, namely Networks & TAZs, baseline data, travel survey data, passenger travel, long distance passenger, freight, calibration and a reserve fund. The description of the model given to the respondents was:

> As envisioned, the plan is to develop a Basic 3-Step Model. It is expected that the model would not include a mode choice component, and follow a fairly basic model structure. You plan to use model parameters from NCHRP 735: Long Distance and Rural Travel Transferable Parameters for Statewide Travel Forecasting Models (http://www.trb.org/Main/Blurbs/168389.aspx) and NCHRP 716: Travel Demand Forecasting: Parameters and Techniques (http://www.trb.org/Publications/Blurbs/167055.aspx). Together these reports provide information on travel model parameters that can be transferred from other models, avoiding the need to estimate those parameters from local travel survey data. You do plan to collect new traffic counts with the aim of calibrating the model to match those counts.
>
> You will not explicitly model long-distance passenger travel. To capture truck travel, you plan to perform an OD matrix estimation from your truck counts to generate a static truck trip table. After calibrating the model, you will conduct some basic sensitivity testing. You need to budget for some ongoing effort (per year) to maintain the networks, update the data inputs, troubleshoot problems, and so forth. Please assume that applying the model to generate project-level forecasts is a separate cost allocated to the project. Please also indicate how much you would ask for in reserve funds to protect against unanticipated costs.

For each model component, we asked respondents to specify both a dollar amount for the costs of external contractors or consultants and the number of person-hours of in-house staff time you expect to dedicate to the effort. In the results below, person-years of in-house staff were converted to a dollar amount assuming a person work 2000 hours per year at a fully-loaded rate of $100 dollars per hour, which is a rate that DOTs may expect to pay consultants.

Table 13 presents the results of this cost-estimating exercise, with Figure 6 showing the associated box-and-whiskers plots. The data are segmented by the type of respondent—those from small states, from large states, and consultants. Consultants were told to assume the model was being developed for a medium-large state—not California, but large by our definition in this report.

These data show fairly consistent estimates across the three categories of respondents, with the average total cost between $530,000 and $650,000. It is interesting that the estimates for large states are often lower than for small states. This may be because the staff we talked to at the larger states brought more experience, and were therefore more comfortable estimating a smaller cost.

The largest component of that cost is associated with the networks and TAZs task, and involves the laborious process of coding highway networks, defining a TAZ system, and compiling socio-economic data. Most respondents assumed that this would be done by in-house staff. The roughly $200,000 cost would be equivalent to one person-year of effort, when converted back to staff hours assuming a cost of $100/hour and 2000 hours per year.

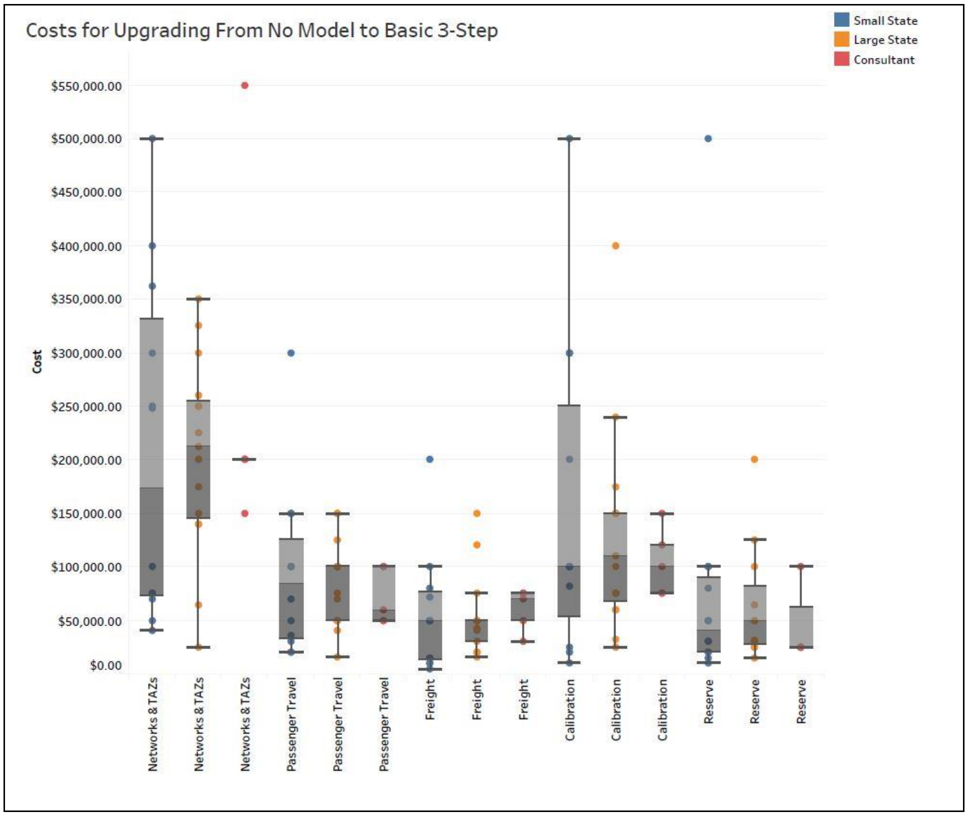
While the range of estimates is substantial, it may be reasonable to develop an entry-level statewide model for a person-year of staff effort, plus roughly $300,000 of consultant costs. The scoping of this model does not include any data collection.

It is necessary to pay someone to operate and maintain the model. Based on the cost conversions, this would be between a 1/4 and a 1/2 of a FTE.

Table 13 Cost Estimates for Upgrading from No Model to Basic 3-Step Model

Category	Tasks	Cost (Lower Quartile – Upper Quartile)		
		Small State	Large State	Consultant
Networks & TAZs	Code highway networks, TAZ system, develop socio-economic data.	$206,000 ($73,000-$331,000)	$204,000 ($145,000-$255,000)	$260,000 ($200,000-$550,000)
Baseline Data	None	N/A	N/A	N/A
Survey Data	None	N/A	N/A	N/A
Passenger Travel	Develop Basic 3-step model (no-mode choice) with parameters from NCHRP 735 and NCHRP 716	$94,000 ($33,000-$125,000)	$85,000 ($50,000-$100,000)	$72,000 ($50,000-$100,000)
Long-Distance Passenger Travel	None	N/A	N/A	N/A
Freight Transportation	Perform OD matrix estimation to create static truck trip table	$55,000 ($13,000-$76,000)	$55,000 ($30,000-$50,000)	$60,000 ($50,000-$75,000)
Calibration and Validation	Calibrate and validate model, conduct sensitivity testing	$153,000 ($54,000-$250,000)	$130,000 ($68,000-$150,000)	$104,000 ($75,000-$120,000)
Reserve Fund	Additional budget allocation to protect against unexpected circumstances.	$84,000 ($20,000-$90,000)	$65,000 ($28,000-$82,000)	$44,000 ($25,000-$63,000)
Total	(Excluding annual maintenance)	$645,000 ($245,000-$1,031,000)	$528,000 ($398,000-$650,000)	$531,000 ($410,000-$500,000)
Annual Maintenance & Troubleshooting	Maintain networks, update socio-economic data, troubleshoot problematic model results/errors.	$36,000 ($12,500-$60,000)	$136,000 ($25,000-$175,000)	$86,000 ($40,000-$100,000)

Figure 6 Cost Estimate Distribution for Upgrading from No Model to Basic 3-Step Model



5.4 Cost Estimates of 4-Step Models

In the second cost estimation scenario, we asked respondents to imagine that the DOT where they recently started a new job already has in place a Basic 3-Step Model that was developed about 10 years ago and has been in regular use. Their supervisor, the Director of Planning, has asked them to consider upgrading the statewide model to an Enhanced 4-Step Model. The scope of that model is described as:

> As envisioned, the plan is to add a mode choice component, and revisit the overall model structure to add sophistication where it is warranted. For example, you might consider more trip purposes or an improved approach to modeling time-of-day. You will purchase an add-on sample from the upcoming National Household Travel Survey (NHTS) to estimate the model parameters from local data. In addition, you plan to collect new traffic counts for the purpose of model calibration and validation, and purchase data from a cell phone or GPS vendor to derive external-external (EE), external-internal (EI) and internal-external (IE) trip tables.
>
> You plan to explicitly model long-distance passenger travel, by adapting the National Long Distance Travel Model (NLDTM) to work for your state. This would include an intercity mode choice components, with intercity air, passenger rail and bus networks adapted from those in the NLDTM. You will develop a freight model using commodity flow data from the Freight Analysis Framework (FAF). This FAF-based model will only assign truck-trips to the network.
>
> After calibrating and validating the model, you will conduct some basic sensitivity testing. You need to budget for some ongoing effort (per year) to maintain the networks, update the data inputs, troubleshoot problems, and so forth. Please assume that applying the model to generate project-level forecasts is a separate cost allocated to the project. Please also indicate how much you would ask for in reserve funds to protect against unanticipated costs.

The remainder of the process is the same as previously reported.

Table 14 and Figure 7 present the results of this cost-estimating exercise. Here, there is a much clearer difference by state size, with small states estimating an average total cost of about $675,000 and large states estimating an average total cost of about $1.8 million.

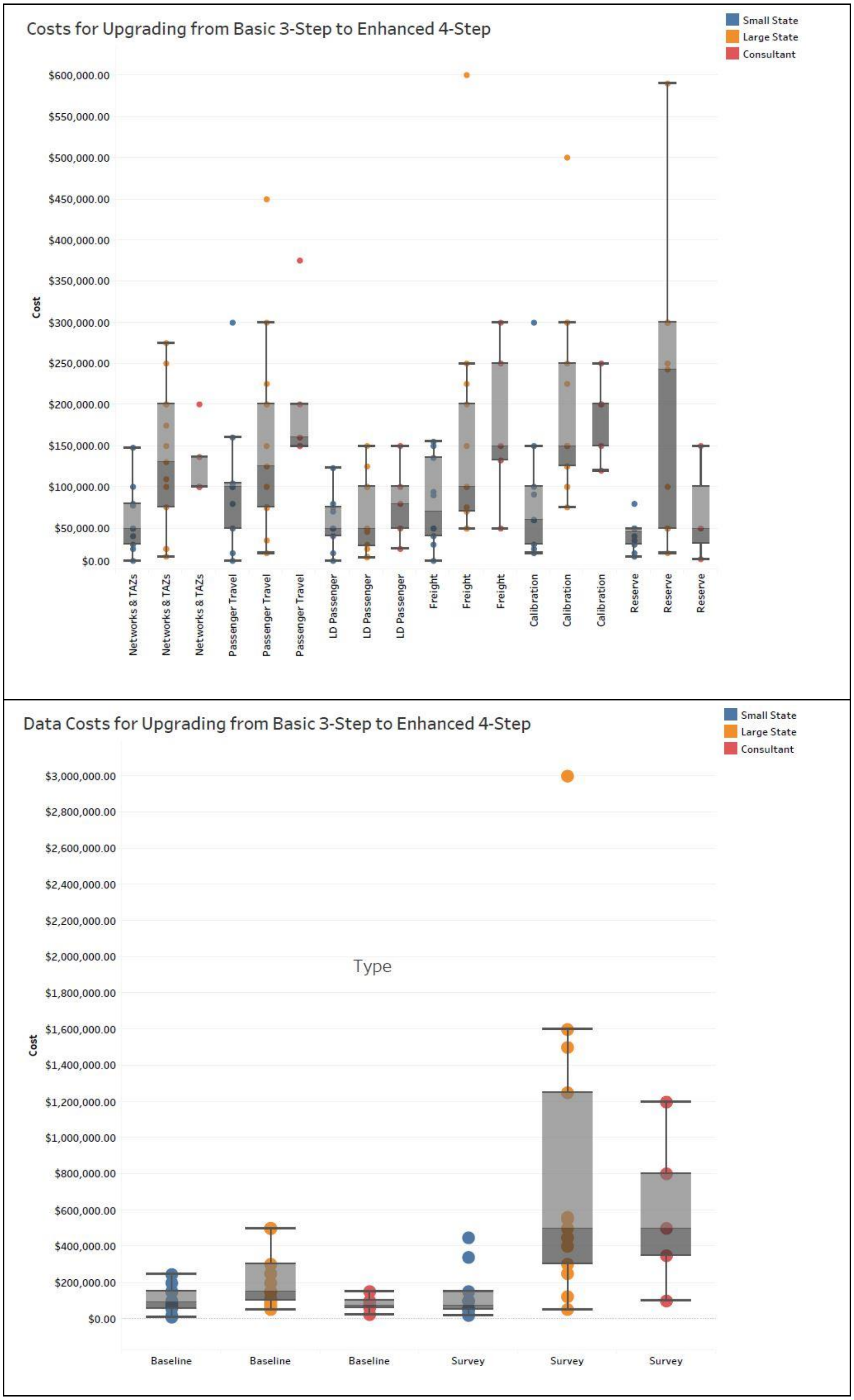
The biggest component of this cost is data collection, with small states estimating a total data cost of about $240,000, and large states estimating a total data cost of about $1,000,000. It is interesting that the cost of developing the core passenger travel models is a modest portion of the total cost, with the estimated cost of freight models, and model calibration/validation almost as high.

Annual maintenance costs are similar to that of the 3-step model, with the exception f the consultant estimate that increased to about 1 FTE.

Table 14 Cost Estimates for Upgrading from Basic 3-Step to Enhanced 4-Step Model

Category	Tasks	Cost (Lower Quartile – Upper Quartile)		
		Small State	Large State	Consultant
Networks & TAZs	Code urban transit networks, code intercity air, rail & bus networks	$61,000 ($30,000-$80,000)	$133,000 ($75,000-$200,000)	$127,000 ($100,000-$136,000)
Baseline Data	Purchase base IE/EI/EE trip tables from GPS or cell phone data	$108,000 ($56,000-$150,000)	$219,000 ($100,000-$300,000)	$82,000 ($60,000-$100,000)
Survey Data	Buy into NHTS add-on sample	$134,000 ($50,000-$150,000)	$811,000 ($300,000-$1,250,000)	$590,000 ($350,000-$800,000)
Passenger Travel	Develop 4-step model with estimated model parameters	$102,000 ($50,000-$104,000)	$156,000 ($75,000-$200,000)	$207,000 ($150,000-$200,000)
Long-Distance Passenger Travel	Adapt National Long-Distance Model	$57,000 ($40,000-$75,000)	$67,000 ($28,000-$100,000)	$81,000 ($50,000-$100,000)
Freight Transportation	Adapt commodity flows from FAF with truck flows assigned to network	$80,000 ($40,000-$135,000)	$153,000 ($70,000-$200,000)	$176,000 ($132,000-$250,000)
Calibration and Validation	Calibrate and validate model, conduct sensitivity testing	$90,000 ($30,000-$100,000)	$196,000 ($125,000-$250,000)	$184,000 ($150,000-$200,000)
Reserve Fund	Additional budget allocation to protect against unexpected circumstances.	$42,000 ($30,000-$50,000)	$205,000 ($50,000-$300,000)	$71,000 ($31,000-$100,000)
Total	(Excluding annual maintenance)	$675,000 ($445,000-$868,000)	$1,815,000 ($1,300,000-$2,125,000)	$1,490,000 ($1,275,000-$1,800,000)
Annual Maintenance & Troubleshooting	Maintain networks, update socio-economic data, troubleshoot problematic model results/errors.	$49,000 ($23,000-$75,000)	$104,000 ($50,000-$100,000)	$221,000 ($80,000-$300,000)

Figure 7 Cost Estimate Distribution for Upgrading from Basic 3-Step to Enhanced 4-Step Model



Consultants were told to estimate the costs for a medium to large size state—not California, but large by the definitions used in this report. Our expectations of the consultant cost estimates was two-fold. First, we expected that they may provide more reliable cost estimates because they have more experience developing cost estimates for projects in different locations. Second, we expected that they might be incentivized to provide higher cost estimates in order to protect against the risk of going over-budget. It is interesting, then to observe that the consultant cost estimates are in many cases lower than those provided by large states.

5.5 Cost Estimates of Activity-Based Models

In the third cost estimation scenario, we asked respondents to imagine the DOT where they recently started a new job already has in place an Enhanced 4-Step Model. It was developed about 10 years ago and has been in regular use since then, with periodic updates. Their supervisor, the Director of Planning, has asked them to consider upgrading the statewide model to an Activity-Based Model. The model is specified as follows:

> As envisioned, the Activity-Based Model would switch from the traditional trip-based modeling paradigm and instead model tours, which are a sequence of trips starting and ending at home. It would use a more complex structure for generating and scheduling activities and tours than the previous model. Destination choice and mode choice would follow a similar structure to the current models, but would be conducted first for tours, and then for individual trips within the tour. The demand models would operate using microsimulation. That means that a population synthesizer would run to create a table of the simulated population of the state. The core choice models would be applied to individual person records, simulating discrete outcomes, rather than applying the probabilities to the aggregate number of trips in the trip tables. After the trip mode choice step, the results would be compiled into trip tables, and the assignment models would remain the same as they are in the previous model.
>
> You plan to design and collect travel surveys to support the estimation of these models. These would include a household travel survey, and any other surveys you feel are warranted. In addition, you plan to collect new traffic counts for the purpose of model calibration and validation. You plan to purchase data from a cell phone or GPS vendor to serve as a base trip table against which to calibrate your model, and which can be used to pivot the results.
>
> You plan to develop an explicit model of long-distance passenger travel. You will develop a freight model that considers intermodal freight movements, is sensitive to changes in congestion, the location of employment, and policies of interest.
>
> After calibrating and validating the model, you will conduct some basic sensitivity testing. You need to budget for some ongoing effort (per year) to maintain the networks, update the data inputs, troubleshoot problems, and so

> forth. Please assume that applying the model to generate project-level forecasts is a separate cost allocated to the project. Please also indicate how much you would ask for in reserve funds to protect against unanticipated costs.

Table 15 and Figure 8 show the results of this costing exercise. Small states estimated the cost of an Activity-Based Model and the associated components and data to be about $1,200,000, large states estimated the total cost at about $5,000,000, and consultants estimated the total cost at about $2,700,000.

Again, we observe that the data collection costs are the biggest single component, ranging from 43% of the total cost estimate for small states to 66% of the total cost estimate for large states. The question of what to do for surveys remains key to the budget question.

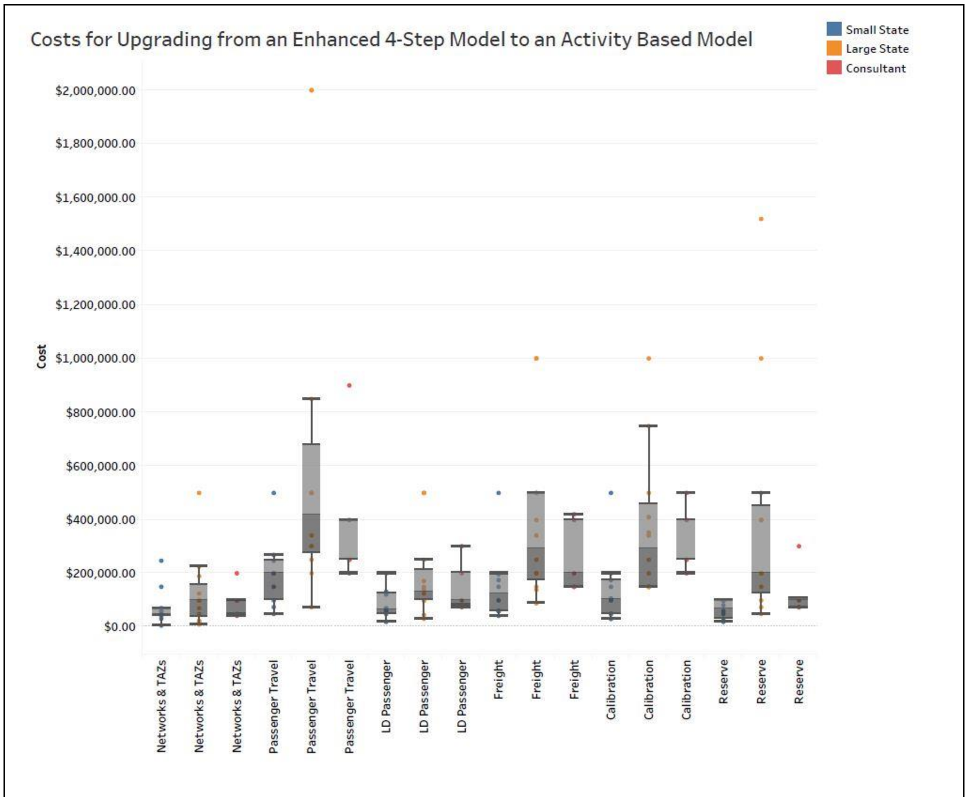
It is interesting to note the cost of the passenger travel models--$200,000 as estimated by small states, $650,000 as estimated by large states, and $400,000 as estimated by consultants. This is the portion of the model that defines it as an Activity-Based Model, and is higher than the equivalent cost for the Enhanced 4-Step Model (between $100,000 and $200,000). However, it remains a moderate portion of the total cost, with long-distance, freight and networks also being important components, and data being a major driver.

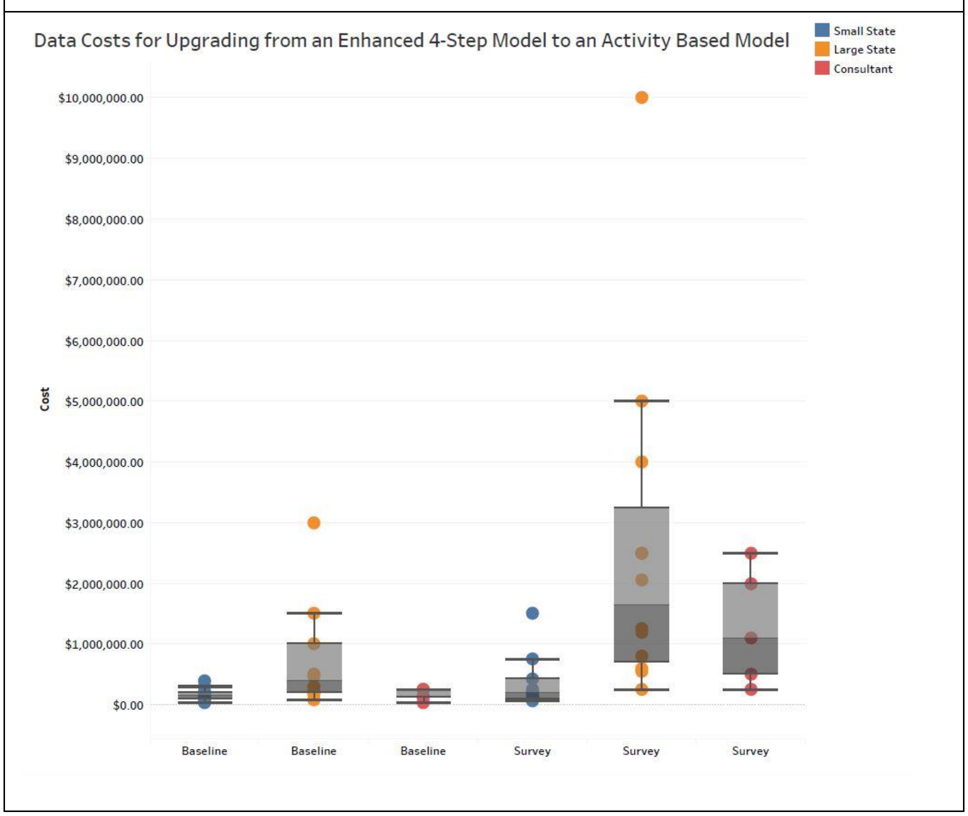
Annual maintenance costs were estimated to be higher for this more complex model system, approach ½ FTE for small states, 1 FTE for large states, and 1.5 FTE as estimated by consultants.

Table 15 Cost Estimates for Upgrading from Enhanced 4-Step to Activity-Based Model

Category	Tasks	Cost (Lower Quartile – Upper Quartile)		
		Small State	Large State	Consultant
Networks & TAZs	Use existing passenger networks and TAZ system, code freight intermodal networks	$75,000 ($40,000-$70,000)	$126,000 ($38,000-$158,000)	$98,000 ($50,000-$100,000)
Baseline Data	Purchase full base trip tables from GPS or cell phone data	$176,600 ($100,000-$200,000)	$744,000 ($200,000-$1,000,000)	$157,000 ($120,000-$250,000)
Survey Data	Design and conduct local travel surveys	$373,000 ($100,000-$420,000)	$2,558,000 ($700,000-$3,250,000)	$1,270,000 ($500,000-$2,000,000)
Passenger Travel	Develop activity-based model. Estimate model parameters. Develop application framework using population synthesizer.	$199,000 ($100,000-$248,000)	$651,000 ($275,000-$675,000)	$400,000 ($250,000-$400,000)
Long-Distance Passenger Travel	Develop custom long-distance travel model	$86,000 ($50,000-$125,000)	$184,000 ($100,000-$210,000)	$151,000 ($80,000-$200,000)
Freight Transportation	Develop policy-sensitive freight model with non-Truck freight modes	$153,900 ($60,000-$196,000)	$397,500 ($175,000-$500,000)	$264,000 ($150,000-$400,000)
Calibration and Validation	Calibrate and validate model, conduct sensitivity testing	$139,000 ($50,000-$175,000)	$367,000 ($150,000-$455,000)	$320,000 ($250,000-$400,000)
Reserve Fund	Additional budget allocation to protect against unexpected circumstances.	$66,000 ($30,000-$100,000)	$418,000 ($125,000-$450,000)	$131,000 ($75,000-$106,000)
Total	(Excluding annual maintenance)	$1,268,000 ($950,000-$1,394,000)	$4,974,000 ($2,145,000-$7,944,000)	$2,792,000 ($1,500,000-$4,170,000)
Annual Maintenance & Troubleshooting	Maintain networks, update socio-economic data, troubleshoot problematic model results/errors.	$80,000 ($35,000-$125,000)	$184,000 ($100,000-$150,000)	$289,000 ($100,000-$500,000)

Figure 8 Cost Estimate Distribution for Upgrading from Enhanced 4-Step to Activity-Based Model





5.6 How to Use These Data

This chapter presents cost data from several sources. It does not boil to a single number. Instead, the data are broken out by task, with ranges included, allowing agencies to develop a customized cost estimate based on their selection of features, their state size, and their judgment for where they may fall within the range. To facilitate that process, we have outlined a series of steps in Appendix E to accompany a cost estimating worksheet in Appendix F.

Those interested in developing a new model should also consider using NCHRP Report 852: Method Selection for Travel Forecasting (Outwater, Hathaway, Kittelson & Associates, Oregon Systems Analytics LLC, & Kieth Lawton Consulting, Inc., 2017) as a resource. The report is accompanied by a software tool which guides the user through the selection of travel forecasting methods and techniques. It considers application needs, and the model starting point and produces scores and cost ranges for recommended options. Those costs can be considered as an additional observation.

Chapter 6. Estimating the Utility of Statewide Models

The previous chapter considered the costs of developing and maintaining a statewide travel demand model. This chapter considers their utility. There is no formal requirement that DOTs operate a statewide model, so if the utility of the tool does not exceed its cost, then the wise decision is to avoid engaging in statewide modeling.

So why would a state wish to develop a statewide model? And why might a state wish to upgrade its statewide model? They may do so because they see value in the model as a tool for policy analysis. Chapter 3 discusses the role of statewide models as policy analysis tools, focusing on the types of policies that states use their models to analyze, on the perceived effectiveness of their models to analyze those policies, and on their value relative to the next best alternative.

This chapter goes a step further in seeking to quantify the utility of a statewide model in dollar terms. It does so through a series of willingness-to-pay exercises, which are described in Chapter 2 and reviewed here. During the interviews, a few respondents suggested alternative methods to quantify the utility of statewide models, and some of those are discussed here as well. It is a challenging problem, because it is a question of the value of information, and there is uncertainty surrounding the quality of that information and its influence on decision making. In talking with the DOTs, the decision to build a statewide model was often driven by a specific need, and the motivation is often qualitative or anecdotal. The end of this chapter summarizes the motivations that came up repeatedly in these conversations.

We hope these data provide a useful starting point for thinking about the problem in a structured way as DOT staff combine them with their own judgments to make decisions about whether and how to invest in statewide models.

6.1 Willingness-to-Pay for Model Upgrades

In the "willingness to pay" scenario exercise, we asked respondents for their recommendations on whether it would make sense to proceed with the statewide model development or upgrade projects described, at a given price point. The goal was to quantify the value they see in statewide models.

The questions were set up in the form of a contingent valuation question (Mitchell and Carson, 1989; Bateman and Willis, 2001), in which respondents were told how much a state DOT would have to pay to develop or upgrade the statewide model, under a given policy focus area and the model development option for a hypothetical state. They are then asked to make go/no-go decisions. We asked them to define their responses as follows:

- Go – they believe that the value of the model capabilities exceeds the cost specified, and the DOT should proceed with the model development/upgrade project.

- No-go – they believe that the value of the model capabilities does not exceed the cost specified, and the DOT should maintain the status quo.

Within each of the scenarios, we varied the cost from the starting estimate to understand the limits of their recommendation.

The cost estimates were expressed in terms of "ten-year cost per capita". This was defined as the total amount spent over a 10 year period, divided by the population of the state. The total cost includes the cost of the developing the model, the associated cost of data collection, and the cost to pay staff to operate and maintain the model. For example, a DOT might have paid $1,000,000 to develop a statewide model, and pay one staff person $100,000 per year (including fringe) to operate and maintain the model. This state would have a total cost of $2,000,000 over 10 years. If 4,000,000 people live in the state, the 10-year cost per capita would be $0.50.

This section of the interview included nine scenarios, which differed by the policy focus area and the model development option. Each respondent considered all nine scenarios, so the values reflect the collective judgment of all respondents.

Table 16 shows the results of this exercise. For a rural highways policy focus, respondents are willing to pay an average of $0.61 per capita over ten years to develop go from no statewide model to a Basic 3-Step Model. This would be $610,000 for a state with a population of 1,000,000, and $6,100,000 for a state with a population of 1,000,000. Moving down the rows, as the range of policies considered expands, the willingness to pay tends to increase. This is logical, because each policy focus is inclusive of all the policies above it. A few respondents, however, did note that they saw the Basic 3-Step Model as inadequate to address some of the more complex policies (including Congestion & Multi-Modal policies), and that they would not be willing to pay for a model that only meets a portion of their policy analysis needs.

Going across the columns, the willingness-to-pay values are additive. For the scenario of upgrading from a Basic 3-Step Model to an Enhanced 4-Step Model, respondents were instructed that the agency already has a Basic 3-Step Model, and the cost of developing that model is a sunk cost. If they make a "no-go" decision on the project, they still have that Basic 3-Step Model in place and can continue to use it, so the judgment is about whether or not to spend additional money to develop a model with more features. The implication of that is that if someone is willing to pay $0.61 per capita to go from no model to a Basic 3-Step Model, and $0.54 per capita to go from a Basic 3-Step Model to an Enhanced 4-Step Model, they should also be willing to pay $1.15 per capita to go directly from no model to an Enhanced 4-Step Model. The question was not directly asked in that way, although in retrospect, it would have been a useful quality check on the result.

Table 16 Willingness to Pay for Model Upgrades, in 10-Year Cost per Capita

Average (Lower Quartile – Upper Quartile)

	Model Development Options

		M1	M2	M3
		Start from: No Model	*Start from:* Basic 3-step model	*Start from:* Enhanced 4-step model
Policy Focus		*Upgrade to:* Basic 3-step model with transferred model parameters, static truck trip tables.	*Upgrade to:* Enhanced 4-Step Model with estimated parameters, National Long-Distance Model, FAF-based commodity flows model, NHTS add-on sample.	*Upgrade to:* Activity-based model with estimated parameters, custom long-distance travel model, policy-sensitive freight model, custom travel surveys.
P1	Rural highways: Primary need is to evaluate highway projects outside urban areas.	\$0.61 (\$0.28-\$0.69)	\$0.54 (\$0.09-\$0.78)	\$0.28 (\$0.00-\$0.37)
P2	Congestion & multi-modal: Also a need to evaluate projects in urban areas, transit projects, truck projects and/or rail/intermodal projects.	\$0.78 (\$0.28-\$0.85)	\$0.78 (\$0.30-\$0.88)	\$0.71 (\$0.30-\$1.00)
P3	Policy, pricing & environment: A need to test broader policy or global scenarios, such as congestion pricing, demand management, growth scenarios, demographic changes, environment, equity and connected & autonomous vehicles.	\$0.83 (\$0.25-\$1.00)	\$0.87 (\$0.33-\$1.13)	\$0.88 (\$0.40-\$1.08)

The same is true for upgrading from an Enhanced 4-Step Model to an Activity-Based Model. For the Rural Highways policy focus, respondents are willing to pay, on average, an additional $0.28 per capita to upgrade, or $1.43 total value over no model. For this particular scenario, several respondents indicated that they did not think an Activity-Based Model was useful for a Rural Highways policy focus, and they would not want to upgrade even at zero cost due to the added complexity.

The declining values in the Rural Highways focus as you proceed to the right in the table indicate a declining marginal utility for the model upgrades. There is a big jump to go from no-model to a model, but less of a jump to add features to that model.

For the Congestion & Multi-Modal policy focus, the utility of going from no model to a Basic 3-Step Model is estimated as $0.78 per capita over 10 years, and the estimated utility of upgrading to an Enhanced 4-Step Model is the same. There were a number of respondents who suggested that they clearly felt that an Enhanced 4-Step Mode was warranted for this policy focus, and they would be unhappy with a Basic 3-Step Model. The estimated utility of upgrading to an Activity-Based Model is slightly less, but still 2.5 times higher than the utility of upgrading to an ABM for the Rural Highways Policy Focus.

For the Policy, Pricing & Environment Policy Focus, the estimated utility is higher because the range of applications is broader. Here, the values increase slightly for the upgrade, reflecting a sentiment expressed by some respondents that the simpler models may be inadequate to address the more complex policy questions.

Some additional observations from the interviews:

- Five states reported the same WTP across policy focus areas. This group believed that WTP is not dependent on policy focus.
- Some respondents reported a WTP of zero if the model was seen as an overkill (in the case of M3P1), or too limited for the type of policy (the case of M1P3).
- Five respondents suggested Activity based model (M3) has no value regardless of policy focus, citing “too complicated to maintain” or “would rather increase MPO modeling budget”. Four out of these five states were in the Policy, Pricing & Environment group, i.e. these states face a broad and complex set of policy question, and yet they do not see the added value of activity based model.
- Two respondents suggested that a basic three-step model does not provide any value, even if the state’s policy focus is rural highways (P1). One respondent felt that interchange modifications can be important for rural highway improvement and a basic three-step model is insufficient for such analysis.

It may be helpful to consider these estimated utilities in the context of costs.

Table 10 reported the total per-capita spending on statewide modeling over the past 10 years—the same units as our estimated utilities. Those costs are repeated in Table 17 along with the utilities. The utilities are reported both as marginal utilities and as cumulative utilities (the sum of the row values to that point). These data would suggest that the average perceived cost-benefit ratio of statewide models is between about 2.5 and 7.5, depending on the type of model and the policy focus. These results do not suggest that states should spend up to the willingness-to-pay limit. It is still best to minimize costs, and the results suggest that the actual costs are significantly less than the perceived value of statewide models.

Table 17 Total per-capita Spending vs Utility of Statewide Model over 10 Years

	Category	Basic 3-Step Model	Enhanced 4-Step Model	Activity-Based Model
Average 10-Year Spending per Capita	Population < 3,750,000	$0.25	$0.15	$0.42
	Population >= 3,750,000		$0.22	$0.39
Average 10-Year Willingness-to-Pay per Capita*	Rural Highways Focus	$0.61	$0.54 ($1.15)	$0.28 ($1.43)
	Congestion & Multi-Modal Focus	$0.78	$0.78 ($1.56)	$0.71 ($2.27)
	Policy, Pricing & Environment Focus	$0.83	$0.87 ($1.70)	$0.88 ($2.58)

* Upper values are marginal utility, lower values in parentheses are total utility, which is the sum of that cell and the cells to the left.

The state that spends the most per capita on statewide model reports spending just under $1.00 per capita over the past 10 years. It is a large state with a Policy, Pricing & Environment focus and an Activity-Based Model. That category has an estimated utility of $2.58 per capita total utility, relative to having no model. By these metrics, the state is perceived to be getting good value for its investment.

6.2 Other Approaches to Estimating the Utility of a Model

During the interviews, several respondents offered alternative means of valuing statewide models. A common argument was that the utility of a model lies in its ability to improve the odds of "making the right decision" about a transportation project. Given that a major project can cost tens or hundreds of millions of dollars, the potential cost of a mistake is high, relative to the cost of analysis.

The challenge is that it is difficult to know how much a particular model might improve the information available, and whether that information might affect the decision in a positive direction. To take an extreme example, it may be the case that the cities in China are growing so rapidly, and there is so much demand, that any transportation infrastructure you build will have large positive benefits. In such cases, it may be more important to get started on the construction, than to analyze the details a priori. There may also be cases where the effectiveness of the information provided by a model is not much higher than the next best alternative, as indicated for certain policies in Chapter 3.

Nonetheless, assuming that there is positive utility to statewide modeling, as the results above would suggest, it is logical to think that the utility of the model would be proportional to the capital budget for transportation projects. More specifically, some respondents suggested that the value may be a function of the capacity expansion budget for a DOT, because those are the projects where modeling analysis can be expected to have the most influence. This may be more restrictive if a DOT budget is dominated by its maintenance fund. But what is the right level?

One respondent suggested that the value may show up in the context of financing a toll project. The paraphrased logic is as follows:

> Consider a mega-project that costs $2 billion. For pricing, the model tells you how much you can finance with tolls. The model will get you +/- 20%. Without a model your error is 50%. The model would therefore reduce the error from +/- $500 million to +/- $200 million. Reducing the forecast error would allow the agency to be more aggressive in the financing and save money. Therefore, we should be willing to pay a portion of the $300 million error reduction.

While the numbers in this example are purely hypothetical, it represents an interesting line of logic for large projects specifically.

One respondent suggested that statewide modeling can be viewed as analogous to market research in a private firm. If an average company spends 1% of its budget on market research, then that might be a reasonable benchmark for states. Another analogy may be to metropolitan planning organizations (MPOs), where the MPO takedown from federal transportation spending has historically been 1.25%. While that includes planning and research more broadly, not just modeling, it does relate to project selection.

6.3 The Case for Statewide Modeling: What the States Told Us

In talking with the DOTs that operate statewide models, none cited a specific cost-benefit analysis of the value of modeling as the motivation for developing a statewide model. In part, this was because no such analysis has previously been available. Assuming there was sufficient institutional continuity, the respondents were able to identify the motivation for developing a statewide model. Those motivations are both diverse, and insightful. For example:

- Arizona was motivated by highway project selection and environmental analyses applications including: design-concept reports, corridor studies, and major highway improvements. Specific projects such as I-11, the North-South Freeway and SR-24 contributed to their decision to develop a statewide model, as did rapid population growth and the desire for consistent statewide estimates.

- Arkansas is a “bridge” state, with a high level of traffic through the state. They were interested in understanding where it was coming from and going.
- Colorado was interested in maximizing the ability of Colorado’s modelers to cooperate better. Specifically, rapid growth along the Front Range means that there is significant traffic flow between bordering MPO areas, and there was a need for a tool that could capture that interaction.
- Florida was experiencing rapid growth in the 1980s and the model started as a growth management tool.
- Georgia developed their statewide model in the context of a freight study.
- Iowa was in a position where they were already providing modeling support to MPOs, and wanted a tool that would also cover the non-MPO areas.
- The Kansas statewide model started as a regional model focused on the Kansas Turnpike.
- The Maine statewide model was developed in the context of a proposal to widen the Maine Turnpike, but a major related issue is travel associated with the logging and paper industries in Maine.
- North Carolina was interested in a tool that would provide consistent estimates throughout the state for the purpose of project prioritization.
- Texas developed a statewide model in the 1990s for the purpose of analyzing the effects of NAFTA.

Scanning this list reveals that many were developed in the context of specific projects associated with that particular state. There are also themes that emerged and were mentioned by multiple respondents. These themes go beyond the motivation for developing a model in the first place, and are often areas where respondents saw the model as particularly useful. They are summarized in sections 6.3.1 through 6.3.7.

6.3.1 Forecasting Traffic for New Facilities

Several respondents mentioned that while time-series methods may be suitable for forecasting traffic on existing roads, they cannot be applied in a meaningful way to forecast traffic on new facilities. To the degree that a DOT is interested in considering new transportation facilities in areas that are not already covered by an MPO model, these respondents felt that a statewide model was required.

6.3.2 Bridge Analysis

Three of the states reported that their statewide models had been useful in the analysis of bridges. The analysis, as reported, dealt primarily with investigating whether a bridge should be repaired/replaced or if a new bridge being built would be functionally and economically sensible. The three states that reported successes in bridge analysis are Maine, Michigan, and Oregon.

Maine used their statewide model to estimate the disbenefits of not carrying out a bridge replacement. The way this was done was by estimating the VMT (Vehicle Miles

Traveled) and VHT (Vehicle Hours Traveled) with and without the bridge. This estimate was used to gain a TIGER grant which was used to replace a bridge between Richmond and Dresden (the Kennebec River Bridge).

Michigan used their statewide model to help with the evaluation of long distance travel between Canada and Detroit when looking at the option of adding a new bridge. They stated that without their statewide model they would have had to rely primarily on the SEMCOG (Detroit MPO) model, which would not have been able to capture long-distance travel, given the geographic scope of the MPO area.

Oregon used their statewide model to create a "Rough Roads" report, and to analyze the value of bridges to the state economy for the purpose of prioritizing the maintenance and repair of those bridges. The "Rough Roads report was able to quantify the value of bridge repairs, and was instrumental in getting associated funding allocated.

6.3.3 Detour Analysis and Emergency Route Analysis

Three of the interviewed states reported having success stories with using their statewide models for detour analysis, route analysis, and/or emergency route analysis. Those three states were Iowa, Vermont, and Florida.

From the flooding of the Missouri river around 2014, Iowa was able to use their statewide model to determine how people would divert to avoid flooded areas. They were also able to determine where interstates would be heavily impacted by the detouring caused by the flooding, which was crucial in understanding where the heaviest impacts would be.

Vermont used their statewide model for both route analysis and emergency route analysis. For the route analysis they look at construction projects and were able to model how construction projects would affect routes of traffic. They also used the model to work with emergency route analysis following Hurricane Irene. They turned the statewide model into something that could provide emergency route analysis on the fly and did exercises with the statewide model to make sure that the model was able to properly determine the best route in the case of emergency.

Florida used their statewide model to look into the use of hard shoulders for hurricane evacuations. They also considered reversible lanes, but decided upon hard shoulders due to concerns that reversible lanes may lead to more crashes. The statewide model was used in both of these situations and now hard shoulders are used for evacuation purposes in case of emergencies.

6.3.4 External Flows for Urban Models

As with the bridge analysis, three of the interviewed states discussed the role their statewide model played in integrating with the states MPO models. Specifically, the integration is based on extracting external-external (EE), external-internal (EI), and internal-external (IE) flows from the statewide model for use in the MPO models.

6.3.5 Economic Analysis

Several states reported having successes with using their statewide models for carrying out economic analysis. For example, Michigan used their statewide to analyze expansion and preservation projects and how the economy would be affected by each.

Georgia used their statewide model to look at the future growth of a corridor of I-75 from Atlanta to Chattanooga. The statewide model was also used to look at freight studies related to the growth of this corridor and how the Georgia economy would prosper. They also reported that various other economic analyses were carried out using their statewide model.

In the case of economic analysis, a statewide travel model should be viewed as necessary, but not sufficient. The statewide travel model would provide an understanding of the traffic flows, and importantly the freight flows, as well as the travel time savings and associated benefits of a project. An economic impacts model, either integrated with or appended to the statewide travel model, is then necessary to translate those travel time savings and associate benefits into economic impacts.

6.3.6 Project Prioritization

Several states are using their statewide models for project prioritization. The goal in this case is to implement an analytical method to assist in ranking projects for inclusion in the statewide transportation plan. States reported using prioritization metrics that include projected travel time savings and congestion relief, among others. In order for the rankings to be fair throughout the state, it is necessary that they be measured using a consistent tool. If the analysis were to rely only on MPO models, it might create situations where differences in the model form or assumptions drive difference in the results more so than differences in the projects themselves. Further, it would leave a situation where there may not be an appropriate tool for ranking projects in non-MPO areas in the same manner.

6.3.7 Limitations

A number of respondents made a point to say that statewide models have some clear limitations, and that it is important not to have unrealistically high expectations for what they will do.

One state reported that the statewide model is not a tool for every aspect of modeling or work. The main examples that were reported were that the model is not a tool for analyzing toll settings and it is not a tool for analyzing turn lanes. It was also reported that the statewide model can be somewhat insensitive to some types of project improvements, such as pricing scenarios in their case.

Another reported issues in how precise the model can be compared to how precise they need the model to be. The interviewees reported challenges achieving an adequate level of convergence in their statewide model. In this case, the model has 5,000 TAZs and a detailed highway network, so it takes a large number of iterations in highway assignment at a significant computational cost to achieve a tight level of convergence. Convergence issues can be exasperated when considering the broader feedback between the demand and supply models. The practical issue is that insufficient convergence can lead to noisy results when two scenarios, such as a build and a no-build, are compared. When a project is small relative to the size of the network—picture an interchange project or minor arterial expansion in the scope of a relatively large state—then the resulting noise can overwhelm the measure of project impacts.

That same state reported limitations due to the coarseness of the model. In this case, the interest is in design traffic estimates throughout the state. At a project-level it may be desirable to have a more detailed roadway network or a more disaggregate zone system, but that level of detail may be difficult to achieve throughout the state.

In a few cases, states reported a need to a need to analyze a particular policy that went unfulfilled or was delayed because the statewide model was not ready or did not have the appropriate features. This included an inter-city rail project in a state that chose to phase the development of their statewide model, first developing a basic 3-step model, and then upgrading to an enhanced 4-step model. Because the initial development took longer than expected, the analysts were not able to meet the project schedule to evaluate the rail proposal. In another case, the modeling staff at a DOT did not anticipate a particular type of forecast that was requested while the model was being developed. They scrambled to engage a consultant to further upgrade the model and deliver the requested forecast. The respondent noted that if they had anticipated the request and planned accordingly, they could have saved both time and money.

Chapter 7: Summary and Conclusions

The objective of this research is to assess the costs and the utility of statewide travel demand models. The resulting report serves as a resource for technical and planning staff at DOTs. By reporting and quantifying the costs and benefits of different approaches, it allows those staff to make informed decisions about whether and how to engage in statewide modeling.

The research method involved structured interviews with statewide modelers and transportation planners from 29 DOTs and 5 consulting firms. The discussion below summarizes major findings from those interviews.

7.1 Cost

The respondents were presented three model development options, and asked to estimated the cost of each. The included going from no model to a Basic 3-Step Model, upgrading from a Basic 3-Step Model to an Enhanced 4-Step Model, and upgrading from an Enhanced 4-Step Model to an Activity-Based Model. Chapter 5 presents the results of this cost estimating exercise, and

Table 18 summarizes the total cost of model development and data collection. The columns in

Table 18 are for the different model development options, and the rows are segmented by the type of respondent: those from DOTs at small states, those from DOTs at large states, and those from consulting firms. Each cell presents the average estimate, as well as the lower quartile and upper quartile estimates.

Table 18 Summary of Estimated Model Development and Data Collection Costs

Average (Lower Quartile – Upper Quartile)

		Model Development Options		
		M1	M2	M3
		Start from: No Model	*Start from:* Basic 3-step model	*Start from:* Enhanced 4-step model
State Size		*Upgrade to:* Basic 3-step model with transferred model parameters, static truck trip tables.	*Upgrade to:* Enhanced 4-Step Model with estimated parameters, National Long-Distance Model, FAF-based commodity flows model, NHTS add-on sample.	*Upgrade to:* Activity-based model with estimated parameters, custom long-distance travel model, policy-sensitive freight model, custom travel surveys.
S1	Small State < 3.75 million population	$645,000 ($245,000-$1,031,000) Data Cost: N/A	$675,000 ($445,000-$868,000) Data Cost: 36%	$1,268,000 ($950,000-$1,394,000) Data Cost: 43%
S2	Large State >= 3.75 million population	$528,000 ($398,000-$650,000) Data Cost: N/A	$1,815,000 ($1,300,000-$2,125,000) Data Cost: 57%	$4,974,000 ($2,145,000-$7,944,000) Data Cost: 66%
S3	Consultant Estimate	$531,000 ($410,000-$500,000) Data Cost: N/A	$1,490,000 ($1,275,000-$1,800,000) Data Cost: 45%	$2,792,000 ($1,500,000-$4,170,000) Data Cost: 51%

The analysis revealed that a large portion of the cost of statewide modeling is associated with data collection. Each cell in

Table 18 also shows the percent of the cost associated with data collection. This includes both household travel surveys, and base-year data such as commercial speed data and trip tables derived from mobile phone data. The scenarios were defined such that the development of a Basic 3-Step Model would not involve any data collection, and would instead rely on model parameters transferred from other states or national reports. The interviews revealed very different judgments about the level of data collection desired to support statewide modeling (as well as for other uses), with that level being an important driver of the cost.

While these costs can provide a starting point for budgeting, they represent a specific model scope. The interviews revealed a diversity of approaches currently used in practice, many of which draw elements from more than one of the modeling approaches presented here. Chapter 5 presents more detailed tabulations, while Appendix F provides a worksheet that can be used to develop a customized cost estimate by selecting the desired components from different model types.

It is also important to note that statewide modeling is not a one-time cost. There is a need to operate and maintain the models, and to keep the data they use current. The tables in Chapter 5 include estimates for these costs. Whereas most states rely on contractors to develop their models, all but one state interviewed relies on their own staff to fill these maintenance roles.

7.2 Utility

DOTs reported using statewide models for a range of applications, as discussed in Chapter 4. The most common were to generate highway forecasts outside of urban areas, to evaluate alternative growth scenarios, and to evaluate pricing scenarios. They also rated statewide models as more effective than non-model alternatives for analyzing some types of projects, with the effectiveness varying by the type of model.

States reported a variety of motivations for developing statewide models. Often, statewide models were developed to support a specific project or study, and then continued in use after the completion of that study. Specific applications that were identified by multiple respondents as important motivators for statewide models include: forecasting traffic for new facilities, bridge analysis, detour and emergency route analysis, providing external flows for urban models, feeding into economic analysis, and providing a consistent basis for project prioritization.

Respondents repeatedly gave the advice that it is important to match your model to your policy interests. They suggested that the advantage of more sophisticated models was the ability to analyze a broader range of policies, and that such models had little value if the agency is not interested in those capabilities. Even with an interest in such policies, there was disagreement over the value of activity-based models. Some states saw them as useful tools, while others did not think they were worth the added complexity.

In an effort to quantify the value of statewide models, and to see how different model types align with different policy interests, respondents were given a series of scenarios in which they were asked how much they would be willing to pay for each model upgrade, given a specific policy focus of their agency. The three possible policy foci are: Rural Highways, Congestion and Multimodal, and Policy, Pricing and Environment. Each is summarized in blue in

Table 19, and each includes all of the applications considered in the policy focus before it.

Table 19 shows the results of this willingness to pay exercise. The values are the willingness to pay, reported as a 10-year cost per capita. For example, a state with 1 million population would be willing to pay $610,000 over 10 years ($0.61 x 1,000,000) to go from no model to a Basic 3-Step Model if their policy focus is rural highways. This would include the cost of developing the model, collecting data, and paying staff to operate and maintain it. The per capita framing recognizes that the same model serving a state with more people would have more utility. The values build upon each other. On average, a state with a rural highways policy focus would be willing to pay an additional $0.54 per capita to upgrade from a Basic 3-Step Model to an Enhanced 4-Step Model.

Table 19 Willingness to Pay for Model Upgrades, in 10-Year Cost per Capita

Average (Lower Quartile – Upper Quartile)

		Model Development Options		
		M1	M2	M3
		Start from: No Model	*Start from:* Basic 3-step model	*Start from:* Enhanced 4-step model
Policy Focus		*Upgrade to:* Basic 3-step model with transferred model parameters, static truck trip tables.	*Upgrade to:* Enhanced 4-Step Model with estimated parameters, National Long-Distance Model, FAF-based commodity flows model, NHTS add-on sample.	*Upgrade to:* Activity-based model with estimated parameters, custom long-distance travel model, policy-sensitive freight model, custom travel surveys.
P1	Rural highways: Primary need is to evaluate highway projects outside urban areas.	\$0.61 (\$0.28-\$0.69)	\$0.54 (\$0.09-\$0.78)	\$0.28 (\$0.00-\$0.37)
P2	Congestion & multi-modal: Also a need to evaluate projects in urban areas, transit projects, truck projects and/or rail/intermodal projects.	\$0.78 (\$0.28-\$0.85)	\$0.78 (\$0.30-\$0.88)	\$0.71 (\$0.30-\$1.00)
P3	Policy, pricing & environment: A need to test broader policy or global scenarios, such as congestion pricing, demand management, growth scenarios, demographic changes, environment, equity and connected & autonomous vehicles.	\$0.83 (\$0.25-\$1.00)	\$0.87 (\$0.33-\$1.13)	\$0.88 (\$0.40-\$1.08)

7.3 Cost versus Utility

A corollary question is how the costs relate to the utility. Table 20 shows one way of viewing this relationship. The first two rows show the average reported 10-year spending per capita on statewide modeling. This is what states reported they actually spent, not what they estimated for the above scenarios. The bottom three rows show the willingness to pay, taken from Table 20. The fact that the willingness to pay values are higher than the reported spending suggests that states are perceived to be getting good value for their investment in statewide modeling.

Table 20 Total per-capita Spending vs Utility of Statewide Model over 10 Years

	Category	Basic 3-Step Model	Enhanced 4-Step Model	Activity-Based Model
Average 10-Year Spending per Capita	Population < 3,750,000	$0.25	$0.15	$0.42
	Population >= 3,750,000		$0.22	$0.39
Average 10-Year Willingness-to-Pay per Capita*	Rural Highways Focus	$0.61	$0.54 ($1.15)	$0.28 ($1.43)
	Congestion & Multi-Modal Focus	$0.78	$0.78 ($1.56)	$0.71 ($2.27)
	Policy, Pricing & Environment Focus	$0.83	$0.87 ($1.70)	$0.88 ($2.58)

* Upper values are marginal utility, lower values in parentheses are total utility, which is the sum of that cell and the cells to the left.

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Appendix A: Literature Review

NCHRP Project 8-36C, Task 137

Assessing the Utility and Costs of Statewide Travel Demand Models

Literature Review

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With:

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December 13, 2016

TRANSPORTATION RESEARCH BOARD
NAS-NRC
LIMITED USE DOCUMENT

1. Introduction

The goal of this research is to assess the expected cost and utility that can be expected to accrue from developing or upgrading a statewide travel demand model. It will quantify the costs of statewide models, and both identify *and* quantify the benefits of statewide models in a range of situations. It will accomplish this using a novel approach that combines data on the revealed outcomes of existing statewide models, with the collective professional judgment of statewide modelers.

This literature review draws evidence from existing studies on the utility and cost of statewide models. It will be used in the study in three ways:

1. To document the revealed outcomes of existing statewide models,
2. To help define the modeling and policy scenarios based on the distribution of current practice, and
3. To provide a shared context for the scenario-based survey.

The third use is of particular importance because respondents will be asked to use their judgment to estimate the cost and utility for a set of modeling and policy scenarios. The literature review will be provided to the respondents for review prior to the survey, allowing them to become familiar with current practice and recent developments in statewide modeling, and make more informed judgments. To be respectful of their time, this review is deliberately parsimonious, with readers referred to the source reports for further details.

2. Previous Statewide Model Evaluations

Several past summaries of statewide modeling practice are available.

2.1 Summary of Past Evaluations

Early efforts to share information on statewide modeling include a 1998 conference on the topic (Transportation Research Board, 1999) and a *Guidebook on Statewide Travel Forecasting* (Horowitz, 1999) from the same time period. The *Guidebook* provides a detailed information on the available methods of forecasting, both with a model and with time-series methods (i.e. without a statewide model). Much of this is still relevant today, providing what could be considered “Forecasting 101”. The recommendations are worth re-visiting here for the purpose of asking which remain relevant, and how well we have followed them over the past 17 years. Of these, three relate to the data, with a focus on leveraging existing data sources as a starting point, followed by custom data collection for further enhancements. Two relate to the model form, with consideration both for consistency with the data and for the differences between urban and statewide travel. One recommendation it suggests that statewide models should not be used to evaluate the effects of small-scale projects, due to the need for detailed adjustments.

Finally, three recommendations relate to what could be termed the process of forecasting—not just developing the most sophisticated tool possible, but considering external evidence and critically evaluating the performance of this tool:

- Examine, simultaneously, alternative methods of modeling.
- Make use of expert panels in the modeling process.
- At future dates, assess the performance of the model(s) used.

It is these process areas, that the authors of the current report are most disappointed with our progress as an industry, and which may offer value in improving both the accuracy of forecasts and the consideration of risk.

Another large-scale attempt to share perspectives on statewide modeling occurred in 2004 with a peer exchange on the topic (Giaimo & Schiffer, 2005). At the time it was noted that statewide modeling was a recent phenomenon, with most statewide models developed over the previous 10 years. The methods in use at the time were relatively immature, and categorized based on the treatment of long-distanche passenger and freight travel. As noted in an analysis of flows in the urban and rural portions of Arizona, long-distance passenger and freight travel (as well as internal-external and external-external travel depending on the model boundaries) constitute a much larger share of vehicle miles traveled in a statewide context than in an urban context (Erhardt, 2012). A number of states at the time simply scaled up the urban modeling paradigm, with no consideration for these special markets. A few had some limited consideration, and two (Oregon and Ohio) were in the midst of ambitious integrated model development projects. The major motivations for developing statewide models was to support corridor studies or statewide system analyses previously done with ad-hoc methods. Major lessons from the peer exchange were 1) that support and interaction with decision-makers and end users is key to success, 2) it is easy to under-estimate the costs, and 3) data is a limiting factor.

NCHRP Synthesis 358 (Horowitz, 2006) documents the state of the practice in statewide modeling as of 2005 through a survey of state transportation agencies. At the time, 22 states had operational statewide models, with 6 more states in the process of developing a model. Minnesota had a partial model and Hawaii is a special case as an island state. The synthesis found that statewide models were used for a range of applications, including intercity corridor planning, providing consistency of forecasts throughout the state, and providing inputs to metropolitan models. It reported that the cost of developing statewide models varied from less than $100,000 to millions of dollars.

NCHRP Project 08-36, Task 76c (Horowitz, 2008) considered the relationship between statewide models and planning values and goals. It makes the point that models should be crafted to meet the needs of the stated planning values and goals.

In 2016, NCHRP Project 20-05, Topic 47-17 revisited the topic, providing a synthesis of Statewide and Mega-Regional Models (Donnelly & Moeckel, 2016). At this point, 29 states reported that they currently operate a statewide model, with 5 additional states developing new statewide models. In addition, 5 states did not respond to the survey, at least 3 of which are known to operate statewide models (Delaware, New Jersey and

Tennessee). Over the past decade, statewide models are continuing to become the norm, with the number of states operating or developing a statewide model has increased from 28 to 37. The findings of this report are discussed in further detail in the subsequent section on the current state of statewide modeling.

Several individual states have conducted feasibility studies of implementing statewide models.

Minnesota did so by surveying in-state stakeholders and statewide modelers in other states (Varma, 2007). The survey asked each group "Given the definition above, how valuable is development of a statewide travel model (STM)? Please use a scale of 0 (no value) to 5 (very valuable)." Officials at the Minnesota Department of Transportation (DOT) rated the average value at 3.25, while respondents at Metropolitan Planning Organizations (MPOs) in Minnesota rated the value somewhat higher: 4.2. The responses from officials at other state DOTs varied depending on whether or not they had a statewide model. Those who did, or were planning to develop one, rated its value at 4.0 (with one state in the process of development a STM giving a 3.0 rating), while those in states with no plans to develop an STM rating its value as 1.0. This result is not surprising given their respective decisions. The research recommended the incremental development of an STM, but as of 2016, Minnesota reported having no statewide model.

Researchers conducted an evaluation in South Dakota in 2008 (Sapkota & Schwinger, 2008). They found a perceived need for a better forecasting tool, but recommended against developing a 4-step travel model due to data limitations. Specifically, they cited the lack of behavioral data on rural trip making characteristics as a limiting factor. As of 2012, this limitation is mitigated by the availability of NCHRP Report 735: Long-Distance and Rural Travel Transferrable Parameters for Statewide Models (Schiffer, 2012). The South Dakota report also noted that traffic analysis zones (TAZs) in rural areas are typically very coarse, and very coarse zones limit the usefulness of a model for project-level analysis. This issue of TAZ resolution continues to be a problem for statewide models (Donnelly & Moeckel, 2016).

Researchers at the University of Maryland provided an evaluation of the Maryland Statewide Transportation Model and recommendations for prioritizing upgrades (Zhang, Cirillo, Xiong, & Hetrakul, 2011). As part of this, the authors conducted a review of statewide modeling practice in other states, and concluded "It is apparent from this review that investment in state-of-the-practice statewide transportation models is a necessary step toward rational and effective transportation decision-making at the statewide and corridor levels." They also note the relationship between the modeling paradigm and the types of applications for which the model is used.

2.2 Lessons from Past Evaluations

None of these past studies satisfactorily answer the questions posed to this research about the costs and utility of statewide models. In part, this may be because there is a greater focus on documenting existing practice, rather than specifically on the question of costs and utility. However, it is also in part because quantifying the costs and benefits is an inherently difficult problem. The most important lessons and issues are described below.

Sample Sizes are Small

The strongest form of evidence about the costs and utility of statewide models is based on the revealed outcomes of existing models. However, revealed outcome evidence in this situation is inherently limited due to the moderate number of states with relevant experience (37 states currently operating or developing a statewide model) and high variation in situations across the states. When a DOT is faced with a decision of what to do in their own state, this means that there are few states with a similar situation to base the experience upon.

Benefits Depend on Applications

With the exception of the Minnesota survey, the evaluations to date focus on a qualitative assessment of the benefits of statewide models. This is reasonable, because it is easy to ask agencies to list the benefits they have achieved from their statewide models. However, there is a risk of that process being reduced to a box-checking exercise. More valuable is information about the value or importance of those benefits, and how that importance relates to the specific planning needs of state transportation agencies. For example, a mostly rural state with a strong policy focus on transportation system preservation may face a very different set of planning issues than a fast-growing urban state with major congestion challenges. Likewise, a state with a long history of statewide modeling may have institutional relationships that allow a broader set of benefits than a state looking to develop a new statewide model may be able to achieve.

It is clear from these past evaluations that the benefits of statewide models very much depend on the applications for which they are used, with statewide models often developed with specific applications in mind. NCHRP Project 08-94 is currently aiming to develop a tool to help identify the appropriate travel forecasting methods for different types of applications (RSG, Kittelson & Associates, Inc., Oregon Systems Analytics LLC, & Keith Lawton Consulting, Inc., 2016). Any assessment of the value of statewide models must consider the likely applications, with implications for the design of our scenario based survey.

Costs are Difficult to Measure

The costs reported in NCHRP Synthesis 358 range from $25,000 to $6,000,000. This indicates a range of experience and makes it difficult to pinpoint an expected cost for developing a statewide model. NCHRP Project 20-05, Topic 47-17 found that the average expenditure on statewide modeling in the last year was $698,000, but that this number was skewed by one agency that spent $11,000,000 last year. Excluding this outlier gives an average expenditure last year of $343,000. The standard deviation of expenditures was nearly twice as high as the average, again indicating a very large range. The report notes some of the challenges in trying to pin down the appropriate cost range.

This outcome is consistent with the authors own experience attempting to specify the costs of advanced travel models for NCHRP Synthesis 406 (Donnelly, Erhardt, Moeckel, & Davidson, 2010). In interviewing agencies who had developed advanced models, we found that some agencies were reluctant or unable to specify the full model development cost, and many cautioned against attempts to generalize their own experience. This was for a few reasons. Consulting and other external costs were typically well documented, but these varied based on the level of staff time dedicated to the project, which was often more difficult to track precisely. Agencies that were at the cutting edge of developing new methods spent more, but the costs were expected to be lower for subsequent projects. In addition, the methods, extent of data collection, size of the agency, and planning needs varied such that for a limited number of agencies it was difficult to identify a "typical" experience. The same can be expected to be true for statewide models.

Data and Methods are Quickly Evolving

While the synthesis findings are a positive step, the field has advanced significantly over the past 10 years in ways that may change the balance of costs and benefits. These advances include improved methods of forecasting long-distance travel (Moeckel, Fussell, & Donnelly, 2015; Rohr et al., 2013), the documentation of transferable model parameters for statewide models (Schiffer, 2012), the development of a national travel demand model (Lu, Chen, & Zhang, 2015) and a national long-distance travel model (Outwater, Bradley, Ferdous, Bhat, et al., 2015), and the release of new versions of the Freight Analysis Framework (FAF).

Of particular interest are developments in the available data. Data was cited several times as a constraint in developing statewide models, as discussed in the South Dakota example. At its most basic form, it is necessary to develop an appropriate set of statewide networks, a TAZ system and the associated socioeconomic data. This in itself can involve a significant investment of staff resources. Custom travel surveys can be costly, and the state of long-distance travel data remains generally poor due in part low frequency of long-distance trips (Erhardt, in-review). However, there has been significant change over the past several years in the types and quantity of data available to statewide modelers, as well as the potential for integration with national models (Donnelly & Moeckel, 2016).

Collectively, these developments may provide an opportunity to develop either more effective or more economical statewide models than was possible 10 years ago, making it important to update the findings. Therefore, it is important that decisions about developing new or upgraded models consider not only the experience of agencies who developed models five or ten years ago, but also the availability of these current resources. Section 3 describes the current state of statewide modeling and the resources available in further detail.

Questionnaires can give Inconsistent Results

The standard method of conducting a synthesis of practice, as employed by NCHRP Synthesis 358 and NCHRP Project 20-05, Topic 47-17 is to conduct a survey using a paper or online questionnaire, and supplement the questionnaire responses with case studies. The questionnaire responses provide an overview of current practice, and the case studies allow for additional detail and explanation, but are limited to a small number of cases. The authors of Topic 47-17 describe the inconsistent responses they got to their questionnaire, which reduced their confidence in the validity of the results. They note that it would be relatively easy to clear up any confusion if you were interacting directly with the person, but the lack of interaction makes that follow up difficult. They are clear about their recommendations for future studies:

> "In a future study, it should be considered setting aside sufficient time and resources to conduct phone interviews instead of online surveys with every state to capture such inconsistencies during the interview...While such an approach would require a substantially higher effort to collect information, it appears to be the only viable approach to collect detailed information without inconsistencies in the answers."

There is precedent for such an approach, as NCHRP Synthesis 406 relied on a sample of 30 structured interviews, which allowed for the respondents to provide substantially more detail and explanation than could be accomplished in a non-interaction session.

A New Approach is Warranted

The existing syntheses of statewide modeling practice from 2006 and 2016 do much to document the current state of statewide modeling and the revealed outcomes of existing models. However, it is clear that the existing syntheses are insufficient for making an informed recommendation for whether and how to engage in statewide modeling for the reasons described above.

This research seeks to build upon these syntheses to:

1. Provide a larger number of responses for a more limited set of situations,
2. Relate the benefits more directly to the applications,
3. Capture cost information in a consistent manner,
4. Base the assessment in the present, with recognition of recently available resources, and
5. Collect this information via telephone or in-person interviews.

It will attempt this through the use of a novel, scenario-based survey that will ask statewide modelers to exercise their judgment in response to a set of hypothetical decisions they may be faces with upon taking a job at a new DOT. The details of this approach and these scenarios will be described in the relevant section of the final report.

3. Current State of Statewide Modeling

This section summarizes the current state of statewide modeling, including resources available for developing statewide models. The information is drawn from NCHRP Project 20-05, Topic 47-17 and the associated questionnaire responses, but summarized here to provide a concise overview for participants in the scenario-based survey.

3.1 Deployment

Figure 9 shows the status of statewide models in the United States, as documented by Donnelly and Moeckel (2016). 29 states reported that they currently operate a statewide model, with 5 additional states developing new statewide models. In addition, 5 states did not respond to the survey, at least 3 of which are known to operate statewide models (Delaware, New Jersey and Tennessee).

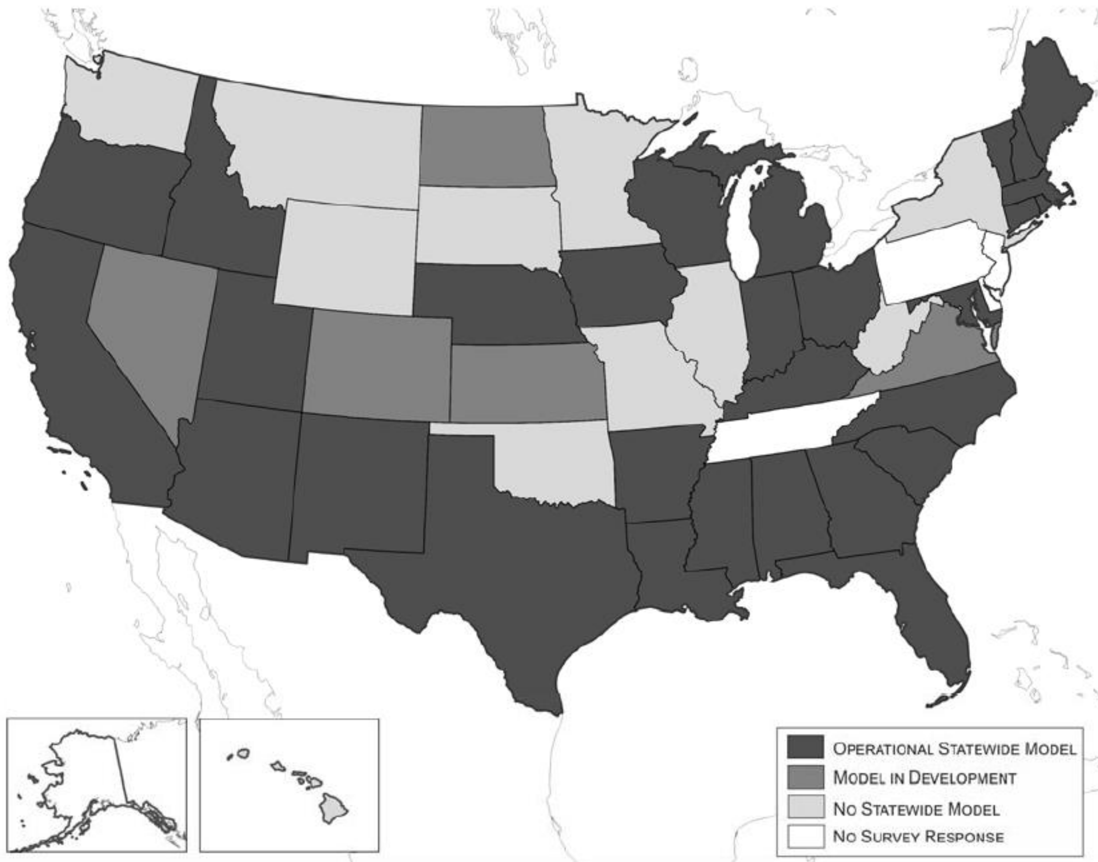

Figure 9: Status of Statewide Models (Donnelly & Moeckel, 2016)

3.2 Uses

Donnelly and Moeckel (2016) group the uses of statewide models into three categories: infrastructure scenarios that test changes to the built environment, policy scenarios that test changes such as tolls or regulations, and global scenarios that test large-scale and often exogenous changes such as the overall rate of growth. Their survey results, shown in Figure 10, indicate that the most common uses of statewide models are to test highway infrastructure scenarios, with a number of states also testing toll policy, pricing and other scenarios.

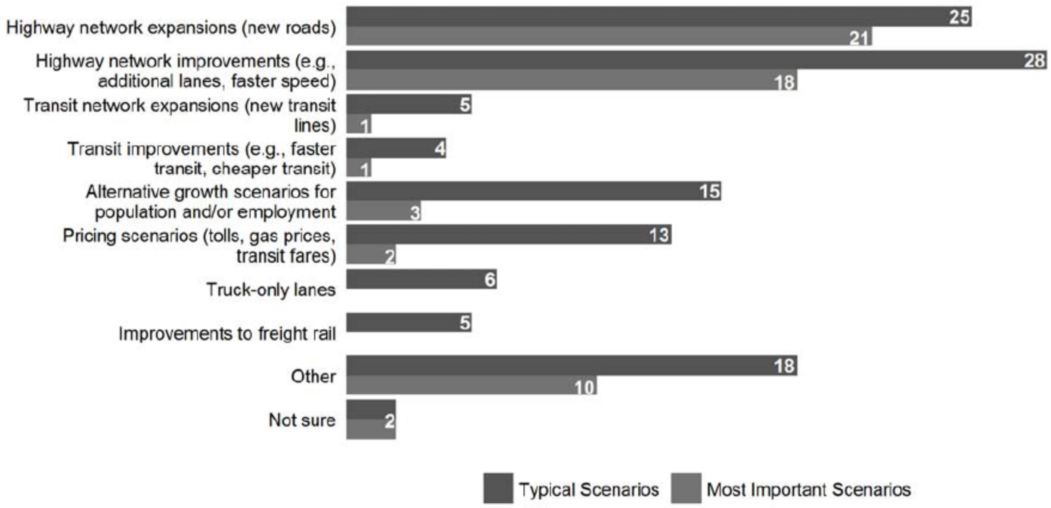

Figure 10 Typical Scenarios Tested with Statewide Models (Donnelly & Moeckel, 2016)

It is not clear from these results how many states use their models to test relatively small-scale projects versus using them exclusively for large corridor studies, nor is it clear whether the highway scenarios tested include those in urban areas, or are limited to locations outside major MPO boundaries. Both pieces of information are important to evaluating the value of a model when a portion of the state is covered by an MPO model that is likely to have more spatial detail.

3.3 Types of Models

A range of model types are currently in use at state DOTs. For statewide models, the long-distance and freight markets are of particular importance (Erhardt, 2012), and Donnelly and Moeckel break the methods for these types of travel separately than for short-distance personal travel.

Figure 11 shows the basic types of statewide models currently in use. For short-distance person travel, the most common approach is a four-step or three-step (without mode choice) model, with 25 in operation and six more in development. Five states report that they are currently operating an activity-based model, with two more currently developing an activity-based model. One of these two, Maryland, is upgrading from a four-step model.

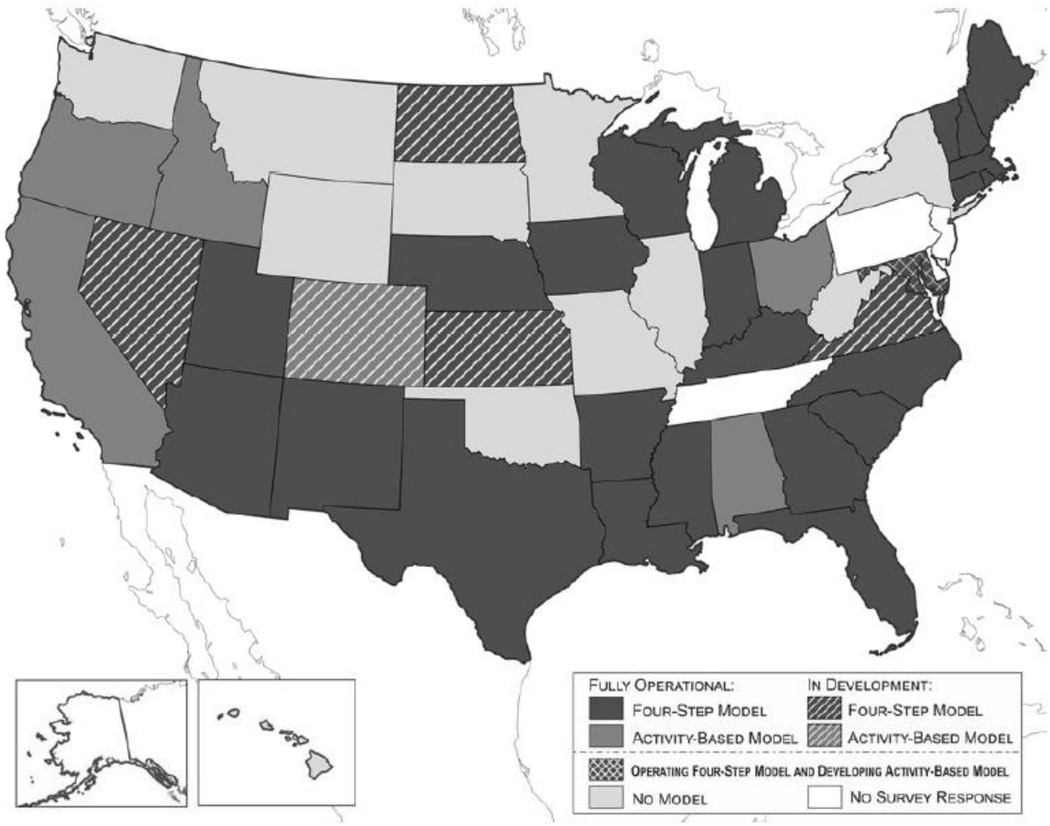

Figure 11 Types of Statewide Models (Donnelly & Moeckel, 2016)

Thirteen states report using an explicit long-distance travel model, in combination with their short-distance personal travel model.

Most, but not all, states consider truck travel explicitly. 26 state states use a model of long-distance trucks or freight, and 19 use a model for short-distance truck travel. Two more states use a static truck trip table.

In addition, some states use a complementary set of models that go beyond modeling travel. There is a variety of practice for generating economic forecasts. These are important because they provide the employment inputs to travel models for future years. Six DOTs use their own economic growth model, while the others most often use exogenous forecasts prepared by other state agencies or by external providers. Three states have an operational statewide land-use model integrated with their travel model, while two states reported that they are currently developing a land-use model. Eight states report being involved in environmental impacts modeling, most often using EPA's MOVES model for emissions analysis.

These aspects of statewide models can be and are combined in different ways. The definition of the scenarios for this project will consider these combinations in a logical way.

3.4 Costs

Figure 12 shows the reported expenditures on statewide models in recent years. As noted above, there are several caveats to these values. The values are skewed by one state that spent $11,000,000 last year. Excluding this outlier gives an average expenditure last year of $343,000. In addition, there are challenges to reporting and tracking these expenses, and a high level of variation in the results.

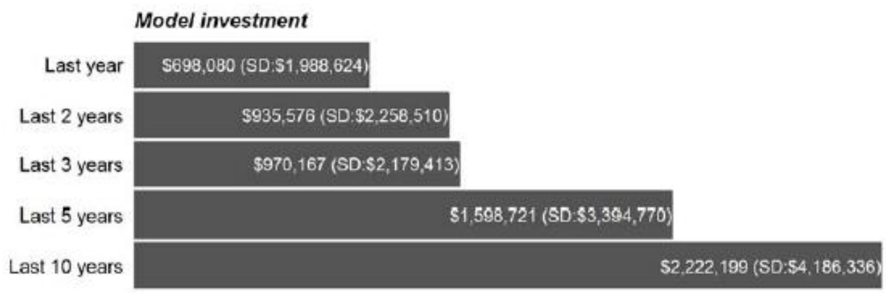

Figure 12 Reported Expenditures on Statewide Modeling, SD = Standard Deviation (Donnelly & Moeckel, 2016)

In addition to monetary costs, states also dedicate staff resources to statewide modeling. The number of full-time equivalent employees at DOTs dedicated to statewide modeling ranged from zero to six. However, this includes those states that do not operate a statewide model, which generally have no staff dedicated to the task. Among those states that are involved in statewide modeling, only two report having less than 0.1 FTE dedicated to the task and relying instead on consultants or partner agencies. Among states engaged in statewide modeling, the average number of FTEs dedicated to the task is 1.6, with a median of 1. It appears that most states see value in having someone in-house at the helm, which is consistent with past research indicating the value of an in-house champion for modeling projects (Donnelly et al., 2010; Giaimo & Schiffer, 2005).

3.5 Recent Developments and Resources Available

As noted above, there are a number of resources available that may make is possible to develop a statewide model more effectively or efficiently than was possible a few years ago.

These start from the proliferation of statewide models that use a variety of methods. As these models and methods become more common, it is reasonable to expect that subsequent model development efforts will be less cumbersome than those on the leading edge. This should occur as agencies share information on what did or did not work, and as consultants develop experience that can be transferred from one state to another.

Passenger Travel

Recent developments relevant to statewide modeling of passenger flows include the development of dedicated long-distance personal travel models (Erhardt, Freedman, Stryker, Fujioka, & Anderson, 2007; Rohr et al., 2013), the enhancement of those models to annual and seasonal scheduling effects (LaMondia & Bhat, 2011; LaMondia, Bhat, & Hensher, 2008), improvements to long-distance mode choice modeling (Moeckel et al., 2015), the validation of long-distance forecasting methods (Börjesson, 2014), and conceptual models of the effect of improving information and communications technology on long-distance travel (Erhardt, in-review).

Of particular relevance are two efforts that aim to make statewide models more transferrable by providing a common set of resources. NCHRP Report 735 (Schiffer, 2012) documents transferrable long-distance and rural parameters for use in statewide models. In doing so, it provides a resource that can be used to get a statewide model up and running without the upfront time and cost associated with conducting travel surveys. There are still benefits associated with local data collection, but the entry cost may be lower with transferrable parameters. Second, an effort recently developed a national long-distance travel model for the US (Outwater, Bradley, Ferdous, Bhat, et al., 2015; Outwater, Bradley, Ferdous, Pendyala, et al., 2015; Outwater, Bradley, Ferdous, Trevino, & Lin, 2015). This national model has since been used as the long-distance component of the Tennessee statewide model, avoiding the need for Tennessee to develop its own long-distance model (Bernardin Jr, Ferdous, Sadrsadat, & Chen, 2016).

Freight Transportation

Significant progress has been made in freight modeling as well. This can be separated into short-distance and long-distance categories. Recent work has focused on developing tour-based truck models (Gliebe, Cohen, & Hunt, 2007; Kuppam et al., 2014; Smith, Chen, Sana, & Outwater, 2013), which is logical because delivery trucks in particular rarely make direct out-and-back movements, relying instead on tours with many stops to maximize efficiency. A second area of research has been in modeling supply chains (Pourabdollahi, Karimi, Mohammadian, & Kawamura, 2016; Tatineni & Demetsky, 2005), as well as efforts to integrate multiple layers of freight models (Moeckel & Donnelly, 2016).

A reasonable starting point for basic freight models may be the Quick Response Freight Manual II (QRFM2) (Beagan, Fischer, & Kuppam, 2007). While it predates some of this more recent research, it provides a solid overview of more foundational approaches that can be used to incorporate freight into statewide models, such as basic 3- or 4-step truck models or commodity flow models.

Long-distance truck models at the statewide level tend to be dominantly commodity flow models (Donnelly & Moeckel, 2016), often using Freight Analysis Framework (FAF) or Transearch data to provide the commodity flows. Both can be valuable resources for developing a commodity flow model.

The FAF is currently in version 4, known as FAF4 (Fullenbaum & Grillo, 2016). It provides estimates of the tonnage and value of commodities by type and mode flowing between 132 zones in the US. Forecasts are provided in 5 year increments to 2045. Factors can be applied to disaggregate the flows and convert the tonnage to truck trips as has been done in the Ohio and Arizona statewide models. Transearch provides the same type of commodity flow data, but using a different methodology and through a commercial provider (Beagan et al., 2007).

Data

As noted above, data can be a limiting constraint in developing a statewide model. Therefore, it is important that someone considering developing a statewide model be familiar with the major data sources of relevance. These data sources are quickly evolving, with non-traditional “Big Data” sources becoming available from commercial providers or elsewhere. Donnelly and Moeckel (2016) provide a more detailed discussion of these resources.

One of the more labor intensive aspects of developing a first model can be coding networks. GIS representations of the street networks often provide a starting point, but significant manual effort is often required to ensure the connectivity and attribution required for a functional model, as well as to add centroid connectors. Commercial network data, such as those used in GPS navigators, offer the potential to reduce this effort, although challenges remain such as ensuring the proper attribution and dealing with centroid connectors. Transit networks can also be cumbersome, and are often coded from MPO networks. The General Transit Feed Specification (GTFS) is a standard data format that transit agencies use to publish their data so it can be used in applications such as routing in Google Maps. Scripts can be written to read GTFS data and convert it to a format appropriate for model input, such as in a citywide dynamic traffic assignment model developed in San Francisco (Erhardt et al., 2013).

TAZ systems usually start from Census geographies, but are often refined to aggregate in certain areas or sometimes to ensure logical boundaries with roadways. Census data generally provides good base-year household information, and employment data can be obtained either from state unemployment insurance records, commercial marketing databases, or the Longitudinal Employer-Household Dynamics (LEHD) data. The LEHD is a Census Bureau product that provides employment estimates by industry at the scale of Census tracts, although with some obfuscation to avoid privacy issues. It is available throughout the US.

Household travel surveys provide the most complete information about personal travel, and are the only source that allows behavioral travel models to be estimated, because they contain information about the movements trip purposes of individual travelers. The most commonly used household travel survey in statewide modeling is the National Household Travel Survey (NHTS), with the 2016 version currently in progress and 2009 as the most recent available version. The NHTS allows states to purchase add-on samples, which increases the sample size in their state, but avoids a stand-alone survey.

An important hole for statewide modeling data is poor data on long-distance travel. The 2009 NHTS did not include a long-distance component, so several recent studies relied on either the 2001-2002 NHTS or the 1995 American Travel Survey (ACS) (Erhardt, in-review). The basic challenge is that long-distance trips occur infrequently, so it is necessary to expand the sampling period to a period longer than one travel day to obtain a reasonable sized sample.

More recently, a number of non-traditional data sources are becoming available. Of particular note are data sources derived primarily from mobile phone location information, with proprietary algorithms applied to process those data. These include AirSage and StreetLight, which can provide trip tables. The data do not provide travel behavior data appropriate for estimating models, but they have larger sample sizes and can be used for a trip table of external flows, or of total travel where none exists previously. INRIX and other providers sell travel time data as well.

On the freight side, the FAF and Transearch remain important sources of commodity flows. More specific information on truck movements is provided by the American Trucking Research Institute (ATRI), which compiles and sells data from GPS devices on trucks. Active work is underway to figure out how to best utilize the ATRI data (Kuppam et al., 2014; Thakur et al., 2015; Zanjani et al., 2015). More detailed information local information can be obtained from commercial vehicle surveys or roadside truck surveys, with new strategies being employed to improve these types of surveys (Maoh, Khan, & Madar, 2016).

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Appendix B: Information for Interviewees (a.k.a. “The Cheat Sheet”)

NCHRP Project 8-36C, Task 137

Assessing the Utility and Costs of Statewide Travel Demand Models

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Information for Interviewees
a.k.a. "The Cheat Sheet"

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May 12, 2017

TRANSPORTATION RESEARCH BOARD
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Contents

1. Overview of the Process

RAND and the University of Kentucky are conducting a study for the National Cooperative Highway Research Program (NCHRP) to develop an understanding of the costs associated with the development of different types of statewide travel demand models (TDMs) and the value to state DOTs of having these models, given the focus of their policy analysis.

The goal of the project is to provide a resource to DOT staff such that they can make a more informed decision about whether they should implement or upgrade a statewide model, and if so, how much they should budget for doing so. To do this, we are undertaking a series of interviews with representatives of state DOTs and selected other individuals. The interviews will provide a means of understanding the actual costs and reported benefits of existing statewide models, as well as a means of gathering the respondents' collective judgment about how DOTs should proceed in different scenarios.

1.1 What to expect

You have been identified as someone knowledgeable of statewide modeling and of transportation planning issues in your state. We would value your participation to make this a successful project. Even if your state does not currently operate a statewide travel model, we would still value your participation, as it is important for us to incorporate the perspective of agencies that have not chosen to develop a statewide model.

The interview will be composed of three parts:

1. **About You and Your Agency:** You will be asked a series of questions on behalf of the agency that you represent. This will include information on the type of statewide model (if any) your agency currently uses, the costs of developing and maintaining that model, and the types policies that you are commonly asked to analyze.
2. **Scenarios: Estimating Costs:** In this section, imagine that you have started a job at a new DOT. You will be given three scenarios in which you are considering either developing a new statewide model, or upgrading an existing statewide model. For each scenario, you will be asked to develop a budget estimate.
3. **Scenarios: Go/No-Go Decisions:** Again, imagine that you have started a job at a new DOT. You will be given a series of scenarios in which you must recommend a go/no-go decision for whether this new DOT should proceed with a statewide modeling project at the cost specified. This section will include a total of nine scenarios, which vary based on the policies to be analyzed and on the type of model considered.

1.2 How to prepare

We understand that making recommendations for a budget and for a go/no-go decision can be can be challenging. Therefore, we have assembled some materials to help you make informed recommendations. These include:

1. **Literature Review:** The accompanying literature review summarizes and synthesizes reports about statewide modeling practice, including the data and methods commonly used in statewide models.
2. **Information for Interviewees:** This is the document you are currently reading, which we will also refer to as "The Cheat Sheet". This document categorizes existing statewide modeling practices by theme, considering the size of the state, the type of model used, and the policies commonly analyzed. It also provides existing cost data.

We ask that you review both documents prior to the interview. You may find it useful to keep this "Cheat Sheet" on hand when responding to the cost estimating scenarios or the go/no-go scenarios, so you know what other states are doing as you answer.

We also ask that you review our categorizations of your state in Section 2 and record the cost information requested in Section 3. We will collect this information from you at the interview itself. You will have the opportunity to ask questions or provide further comments at that point.

2. Categorizing Existing Statewide Modeling Practice

A key challenge in conducting this research is that the circumstances of each individual state vary. If our findings are too specific to individual circumstances, they may not apply to other states, but if they are so general as to apply universally, we may lose important distinctions. Therefore, we are aiming to achieve some balance between these two objections by grouping statewide modeling modelling practice in three dimensions:

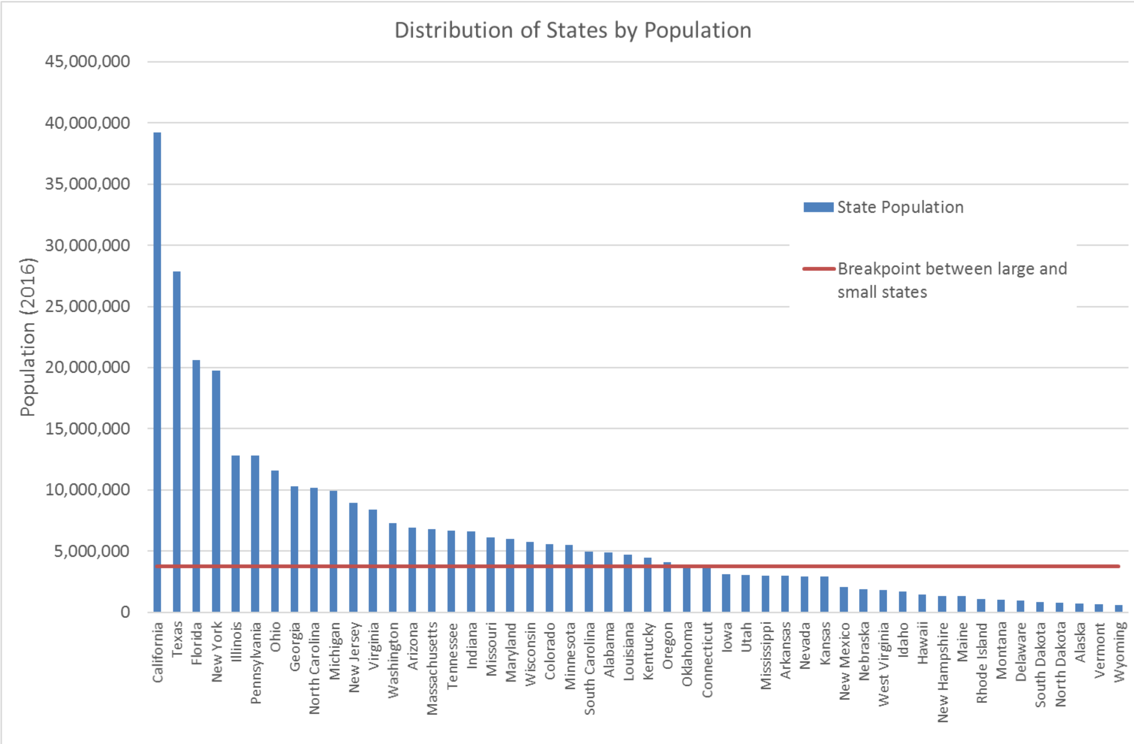
1. State Size
   a. Small state
   b. Large state
2. Model Type
   a. Basic 3-step model
   b. Enhanced 4-step model
   c. Activity-based model
3. Policy Focus
   a. Rural highways theme
   b. Congestion & multi-modal theme
   c. Policy, pricing & environment theme

The remainder of this section defines these categories in more detail, and shows the research team's initial assessment of which states fit within each category. This assessment is based on responses to a previous synthesis survey, NCHRP Project 20-05 Topic 47-17: Statewide and Mega-regional Models. The questions from that study do not perfectly align with the desired categories, so we have used our own judgment to interpret the responses. **Please review our categorization for your state, and record any corrections.**

2.1 State Size

For this exercise, a large state is defined as one with a population of 3.75 million or more. This definition gives 28 large states, with Oklahoma as the smallest large state, and 22 small states with Connecticut as the largest. Figure 1 shows the breakpoint and the distribution of states into large and small categories by population.

Figure 1: Classification of States into "Large" and "Small"



2.2 Model Type

We expect that both the cost and utility of a statewide model will depend on the specific features of that model. Therefore, we are grouping each statewide model into one of three categories, labeled as: a basic 3-step model; an enhanced 4-step model; or an activity-based model. Recognizing that the possible variation in features is more complex than the names implies, Table 1 shows additional features of each group.

Table 21: Model Type Definitions

Attributes\Model scenarios	Basic 3-Step Model	Enhanced 4-Step Model	Activity-Based Model
Networks & TAZs	Highway networks, TAZ system, socio-economic data	Highway networks, TAZ system, socio-economic data, urban transit networks, intercity air, rail & bus networks	Highway networks, TAZ system, socio-economic data, urban transit networks, intercity air, rail & bus networks, freight intermodal network
Baseline Data	Traffic Counts	Traffic Counts, Base IE/EI/EE trip tables from GPS or cell phone data	Traffic Counts, Full base trip tables from GPS or cell phone data
Survey Data	None	NHTS Add-On Sample	Custom Travel Surveys
Passenger Travel	Basic 3-step model (no-mode choice) with parameters from NCHRP 735 and NCHRP 716	4-step model with estimated model parameters	Activity-based model with estimated model parameters. Uses population synthesizer.
Long-Distance Passenger Travel	No explicit long-distance model	Adapted National Long-Distance Model	Develop custom long-distance travel model
Freight Transportation	Static truck trip table	Commodity flows adapted from FAF with truck flows assigned to network	Policy-sensitive freight model with non-Truck freight modes

What we have titled a basic 3-step model could be considered an ‘entry-level’ statewide model. It has basic functionality, is responsive to changes in TAZ data and highway networks. It does not include any custom data collection, other than some traffic counts. It does not have any special purpose models, such as an explicit long-distance travel model. The parameters are transferred based on recommendations in NCHRP 735: Long Distance and Rural Travel Transferable Parameters for Statewide Travel Forecasting Models (http://www.trb.org/Main/Blurbs/168389.aspx) and NCHRP 716: Travel Demand

Forecasting: Parameters and Techniques (http://www.trb.org/Publications/Blurbs/167055.aspx).

The second group, titled enhanced 4-step model, is a trip-based model with a greater degree of customization. We assume it to include urban transit networks and a mode choice model, and have an internal-external and external-external trip table as input that could be derived from an OD survey, or from mobile phone data. The coefficients may be estimated from an NHTS add-on sample, or other travel survey. It may have an explicit long-distance travel model and a commodity flow model that assigns trucks to the network.

The third group is an activity-based travel model, and broadly reflects a high degree of customization. It would operate using a population synthesizer (where the movements of individual travelers are simulated, rather than merely flows between zones), and reflect trip-chaining behavior. Model parameters are estimated from travel surveys. It includes an explicit long-distance travel model, and a detailed freight model that considers intermodal freight movements.

Table 2 shows our initial assessment of where each state fits within each group. We have marked each column with a 1, 2 or 3 depending on which description we think it is more similar to, and assigned it to an overall group based on the preponderance of features. For example, Arizona does not report having a mode choice model (thus it technically uses a 3-step model), but it reports other features reflecting specific enhancements. Therefore, we think it is most similar to the ‘enhanced 4-step model’ group.

Please review our classifications for your state, and circle the categories at the bottom of Table 2 that you believe are most similar to your state’s practice.

Table 2: Classification of Models by Type

State	Model Attributes						
	Networks & TAZs	Baseline Data	Survey Data	Passenger Travel	Long-Distance Passenger Travel	Freight Transport.	Overall Classification
Alabama	1	1	2	3	3	2	**3**
Alaska	No Survey Response						
Arizona	1	1	2	1	3	3	**2**
Arkansas	2	1	2	2	1	3	**2**
California	2	2	3	3	1	3	**3**
Colorado	2	2	3	3	3	3	**3**
Connecticut	2	1	3	2	1	1	**2**
Delaware	No Survey Response						
Florida	2	2	2	1	1	3	**2**
Georgia	2	1	2	2	1	3	**2**
Hawaii	No Model						
Idaho	2	1	3	3	3	3	**3**
Illinois	No Model						
Indiana	2	1	2	2	1	2	**2**
Iowa	2	2	2	1	2	3	**2**
Kansas	2	2	1	1	1	1	**1**
Kentucky	2	2	2	2	1	3	**2**
Louisiana	2	1	2	1	1	3	**2**
Maine	2	2	2	1	1	3	**2**
Maryland	1	1	2	3	3	3	**3**
Massachusetts	2	2	3	2	1	1	**2**
Michigan	2	1	2	2	1	2	**2**
Minnesota	No Model						
Mississippi	2	2	2	1	1	3	**2**
Missouri	No Model						
Montana	No Model						
Nebraska	2	1	1	2	1	1	**1**
Nevada	2	1	1	2	1	1	**1**
New Hampshire	2	1	3	2	1	1	**2**
New Jersey	No Survey Response						
New Mexico	2	1	1	1	1	2	**1**
New York	No Model						
North Carolina	2	1	2	2	3	3	**2**
North Dakota	2	1	3	1	1	2	**2**
Ohio	2	1	3	3	3	3	**3**
Oklahoma	No Model						
Oregon	2	1	3	3	3	2	**3**
Pennsylvania	No Survey Response						
Rhode Island	2	2	1	1	1	1	**1**
South Carolina	2	1	2	2	1	3	**2**
South Dakota	No Model						
Tennessee	No Survey Response						
Texas	2	1	2	2	3	3	**2**
Utah	2	1	3	2	3	3	**2**
Vermont	2	1	2	2	1	1	**1**
Virginia	2	2	2	2	3	3	**2**
Washington	No Model						
West Virginia	No Model						
Wisconsin	2	1	2	2	3	3	**2**
Wyoming	No Model						
Classification Codes	1-Hwy only	1-Counts only	1-None	1-3 step with transferred parameters	1-None	1-Static trip table	**1-Basic trip based model**
	2-Hwy & transit	2-Counts & GPS or cell phone data	2-NHTS add-on	2-4 step with estimated parameters	2-Adapted national LDT model	2-Commodity flows from FAF	**2-Enhanced 4-step model**
			3-Custom survey	3-Activity based	3-Custom LDT model	3-Policy sensitive freight model	**3-Activity based model**

2.3 Policy Focus

Analysts at state DOTs may be asked to provide insight to a range of policy questions relevant to their state. Different states may place a greater focus on different policies. In Table 3, we group these into three main policy focus areas.

Table 3: Overview of Policy Focus Areas

	Rural Highways	Congestion & Multi-Modal	Policy, Pricing and Environment
Highway forecasts outside urban areas	X	X	X
Highway forecasts in urban areas		X	X
Transit projects		X	X
Evaluating walk and bike mode shares		X	X
Truck-only lanes, truck climbing lanes and truck passing lanes		X	X
Freight rail & intermodal freight projects		X	X
Pricing scenarios (tolls, gas prices, transit fares, congestion pricing)			X
Travel demand management			X
Alternative growth scenarios			X
Effects of changing demographics (aging population, immigration, etc.)			X
Air quality, greenhouse gas and environmental analysis			X
Equity analysis & environmental justice			X
Connected & autonomous vehicles			X

For the Rural Highways policy focus, the DOT is primarily involved in evaluating highway projects outside the states urban areas. It is expected that the MPO models would be used within the urban areas.

In the Congestion & Multi-Modal focus area, the state is still interested in evaluating rural highway projects, but is also involved in evaluating projects where congestion is a major issue, or where non-car modes are of particular importance. A statewide model may be used to provide consistent estimates throughout the state, including in the urban areas, or it might be used for specific projects such as evaluating freight inter-modal facilities, truck-only lanes, or bicycle and pedestrian issues.

In the Policy, Pricing & Environment focus area, DOT analysts may be involved in all of the above projects, but also be asked to evaluate broad policy issues, such as alternative growth scenarios, pricing studies, or the effects of changing demographics.

Table 5 shows our initial assessment of the policies analyzed by each state DOT. A 1 in the columns indicates that the policy is analyzed, and a 2 indicates that the policy is a priority. The last column provides our initial assessment of the policy focus group. These values are set based on responses to a similar set of questions asked by NCHRP Project 20-05 Topic 47-17. **Those questions do not perfectly align with these categories, so we ask you to review Table 4 and provide your own assessment of the policies of interest to your state in the last row of the table.**

Table 4: Policy Focus Classifications

	Type of Scenario (0-Not used; 1-Used; 2-Priority)													
State	Rural Highways	Urban Highways	Transit	Walk & Bike	Trucks	Freight & Inter-modal	Pricing	Travel Demand Mgmt	Growth scenarios	Changing Demo-graphics	Air & Environ-ment	Equity	Connected & autono-mous vehicles	Overall Classification
Alabama	2	2	0	0	0	0	1	0	0	0	0	0	0	3-Policy, Pricing & Environment
Alaska	No Survey Response													
Arizona	2	2	0	0	0	0	1	0	1	0	0	0	0	3-Policy, Pricing & Environment
Arkansas	2	2	0	0	1	0	1	0	1	0	0	0	0	3-Policy, Pricing & Environment
California	2	2	1	0	1	1	2	0	1	0	0	0	0	2-Congestion & Mulit-modal
Colorado	0	0	0	0	0	0	0	0	0	0	0	0	0	1-Rural Highways
Connecticut	2	2	2	0	0	0	0	0	1	0	0	0	0	2-Congestion & Mulit-modal
Delaware	No Survey Response													
Florida	2	2	0	0	0	0	0	0	0	0	0	0	0	1-Rural Highways
Georgia	2	2	0	0	0	0	0	0	0	0	0	0	0	1-Rural Highways
Hawaii	No Model													
Idaho	2	2	0	0	0	0	0	0	0	0	0	0	0	1-Rural Highways
Illinois	No Model													
Indiana	2	2	0	0	1	0	1	0	1	0	0	0	0	3-Policy, Pricing & Environment
Iowa	2	2	1	0	1	1	0	0	2	0	0	0	0	2-Congestion & Mulit-modal
Kansas	2	2	0	0	0	1	2	0	0	0	0	0	0	3-Policy, Pricing & Environment
Kentucky	2	2	0	0	0	0	1	0	2	0	0	0	0	3-Policy, Pricing & Environment
Louisiana	2	2	0	0	0	0	0	0	0	0	0	0	0	1-Rural Highways
Maine	0	0	0	0	0	0	1	0	0	0	0	0	0	3-Policy, Pricing & Environment
Maryland	2	2	1	0	1	0	1	0	2	0	0	0	0	3-Policy, Pricing & Environment
Massachusetts	0	0	0	0	0	0	0	0	0	0	0	0	0	1-Rural Highways
Michigan	2	2	0	0	0	0	0	0	0	0	0	0	0	1-Rural Highways
Minnesota	No Model													
Mississippi	2	2	0	0	0	0	1	0	1	0	0	0	0	3-Policy, Pricing & Environment
Missouri	No Model													
Montana	No Model													
Nebraska	2	2	0	0	0	0	0	0	0	0	0	0	0	1-Rural Highways
Nevada	0	0	0	0	0	0	0	0	0	0	0	0	0	1-Rural Highways
New Hampshire	0	0	0	0	0	0	0	0	0	0	0	0	0	1-Rural Highways
New Jersey	No Survey Response													
New Mexico	2	2	0	0	0	0	0	0	1	0	0	0	0	3-Policy, Pricing & Environment
New York	No Model													
North Carolina	2	2	0	0	0	0	0	0	1	0	0	0	0	3-Policy, Pricing & Environment
North Dakota	0	0	0	0	0	0	0	0	0	0	0	0	0	1-Rural Highways
Ohio	2	2	0	0	0	1	1	0	0	0	0	0	0	2-Congestion & Mulit-modal
Oklahoma	No Model													
Oregon	1	1	0	0	0	0	1	0	0	0	0	0	0	3-Policy, Pricing & Environment
Pennsylvania	No Survey Response													
Rhode Island	2	2	2	0	0	0	0	0	1	0	0	0	0	2-Congestion & Mulit-modal
South Carolina	2	2	0	0	0	0	0	0	0	0	0	0	0	1-Rural Highways
South Dakota	No Model													
Tennessee	No Survey Response													
Texas	1	1	0	0	0	1	1	0	1	0	0	0	0	3-Policy, Pricing & Environment
Utah	2	2	0	0	0	0	0	0	1	0	0	0	0	3-Policy, Pricing & Environment
Vermont	2	2	0	0	1	0	0	0	1	0	0	0	0	2-Congestion & Mulit-modal
Virginia	2	2	0	0	0	0	0	0	0	0	0	0	0	1-Rural Highways
Washington	No Model													
West Virginia	No Model													
Wisconsin	0	0	0	0	0	0	0	0	0	0	0	0	0	1-Rural Highways
Wyoming	No Model													
My state														

2.4 Summary

Table 5 shows a combined view of how the states, their policy focus areas, and their models are grouped. **Please review this information, and circle the box where you feel your state best fits.**

Table 5: Overview of Size, Policy and Model Type Classifications

<table>
<tr><th rowspan="2">State Size</th><th rowspan="2">Policy Focus Area</th><th colspan="4">Model Classification</th></tr>
<tr><th>No Model or No Response</th><th>Basic 3-Step Model</th><th>Enhanced 4-Step Model</th><th>Activity-Based Model</th></tr>
<tr><td rowspan="3">Population < 3,750,000</td><td>Rural Highways</td><td rowspan="3">Alaska, Delaware, Hawaii, Montana, South Dakota, West Virginia, Wyoming</td><td>Nebraska, Nevada</td><td>New Hampshire, North Dakota</td><td>Idaho</td></tr>
<tr><td>Congestion & Multi-Modal</td><td>Rhode Island, Vermont</td><td>Connecticut, Iowa</td><td></td></tr>
<tr><td>Policy, Pricing & Environment</td><td>Kansas, New Mexico</td><td>Arkansas, Maine, Mississippi, Utah</td><td></td></tr>
<tr><td rowspan="3">Population >= 3,750,000</td><td>Rural Highways</td><td rowspan="3">Illinois, Minnesota, Missouri, New York, New Jersey, Oklahoma, Pennsylvania, Tennessee, Washington</td><td></td><td>Florida, Georgia, Louisiana, Massachusetts, Michigan, South Carolina, Virginia, Wisconsin</td><td>Colorado</td></tr>
<tr><td>Congestion & Multi-Modal</td><td></td><td></td><td>California, Ohio</td></tr>
<tr><td>Policy, Pricing & Environment</td><td></td><td>Arizona, Indiana, Kentucky, North Carolina, Texas</td><td>Alabama, Maryland, Oregon</td></tr>
</table>

3. Cost Data

In planning and budgeting for a statewide model, it is useful to know what other statewide models have cost. The costs we consider are divided into external costs—to pay consultants, license software, purchase data, etc.—versus internal costs of staff time.

Two existing synthesis reports have collected data on the cost of statewide models, so we start from those. In 2005, NCHRP Synthesis 358 asked:

> "How much did/will it cost to develop the model?"

In 2016, NCHRP 20-05 Topic 47-17 asked,

> "How much money did your State invest into statewide modeling over the last few years (including data purchase, surveys, hard- and software, consultant fees, but excluding costs for staff). Please provide data for several lines if readily accessible to you.
>
> > Over the last year, we spent about:
> > Over the last 2 years, we spent about:
> > Over the last 3 years, we spent about:
> > Over the last 5 years, we spent about:
> > Over the last 10 years, we spent about:"

It also asked:

> "How many employees (full-time equivalent) at your agency work predominately in statewide modeling?"

Table 6 shows the responses to these questions, from 11 years apart, in the latter 2016 case focusing on the total cost over 10 years. Several observations can be made in this table. First, the data are not perfect, and there appear to be some missing responses. Second, the relationship between the 2005 and 2016 responses is dependent on the potential overlap in the periods and the interpretation therein. For example, Ohio reported that they did/will spend $6,000,000 in 2005, and in 2016 they reported that they spent $8,691,000 over the past 10 years. It appears that the initial $6,000,000 is included in the latter total. In contrast, Texas reported spending $1,700,000 in 2005, but in 2016 reported spending only $450,000 over the last 10 years. It appears here that there was an initial cost of development reported in 2005, and the 2016 value accounts for smaller updates and maintenance. It makes sense that there should be a lower ongoing maintenance cost.

Table 6: Costs of Statewide Modeling

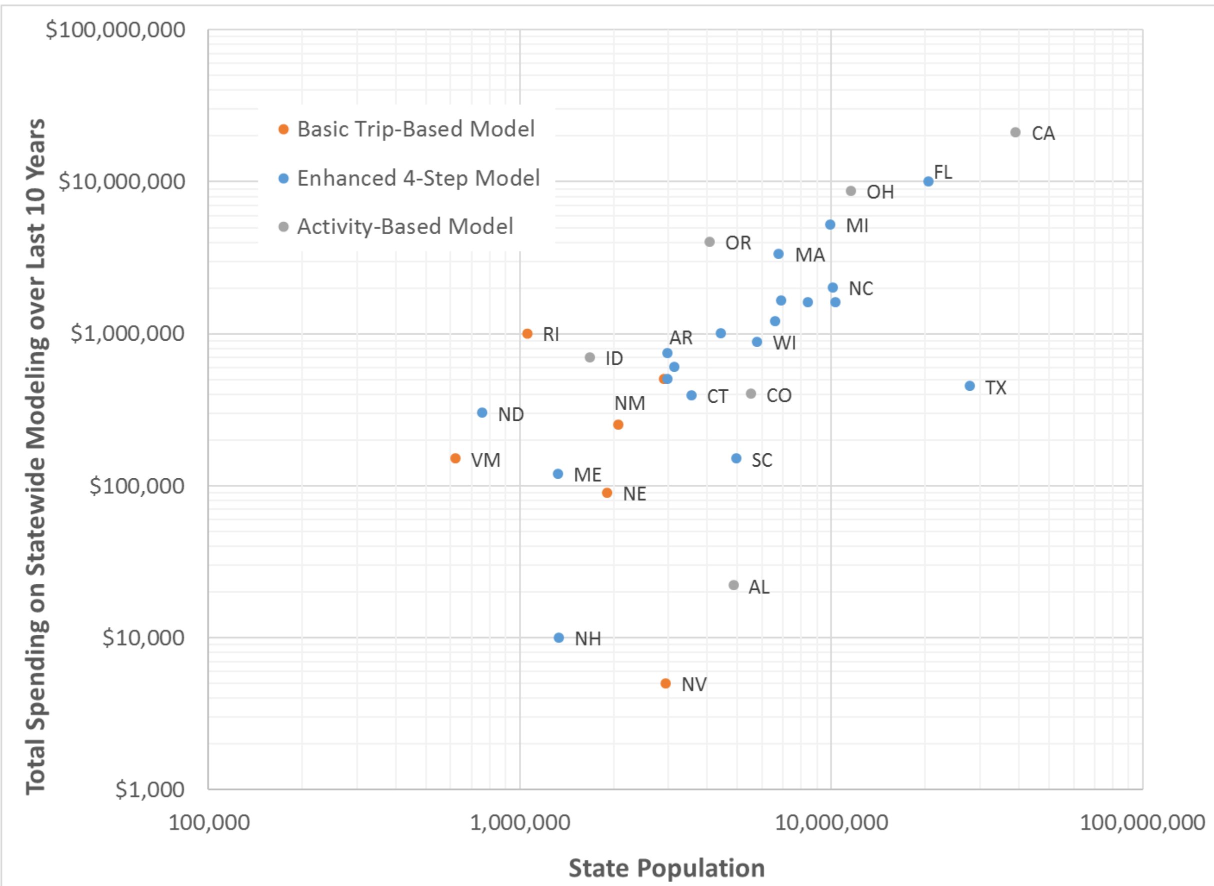
State	Population	Model Classification	Cost, as of 2005*	Dedicated FTEs**	Total spending over last 10 years, as of 2016**
Alabama	4,863,300	Activity Based		2	$22,000
Alaska	741,894	No Survey Response			
Arizona	6,931,071	Enhanced 4-Step		1	$1,650,000
Arkansas	2,988,248	Enhanced 4-Step		0.75	$747,389
California	39,250,017	Activity Based	$200,000	2	$21,000,000
Colorado	5,540,545	Activity Based	$400,000	4	$400,000
Connecticut	3,576,452	Enhanced 4-Step		1.5	$390,800
Delaware	952,065	No Survey Response			
Florida	20,612,439	Enhanced 4-Step	$1,500,000	6	$10,000,000
Georgia	10,310,371	Enhanced 4-Step	$65,000	0	$1,600,000
Hawaii	1,428,557	None		0	$0
Idaho	1,683,140	Activity Based		1.25	$700,000
Illinois	12,801,539	None		0	$0
Indiana	6,633,053	Enhanced 4-Step	$1,500,000	5	$1,200,000
Iowa	3,134,693	Enhanced 4-Step	$300,000	0.75	$600,000
Kansas	2,907,289	Basic 3-Step		2	$500,000
Kentucky	4,436,974	Enhanced 4-Step	$370,000	1	$1,000,000
Louisiana	4,681,666	Enhanced 4-Step	$500,000	1	$0
Maine	1,331,479	Enhanced 4-Step	$500,000	0.55	$120,000
Maryland	6,016,447	Activity Based		2	$0
Massachusetts	6,811,779	Enhanced 4-Step	$800,000	0.05	$3,350,000
Michigan	9,928,300	Enhanced 4-Step	$1,000,000	5	$5,227,012
Minnesota	5,519,952	None		0	$0
Mississippi	2,988,726	Enhanced 4-Step		1	$500,000
Missouri	6,093,000	None	$500,000	0	$0
Montana	1,042,520	None		0	$0
Nebraska	1,907,116	Basic 3-Step		1	$90,000
Nevada	2,940,058	Basic 3-Step		2	$5,000
New Hampshire	1,334,795	Enhanced 4-Step	$2,000,000	0	$10,000
New Jersey	8,944,469	No Survey Response	$500,000		
New Mexico	2,081,015	Basic 3-Step		1	$250,000
New York	19,745,289	None		0	$0
North Carolina	10,146,788	Enhanced 4-Step		0.5	$2,000,000
North Dakota	757,952	Enhanced 4-Step		1	$300,000
Ohio	11,614,373	Activity Based	$6,000,000	1.25	$8,691,200
Oklahoma	3,923,561	None		0	$0
Oregon	4,093,465	Activity Based		1	$4,000,000
Pennsylvania	12,784,227	No Survey Response			
Rhode Island	1,056,426	Basic 3-Step		2	$1,000,000
South Carolina	4,961,119	Enhanced 4-Step	$25,000	0.25	$150,000
South Dakota	865,454	None		0	$60,000
Tennessee	6,651,194	No Survey Response			
Texas	27,862,596	Enhanced 4-Step	$1,700,000	1	$450,000
Utah	3,051,217	Enhanced 4-Step		1.5	$0
Vermont	624,594	Basic 3-Step	$730,000	0.5	$150,000
Virginia	8,411,808	Enhanced 4-Step	$1,500,000	1	$1,600,000
Washington	7,288,000	None		0	$90,000
West Virginia	1,831,102	None		2	$0
Wisconsin	5,778,708	Enhanced 4-Step	$850,000	1	$879,157
Wyoming	585,501	None		0	$0

*As reported in NCHRP Synthesis 258, Spring 2005. **As reported in NCHRP 20-05 Topic 47-17, Summer 2016.

Table 6 also shows a high variation in the reported cost for states that have a statewide model. At least part of this variation is related to the population of the state, with bigger states tending to spend more. Figure 2 illustrates this effect, showing the population against spending. Due to the high variation in both, it is plotted on a log-log scale, and clearly shows a correlation. For example, the $21,000,000 California reports spending on statewide modeling over the past 10 years is in line with other states, relative to their size. This may reflect a combination of either a greater challenge of modeling a more complex state, or a larger DOT budget.

Among the outliers, Texas had a $1,700,000 cost reported in the 2005 survey, and New Hampshire had a $2,000,000 cost reported in the 2005 survey. Adding these costs would move those two states more in line with the broader cloud.

Figure 2: State Population vs 10-Year Spending on Statewide Modeling



Tables 7, 8 and 9 present the same information summarized by the type of model and the size of the state. Among states with a model, it appears common to have 1 or 2 FTEs (Full-Time Equivalents) dedicated to statewide modeling. The average spending on statewide modeling is generally between 15 and 42 cents per capita over the past 10 years, with Oregon spending the most at 98 cents per capita.

Table 7: FTEs Dedicated to Statewide Modeling

Average (Range)

State Size	Basic 3-Step Model	Enhanced 4-Step Model	Activity-Based Model
Population < 3,750,000	1.4 (0.5 to 2)	0.9 (0 to 1.5)	1.3 (1.25 to 1.25)
Population >= 3,750,000		1.8 (0 to 6)	2.0 (1 to 4)

Table 8: Total Spending on Statewide Modeling over Last 10 Years

Average (Range)

State Size	Basic 3-Step Model	Enhanced 4-Step Model	Activity-Based Model
Population < 3,750,000	$333,000 ($5,000 to $1,000,000)	$334,000 ($0 to $747,000)	$700,000 ($700,000 to $700,000)
Population >= 3,750,000		$2,239,000 ($0 to $10,000,000)	$5,686,000 ($0 to $21,000,000)

Table 9: Total Per-Capita Spending on Statewide Modeling over Last 10 Years

Average (Range)

State Size	Basic 3-Step Model	Enhanced 4-Step Model	Activity-Based Model
Population < 3,750,000	$0.25 ($0.00 to $0.95)	$0.15 ($0.00 to $0.40)	$0.42 ($0.42 to $0.42)
Population >= 3,750,000		$0.22 ($0.00 to $0.53)	$0.39 ($0.00 to $0.98)

While the above information is a useful starting point for understanding the total costs, it would be useful to better understand the elements that contribute to that total. **To support this, we ask you to fill Table 10 with the amount your state has spent on statewide modeling. Please provide your best estimate of the external cost and staff time dedicated to each element.** We will review and collect this information at the interview.

Table 10: Your Agency's Spending on Statewide Modeling

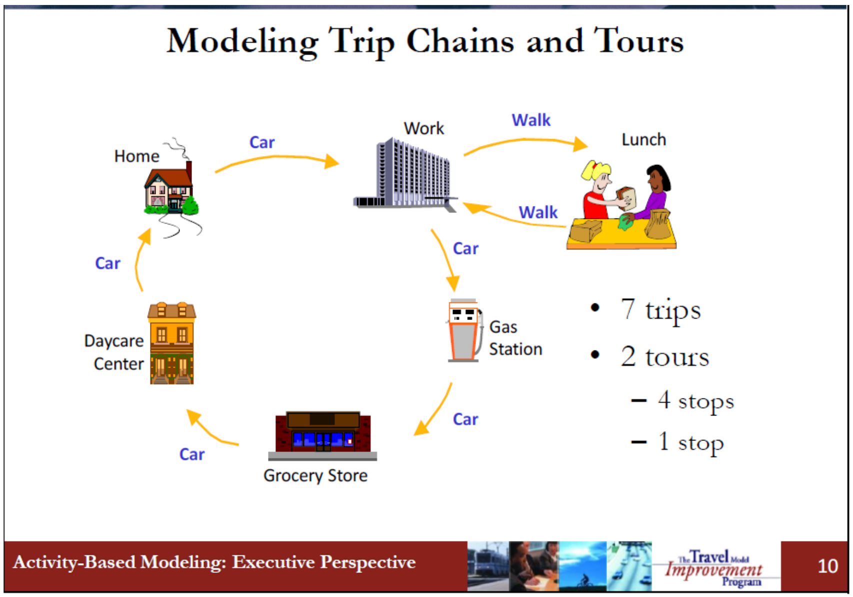
Category	Tasks	Cost ($) (external consultants, purchases)	In house staff cost (person-hours) (2080 hrs/yr)	Notes & Assumptions
Networks & TAZs	Code highway networks, urban transit networks, intercity networks, freight intermodal networks, TAZ system, develop socio-economic data.			
Baseline Data	Collect traffic counts or speed data, purchase GPS or mobile phone data.			
Survey Data	Conduct household travel surveys or other surveys, purchase NHTS add-on samples.			
Passenger Travel	Develop passenger travel models, estimate coefficients, software implementation.			
Long-Distance Passenger Travel	Develop long-distance passenger travel models, estimate coefficients, software implementation.			
Freight Transportation	Develop freight & commercial vehicle models, estimate coefficients, software implementation.			
Calibration and Validation	Calibrate and validate model, conduct sensitivity testing.			
Annual Maintenance & Troubleshooting (cost per year)	Maintain networks, update socio-economic data, troubleshoot problematic model results/errors.			
Other	Other costs not listed above (please explain).			

Appendix: Topic "Fact Sheets"

The following pages contain "fact sheets" with general information on specific topics or resources referenced in the survey.

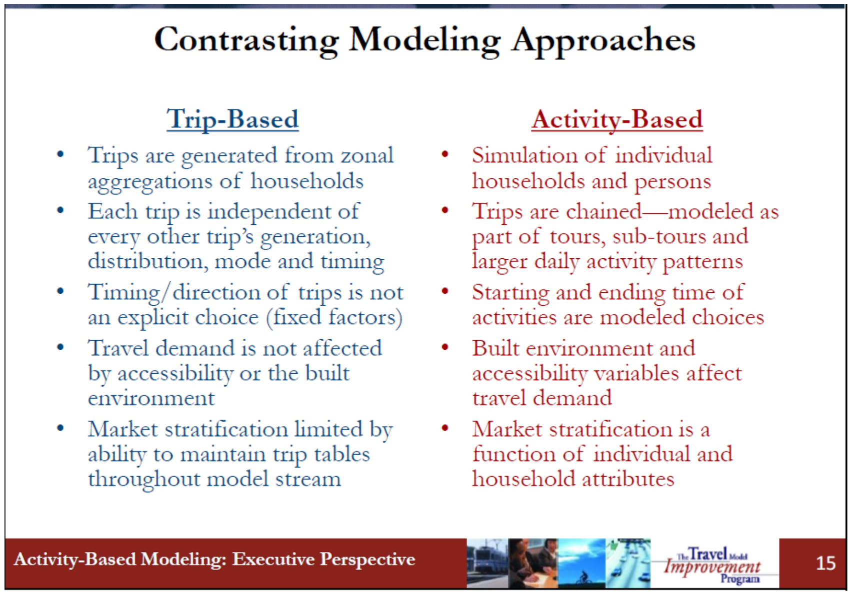
A1. Activity-Based Models

Activity-based models (ABMs) are a type of travel model that uses a different structure from the traditional 4-step, or trip-based, modeling approach. The term "activity-based" comes from the notion that travel is a derived demand—we don't make trips because we like to drive around, we make trips because we want to participate in an activity at the other end. Activities may include working, shopping, socializing and so forth. Some ABMs explicitly model these activities, but others would be more accurately described as tour-based models, because the basic unit of analysis is a tour. A tour is a sequence of trips that starts and ends at home (or work), as illustrated in the figure below. By chaining these trips together, ABMs capture the interdependence of the trips, specifically providing more information about non-home-based trips whose starting and ending points are determined by the trips before and after them in the sequence.



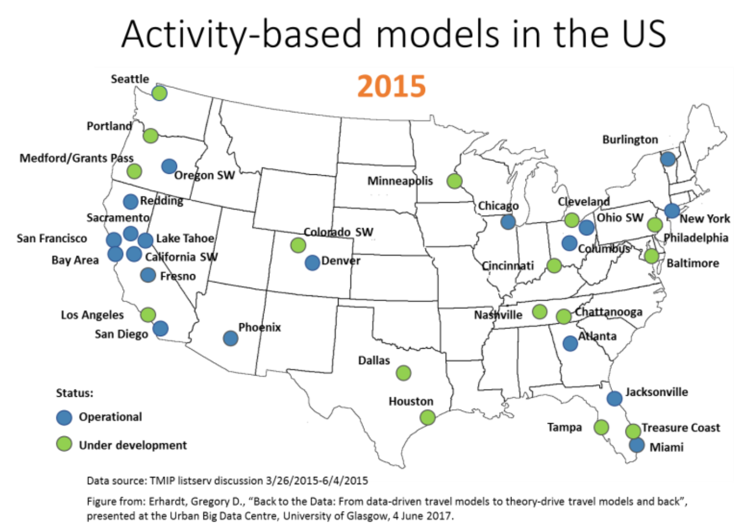
Source: FHWA 2012

Activity-based models have several other differences from trip-based models, some of which are listed on the slide below. One important feature, which is common to the ABMs in the US, but not necessarily in Europe, is that they typically operate using on a synthetic population. A synthetic population is a simulated set of person and household records for everyone in the model area. The ABM uses an underlying set of choice models, combined with Monte Carlo simulation, to simulate the daily movements of every person in the synthetic population. This approach makes it easier to add new variables, allowing the model to capture more complex structures. As the number of market segments increases, it is actually more computationally efficient that operating on aggregate flows of trips between zones. Before traffic assignment, the tours are split into trips, the trips are tabulated into trip tables, and those trip tables are assigned to the network.



Source: FHWA 2012

Activity-based models first emerged in practical use in the US in the early 2000s. By 2015 they have become more common, as shown in the map below.



Further Reading:

Castiglione, Joe, Mark Bradley, and John Gliebe. *Activity-Based Travel Demand Models: A Primer*. The Strategic Highway Research Program. Transportation Research Board, May 2014. http://onlinepubs.trb.org/onlinepubs/shrp2/SHRP2_C46.pdf

Donnelly, Rick, Gregory D. Erhardt, Rolf Moeckel, and William A. Davidson. "Advanced Practices in Travel Forecasting." NCHRP Synthesis 406. National Cooperative Highway Research Program. Transportation Research Board, 2010. http://www.trb.org/Publications/Blurbs/163651.aspx

Federal Highway Administration. "TMIP Activity Based Model Webinar Series Instructor's Manual," 2012. http://media.tmiponline.org/clearinghouse/ABM_Instructors_Manual/AB_Webinar_Complete.pdf

A2. Transferrable Parameters

Description from TFResource (http://tfresource.org/Category:Statewide_models):

"NCHRP Report 735 Transferable Parameters for long distance and rural trip-making (2012) is a valuable source of information on long distance travel. The NCHRP report explains how statewide models have fundamental differences from urban models due to long distance trip making and rural trips. The report contains chapters on:

- long distance data sources;
- transferability and typologies;
- trip generation parameters and benchmark statistics;
- auto occupancy and mode choice parameters; and
- conclusions /comparisons.

The report also contains the following appendices:

- Recent examples of long-distance travel demand studies (ORNL, UMD);
- Travel behavior data from other countries;
- Modal-based travel data;
- Other demographic and origin-destination data;
- Urban versus rural truck trips; and
- Review of statewide models."

Description from TRB blurb (http://www.trb.org/Publications/Blurbs/167055.aspx):

"TRB's National Cooperative Highway Research Program (NCHRP) Report 716: Travel Demand Forecasting: Parameters and Techniques provides guidelines on travel demand forecasting procedures and their application for helping to solve common transportation problems.

The report presents a range of approaches that are designed to allow users to determine the level of detail and sophistication in selecting modeling and analysis techniques based on their situations. The report addresses techniques, optional use of default parameters, and includes references to other more sophisticated techniques."

Further Reading:

Schiffer, Robert G. *Long-Distance and Rural Travel Transferable Parameters for Statewide Travel Forecasting Models*. NCHRP Report 735. Washington, D.C: Transportation Research Board, 2012. http://www.trb.org/Main/Blurbs/168389.aspx

Cambridge Systematics, Vanasse Hangen Brustlin, Gallop Corporation, Chandra R. Bhat, Shapiro Transportation Consulting, and Martin/Alexiou/Bryson. *Travel Demand Forecasting: Parameters and Techniques*. NCHRP Report 716. Washington, D.C.: Transportation Research Board, 2012. http://www.trb.org/Publications/Blurbs/167055.aspx

A3. National Long Distance Travel Model (NLDTM)

Description from Bernardin (2016):

"The new national long distance passenger travel model system, rJourney, was developed, implemented, and tested as part of a multi-year project titled "Foundational Knowledge to Support a Long-Distance Passenger Travel Demand Modeling Framework", funded by the Federal Highway Administration (FHWA). The model is a tour-based model system that predicts all long distance passenger trips made by all households in the United States.1 Specifically, for each tour undertaken by a household, the model predicts tour purpose (commute, employer's business, visit friends/relatives, leisure/vacation, and personal business), duration of stay, travel party size, scheduling across months of the year, tour mode (auto, air, rail and bus), and destination. The overall model framework of rJourney is presented in Figure 1.

The key model components of rJourney are:

- Vehicle Ownership Model,
- Tour Generation/Frequency Models,
- Tour Scheduling and Duration Models,
- Tour Destination-Choice Models, and
- Tour Mode Choice Models.

To run rJourney, the following inputs are required: (1) estimated coefficients for the various choice models, (2) a synthesized population representing all U.S. households, controlled to public Census Tract level data, (3) estimates of population, employment, and other key land use variables at the zone level, and (4) zone-to-zone network time and cost measures for auto, bus, rail and air. The choice models were estimated using household travel survey data for long distance travel for California, Colorado, New York, Ohio, and Wisconsin. The National Highway Planning Network (NHPN) was the main source of the modeled highway network.

NHPN, developed by FHWA, is a geospatial database that comprises interstates, principal arterials, and rural minor arterials (over 450,000 miles of existing and planned highways in the country). For model implementation, the intersection of counties and PUMAs was used to define a zone system of 4,486 "National Use Modeling Areas" (NUMA's). In urban areas, NUMA's tend to be PUMA's, while in rural areas they tend to be counties."

The NLDTM has been adapted for use in the Tennessee statewide model (Bernardin 2016).

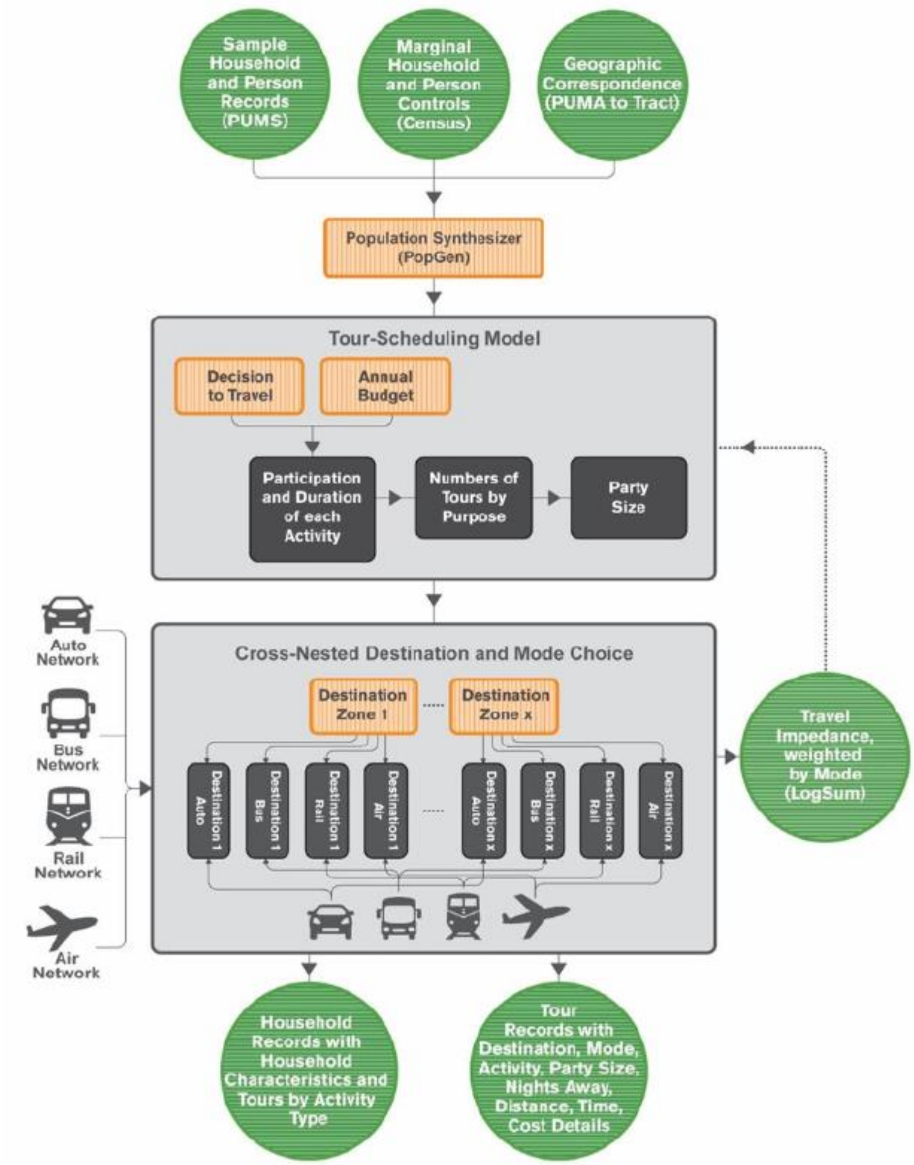


Figure 1. rJourney Framework

Further Reading:

Outwater, Maren, Mark Bradley, Nazeen Ferdous, Ram Pendyala, Venu Garikapati, Chandra Bhat, Subodh Dubey, Jeff LaMondia, Stephane Hess, and Andrew Daly. *Foundational Knowledge to Support a Long-Distance Passenger Travel Demand Modeling Framework: Final Report*. Federal Highway Administration, March 2015. http://www.rsginc.com/sites/default/files/publications/Long%20Distance%20Model%20Framework%20Final%20Report.pdf

Bernardin Jr, Vincent L., Nazneen Ferdous, Hadi Sadrsadat, and Chin-Cheng Chen. "Integration of the National Long Distance Passenger Model with the Tennessee Statewide Model and Calibration To Airsage Data." In *Innovations in Travel Modeling Conference*. Denver, CO, 2016. http://tfresource.org/images/archive/a/a4/20160425000855!ITM16_Using_Archived_Real_Time_Travel_Speed_Data_for_Model_Calibration_and_Validation.pdf

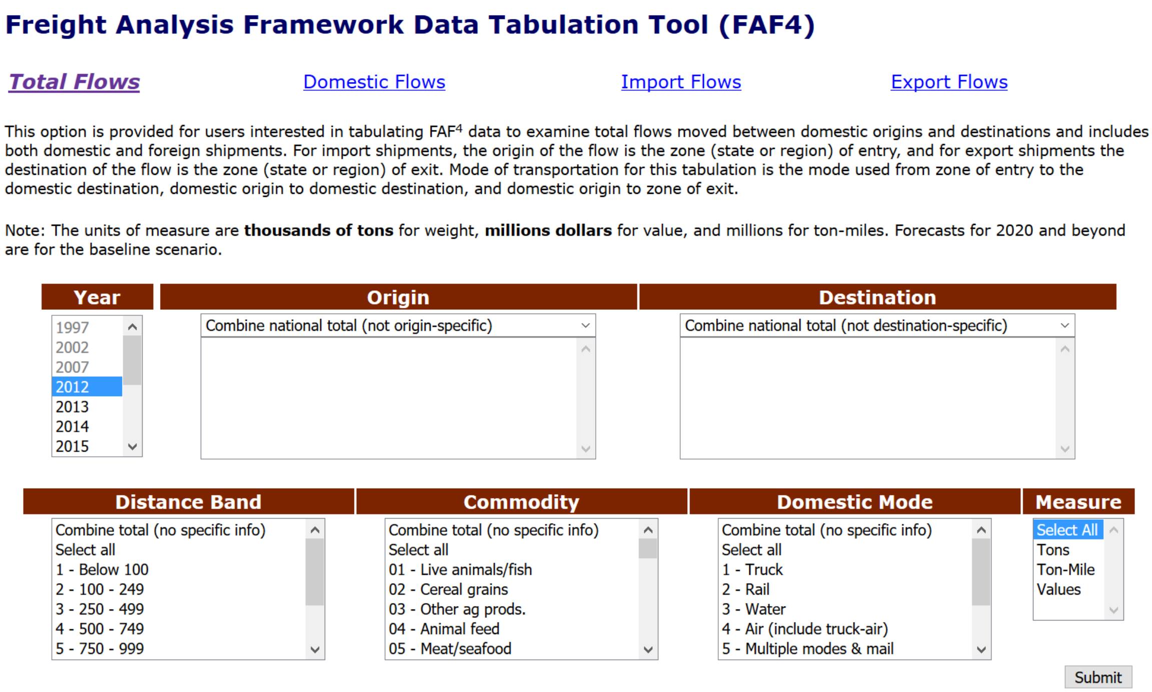
A4. Freight Analysis Framework (FAF)

Text from the FAF website (http://faf.ornl.gov/fafweb/):

"The Freight Analysis Framework (FAF), produced through a partnership between BTS and FHWA, integrates data from a variety of sources to create a comprehensive picture of freight movement among states and major metropolitan areas by all modes of transportation. Starting with data from the 2012 Commodity Flow Survey (CFS) and international trade data from the Census Bureau, FAF incorporates data from agriculture, extraction, utility, construction, service, and other sectors.

FAF version 4 (FAF4) provides estimates for tonnage (in thousand tons) and value (in million dollars) by regions of origin and destination, commodity type, and mode. Data are available for the base year of 2012, the recent years of 2013 - 2015, and forecasts from 2020 through 2045 in 5-year intervals. Data may be accessed through the Data Extraction Tool, downloaded as a complete database, or in summary files.

Throughout 2016, releases of additional FAF4 products will provide state-to-state flows for 1997, 2002, and 2007; truck flows assigned to the highway network for 2012 and 2045; and domestic ton-miles and distance bands."



Further Reading:

http://faf.ornl.gov/fafweb/

Appendix C: Interview Questionnaire

NCHRP Project 8-36C, Task 137

Assessing the Utility and Costs of Statewide Travel Demand Models

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Interview Questionnaire

Interviewee: ___________________________

State: ___________________________

Organization: ___________________________

Position: ___________________________

Phone/Email: ___________________________

Time/Date: ___________________________

Interviewer: ___________________________

Confidentiality

With your permission, conversations will be audio-recorded. At the start of the interview we will discuss with you how your comments will be attributed in the report. We would like to attribute comments or quotations (for example, 'interviewee from UNODC'), and provide opportunity for you to decline this approach (if so, an alternative will be agreed).

Version 4, Modified 6/28/2017

Introduction

Thank you for taking the time to participate in this interview. We expect it to last approximately 2 hours. Before we start we would like to remind you that taking part in the interview is entirely voluntary.

We would like to be able to audio-record the interview. This is mainly to help note taking and we will not transcribe the interviews in full. Where appropriate, we would like to attribute comments or quotations (for example, 'interviewee from UNODC'), while acknowledging your participation in the interview process.

I.1 Are you happy to continue and record the interview and attribute quotes and comments in this way?

Yes / no

[If the answer to the above is no, agree and write down an alternative, which could be no attribution.]

The interview will be composed of three parts:

Part 1: About You and Your Agency: You will be asked a series of questions about the agency that you represent.
Part 2: Scenarios: Estimating Costs: In this section, you are asked to imagine that you have the ability to influence the selection of technical resources for planning. You will be given a series of three model upgrade scenarios and asked to develop a budget estimate for doing so.
Part 3: Scenarios: Go/No-Go Decisions: Again, you are asked to imagine that you have influence over the selection of modeling and technical resources. You will be given a series of scenarios in which you must recommend a go/no-go decision for whether this new DOT should proceed with a statewide modeling project at the cost specified. This section will include a total of nine scenarios, which vary based on the policies to be analyzed and on the type of model considered.

If your state does not operate a statewide model, or if you are a contractor, portions of Part 1 will be truncated, but we would still value your input on Parts 2 and 3.

I.2 Do you have any questions before we begin?

Yes / no

[If yes, discuss the question, and make a note here.]

Part 1. About You and Your Agency

In the invitation to this interview, we included two documents for your reference: a literature review and a "cheat sheet". Our goal in doing so was to provide information on what other states are doing in statewide modeling, which may be helpful in responding to the scenarios.

1.1 Did you have a chance to read the literature review and the "cheat sheet"?

Literature Review:	"Cheat Sheet":
a. Yes	a. Yes
b. Skimmed	b. Skimmed
c. No	c. No

1.2 Could you tell me a bit about <company's/state DOT's> level of involvement in statewide modeling?

[In the course of the conversation, get them to indicate the following:]

a. State DOT that does not operate a statewide model.
b. State DOT with an operational statewide model.
c. State DOT with currently developing a statewide model.
d. Consultant involved in developing/applying statewide models.

1.3 Could you tell me a bit about your role at <company/state DOT> and your level of experience in statewide modelling?

[Get a quick sense of this, but don't go over every option. Do not spend too much time here since this questionnaire is quite long!]

Primary responsibility:

a. Modeler
b. Planner
c. Engineer
d. Manager
e. Other

Experience in statewide modeling:

a. Extensive & hands-on
b. Dabble on the side
c. Oversight responsibility
d. None

Types of experience:

a. Model development
b. Model applications
c. Forecasting without model

Experience from:

a. This organization
b. Another organization
c. Both

Years of experience:

1.4 ***[If DOT with model:]*** **Can you tell me about the history of your statewide modeling program? When did you develop the model and why? How long have you been using it? Has it undergone major revisions, and if so, for what purpose?**

1.5 *[If DOT with model:]* We would like to get a better sense for the details of your statewide model. For each row in the table below, please indicate which of the three options comes closest to describing your statewide model. Please also tell us more about the cases where none of these quite fit your practice.

[Push the respondent to select one option in each row. Note any additional comments below the table.]

Attributes\Model scenarios	**Basic 3-Step Model**	**Enhanced 4-Step Model**	**Activity-Based Model**
Networks & TAZs	Highway networks, TAZ system, socio-economic data	Highway networks, TAZ system, socio-economic data, urban transit networks, intercity air, rail & bus networks	Highway networks, TAZ system, socio-economic data, urban transit networks, intercity air, rail & bus networks, freight intermodal network
Baseline Data	Traffic Counts	Traffic Counts, Base IE/EI/EE trip tables from GPS or cell phone data	Traffic Counts, Full base trip tables from GPS or cell phone data
Survey Data	None	NHTS Add-On Sample	Custom Travel Surveys
Passenger Travel	Basic 3-step model (no-mode choice) with parameters from NCHRP 735 and NCHRP 716	4-step model with estimated model parameters	Activity-based model with estimated model parameters. Uses population synthesizer.
Long-Distance Passenger Travel	No explicit long-distance model	Adapted National Long-Distance Model	Develop custom long-distance travel model
Freight Transportation	Static truck trip table	Commodity flows adapted from FAF with truck flows assigned to network	Policy-sensitive freight model with non-Truck freight modes
Overall Classification	Basic 3-Step Model	Enhanced 4-Step Model	Activity-Based Model

1.6 For each of the topics below, please indicate the following:

1) whether the policy is of interest to your agency, and whether it is a priority

2) whether your agency uses a model to conduct analysis for each policy.

3) If you use a statewide model, we'd like to know how useful your statewide model is at informing decisions about those policies (i.e. what is the utility of the models?). Please indicate how well the statewide model addresses each issue using a 5-point scale.

4) We recognize that using a statewide travel demand model is not the only way to inform policy questions, and transportation planners often bring other information or analyses to the table. These could include trend-line projections, data summaries, literature reviews, or other approaches. For each of the issues identified, we'd like to know how well you feel you could address the issue *without* the use of a statewide model, on a scale of 1 to 5.

Here're some guidelines for the 5 point scale:

1. **Poor:** We cannot provide any information of value

2. **Limited:** We provide some limited information about these policies, but it is primarily because we have to say something. It doesn't really change anything.

3. **Useful:** We can provide useful information for understanding some aspects of the policy, but there is key information we wish we had but don't.

4. **Important:** We can provide the basic information we need to evaluate the most important aspects of the policy.

5. **Excellent:** The information we provide does a good job of supporting our decisions. It covers the key aspects of the policy that decision makers are interested in, and is generally viewed as credible.

<If needed, indicate NA for Not Applicable if the policy is of no interest. However, push the respondent to make a judgment if they are willing.>

Policy	Policy interest level 0. Not of interest 1. Of interest 2. A priority	Use statewide model for analysis? Yes/No.	Model rating (1-5)	Non-model rating (1-5)	Comments
Highway forecasts outside urban areas					
Highway forecasts in urban areas					
Transit projects					
Evaluating walk and bike mode shares					
Truck-only lanes, truck climbing lanes and truck passing lanes					
Freight rail & intermodal freight projects					
Pricing scenarios (tolls, gas prices, transit fares, congestion pricing)					
Travel demand management					
Alternative growth scenarios					
Effects of changing demographics (aging population, immigration, etc.)					
Air quality, greenhouse gas and environmental analysis					
Equity analysis & environmental justice					
Connected & autonomous vehicles					

1.7 *[For everyone at a DOT]* Are there other policies that you are asked to evaluate?

Policy	Policy interest level 0. Not of interest 1. Of interest 2. A priority	Use statewide model for analysis? Yes/No.	Model rating (1-5)	Non-model rating (1-5)	Comments

<Use this as an opportunity to ask follow-up questions about the value it provides and what is missing...>

1.8 *[For everyone at a DOT]* In the table below, we have grouped these policies into three main focus areas. These are described further in the text below. Which of these do you think best describes the focus of your agency?

For the Rural Highways policy focus, the DOT is primarily involved in evaluating highway projects outside the states urban areas. It is expected that the MPO models would be used within the urban areas.

In the Congestion & Multi-Modal focus area, the state is still interested in evaluating rural highway projects, but is also involved in evaluating projects where congestion is a major issue, or where non-car modes are of particular importance. A statewide model may be used to provide consistent estimates throughout the state, including in the urban areas, or it might be used for specific projects such as evaluating freight inter-modal facilities, truck-only lanes, or bicycle and pedestrian issues.

In the Policy, Pricing & Environment focus area, DOT analysts may be involved in all of the above projects, but also be asked to evaluate broad policy issues, such as alternative growth scenarios, pricing studies, or the effects of changing demographics.

	Rural Highways	Congestion & Multi-Modal	Policy, Pricing and Environment
Highway forecasts outside urban areas	X	X	X
Highway forecasts in urban areas		X	X
Transit projects		X	X
Evaluating walk and bike mode shares		X	X
Truck-only lanes, truck climbing lanes and truck passing lanes		X	X
Freight rail & intermodal freight projects		X	X
Pricing scenarios (tolls, gas prices, transit fares, congestion pricing)			X
Travel demand management			X
Alternative growth scenarios			X
Effects of changing demographics (aging population, immigration, etc.)			X
Air quality, greenhouse gas and environmental analysis			X
Equity analysis & environmental justice			X
Connected & autonomous vehicles			X

1.9 Based on your responses above, it looks like <state DOT> would best be classified in the following location in the table below. Does that look like a fair assessment to you?

<Interviewer to point to location based on previous responses>

State Size	Policy Focus Area	Model Classification			
		No Model or No Response	Basic 3-Step Model	Enhanced 4-Step Model	Activity-Based Model
Population < 3,750,000	Rural Highways				
	Congestion & Multi-Modal				
	Policy, Pricing & Environment				
Population >= 3,750,000	Rural Highways				
	Congestion & Multi-Modal				
	Policy, Pricing & Environment				

1.10 *[For everyone at a DOT]* Can you tell us about the most important issues facing <state DOT>? Can you provide the necessary information to decision makers about these priority issues (with or without a model)? Explain.

1.11 Do you have any specific success stories or failures from your experience with statewide modeling, such as a project that it was central to?

1.12 Have you made any effort to assess the accuracy of your statewide model (or of other modeling tools)? If so, how, and what did you find?

<If the answer is yes, ask if the data can be shared for the purpose of NCHRP Project 08-110: Traffic Forecast Accuracy Assessment Research.>

1.13 Now we'd like to get a sense for how much <state DOT> has spent on different aspects of statewide modeling, both for model development and ongoing maintenance. If you've filled this information out on the Cheat Sheet, let's record that here and review your responses. Please provide your best estimate of the external cost and staff time dedicated to each element. *<Interviewer to go over the meaning of each element.>*

Category	Tasks	Cost ($) (external consultants, purchases)	In house staff cost (person-hours) (2080 hrs/yr)	Notes & Assumptions
Networks & TAZs	Code highway networks, urban transit networks, intercity networks, freight intermodal networks, TAZ system, develop socio-economic data.			
Baseline Data	Collect traffic counts or speed data, purchase GPS or mobile phone data.			
Survey Data	Conduct household travel surveys or other surveys, purchase NHTS add-on samples.			
Passenger Travel	Develop passenger travel models, estimate coefficients, software implementation.			
Long-Distance Passenger Travel	Develop long-distance passenger travel models, estimate coefficients, software implementation.			
Freight Transportation	Develop freight & commercial vehicle models, estimate coefficients, software implementation.			
Calibration and Validation	Calibrate and validate model, conduct sensitivity testing.			
Annual Maintenance & Troubleshooting (cost per year)	Maintain networks, update socio-economic data, troubleshoot problematic model results/errors.			
Other	Other costs not listed above (please explain).			

1.14 Please note any key factors in determining the cost of the above model.

a. State population:

b. Number of TAZs:

c. Highway network detail (number of links, or lowest class of roads included):

d. Non-highway networks included:

e. Other cost determinants:

1.15 What advice would you give to a state that is considering developing a new statewide model?

Part 2. Scenarios: Estimating Costs

In this section, we would like get a better handle on the costs of statewide modeling. However, rather than asking you how much you spent, we are going to change the question and ask how much you would budget for a statewide model. There are a few reasons for this:

1. It gives us a way to get a range of cost estimates for a similar modeling approach, effectively increasing our sample size.
2. It establishes the cost in the present, recognizing that it may be easier to develop a travel model now than it was 10 years ago with access to new data sets, better software, and more developed methods.
3. It is the question we actually want to answer.

We will ask you to estimate the costs for three scenarios:

1. Starting from no statewide model, and implementing a Basic 3-Step Model.
2. Starting from a Basic 3-Step Model, and upgrading it to an Enhanced 4-Step Model.
3. Starting from an Enhanced 4-Step Model, and upgrading it to an Activity-Based Model.

You will notice that these scenarios correspond to the model categories we dealt with above. These questions are "open-book," so feel free to reference the Cheat Sheet, the Literature Review, or your answers above in answering these questions. We understand that there will be some uncertainty in these estimates, and can only ask that you try your best.

In answering these questions, you are no longer a representative of <state DOT>. Imagine, instead, that you recently started a new job as the manager of planning analysis at a different DOT. This DOT is at a <large/small> state, similar in size to the state you recently left, generally considered to be a 'peer' agency.

Scenario 2.1 Time Series Methods → Basic 3-Step Model

Imagine that you have left your current position to start a new job as the manager of planning analysis at a DOT for a <*large/small*> state. This DOT does not currently have a statewide model, and instead uses time-series methods, such as growth factors, when projecting demand for highway projects. Your supervisor, the Director of Planning, has asked you to consider developing a statewide model. You have been asked to provide costing broken out into several categories, as listed in the tables below.

As envisioned, the plan is to develop a Basic 3-Step Model. It is expected that the model would not include a mode choice component, and follow a fairly basic model structure. You plan to use model parameters from NCHRP 735: Long Distance and Rural Travel Transferable Parameters for Statewide Travel Forecasting Models (http://www.trb.org/Main/Blurbs/168389.aspx) and NCHRP 716: Travel Demand Forecasting: Parameters and Techniques (http://www.trb.org/Publications/Blurbs/167055.aspx). Together these reports provide information on travel model parameters that can be transferred from other models, avoiding the need to estimate those parameters from local travel survey data. You will calibrate the model to match existing traffic counts.

You will not explicitly model long-distance passenger travel. To capture truck travel, you plan to perform an OD matrix estimation from your truck counts to generate a static truck trip table. After calibrating the model, you will conduct some basic sensitivity testing. You need to budget for some ongoing effort (per year) to maintain the networks, update the data inputs, troubleshoot problems, and so forth. Please assume that applying the model to generate project-level forecasts is a separate cost allocated to the project. Please also indicate how much you would ask for in reserve funds to protect against unanticipated costs.

For each category, please specify both a dollar amount for the costs of external contractors or consultants and the number of person-hours of in-house staff time you expect to dedicate to the effort.

By default, we will assume that the population of the state, the number of TAZs, and level of network detail are on par with what you listed in Part 1 (Question 1.19). If there is a reason to deviate on those dimensions, please note that with the interviewer. Also, note any other important assumptions in your cost estimates.

2.1 In the table below, estimate the costs for developing a Basic 3-Step Model?

<Interviewer to go over the meaning of each element.>

Category	Tasks	Cost ($) (external consultants, purchases)	In house staff cost (person-hours) (2080 hrs/yr)	Notes & Assumptions
Networks & TAZs	Code highway networks, TAZ system, develop socio-economic data.			
Baseline Data	None			
Survey Data	None			
Passenger Travel	Develop Basic 3-step model (no-mode choice) with parameters from NCHRP 735 and NCHRP 716			
Long-Distance Passenger Travel	None			
Freight Transportation	Perform OD matrix estimation to create static truck trip table			
Calibration and Validation	Calibrate and validate model, conduct sensitivity testing			
Reserve Fund	Additional budget allocation to protect against unexpected circumstances.			
Total	(Excluding annual maintenance)			
Annual Maintenance & Troubleshooting	Maintain networks, update socio-economic data, troubleshoot problematic model results/errors.			

Scenario 2.2 Basic 3-Step Model → Enhanced 4-Step Model

Now, imagine that the DOT where you recently started a new job already has in place a Basic 3-Step Model that was developed about 10 years ago and has been in regular use.

Your supervisor, the Director of Planning, has asked you to consider upgrading the statewide model to an Enhanced 4-Step Model. You have been asked to provide costing broken out into several categories, as listed in the tables below.

As envisioned, the plan is to add a mode choice component, and revisit the overall model structure to add sophistication where it is warranted. For example, you might consider more trip purposes or an improved approach to modeling time-of-day. You will purchase an add-on sample from the upcoming National Household Travel Survey (NHTS) to estimate the model parameters from a local data. In addition, you plan to purchase data from a cell phone or GPS vendor to derive external-external (EE), external-internal (EI) and internal-external (IE) trip tables.

You plan to explicitly model long-distance passenger travel, by adapting the National Long Distance Travel Model (NLDTM) to work for your state. This would include an intercity mode choice components, with intercity air, passenger rail and bus networks adapted from those in the NLDTM. You will develop a freight model using commodity flow data from the Freight Analysis Framework (FAF). This FAF-based model will only assign truck-trips to the network.

After calibrating and validating the model, you will conduct some basic sensitivity testing. You need to budget for some ongoing effort (per year) to maintain the networks, update the data inputs, troubleshoot problems, and so forth. Please assume that applying the model to generate project-level forecasts is a separate cost allocated to the project. Please also indicate how much you would ask for in reserve funds to protect against unanticipated costs.

For each category, please specify both a dollar amount for the costs of external contractors or consultants and the number of person-hours of in-house staff time you expect to dedicate to the effort.

By default, we will assume that the population of the state, the number of TAZs, and level of network detail are on par with what you listed in Part 1 (Question 1.19). If there is a reason to deviate on those dimensions, please note that with the interviewer. Also, note any other important assumptions in your cost estimates.

2.2 In the table below, estimate the costs for upgrading from a Basic 3-Step Model to an Enhanced 4-Step Model?

<Interviewer to go over the meaning of each element.>

Category	Tasks	Cost ($) (external consultants, purchases)	In house staff cost (person-hours) (2080 hrs/yr)	Notes & Assumptions
Networks & TAZs	Code urban transit networks, code intercity air, rail & bus networks			
Baseline Data	Purchase base IE/EI/EE trip tables from GPS or cell phone data			
Survey Data	Buy into NHTS add-on sample			
Passenger Travel	Develop 4-step model with estimated model parameters			
Long-Distance Passenger Travel	Adapt National Long-Distance Model			
Freight Transportation	Adapt commodity flows from FAF with truck flows assigned to network			
Calibration and Validation	Calibrate and validate model, conduct sensitivity testing			
Reserve Fund	Additional budget allocation to protect against unexpected circumstances.			
Total	(Excluding annual maintenance)			
Annual Maintenance & Troubleshooting	Maintain networks, update socio-economic data, troubleshoot problematic model results/errors.			

Scenario 2.3 Enhanced 4-Step Model → Activity-Based Model

One more scenario…

This time, imagine that the DOT where you recently started a new job already has in place an Enhanced 4-Step Model. It was developed about 10 years ago and has been in regular use since then, with periodic updates. Your supervisor, the Director of Planning, has asked you to consider upgrading the statewide model to an Activity-Based Model. You have been asked to provide costing broken out into several categories, as listed in the tables below.

As envisioned, the Activity-Based Model would switch from the traditional trip-based modeling paradigm and instead model tours, which are a sequence of trips starting and ending at home. It would use a more complexstructure for generating and scheduling activities and tours than the previous model. Destination choice and mode choice would follow a similar structure to the current models, but would be conducted first for tours, and then for individual trips within the tour. The demand models would operate using microsimulation. That means that a population synthesizer would run to create a table of the simulated population of the state. The core choice models would be applied to individual person records, simulating discrete outcomes, rather than applying the probabilities to the aggregate number of trips in the trip tables. After the trip mode choice step, the results would be compiled into trip tables, and the assignment models would remain the same as they are in the previous model.

You plan to design and collect travel surveys to support the estimation of these models. These would include a household travel survey, and any other surveys you feel are warranted. In addition, you plan to purchase data from a cell phone or GPS vendor to serve as a base trip table against which to calibrate your model, and which can be used to pivot the results.

You plan to develop an explicit model of long-distance passenger travel. You will develop a freight model that considers intermodal freight movements, is sensitive to changes in congestion, the location of employment, and policies of interest.

After calibrating and validating the model, you will conduct some basic sensitivity testing. You need to budget for some ongoing effort (per year) to maintain the networks, update the data inputs, troubleshoot problems, and so forth. Please assume that applying the model to generate project-level forecasts is a separate cost allocated to the project. Please also indicate how much you would ask for in reserve funds to protect against unanticipated costs.

For each category, please specify both a dollar amount for the costs of external contractors or consultants and the number of person-hours of in-house staff time you expect to dedicate to the effort.

By default, we will assume that the population of the state, the number of TAZs, and level of network detail are on par with what you listed in Part 1 (Question 1.19). If there is a reason to deviate on those dimensions, please note that with the interviewer. Also, note any other important assumptions in your cost estimates.

2.3 In the table below, estimate the costs for upgrading from an Enhanced 4-Step Model to an Activity-Based Model?

<Interviewer to go over the meaning of each element.>

Category	Tasks	Cost ($) (external consultants, purchases)	In house staff cost (person-hours) (2080 hrs/yr)	Notes & Assumptions
Networks & TAZs	Use existing passenger networks and TAZ system, code freight intermodal networks			
Baseline Data	Purchase full base trip tables from GPS or cell phone data			
Survey Data	Design and conduct local travel surveys			
Passenger Travel	Develop activity-based model. Estimate model parameters. Develop application framework using population synthesizer.			
Long-Distance Passenger Travel	Develop custom long-distance travel model			
Freight Transportation	Develop policy-sensitive freight model with non-Truck freight modes			
Calibration and Validation	Calibrate and validate model, conduct sensitivity testing			
Reserve Fund	Additional budget allocation to protect against unexpected circumstances.			
Total	(Excluding annual maintenance)			
Annual Maintenance & Troubleshooting	Maintain networks, update socio-economic data, troubleshoot problematic model results/errors.			

2.4 How confident do you feel in the cost estimates you provided above?

a. Pretty good. I bet I'm within 20%.
b. Not bad. I think I'm within 50%.
c. Ballpark. Consider it an order-of-magnitude estimate.
d. I have no clue!

[Note any specific concerns or issues, and differences between which estimates.]

2.5 Having gone through this exercise, is there anything specific you think other states should consider when budgeting for statewide modeling projects?

Part 3. Scenarios: Go/No-Go Decisions

In this section, we would like your recommendations on whether it would make sense to proceed with the statewide model development or upgrade projects described above. This will help other statewide modelers place their decisions within the context of the collective judgment of their peers.

This section will include nine scenarios, which vary by the policy focus area and the model development option. The table on the next page summarizes the scenarios.

In answering these questions, you are no longer a representative of <state DOT>. Imagine, instead, that you recently started a new job as the manager of planning analysis at a different DOT. This DOT is at a <large/small> state, similar in size to the state you recently left, generally considered to be a 'peer' agency.

For each of these scenarios, we will ask you to make a go/no-go decision. The responses are defined as:

- Go – You believe that the value of the model capabilities will exceed the cost specified, and the DOT should proceed with the model development/upgrade project.
- No-go – You believe that the value of the model capabilities do not exceed the cost specified, and the DOT should maintain the status quo.

Within each of the nine scenarios, we will vary the cost from the starting estimate to understand the limits of your recommendation. The cost estimates will be expressed in terms of "10-year cost per capita".

For reference, 10-year spending on transportation infrastructure in the US exceeded $1 trillion from 2001 through 2010[2], for an average cost of $3,300 per person. Most of that money flowed through the state DOTs. A DOT that spent $0.33 per capita on statewide modeling over that period would have spent about 0.01% of the transportation infrastructure cost.

[2] The International Transport Forum. "Spending on Transport Infrastructure 1995-2011: Trends, Policies, Data." Organisation for Economic Co-operation and Development, May 2013. http://www.internationaltransportforum.org/pub/pdf/13SpendingTrends.pdf.

This table shows a summary of the scenarios we will go through.

		Model Development Options		
		M1	M2	M3
		Start from: No Model	*Start from:* Basic 3-step model	*Start from:* Enhanced 4-step model
Policy Focus		*Upgrade to:* Basic 3-step model with transferred model parameters, static truck trip tables.	*Upgrade to:* Enhanced 4-Step Model with estimated parameters, National Long-Distance Model, FAF-based commodity flows model, NHTS add-on sample.	*Upgrade to:* Activity-based model with estimated parameters, custom long-distance travel model, policy-sensitive freight model, custom travel surveys.
P1	Rural highways: Primary need is to evaluate highway projects outside urban areas.	Scenario P1-M1	Scenario P1-M2	Scenario P1-M3
P2	Congestion & multi-modal: Also a need to evaluate projects in urban areas, transit projects, truck projects and/or rail/intermodal projects.	Scenario P2-M1	Scenario P2-M2	Scenario P2-M3
P3	Policy, pricing & environment: A need to test broader policy or global scenarios, such as congestion pricing, demand management, growth scenarios, demographic changes, environment, equity and connected & autonomous vehicles.	Scenario P3-M1	Scenario P3-M2	Scenario P3-M3

Scenario P1-M1

Imagine that you have left your current position to start a new job as the manager of planning analysis at a DOT for a *<large/small>* state.

The policy focus of this DOT is **Rural Highways**. The DOT is primarily involved in evaluating highway projects outside the states urban areas. It is expected that the MPO models would be used within the urban areas.

This DOT does not currently have a statewide model, and instead uses time-series methods, such as growth factors, when projecting demand for highway projects.

Your supervisor, the Director of Planning, has asked you to make a recommendation for whether or not the state should develop a **Basic 3-Step Model**. The features of the model are consistent with what is described in Section 2.

3.1 For the costs shown, should a <large/small> DOT with a Rural Highways policy focus develop a Basic 3-Step Model?

<Interviewer to record the responses in the table below.>

What if the costs were <*twice/half*> that estimate? Would your recommendation be the same?

<If the answer is GO, interviewer to increase the costs. If the answer is NO-GO, interviewer to decrease the cost. Continue to double or half the cost until the response changes. Offer no more than 4 cost pivots.>

Is there any price at which your recommendation would change?

What is the most you would recommend the DOT pay?

<table>
<tr><td colspan="2">Policy Focus
P1</td><td colspan="2">Rural highways: Primary need is to evaluate highway projects outside urban areas.</td></tr>
<tr><td colspan="2" rowspan="2">Model Development Option
M1</td><td colspan="2">Start from: Time-series methods (such as growth factors)</td></tr>
<tr><td colspan="2">Upgrade to: Basic 3-step model with transferred model parameters, static truck trip tables.</td></tr>
<tr><td></td><td>10-year cost per capita</td><td>Recommendation (Go/No-Go)</td><td>Notes & Assumptions</td></tr>
<tr><td>Base</td><td>$0.25</td><td></td><td></td></tr>
<tr><td>1</td><td></td><td></td><td></td></tr>
<tr><td>2</td><td></td><td></td><td></td></tr>
<tr><td>3</td><td></td><td></td><td></td></tr>
<tr><td>4</td><td></td><td></td><td></td></tr>
<tr><td>Max/Min</td><td></td><td></td><td></td></tr>
</table>

Scenario P2-M1

Imagine that you have left your current position to start a new job as the manager of planning analysis at a DOT for a *<large/small>* state.

The policy focus of this DOT is **Congestion & Multi-Modal**. The state is still interested in evaluating rural highway projects, but is also involved in evaluating projects where congestion is a major issue, or where non-car modes are of particular importance. A statewide model may be used to provide consistent estimates throughout the state, including in the urban areas, or it might be used for specific projects such as evaluating freight inter-modal facilities, truck-only lanes, or bicycle and pedestrian issues.

This DOT does not currently have a statewide model, and instead uses time-series methods, such as growth factors, when projecting demand for highway projects.

Your supervisor, the Director of Planning, has asked you to make a recommendation for whether or not the state should develop a **Basic 3-Step Model**. The features of the model are consistent with what is described in Section 2.

3.2 For the costs shown, should a <large/small> DOT with a Congestion & Multi-Modal policy focus develop a Basic 3-Step Model?

<Interviewer to record the responses in the table below.>

What if the costs were <*twice/half*> that estimate? Would your recommendation be the same?

<If the answer is GO, interviewer to increase the costs. If the answer is NO-GO, interviewer to decrease the cost. Continue to double or half the cost until the response changes. Offer no more than 4 cost pivots.>

Is there any price at which your recommendation would change?

What is the most you would recommend the DOT pay?

Policy Focus P2		**Congestion & multi-modal:** Also a need to evaluate projects in urban areas, transit projects, truck projects and/or rail/intermodal projects.	
Model Development Option M1		*Start from*: Time series methods (such as growth factors)	
		Upgrade to: **Basic 3-step model** with transferred model parameters, static truck trip tables.	
	10-year cost per capita	Recommendation (Go/No-Go)	Notes & Assumptions
Base	$0.25		
1			
2			
3			
4			
Max/Min			

Scenario P3-M1

Imagine that you have left your current position to start a new job as the manager of planning analysis at a DOT for a *<large/small>* state.

The policy focus of this DOT is **Policy, Pricing & Environment**. DOT analysts may be involved in all of the above projects (including rural highway projects, congestion related projects and multi-modal projects), but also be asked to evaluate broad policy issues, such as alternative growth scenarios, pricing studies, or the effects of changing demographics.

This DOT does not currently have a statewide model, and instead uses time-series methods, such as growth factors, when projecting demand for highway projects.

Your supervisor, the Director of Planning, has asked you to make a recommendation for whether or not the state should develop a **Basic 3-Step Model**. The features of the model are consistent with what is described in Section 2.

3.3 For the costs shown, should a <large/small> DOT with a Policy, Pricing & Environment policy focus develop a Basic 3-Step Model?

<Interviewer to record the responses in the table below.>

What if the costs were <*twice/half*> that estimate? Would your recommendation be the same?

<If the answer is GO, interviewer to increase the costs. If the answer is NO-GO, interviewer to decrease the cost. Continue to double or half the cost until the response changes. Offer no more than 4 cost pivots.>

Is there any price at which your recommendation would change?

What is the most you would recommend the DOT pay?

Policy Focus P3		**Policy, pricing & environment**: A need to test broader policy or global scenarios, such as congestion pricing, demand management, growth scenarios, demographic changes, environment, equity and connected & autonomous vehicles..	
Model Development Option M1		*Start from*: Time series methods (such as growth factors)	
		Upgrade to: **Basic 3-step model** with transferred model parameters, static truck trip tables.	
	10-year cost per capita	Recommendation (Go/No-Go)	Notes & Assumptions
Base	$0.25		
1			
2			
3			
4			
Max/Min			

Scenario P1-M2

Imagine that you have left your current position to start a new job as the manager of planning analysis at a DOT for a *<large/small>* state.

The policy focus of this DOT is **Rural Highways**. The DOT is primarily involved in evaluating highway projects outside the states urban areas. It is expected that the MPO models would be used within the urban areas.

This DOT currently operates a Basic 3-Step Model.

Your supervisor, the Director of Planning, has asked you to make a recommendation for whether or not the state should develop an **Enhanced 4-Step Model**. The features of the model are consistent with what is described in Section 2.

3.4 For the additional costs shown, should a <large/small> DOT with a Rural Highways policy focus develop an Enhanced 4-Step Model?

<Interviewer to record the responses in the table below.>

What if the costs were <*twice/half*> that estimate? Would your recommendation be the same?

<If the answer is GO, interviewer to increase the costs. If the answer is NO-GO, interviewer to decrease the cost. Continue to double or half the cost until the response changes. Offer no more than 4 cost pivots.>

Is there any price at which your recommendation would change?

What is the most you would recommend the DOT pay?

Policy Focus P1		**Rural highways**: Primary need is to evaluate highway projects outside urban areas.	
Model Development Option M2		*Start from:* Basic 3-step model	
		Upgrade to: **Enhanced 4-Step Model** with estimated parameters, National Long-Distance Model, FAF-based commodity flows model, NHTS add-on sample.	
	10-year cost per capita	Recommendation (Go/No-Go)	Notes & Assumptions
Base	<Choose one: $0.15 if it's a small state, or $0.22 if it's a large state>		
1			
2			
3			
4			
Max/Min			

Scenario P2-M2

Imagine that you have left your current position to start a new job as the manager of planning analysis at a DOT for a *<large/small>* state.

The policy focus of this DOT is **Congestion & Multi-Modal**. The state is still interested in evaluating rural highway projects, but is also involved in evaluating projects where congestion is a major issue, or where non-car modes are of particular importance. A statewide model may be used to provide consistent estimates throughout the state, including in the urban areas, or it might be used for specific projects such as evaluating freight inter-modal facilities, truck-only lanes, or bicycle and pedestrian issues.

This DOT currently operates a Basic 3-Step Model.

Your supervisor, the Director of Planning, has asked you to make a recommendation for whether or not the state should develop an **Enhanced 4-Step Model**. The features of the model are consistent with what is described in Section 2.

3.5 For the additional costs shown, should a <large/small> DOT with a Congestion & Multi-Modal policy focus develop an Enhanced 4-Step Model?

<Interviewer to record the responses in the table below.>

What if the costs were <*twice/half*> that estimate? Would your recommendation be the same?

<If the answer is GO, interviewer to increase the costs. If the answer is NO-GO, interviewer to decrease the cost. Continue to double or half the cost until the response changes. Offer no more than 4 cost pivots.>

Is there any price at which your recommendation would change?

What is the most you would recommend the DOT pay?

<table>
<tr><td colspan="2">Policy Focus
P2</td><td colspan="2">Congestion & multi-modal: Also a need to evaluate projects in urban areas, transit projects, truck projects and/or rail/intermodal projects.</td></tr>
<tr><td colspan="2" rowspan="2">Model Development Option
M2</td><td colspan="2">Start from: Basic 3-step model</td></tr>
<tr><td colspan="2">Upgrade to: Enhanced 4-Step Model with estimated parameters, National Long-Distance Model, FAF-based commodity flows model, NHTS add-on sample.</td></tr>
<tr><td></td><td>10-year cost per capita</td><td>Recommendation (Go/No-Go)</td><td>Notes & Assumptions</td></tr>
<tr><td>Base</td><td><Choose one:

$0.15 if it’s a small state, or

$0.22 if it’s a large state></td><td></td><td></td></tr>
<tr><td>1</td><td></td><td></td><td></td></tr>
<tr><td>2</td><td></td><td></td><td></td></tr>
<tr><td>3</td><td></td><td></td><td></td></tr>
<tr><td>4</td><td></td><td></td><td></td></tr>
<tr><td>Max/Min</td><td></td><td></td><td></td></tr>
</table>

Scenario P3-M2

Imagine that you have left your current position to start a new job as the manager of planning analysis at a DOT for a *<large/small>* state.

The policy focus of this DOT is **Policy, Pricing & Environment**. DOT analysts may be involved in all of the above projects (including rural highway projects, congestion related projects and multi-modal projects), but also be asked to evaluate broad policy issues, such as alternative growth scenarios, pricing studies, or the effects of changing demographics.

This DOT currently operates a Basic 3-Step Model.

Your supervisor, the Director of Planning, has asked you to make a recommendation for whether or not the state should develop an **Enhanced 4-Step Model**. The features of the model are consistent with what is described in Section 2.

3.6 For the additional costs shown, should a <large/small> DOT with a Policy, Pricing & Environment policy focus develop an Enhanced 4-Step Model?

<Interviewer to record the responses in the table below.>

What if the costs were <*twice/half*> that estimate? Would your recommendation be the same?

<If the answer is GO, interviewer to increase the costs. If the answer is NO-GO, interviewer to decrease the cost. Continue to double or half the cost until the response changes. Offer no more than 4 cost pivots.>

Is there any price at which your recommendation would change?

What is the most you would recommend the DOT pay?

<table>
<tr><td colspan="2">Policy Focus
P3</td><td colspan="2">Policy, pricing & environment: A need to test broader policy or global scenarios, such as congestion pricing, demand management, growth scenarios, demographic changes, environment, equity and connected & autonomous vehicles..</td></tr>
<tr><td colspan="2" rowspan="2">Model Development Option
M2</td><td colspan="2">Start from: Basic 3-step model</td></tr>
<tr><td colspan="2">Upgrade to: Enhanced 4-Step Model with estimated parameters, National Long-Distance Model, FAF-based commodity flows model, NHTS add-on sample.</td></tr>
<tr><td></td><td>10-year cost per capita</td><td>Recommendation (Go/No-Go)</td><td>Notes & Assumptions</td></tr>
<tr><td>Base</td><td><Choose one:
$0.15 if it’s a small state, or
$0.22 if it’s a large state></td><td></td><td></td></tr>
<tr><td>1</td><td></td><td></td><td></td></tr>
<tr><td>2</td><td></td><td></td><td></td></tr>
<tr><td>3</td><td></td><td></td><td></td></tr>
<tr><td>4</td><td></td><td></td><td></td></tr>
<tr><td>Max/Min</td><td></td><td></td><td></td></tr>
</table>

Scenario P1-M3

Imagine that you have left your current position to start a new job as the manager of planning analysis at a DOT for a *<large/small>* state.

The policy focus of this DOT is **Rural Highways**. The DOT is primarily involved in evaluating highway projects outside the states urban areas. It is expected that the MPO models would be used within the urban areas.

This DOT currently operates an Enhanced 4-Step Model.

Your supervisor, the Director of Planning, has asked you to make a recommendation for whether or not the state should develop an **Activity-Based Model**. The features of the model are consistent with what is described in Section 2.

3.7 For the additional costs shown, should a <large/small> DOT with a Rural Highways policy focus develop an Activity-Based Model?

<Interviewer to record the responses in the table below.>

What if the costs were <*twice/half*> that estimate? Would your recommendation be the same?

<If the answer is GO, interviewer to increase the costs. If the answer is NO-GO, interviewer to decrease the cost. Continue to double or half the cost until the response changes. Offer no more than 4 cost pivots.>

Is there any price at which your recommendation would change?

What is the most you would recommend the DOT pay?

<table>
<tr><td colspan="2">Policy Focus
P1</td><td colspan="2">Rural highways: Primary need is to evaluate highway projects outside urban areas.</td></tr>
<tr><td colspan="2" rowspan="2">Model Development Option
M3</td><td colspan="2">Start from: Enhanced 4-Step Model</td></tr>
<tr><td colspan="2">Upgrade to: Activity-based model with estimated parameters, custom long-distance travel model, policy-sensitive freight model, custom travel surveys.</td></tr>
<tr><td></td><td>10-year cost per capita</td><td>Recommendation (Go/No-Go)</td><td>Notes & Assumptions</td></tr>
<tr><td>Base</td><td><Choose one:
$0.42 if it’s a small state, or
$0.39 if it’s a large state></td><td></td><td></td></tr>
<tr><td>1</td><td></td><td></td><td></td></tr>
<tr><td>2</td><td></td><td></td><td></td></tr>
<tr><td>3</td><td></td><td></td><td></td></tr>
<tr><td>4</td><td></td><td></td><td></td></tr>
<tr><td>Max/Min</td><td></td><td></td><td></td></tr>
</table>

Scenario P2-M3

Imagine that you have left your current position to start a new job as the manager of planning analysis at a DOT for a *<large/small>* state.

The policy focus of this DOT is **Congestion & Multi-Modal**. The state is still interested in evaluating rural highway projects, but is also involved in evaluating projects where congestion is a major issue, or where non-car modes are of particular importance. A statewide model may be used to provide consistent estimates throughout the state, including in the urban areas, or it might be used for specific projects such as evaluating freight inter-modal facilities, truck-only lanes, or bicycle and pedestrian issues.

This DOT currently operates a Basic 3-Step Model.

Your supervisor, the Director of Planning, has asked you to make a recommendation for whether or not the state should develop an **Activity-Based Model**. The features of the model are consistent with what is described in Section 2.

3.8 For the additional costs shown, should a <large/small> DOT with a Congestion & Multi-Modal policy focus develop an Activity-Based Model?

<Interviewer to record the responses in the table below.>

What if the costs were <*twice/half*> that estimate? Would your recommendation be the same?

<If the answer is GO, interviewer to increase the costs. If the answer is NO-GO, interviewer to decrease the cost. Continue to double or half the cost until the response changes. Offer no more than 4 cost pivots.>

Is there any price at which your recommendation would change?

What is the most you would recommend the DOT pay?

<table>
<tr><td colspan="2">Policy Focus
P2</td><td colspan="2">Congestion & multi-modal: Also a need to evaluate projects in urban areas, transit projects, truck projects and/or rail/intermodal projects.</td></tr>
<tr><td colspan="2" rowspan="2">Model Development Option
M3</td><td colspan="2">Start from: Enhanced 4-Step Model</td></tr>
<tr><td colspan="2">Upgrade to: Activity-based model with estimated parameters, custom long-distance travel model, policy-sensitive freight model, custom travel surveys.</td></tr>
<tr><td></td><td>10-year cost per capita</td><td>Recommendation (Go/No-Go)</td><td>Notes & Assumptions</td></tr>
<tr><td>Base</td><td><Choose one:
$0.42 if it’s a small state, or
$0.39 if it’s a large state></td><td></td><td></td></tr>
<tr><td>1</td><td></td><td></td><td></td></tr>
<tr><td>2</td><td></td><td></td><td></td></tr>
<tr><td>3</td><td></td><td></td><td></td></tr>
<tr><td>4</td><td></td><td></td><td></td></tr>
<tr><td>Max/Min</td><td></td><td></td><td></td></tr>
</table>

Scenario P3-M3

Imagine that you have left your current position to start a new job as the manager of planning analysis at a DOT for a *<large/small>* state.

The policy focus of this DOT is **Policy, Pricing & Environment**. DOT analysts may be involved in all of the above projects (including rural highway projects, congestion related projects and multi-modal projects), but also be asked to evaluate broad policy issues, such as alternative growth scenarios, pricing studies, or the effects of changing demographics.

This DOT currently operates a Basic 3-Step Model.

Your supervisor, the Director of Planning, has asked you to make a recommendation for whether or not the state should develop an **Activity-Based Model**. The features of the model are consistent with what is described in Section 2.

3.9 For the additional costs shown, should a <large/small> DOT with a Policy, Pricing & Environment policy focus develop an Activity-Based Model?

<Interviewer to record the responses in the table below.>

What if the costs were <*twice/half*> that estimate? Would your recommendation be the same?

<If the answer is GO, interviewer to increase the costs. If the answer is NO-GO, interviewer to decrease the cost. Continue to double or half the cost until the response changes. Offer no more than 4 cost pivots.>

Is there any price at which your recommendation would change?

What is the most you would recommend the DOT pay?

Policy Focus P3		**Policy, pricing & environment**: A need to test broader policy or global scenarios, such as congestion pricing, demand management, growth scenarios, demographic changes, environment, equity and connected & autonomous vehicles..	
Model Development Option M3		*Start from*: Enhanced 4-Step Model	
		Upgrade to: **Activity-based model** with estimated parameters, custom long-distance travel model, policy-sensitive freight model, custom travel surveys.	
	10-year cost per capita	Recommendation (Go/No-Go)	Notes & Assumptions
Base	<Choose one: $0.42 if it's a small state, or $0.39 if it's a large state>		
1			
2			
3			
4			
Max/Min			

3.10 How confident do you feel in the recommendations you provided above?

a. Pretty good.
b. Not bad.
c. Ballpark.
d. I have no clue!

[Note any specific concerns or issues.]

3.11 Would you care to explain your reasoning for your responses, or expand further upon them?

<copy max WTP from the previous 9 scenarios>

		Model Development Options		
		M1	M2	M3
		Start from: No Model	*Start from:* Basic 3-step model	*Start from:* Enhanced 4-step model
Policy Focus		*Upgrade to:* Basic 3-step model with transferred model parameters, static truck trip tables.	*Upgrade to:* Enhanced 4-Step Model with estimated parameters, National Long-Distance Model, FAF-based commodity flows model, NHTS add-on sample.	*Upgrade to:* Activity-based model with estimated parameters, custom long-distance travel model, policy-sensitive freight model, custom travel surveys.
P1	Rural highways: Primary need is to evaluate highway projects outside urban areas.	Max WTP	Max WTP	Max WTP
P2	Congestion & multi-modal: Also a need to evaluate projects in urban areas, transit projects, truck projects and/or rail/intermodal projects.	Max WTP	Max WTP	Max WTP
P3	Policy, pricing & environment: A need to test broader policy or global scenarios, such as congestion pricing, demand management, growth scenarios, demographic changes, environment, equity and connected & autonomous vehicles.	Max WTP	Max WTP	Max WTP

3.12 Which model upgrade gives the highest return on investment? For each policy focus, please rank the model upgrades, where 1 is highest return on investment and 3 is lowest.

		Model Development Options		
		M1	M2	M3
		Start from: No Model	*Start from:* Basic 3-step model	*Start from:* Enhanced 4-step model
Policy Focus		*Upgrade to:* Basic 3-step model with transferred model parameters, static truck trip tables.	*Upgrade to:* Enhanced 4-Step Model with estimated parameters, National Long-Distance Model, FAF-based commodity flows model, NHTS add-on sample.	*Upgrade to:* Activity-based model with estimated parameters, custom long-distance travel model, policy-sensitive freight model, custom travel surveys.
P1	Rural highways: Primary need is to evaluate highway projects outside urban areas.			
P2	Congestion & multi-modal: Also a need to evaluate projects in urban areas, transit projects, truck projects and/or rail/intermodal projects.			
P3	Policy, pricing & environment: A need to test broader policy or global scenarios, such as congestion pricing, demand management, growth scenarios, demographic changes, environment, equity and connected & autonomous vehicles.			

3.13 Having gone through this exercise, do you have any additional advice for states as they select a modeling approach to meet their policy needs?

Wrap-Up

Thank you for taking the time for the interview today. We will be completing our interviews and writing our draft report in the coming months. Your responses and the context you have provided around them will be valuable to us as we do so. We hope that we can follow-up for clarification if we find that we need to do so.

W.1 Now that we have completed the interview, do you have any additional overall comments you would like to make or questions that you would like to raise?

Appendix D: Interview Participants

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Bryan Fair – Metropolitan Planning
Jim Doolin – Metropolitan Planning
Aaron Moses – Location (Design)
Rod Wilburn – J.R. Wilburn and Associates, Inc.

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Appendix E: Cost Estimating Instructions

The recommended steps are outlined below. The worksheet summarizes these steps. Users will progress from left to right on the worksheet,

Step 1: Identify closest task within each category. The cost estimation is developed on the basis of choosing one of the three specific tasks for each task category. For example, in the long-distance passenger travel category, the analyst would choose either None, Adapt National Long-Distance Model, or Develop Custom Long-Distance Model. We understand that the proposed approach may not fit these categories perfectly, but the idea is to choose the category that is closest to the intended model. Any of these three long-distance passenger travel models can then be combined with any of the three passenger travel models.

Users should circle or highlight the chosen approach for each category to indicate their preference.

The exception to the "choose one" approach is for Networks & TAZs where the user may choose zero, one, two, or three options, depending on the starting point. If it is a new model, the first option must be chosen. The latter two options depend on whether the model is to include transit networks and freight intermodal networks.

Step 2: Identify source table for costs. Once the approach is chosen for each category, the next column provides a means to identify the source of cost information to be used. The table corresponding to the option chosen should be selected—either Table 13 for the Basic 3-Step Model option, Table 14 for the Enhanced 4-Step Model option, or Table 15 for the Activity-Based Model option. This table number corresponds to those tables in the report as the source of information.

Step 3: Identify column source for costs. Next, the user should identify the column within each of those tables to pull the costs from. The tables include costs estimated by small states, by large states and by consultants.

Small states should generally select the lowest of the three options, which will usually be the small state column. In some cases, the costs estimated by small states are lower than those estimated by large states. We view this as anomalous, and do not see a reason to perpetuate that outcome.

Large states have a choice of whether they perceive the estimates by their peers, or the estimates by the consultants as more credible. The authors are inclined to recommend the consultant estimates if the two disagree, because the consultants are likely to have more experience estimating model costs, and the observed ranges tend to be narrower. Users are free to make their own judgment, though.

The selected column should be circled for each category.

Step 4: Copy mean cost, lower quartile and upper quartile from the source table and column. The user should then look in this report, and copy the cost estimates from the selected table and column onto the worksheet. The user should copy the average value, as well as the lower quartile and upper quartile values into the appropriate spaces on the table.

Step 5: Select the mean, lower quartile, or upper quartile for each category. Make manual adjustments as warranted. For each task category, the user should decide whether to base their own cost estimate on the lower quartile value, the mean value, or the upper quartile value. That decision should be based on factors such as how big the state is, how detailed the approach will be, and how many features the user expects to build into the model within that category. Manual adjustments or deviations from these ranges may be warranted if the user feels there are factors that would push their own costs beyond the reported ranges.

It is possible that the user wants to include some tasks that are not listed here. Those should be included in the last row of the table, with their associated costs, and do not correspond to data presented in this report.

Step 6: Allocate the costs between external costs and staff time. Assume 1 hour staff time = $100. Agencies may wish to do a portion of the work in-house using their own staff. Based on the interviews, this is the default for the Networks and TAZs task, as well as Annual Maintenance and Troubleshooting task. When the data were collected for this project, the staff time estimates were converted to dollars using a rate of $100 per hour.

If agencies conduct work in house, it would reduce the external dollar costs. For each task, the user should allocate the percentage of the task they intend to complete in-house. That percentage can be used to calculate the split between the external and internal costs. The internal costs should then be converted to hours, using a rate of $100 = 1 hour. The end result should be an allocated cost with dollars for the external costs, and hours for the staff time.

Step 7: Explain the choice of mean, lower quartile, or upper quartile and any manual adjustments. Users should provide a brief explanation for why they recommended the cost they did for each model category.

Step 8: Calculate subtotals and totals. Users should then sum the sum the columns to get the indicated subtotals and totals in the second table. The items associated with each subtotal are identified in the table. The costs from tables, the recommended costs, and the allocated costs should all be summed to provide points of comparison and serve as a check.

The user should then calculate the total 10 year cost per capita as the sum of the total up-front cost, plus 10 times the annual maintenance and troubleshooting cost, divided by the state population. This will serve as another useful point of comparison.

All cost data were collected in 2017, and can be considered to reflect current dollars. The costs may be adjusted for inflation for future years.

Upon completion of the worksheet, a series of reasonableness checks should be conducted. These should include:

Comparing the recommended costs to the reported spending in

1. Table 11 and Table 12.

Calculating the total per-capita cost over a 10 year period, including model development costs and staff costs, and comparing it to the values in

2. Table 10.
3. Comparing the total per-capita cost to the willingeness to pay, as reported in Table 16.

Finally, it would be prudent to have any cost estimates reviewed by a peer. The contact information for interview participants is included in Appendix D of this report. Those individuals may be a good starting point for agencies looking for someone to help with a budget review.

Appendix F: Cost Estimating Worksheet

		Step 1: Identify closest task within each category	**Step 2: Identify source table for costs**	**Step 3: Identify column source for costs**	**Step 4: Copy mean cost, lower quartile and upper quartile from the source table and column**	**Step 5: Select the mean, lower quartile, or upper quartile for each category. Make manual adjustments as warranted.**	**Step 6: Allocate the costs between external costs and staff time. Assume 1 hrs staff = $100.**		**Step 7: Explain the choice of mean, lower quartile, or upper quartile and any manual adjustments.**
Item	Category	Tasks	Source Table	Source Column	Costs from Tables	Recommended Cost	Allocated Cost External Costs (dollars)	Staff Time (hours)	Explanation
1	Networks & TAZs	Code highway networks, TAZ system, develop socio-economic data.	Table 13	Small State, Large State, or Consultant	Lower Quartile: Upper Quartile:		% In-House:		
		Code urban transit networks, code intercity air, rail & bus networks	Table 14						
		Use existing passenger networks and TAZ system, code freight intermodal networks	Table 15						
2	Baseline Data	Collect traffic counts	Table 13	Small State, Large State, or Consultant	Lower Quartile: Upper Quartile:		% In-House:		
		Collect traffic counts, Purchase base IE/EI/EE trip tables from GPS or cell phone data	Table 14						
		Collect traffic counts, Purchase full base trip tables from GPS or cell phone data	Table 15						
3	Survey Data	None	Table 13	Small State, Large State, or Consultant	Lower Quartile: Upper Quartile:		% In-House:		
		Buy into NHTS add-on sample	Table 14						
		Design and conduct local travel surveys	Table 15						
4	Passenger Travel	Develop Basic 3-step model (no-mode choice) with parameters from NCHRP 735 and NCHRP 716	Table 13	Small State, Large State, or Consultant	Lower Quartile: Upper Quartile:		% In-House:		
		Develop 4-step model with estimated model parameters	Table 14						
		Develop activity-based model. Estimate model parameters. Develop application framework using population synthesizer.	Table 15						
5	Long-Distance Passenger Travel	None	Table 13	Small State, Large State, or Consultant	Lower Quartile: Upper Quartile:		% In-House:		
		Adapt National Long-Distance Model	Table 14						
		Develop custom long-distance travel model	Table 15						

		Step 1: Identify closest task within each category	Step 2: Identify source table for costs	Step 3: Identify column source for costs	Step 4: Copy mean cost, lower quartile and upper quartile from the source table and column	Step 5: Select the mean, lower quartile, or upper quartile for each category. Make manual adjustments as warranted.	Step 6: Allocate the costs between external costs and staff time. Assume 1 hrs staff = $100.		Step 7: Explain the choice of mean, lower quartile, or upper quartile and any manual adjustments.
Item	Category	Tasks	Source Table	Source Column	Costs from Tables	Recommended Cost	Allocated Cost External Costs (dollars)	Staff Time (hours)	Explanation
6	Freight Transportation	Perform OD matrix estimation to create static truck trip table Adapt commodity flows from FAF with truck flows assigned to network Develop policy-sensitive freight model with non-Truck freight modes	Table 13 Table 14 Table 15	Small State, Large State, or Consultant	Lower Quartile: Upper Quartile:		% In-House:		
7	Calibration and Validation	Calibrate and validate model, conduct sensitivity testing	Table 13 Table 14 Table 15	Small State, Large State, or Consultant	Lower Quartile: Upper Quartile:		% In-House:		
8	Reserve Fund	Additional budget allocation to protect against unexpected circumstances.	Table 13 Table 14 Table 15	Small State, Large State, or Consultant	Lower Quartile: Upper Quartile:		% In-House:		
9	Additional Tasks	Additional budget allocation to protect against unexpected circumstances.					% In-House:		
10	Annual Maintenance & Troubleshooting	Maintain networks, update socio-economic data, troubleshoot problematic model results/errors.	Table 13 Table 14 Table 15	Small State, Large State, or Consultant	Lower Quartile: Upper Quartile:		% In-House:		

Step 8: Calculate subtotals and totals

	Calculation	Costs from Tables	Recommended Cost	Allocated Cost	
				External Costs (dollars)	Staff Time (hours)
Data Subtotal	Items 2 + 3	Lower Quartile: Upper Quartile:		% In-House:	
Model Subtotal	Items 1 + 4 + 5 + 6 + 7 + 8 + 9	Lower Quartile: Upper Quartile:		% In-House:	
Total Up-Front Cost	Data Subtotal + Model Subtotal	Lower Quartile: Upper Quartile:		% In-House:	
Annual Maintenance & Troubleshooting	Item 10	Lower Quartile: Upper Quartile:		% In-House:	
Total 10-Year Cost per Capita	(Total Up-Front Cost + 10 * Annual Maintenance & Troubleshooting) / State Popluation	Lower Quartile: Upper Quartile:		% In-House:	

Appendix G: Advice from the Respondents

While conducting the interviews, we took the opportunity to solicit advice from the respondents. We asked this at a few points in the interview, including:

> What advice would you give to a state that is considering developing a new statewide model?
>
> Having gone through this exercise (the cost estimating scenarios), is there anything specific you think other states should consider when budgeting for statewide modeling projects?
>
> Having gone through this exercise (the go/no-go scenarios), do you have any additional advice for states as they select a modeling approach to meet their policy needs?

Several themes emerged, which are summarized here.

Match your model to your policy needs

A key theme that emerged from our conversations with virtually all the interviewees, and from the willingness to pay responses, is the importance of matching model capabilities to policy needs and avoid the temptation of making the model more sophisticated than it needs to be. The basic advice given is: at the outset, it is important to identify what questions the agency want the model to be able to answer (e.g. rural highway forecasts, congestion reduction, multimodality, pricing strategies, or other complex policy questions). This requires a clear understanding of the priorities of upper management and other stakeholders to ensure the model will satisfy their needs. A number of interviewees also noted the need for anticipating future policy questions. One interviewee quipped "build the model not just for the present but for 5 years from now". Doing so will avoid costs later to upgrade.

Additionally, while in the scenario exercises our interview protocol did not specify the growth rate of the state in the hypothetical situation, some interviewees noted that growth rate is an important dimension to consider; if a state is experiencing rapid population and economic growth, a more sophisticated model is warranted.

Engage the entire community.

Nearly all of the interviewees talked about stakeholder engagement, as it is crucial at several levels. First, engagement helps to identify questions early on that need to be answered (as discussed in the "match your model to your policy needs" section above). Second, it is important for getting buy-in; i.e. if the community feels that they were consulted in the process, then they are more likely to have confidence in the output. Third, it encourages wider application of the model. As one interviewee noted, "to get the biggest return from the model is to use it". Another interviewee commented: "Once the model has been made aware to the people, people started asking for the model to use it and the demand on the model has increased exponentially." This leads to a final point about expanding the community, as some interviewees mentioned emerging applications of statewide models, e.g. resilience / emergency / hurricane evacuation (Florida and Vermont), and understanding tourism (Florida and at least one other state).

A key component of this engagement is having a person in place who can do it. Modeling is not a purely a back-room activity where the stereotypical engineer toils away in a cubicle interacting with no one but a computer for marathon coding sessions. While that may be an important component of the job, it is also important to have someone who can engage the broader user base and serve as a translator between their needs, and what can be accomplished in a model, and between the technical results and the relevant insights. These roles can be filled by the same person, although such individuals can be difficult to find, so they can also be filled by different members of a team. For example, a DOT developing a new statewide model may hire someone new to fulfill the technical role, but pair that person with an experienced planner who knows the organization and the people, and can serve as an ambassador for the model and a mentor for the analyst. Without that support, someone new coming in to fill that role may not be set up for success.

Similarly, it is hard to fill this role by relying on consultants. While consultants may be effective in developing statewide models, because they are likely to have experience doing so, it remains extremely valuable to have someone internal in this "translator" role who can go to meetings, have the necessary conversations, and be responsive without a contract modification.

Only one state that was interviewed was able to rely on someone external—in their case an individual at the state university—as their primary statewide modeler. This arrangement relied on a strong relationship, and a contracting structure that provided a fixed amount each year with the understanding that model applications and requests for assistance would be prioritized, and model development activities would proceed at a pace determined by any remaining budget.

One way of viewing this is, "A good modeler trumps a good model." What that means is that the details of the model and its specific features, while the focus of this report, may be less important than having an individual who can use it effectively.

Finally, once the community is engaged, it is important to keep them engaged. Asking stakeholders what they want, and then expecting them to wait a few years to get it risks alienating those stakeholders. Therefore, states should consider phasing the development of their statewide models to demonstrate success early. The trade-off is that it that phased development may be more costly, in part because the model needs to be calibrated multiple times. Nonetheless, it is valuable to identify a realistic timeframe for when the model and associated staff can start producing useful results.

Provide modeling support to small MPOs

An important constituent are the MPOs in a state, and a cooperative relationship can be extremely valuable. We already discussed that some states use their statewide model to provide external flows as input to the MPO models.

Another arrangement used in a number of states is one where DOT staff conduct the modeling as a service to the smaller MPOs in the state. While the larger MPOs tend to have the resources to hire travel modelers and invest in their models, it is more challenging to do so in a small MPO. In particular, hiring a capable travel modeler may be difficult for an agency with only a handful of staff, a part-time demand for the role, and no one who can be a technical peer to the individual. The advantage of the DOT taking on the role is one of economies of scale. If four small MPOs each have the demand for a 0.25 FTE modeler, one DOT employee can fill that role, and also have other technical staff working on statewide modeling or related tasks.

Four states use a form of this approach.

In the first, there are eight MPOs, two of which have their own models. For the others, the statewide model serves as a tool that they can use.

In in the second, the DOT provides modeling support for the MPOs with a population less than 200,000. DOT staff development models for those small MPOs in house (urban models, not statewide models), and is responsible for applications. For the larger MPOs, the MPO develops their own models and applies them for local projects, but MDOT applies the MPO models for state projects within the MPO boundaries.

In two additional states, the large MPOs develop and apply their own models, but DOT staff develop and apply models for the small MPOs. In doing so, they have moved towards a standard model across the small MPOs. While the model differs in its inputs, the structure of the model is identical across all the small MPOs. This makes it more efficient for DOT staff to use and maintain, because they only have to learn one model and not several, and because they can avoid duplicative work.

The financial and institutional details of these arrangements were not explored, but since there are potential cost savings they should be tractable. In some cases, this modeling support preceded the development of a statewide model, which was advantageous because the individuals involved were then in a position to shepherd a statewide model to success.

Don't cheap out on the data (unless you do!)

Data collection is expensive. As discussed in previously, purchasing NHTS add-on samples costs upwards of $210 per household, and a custom survey costs more than that (according to Table 15, $100,000-$420,000 for small states, and $700,000-$3,250,000 for large states). Typically, thousands of households are required for model estimation, so data collection costs can reach millions of dollars. Nevertheless, many interviewees stressed the importance of investing in data collection, because the quality of the model prediction is strongly dependent on the quality of the data ("garbage in, garbage out" was mentioned in several interviews). Poor data quality can cause problems in the model estimation phase, which can be costly to resolve.

At the same time, multiple respondents expressed exactly the opposite view—that you should beg, borrow and steal whenever possible, especially with respect to data. One way to save on data and development costs, at least in the initial model development phases, is to borrow and adapt as much existing data and models as possible. Borrowing data helps to get a model up and running in a relatively short time. In the case of Arizona, back in the late 2000s AZDOT were able to borrow data from Tennessee and a number other sources in order to develop a (in the words of our interviewee) "crude" first generation model. While "crude", the first generation model served to demonstrate what a model can do and get management buy-in to invest in upgrading the model.

Interviewees from states with large MPOs also mentioned being able to borrow data, network or model parameters from the MPOs to reduce development costs. In fact, this is how the Basic 3-Step Model scenario is scoped—to use transferrable parameters as documented in two NCHRP reports.

There is clear disagreement on the issue, and ultimately it is a judgment that each state must make for itself.