Determination of the State of the Practice in Metropolitan Area Travel Forecasting

Findings of the Surveys of Metropolitan Planning Organizations

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By

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Acknowledgement

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Staff of Vanasse Hangen Brustlin, Inc. who participated include Ramanujan Jagannathan who developed and managed the software for the web-based survey; Srividya Vadlamani and David Anspacher who prepared data tabulations, reviewed the data to gain insights, and prepared appropriate graphics; and Philip Shapiro who offered advice based on his many years of work in applied travel forecasting. Jon Williams of TRB provided direction, technical guidance, and insights on the use of travel-forecasting procedures.

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EXECUTIVE SUMMARY

The procedures used by Metropolitan Planning Organizations (MPOs) for travel forecasting include both—

- The general methodology applied for an element of the four-step, or similar, process (e.g., trip distribution using a gravity model)
- The details of the application of the methodology (e.g., gravity model is doubly constrained for home-based work [HBW] trips)

This report is descriptive. A web-based survey of more than 200 MPOs and in-depth interviews with a smaller sample of MPOs provided data that characterize and describe both the general methodology and many, but not all, of the details of methodology application. In this sense, the information presented documents the state of the practice. What the surveys and interviews could not do is reveal whether or not the models produce accurate forecasts. MPOs do not have systematic procedures to assess the degree to which either the forecasts of exogenous variables driving the travel forecasting models (e.g., population, employment, household size and composition, auto ownership) or the resulting forecasts of travel demand are accurate or inaccurate. Most agencies reported general satisfaction with their forecasting procedures and the ability of the MPO to use the models to address the questions being asked by their constituent jurisdictions. A few MPOs are undertaking efforts to develop or apply new methods to address a range of issues, including congestion, peak spreading, and freight movement.

In terms of the general procedures used for travel demand forecasting, the findings are as follows:

- The great majority of MPOs are using trip-based, four-step travel-forecasting procedures.
- A few MPOs are using activity- or tour-based methods. Many MPOs omit the mode choice step in travel forecasting. Some MPOs do not use travel forecasting.
- Trip Generation—The unit of travel for medium-sized (hereafter medium) and large MPOs is “total person trips”; for small MPOs the travel unit “vehicle trips” is the travel unit for almost as many MPOs as is “total person trips.” The trip generation relationship is defined by cross-classification for trip productions and by a function derived from regression analysis for trip attractions.
- Trip Distribution—a gravity model distributing person trips on the basis of travel time over the highway network is the dominant methodology. An impedance function that combines highway and transit times or other factors is used by a significant portion of the large MPOs. Fewer than half of the reporting MPOs apply some type of adjustment factors in the distribution models.
- Mode Choice—A mode choice model for HBW trips is used by 95% of the large MPOs, 54% of the medium MPOs, and 21% of the small MPOs. The functional form of the mode choice models is overwhelmingly multinomial or nested logit.
- Assignment—Equilibrium assignment of highway trips is used by 76% of all MPOs and 91% of large MPOs. Transit trips are assigned by 94% of the large, 56% of the medium, and 34% of the small MPOs.

- Postprocessing—Just more than half of all MPOs and 97% of large MPOs reported postprocessing of assignments for mobile source emissions analysis. Feedback of highway and transit times to model components is reported as follows:
  - To auto ownership: 16% of all MPOs; 42% of large MPOs
  - To trip generation: 16% of all MPOs; 33% of large MPOs
  - To trip distribution: 46% of all MPOs; 88% of large MPOs
  - To mode choice: 42% of all MPOs; 85% of large MPOs
  - To land use: 12% of all MPOs; 41% of large MPOs

The majority of MPOs serve metropolitan areas with populations of less than 200,000. For these small MPOs, and even for most medium MPOs serving areas with populations between 200,000 and 1 million, the primary purpose for which models are applied relates to roadway planning. The summary of travel-forecasting methods previously mentioned is a reasonable description of their practices. MPOs in larger urban areas tend to face more complex problems. These areas may have greater levels of congestion, may be considering alternative forms of development that seek to deemphasize auto use, may be planning transit New Starts projects, or may be considering various forms of roadway pricing. The traditional four-step models may not have adequate sensitivities to the policies to be evaluated. Some of these areas have developed or are strongly considering development of "advanced" models that are activity based or that include population synthesis, destination choice, or alternative assignment methods.

Model validation (static validation) is most often based on matching travel behavior as reported in the household survey used to estimate the models and matching traffic counts, which are reported to be of widely varying quality. The Census Transportation Planning Package provides an independent source for validation of the generation and distribution of work trips, but few if any sources exist that can be used for independent validation of other aspects of the travel-forecasting process.

Backcasting to assess the validity of models over time is rare. Formal sensitivity analysis to assess how forecasts are likely to respond to changes in demographic, economic, or transportation system factors is done by a few agencies, but it is not common practice.

The resources available to most MPOs for travel forecasting are limited. The majority of MPOs in areas of population less than 200,000 rely on the state transportation agency or consultants for model development and application. Even in larger agencies that travel, forecasting staff are typically fewer than 10, and the annual budget for travel forecasting is less than $1 million. MPOs reported that they want procedures that "work" in the sense that the procedures can be applied with existing software by agency staff in reasonable amount of time and yield reasonable forecasts. MPO models are validated and updated periodically. Almost three-quarters of MPOs reported updating their models since 2001. Making major changes in the structure or details of a model application requires more resources than are readily available and may bring into question decisions that were made using the previous model set. For these reasons, MPOs are conservative, reporting a reluctance to adopt new methods until they are proven to offer better results than the current procedures.

INTRODUCTION

"… models are highly imprecise, their inputs are extremely difficult to predict, and the formulations of future travel demand are almost sure to be inaccurate to some extent."[1]

Similar statements to the quote here could be found in many sources. The methods and models used by metropolitan planning organizations (MPOs) to forecast travel have evolved over more than half a century, building on work begun by T.J. Fratar in the 1940s to predict patterns of urban travel on the basis of changes in population and employment. This work was continued by Alan Voorhees and the staff of the Bureau of Public Roads in the 1950s to include a measure of spatial separation in forecasting travel and to take advantage of the then-emerging availability of digital computing.[2] By 1965, a basic set of procedures and software was available that permitted a planning agency to construct networks representing highway systems, build the shortest paths, forecast travel, and assign trips to the networks.

If an assessment of the state of the practice in travel demand forecasting had been prepared in 1965, it would have found the following:

- Agencies and planning processes were established in response to the 1962 Highway Act.
- Large-scale household surveys, often with in-person interviews, were conducted in many locations.
- Many agencies had developed representations of highway networks and had mainframe software from at least two sources that could be applied.
- Networks used average daily speeds and capacities.
- Trip generation analyses for productions and attractions were being performed using regression analysis and data from home-interview surveys. Many agencies had seven or more person trip purposes. Trucks, often light and heavy, were classified as other "purposes," as were taxis.
- The gravity model was being used by advanced studies; others were using Fratar expansions. The Intervening Opportunity Model was in use in at least two metropolitan areas.
- Traffic assignment was generally all or nothing. Capacity restraint methods were available, applied as averaging of multiple loadings.
- There were no standard methods for transit analysis.
- Land-use models were being explored.

By 1975, the changes would have been as follows:

- Some use of peak and off-peak networks had been implemented, with different speeds and capacities.
- There was a greater use of category tables to determine link speeds and capacities.
- Cross-classification was the accepted method for trip generation analysis (productions).

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[1] Brinkman, P. Anthony. *The Ethical Challenges and Professional Response of Travel Demand Forecasters*. Ph.D. dissertation, University of California, Berkeley, 2003.

[2] Fratar, T.J., Voorhees, A.M., Raff, M.S. Forecasting Distribution of Interzonal Vehicular Trips by Successive Approximations/with Discussion. *Proceedings of the Highway Research Board*, Vol. 33, 1954.

- Number of trip purposes was reduced. Most agencies used HBW, home-based other (HBO), non-home based (NHB), and truck.
- Capacity restraint was in general use. Typically use was iterative; some was incremental.
- Transit network development and analysis software was available (Urban Transportation Planning System (UTPS).
- Mode choice models (stratified curves, differential utility) were in use.
- Land-use models were being explored.

By 1985,

- Large-scale household travel surveys were no longer conducted. Small-scale telephone-based surveys became the norm.
- Logit models were the accepted form for mode choice.
- Feedback of congested times was provided to distribution and mode choice.
- Land-use models were being explored.

By 1995,

- Equilibrium assignment was the accepted procedure.
- Assignment applications were multiclass.
- Nested logit mode choice models were in use in many agencies.
- Non-motorized trips were included in trip generation in some models.
- Work-based purposes were used in trip generation and distribution.
- Land-use models were being explored.

Since 1995,

- Some MPOs use stated preference survey findings in model development.
- Postprocessing is used for speeds and volumes for emissions analysis.
- There is some use of destination choice models.
- Tour-based models are first applied in MPOs.
- There is some use of auto ownership models preceding trip generation.
- There is some use of sample enumeration and synthetic households to define trip patterns.
- Nonmotorized trips are used in some mode choice models.
- Land-use models are being explored, with some application.
- GIS systems are used extensively for data storage and analysis and presentation of findings.
- Much faster and less expensive computers with greater capabilities are available.

In spite of the advances in travel-forecasting procedures, students of the process have identified many shortcomings of the conventional procedures and the ways they are applied. Common criticisms include the following:

- Lack of integration of land-use and transportation forecasting
- Failure to properly account for and reflect all factors affecting traveler behavior
- Failure to account for interactions among household members

- Inability to properly address trip chaining
- Lack of consistency in the several elements of the four-step process
- Need for extensive use of "adjustment factors" of various types to properly replicate observed conditions
- Inability to represent all the ways travelers may respond to congestion or pricing

In response to these criticisms, academic researchers, consulting firms, software vendors, and MPOs have proposed ways to improve the process. The suggested enhancements range from minor changes in the ways the traditional methods are applied, implementation of new algorithms, or inclusion of other factors in functional formulations to entirely new paradigms of traveler choice and behavior.

MPOs strive to use travel-forecasting methods that will allow them to address the key policy questions being asked by the participating agencies, that provide information in a timely manner, and that can be developed and applied with the resources available to the agency. Although some agencies, faced with new questions, will seek to develop and apply advanced methods, many prefer to maintain methods that meet their planning needs and are consistent with the state of the practice. It became apparent in previous TRB work that there is no readily available documentation to which an MPO can turn to find the common practice in travel forecasting. In response, TRB formed a committee to assist in developing a statement of the state of the practice.

The committee engaged Vanasse Hangen Brustlin, Inc. (VHB) to assist in gathering information needed to make a Determination of the State of the Practice in Metropolitan Area Travel Forecasting. As an initial step, a survey was conducted to develop an inventory of the practices and procedures currently in use by MPOs. Based in part on the information obtained in that survey, the committee identified other issues that should be explored in greater depth with a smaller group of MPOs. The agencies selected for those in-depth interviews were not the typical or average MPO. Rather, the agencies selected were drawn from those known to have undertaken development of "advanced" practices or to be active in organizations such as the Association of Metropolitan Planning Organizations (AMPO). Information was also obtained from the five MPOs represented on the TRB committee.

This report documents the scope of the web-based survey and presents findings on the basis of the responses received, the information gained in the in-depth interviews, information provided by the MPOs represented on the committee, commentary in the literature on the state of the practice, and the experience of project staff participating in model peer reviews.

WEB-BASED SURVEY OF MPOS: OVERVIEW OF THE WEB-BASED SURVEY

The intent of the web-based survey was to obtain information from a broad sample of MPOs that described the travel-forecasting procedures of each agency in sufficient detail to permit assessment and categorization of their methods. Design of the survey began with review of the project scope of work as developed by the committee. Of particular note was the list of 21 specific questions raised by the committee. In addition, the project team drew on its experience to develop questions that would assist in documenting current practice.

The survey was developed as a web-based instrument that could be completed online by each MPO. To aid in processing, almost all questions were "closed end," permitting only specific responses. Recognizing that there would be many circumstances in which an agency's practice would not be described by a prespecified response, an opportunity was provided for further comment for some questions.

An initial draft survey was prepared and circulated for comment. Following revision, this survey was pretested at two large and one medium MPO. On the basis of comments from the staff of the pretest agencies and others, the survey instrument was further revised.

Listings of MPOs and their e-mail addresses were developed from lists provided by FHWA and AMPO. Using these lists, an e-mail was sent by TRB to each MPO with a request that it visit a specified web site to complete the survey. MPOs were assured that responses would never be attributed to a specific MPO but reported only in aggregate. Each e-mail contained a user name and password unique to the specific MPO. As would be expected, some follow-up work was required to find proper addresses for MPO e-mails that "bounced" and to identify addresses for MPOs not fully identified on the source listings. In addition, considerable assistance was provided to a number of the responding MPOs.

Prior research by TRB had determined that for MPOs in many states, all or a substantial part of the travel forecasting was done by the state transportation agency. For those states, the survey was set-up so that both the MPO and the state agency could access the database and provide information. In these states, there are many similarities among the procedures used in each of the MPOs; therefore, the states were also provided with a procedure for copying the information relating to travel forecasting from the response for a given MPO to that response for another MPO. Each of these MPOs could provide responses unique to its area.

The surveys were originally distributed on June 27, 2005, with a requested response by July 15, 2005. Reminder and follow-up e-mails were sent as July 15 approached. A special effort was made by TRB with assistance from AMPO and others, to obtain information from the MPOs classified as "large"; that is, in areas with population exceeding 1 million. In response to requests, the survey database was kept open, and responses were solicited until August 13. Tabulations and comments presented to the TRB committee in September 2005 were based on data received as of August 13, 2005. Information from nine other MPOs was received after August 13. Data from these additional responses are included in this document.

As in any large survey, there were misunderstandings of some questions by a few respondents and there were data entry errors by other respondents. Errors of this type were found as analyses were conducted. These frequently appeared as outliers or as anomalous or apparently spurious results. To minimize such erroneous responses, a series of logic checks was applied to the dataset. Where possible errors appeared, the original survey response was examined in detail in an attempt to correct the information. These changes, too, have been incorporated. In spite of

these efforts, some incorrectly reported information, caused by misinterpretation of the intent of a question or simple error in entering a response, may remain.

WEB-BASED SURVEY FINDINGS

Content and Major Topics

The survey covered 12 general topic areas:

- Agency identification and contact information
- General description of the MPO
- Description of the area in which the MPO is located
- Data forecasts
- Planning issues and uses of models
- Model validation
- Trip generation and trip distribution
- Mode choice
- Managed lanes
- Trip assignment
- Additional questions
- Documentation

The survey called for 15 items of information related to identification of the MPO and the persons responding to the survey. In addition, there were 91 numbered questions. However, many questions had subquestions that were presented or not presented, depending on the answers to previous questions. Overall, there were nearly 1,100 items for which a response could be requested. The survey questionnaire is included in Appendix A.

Number of Responses

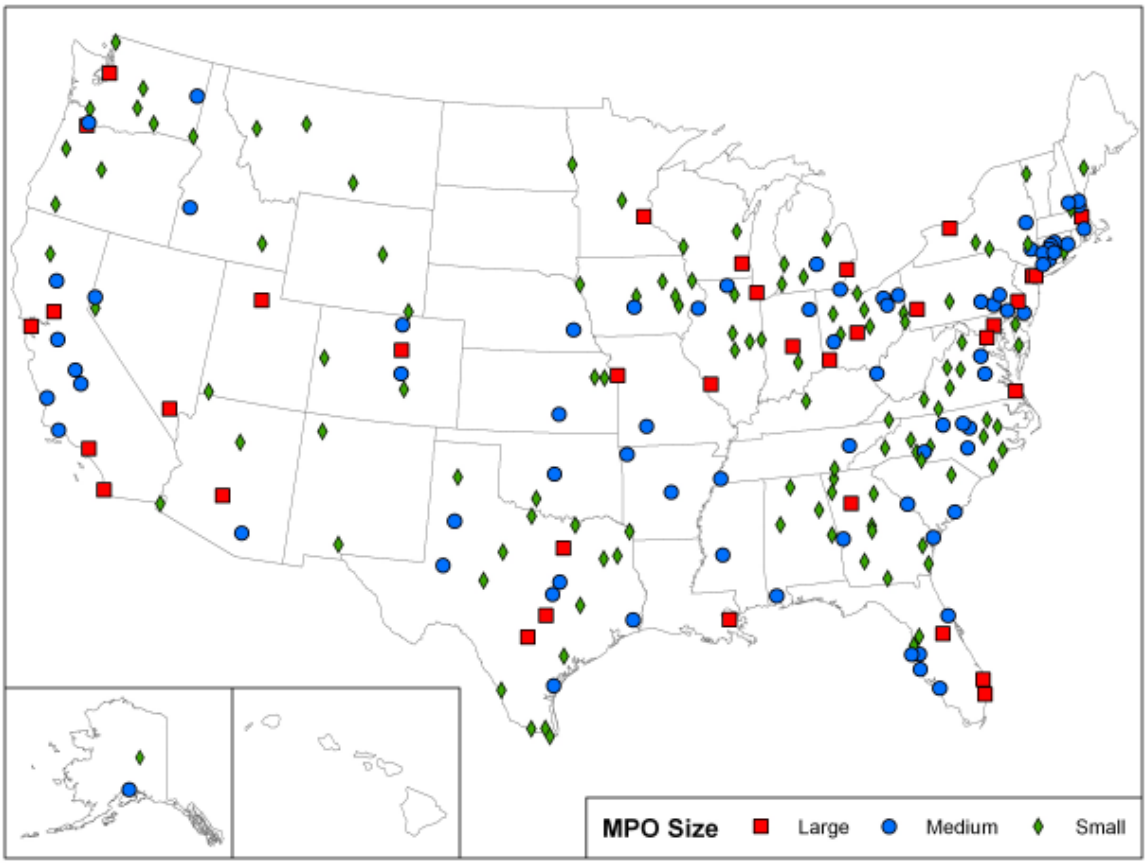
The survey was sent to each of the 381 MPOs. In addition, each state transportation agency was sent an e-mail with a link to the survey and a notification that the survey request had been sent to the MPOs in the state. States and MPOs were asked to coordinate and cooperate in responding to the survey. This was of particular importance for those MPOs where most of the travel demand forecasting work, including model development or application, is done by the state transportation agency. In these states, the state agency completed and submitted the survey for each MPO. As shown in Table 1, data were received from 228 MPOs. Because not all questions were answered for each MPO, the number of responses is not the same for all questions.

Figure 1 illustrates the locations of the MPOs responding to the survey. All states, except Hawaii, are represented in the responses.

Table 1: Surveys Sent and Responses Received, By MPO Size

MPO Classification	Surveys Sent	Responses Received	Percentage Responding
Small (population less than 200,000)	205	116	57%
Medium (population between 200,000 and 1 million)	133	76	57%
Large (population greater than 1 million)	43	36	84%
Total	381	228	60%

Figure 1: MPOs Providing Responses



Descriptors of Responding MPOs

Transportation Management Area—Forty-five percent of all MPOs, and 91% of large MPOs reported that they are a transportation management area (TMA). Even among medium MPOs, 77% report being a TMA.

Air Quality Conditions—MPOs in areas that are in non-attainment or maintenance at specified levels for certain pollutants are subject to certain travel-forecasting model requirements. Air quality non-attainment status of the responding MPOs is provided in Table 2.

Table 2: Percentage of MPOs reporting Air Quality Non-Attainment or Maintenance before May 1, 2005

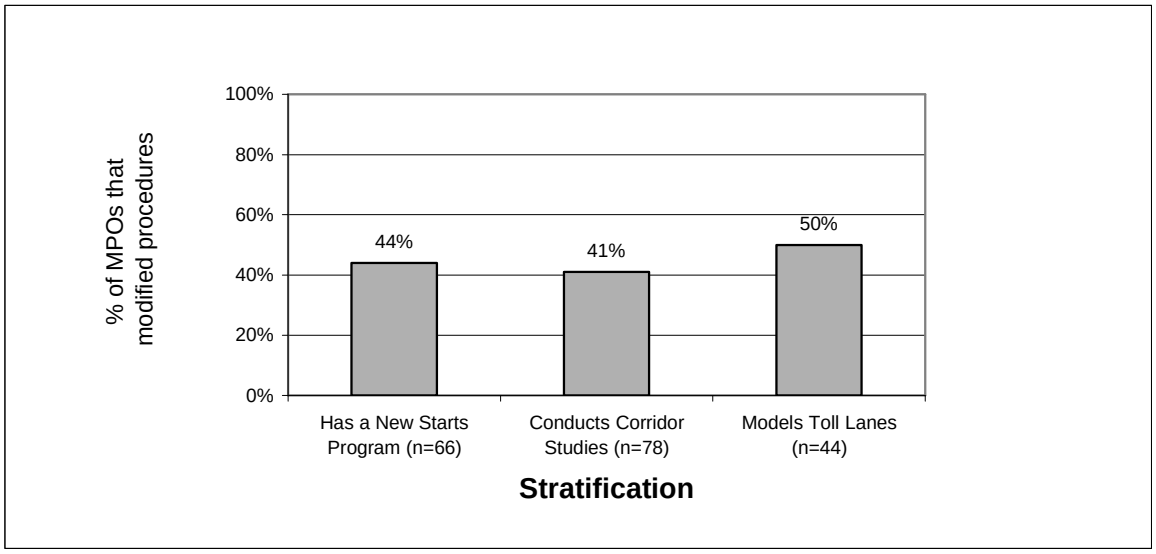
Non-attainment or Maintenance Status	Small	Medium	Large	Total
Ozone (n=214)				
Serious or worse	4%	16%	28%	12%
Not serious	16%	37%	53%	29%
CO (n=198)				
Serious or worse	3%	17%	10%	9%
Not serious	7%	23%	58%	20%
PM 10 (n=188)	10%	21%	37%	18%
PM 2.5 (n=192)	8%	25%	50%	20%
NOx (n=187)	5%	16%	12%	10%
General Non-Attainment or Maintenance Status	92%	72%	30%	54%

Air quality issues are one factor in spurring agencies to make changes in their travel models. Nearly all of the large MPOs, nearly three-quarters of the medium MPOs, and nearly one-third of the small MPOs are in areas that are in non-attainment. Approximately one-third of the large MPOs and 20% of the medium MPOs are in areas in which air quality has been designated serious or worse for ozone. As a result, 55% of the large MPOs and 30% of the medium MPOs reported having modified their travel-forecasting procedures to conduct air quality–related analyses. Modifications to the travel-forecasting procedures are also undertaken in response to the needs for analysis of transportation projects.

Those MPOs that have found it necessary to modify travel-forecasting procedures to conduct air quality analyses are more likely to have a New Starts/Small Starts program, to conduct corridor studies, and to model toll lanes than those MPOs that have not needed to modify travel-forecasting procedures (see Figure 2). However, this difference is largely a result of MPO size.

As illustrated in Figure 2, the MPOs that reported having to modify their travel-forecasting procedures are those that are in the larger metropolitan areas and that are being asked to respond to more complex questions related to transportation investments or policy. The metropolitan areas tend to be also considering major new roadways, transit New Starts, congestion pricing, or High-Occupancy Toll (HOT) facilities.

Figure 2: Percentage of MPOs That Have Modified Travel Forecasting for Air Quality Analyses



More than one-third of all MPOs are in areas in which a transit New Starts project is either in progress or is being contemplated, and 60% are in areas planning a major highway project. Approximately half of the agencies engaging in such studies have modified their models (Table 3).

Table 3: Number of Agencies Modifying Procedures in Response to Transit or Highway Planning Need

	Small	Medium	Large	Total
Is a transit New Starts Ppoject in progress or contemplated? (n=213)				
Yes	14	34	34	82
No	91	38	2	131
If Yes:				
Had to modify procedures	3	16	22	41
Have not modified procedures	11	14	12	37
Is a major highway corridor in progress or planned? (n=209)				
Yes	44	49	33	126
No	59	21	3	83
If Yes:				
Had to modify procedures	19	26	18	63
Have not modified procedures	24	23	15	62

Those MPOs that have New Starts/Small Starts programs are more likely to conduct corridor studies, to model toll lanes, or to perform their own travel forecasting than are MPOs that do not have New Starts/Small Starts programs (see Figure 3 and Figure 4).

Figure 3: Percentage of MPOs That Have a New Starts/Small Starts Program (Stratified by Whether MPO conducts Corridor Studies or Models Toll Lanes)

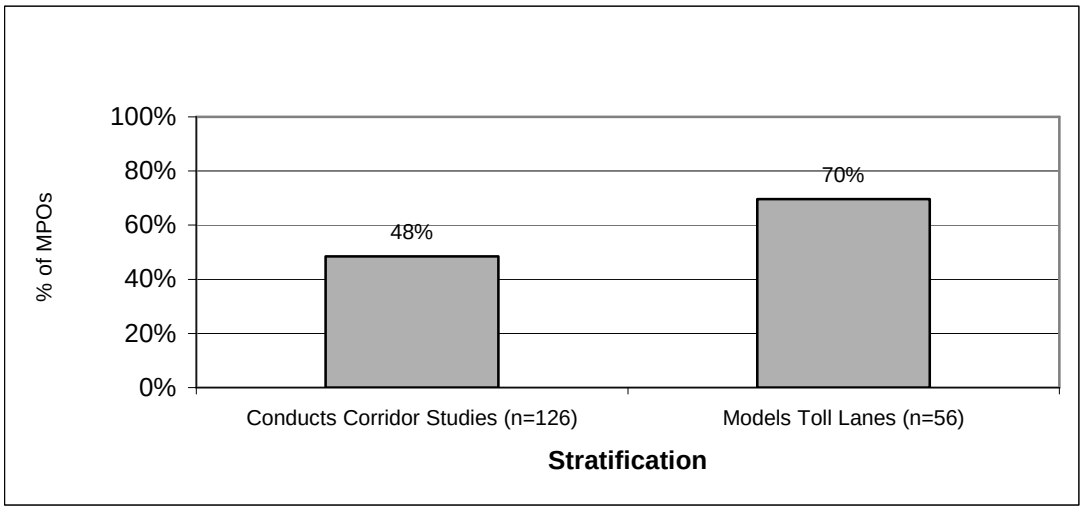
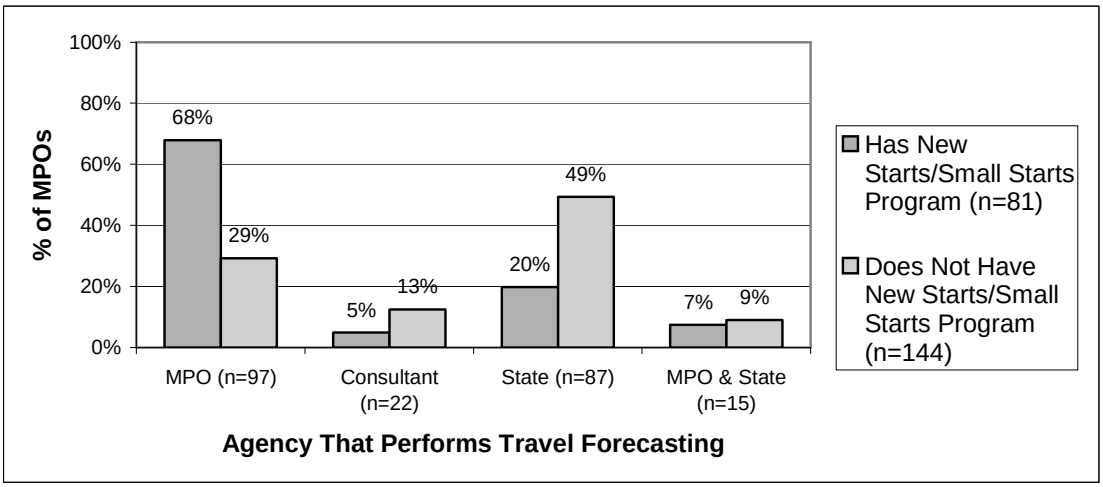


Figure 4: Agency Performing the Travel Forecasting (Stratified by Those That Have a New Starts/Small Starts Program)



Those MPOs that have a New Starts/Small Starts program or that model toll lanes are more likely to conduct corridor studies than those MPOs that do not (see Figure 5). In addition, MPOs that perform their own travel forecasting either by themselves or with a consultant or the state are more likely to conduct corridor studies than MPOs that do not participate in travel

forecasting (see Figure 6). For example, 71% of the MPOs that perform their own travel forecasting have been engaged in a corridor study.

Figure 5: Percentage of MPOs That Conduct Corridor Studies (Stratified by Whether MPO Has New Starts Programs or Models of Toll Lanes)

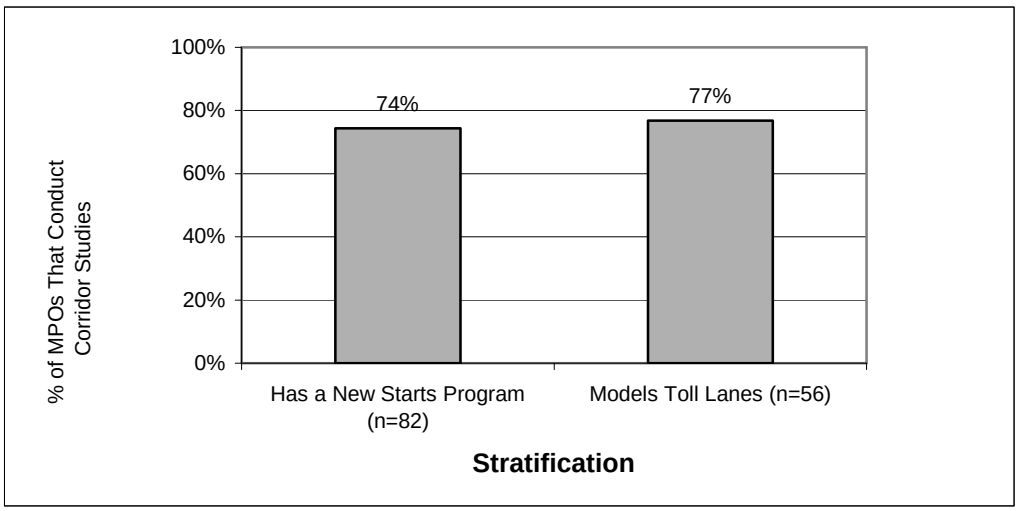
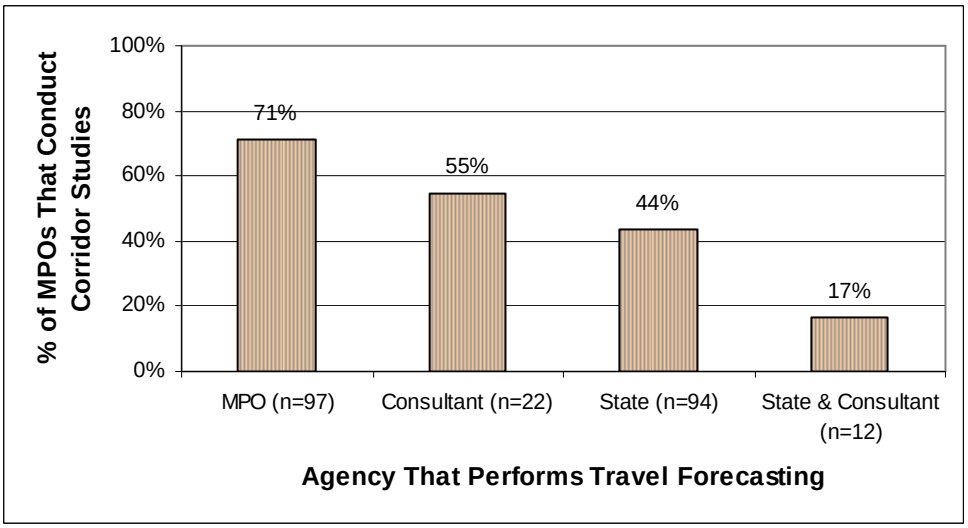


Figure 6: Percentage of MPOs That Conduct Corridor Studies (Stratified by Agency Performing Travel Forecasting)

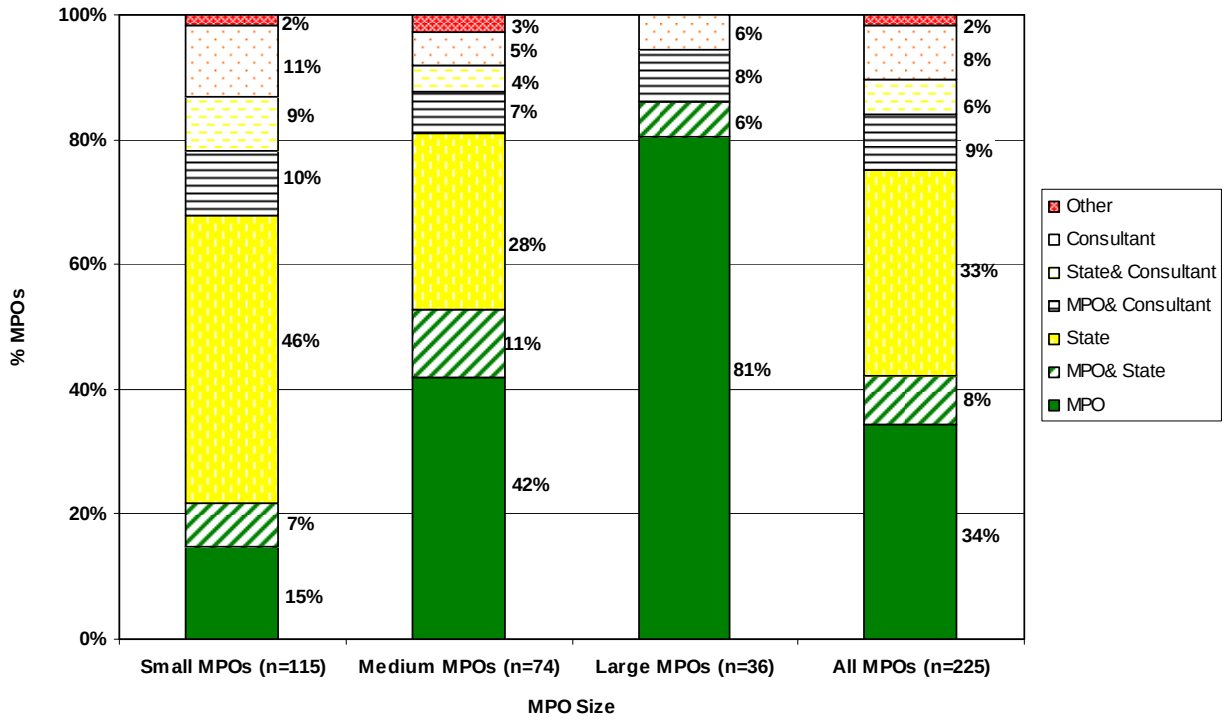


Long-range planning and air quality conformity analyses are the primary applications for which travel-forecasting procedures are applied. More than 95% of agencies reported using a travel demand model for long-range planning or conformity analyses. Only 25% of all MPOs (40% of large MPOs) reported using models for other applications.

Who Does Modeling Work

The majority of travel-forecasting work is carried out either by the MPO or by the state transportation agency (Figure 7). For smaller MPOs, the states play a major role, whereas in larger areas, the MPOs dominate.

Figure 7: Participants in Travel Forecasting



MPOs that have a New Starts/Small Starts program or that conduct corridor studies are more likely to have a consultant perform their travel forecasting and are less likely to have the state perform their travel forecasting than those that do not (see Figure 8). In part this is because of the specialized nature of mode choice modeling, but the limited resources available to most MPOs are also relevant. New mode choice model development efforts require significant efforts—more than can easily be absorbed by an MPO without its normal staff.

MPOs that model toll lanes are more likely to conduct their own travel forecasting and less likely to have the state conduct their travel forecasting than MPOs that do not model toll lanes (see Figure 8). MPOs that have a high population growth rate tend to be more likely to have a consultant perform their travel forecasting and less likely to perform their own travel forecasting than MPOs with low and medium population growth rates (see Figure 9). This may be because the resources allocated to the MPO have not yet caught up with the new growth.

Figure 8: Relationship of Agency That Conducts Travel Forecasting to New Starts Programs, Corridor Studies and Modeling of Toll Lanes

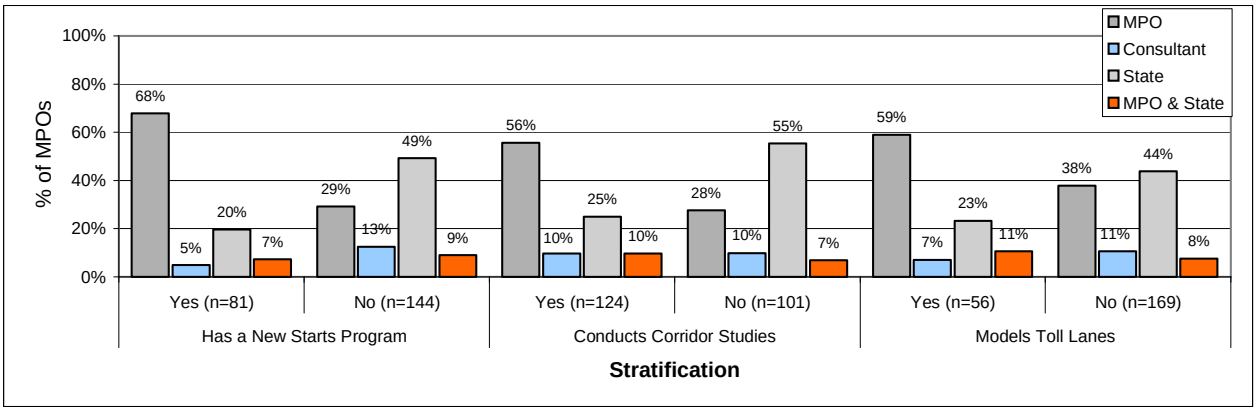
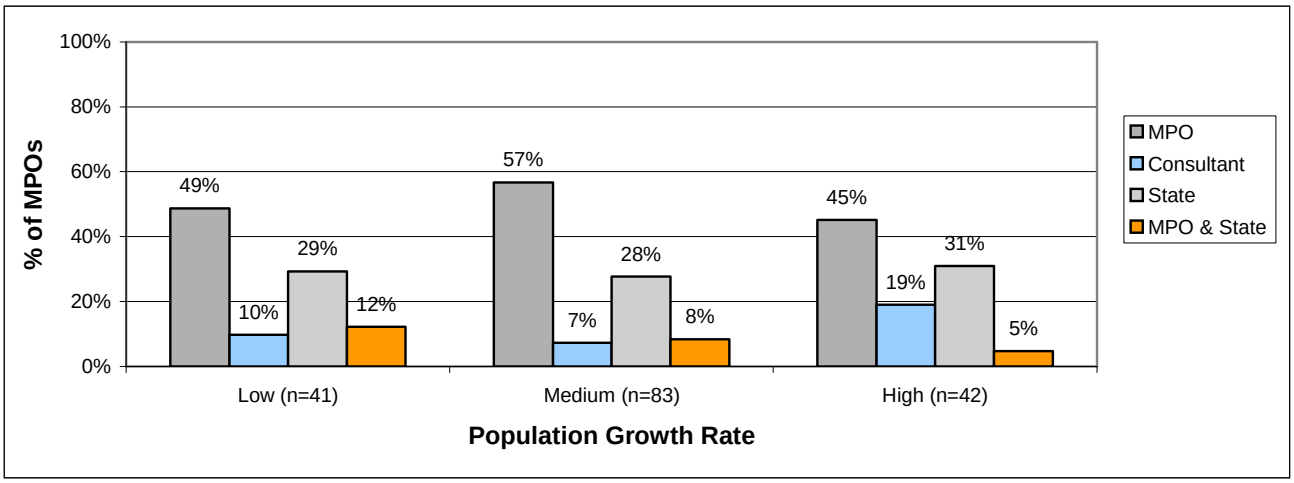


Figure 9: Relationship of Agency That Conducts Travel Forecasting to MPO Population Growth Rate

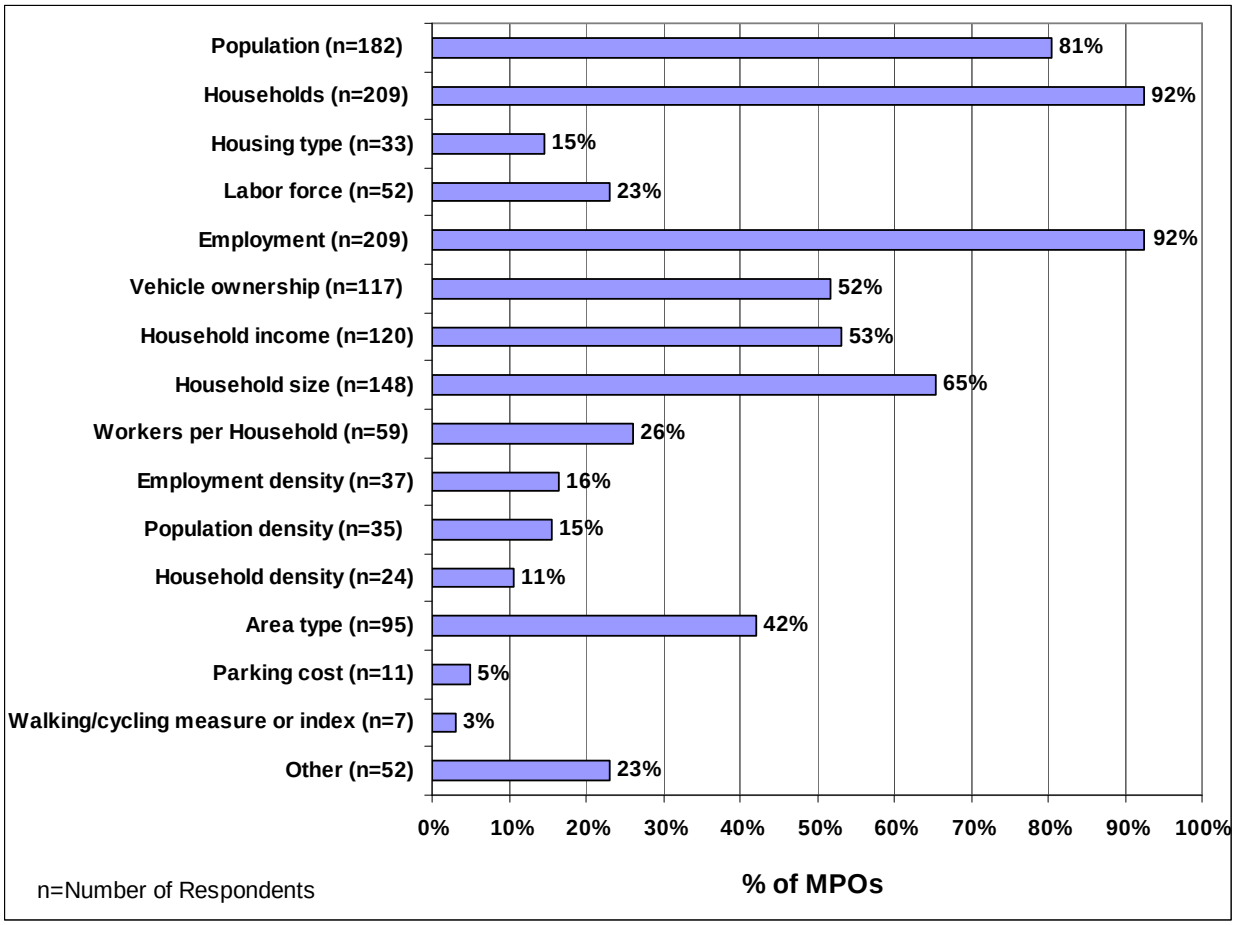


Findings by Model Component

Data Forecasts

Agencies make use of a number of exogenous factors in the preparation of travel forecasts (see Figure 10). Almost all MPOs require forecasts of population, households, and employment. Approximately half also forecast household size, auto ownership, or income.

Figure 10: Demographic Factors Used in Trip Generation–All MPOs



Although few MPOs use housing type/condition, the higher the population growth rate is, the more likely the MPO is to use this demographic in its model (see Figure 11). MPOs that conduct their own travel forecasting are more likely to use housing type/condition in their models than MPOs for which the state conducts the travel forecasting (see Figure 12).

Figure 11: Percentage of MPOs That Use Housing Type/Condition in Travel Forecasting (Stratified by Population Growth Rate)

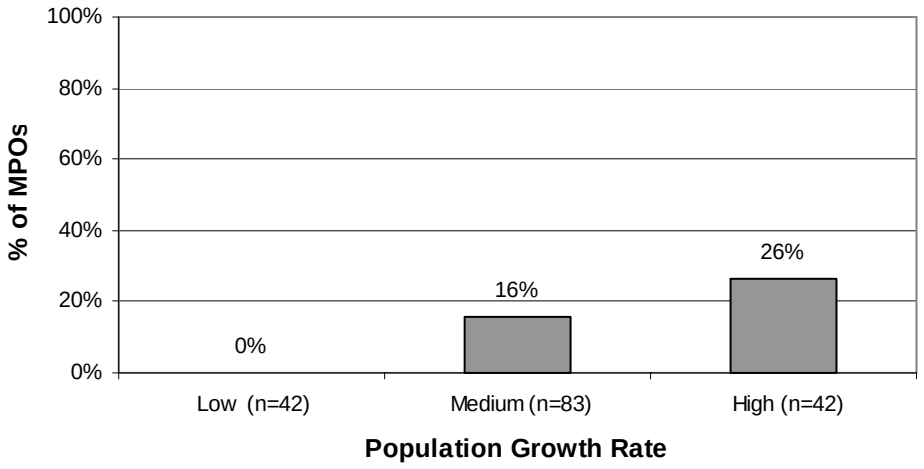
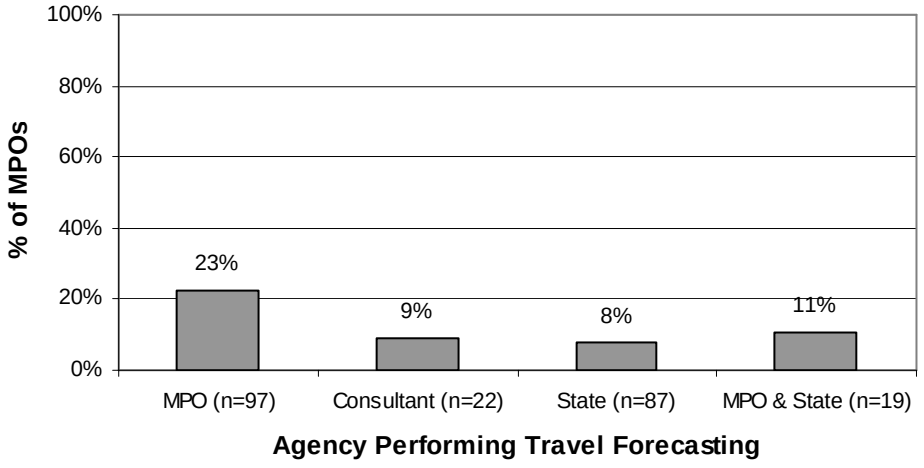


Figure 12: Percentage of MPOs That Use Housing Type/Condition Data in Travel Forecasting (Stratified by Agency Performing Travel Forecasting)



MPOs that conduct corridor studies and that model toll lanes are more likely to include labor force figures in the trip generation model that those MPOs that do not conduct corridor studies or model toll lanes (see Figure 13). In addition, MPOs with a lower population growth rate are more likely to use labor force data in trip generation than those with a higher population growth rate (see Figure 14).

Figure 13: Percentage of MPOs That Use Labor Force Data in Travel Forecasting (Stratified by Use of Corridor Studies and Toll Lanes)

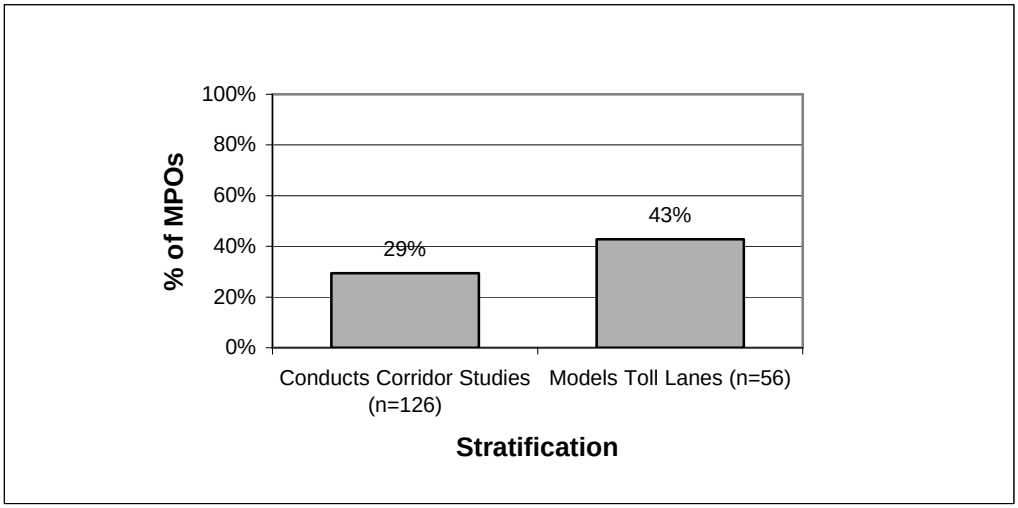
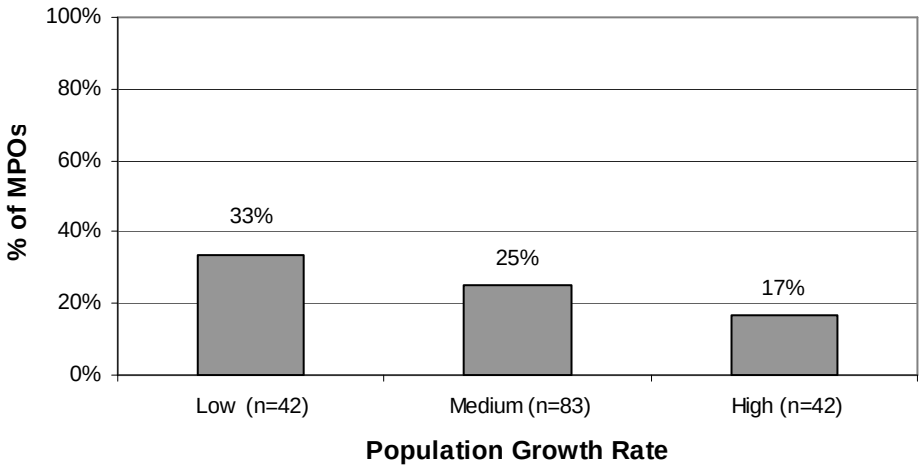
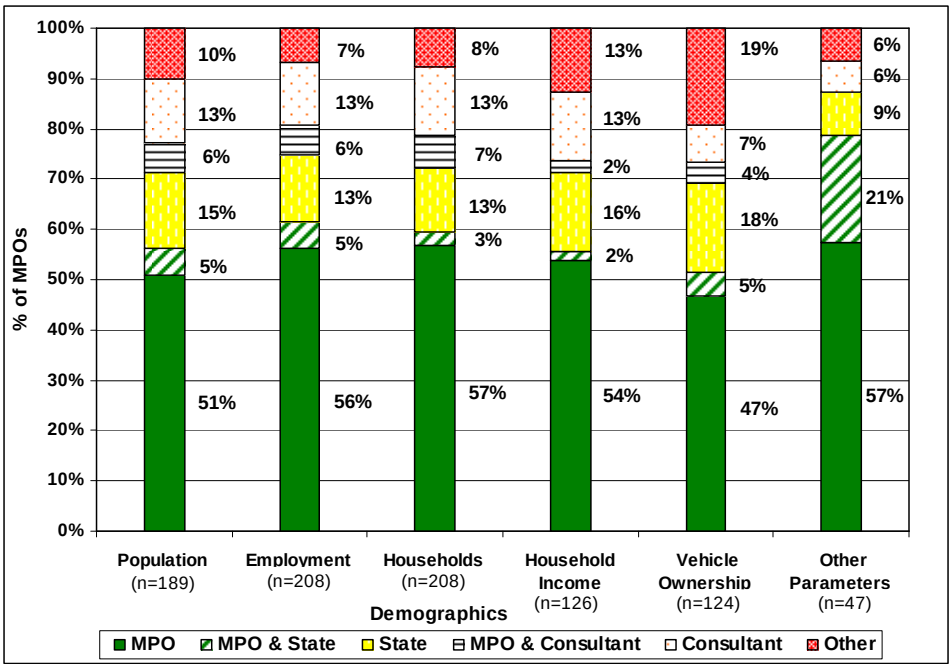


Figure 14: Percentage of MPOs That Use Labor Force Data in Travel Forecasting (Stratified by MPO Population Growth Rate)



In general, the MPO (with or without assistance from others) is responsible for preparation of data forecasts (see Figure 15).

Figure 15: Responsibility for Demographic Forecasts



For the primary variables—population, households and employment—most MPOs reported using a "top-down model," suggesting that regional totals are taken from forecasts prepared for larger units and then allocated to MPO areas (Figure 16).

Figure 16: Methods Used for Demographic Forecasts

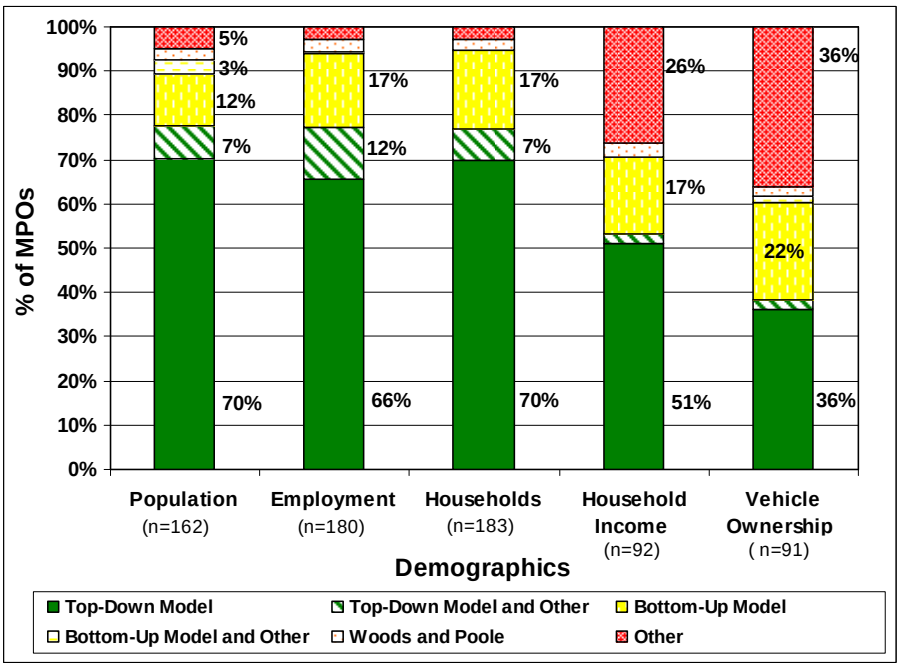
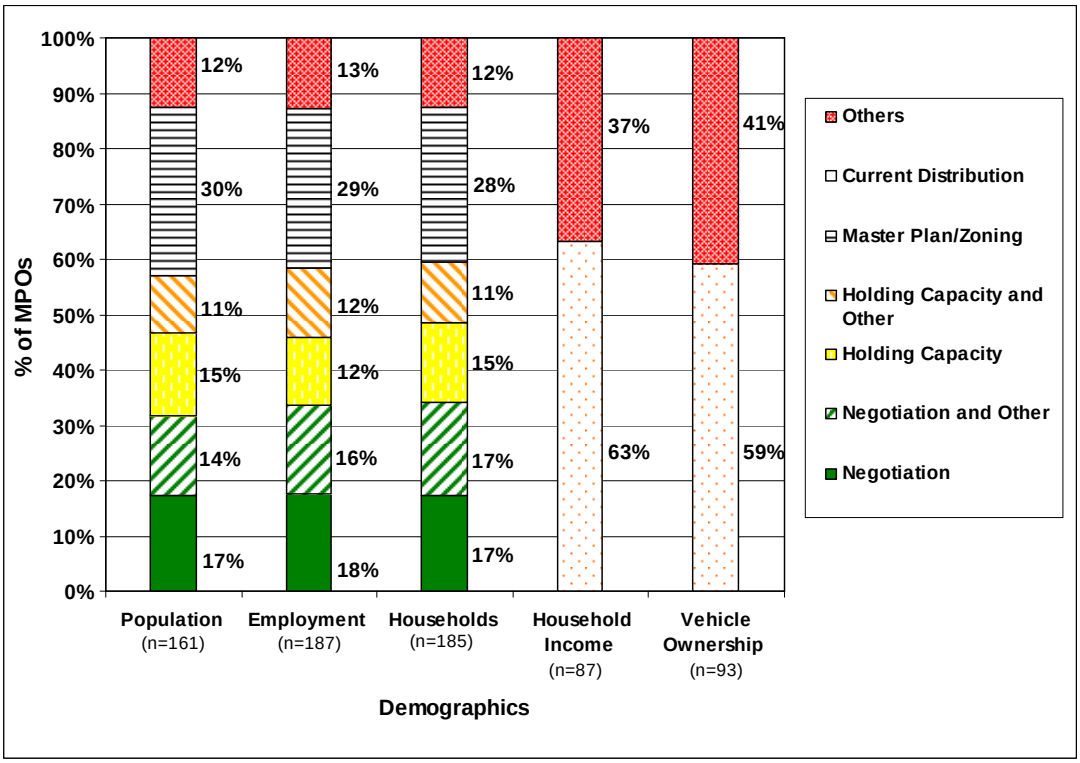


Figure 17: Methods of Allocating Forecasts to Traffic Analysis Zones—All MPOs

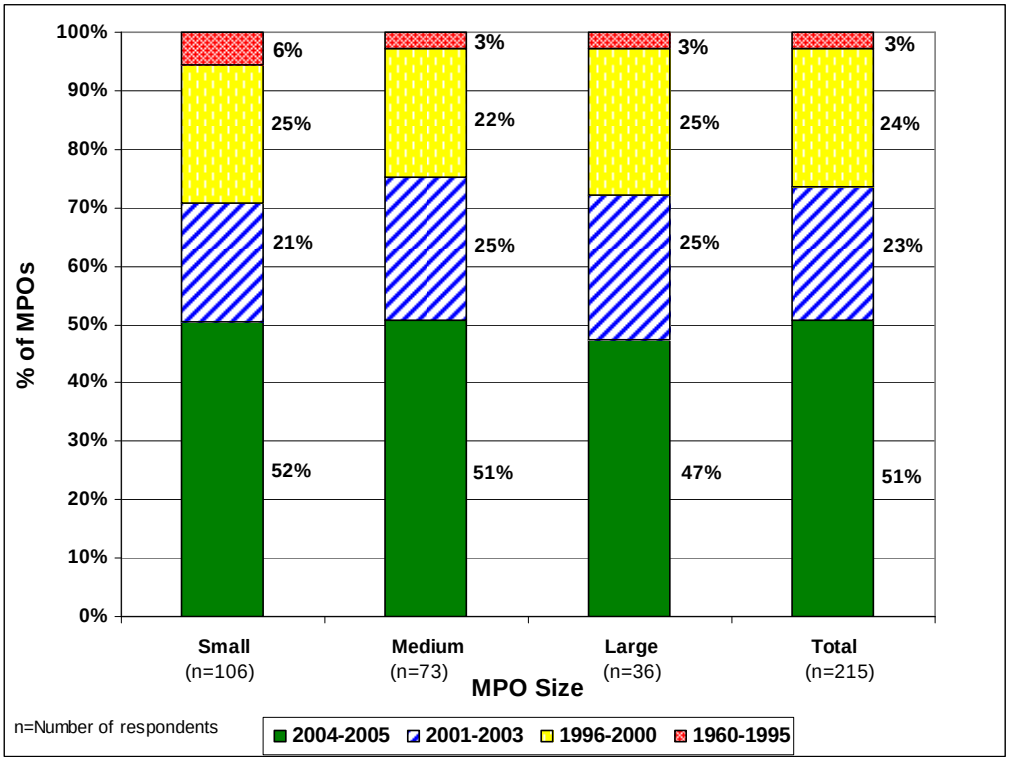


Allocation of basic forecasts—population, households, and employment—to traffic analysis zones (TAZs) within a region is done by negotiation or based on master plans in more than half of reporting MPOs (Figure 17). Income and auto ownership are treated differently, with allocations based on current distributions or other techniques, generally models of some type.

Travel-Forecasting Model Set

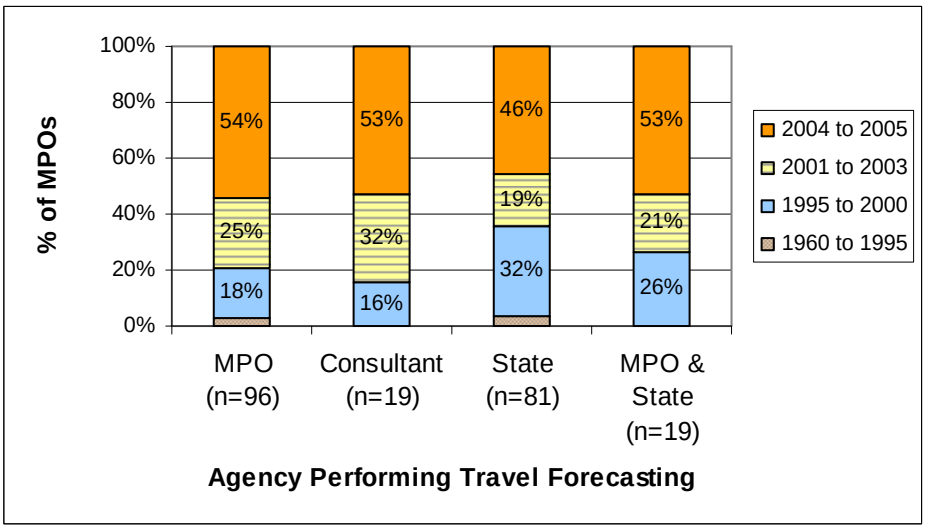
Approximately half of all MPOs are using travel-forecasting model sets that have been updated in the last two years; very few are using model sets that have not been updated in the past decade (see Figure 18).

Figure 18: Year of Update of Travel-Forecasting Model Set



MPOs that perform their own travel forecasting are more likely than MPOs that have the state perform their travel forecasting to have updated their travel demand model since 2001 (see Figure 19).

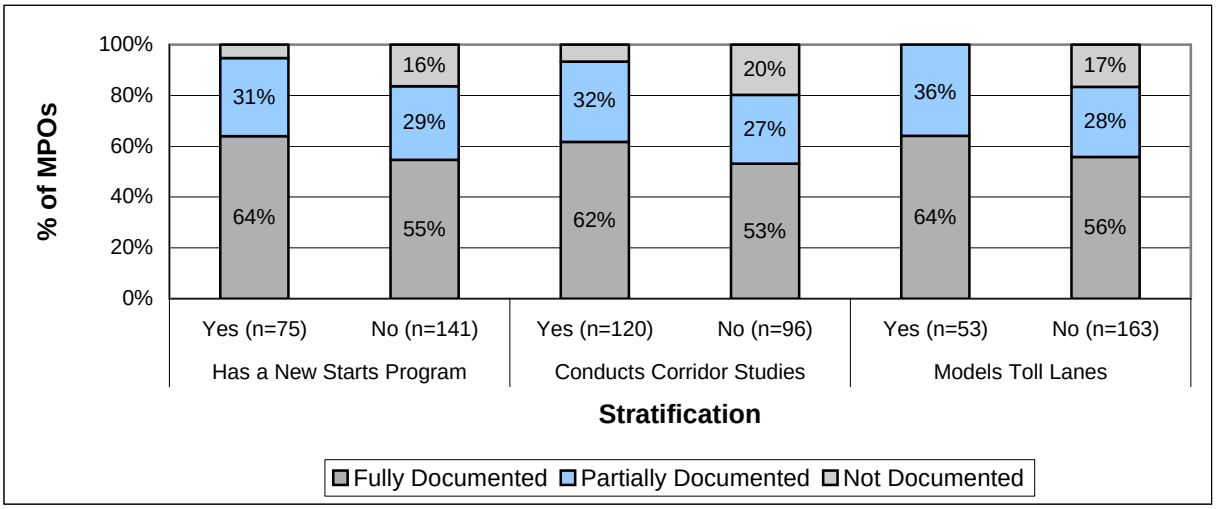
Figure 19: Most Recent Update of MPOs' Travel Demand Set (Stratified by Agency That Performs the Travel Forecasting)



Overall, approximately 57% of MPOs have documented their most recently updated model set. MPOs that have a New Starts/Small Starts program, that have conducted corridor

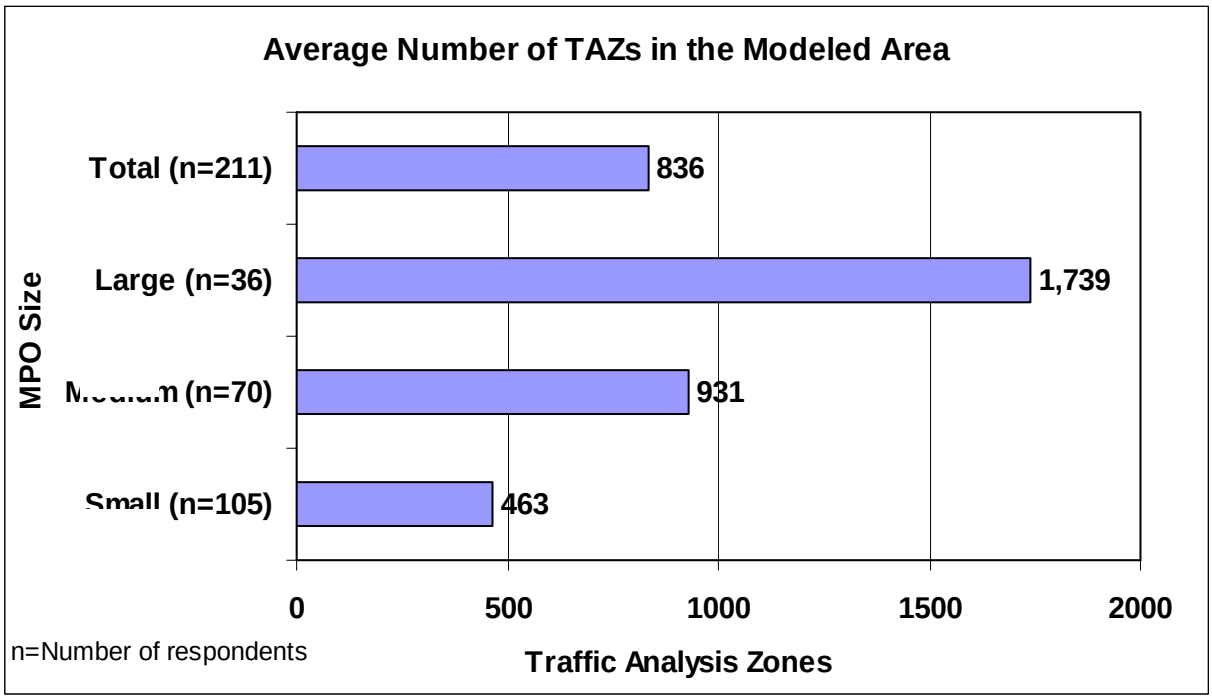
studies, or that model tolls are more likely to have documented their most recently updated model set than those that do not (see Figure 20).

Figure 20: Documentation of MPOs' Most Recently Updated Model Set (Stratified by Whether the MPO Has a New Starts Program, Conducts Corridor Studies, or Models Toll Lanes)



The model components addressed in the most recently updated model are typically trip generation, trip distribution, and highway assignment (more than 80% of MPOs). Approximately half of MPOs updated a mode choice element, and 20–25% updated postprocessing procedures. Six MPOs reported transitioning from a four-step model to another model form. These agencies have implemented model sets that may be considered tour-based or activity-based. In one case, a small MPO uses the same model set as the much larger adjacent MPO. The large MPO has shifted to an activity-based model. As a result, the small MPO also reported shifting to a new model form. The number of TAZs is, on average, 463 for small MPOs, 931 for medium-sized MPOs, and 1,739 for large MPOs (Figure 21).

Figure 21: Average Number of TAZs



Related to size of area, there is less variation with average TAZs per square mile of 0.9, 0.8, and 0.5 for small, medium, and large MPOs, respectively (Figure 22). The number of external stations averages 32 for all MPOs (24 for small, 37 for medium, and 46 for large) (Figure 23).

Figure 22: Distribution of TAZ Density

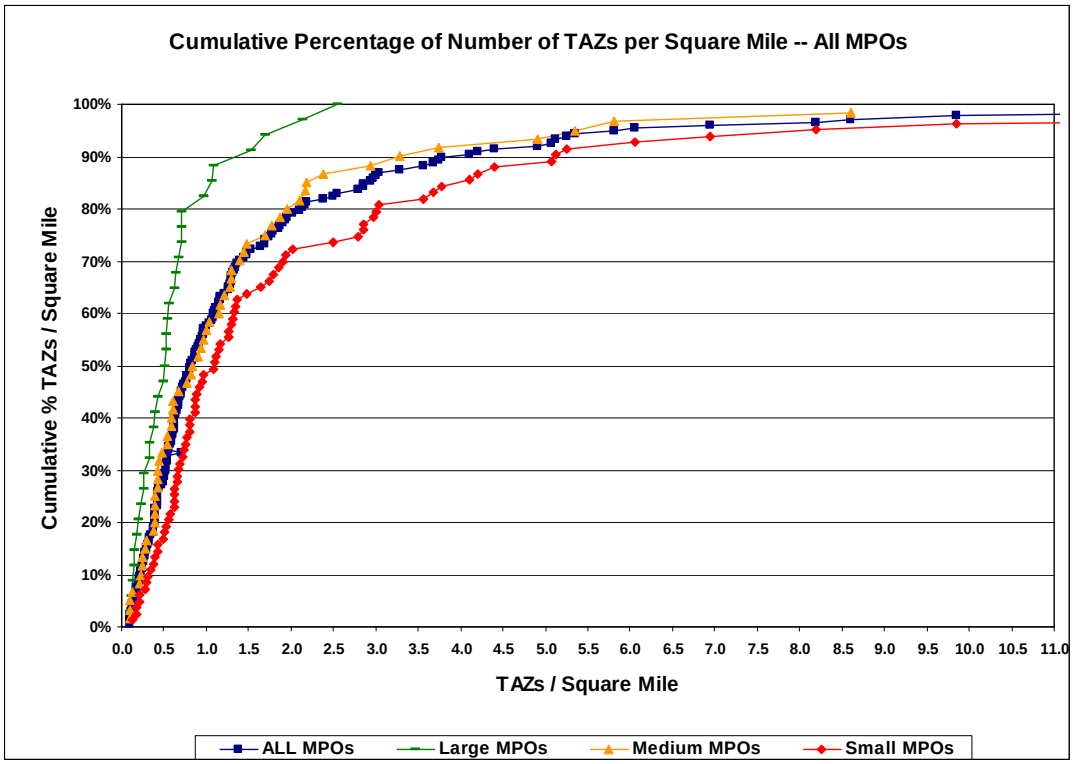
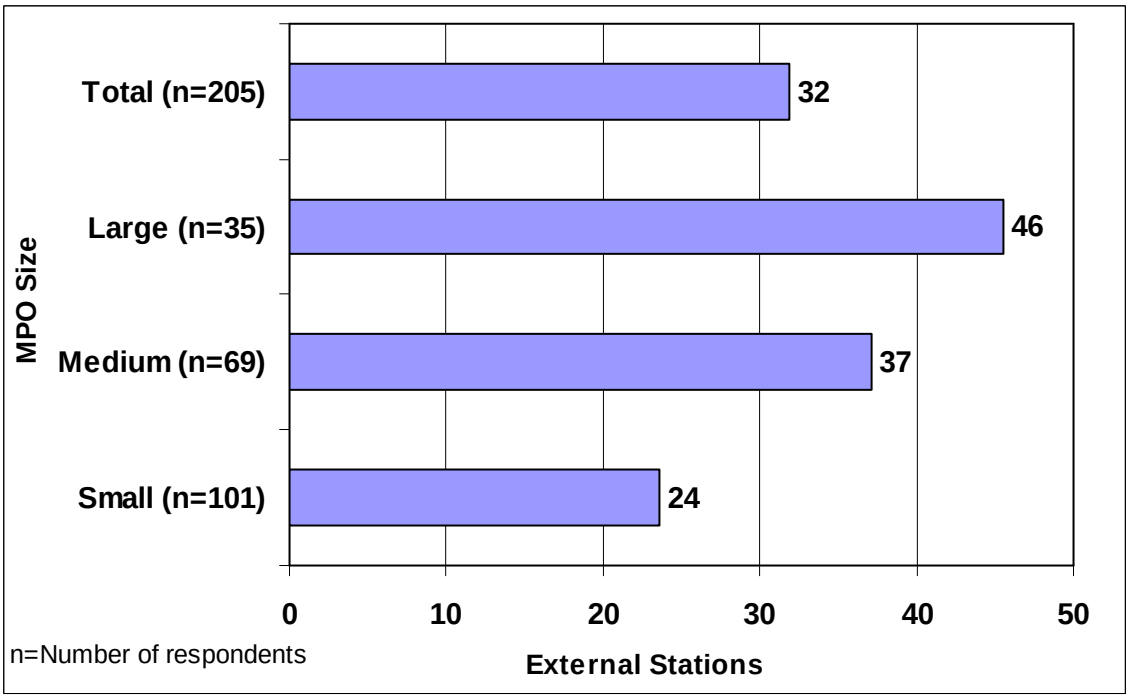


Figure 23: Average Number of External Stations



The highway networks range in size from 4,213 links for small areas to more than 20,000 for large areas (Figure 24). The number of nodes ranges from 2,950 to 11,367 (Figure 25).

Figure 24: Average Number of Links in the Highway Network

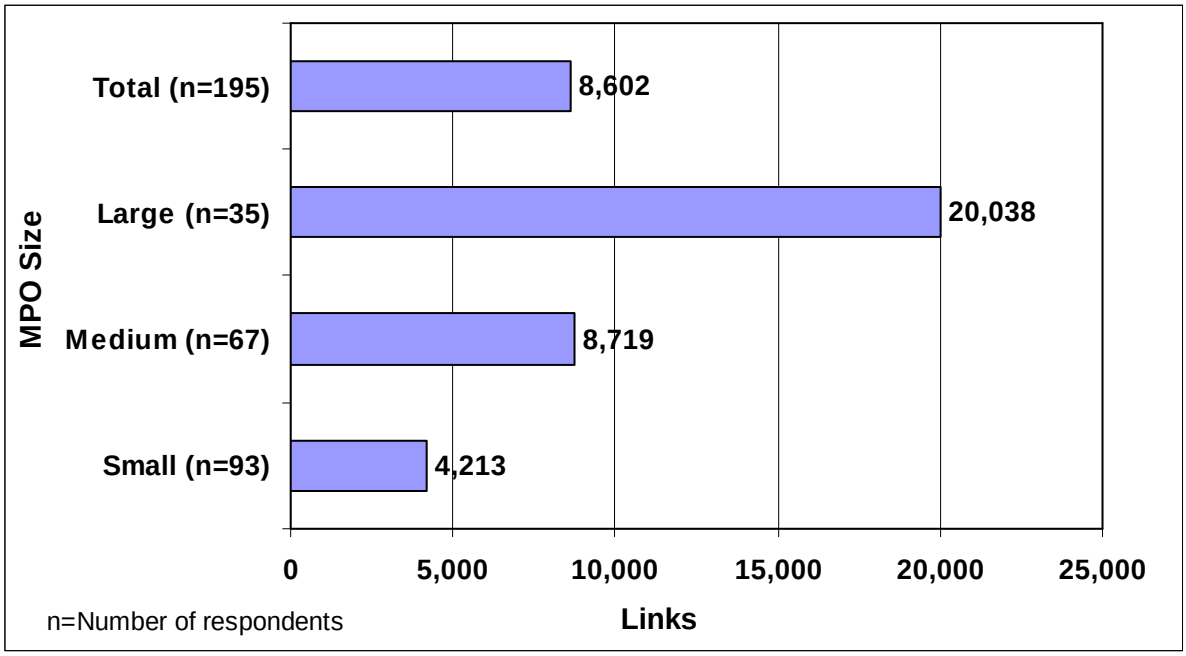
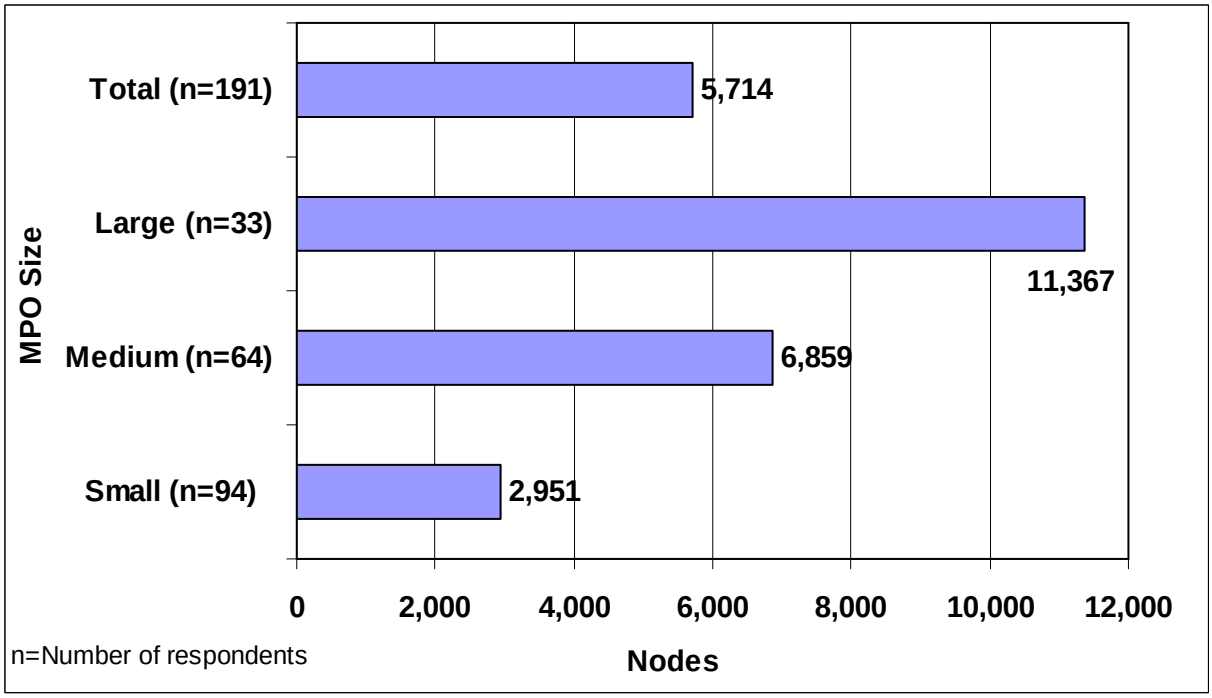


Figure 25: Average Number of Nodes in the Highway Network



The highway networks coded by MPOs tend to include all or almost all freeway, major arterial, and minor arterial mileage. On average, less than 25% of local mileage is represented. The greatest variation is in collector mileage, with large areas including varying proportions of collector mileage whereas small areas include almost 100% of collector miles (Figures 26-29).

Figure 26: Proportion of Roadway Miles Included in Network—All MPOs (n=228

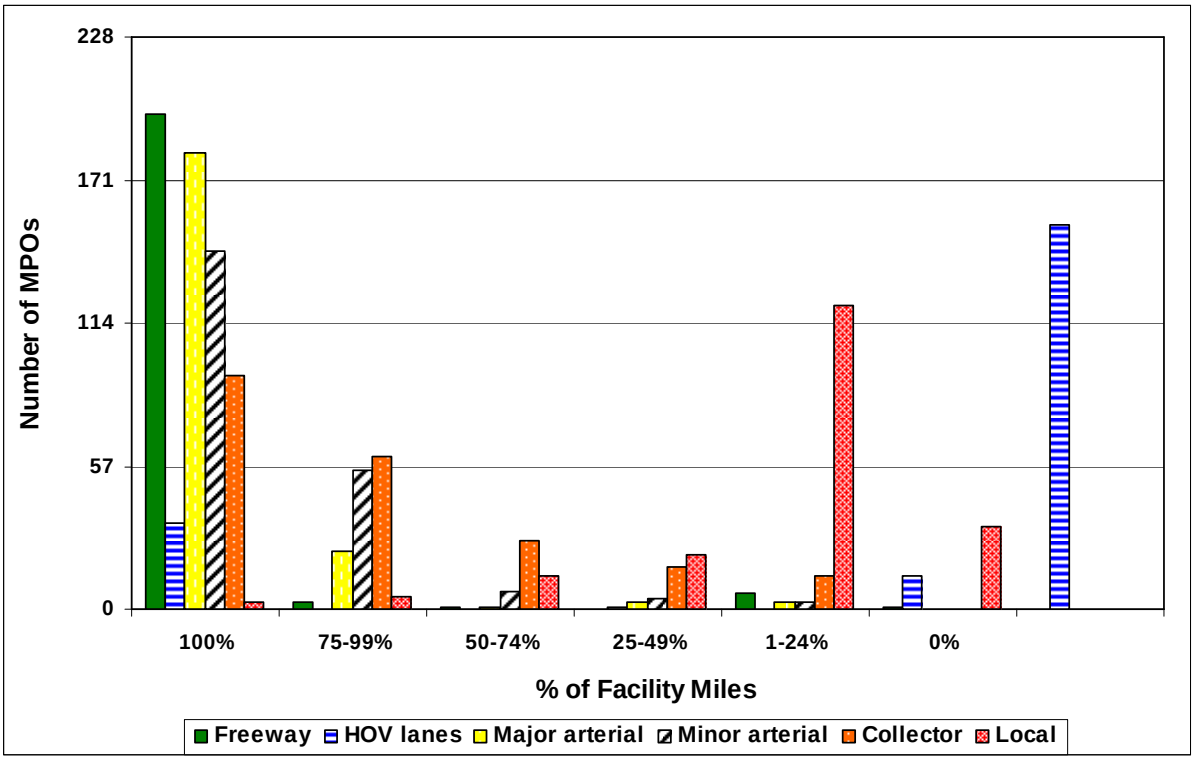


Figure 27: Proportion of Roadway Miles Included in Network—Large MPOs (n=36)

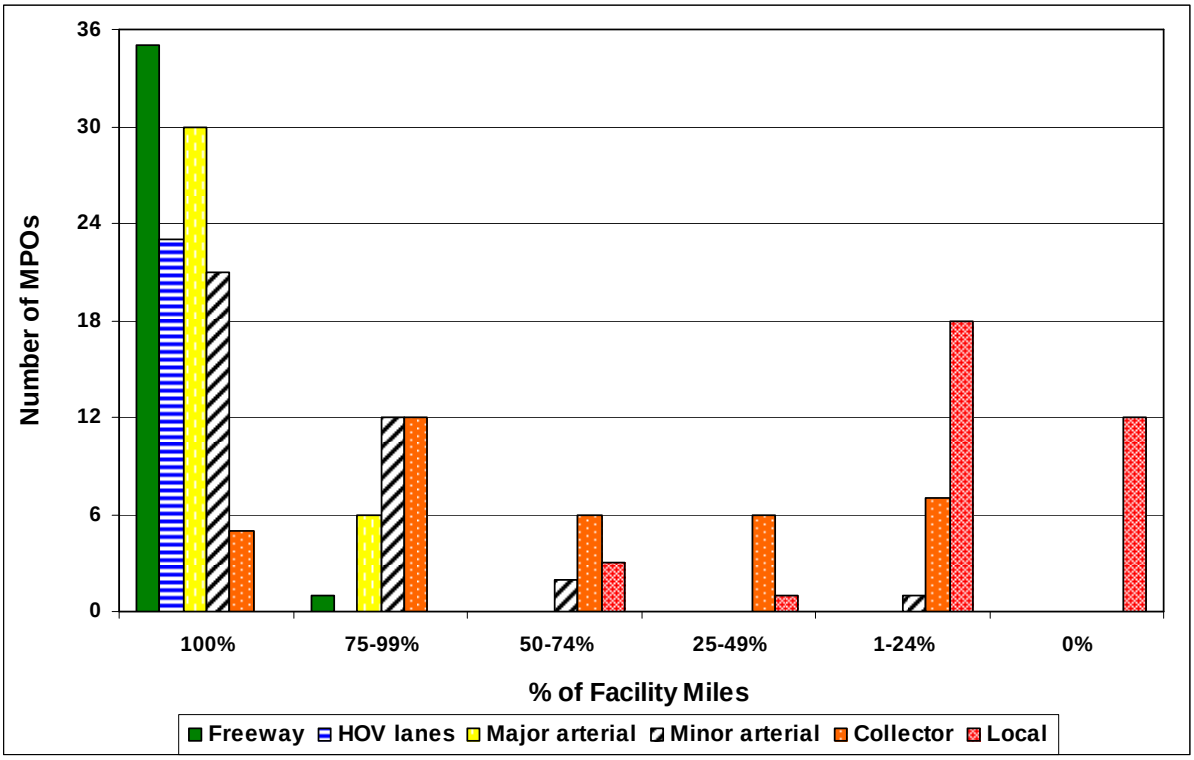


Figure 28: Proportion of Transit Facility Miles Included in Network—All MPOs (n=228)

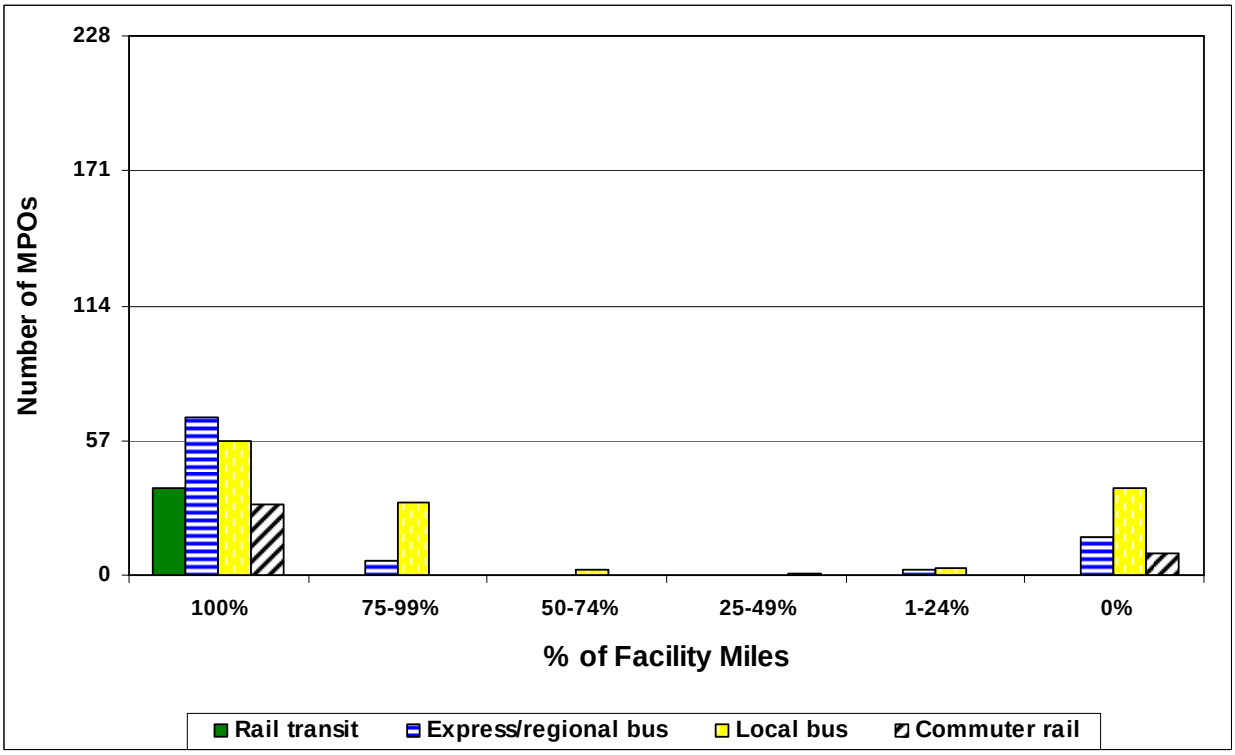
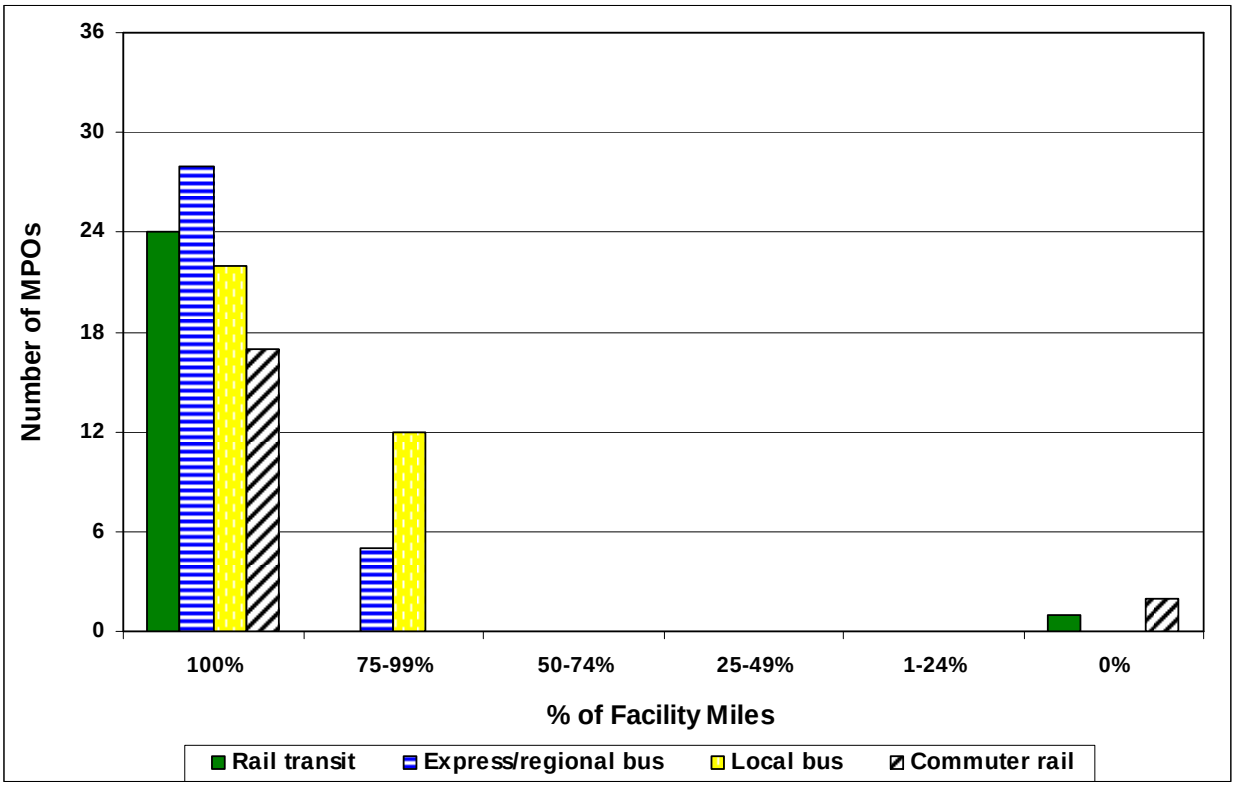


Figure 29: Proportion of Transit Facility Miles Included in Network—Large MPOs (n=36)



Approximately 86% of the travel-forecasting models used by MPOs have been validated since 2001 (see Figure 30). Validation typically involves comparing work trips forecast by the model to patterns of work travel reported in the Census Transportation Planning Package (CTPP) and comparison of assigned highway link volumes to traffic counts. In most cases, a model is considered to be validated on the basis of achieving the suggested levels of tolerable root mean square (RMS) error for link volumes. Continued uses of models validated before 2001 are reported by only 14% of the MPOs.

Figure 30: Year in Which Current Model Was Validated

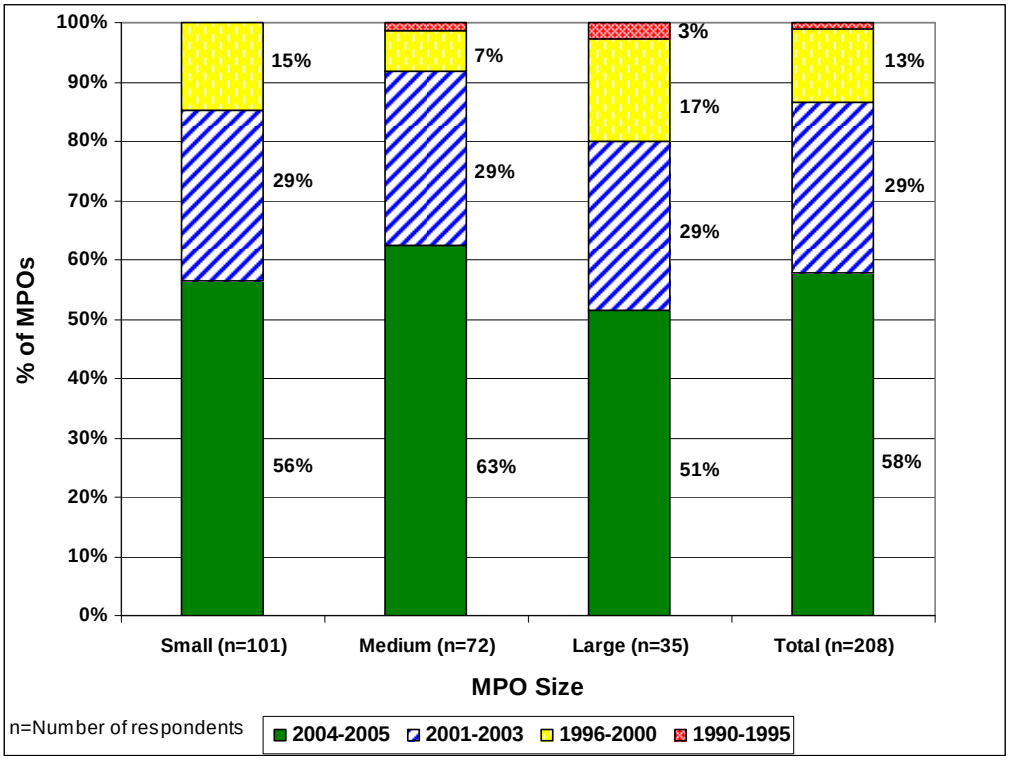
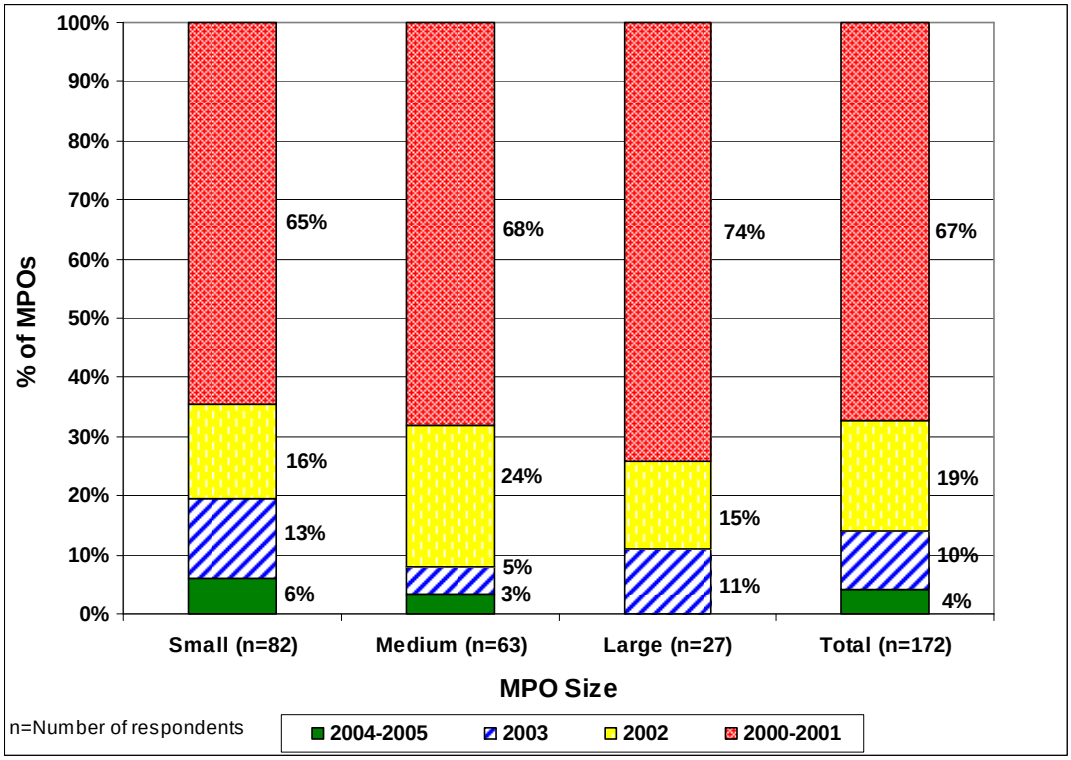
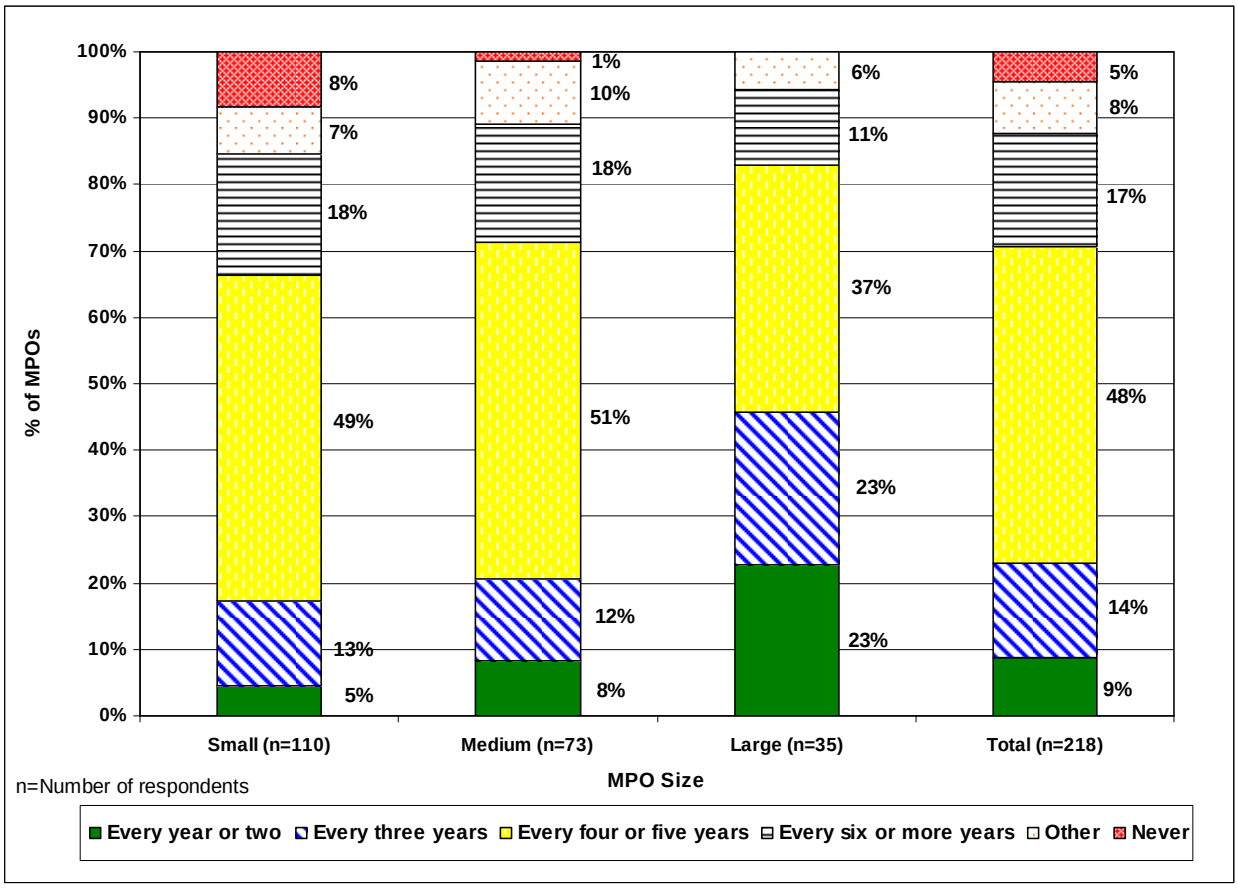


Figure 31: Year in Which Validation Data Were Collected



The frequency of model validation varies with the size of the MPO, with approximately half of large agencies validating at least every three years, whereas medium-sized and small agencies tend to validate on a longer cycle. Only 18% of small MPOs and nearly 20% of medium MPOs validate their models at least every three years (see Figure 32).

Figure 32: Frequency of Model Validation



MPOs that have a New Starts/Small Starts program or that model toll lanes are more likely to have validated their model in the past three years than those that do not (see Figure 33). In addition, MPOs that conduct their own travel forecasting tend to validate their models more regularly than when the state performs the update (see Figure 34). These differences are largely a result of MPO size (see Figure 32). MPOs that have a New Starts program or model toll lanes or that perform their own travel forecasting are more likely to be larger than MPOs that do not.

Figure 33: Frequency That Model Is Validated (Stratified by Whether the MPO Has a New Starts Program or Models Toll Lanes)

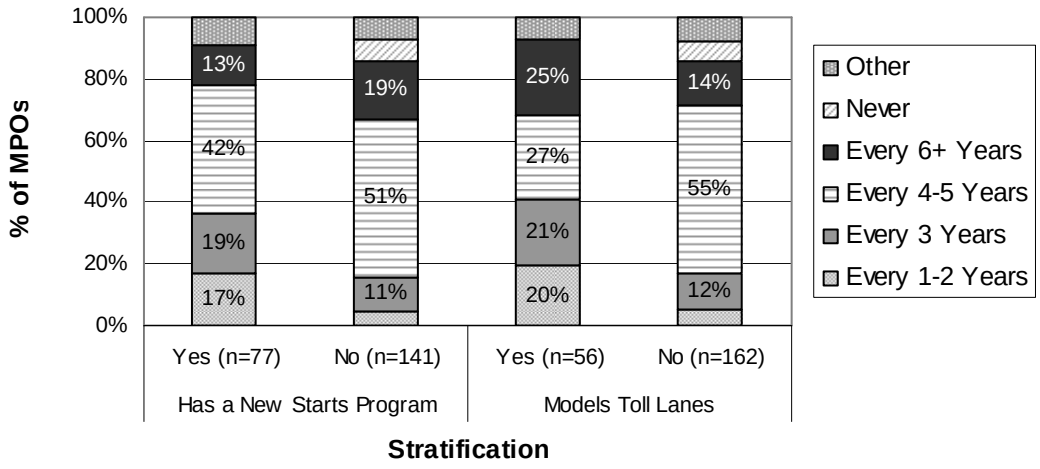
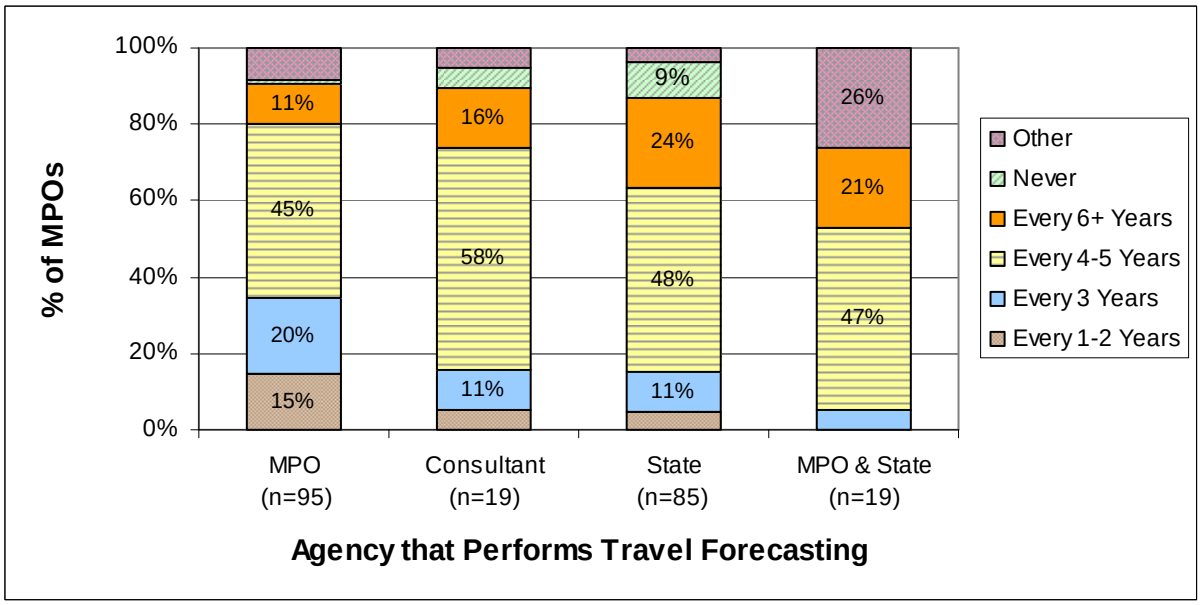
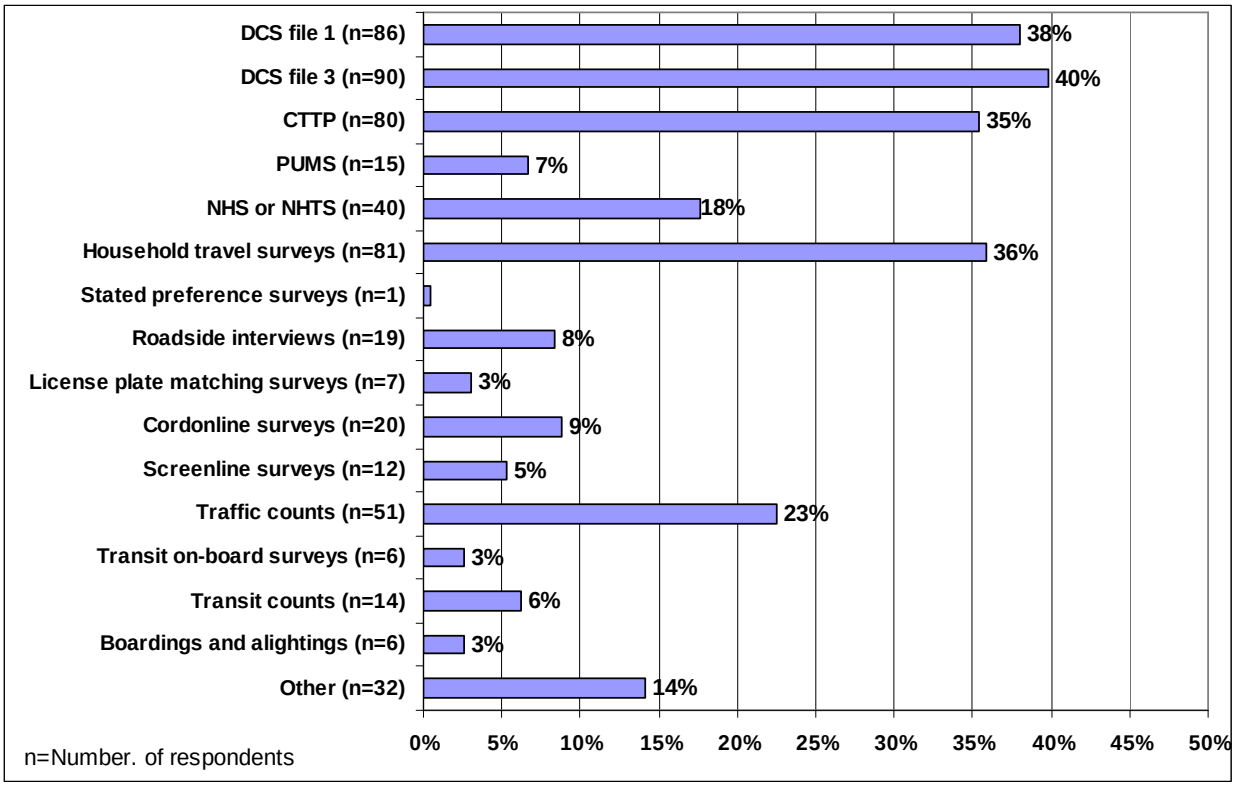


Figure 34: Frequency That Model Is Validated (Stratified by the Agency That Performs the Travel Forecasting)



Agencies tend to rely on national sources of data for validating their trip generation models (Decennial Census Survey [DCS], CTTP, National Household Travel Survey [NHTS]). Less than 10% of the MPOs reported having a home interview survey used for validating trip generation rates (see Figure 35).

Figure 35: Data Sources for Validation of Trip Generation Model—All MPOs



MPOs that have a New Starts/Small Starts program, that conduct corridor studies, or that model toll lanes are more likely to use CTPP data to validate the trip generation model than MPOs without them (see Figure 36).

MPOs that conduct their own travel forecasting are less likely to use DCS File 3 data than when the state conducts the travel forecasting. (see Figure 37).

Figure 36: Percentage of MPOs That Use CTPP Data to Validate the Trip Generation Model, (Stratified by Whether the MPO has a New Starts Program, Conducts Corridor Studies, or Models Toll Lanes)

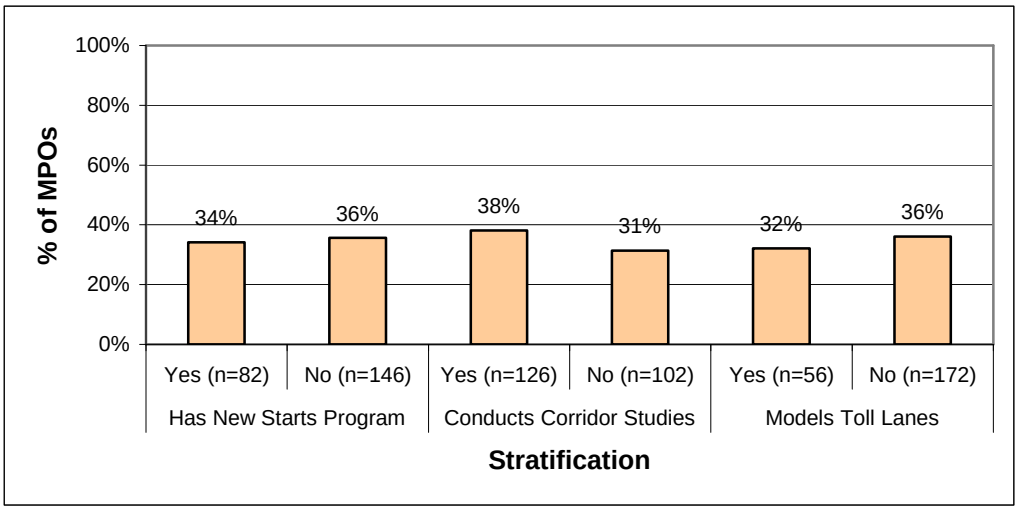
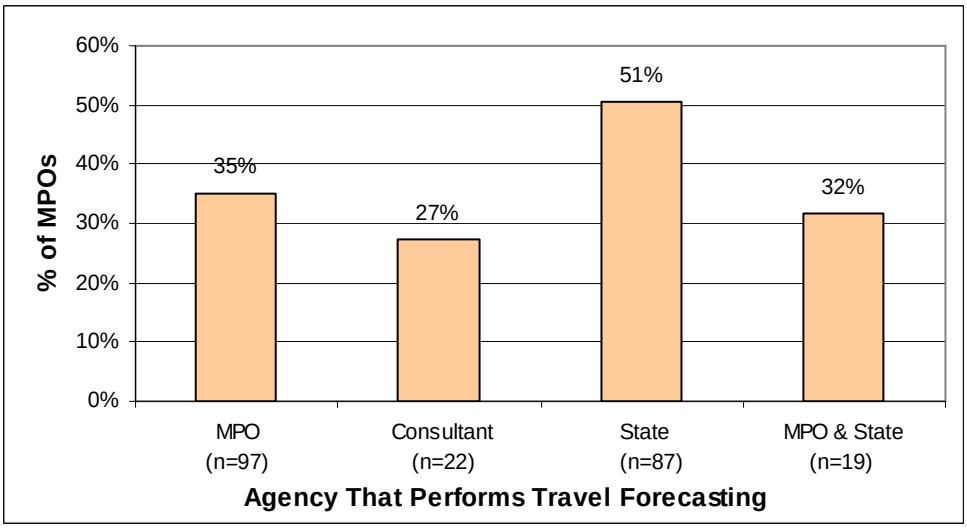
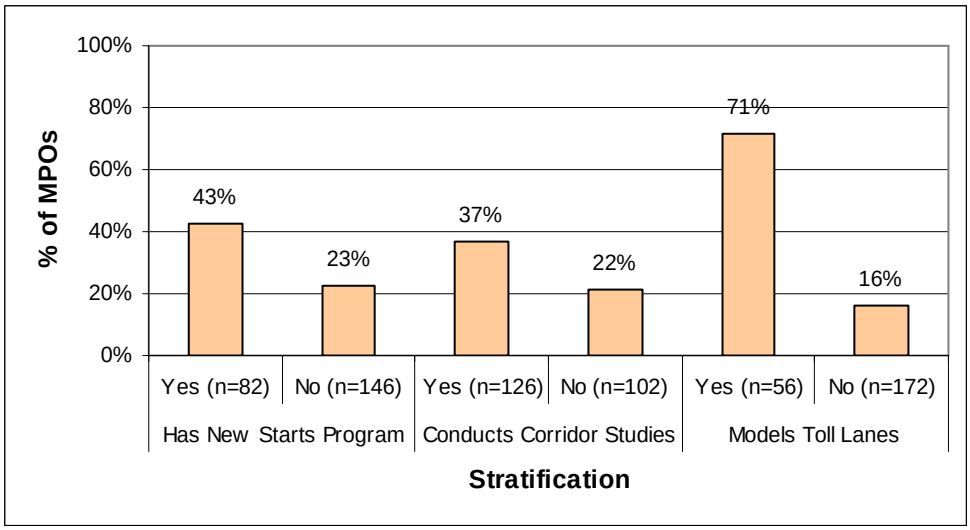


Figure 37: Percentage of MPOs That Use DCS File 3 Data to Validate the Trip Generation Model (Stratified by the Agency That Performs the Travel Forecasting)



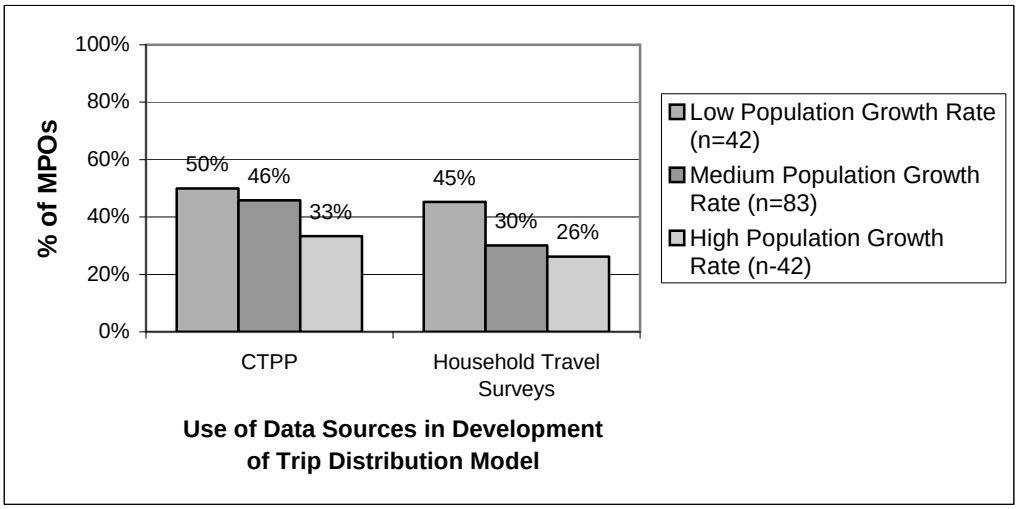
MPOs that have a New Starts/Small Starts program, that conduct corridor studies, or that model toll lanes are more likely to use household travel surveys to validate their trip distribution models than MPOs that do not (see Figure 38).

Figure 38: Percentage of MPOs That Use Household Travel Surveys to Validate the Trip Distribution Model (Stratified by Whether the MPO has a New Starts Program, Conducts Corridor Studies, or Models Toll Lanes)



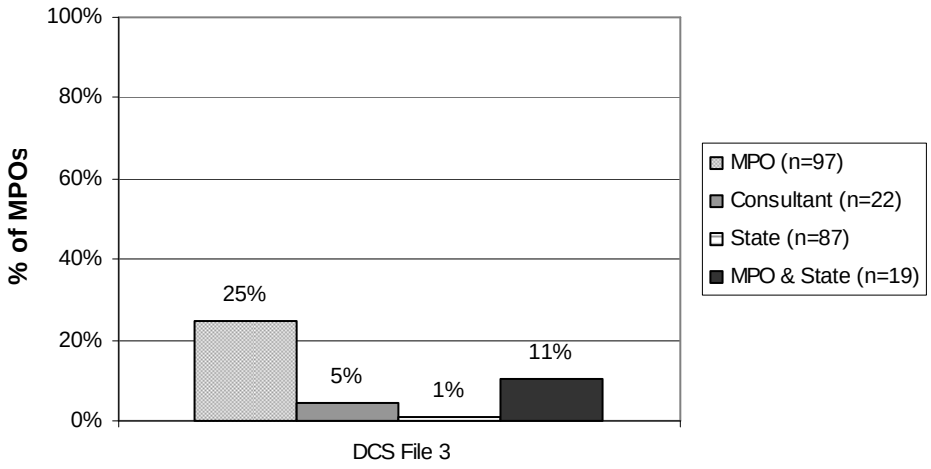
MPOs with lower population growth rates are more likely to use CTPP data and household travel surveys than MPOs with higher population growth rates (see Figure 39).

Figure 39: Percentage of MPOs That Use CTPP Data and Household Travel Surveys to Validate the Trip Distribution Model (Stratified by Population Growth Rate of the MPO)



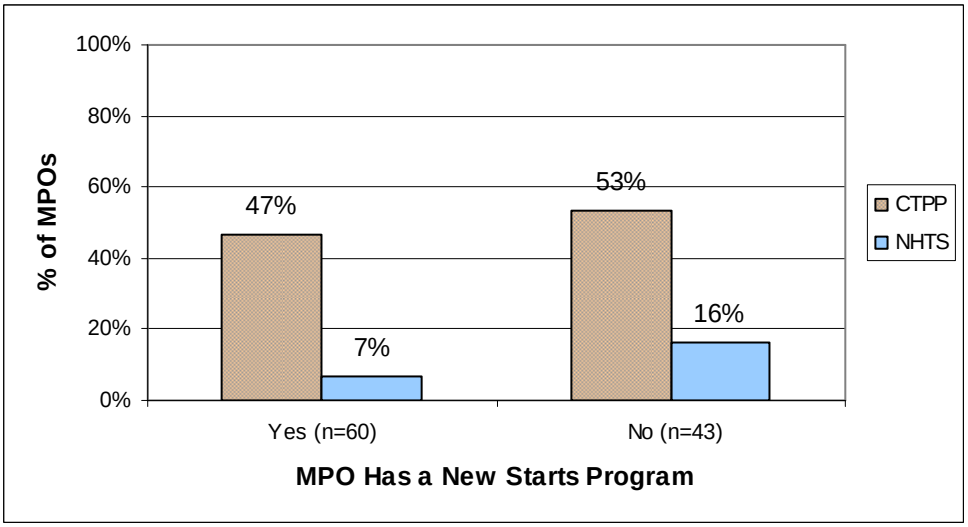
MPOs that conduct the travel forecasting on their own are more likely to use data from DCS File 3 to validate their trip distribution model than when the state conducts the travel forecasting (see Figure 40).

Figure 40: Percentage of MPOs That Use DCS File 3 Data to Validate the Trip Distribution Model (Stratified by the Agency Performing the Travel Forecasting)



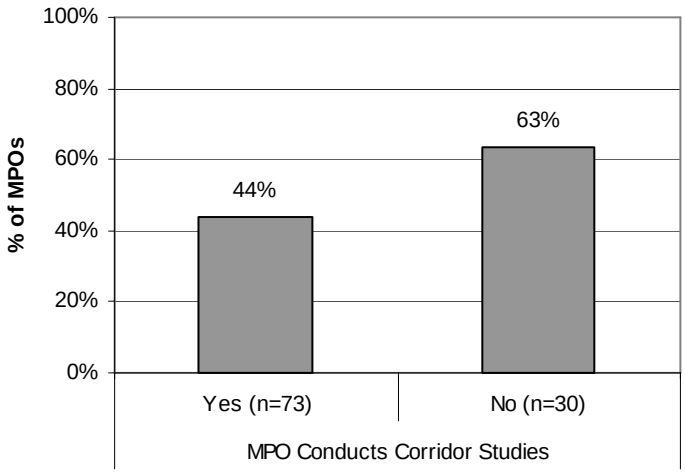
MPOs that have a New Starts/Small Starts program are less likely to use data from the CTPP and NHTS to validate the mode choice model than MPOs without a New Starts/Small Starts program (see Figure 41).

Figure 41: Percentage of MPOs That Use CTPP or NHTS Data to Validate their Mode Choice Model (Stratified by whether the MPO has a New Starts Program)



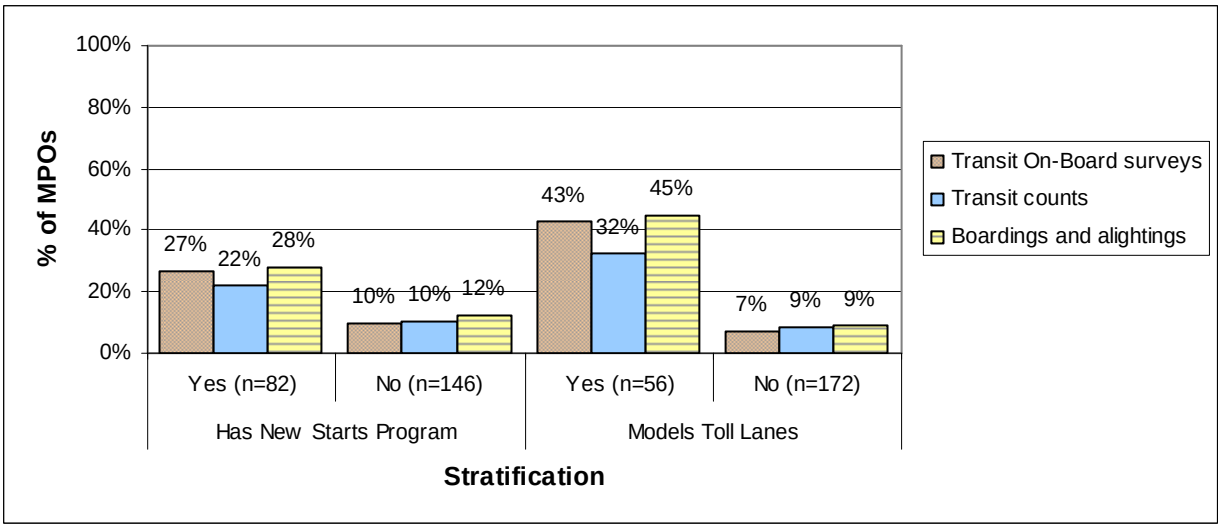
MPOs that conduct corridor studies are less likely to use CTPP data than MPOs that do not conduct corridor studies (see Figure 42).

Figure 42: Percentage of MPOs That Use CTPP Data to Validate their Mode Choice Model (Stratified by Whether the MPO Conducts Corridor Studies)



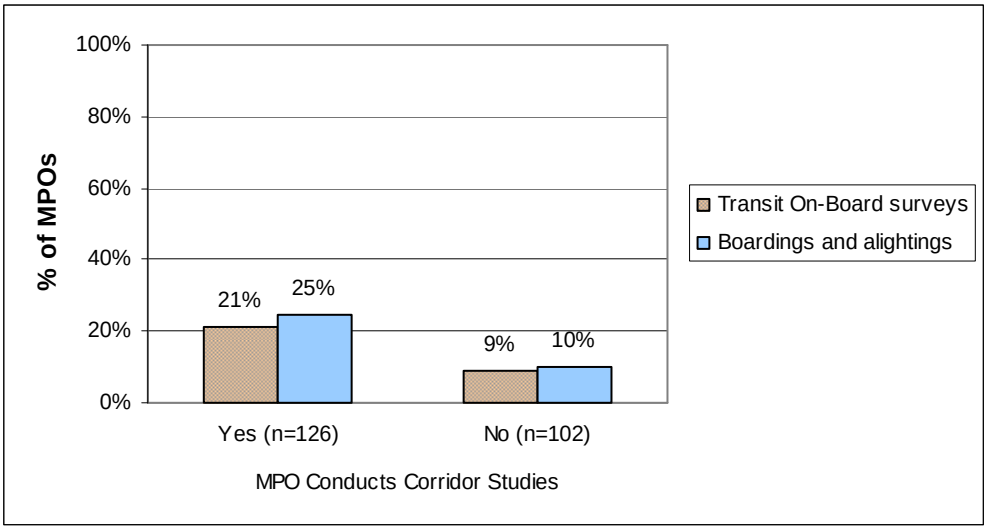
MPOs that have New Starts/Small Starts programs or that model toll lanes are more likely to use transit on-board surveys, transit counts, and boardings and alightings to validate the trip assignment model than MPOs that do not have New Starts/Small Starts programs or model toll lanes (see Figure 43). In large measure, this is likely because transit assignment accuracy becomes an issue for most MPOs only when the forecasts are being used to support an application for funding under the Federal Transit Administration (FTA) New Starts program.

Figure 43: Percentage of MPOs That Use Transit On-board Surveys, Transit Counts, and Boardings/Alightings to Validate their Trip Assignment Model (Stratified by Whether the MPO Has a New Starts Program or Models Toll Lanes)



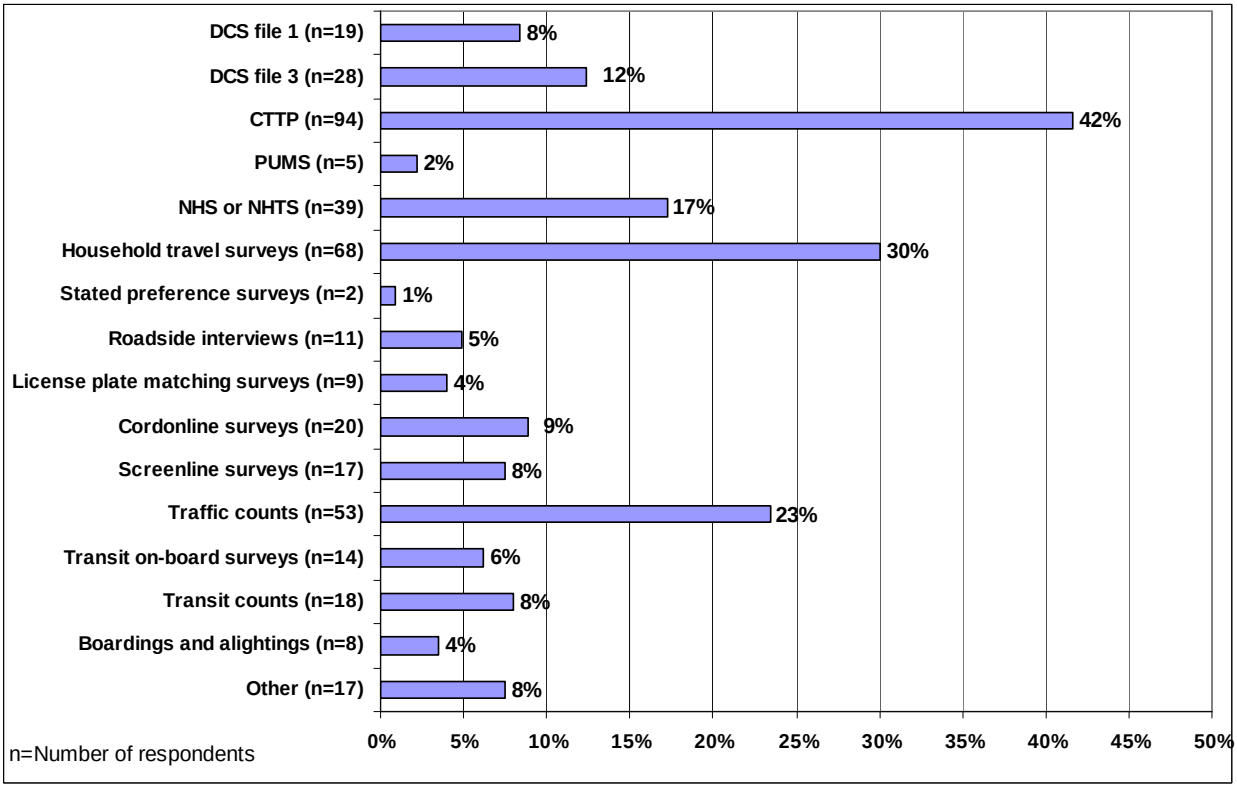
MPOs that conduct corridor studies are more likely to use transit on-board surveys and boardings and alightings than do MPOs that do not conduct corridor studies (see Figure 44).

Figure 44: Percentage of MPOs That Use Transit On-board Surveys and Boardings/Alightings to Validate Their Trip Assignment Model (Stratified by Whether the MPO Conducts Corridor Studies)



Census datasets are also widely used to validate the trip distribution model. Local roadside interview data and transit boarding/alighting data are useful but less significant sources (see Figure 45).

Figure 45: Data Sources Used for Validation of Trip Distribution—All MPOs

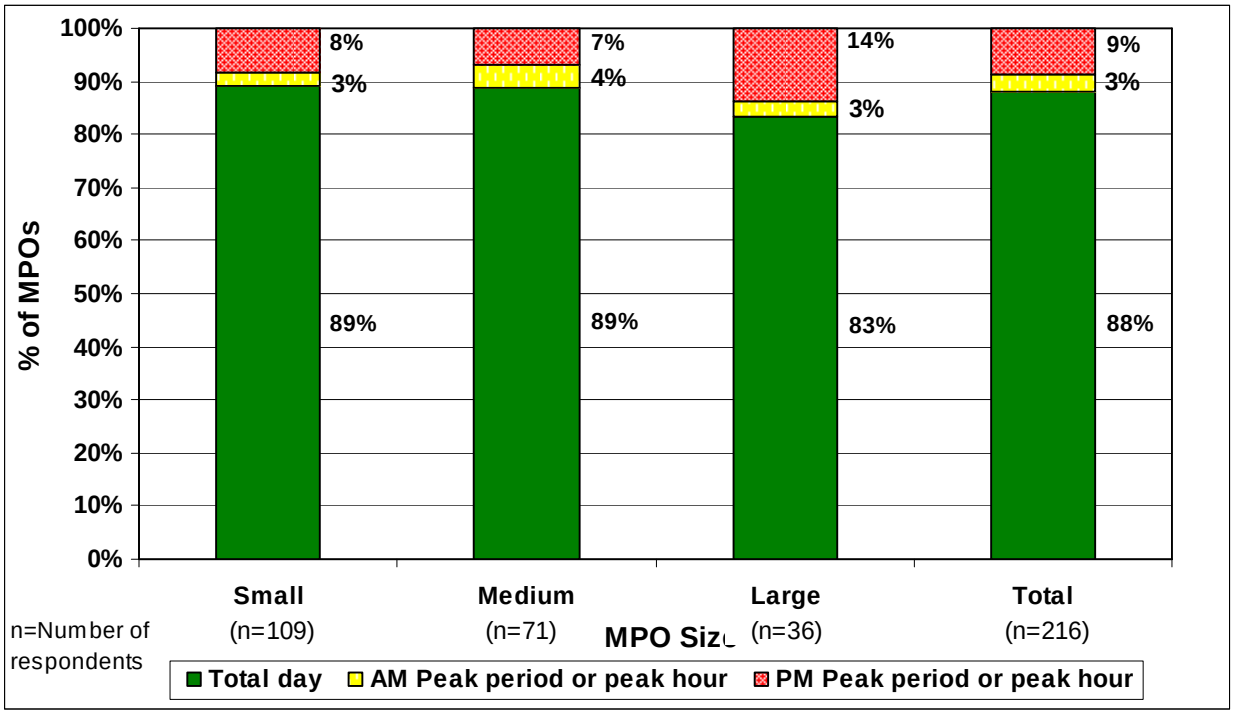


There is a substantial difference in the approach to validation by agency size. Approximately three-quarters of large MPOs reported validating each component of their models, whereas only 40% of small agencies validate the individual components.

Trip Generation

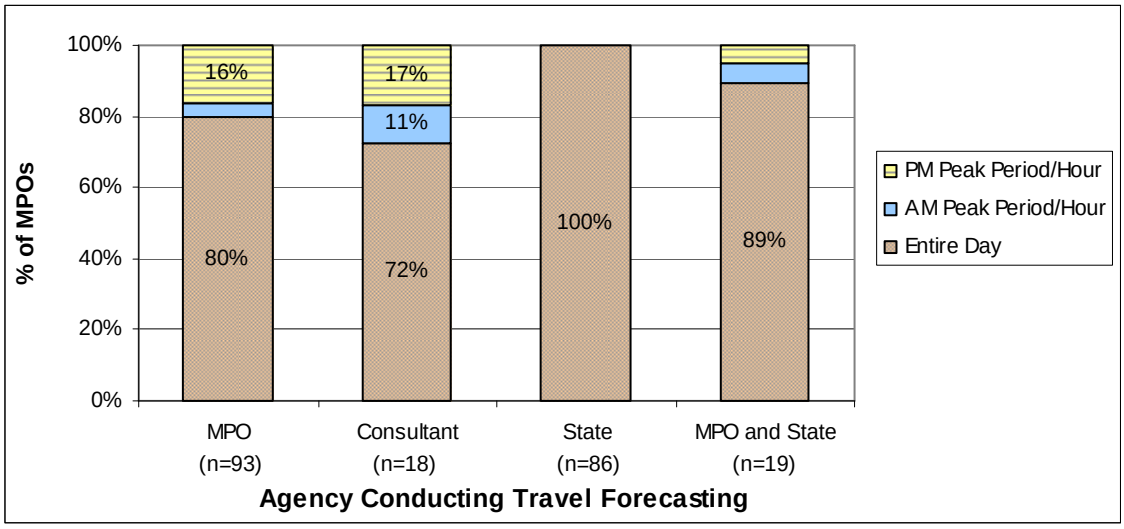
Total daily trip ends, productions, and attractions, are generated by more than 85% of MPOs (see Figure 46). Approximately 10% of MPOs generate trip ends for the PM peak period and approximately 5% for the AM peak period.

Figure 46: Time Period for Trip Generation Model (Stratified by MPO Size)



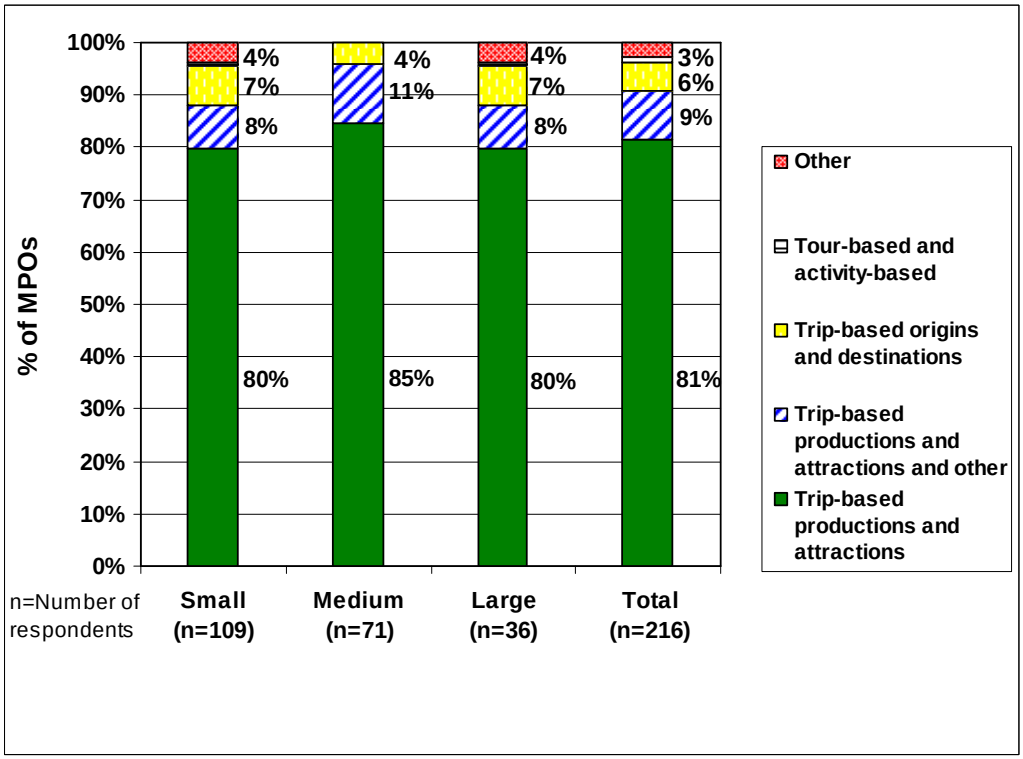
However, MPOs for which travel forecasting is conducted by the state are more likely to generate trip ends for the entire day than are MPOs that conduct their own travel forecasting (see Figure 47). As with other similar topics, this is likely due in large measure to the fact that metropolitan areas for which the state performs travel forecasting tend to be smaller than those for which the MPO prepared the forecasts.

Figure 47: Time Period for Trip Generation Model (Stratified by Agency Performing the Travel Forecasting)



The vast majority of MPOs (81%) generate trip-based productions and attractions for one or more trip types (see Figure 48). A few agencies, mainly medium-sized MPOs, use a combination of trip-based productions and attractions and trip-based origins and destinations. A few agencies generate trip-based origins and destinations for at least one trip purpose. Two agencies reported using a combination of tour-based generation and an activity-based generation.

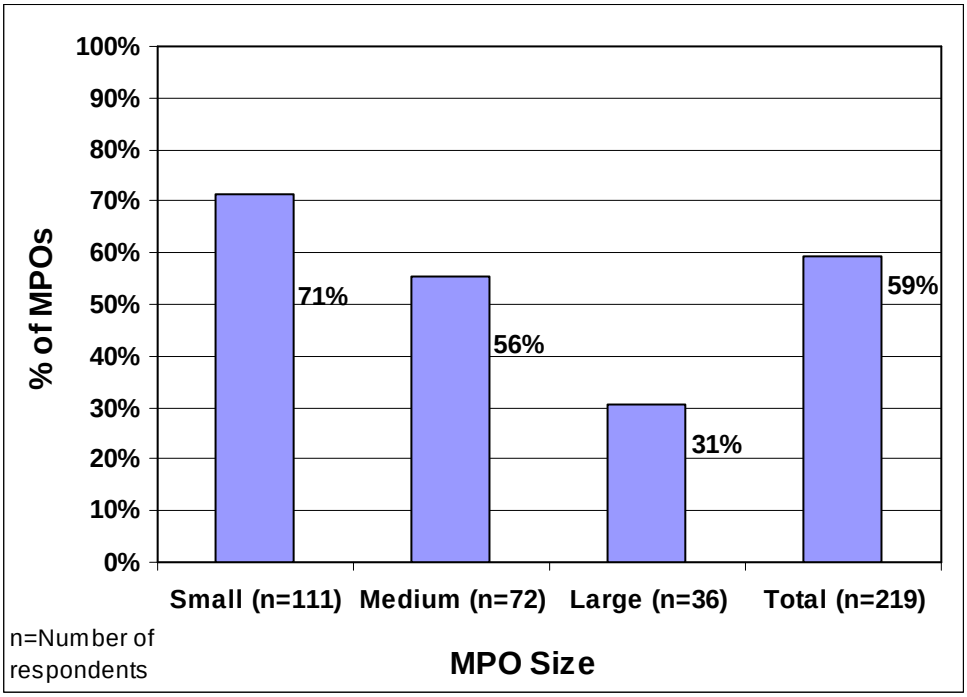
Figure 48: Trip Generation Approach Used in the Model (Stratified by MPO Size)



MPOs use many different categorizations of travel for their trip generation models with many different naming conventions. Our survey offered the choice of eight of the most common person travel categories, three vehicle travel categories, and an "other" category. The responses received included 86 different combinations of trip purpose categories. The number of trip purpose categories reported by agencies ranges from one to eight Almost all MPOs (215) reported home-based work (HBW) as a purpose used in trip generation; 203 reported HBO and NHB. The single most common set (HBW, HBO, and NHB) of trip purpose categories was reported by 11% of all MPOs. The next most commonly used grouping (HBW, HBO, NHB, trucks, and other) was reported by 10% of agencies, although 5% reported HBW, HBO, NHB, and trucks).

Overall 58% of MPOs reported using four person trip categories (see Figure 49). These are HBW, home-based retail (HBR), NHB, and one other purpose. Only 31% of large MPOs use only these purposes.

Figure 49: MPOs Reporting Trip Generation Only for HBW, HBR, NHB, and One Other Purpose

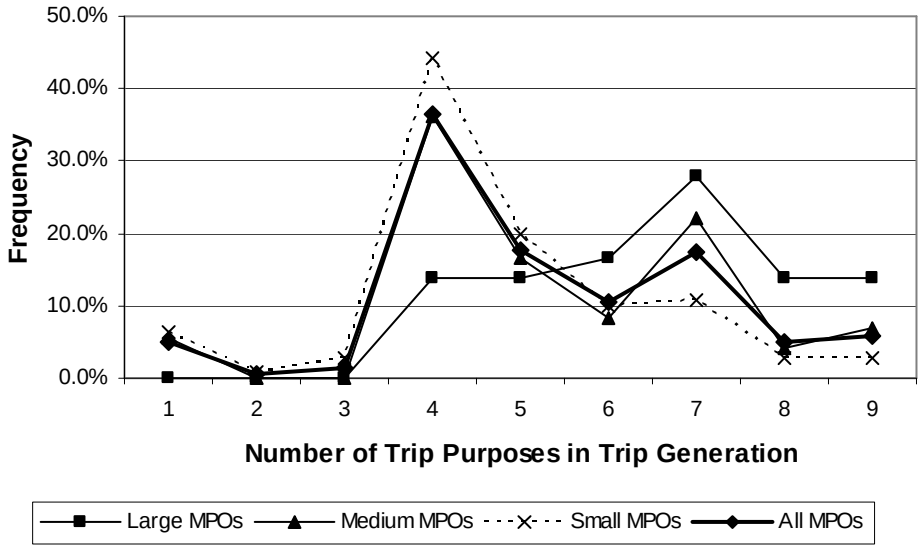


Other trip generation categories are not so widely used. HBR was reported by 105 MPOs, home-based shop (HBS) by 87 MPOs, home-based non-retail (HBNR) by 49 MPOs, and college/university (HBCU) by 55 MPOs. Sixty-six MPOs reported using a work-based trip category. Trucks or commercial vehicle trips are generated by 161 MPOs; taxi trips are generated by only 21 MPOs.

Among the "other" categories reported are airport-based or air passenger travel, trips to–from a special generator (e.g., amusement park, casino, military base), and internal–external trips.

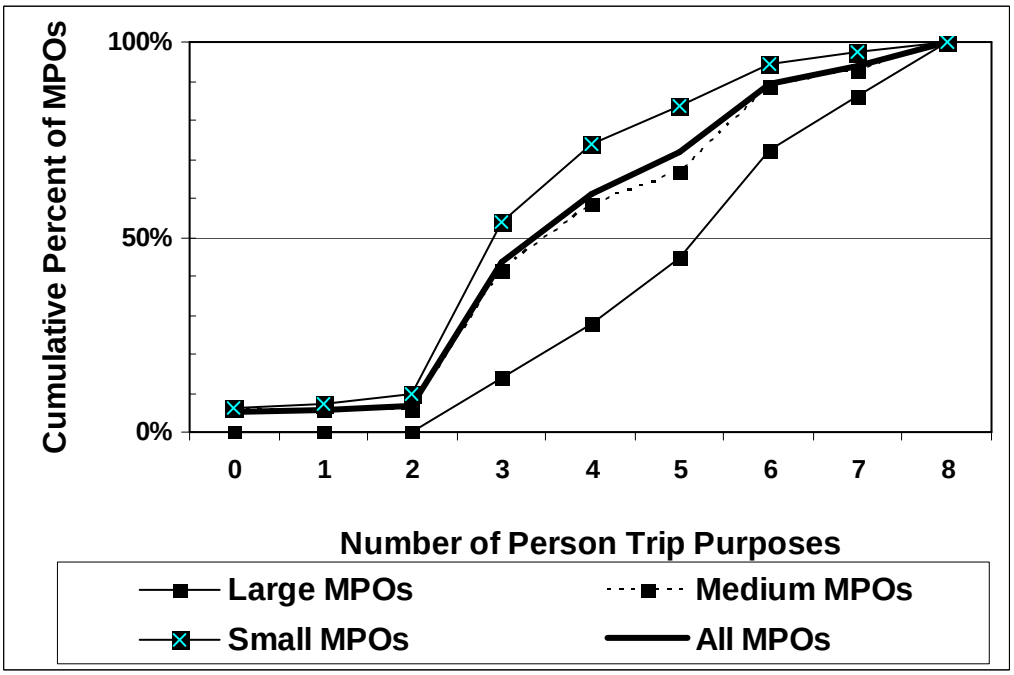
Few MPOs use fewer than three categories for trip generation (see Figure 50).

Figure 50: Frequency Distribution of Number of Trip Purposes in Trip Generation



The 50th percentile value for the number of trip purposes used in trip generation is approximately three for small and medium-sized MPOs. Large MPOs tend to use more trip categories, with a 50th percentile of just more than five categories (see Figure 51).

Figure 51: Number of Trip Purposes Used in Trip Generation



The unit of travel for trip generation is typically person trips, with smaller agencies forecasting vehicular trips and larger agencies forecasting total person trips (see Tables 4 and 5).

Table 4: Unit of Travel used in Trip Generation—All MPOs

Trip Types	All MPOs									
	Vehicular Trips		Motorized Person Trips		Total Person Trips		Tours		Other	
	No.	%	No.	%	No.	%	No.	%	No.	%
HBW	88	41%	32	15%	91	42%	2	1%	2	1%
HBR	24	23%	15	14%	63	60%	2	2%	1	1%
HBNR	18	37%	3	6%	27	55%	0	0%	1	2%
HBS	17	20%	13	15%	51	60%	2	2%	2	2%
HBCU	10	19%	5	9%	35	65%	2	4%	2	4%
HBO	79	40%	33	17%	85	43%	2	1%	1	1%
NHB	79	40%	32	16%	87	44%	0	0%	1	1%
WB	16	25%	12	19%	31	49%	2	3%	2	3%
Trucks	90	98%	0	0%	0	0%	1	1%	1	1%
Commercial Vehicles	54	95%	0	0%	0	0%	3	5%	0	0%
Taxis	19	95%	0	0%	0	0%	0	0%	1	5%

n=228 MPOs
HBW = home-based work, HBR = home-based retail, HBNR = home-based non-retail, HBS = home-based school, HBCU = home-based college/university, HBO = home-based other, NHB = non–home based, WB = work based

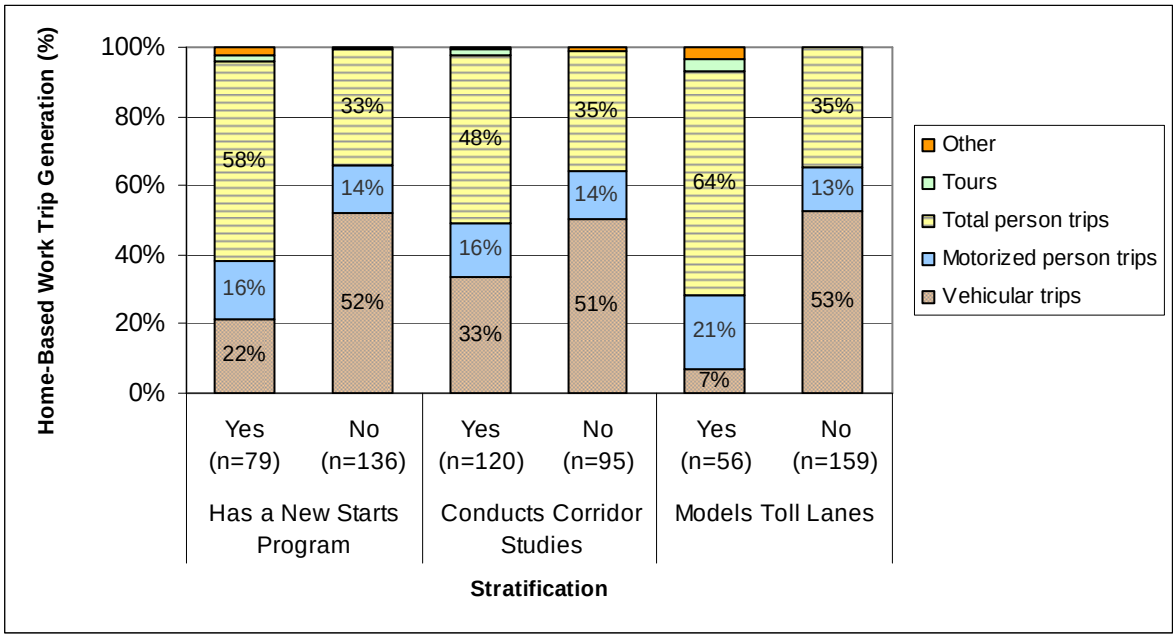
Table 5: Unit of Travel Used in Trip Generation—Large MPOs

Trip Types	Large MPOs									
	Vehicular Trips		Motorized Person Trips		Total Person Trips		Tours		Other	
	No.	%	No.	%	No.	%	No.	%	No.	%
HBW	3	8%	4	11%	26	72%	1	3%	2	6%
HBR	2	8%	3	12%	19	73%	1	4%	1	4%
HBNR	1	8%	0	0%	11	85%	0	0%	1	8%
HBS	2	8%	1	4%	20	77%	1	4%	2	8%
HBCU	0	0%	1	5%	15	79%	1	5%	2	11%
HBO	3	9%	5	15%	23	70%	1	3%	1	3%
NHB	2	6%	5	16%	24	75%	0	0%	1	3%
WB	1	8%	0	0%	8	67%	1	8%	2	17%
Trucks	18	95%	0	0%	0	0%	1	5%	0	0%
Commercial Vehicles	12	92%	0	0%	0	0%	1	8%	0	0%
Taxis	9	100%	0	0%	0	0%	0	0%	0	0%

n=36 MPOs
HBW = home-based work, HBR = home-based retail, HBNR = home-based non-retail, HBS = home-based school, HBCU = home-based college/university, HBO = home-based other, NHB = non–home based, WB = work based

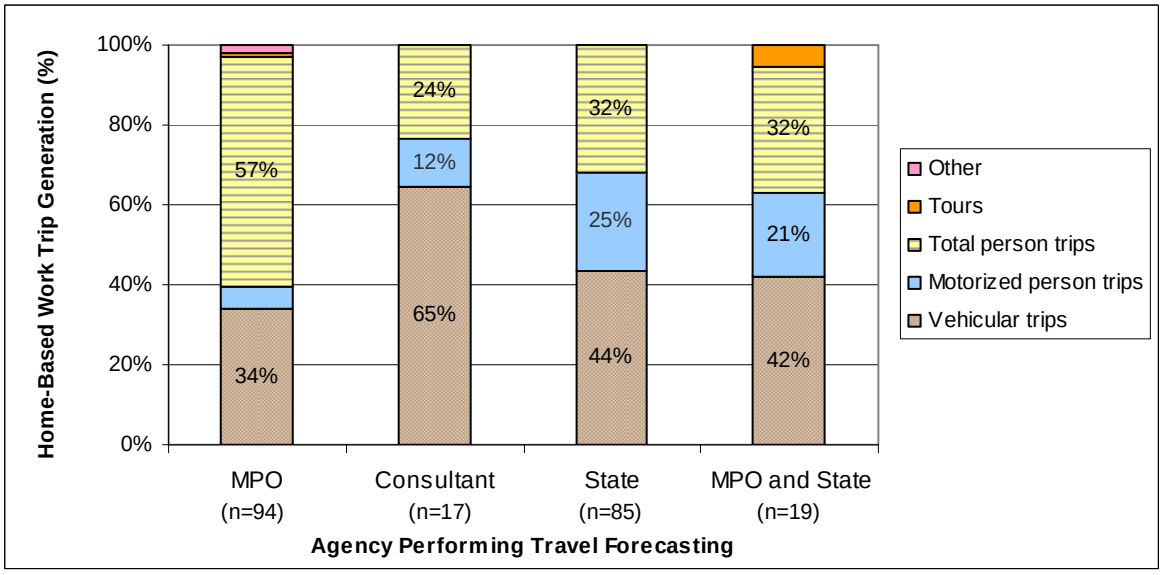
MPOs that have New Starts/Small Starts programs, conduct corridor studies, or model toll lanes are more likely to use total person trips for generating HBW trips. Those MPOs without New Starts/Small Starts programs that do not conduct corridor studies or do not model toll lanes are more likely to use vehicular trips (see Figure 52).

Figure 52: Unit of Travel Used in Distributing HBW Trips (Stratified by Whether MPO Has a New Starts Program, Conducts Corridor Studies, or Models Toll Lanes)



MPOs that perform their own travel forecasting are more likely to use total person trips for generating HBW trips than MPOs for which the state performs the travel forecasting (see Figure 53). A few MPOs have implemented models that use tours rather than trips as the basic pattern for HBW trips. The models also include a submodel to estimate the location of the intermediate stop or stops. Tours are typically used by agencies that have activity-based models, but may also be used with four-step models.

Figure 53: Unit of Travel Used in Distributing HBW Trips (Stratified by Agency Performing the Travel Forecasting)



The trip production model is typically cross-classification for person travel; only 11% of MPOs reported using a regression model or some other model form for HBW productions. The most used cross-classification variables are household size and autos per household (Table 6).

The few agencies that have implemented activity-based models have also used synthetic household analysis, rather than direct trip generation, to determine the number and types of trips made by households.

Table 6: Form of the Trip Production Model (All MPOs)

Trip Type	All MPOs																			
	Cross-Classification																Regression		Other	
	Income		Household Size		Workers/HH		Auto/HH		Location		Density		Housing Type		Other					
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	No.	No.	%	No.	%	No.	%
HBW	71	33%	104	48%	54	25%	90	41%	30	14%	8	4%	19	9%	5	2%	23	11%	16	7%
HBR	32	15%	72	33%	16	7%	51	24%	20	9%	7	3%	8	4%	1	0%	14	6%	4	2%
HBNR	19	9%	24	11%	10	5%	17	8%	7	3%	4	2%	4	2%	1	0%	10	5%	0	0%
HBS	18	8%	40	18%	7	3%	26	12%	20	9%	2	1%	7	3%	20	9%	16	7%	13	6%
HBCU	9	4%	13	6%	3	1%	4	2%	4	2%	3	1%	2	1%	1	0%	7	3%	5	2%
HBO	62	29%	120	55%	20	9%	73	34%	28	13%	7	3%	19	9%	13	6%	25	12%	13	6%
NHB	58	27%	106	49%	19	9%	63	29%	25	12%	5	2%	11	5%	5	2%	44	20%	18	8%
WB	16	7%	16	7%	20	9%	19	9%	20	9%	5	2%	3	1%	5	2%	17	8%	9	4%
Trucks	3	1%	6	3%	3	1%	3	1%	9	4%	1	0%	1	0%	7	3%	53	24%	25	12%
Commercial Vehicles	1	0%	2	1%	1	0%	0	0%	1	0%	0	0%	0	0%	3	1%	36	17%	11	5%
Taxis	2	1%	2	1%	2	1%	1	0%	1	0%	0	0%	0	0%	1	0%	4	2%	4	2%

n=228 MPOs

HBW = home-based work, HBR = home-based retail, HBNR = home-based non-retail, HBS = home-based school,
HBCU = home-based college/university, HBO = home-based other, NHB = non–home based, WB = work based other, NHB = non-home–based, WB = work based

The most common form of a trip attraction model is one based on a regression equation. The independent variable used in the trip attraction function was not reported. In almost all cases, the independently generated forecasts of trip productions and trip attractions are balanced before trip distribution (see Table 7).

Table 7: Are Productions and Attractions Balanced Before Trip Distribution – All MPOs

Trip Type	Yes	
	No.	%
HBW	204	97%
HBR	95	95%
HBNR	42	91%
HBS	76	92%
HBCU	45	87%
HBO	189	96%
NHB	188	96%

n=228
HBW = home-based work, HBR = home-based retail, HBNR = home-based non-retail, HBS = home-based school, HBCU = home-based college/university, HBO = home-based other, NHB = non–home based, WB = work based

For most purposes, in most MPOs, the forecast trips generated are normalized to the forecast of productions. In approximately 12% of MPOs, HBW trips are normalized to attractions. In approximately one-third of MPOs that forecast college or university trips, the trips are normalized to attractions (see Table 8).

Table 8: Method for Balancing Productions and Attractions – All MPOs

Trip Type	Normalized to Productions		Normalized to Attractions		Average of Productions and Attractions		Other	
	No.	%	No.	%	No.	%	No.	%
HBCU	30	13%	11	5%	2	1%	8	4%
HBNR	33	14%	3	1%	4	2%	6	3%
HBO	163	71%	9	4%	11	5%	10	4%
HBR	82	36%	5	2%	4	2%	7	3%
HBS	60	26%	7	3%	4	2%	9	4%
HBW	155	68%	27	12%	13	6%	12	5%
NHB	129	57%	38	17%	10	4%	11	5%

n=228
HBW = home-based work, HBR = home-based retail, HBNR = home-based non-retail, HBS = home-based school, HBCU = home-based college/university, HBO = home-based other, NHB = non–home based, WB = work based

Trip Distribution

A few MPOs reported that they do not perform travel forecasting. Those MPOs, therefore, do not distribute trips. MPOs that prepared forecasts do run distribution models. Almost all MPOs distribute HBW, HBO, and NHB trips. Approximately one-third of all MPOs and two-thirds of large MPOs distribute some type of shopping or service trips (see Table 9).

Large MPOs tend to distribute person trips (an average of approximately 50% for all trip purposes), whereas distribution of vehicle trips is more common for small and medium-sized MPOs.

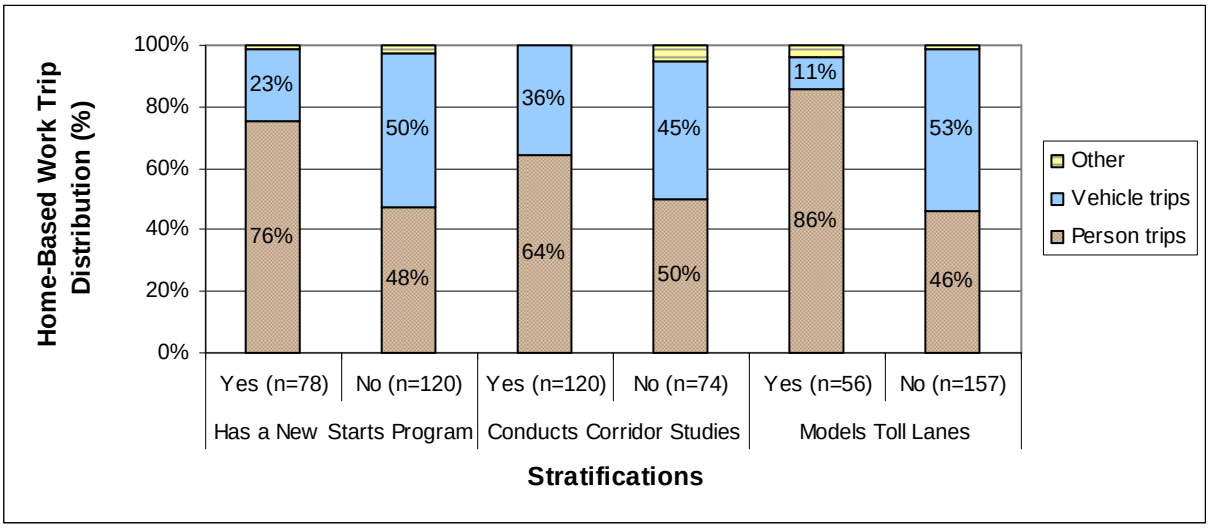
Table 9: Trip Purposes Distributed and Unit of Trip Making

Trip Purpose	Percentage of MPOs Distributing This Purpose				Percentage of MPOs Distributing This Purpose That Distribute Person Trips			
	All	Small	Medium	Large	All	Small	Medium	Large
HBW	93%	91%	93%	100%	54%	40%	61%	89%
HBR	45%	35%	47%	69%	34%	23%	38%	61%
HBNR	21%	17%	20%	33%	12%	7%	13%	28%
HBS	37%	27%	38%	69%	28%	17%	30%	58%
HBCU	24%	16%	22%	53%	18%	10%	17%	47%
HBO	87%	85%	87%	94%	51%	36%	58%	83%
NHB	88%	84%	91%	94%	53%	38%	61%	83%
WB	28%	22%	34%	31%	19%	13%	26%	22%
Trucks	38%	33%	43%	44%	0%	0%	0%	0%
Commercial Vehicles	25%	22%	20%	42%	0%	0%	0%	0%

HBW = home-based work, HBR = home-based retail, HBNR = home-based non-retail, HBS = home-based school, HBCU = home-based college/university, HBO = home-based other, NHB = non–home based, WB = work based

Although Figure 54 shows that MPOs with a New Starts/Small Starts program or that model toll lanes are more likely to distribute person trips in their model for HBW trips, this difference is associated with the large size of these MPOs (see Table 9). However, MPOs that conduct corridor studies are also more likely to distribute person trips in their model for HBW trips. The results for HBW are comparable to results for other trip types.

Figure 54: Frequency of HBW Trip Distribution (Stratified by Whether MPO Has a New Starts Program, Conducts Corridor Studies, or Models Toll Lanes)



The time period impedances used in HBW trip distribution by most agencies tend to be total day (69%) or morning peak (17%) (see Table 10). Large agencies are far more likely to use morning peak impedances (55%); only one-third of large agencies reported using total day impedances to distribute HBW trips.

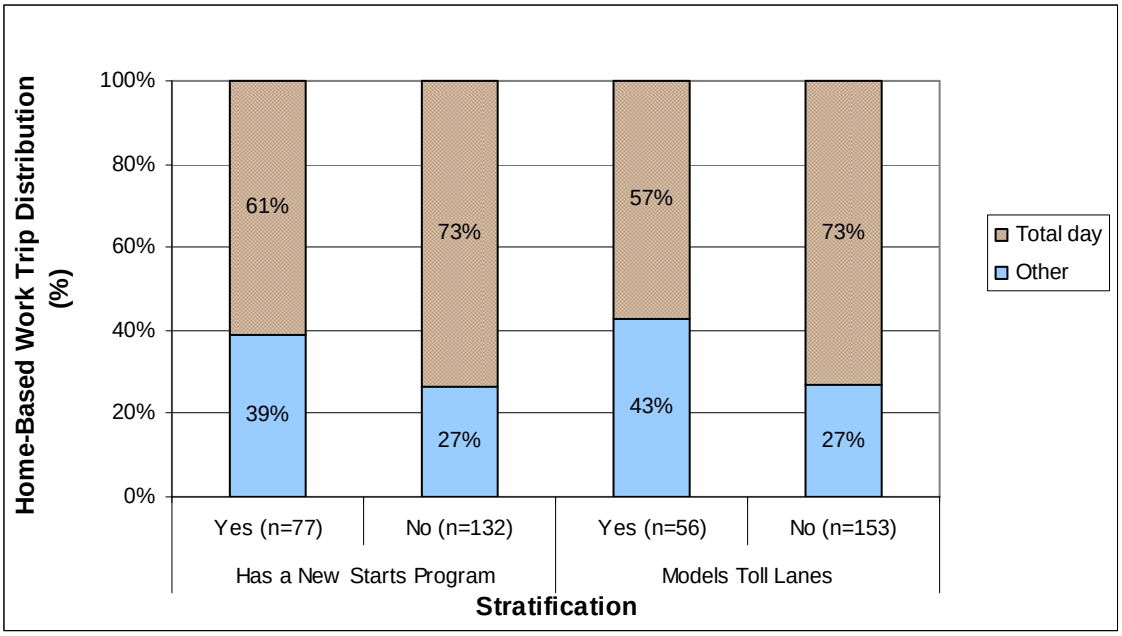
Table 10: Impedances Used to Distribute Trips – All MPOs

Distribute This Purpose:	Percentage of MPOs Using Impedance									
	Total day		AM Peak		PM Peak		Midday		Evening and Night	
	No.	%	No.	%	No.	%	No.	%	No.	%
HBW	144	69%	35	17%	28	13%	2	1%	0	0%
HBR	55	56%	5	5%	7	7%	32	32%	0	0%
HBNR	22	50%	4	9%	7	16%	11	25%	0	0%
HBS	54	67%	9	11%	7	9%	11	14%	0	0%
HBCU	28	55%	7	14%	8	16%	8	16%	0	0%
HBO	138	71%	6	3%	15	8%	36	18%	0	0%
NHB	132	69%	5	3%	22	12%	32	17%	0	0%
WB	33	56%	5	8%	13	22%	8	14%	0	0%
Trucks	69	75%	3	3%	4	4%	16	17%	0	0%
Commercial Vehicles	28	49%	3	5%	0	0%	26	46%	0	0%

HBW = home-based work, HBR = home-based retail, HBNR = home-based non-retail, HBS = home-based school, HBCU = home-based college/university, HBO = home-based other, NHB = non–home based, WB = work based

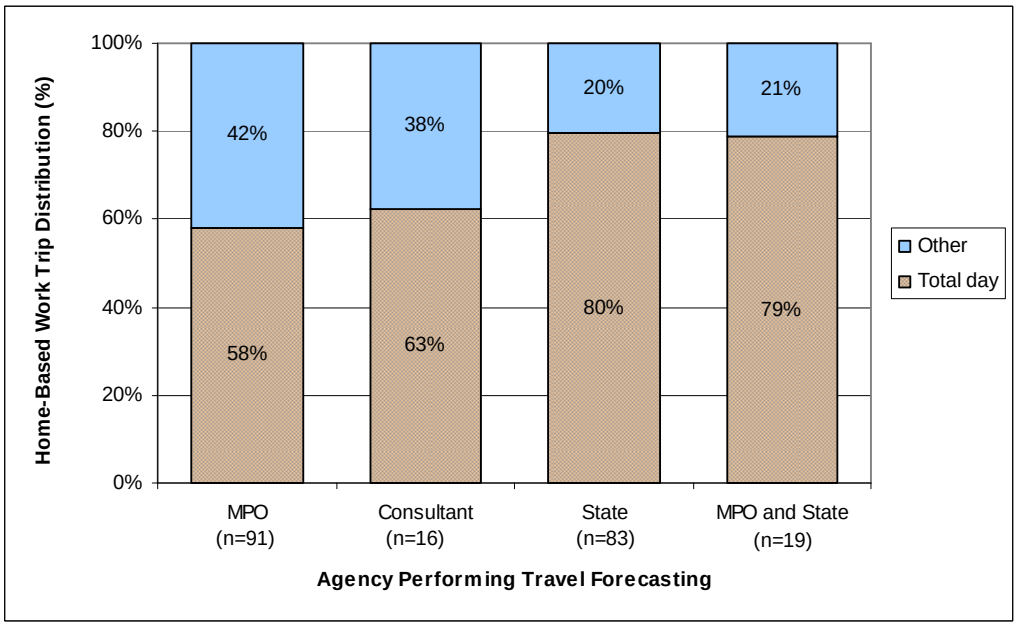
MPOs that have a New Starts/Small Starts program or that model toll lanes are less likely to use the total day impedances to distribute the trip distribution model for HBW trips than MPOs without New Starts/Small Starts programs or that do not model toll lanes (see Figure 55). However, this difference is likely because MPOs that have New Starts/Small Starts programs or that model toll lanes tend to be larger MPOs, whereas those that do not tend to be smaller MPOs.

Figure 55: HBW Trip Distribution by Time Impedance (Stratified by whether MPO has a New Starts Program or Models Toll Lanes)



When states perform the travel forecasting, they are significantly more likely to use the total day impedances for the trip distribution model for HBW trips than when MPOs conduct their own travel forecasting (see Figure 56). Again, this difference is likely related to MPO size, because large MPOs are more likely to perform their own travel forecasting, whereas small MPOs are more likely to have their travel forecasting conducting by the state (see Figure 7).

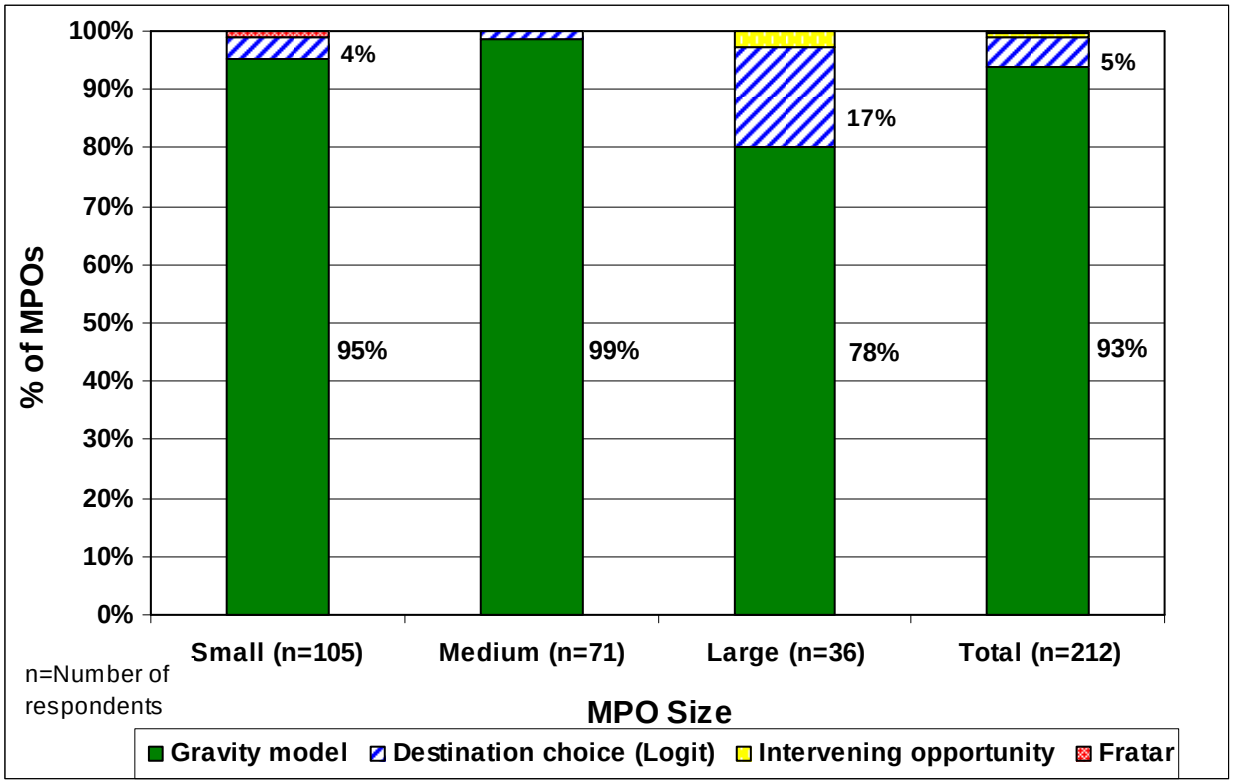
Figure 56: HBW Trip Distribution by Time Impedance (Stratified by Agency that Conducts the Travel Forecasting)



For other trip purposes, the situation is different. Retail trips and HBO trips are often distributed by large MPOs using midday or total day travel impedances.

Distribution models are overwhelmingly based on gravity models (93%). Eleven agencies reported using a destination choice model for HBW trips. These agencies also use destination choice for distribution of HBO and HBCU (college/university) trips. Several use destination choice for other trip purposes.

Figure 57: Form of the Trip Distribution Model—HBW



The impedance measure used to distribute HBW trips by 70–80% of small and medium-sized MPOs is time over the highway network or a combination of time and distance over the highway network. Among large MPOs, only approximately one-third reported using simple highway time or a combination of highway time and distance. More than half of large MPOs distribute trips using factors in addition to highway time or highway distance. A logsum measure from the mode choice model is used by 25% of large agencies, with another 25% using a combination of highway and transit time or a combination of time and cost. The impedance measure used for HBW tends to be used for other person trip categories. Truck and commercial trips are distributed using highway time or time and cost.

Approximately 30% of the MPOs of all sizes reported using K-factors in their HBW trip distribution models. Fifteen percent of the MPOs use other similar types of adjustment factors in their HBW trip distribution model (see Table 11). Approximately one-quarter of MPOs (half of those using adjustment factors) responded they did not know the percentage of the TAZ to TAZ interchanges to which adjustments were applied. In follow-up interviews, a few MPOs reported that they did not use K-factors or similar adjustment factors because they had no independent

source against which the model forecasts could be compared. Others reported that they did not use adjustment factors in their distribution models because they were not focusing on replicating known conditions but rather on the sensitivities when forecasting future conditions.

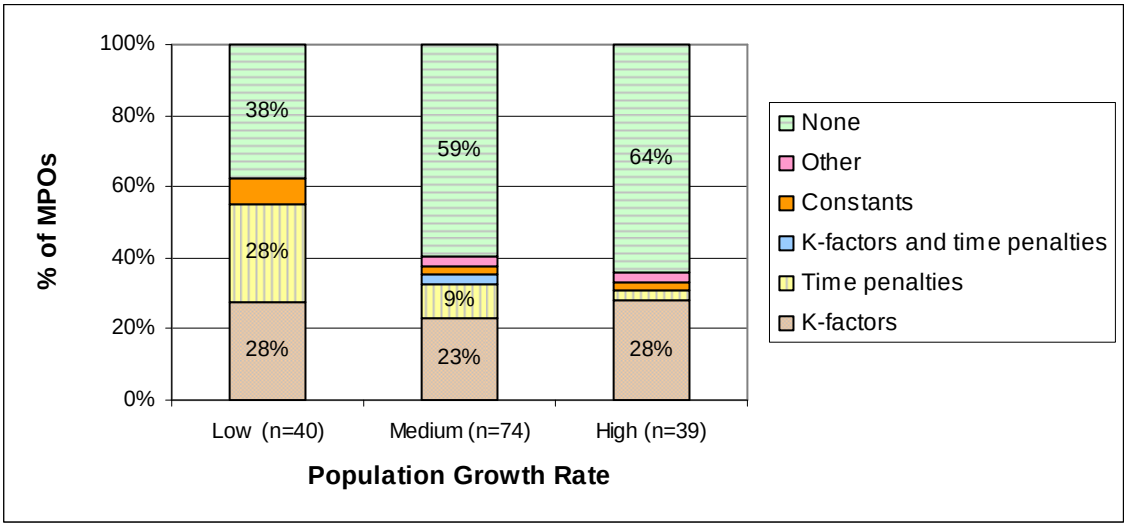
Table 11: Use of Distribution Model Adjustment Factors

Trip Type	Total	K-Factors		Time Penalties		Destination Constants		Other		No Factor	
	No.	No.	%	No.	%	No.	%	No.	%	No.	%
HBW	208	60	29%	22	11%	6	3%	5	2%	115	55%
HBR	100	20	20%	17	17%	3	3%	2	2%	58	58%
HBNR	44	12	27%	4	9%	1	2%	2	5%	25	57%
HBS	77	15	19%	13	17%	5	6%	2	3%	42	55%
HBCU	52	14	27%	4	8%	5	10%	2	4%	27	52%
HBO	195	51	26%	22	11%	4	2%	5	3%	113	58%
NHB	194	51	26%	22	11%	2	1%	4	2%	115	59%
WB	60	11	18%	11	18%	4	7%	2	3%	32	53%
Trucks	91	19	21%	3	3%	1	1%	4	4%	64	70%
Commercial Vehicles	55	3	5%	4	7%	0	0%	4	7%	44	80%

HBW = home-based work, HBR = home-based retail, HBNR = home-based non-retail, HBS = home-based school, HBCU = home-based college/university, HBO = home-based other, NHB = non–home based, WB = work based

Although the majority of MPOs do not use adjustment factors to distribute HBW trips, a majority of MPOs with low population growth use some form of adjustment factor. Low-growth MPOs are more likely than medium- or high-growth MPOs to use time penalties as an adjustment factor (see Figure 58).

Figure 58: Use of Adjustment Factors to Distribute HBW Trips (Stratified by Population Growth Rate)

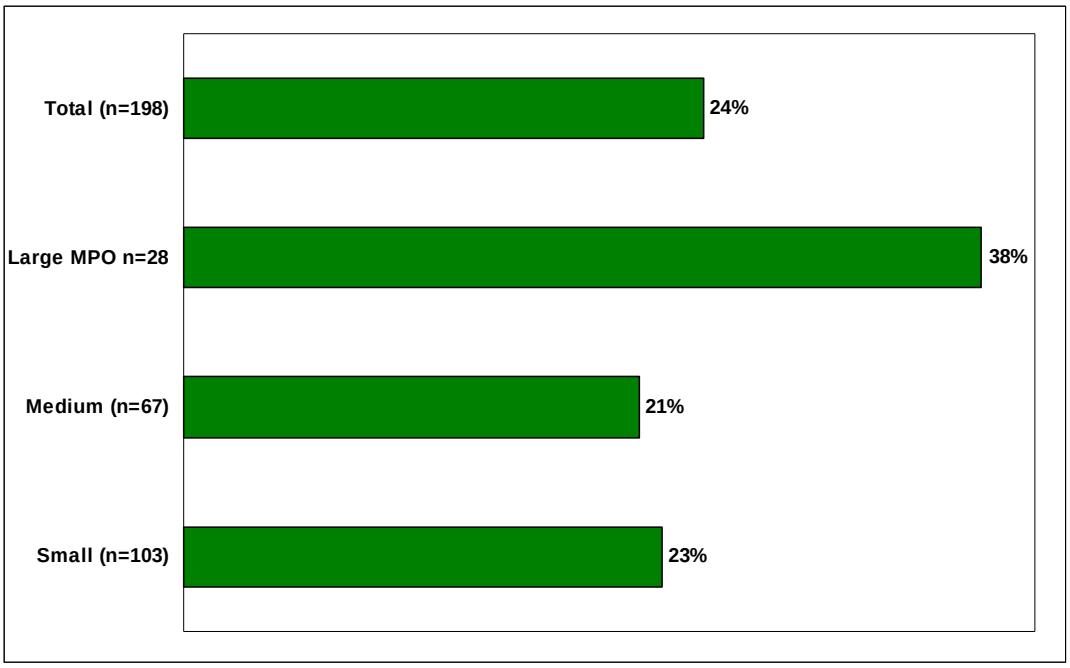


Approximately two-thirds of the reporting MPOs apply the gravity model doubly constrained, whereas one-third reported a singly constrained application with output attractions

not forced to equal input attractions. Roughly 13% reported that they did not know whether a gravity model was applied.

Approximately one-quarter of small and medium-size MPOs and one-third of large MPOs reported that they are exploring replacing their existing model with an activity-based or tour-based model (Figure 59).

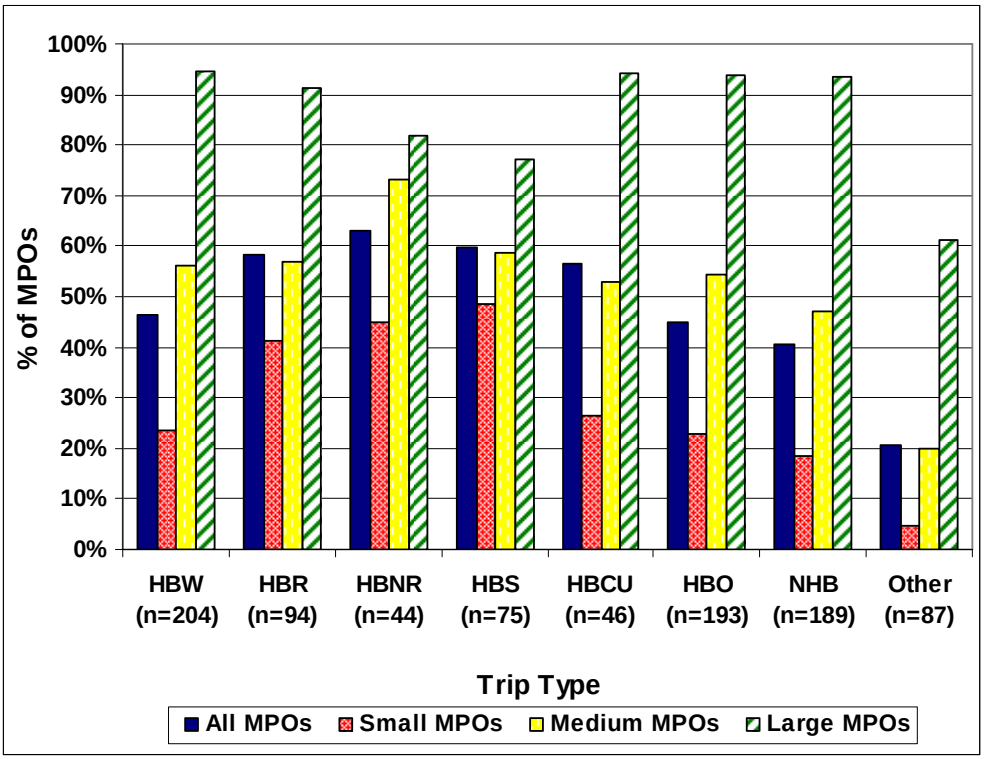
Figure 59: Agencies Considering Activity-Based or Tour-Based Model



Mode Choice

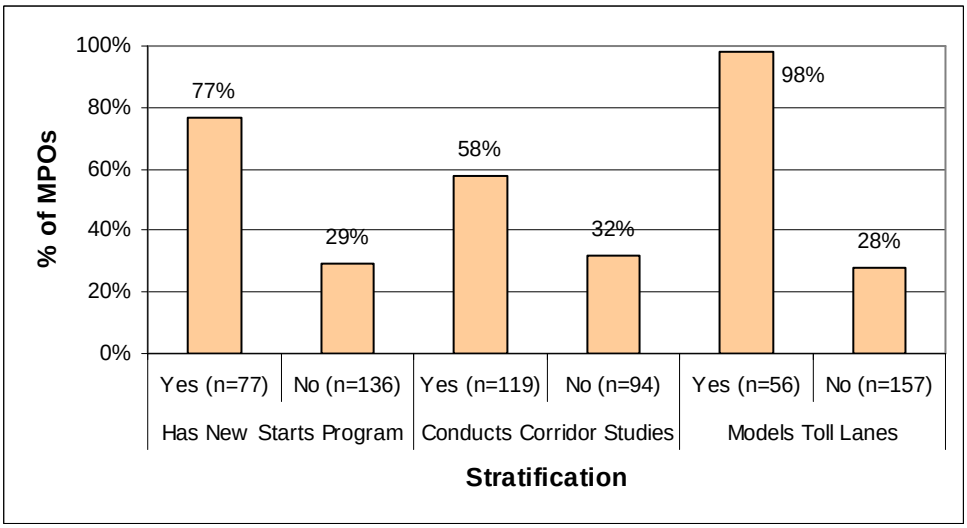
Use of a mode choice model is the norm for large MPOs. For the typical set of trip purposes, more than 90% of large MPOs reported use of a mode choice model. Only 25–48% of small MPOs reported mode choice models for most purposes (see Figure 60).

Figure 60: Existence of Mode Choice Model



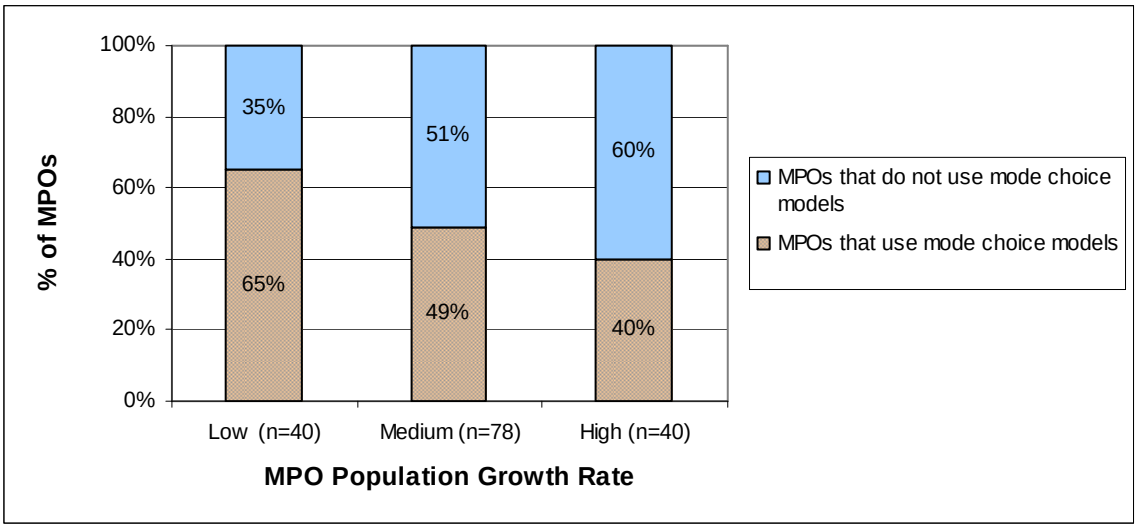
Those MPOs with New Starts/Small Starts program, that conduct corridor studies, or that model toll lanes are significantly more likely to use a mode choice model for HBW trips (see Figure 61). However, for MPOs that have New Starts programs or that model toll lanes, this is largely a result of MPO size (see Figure 60).

Figure 61: Percentage of MPOs With Mode Choice Model (Stratified by Whether MPO Has a New Starts Program, Conducts Corridor Studies, or Models Toll Lanes)



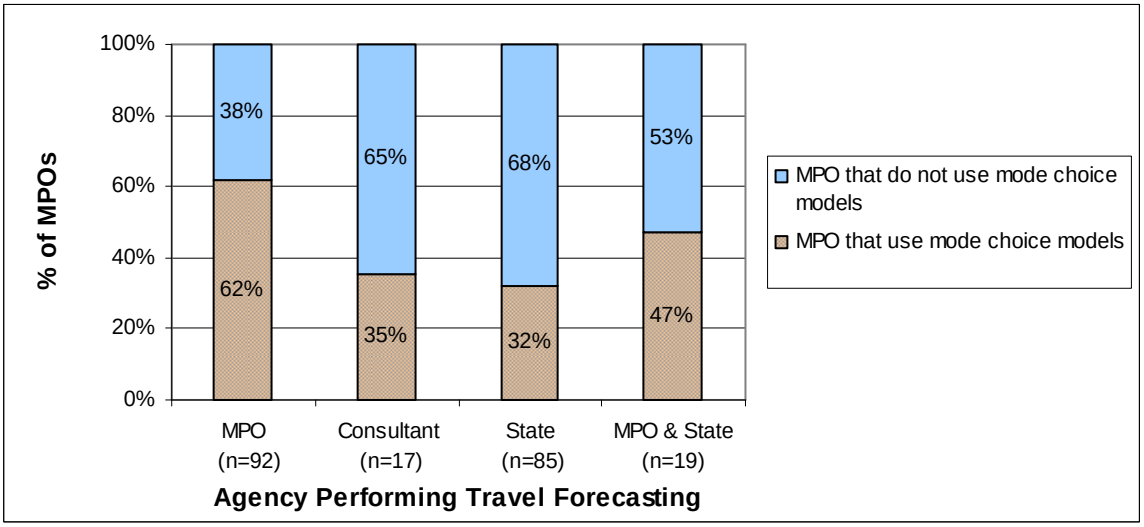
MPOs with higher population growth rates are less likely to use mode choice models than are MPOs with lower population growth rates (see Figure 62). Again, this relationship is likely related to MPO size; MPOs with higher population growth rates are more likely to have smaller populations (see Figure 60).

Figure 62: Percentage of MPOs With Mode Choice Model (Stratified by MPO Population Growth Rate)



MPOs that conduct their own travel forecasting are more likely to use mode choice models than MPOs whose travel forecasting is conducted by the state (see Figure 63).

Figure 63: Percentage of MPOs With Mode Choice Model (Stratified by Agency Performing the Travel Forecasting)

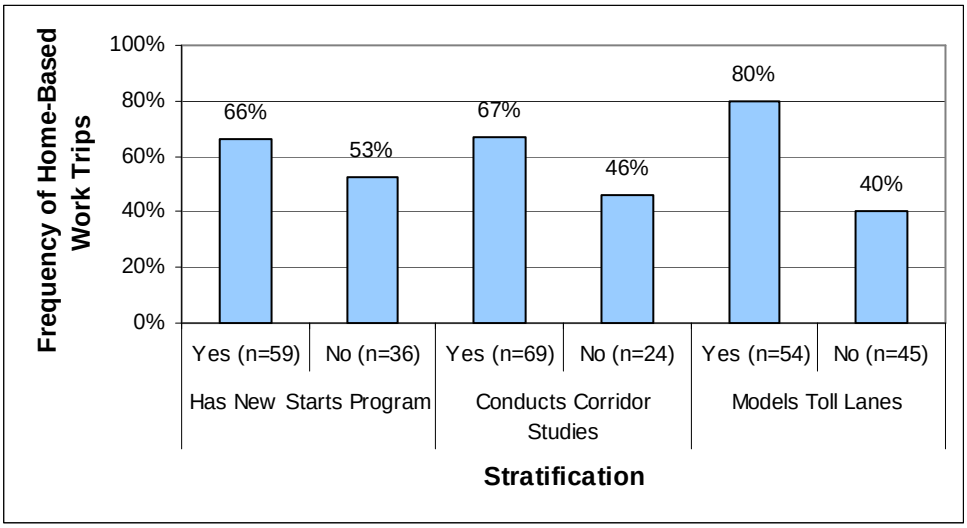


Although a few agencies reported use of a trip-end mode choice model or a model based on diversion curves or a regression model, almost all mode choice models are now either

multinomial logit or nested logit. For large MPOs, three-quarters of the HBW models and three-fifths other purpose mode choice models are nested logit.

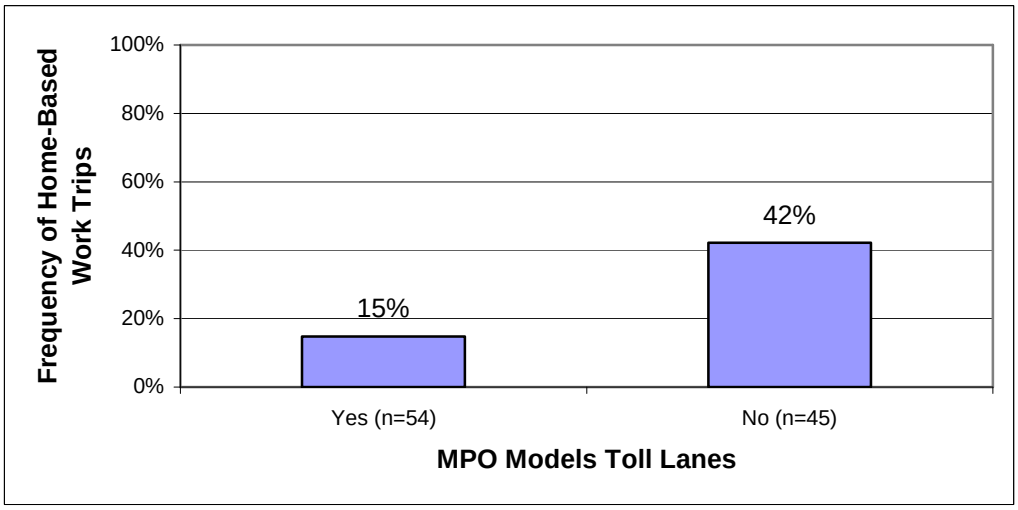
MPOs that have a New Starts/Small Starts program, that conduct corridor studies, or that model toll lanes are more likely to use a nested logit mode choice model for HBW trips than those that do not (see Figure 64). Such models are almost essential if issues such as these are to be analyzed in a four-step framework.

Figure 64: Percentage of MPOs That Use a Nested Logit Mode Choice Model for HBW Trips (Stratified by Whether the MPO Has a New Starts Program, Conducts Corridor Studies, or Models Toll Lanes)



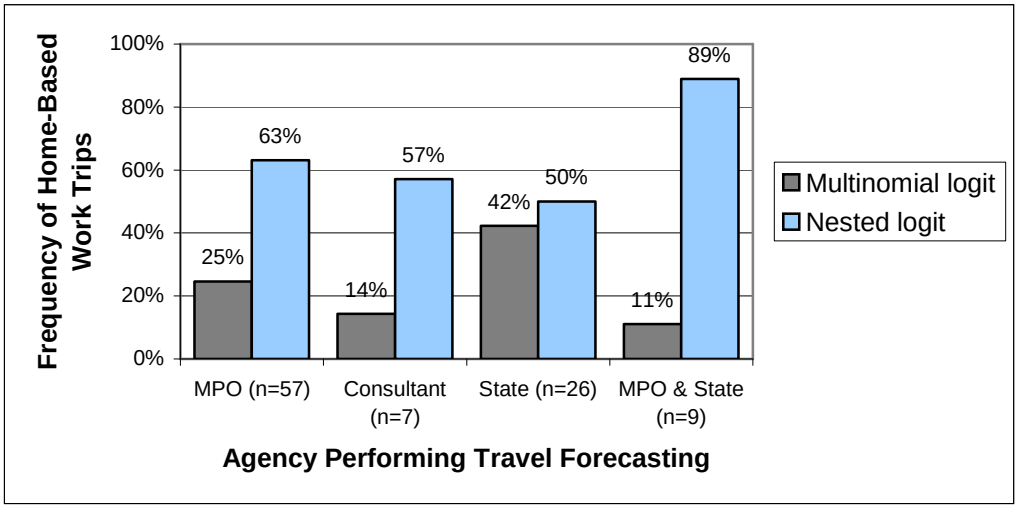
MPOs that model toll lanes are also more likely to use a multinomial logit mode choice model for HBW trips than MPOs that do not (see Figure 65).

Figure 65: Percentage of MPOs That Use a Multinomial Logit Mode Choice Model for HBW Trips (Stratified by Whether the MPO Models Toll Lanes)



States that perform the travel forecasting on behalf of an MPO are more likely to use multinomial logit mode choice models for HBW trips than when the MPO conducts its own travel forecasting, but states are less likely to use nested logit mode choice models (see Figure 66).

Figure 66: Percentage of MPOs That Use a Multinomial Logit Mode Choice Model for HBW Trips (Stratified by Agency Performing the Travel Forecasting)



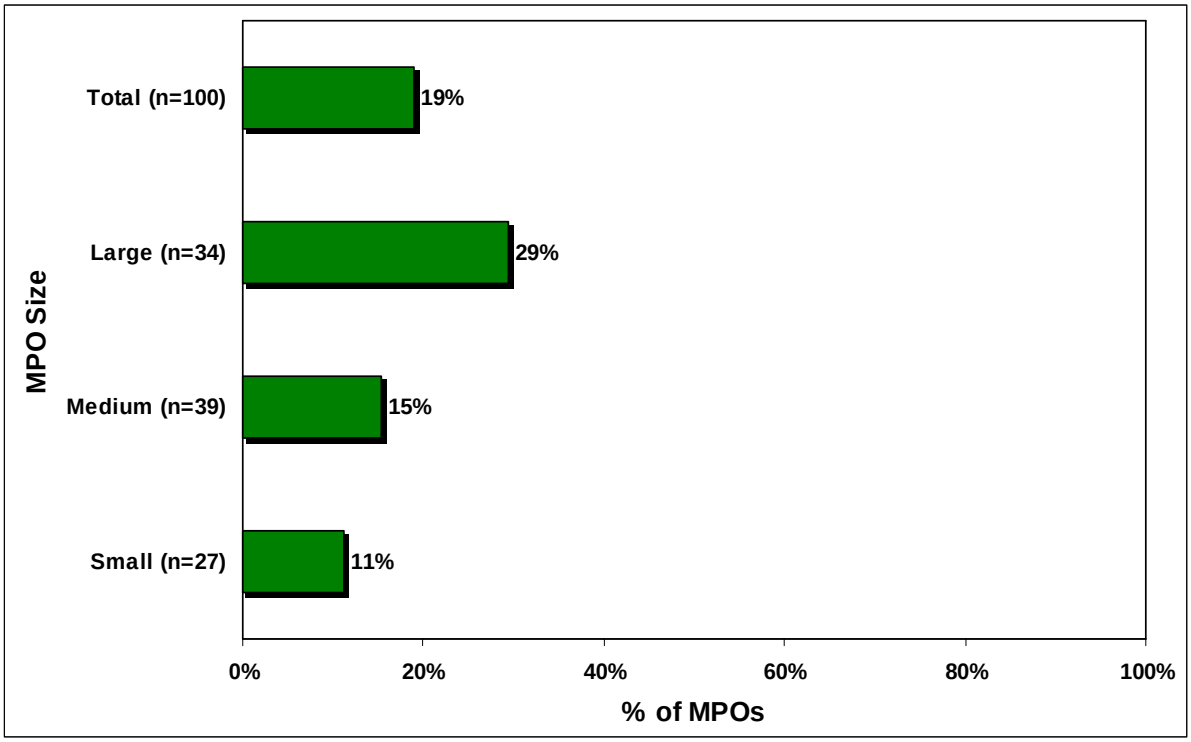
There are many ways that the modes and submodes considered in a travel forecast can be represented in the travel models. Table 12 summarizes the frequency of occurrence of modes and or mode combination in the mode choice models used by large MPOs. The models used by small and medium-sized MPOs have similar patterns.

"Drive Alone," "two-person auto," and "local bus" are the most frequently included modes. "Rail" appears in approximately one-third of the models. Where rail is used, it is typically in a nested structure with walk to rail and drive to rail treated separately. More than one-third of the large MPOs claim to treat "Walk" as a separate mode and 25% list "Bike" as a mode used in their mode choice model. Approximately one-third of the large MPOs reported having a separate mode-of-access model (Figure 67)

Table 12: Modes Used by Large MPOs in Mode Choice Model (n=34)

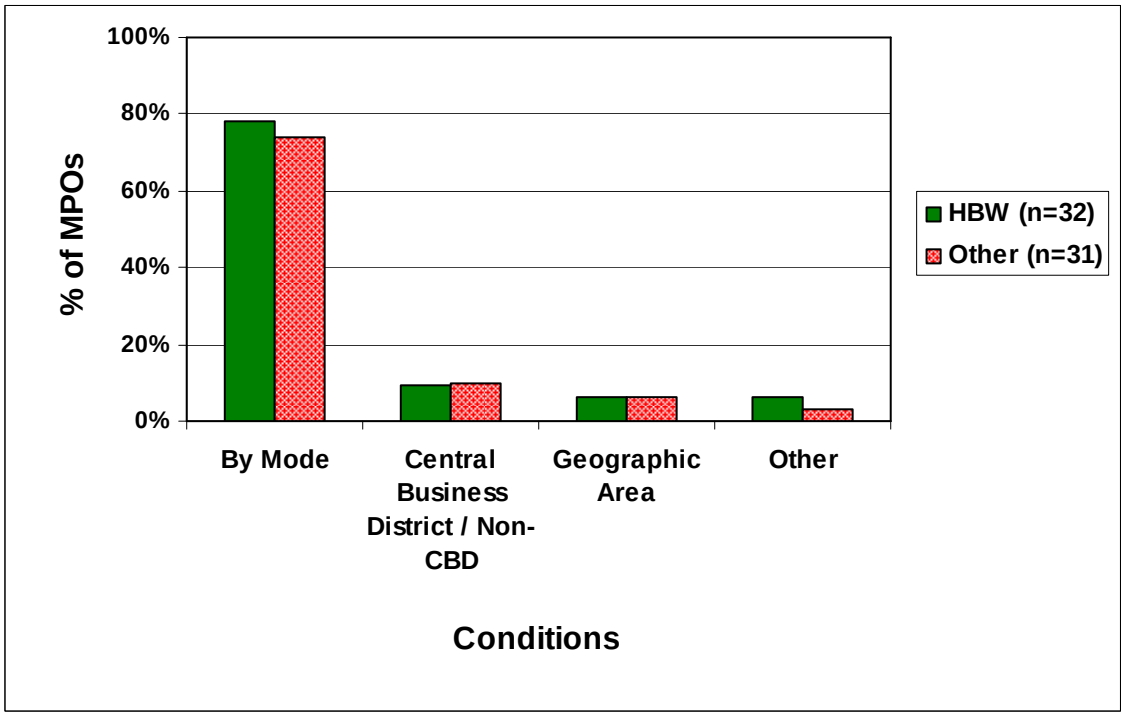
	Percentage of Agencies	
	HBW	Other
Drive alone	74%	68%
Two person auto	62%	50%
Local Bus	56%	56%
Walk to local bus	53%	59%
Drive to local bus	50%	47%
Express/commuter bus	44%	38%
Three or more person auto	38%	29%
Walk	38%	38%
Walk to rail	35%	32%
Drive to rail	35%	32%
Light rail transit	35%	38%
Walk to express bus	32%	29%
Drive to express bus	32%	29%
Premium transit (generic)	29%	26%
Commuter rail	29%	29%
Transit (generic)	26%	29%
Bike	26%	26%
Two or more person auto	24%	12%
BRT	21%	24%
Auto (generic)	18%	15%
Auto passenger	18%	24%
Walk to premium	18%	24%
Three person auto	15%	9%
Drive to premium	15%	18%
Drive to other	15%	9%
Walk to other	12%	9%
Heavy rail	12%	12%
Other	9%	6%
Four person auto	6%	3%
Four or more person auto	6%	3%

Figure 67: Use of a Separate Mode-of-Access Model



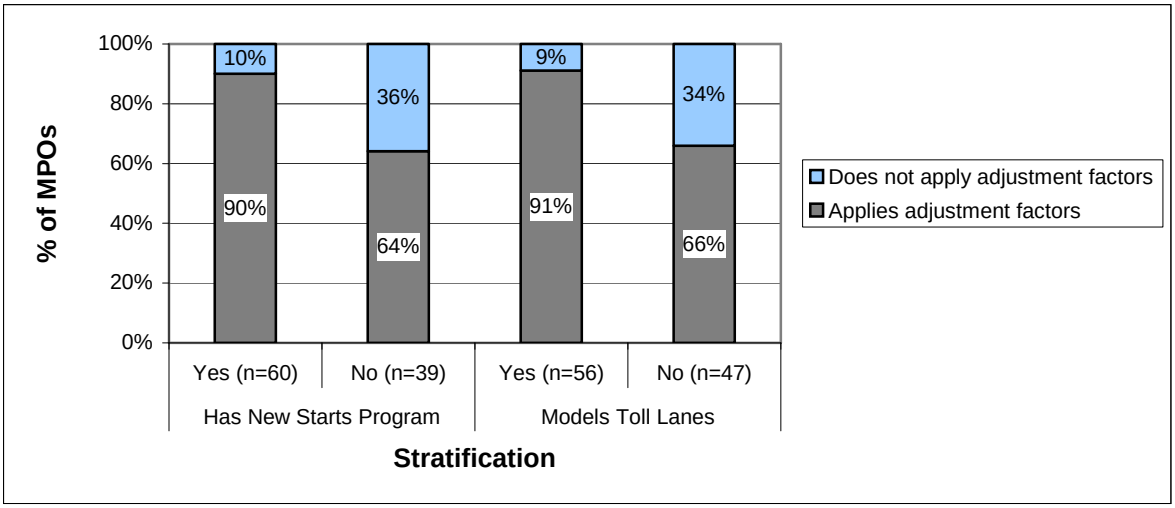
Of the large MPOs reporting use of a mode choice model, most reported applying adjustment factors of some type, most often a by mode end variable (Figure 68).

Figure 68: Use of Adjustment Factors in Mode Choice Models



Those MPOs that have New Starts programs or that model toll lanes are more likely to apply adjustment factors to HBW trips in the mode choice model (see Figure 69)

Figure 69: Percentage of MPOs That Apply Bias Constants to HBW Trips in Mode Choice Models (Stratified by Whether MPO Has a New Starts Program or Models Toll Lanes)



The time period of the impedances used in the mode choice models are generally as shown in Table 13.

Table 13: Time Period of Impedances Used in Mode Choice

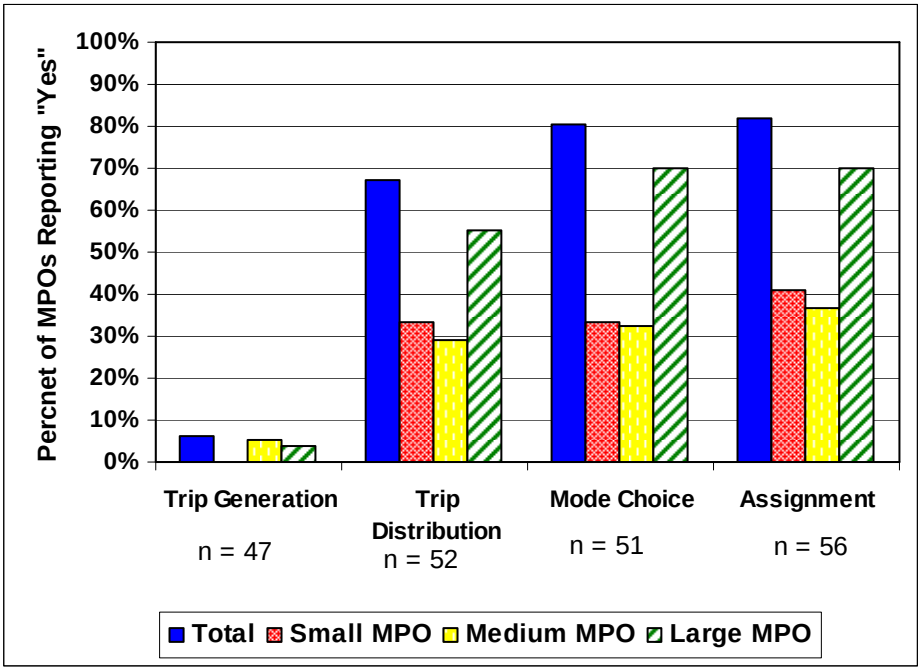
Trip Purpose	Time Period
HBW	AM Peak
HBR	Midday
Home-Based Service	AM Peak, Midday, PM Peak
HBS	AM Peak, Midday
HBCU	AM Peak
HBO	Midday
NHB	Midday
HBW = home-based work, HBR = home-based retail, HBNR = home-based non-retail, HBS = home-based school, HBCU = home-based college/university, HBO = home-based other, NHB = non–home based, WB = work based	

Managed Lanes

Possible use of a toll facility is treated as a mode choice by approximately 15% of medium-sized and large MPOs and by none of the small MPOs.

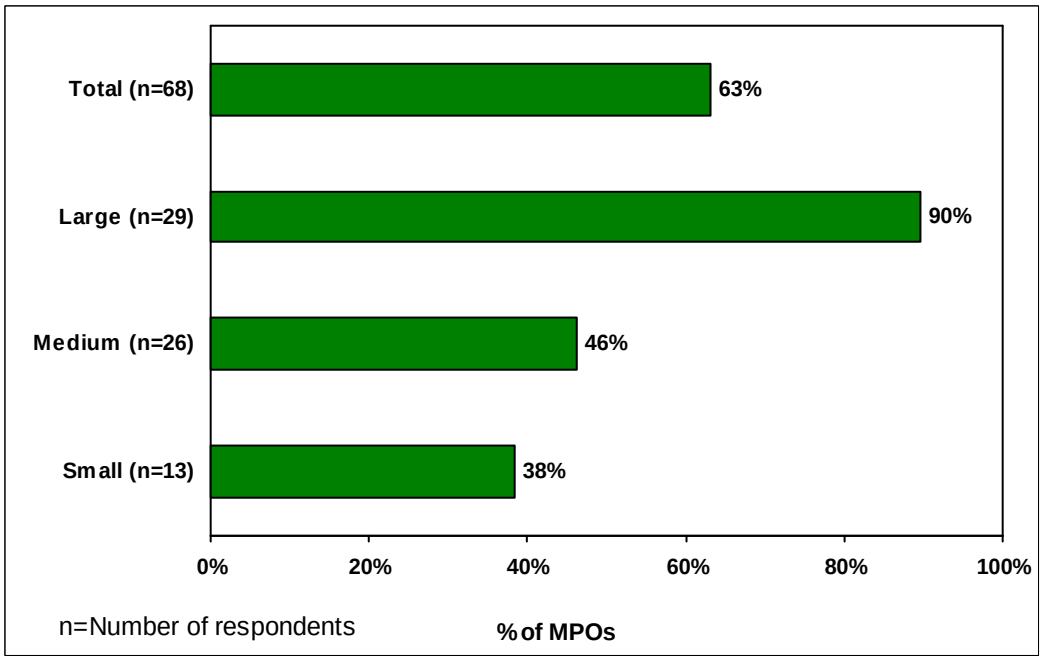
Of the MPOs responding, the cost of tolls is included by most in trip distribution, mode choice, and assignment. A few agencies (less than 10%), reported including toll costs in trip generation (see Figure 70**)**. Approximately 40% of the agencies responding to this question indicated it was "Not Applicable" and a few said they "Don't Know."

Figure 70: Cost of Tolls in Model Components



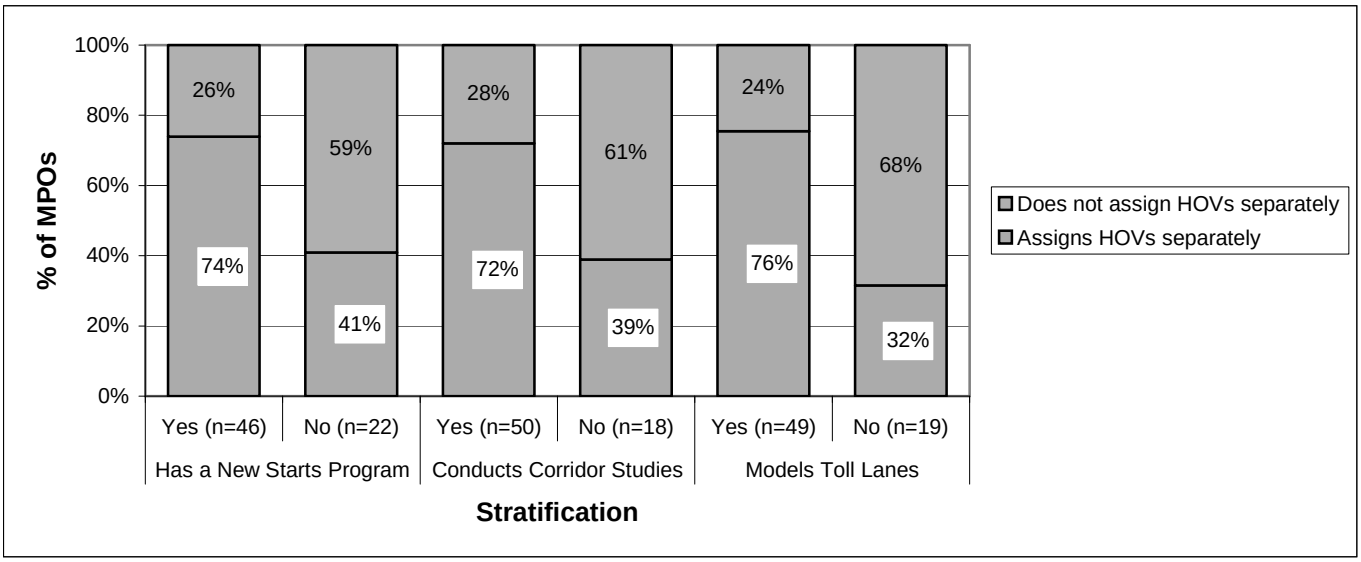
Large agencies that forecast high occupancy vehicle (HOV) travel perform separate assignment of HOVs (see Figure 71). Few small MPOs assign HOVs separately.

Figure 71: Separate Assignment of HOV



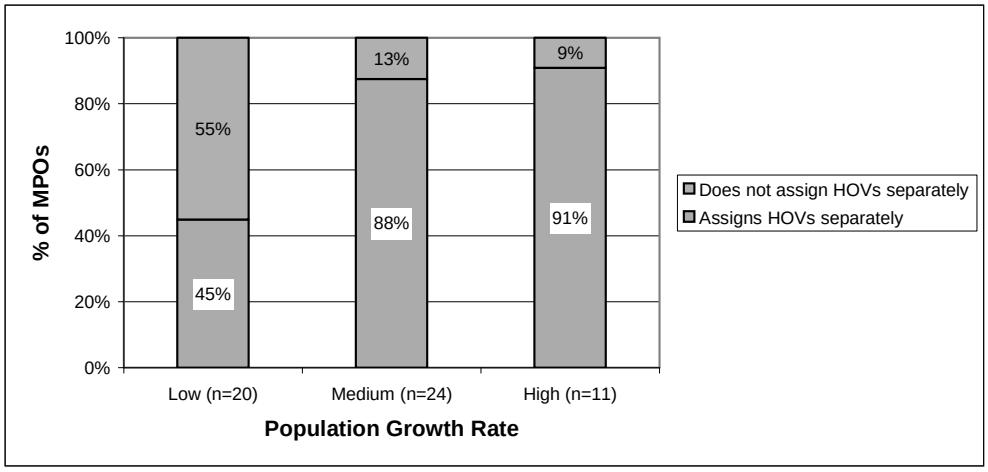
MPOs with New Starts/Small Starts programs, that conduct corridor studies, or that model toll lanes are more likely to assign HOVs separately than those that do not have New Starts/Small Starts programs, that conduct corridor studies, or that model toll lanes (Figure 72). However, separate assignment of HOVs is largely a result of MPO size (see Figure 71).

Figure 72: Percentage of MPOs That Assign HOVs Separately (Stratified by Whether MPO Has a New Starts Program, Conducts Corridor Studies or Models Toll Lanes)



MPOs with higher population growth rates are also more likely to assign HOVs separately (see Figure 73).

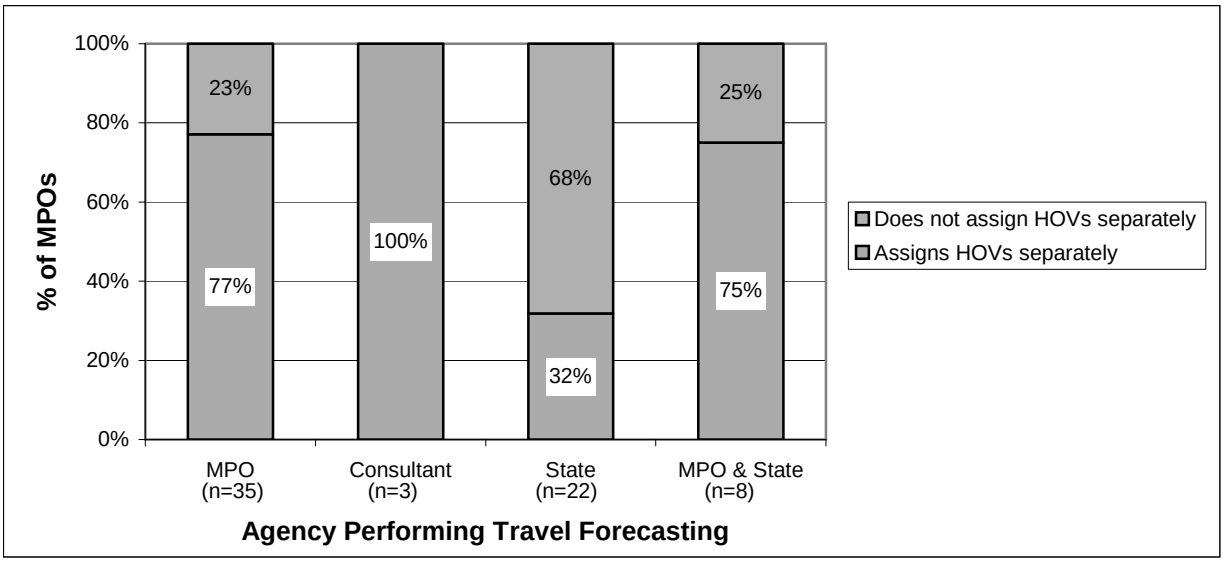
Figure 73: Percentage of MPOs That Assign HOVs Separately (Stratified by MPO Growth Rate)



MPOs that conduct their own travel forecasting are more likely to assign HOVs separately than when the state performs the travel forecasting on behalf of the MPO (Figure 74).

However, this relationship is probably a result of MPO size; large MPOs tend to perform their own travel forecasting (see Figure 71).

Figure 74: Percentage of MPOs That Assign HOVs Separately (Stratified by the Agency Performing the Travel Forecasting)



Trip Assignment

Almost all agencies assign highway trips. Most agencies assign trips for only a single time period, but many agencies, particularly large MPOs, do assignments for multiple periods (see Figure 75). Among small and medium-sized agencies, traffic is typically assigned for a total day, whereas for large MPOs, a morning or afternoon peak period assignment is the norm (Figure 76).

Figure 75: Number of Time Periods for Which Traffic Is Assigned

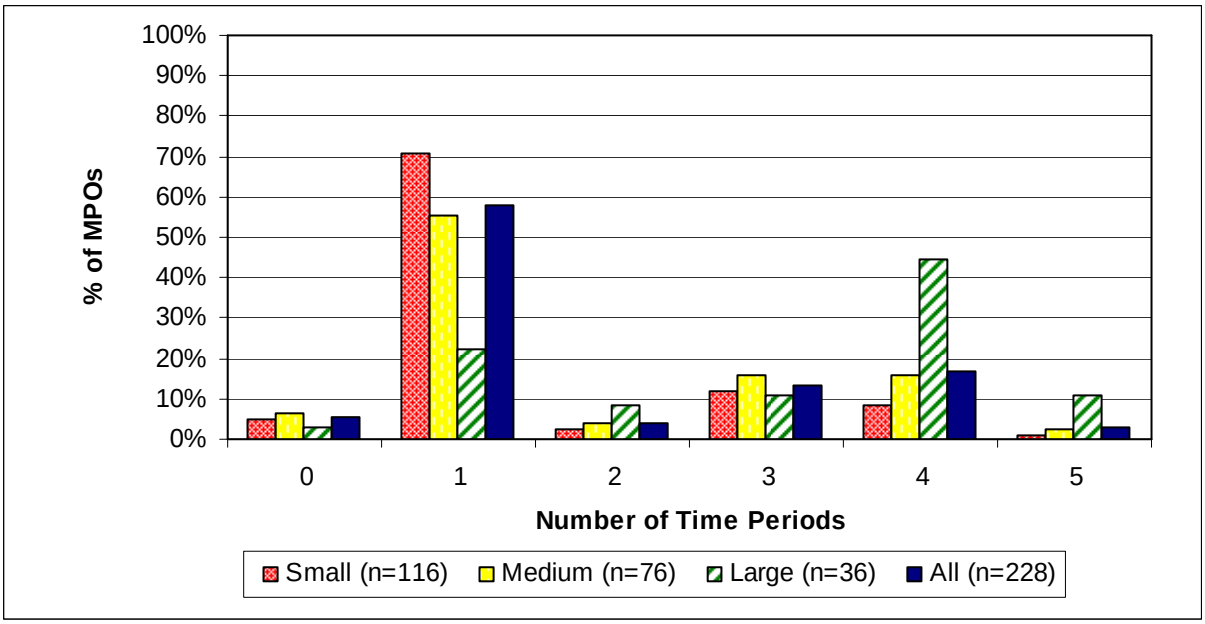
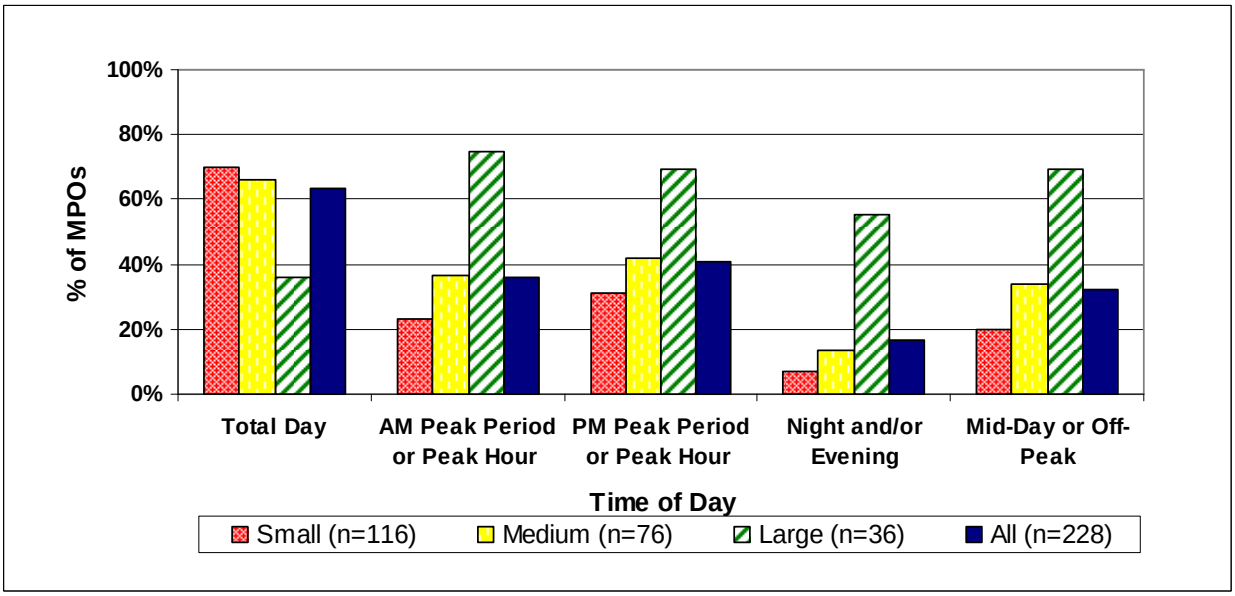
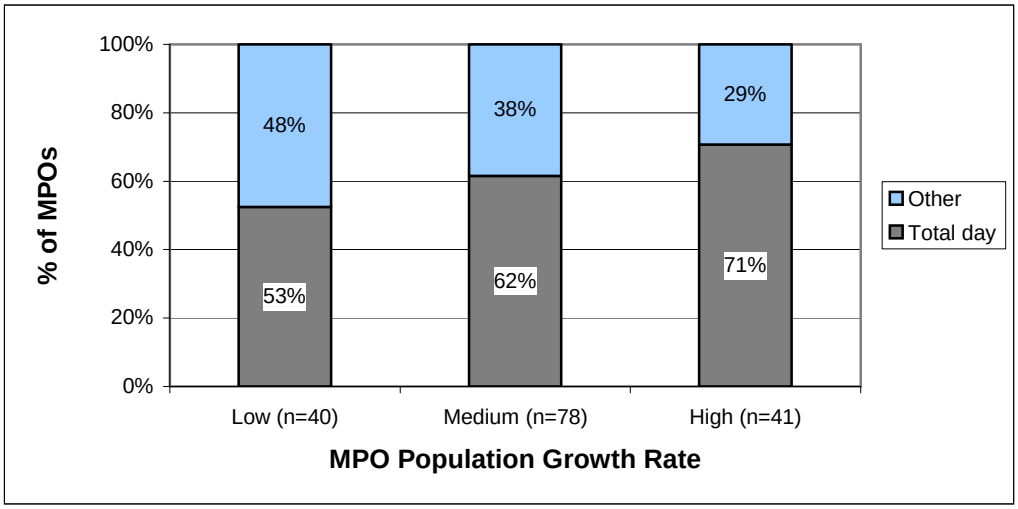


Figure 76: Time Period for Which Highway Traffic Is Assigned



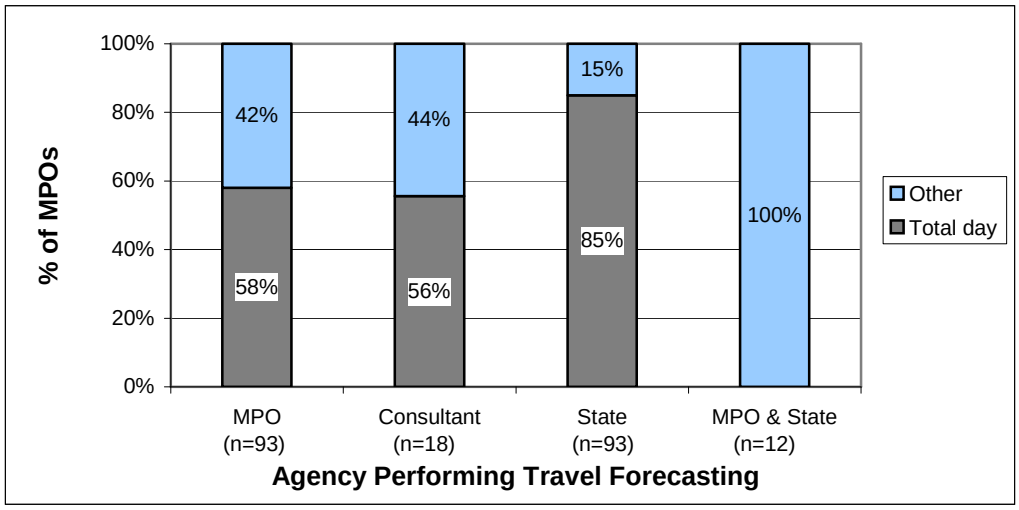
Although the majority of MPOs assign highway trips during the total day, those MPOs with higher growth rates are more likely to assign highway trips during the total day than MPOs with lower growth rates (see Figure 77). This relationship is likely a result of MPO size; MPOs with higher population growth rates tend to have smaller populations, they are more likely to assign highway trips for the total day (see Figure 76).

Figure 77: MPO Assignment of Highway Trips by Time Period (Stratified by MPO Population Growth Rate)



MPOs that conduct their own travel forecasting are less likely to assign highway trips for the total day than MPOs for which the state conducts the travel forecasting (see Figure 78). Again, this is a result of MPO size.

Figure 78: MPO Assignment of Highway Trips by Time Period (Stratified by Agency Performing the Travel Forecasting)



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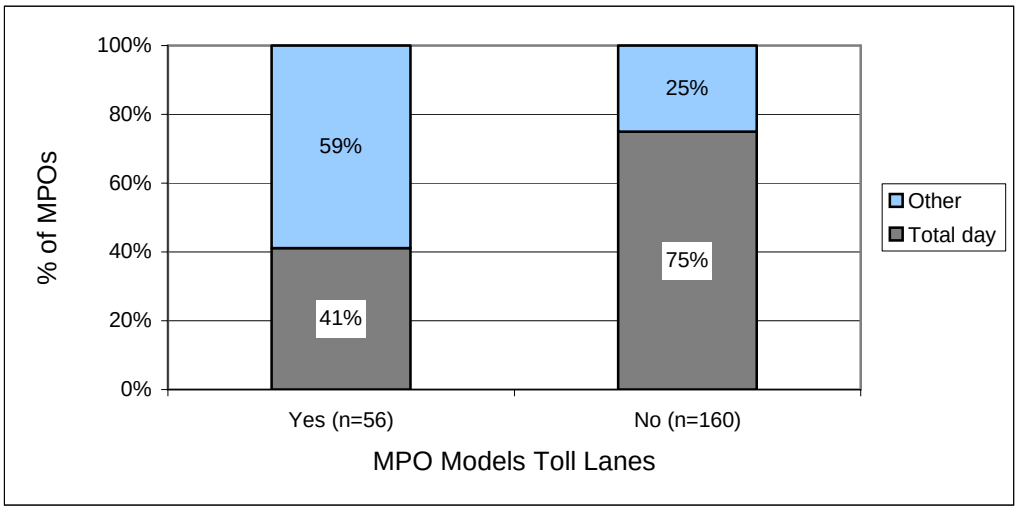
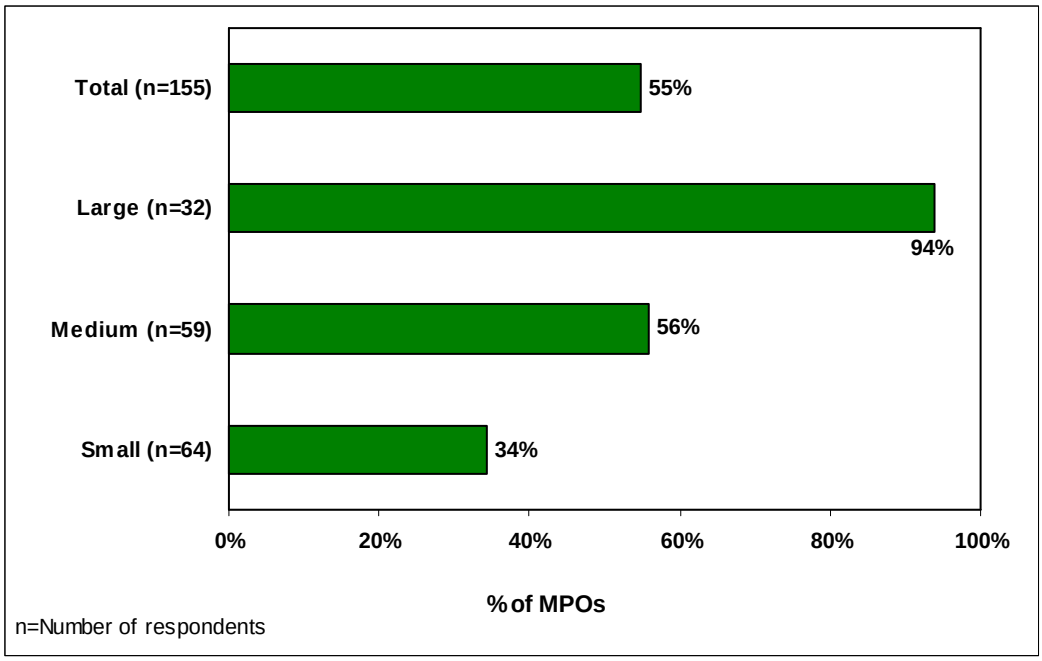
MPOs that model toll lanes are less likely to assign highway trips for the total day than MPOs that do not model toll lanes (see Figure 79). This is a result of MPO size; MPOs that do not model toll lanes tend to have smaller populations, which, as Figure 76 shows, is related to a greater likelihood of assigning highway trips to the total day.

Figure 79: MPO Assignment of Highway Trips by Time Period (Stratified by Whether MPO Models Toll Lanes)



Transit trips are assigned by most of the large MPOs but by only 56% of the medium-sized and by 34% of the smaller MPOs (Figure 80).

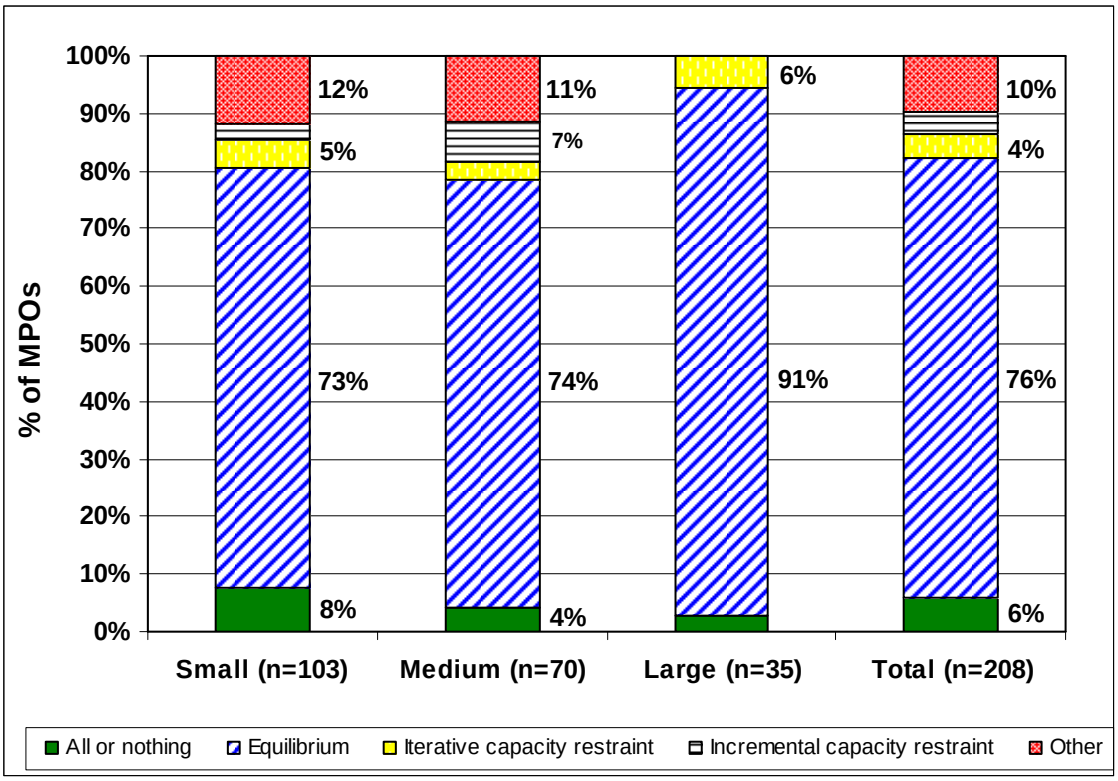
Figure 80: Agencies Assigning Transit Trips



For almost all agencies, highway traffic is assigned using an equilibrium method (Figure 81). Few agencies were able to report the number of iterations required to achieve closure in equilibrium assignment or the closure tolerance used. Many reported that they used the default values of the software package. Few agencies had examined equilibrium assignments to see whether the results were stable, and none of those sampled reported problems such as those

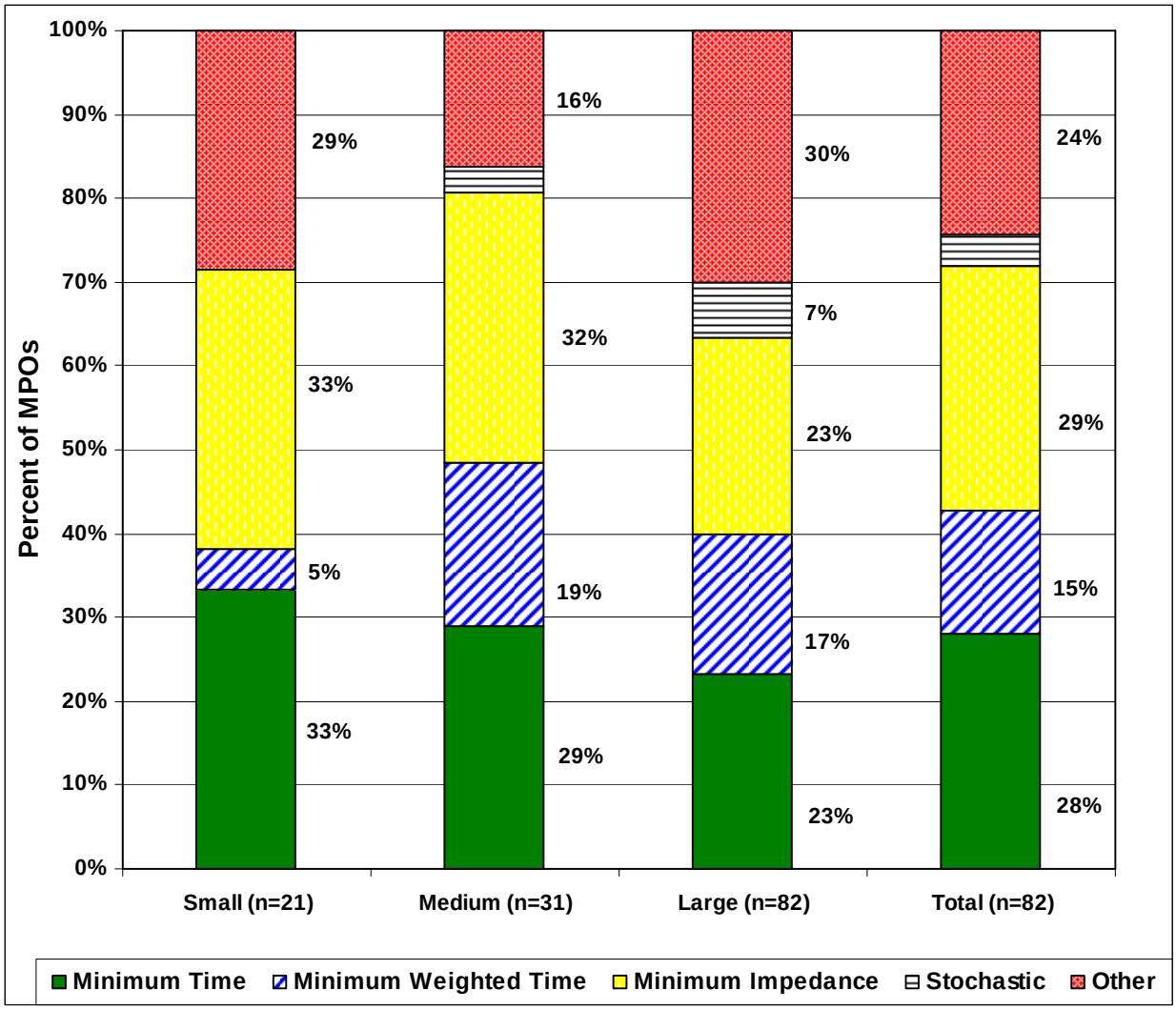
noted in studies conducted for the FTA.[3]Assignment of transit trips (Figure 82) is typically a single path method based on minimum time, weighted or unweighted, or impedance.

Figure 81: Highway Traffic Assignment Method



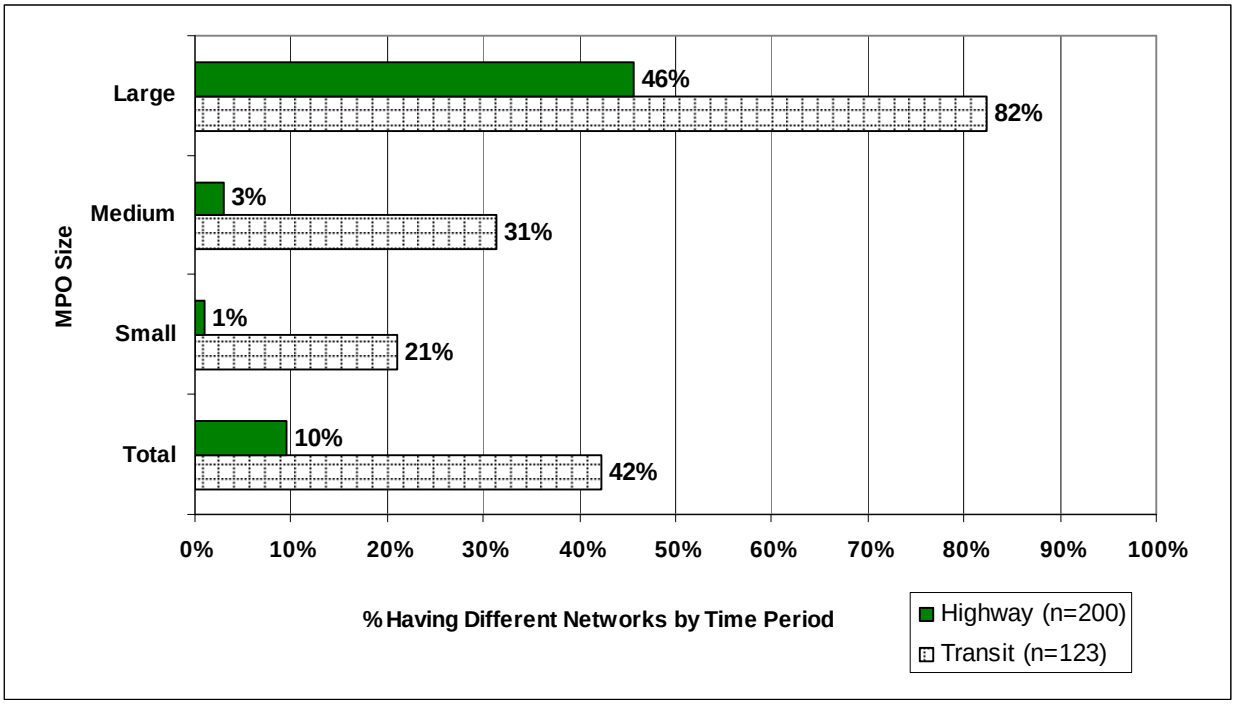
[3] AECOM Consult, Inc. *Research on Highway Congestion Relief.* Working paper prepared for Federal Transit Administration, 2005.

Figure 82: Transit Trip Assignment Method



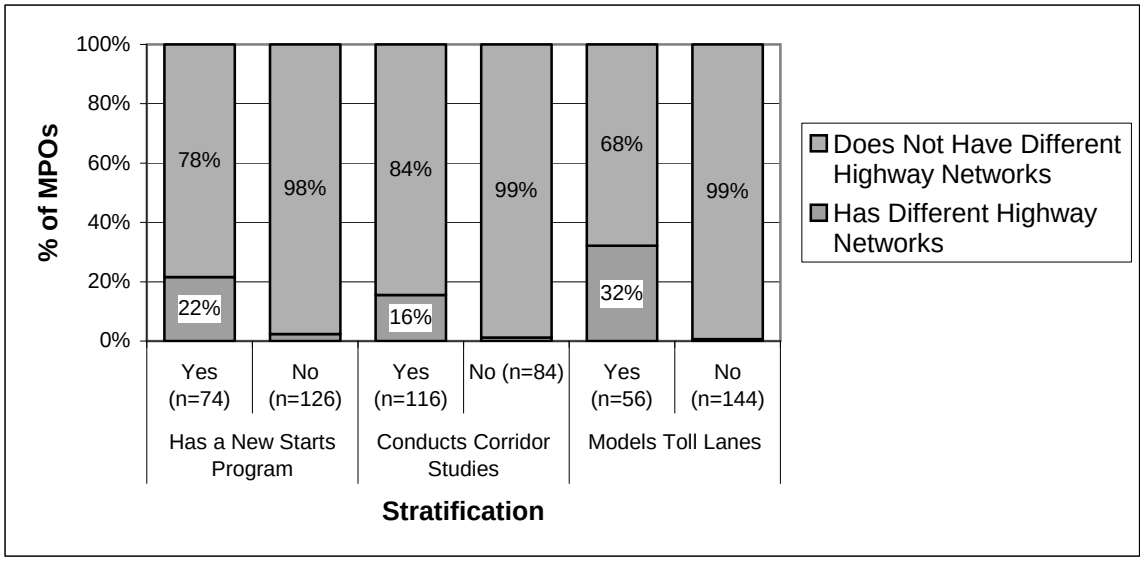
In approximately half of the agencies reporting, the time period used for transit assignment was different than the time period used for highway assignment. Small and medium-sized MPOs use the same highway network for all time periods in the day, although approximately 45% of large agencies have different networks. When large agencies use transit networks, they are almost always different networks by time of day (Figure 83).

Figure 83: Use of Different Networks for Different Time Periods



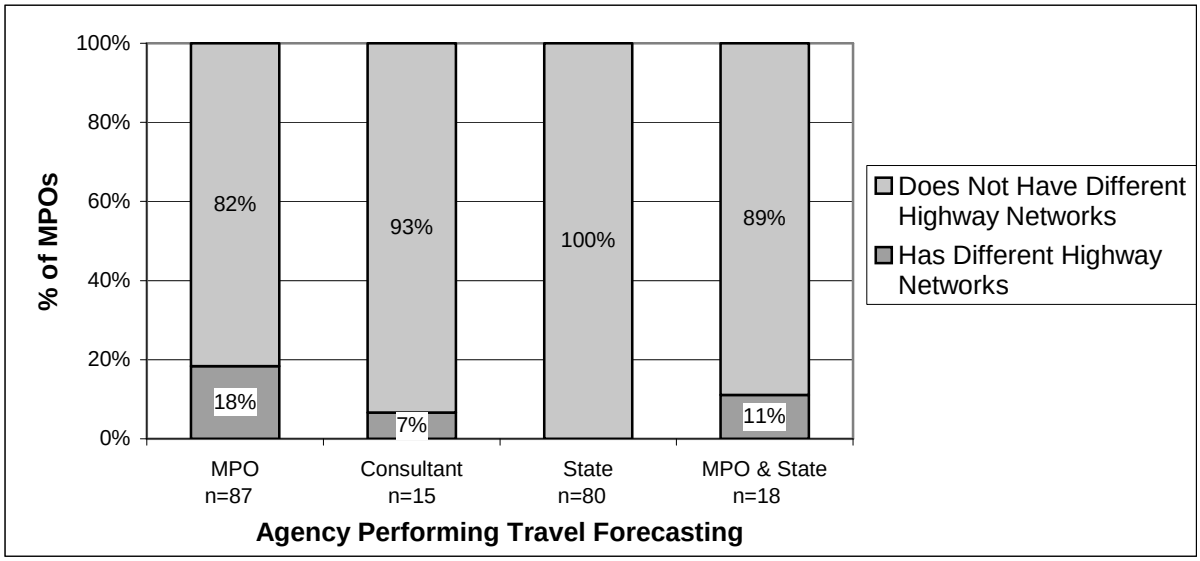
Most MPOs do not have different highway networks for different period of the day. However, MPOs with New Starts/Small Starts programs, that conduct corridor studies, or that model toll lanes are more likely than MPOs that do not to have different highway networks for different periods of the day (see Figure 84).

Figure 84: Use of Different Highway Networks for Different Periods of the Day (Stratified by whether MPO has a New Starts Program, Conducts Corridor Studies or Models Toll Lanes)



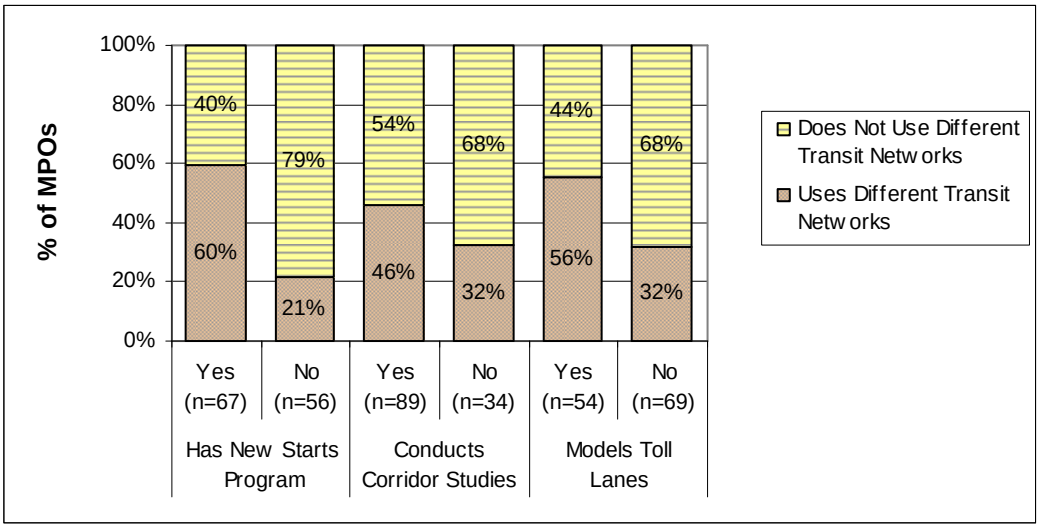
MPOs that conduct their own travel forecasting are more likely to have different highway networks for different periods of the day than MPOs for which the state conducts their travel forecasting (see Figure 85).

Figure 85: Use of Different Highway Networks for Different Periods of the Day (Stratified by Agency Performing Travel Forecasting)



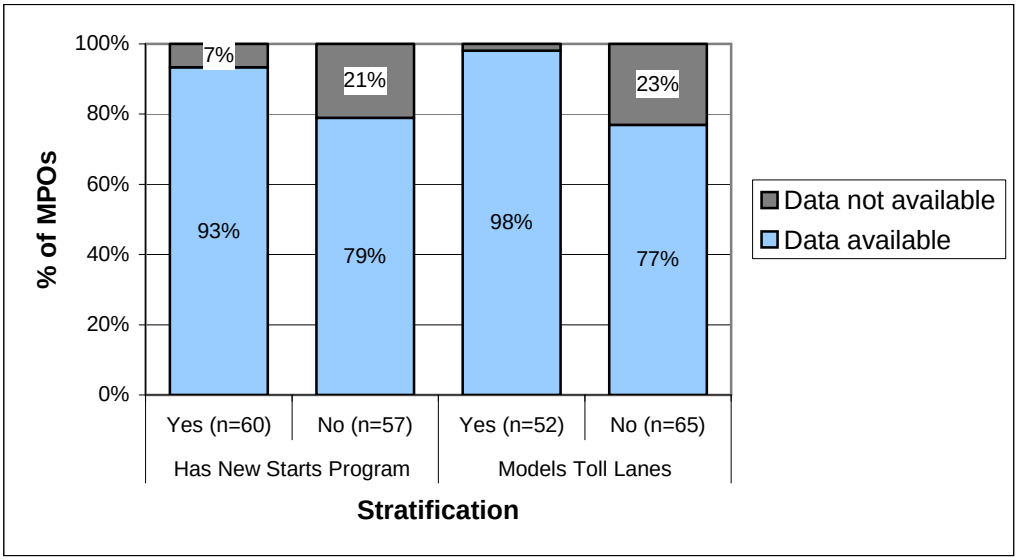
MPOs with New Starts/Small Starts programs, that conduct corridor studies, or that model toll lanes are more likely to have different transit networks for different periods of the day than MPOs that do not (see Figure 86).

Figure 86: Use of Different Transit Networks for Different Time Periods (Stratified by Whether MPO Has a New Starts program, Conducts Corridor Studies, or Model Toll Lanes)



MPOs that have New Starts/Small Starts programs and that model toll lanes are more likely to have station boardings or transit route ridership figures available than MPOs that do not (Figure 87).

Figure 87: Percentage of MPOs With Station Boardings and Transit Ridership Data Available (Stratified by Whether MPO Has a New Starts Program, Conducts Corridor Studies, or Models Toll Lanes)



Model Validation

Agencies were asked to report the number and proportion of the highway links, by classification, for which traffic counts were available for use in validation. Table 14 reports the number of responses received for all MPOs; Table 15 presents the same information for large MPOs. These data can be difficult to interpret. Small and medium-sized MPOs tend to have counts available for more than 50% of freeway links, whereas large MPOs do not. For HOV lanes, counts are available for either all or nearly all of the links or for none of the links. Few agencies have counts for more than 75% of their major arterial links. For large agencies, it is fewer than 50% of the links. For minor arterials, large agencies have counts on less than one-quarter of the links. Also of note is that approximately 20% of agencies, across the board, responded that they did not know for what proportion of the network links counts were available.

Table 14: Highway Links with Counts Available, All MPOs

	Percentage of Highway Network Links for Which Validation Counts Are Available, All MPOs							
	100%	**75–99%**	**50–74%**	**25–49%**	**1–24%**	**0%**	**N/A**	**Don't Know**
Facility Type	**Number of MPOs**							
Freeway	41	39	33	26	36	0	5	33
HOV lanes	8	4	3	3	9	6	125	23
Major arterial	11	22	58	49	34	0	1	35
Minor arterial	10	16	46	59	43	0	0	35
Collector	6	14	33	55	63	1	3	34
Local street mileage	0	5	4	17	79	21	37	33
n=228								

Table 15: Highway Links With Counts Available, Large MPOs

	Percentage of Highway Network Links for Which Validation Counts Are Available, Large MPOs							
	100%	**75–99%**	**50–74%**	**25–49%**	**1–24%**	**0%**	**N/A**	**Don't Know**
Facility Type	**Number of MPOs**							
Freeway	2	10	2	5	9	0	0	7
HOV Lanes	4	4	3	2	4	1	10	4
Major Arterial	1	2	6	9	9	0	0	7
Minor Arterial	0	2	4	11	9	0	0	7
Collector	0	2	3	6	14	1	1	6
Local Street Mileage	0	2	0	1	7	7	8	6
n=36								

Agencies of all sizes engaged in transit analysis reported having passenger counts for a high percentage of all transit types—commuter rail, rail, express bus, and local bus (see Table 16).

Table 16: Transit Passenger Counts Available for Validation

	Percentage of Highway Network Links for Which Validation Counts Are Available, All MPOs							
	100%	75–99%	50–74%	25–49%	1–24%	0%	N/A	Don't Know
Facility Type	**Number of MPOs**							
Rail Transit	7	6	0	1	2	9	148	15
Express/Regional Bus	16	20	2	1	5	13	123	21
Local Bus	24	25	7	3	5	13	99	32
Commuter Rail	8	12	0	0	2	9	148	12
n=228								

A basic test of the validity of the travel forecasting models is the percentage root mean square (RMS) error when base year vehicle trips assigned to the network are compared with counts of traffic volumes. Agencies were asked to provide information about the percentage RMS error for the latest validation runs. Approximately half of the MPOs that responded to the survey provided information approximately the highway assignment RMS error. As illustrated in Figure 88a, 88b, and 88c, RMS error for all link classes and major arterials tends to range from 20–40% and from 0–30% for freeways.

Figure 88a: Frequency Distribution of Reported RMS Error -- All Link Classes

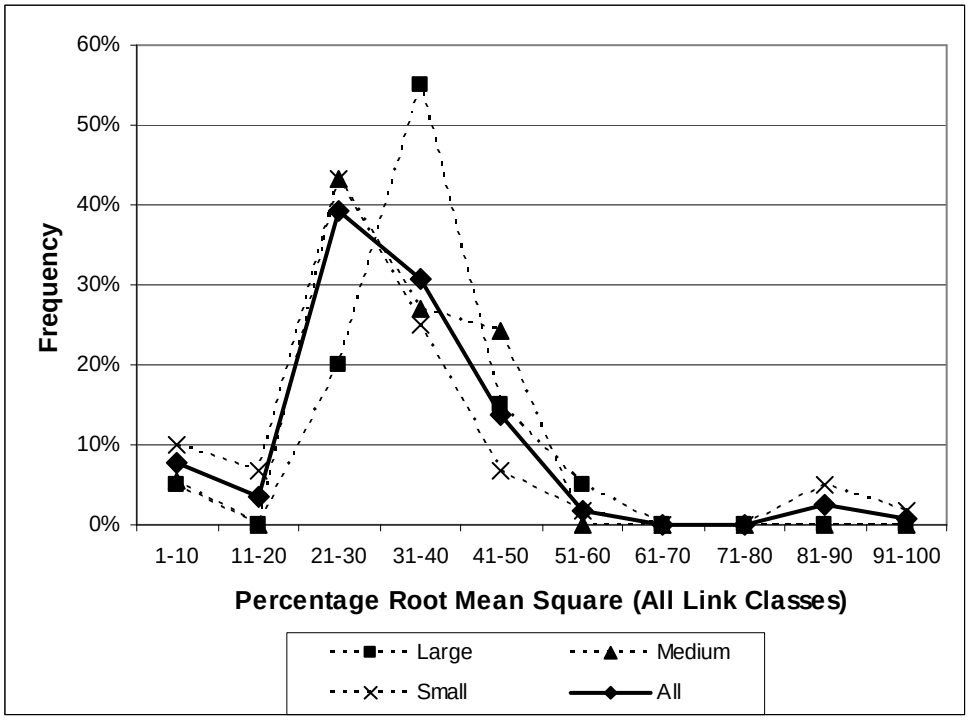


Figure 88b: Frequency Distribution of Reported RMS Error -- Freeways

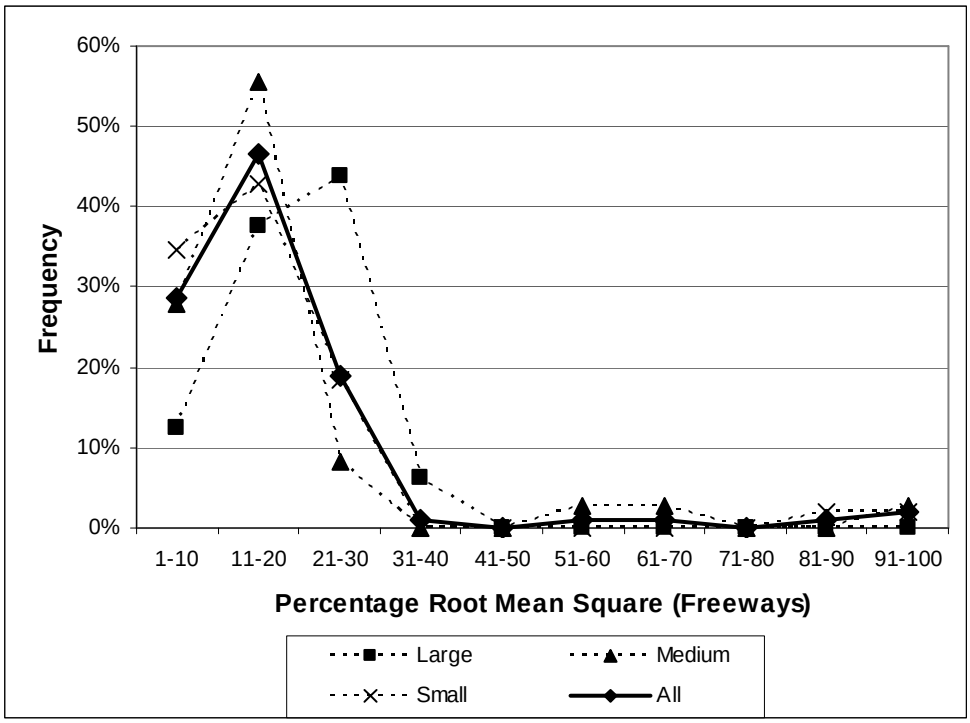
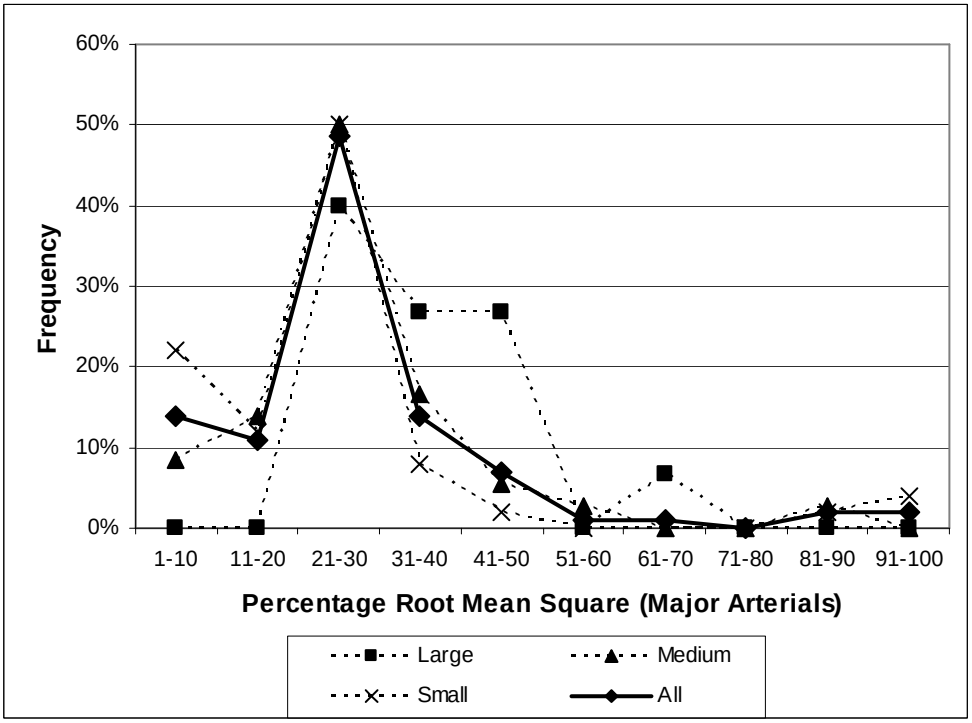
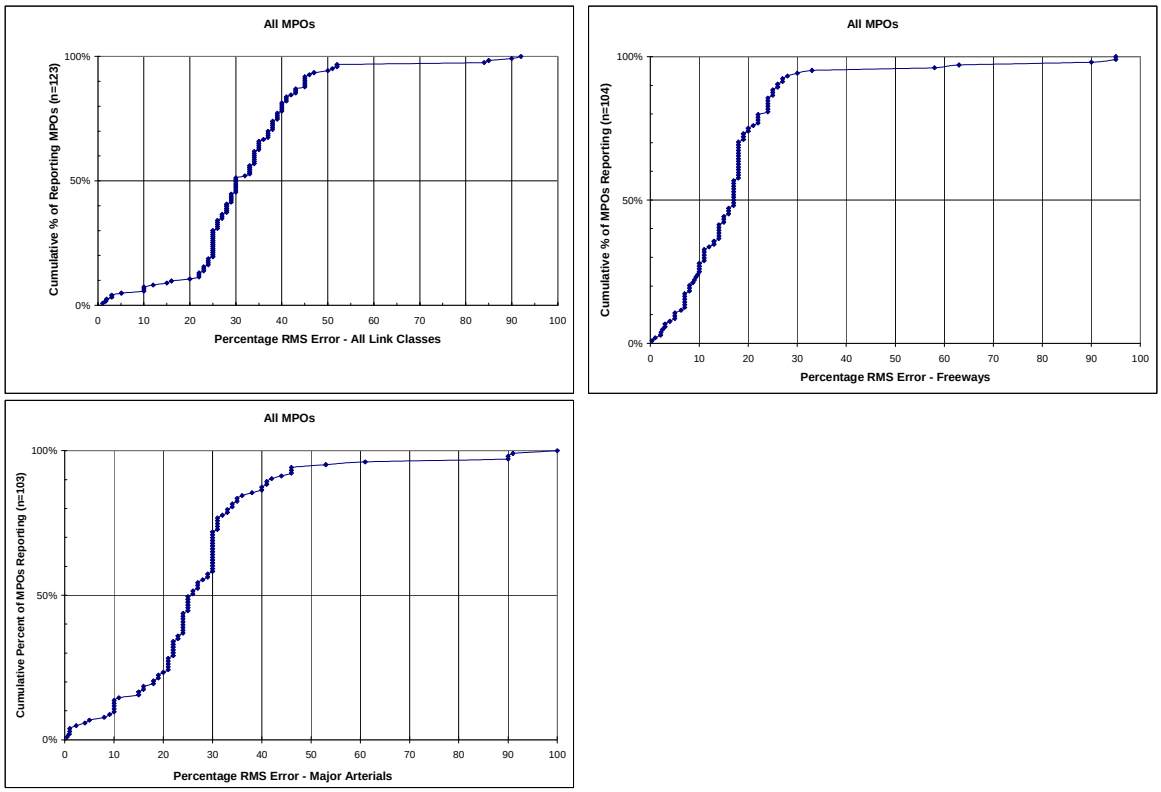


Figure 88c: Frequency Distribution of Reported RMS Error – Major Arterials



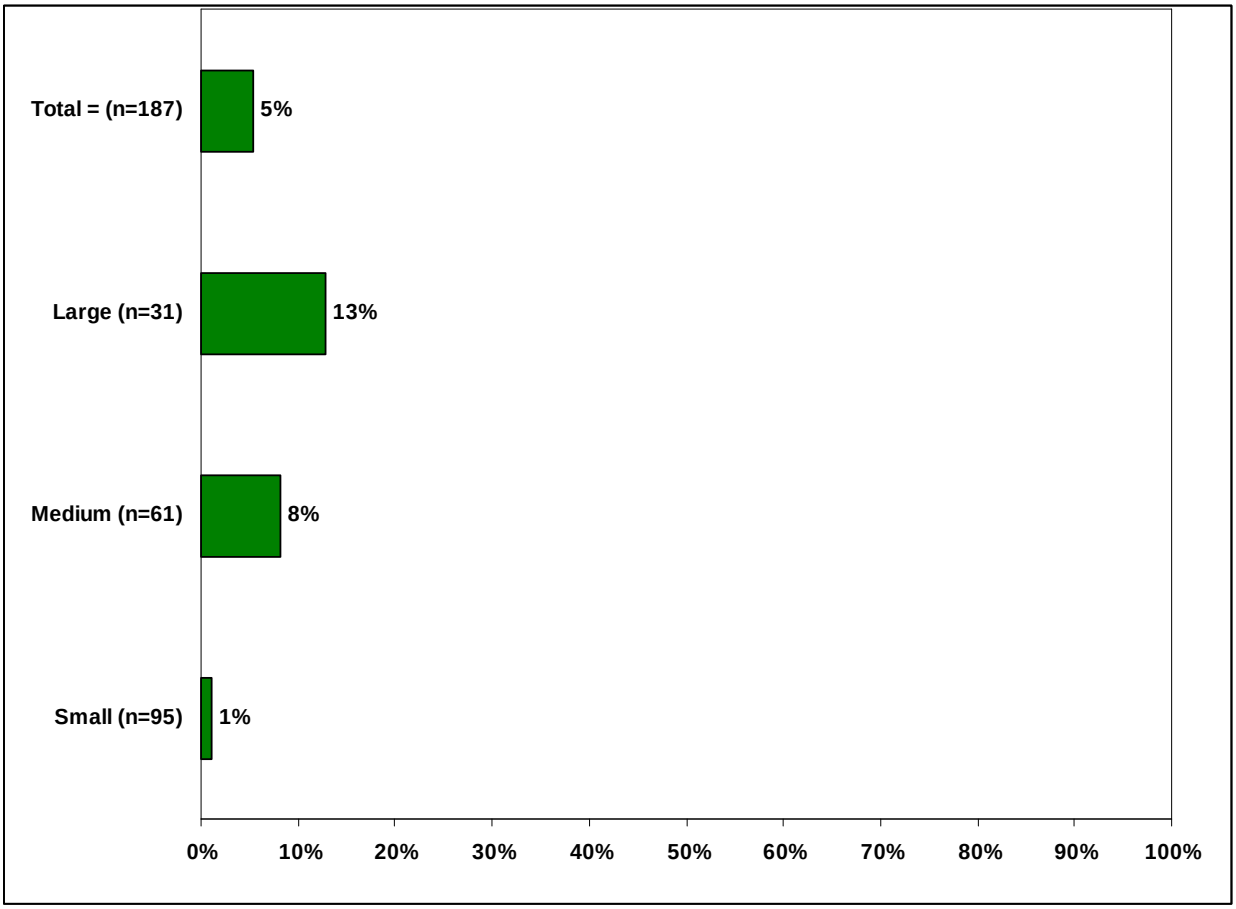
As illustrated in Figure 89, RMS error for all link classes and major arterials tends to have a 50th percentile value of approximately 30%. For freeways, the 50th percentile RMS error is 19%.

Figure 89: Highway Assignment RMS Percentage Error by Facility Type



Only a few agencies used backcasting to a known condition to assess the accuracy or validity of their travel models (see Figure 90).

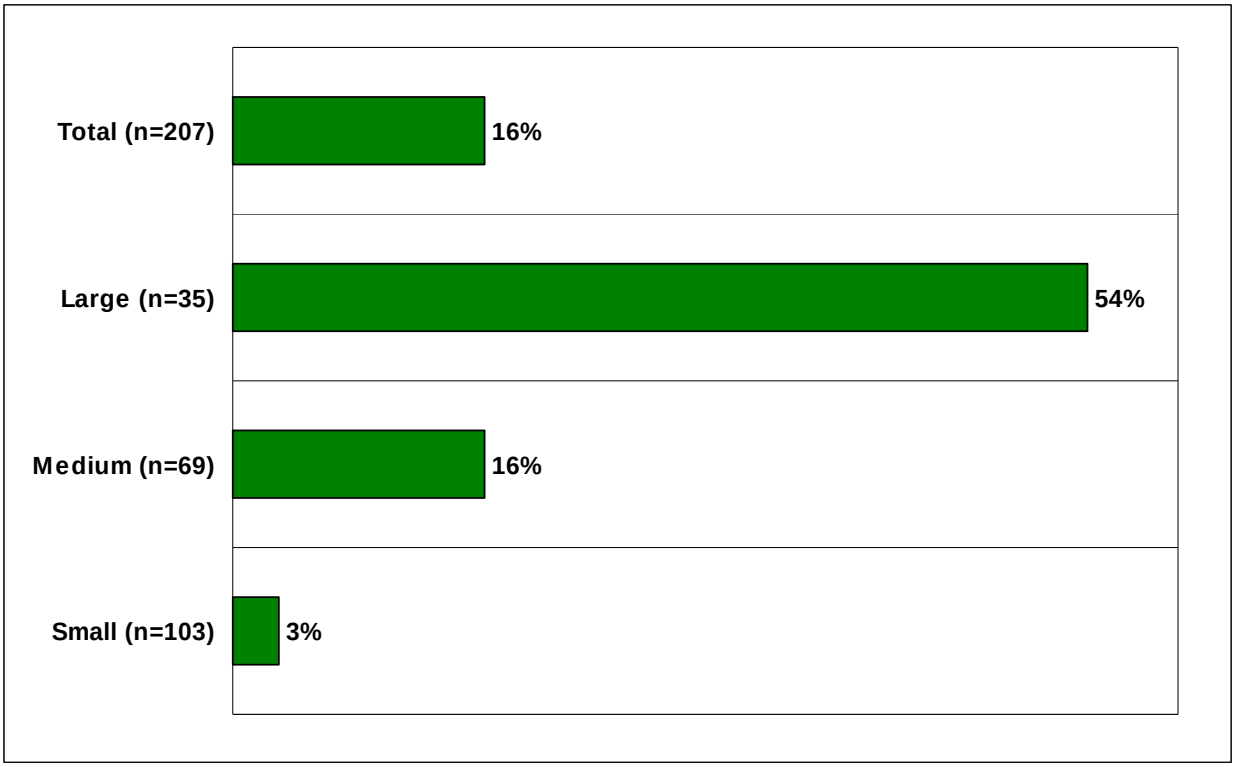
Figure 90: Use of Backcasting to Assess Model Validity



Nonmotorized Trips

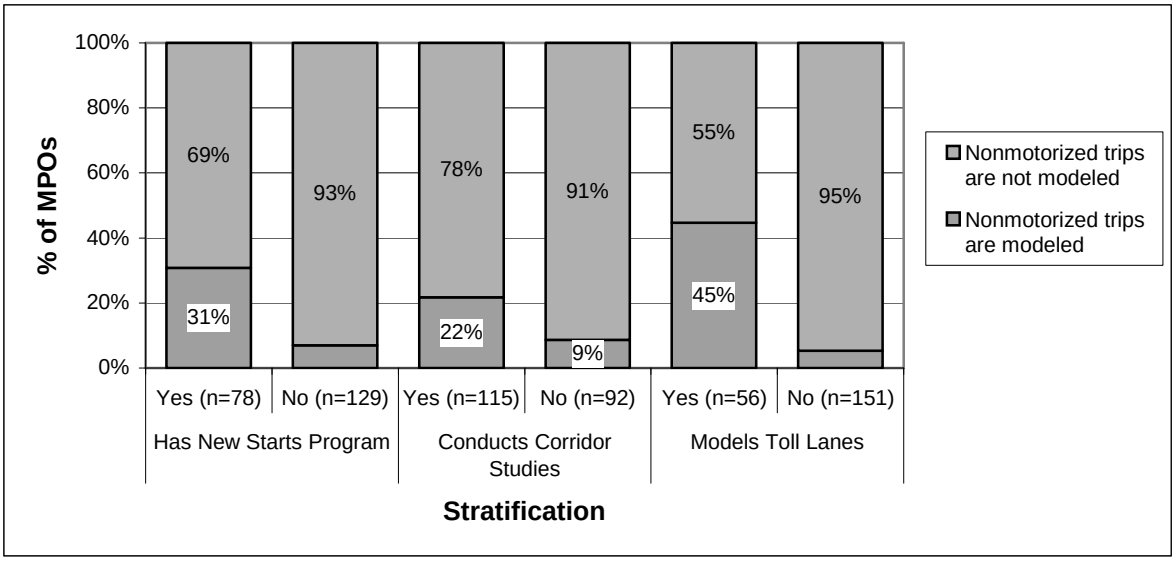
More than half of the large MPOs now report that nonmotorized trips are part of their model set. Few medium-size MPOs and almost no small MPOs model nonmotorized trips (see Figure 91).

Figure 91: Percentage of Agencies Modeling Nonmotorized Trips



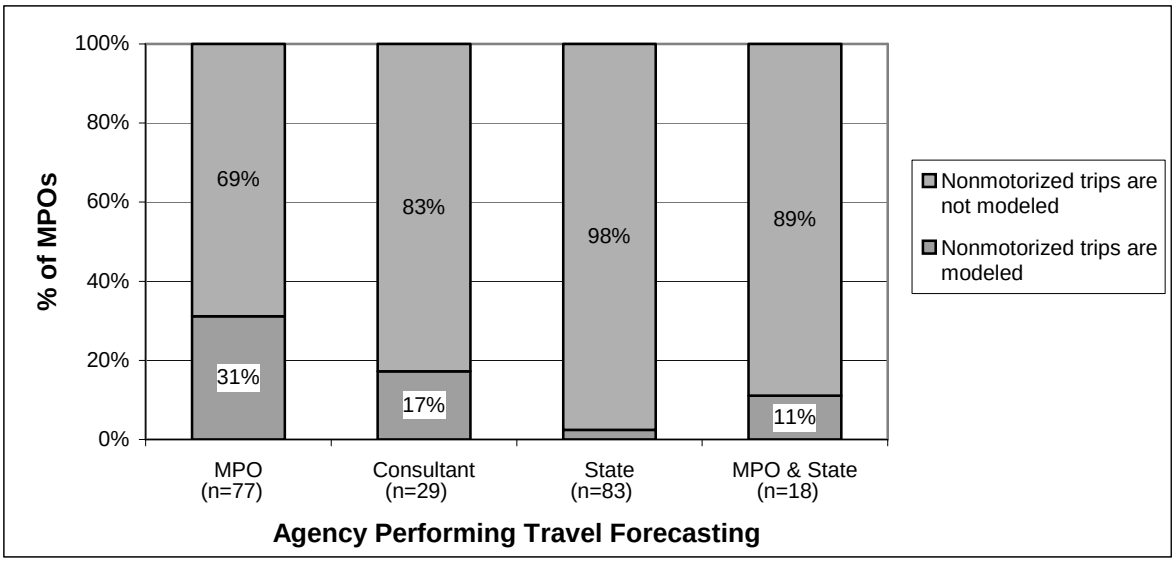
MPOs that have a New Starts/Small Starts program, that conduct corridor studies, or that model toll lanes are more likely to model nonmotorized trips than do MPOs that do not have New Starts/Small Starts program, conduct corridor studies, or model toll lanes (Figure 92).

Figure 92: Percentage of MPOs That Model Nonmotorized Trips (Stratified by Whether MPO Has a New Starts program, Conducts Corridor Studies or Models Toll Lanes)



MPOs that conduct their own travel forecasting are more likely to model nonmotorized trips than MPOs for which the state conducts the travel forecasting (see Figure 93).

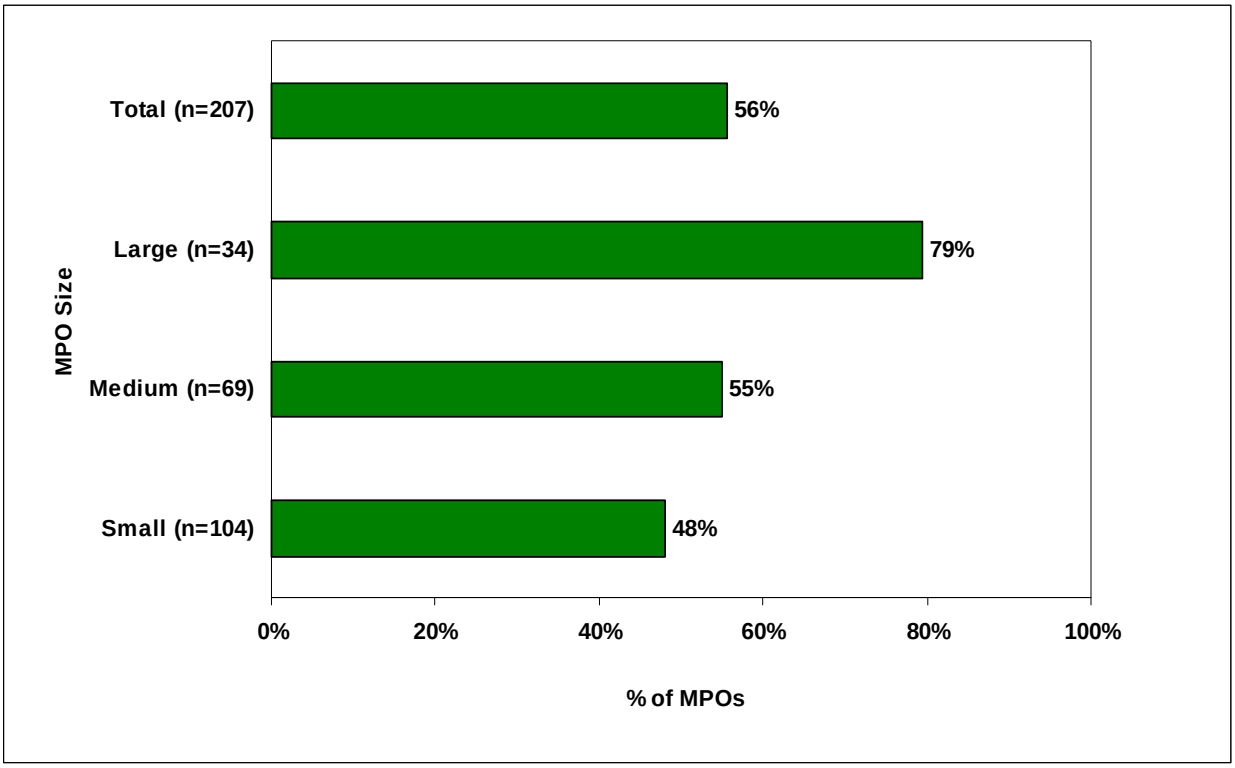
Figure 93: Percentage of MPOs That Model Nonmotorized Trips (Stratified by Agency Performing Travel Forecasting)



Truck Trips

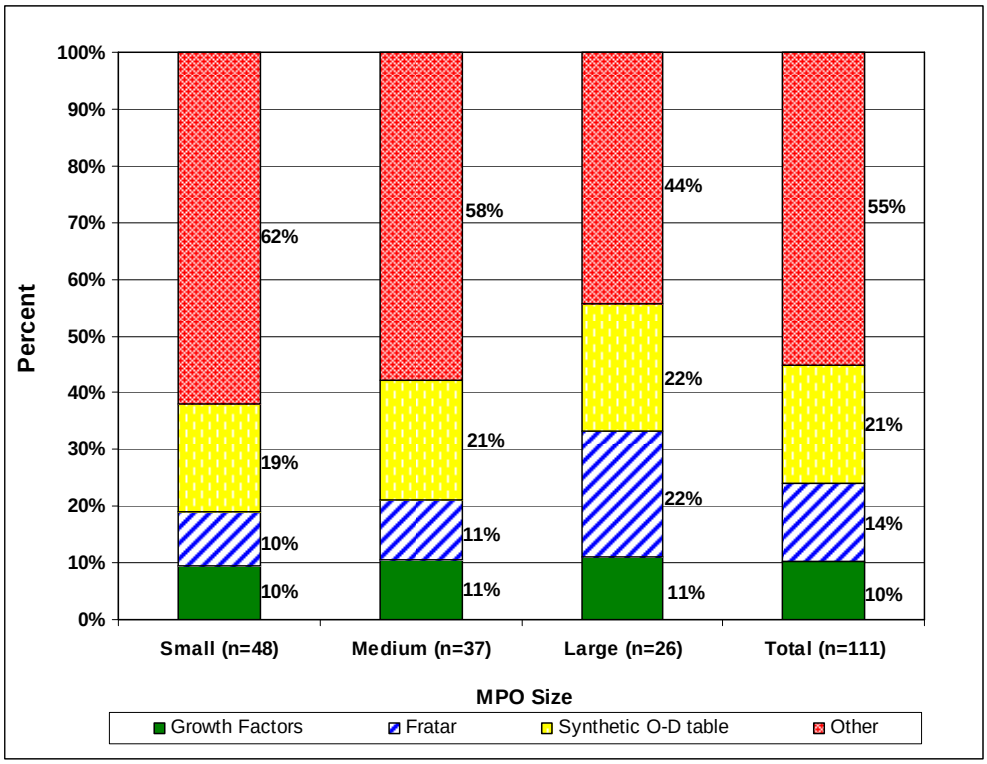
Truck trips are modeled by approximately half of small and medium-sized MPOs and almost 80% of large MPOs (see Figure 94).

Figure 94: Percentage of Agencies Modeling Truck Trips



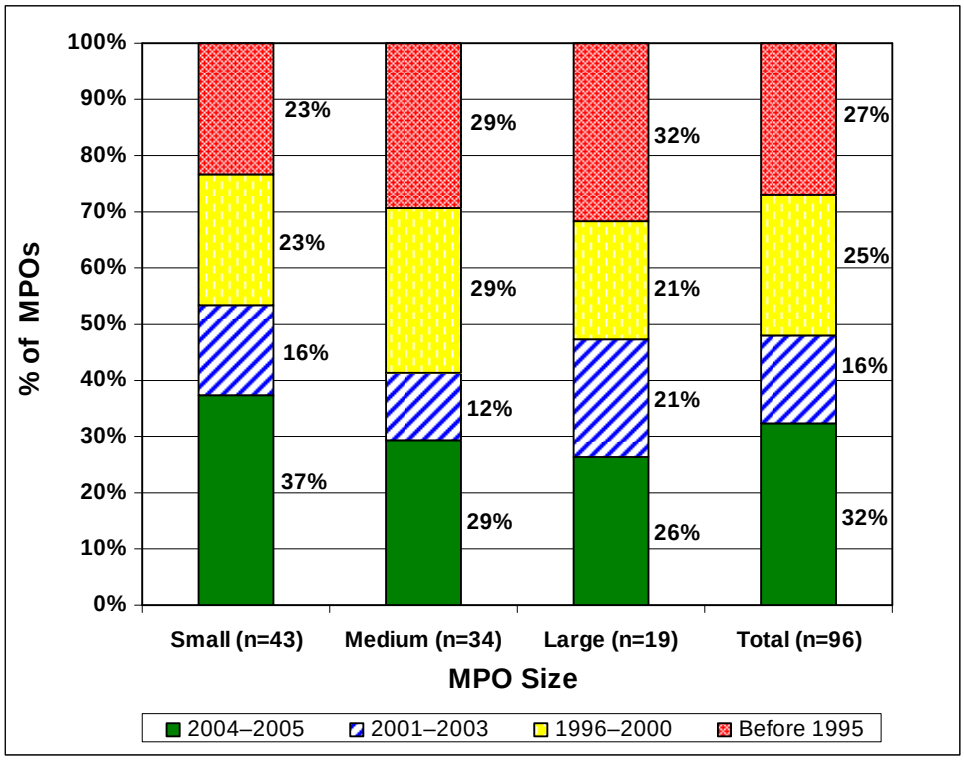
A variety of methods are used to model truck trips. Approximately 20% of the agencies reported using a synthetic trip table; approximately 25% reported using a factoring procedure, including Fratar. The remaining 55% reported using an "other" method, generally a gravity model.

Figure 95: Methods Used to Model Truck Trips



Recently, there appears to have been an interest in truck trip modeling. Only approximately 25% of the models are older than 10 years. Approximately half of the models have been developed since 2000 (see Figure 96). Few agencies, however, model freight movement. Only 12% of large MPOs and less than 2% of other MPOs reported modeling freight.

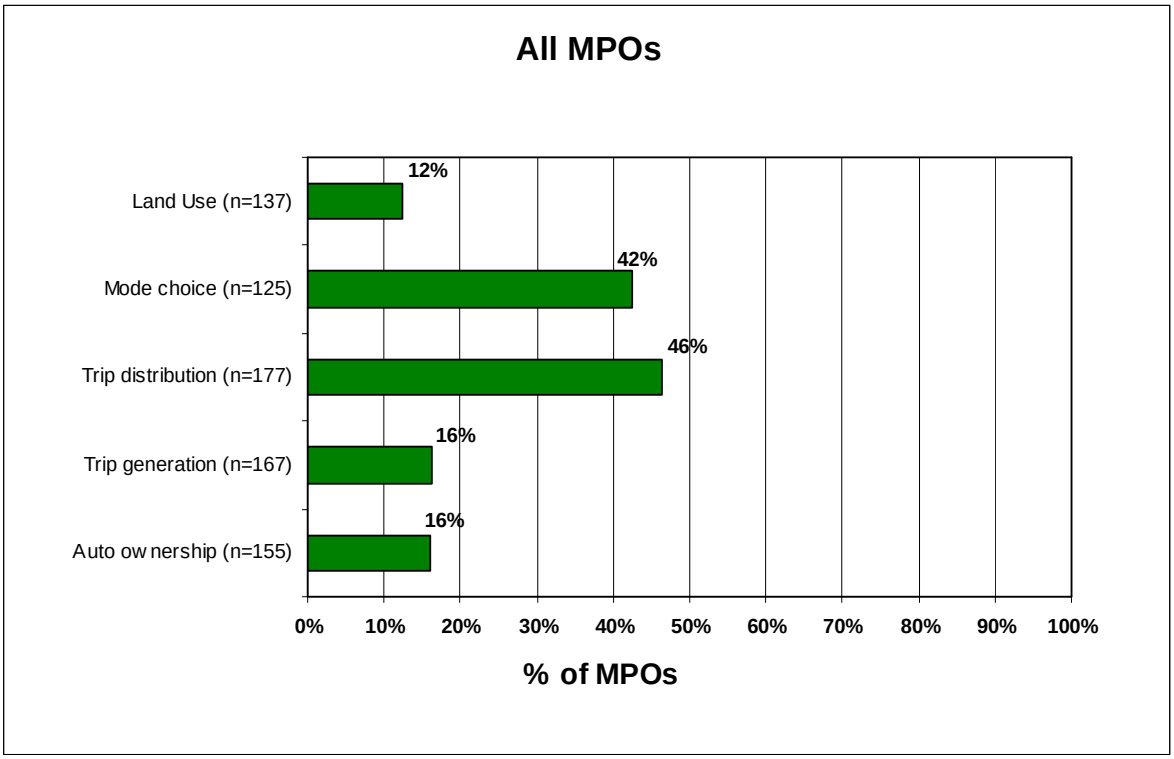
Figure 96: Year in Which Truck Trip Model Was Developed

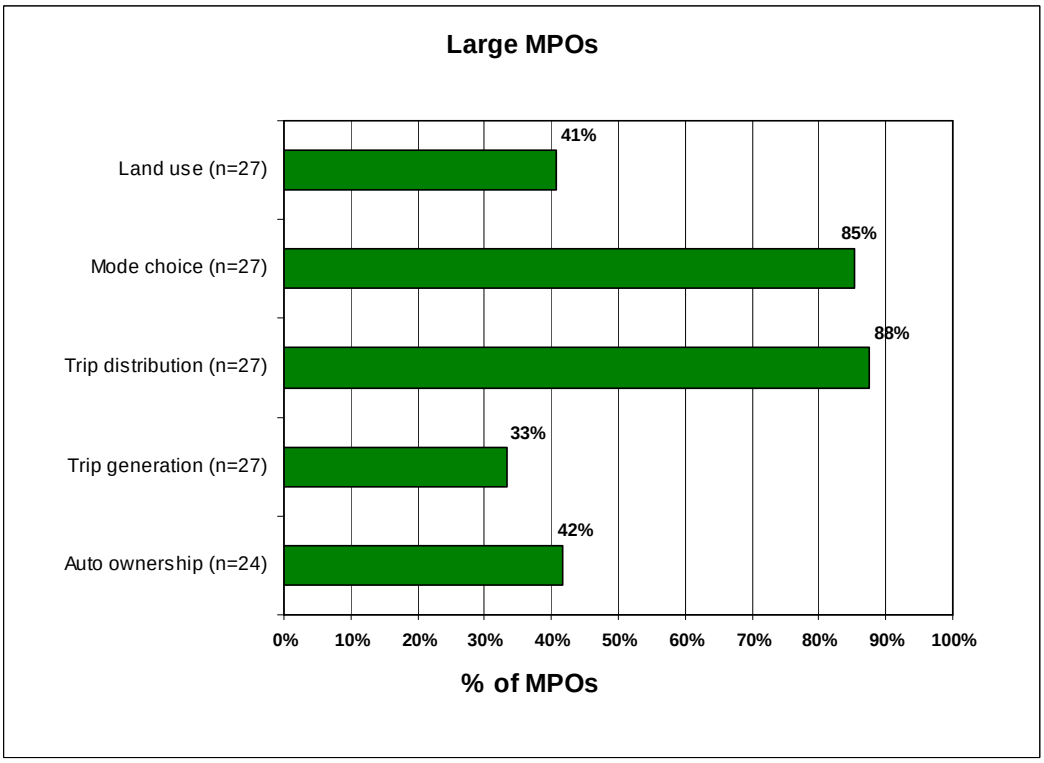


Feedback

The use of feedback as a means to achieve consistency among the several components of travel forecasting models has become more common as the need for such consistency has become more apparent and as advances in computing power have enhanced the ability to iterate at reasonable time and cost. More than 80% of large MPOs feedback times to trip distribution and mode choice; more than 40% feedback congestion effects to forecasts of land use and auto ownership (see Figure 97).

Figure 97: Feedback of Travel Times to Model Components

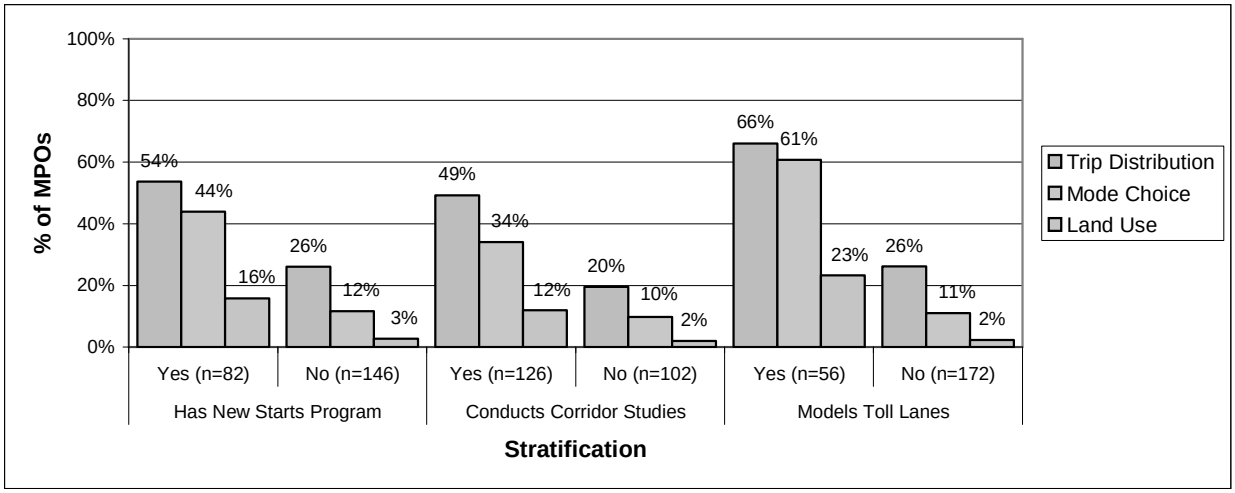




Approximately 40% of medium MPOs feedback times to mode choice and distribution, whereas 30% of medium MPOs feedback to trip distribution. Only a few small or medium-sized agencies feedback to land use, auto ownership, or trip generation.

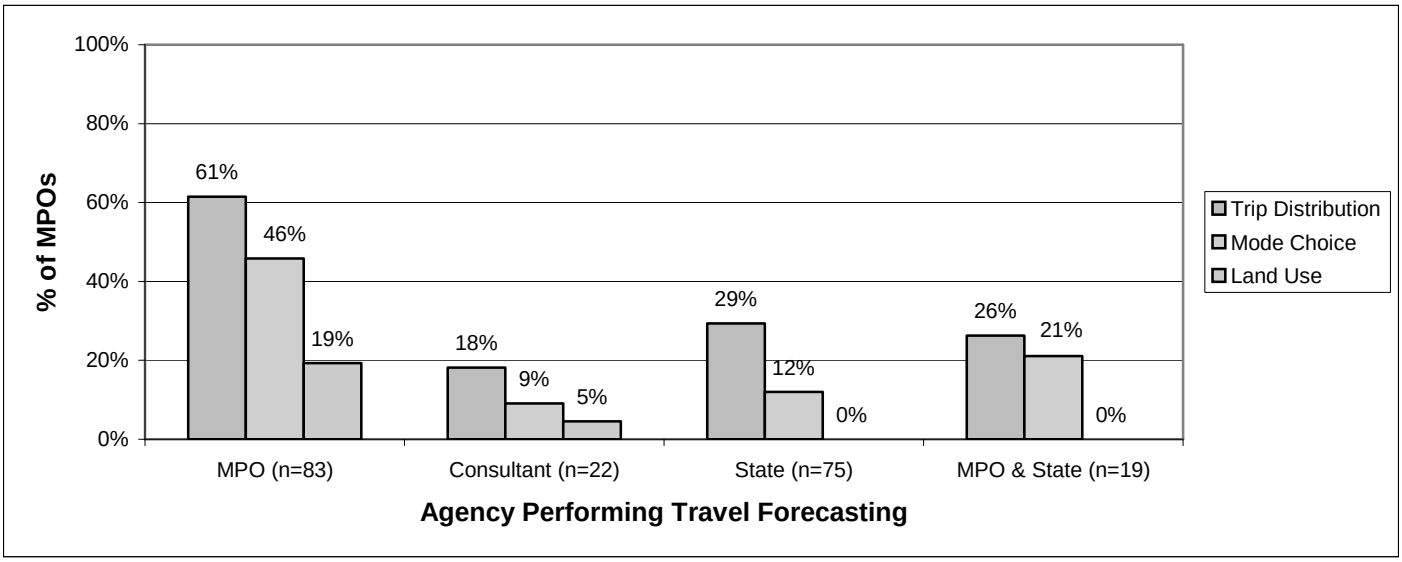
MPOs that have New Starts/Small Starts programs, that conduct corridor studies, or that model toll lanes are more likely to feedback highway and transit travel times in the trip distribution, mode choice, or land-use steps than those that do not have New Starts/Small Starts programs, conduct corridor studies, or model toll lanes (Figure 98).

Figure 98: Feedback of Travel Times to Model Components (Stratified by Whether MPO Has a New Starts Program, Conducts Corridor Studies or Models Toll Lanes)



MPOs that conduct their own travel forecasting are more likely to feedback highway and transit travel times to the trip distribution, mode choice, and land-use steps than MPOs for which the state conducts the travel forecasting (see Figure 99).

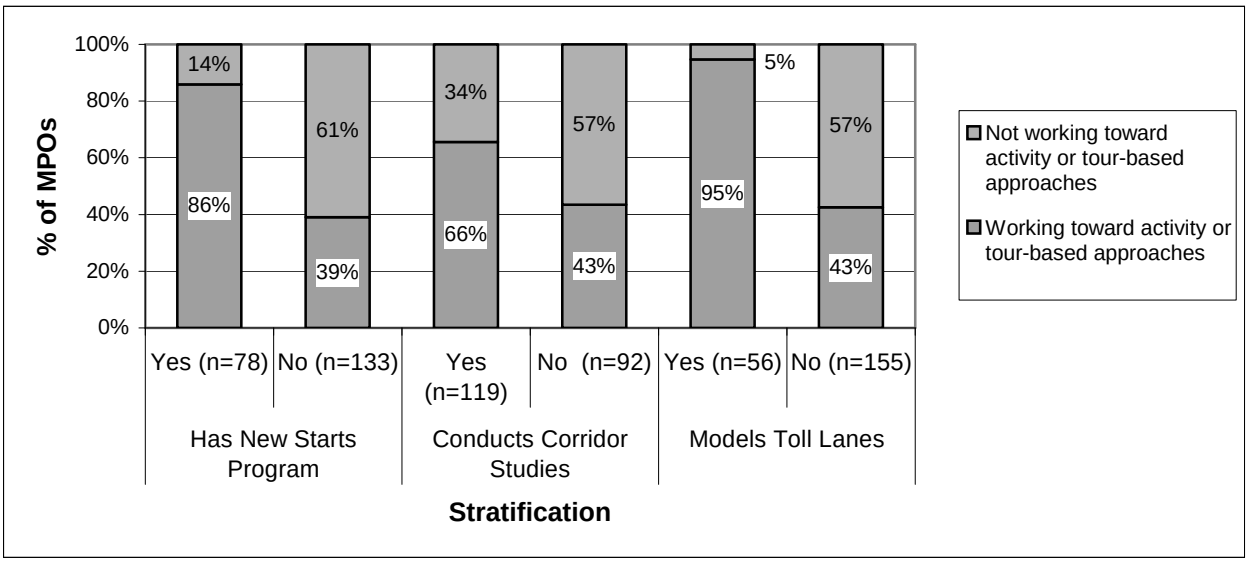
Figure 99: Feedback of Travel Times to Model Components (Stratified by Agency Performing Travel Forecasting)



Activity- or Tour-Based Modeling Approaches

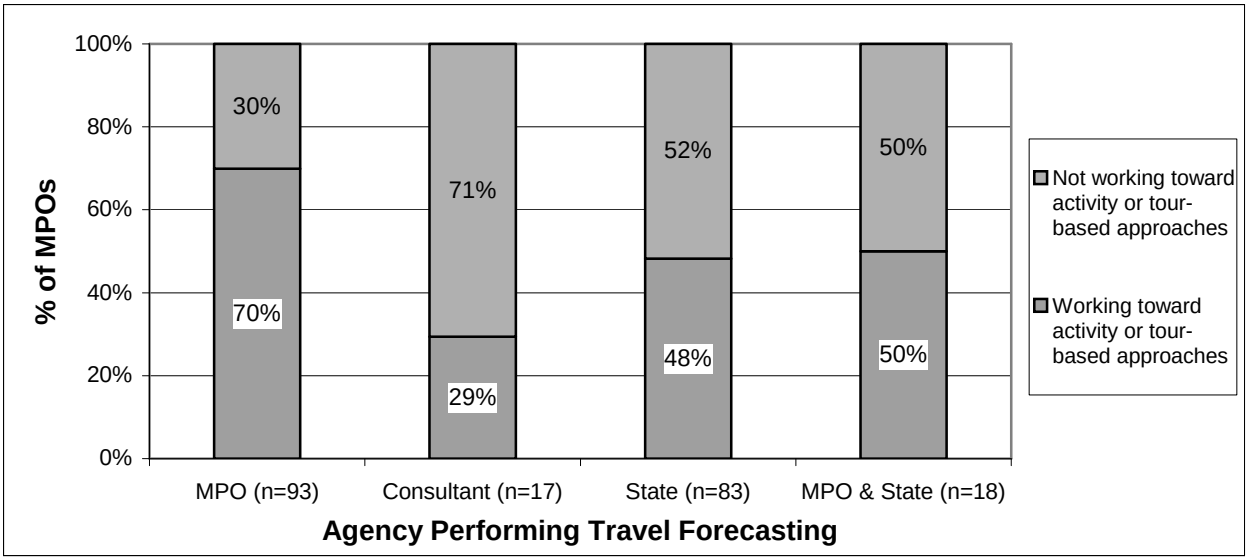
MPOs that have a New Starts/Small Starts program, that conduct corridor studies, or that model toll lanes are significantly more likely to be working toward activity- or tour-based approaches to replace existing models (see Figure 100).

Figure 100: Percentage of MPOs Working Toward Activity- or Tour-Based Approaches (Stratified by Whether MPO Has a New Starts Program, Conducts Corridor Studies, or Models Toll Lanes)



MPOs that conduct their own travel forecasting are also significantly more likely to be working to replace existing models with activity- or tour-based approaches than are MPOs for which the state conducts the travel forecasting (Figure 101).

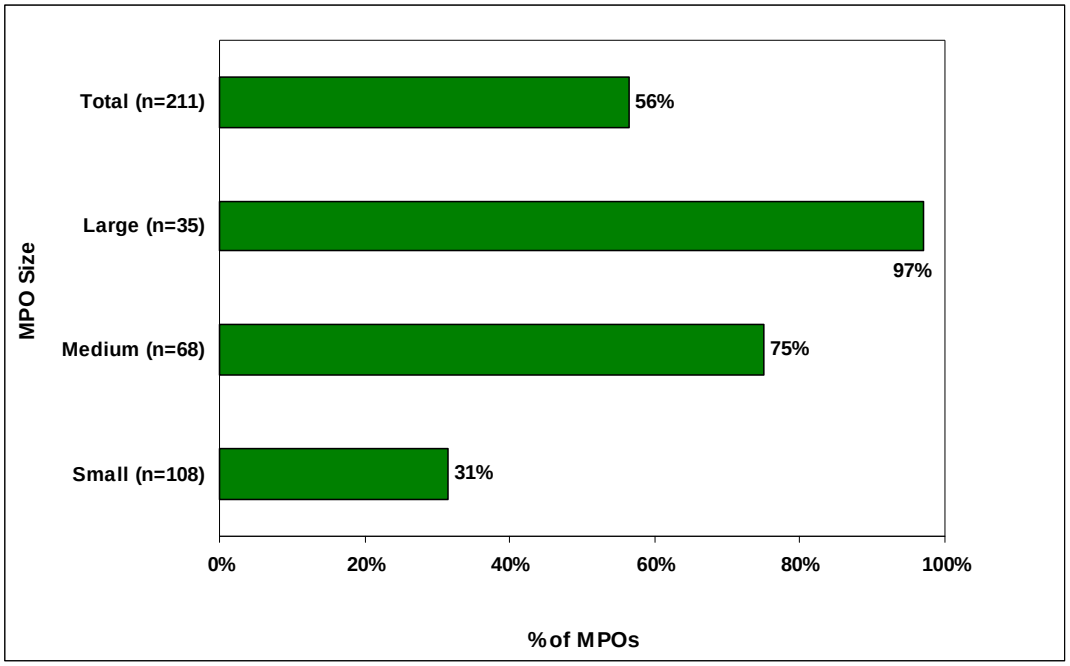
Figure 101: Percentage of MPOs Working Toward Activity- or Tour-Based Approaches (Stratified by Agency Performing Travel Forecasting)



Emissions-Related Modeling

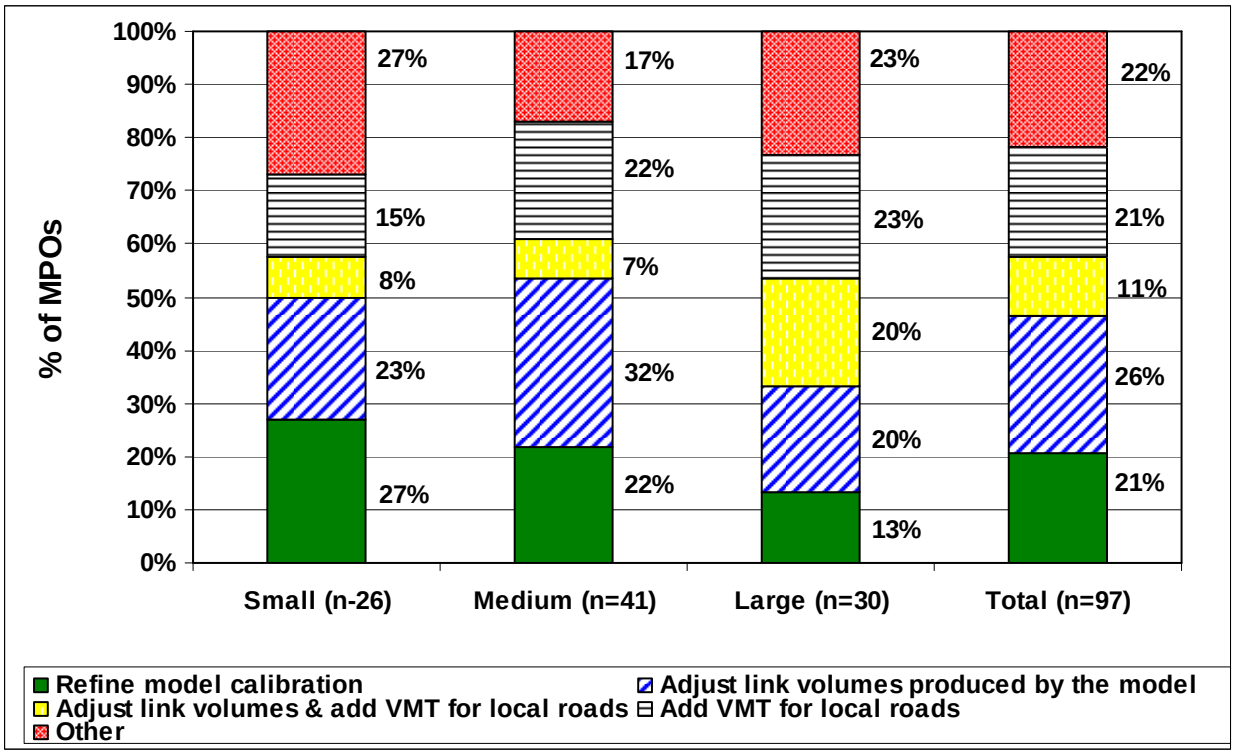
More than half of all MPOs reported postprocessing the results of forecasts developed using the travel models so that the results could be used with an emissions model (see Figure 102).

Figure 102: Agencies Postprocessing Model Results for Mobile Source Emissions Analysis



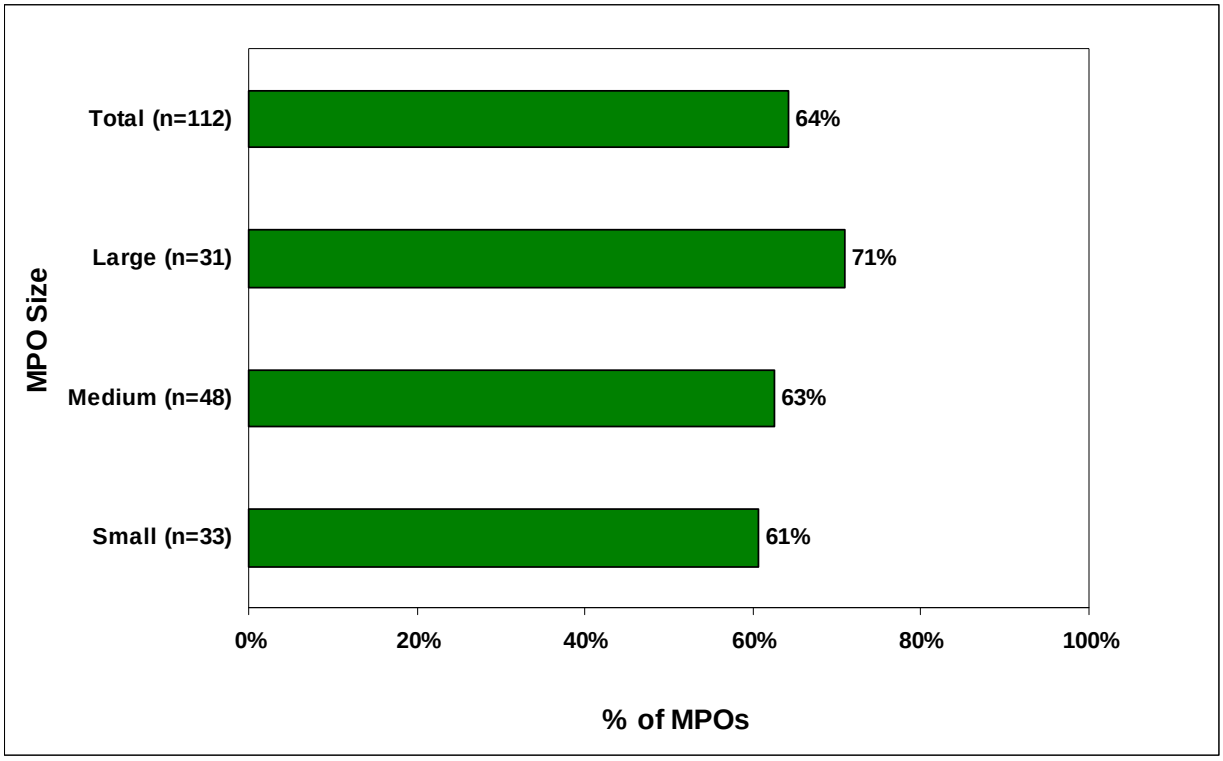
Refining model calibration, adding vehicle-miles of travel (VMT) to account for traffic on local roads that are not modeled, and using other adjustments of link volumes, typically developing estimates of traffic volumes by time of day, are the most common adjustments (see Figure 103).

Figure 103: Postprocessing Methods to Match Highway Performance Monitoring System Data



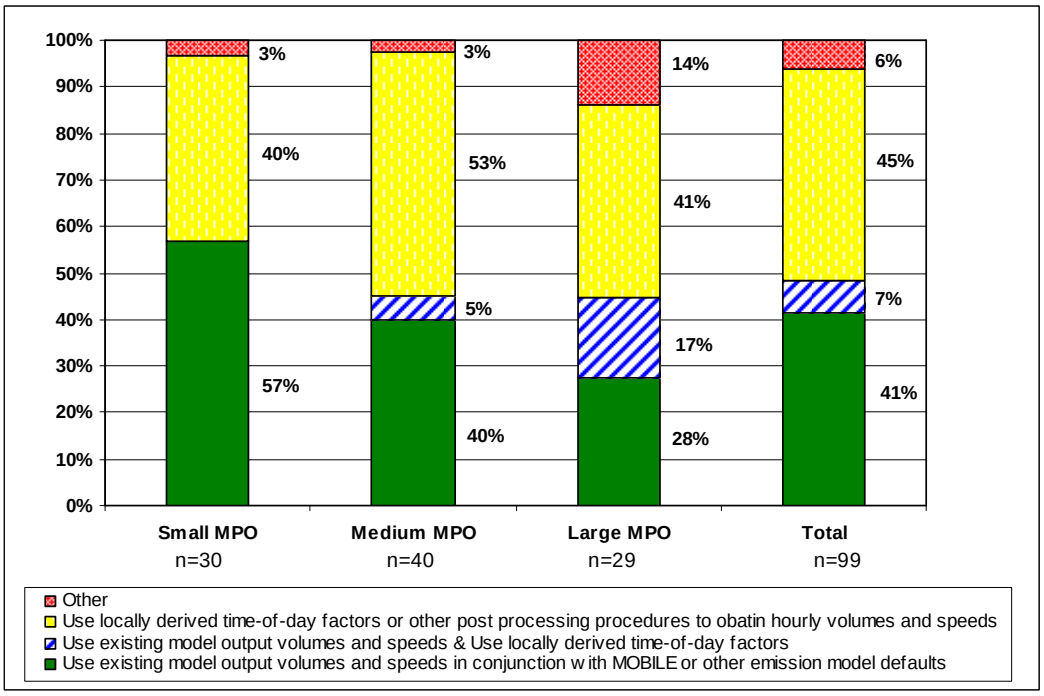
Many agencies also make adjustments for seasonal variations in traffic (see Figure 104).

Figure 104: Adjustment of VMT for Seasonal Variation



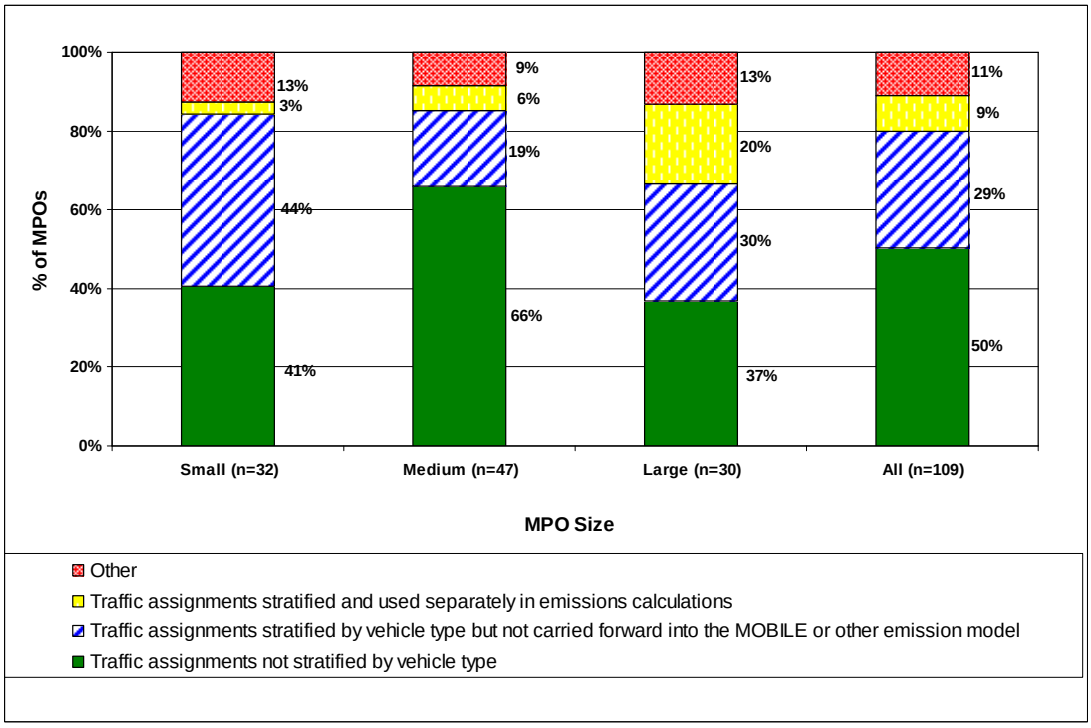
Approximately half of the agencies that adjust forecast traffic volumes and speeds as part of the emission modeling activities use locally derived time-of-day factors (TODFs); 41% use emission model default values; 6% use another procedure (see Figure 105).

Figure 105: Volume and Speed Adjustment for Emissions Modeling



Approximately half of all MPOs that do emissions analysis do not stratify the assignment of vehicle trips to the highway network by vehicle type (see Figure 106). Of those that do stratify by vehicle type in assignment, only approximately half carry that stratification through to the emissions analysis. Among large MPOs, use of the stratified assignment data is more common.

Figure 106: Use of Stratified Assignments in Emissions Analysis



FINDINGS OF IN-DEPTH MPO INTERVIEWS

Summary

In-depth data gathering, including interviews of key MPO staff and supplemental written documentation provided by selected MPOs, offers insights beyond those that could be gleaned from the simple tabulation of survey data. Although the efforts could not be in sufficient depth or detail to assess the degree to which the procedures used by any agency produced accurate or valid forecasts, they do offer a view of practices used or contemplated by at least some of the more active MPOs. The methods and procedures of these agencies cannot be viewed as average, typical, or representative of the practice of most MPOs. Rather, they are a snapshot of what at least a few active agencies have undertaken. If these leading agencies find that the practices are useful, practical, and lead to better forecasts, the practices will likely be more widely adopted and over time will be incorporated in the state of the practice.

On the basis of an initial review of the broad data collected in the web-based survey, the panel requested that the in-depth survey focus on a few key topics. The findings of the interviews on each of these topics are summarized as follows.

- Validation—True validation is hampered by a lack of independent data sources. Even the more active MPOs validate against the same data used to develop the models. The only independent tests are comparison of trip distribution against CTPP for work trips and comparisons of assigned volumes, mostly highway but also transit where applicable, for aggregate forecasts.
- Sensitivity analysis—Formal procedures for sensitivity analysis are in use and are described in the literature.
- Data cleaning or quality—Large agencies have developed formal procedures. Most of these procedures have general applicability and could be used by others.
- Postprocessing—Postprocessing of assignments by MPOs is done mostly for air quality purposes, although procedures for postprocessing of highway assignments to yield improved design volumes are widely available.
- Staffing and budget—Most MPOs appear to have barely enough staff to carryout routine operations. A few have budgets large enough to support staff that can devote at least some time to consideration or development of model improvements.
- Advanced practices—These include not only a major change in the modeling paradigm from trip based to activity based but also incremental improvements to the trip-based four-step process. Several practices were identified that are in use by MPOs included in these studies that have the potential for more widespread application.
- Barriers to improvement—Agencies repeatedly cited the desire to have it demonstrated that new procedures, perceived as more complex or requiring significantly greater effort for development and application, would yield forecasts that are notably better than those produced with currently accepted procedures. “Better” was not specifically defined, but the implication was more accurate forecasts of demand. Another factor in the adoption of improved techniques is the availability of procedures in vendor-supplied software to implement the technique.
- Perceived shortcomings of current methods—Many MPOs would like to have improved procedures for addressing truck trips or freight movement. Agencies also recognize that the

regional travel-forecasting procedures do not provide the detail often requested for design studies or impact analyses.

Overview

The initial stage of the MPO survey research project was a quantitative, online survey that all MPOs across the country were asked to complete in an effort to define the overall state of the practice in regard to transportation demand modeling. To augment the quantitative responses received from the first stage of the study, it was concluded that a second stage consisting of qualitative, open-ended interviews with a number of agencies was needed to expand on those procedures that are "typical" and to probe for those that may be considered "advanced" but have been attempted, are in use, or are under active consideration by at least some MPOs. The MPOs selected to be interviewed would not necessarily be "typical;" rather they were chosen to provide insights into what was being achieved by agencies that were known or rumored to be attempting new approaches or were seen as being active in travel demand forecasting forums.

After discussions with the TRB committee, several topics were identified for which further information, obtained by discussions with a number of MPOs, would be desirable. These topics included the following:

- Validation
- Sensitivity analysis
- Data cleaning or quality
- Postprocessing
- Staffing and budget
- Advanced practices
- Barriers to improvement
- Perceived shortcomings of current methods

The project team identified 13 MPOs or state agencies as possible candidates for these discussions. These agencies were selected on the basis of indications that they were engaged in, or had been engaged in, developing or applying procedures that might be considered as advancing the state of the practice, were active in organizations such as AMPO, or were agencies that developed or applied travel-forecasting models for multiple MPOs within a state. These agencies were contacted by phone and e-mail. Six of these agencies were visited and the remaining agencies were interviewed via phone. Some agencies requested that their responses not be specifically attributed. In an effort to protect the identity of the responding agencies, specific agency names have been removed from the discussion.

In addition, each of the MPOs represented on the TRB panel was provided with a copy of the guide prepared for the interviews with the selected MPOs. Those agencies were asked to provide written responses on the basis of the issues posed in the guide.

Table 1: List of Interviewed Agencies

In Person Interview		Phone Interview	
Agency	*Geographic Region*	*Agency*	*Geographic Region*
East West Gateway Coordinating Council	St. Louis, MO	Atlanta Regional Commission (ARC)*	Atlanta, GA
Mid-Ohio Regional Planning Commission (MORPC)	Columbus, OH	Chicago Area Transportation Study (CATS)*	Chicago IL
North Carolina Department of Transportation (NCDOT)	State of North Carolina	Community Planning Association of Southwest Idaho (COMPASS)	Boise, ID
Ohio Department of Transportation (ODOT)	State of Ohio		
		MetroPlan	Little Rock, AR
Sacramento Area Council of Governments (SACOG)	Sacramento, CA	MetroPlan Orlando	Orlando, FL
Virginia Department of Transportation (VDOT)	State of Virginia	Metropolitan Transportation Commission (MTC)*	San Francisco, CA
		North Central Texas Council of Governments(NCTCOG)*	Dallas–FT. Worth TX
		Pike's Peak Area Council of Governments	Colorado Springs, CO
		Regional Transportation Commission of Southern Nevada	Las Vegas, NV
		Metro	Portland, OR

* Agencies marked with an asterisk were not interviewed in person but did provide answers to the interview questions in written form

This document specifically provides results of these interviews, making note of practices that are unusual, advanced, or offer other special interest topics. In addition, validation, sensitivity analysis, data cleaning, postprocessing, staffing, and budget and barriers to improvements were subjects explored in the discussions. Thus, this document complements and adds depth to the information provided in the document reporting the qualitative measures obtained from the large web-based survey conducted in Stage 1.

Validation

State of the practice: The "common practice" of the majority of agencies includes comparing model results to household surveys, CTPP data analysis, traffic counts, and on-board transit surveys. "Exceptional practices" include backcasting (one agency) and sensitivity analysis (three agencies), the use of aerial photos for validating land uses and special purpose surveys (such as airports, convention centers and visitor destinations) to better validate trip distribution. Formal validation thresholds, when they exist, tend to be limited to achieving the percentage RMS error thresholds for assigned link volumes compared with counts established in FHWA planning guidance.

Common Practice

Most agencies used a combination of four datasets for their validation efforts:

- Household surveys
- Census data (CTPP)
- Traffic counts
- On-board transit surveys

Household Surveys

Because households surveys are the primary data source for most model development, assessing a model against household survey data is not a truly independent validation.
Many of the agencies interviewed reported using some form of household travel survey as part of a model update or validation effort, although the timeliness of the data varied across agencies from recent to old. For example, Agency 3 used a 5,000-house household survey that was completed in early 2000. Likewise, Agency 10 conducted a household study in 2002 in which 1,800 households were interviewed. Typically, when data from a household survey are available, they are used for new model estimation, rather than for validation of the forecasts produced by a previously developed model.

More recently, Agency 7 used a 2004 household travel survey to verify the trip time distribution for the model. In addition, frequency curves from the model were checked against household survey data.

Agency 13 matched the output of the model against a household survey that was completed in 1994 and updated in 1996. This agency verified household characteristics, number of trips per household, transit boardings, and highway traffic counts.

Many of the agencies stated that they were hoping to fund a household survey update within the ensuing year or two, although it was acknowledged that budgetary issues were a concern and would play a large roll in determining the actuality of this plan.

Census Data

CTPP data were used by most agencies interviewed in validating work trip lengths and times. This package, based on data from the 2000 Census, provides a comprehensive source of data on commuters and commuting patterns (including number of vehicles available, travel time to work, and household income, just to name a few variables) at the TAZ, census tract, metropolitan, county, and state levels.

For example, Agency 10 and Agency 11 use CTPP work trips to validate trip distribution. Agency 7 matches intracounty work trips to within 1% of CTPP census data and validated both peak hour and total day outputs. It also matched work trips to within 1.5% of the average length of trip to work. Similarly, Agency 12 uses both 2000 Census CTPP and the Public Use Microdata Set (PUMS) data for validation. Agency 13 uses CTPP for work trip verification.

There are no similar datasets that can be used for validation of trip lengths or trip distributions for purposes other than work. The Nationwide Personal Transportation Survey (NPTS) does have nonwork trip data, but the unaugmented sample size in any area is too small to permit its use for validation.

Traffic Counts

Traffic counts are used by all agencies as part of validation efforts. The data are to be of varying coverage quality. For example, Agency 3 uses traffic counts obtained from the state departments of transportation, which cover approximately 50% of the interstate and arterial network, but they do not have data for collector or lower functionally classified streets. To validate highway assignments, they use screen lines at major geographical barriers as well as attempting to match model output speeds with actual travel time runs developed using GPS data.

Agency 1 receives 24-hour historic count data from the state department of transportation at several permanent locations. The MPO typically validates its model to these permanent counts using weekday counts (Tuesday, Wednesday, and Thursday), excluding summer and winter months because of volatile travel patterns. Because these permanent locations provide data at only a small number of locations, an average daily traffic (ADT) count book provided by the state department of transportation is used as a secondary resource to fill in links where no permanent counting locations are available. Although the ADT count book is not perceived as being very reliable, it does provide “ballpark” data for the validation effort, as the MPO tries to validate by time period and ADT on the basis of absolute values across functional and volume class. Thus, only aggregate ballpark numbers are required. No screen line analysis is done.

Agency 6 has multiple pneumatic tubes established around the state that provide historical count comparisons at many locations. Where historical count information is not available, it uses a “nearest neighbor” growth percentage. In addition, it has developed a procedure for validating traffic counts at representative locations rather than validating for every link. The agency feels link level validation is inappropriate because it requires network and other changes to force fit the link volumes to match.

Agency 10 has a yearly budget for collecting traffic counts and coordinates with the county and city to get as much coverage as possible as well as collecting turning movement counts. It validates highway assignment on the basis of traffic counts.

Agency 11 uses 1,100 traffic counts collected by the state on a 48-hour basis. Many of these counts were contracted out and not done by state staff. The agency validates on the basis of daily volumes.

Agency 9 has hourly bidirection traffic counts collected by the state at ramps, at freeway links, and along arterials. Link volumes are colleted by tubes over a 7-day period. The agency has a history of counts at many of the tube locations that date back 15 years or more. It uses traffic counts to validate to screen lines (with 21 of 27 screen lines being within ±25%).

Agency 7 considers its traffic counts to be a rich set of data with ramp volumes and arterial and tube counts for most of the area. The agency analyzed screen line validation and was

able to get an 84% match. The areas in which the greatest variance between simulated and observed traffic volumes were found were in rural areas that had low volumes.

Agency 12 compiled data for both daily and AM peak periods from observed data (obtained from the state department of transportation) and calculated standard errors to provide a range of valid values. Predicted volumes were compared against these ranges.

Agency 5 reported that it has a comprehensive statewide traffic counting program with many permanent count stations throughout the state. The agency uses this data and a traffic count book for all state maintained roads to validate models.

On-Board Transit Surveys

Several of the agencies that were interviewed do not have transit service used by choice riders; therefore, they did not validate transit service. However, if transit ridership were validated, on-board surveys or a calculation of boardings were used. For example, Agency 1 conducted an on-board survey obtaining a 12% sample of transit riders. These data were then augmented through the use of counters who tallied daily rail boardings by station for the light-rail mode, whereas bus ridership was obtained through drivers tracking boardings and alightings.

Some agencies do transit validation but do not get their data from on-board surveys. For example, Agency 11 validates transit assignment by counting the number of boardings on an aggregated, by line, calculation. These data are obtained through driver and station observer methods.

Many agencies appear to use on-board surveys for validating mode choice proportions but do not validate the resulting transit ridership forecasts against counts. For example, Agency 2 validated mode choice by comparing household income and an on-board transit survey but did not count the number of boardings and alightings at each individual stop location. Agency 10 also conducted an on-board survey in 2004 but did not augment those data with actual boarding information.

Many agencies do not have formal validation thresholds; however, some type of check is often in place. For example, Agency 3 relies on institutional memory of previously acceptable levels to confirm validation thresholds.

On aggregate, agencies do not practice backcasting. However, several mentioned either implementing backcasting or attempting it on a trial basis. For example Agency 3 and Agency 10 are both considering doing a run for 2000 and comparing it to 2005 forecast, and Agency 13 has done so on an ad hoc basis.

Exceptional Practice

We found few examples of validation practices that could be considered exceptional. One of the states has developed model validation standards that are applied to the models of all MPOs within that state.

Agency 10 is attempting to design, fund, and conduct an air passenger survey in an attempt to better validate trip distribution and generation associated with a medium-sized airport located within the region.

Agency 8 uses aerial photos to validate demographic and economic forecasts, which it then distributes to local agencies.

Agency 12 does have certain logical checks in place to ensure internal consistency such as verifying that “employed persons” is less than total population, “average household size” is reasonable, the sum of employment by employment sector matches “total employment” and the

sum of acreage by land use does not exceed total acres. It also informally evaluates forecasts by producing county-to-county reports on trips by trip purpose, review regional mode choice results for every mode choice equilibration cycle, and review regional traffic assignments for every mode choice equilibration cycle.

Agency 13 progresses through a pregeneration model that models number of workers, number of cars, number of children, type of dwelling, accessibility by transit, walkability, and auto ownership by household.

Sensitivity Analysis

State of the practice: Two agencies interviewed have begun dynamic validation—a term used by a specific consulting firm—that involves changing some aspect of the system (e.g., inserting or removing employment or residential units in several zones, changing travel times) and then analyzing the forecast changes in trip making, trip distribution, mode shares, and or congestion of the network. These agencies also remove links from the highway network to determine the impact across screen lines and individual links. In addition, specific aspects of the model are tested in a small number of agencies, but the practice is not widespread and does not involve a comprehensive, robust level of analysis. Agencies that do partake in sensitivity analysis appear to do so on an ad hoc basis.

Agency 7 and Agency 9 perform both static and dynamic validation. Static validation was discussed earlier. Dynamic validation is a form of sensitivity analysis and involves congestion impact analysis of the network after inserting or removing employment or residential units in several zones. If the network is affected as expected, then the model is considered valid. Dynamic validation can also include the removal of a link or the addition of a link to see how the network reacts. It was not clear that any changes were made as a result of the dynamic validation tests.

Interviews suggested that many agencies do not have a formal process for comprehensive sensitivity analysis. However, there are several examples of agencies practicing isolated sensitivity analysis on subsets of the model. For example, Agency 11 does sensitivity analysis in relation to transit forecasts by varying the transit headway and fares while tracking the shifts in mode shares. One of the agencies that provided information for this review documented an extensive set of sensitivity tests.

Some agencies do practice a more systematic approach to sensitivity analysis. Agencies 2 and 6 run the model for 2030 to get a sample data run then adjust the 2000 base year model to mitigate unrealistic outputs found in the 2030 run. For example, it was found that if wait time limits for express bus service were modeled, the future year transit share was not producing a realistic market share; therefore, no limits on wait times were used. This type of comprehensive analysis appears to be sporadic on a nationwide level.

Data Cleaning and Quality Control

State of the practice: Use demographic and economic control totals to verify that aggregate level data are reasonable. Plots of networks are used to review coding.

The demographic data-cleaning efforts of most interviewed agencies did not appear to involve the critical evaluation of data but rather the acquisition of control totals from a credited source and the subsequent building of consensus of decision makers in the region regarding the use of the acquired data. For example, Agency 7 used to have a process in which the regional decision makers would get together and “negotiate” forecasts. It has now moved to obtaining a

control total from a local economist that does regional forecasts up to 2030. These forecasts are then reviewed and approved by a demographic advisory committee before being distributed to local agencies.

It is also common for the MPO to delegate data-cleaning and validation efforts to the local municipalities. For example, Agency 2 does not have a "standard" for network checking. However, it does have a formal quality assurance/quality control process during which all of the independent variables (e.g., population, employment, income, school enrollment) are provided to the local governments and verified at the local level. These forecasts are then reviewed and approved by the MPO board. Because of strong local government control (home rule), it is very hard for the MPO to allocate growth independent of local government long-range plans. Other agencies provide network descriptions to local agencies for review. These reviews, although they relate to what facilities are included in the networks and the characteristics of these facilities, may reflect a list of projects or GIS-based maps and not the actual coded networks.

Agency 13 has specific procedures for checking model outputs, but they are not written down. Human error and data misspecification exceed additional detail in model specification.

Several regions do (e.g., Agency 1 and Agency 10) provide a value-added step in the data input process. Agency 1 is currently collecting, cleaning, and screening both public and private data in an attempt to move toward a point and parcel dataset. This process involves the use of control totals from the permit and planning department in obtaining a cross-classification of household and forecasted populations.

Agency 10 plots travel times in concentric rings out from the Central Business District to see if they make sense. In addition, the MPO works with the local agencies to make sure the demographic and economic forecasts from both agencies match.

Almost all agencies indicate that they engage is some form of quality control, but only a few have formal, documented procedures. One of the larger agencies has a written manual that not only describes the overall process for preparation of travel demand forecasts but also includes lists of specific factors that must be checked in the various phases of developing networks, applying models and testing alternatives. For example, tests done to ensure network accuracy are as follows:

- Compare the coded highway distance with the distance calculated by the coordinate system.
- List links where distances were not coded.
- List links where the facility types were not coded.
- For each level of service, summarize travel times and distances on a district to district basis and compare with previous year results.
- Visually check plots of the built/unloaded highway network for inconsistencies in the number of lanes and facility types.
- Visually check plots of the built/loaded highway network for links with no volume.

All agencies reported that they look over the results of forecasts to make sure they appear reasonable.

Postprocessing

State of the practice: Most agencies apply postprocessing only when needed for air quality analysis.

Many of the agencies that were interviewed do not appear to have postprocessing standards or practices beyond basic levels to conform to air quality mandates. For example, Agency 7 does not do any postprocessing. It simply gives users (e.g., consultants, local municipalities) raw volumes and validation statistics and lets the users decide if they want to adjust volumes and speeds. It does, however, monitor vehicle emissions with MOBILE-6 on the basis of tons per day and estimates VMT by functional classification.

Agency 9 does postprocessing of speeds for air quality purposes and plans to put in place a system to refine future year forecasts on the basis of NCHRP 255.[4] Traffic count volumes are not postprocessed. Agency 8 currently uses methods described in NCHRP Reports 255 and 187 for postprocessing design volumes, and it also analyzes traffic volumes from the model output along specific corridors, calibrating these volumes on the basis of "believability."[5]

Postprocessing at Agency 11 involves adjusting daily traffic volumes according to current peak hour percents. The agency does not have a formal process for design volumes but does not use raw volumes obtained from the model without first reviewing them for what it would consider "possible" volumes. It also takes daily volumes from the model and looks at peak hour percentages to see if they are in line with each other. The agency's postprocessing efforts are directed at providing for air quality conformity analysis.

At Agency 1 and Agency 10, design volumes are postprocessed by a consultant using count data plus forecasted growth. Consultants obtain volume growth percentage between current model year and future model year and then apply the growth percentage to the current traffic counts to obtain future year volumes.

Staffing and Budget

State of the practice: The average MPO has roughly two to three travel demand modelers and spends an annual budget of approximately $150,000 to $200,000, not including model development. However, some agencies, mostly small, have no modeling or travel-forecasting staff and instead rely on the state transportation agency. Conversely, some MPOs in larger metropolitan areas have very large staffs. Most areas reported an increase in both staff and budget over the last three years. Many of the medium or smaller MPOs employ consultants to do the majority of model development whereas MPO staffs concentrate on the application of the model. In many states, the state transportation agency is responsible for development and application of travel demand forecasting procedures for most MPOs.

There was substantial variation in the answers to this question; however, the overall trend indicated an increase in staff and budget allocated specifically for travel demand forecasting tasks over the last three to four years. For example, Agency 3 has five staff people (two on systems evaluation, one on data collection, and two on model development). Before 2003, the agency spent few resources on travel demand modeling tasks; however, in the last three years it has allocated between $200,000 and $500,000 a year for travel demand modeling.

Similarly, Agency 10 has seen a dramatic increase in the availability of travel demand forecasting resources. In 2002, it had one full-time staff modeler. Over the last few years, six

[4] N.J. Pedersen and D.R. Samdahl. National Cooperative Highway Research Report 255: Highway Traffic Data for Urbanized Area Project Planning and Design. National Research Council, Transportation Research Board, Washington, D.C., 1982.

[5] Various Authors. National Cooperative Highway Research Report 187: Quick-Response Urban Travel Estimation Techniques and Transferable Parameters. National Research Council, Transportation Research Board, Washington, D.C., 1978

additional staff members have been added to work specifically on travel demand models tasks. This increase in staff is partly because of a change in the structure of the modeling department. The MPO no longer attempts to develop a model but has a consultant do all of the development work. Staff is then trained in how to use the model. Budget for staff time is less than $500,000 a year. The MPO staff does the majority of model application, although the consultants do the majority of model development.

Agency 2 has six employees (one manager, two modelers, and three users that code and run the networks) devoted to travel demand modeling. It allocates more than $500,000 a year to travel demand modeling, not including development costs. The budget does include data collection, model running, and data preparation (e.g., demographic profiles).

As a state agency designated to provide modeling services for 14 of the 17 MPOs in the state, Agency 4 has 10 staff persons devoted to modeling and forecasting.

A number of the medium-sized MPOs interviewed, like Agency 1 and Agency 8, use consultants to develop the majority of the model. For example, Agency 8 has one staff person, so the majority of work, including the development of the model, is done by consultants. The agency allocates roughly $200,000 to $300,000 a year to modeling. Before three years ago, the budget was closer to $100,000 a year.

Agency 11 has one person from the MPO and another from the state who is devoted to travel demand forecasting. Agency 11 uses its resources to develop the model and the consultants then apply it. The model is typically developed in house and then distributed to consultants for application in planning studies. Approximately $300,000 a year is allocated for travel demand modeling in the region.

Agency 9 has three staff members, including a principal planner who is in charge of project management and land-use input, a senior planner who does network creation and traffic counts, and a GIS expert who prepares parcel level land-use data. The agency allocated approximately $400,000 this year to model development; however, much of that money was for consultants, because it did a new household survey and a mode choice update to the model. The agency is planning to do an onboard origin-destination survey this year and is budgeting for roughly the same funding.

Agency 7 has three staff members in the modeling department, although there are eight in the entire transportation department. The agency budgets for $300,000 to $500,000 a year. Historically it had been around $150,000, but the last three years the budget has increased quite dramatically.

Agency 13 has 11 employees total in the modeling department and estimates a budget of approximately $900,000 a year in model development and associated tasks. It does use consultants for some calibration and verification surveys as well as for oversight and transit model structure development, but the MPO does most of the development and application of the model in general.

ADVANCE PRACTICES

Barriers to Improvements

Most frequent responses: Not enough staff members to carry out advances in modeling techniques and budgets not large enough to try advanced model development. Difficulty in finding staff that are versed in development and application of new procedures. No clear demonstration that "advanced practices" will yield improved forecasts or will permit the agency to address questions that now go unanswered.

The biggest barriers are, as always, staff and budget. Among the agencies from which detailed information was obtained, those that are most active in exploring advanced practice tend to be those with the larger staffs. However, those that have implemented advanced practice do not have unusually large staff and have relied on consultants for development of new procedures.

Staff training time was cited as an impediment to implementation of new procedures. Agency 10 observed that political issues are a related concern. Constituent agencies and consultants in Agency 10's region did not trust the old models. So agency staff, consultants, and elected officials all required training in the new model to feel comfortable with it. The goal of the training from the MPO's viewpoint was to have all stakeholders understand how to use the model and its capabilities, thus ensuring political acceptance of model outputs.

In addition to staff, budget, and political issues, the investment in previous models also appears to be a common barrier to improvement. One region put significant resources into the development of their current four-step model, so it does not plan to invest in another model structure anytime soon. Another agency reported that it invested considerable time and money in development of an activity-based model, which was never completed or used in production. Ultimately, a traditional four-step model was adopted for use by this MPO, and it is hesitant to repeat the process of developing a tour- and activity-based model for fear of wasting resources.

Multiple agencies mentioned that they would not move from a validated four-step model to a more complicated and data-intensive tour-based model until it was proven that the new model structure would produce better results. For example, Agency 13 is contemplating an advance to a tour- and activity-based model framework, but the model must be practical. The agency believes that the current set of activity models are complicated and have not proven to be better than the traditional four-step process.

There is also a concern that if a new model produces radically different results than the previous model, any projects that were justified using data from the previous model may be called into question.

Practices of Special Interest

State of the practice: One of the interviewed agencies has recently developed and is using an activity-based model set. Two of the agencies interviewed had previously developed tour-based models but abandoned the effort because of political and budgetary reasons. Most agencies do not appear interested in developing activity-based or tour-based models at this time, choosing instead to concentrate resources on further refinement of the traditional four-step model. However, several agencies are initiating major efforts to develop an activity-based model. In addition, agencies appear to be interested in, and attempting to develop, truck models and special generator models.

Activity- and Tour-Based Models

The current literature and practice suggest that the current emphasis in advancement of the development of travel demand modeling will be the adoption of tour- and activity-based models. As noted, several agencies have tried to develop tour-based models, but they have abandoned the effort for a variety of reasons, reverting to the traditional four-step model. Other agencies have developed and are using for planning and analysis tour- or activity-based models. For example, one of the MPOs had used a tour-based model developed in the 1990s. However, local decision makers could not reach consensus regarding validity of model results, so it was shelved, and the current three-step model was developed. They are now considering integrating land-use and GIS functions with the model to produce better graphics and operational functions (e.g., signal timing, ramp metering) for public meetings and to better reflect operational changes to the network on a regional basis. Agency 2 has recently implemented an activity-based model. Agency 6, Agency 1, and Agency 12 were the only three agencies that specifically stated they were actively in the process of attempting to advance to an activity- or tour-based model. The City of San Francisco has developed and is using an activity-based model.

Agency 2 reported that the previous model was not providing acceptable forecasts for projects under consideration, including a proposed transit New Starts project. A new model was required. The request for proposals for developing an improved model originally contemplated an improved four-step procedure. The decision to implement an activity-based model was based on a recommendation by the selected consulting firm and encouragement by FHWA and FTA.

The new model has only recently become the "production" model, and the agency is still evaluating the results. It was a bit disappointed in the length of time it took to get the new activity-based model developed and in application (although there is no certainty that a standard four-step would have been in place in any shorter time). The agency also noted that the effort required to implement the model was significantly in excess of the budget, although these costs were absorbed by the consulting firm. There are concerns that agency staff members do not know the computer language used to implement the activity-based model, and this may become a problem if the agency wishes to make changes. It also finds the running times for the model to be excessive.

Improvements to Four-Step Models

To provide more robust four-step models, several agencies are developing specific model improvements. For example, Agency 10 is contemplating developing a special trip purpose that will better reflect military trips. Military personal in the region gather at specific locations for early morning physical training, return home to shower and get ready for the work day, and then make another trip to the work place. Along the same idea, Agency 2 region is interested in developing a model for university student trips. Agency 8 is attempting to develop an airport model as well as refine a visitor model that will include special generators such as large tourists draw venues and the convention center.

Assignment

The agency responsible for development and application of travel demand models for many regions in one state under study has adopted as standard practice some procedures that are not widely reported by others. These include the use of a function that is a linear combination of time and distance for highway path determination and assignment and the use of a function that

accounts for both intersection delay and link delay for capacity restrained assignment. Because of use of the intersection delay function, the agency has reverted to use of iterative capacity restraint rather than equilibrium assignment.

In spite of the practical problems that have been noted with equilibrium assignment, few of the agencies expressed concern, felt that the assignments required an excessive number of iterations to converge, or had investigated whether such problems were arising in their applications. In this vein, none of the agencies reported that they were experiencing supersaturated networks (i.e., assignments in which the demand far exceeds the capacity).

Freight or Truck Modeling

Several agencies mentioned the need for additional truck data and the development of a truck model, including Agency 8, Agency 7, Agency 10, and Agency 6. Many of the same agencies also mentioned integrating microsimulation software packages with the regional travel demand model to provide better graphics for public meetings. Agency 12 has been using a truck model since the early 1990s; however, it is out of date and not very reliable because it is a blend of consultant-estimated models and borrowed models from other regions (most notably the Phoenix area). Agency 6 has developed a truck model that is run for both trip generation and trip distribution segments of the model. Trucks that are based (garaged) in certain TAZs provide the production and attractions for commercial vehicles relative to the entire area. A regression equation based on employment is then added into the analysis to predict truck demand in the future. The data are based on a 1994 survey, conducted in a different MPO area within the same state that separated commercial, auto, and truck trips separately. In addition, Agency 6 does external truck forecasts on the basis of historical trends. Agency 11 developed a three-step truck model using coefficients barrowed from a model calibrated in Vancouver, British Columbia. Agency 13 uses a truck model developed on the basis of a port survey.

Although none of the agencies interviewed has implanted a truck and commercial vehicle model based on a seed matrix and counts of observed vehicles, such a procedure has been developed and applied by the Baltimore Metropolitan Council and several other agencies. At least two of the agencies interviewed expressed interest in developing a similar procedure.

Other

Agency 2 developed a population synthesizer that validated to census households by both size and income according to geography. Destination choice was used for HBW trips and was based on census distributions.

Agency 7 has been developing growth scenarios as a way to deal with growth management issues and is in the process of testing a feedback loop for later addition in the trip assignment step of the model. School trips are based on an enrollment boundary (only in distribution), with future schools and capacity being modeled by working with school boards to obtain a reasonable representation of projected education infrastructure. The region has set aside budget for a freight study, and it is hoping the information gathered can be used to form a truck trip model.

Agency 9 has a visitor model currently in use; however, it wants to update the inputs because the survey used was conducted in 1996. The visitor model combines many visitor trip generations in the mode choice step but breaks out trip generation by type of visitor in the trip distribution step. Essentially, trip generation is computed for many different types of visitors. The agency also validates traffic assignment by adjusting link capacities according to green time

per movement at intersections in aggregate by functional class. It also adjusts free flow speed in the resort area.

Agency 12 is using GIS to analyze point-to-point distances and travel times from a travel survey completed in 2000 in trying to better estimate appropriate zone-to-zone travel times for nonmotorized trips. The agency also uses a "peak spreading model" that alleviates some of the problems associated with oversaturated networks. Agency 12 has also incorporated a work trip departure time choice model that it believes is an improvement over simple TODFs. In addition, it has a transit/auto accessibility variable in the auto ownership choice model and has conducted a substantial amount of research on speed/flow curves. The agency reports that it no longer requires speed postprocessing for either arterials or freeways.

Agency 6 has used home interview survey data collected at one smaller MPO to inform the calibration of a model at another similar MPO. The resulting model validated very well. It intends to extend this approach to other small MPOs in the state.

Agency 6 has developed a technique to convert person trips to auto trips for smaller MPOs, which do not have many choice transit riders. Agency 6 currently uses simple growth factors to estimate future external–external and external–internal trips. It hopes to integrate regional and exurban land-use forecasts for external–internal trips.

Agency 5 is working to standardize all of its models and have them all use one software platform. The plan is for the state to develop all models and have a planner at each MPO apply the models. One MPO, under Agency 5 supervision, reported that it has been using a toll model for a number of years and that it has worked well when forecasting volumes on the toll facilities in that area.

Agency 1 has developed a land-use modeling procedure that is a GIS web application that lets users either in the office or in a public workshop make changes to a parcel-based land-use scenario and produce a number of indicators to show the probable impacts of land-use developments. It has been very useful for developing future land-use scenarios and generating public input and acceptance of future land-use scenarios. The agency is currently undertaking a process to integrate this land-use modeling procedure with its travel-forecasting model.

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DETERMINATION OF THE STATE OF THE PRACTICE IN METROPOLITAN AREA TRAVEL FORECASTING

Agency I.D. and Contacts

MPO Name

Metropolitan Area Served

Mailing Address

Executive Director

Phone Number **Extension**

E- mail

Travel Forecasting Manager

Phone Number **Extension**

E- mail

Name of "Survey Respondent" (Name of the person responsible for providing information in this survey)

Agency by which Survey Respondent is employed

Position/Title of Survey Respondent

Phone Number **Extension**

E- mail

MPO Web Site

General Description of MPO

1.	States participating in MPO						

☐ Alabama	☐ Alaska	☐ Arizona	☐ Arkansas
☐ California	☐ Colorado	☐ Connecticut	☐ Delaware
☐ District of Columbia	☐ Florida	☐ Georgia	☐ Hawaii
☐ Idaho	☐ Illinois	☐ Indiana	☐ Iowa
☐ Kansas	☐ Kentucky	☐ Louisiana	☐ Maine
☐ Maryland	☐ Massachusetts	☐ Michigan	☐ Minnesota
☐ Mississippi	☐ Missouri	☐ Montana	☐ Nebraska
☐ Nevada	☐ New Hampshire	☐ New Jersey	☐ New Mexico
☐ New York	☐ North Carolina	☐ North Dakota	☑ Ohio
☐ Oklahoma	☐ Oregon	☐ Pennsylvania	☐ Rhode Island
☐ South Carolina	☐ South Dakota	☐ Tennessee	☐ Texas
☐ Utah	☐ Vermont	☐ Virginia	☐ Washington
☐ West Virginia	☐ Wisconsin	☐ Wyoming	

2. How many political jurisdictions are voting members of your MPO? 4

3. Names of major cities participating in MPO

4. MPO Area in Square Miles 646.86

5. Is this a Transportation Management Area?

- ○ Yes
- ◉ No

6. Does your metropolitan planning area contain an urbanized area population over 200,000? [Note: This is not exactly the same as a TMA]

- ○ Yes
- ◉ No

7. At any time prior to May 1, 2005, was any portion of the MPO area non- attainment or maintenance for the following:

	Yes	*No*
Ozone	◉	○
CO	○	○
PM10	○	○
PM2.5	◉	○
NO2	○	○

7A. If a portion of the area was designated non-attainment or maintenance for Ozone was it Serious or worse?

- ○ Yes
- ◉ No

7B. If a portion of the area was designated non-attainment or maintenance for CO was it

	Serious or worse?
○	Yes
○	No

8.	**Has it been necessary to modify the travel forecasting procedures in order to conduct analyses related to Air Quality?**
○	Yes
◉	No

9.	**Is a transit New Starts or Small Starts project in progress or contemplated?**
○	Yes
◉	No

9A.	**If a transit New Starts or Small Starts project is in progress or contemplated, have you had to modify the travel forecasting model set for use in New Starts or Small Starts planning?**
◉	Yes
○	No

10.	**Is a major freeway/expressway corridor study in progress or contemplated?**
◉	Yes
○	No

10A.	**If a major freeway/expressway corridor study is in progress or contemplated, have you had to modify the travel forecasting model set for use in corridor planning?**
○	Yes
◉	No

11.	**Which agency performs the travel forecasts for the long-range plan and conformity?**
☑	MPO (in-house)
☑	State ***What Department ?***
☐	County
☐	Municipality
☐	Consultant
☐	Other (Please specify)

12.	**Is a travel demand model used to develop travel forecasts for the long-range plan and conformity?**
◉	Yes
○	No

13.	**In addition to the travel demand model set used for long-range planning and conformity analysis, are other travel demand models used for other purposes?**
○	Yes
◉	No

14.	**Have you used a microsimulation or other operations model for a planning study in**

	the last three years?
◉	Yes
○	No

14A.	**Has a microsimulation or other operations model been used by your agency (or a consultant working in your agency) for a planning study in the past three years?**
☐	TRANSIMS
☐	CORSIM
☐	VISSIM
☐	PARAMICS
☐	AIMSUN
☑	Other (Please specify) SYNCHRO

Area Descriptors

IMPORTANT NOTE: *FOR THE REMAINING QUESTIONS IN THIS SURVEY, PLEASE PROVIDE RESPONSES FOR THE TRAVEL DEMAND MODEL SET USED FOR LONG RANGE PLANNING AND CONFORMITY ANALYSIS*

15.	**Does the area included in the travel model cordon include the entire MPO area?**
◉	Yes
○	No

15A.	**Are areas outside the MPO area included in the models cordon?**
◉	Yes
○	No

16.	**If the MPO contains a nonattainment or maintenance area whose boundaries extend beyond the MPO, does the travel model include the entire nonattainment/maintenance area?**
○	Yes
◉	No
○	N/A

17. List the current and forecast year(s) total demographics *of the MPO region.*

Demographic	*Current Year*	*Current Year Value*	*Forecast Year*	*Forecast Year Value*
Population*	2000	117568	2030	150286
Households or Dwelling Units*	2000	45206	2030	58198
Employed residents*	2000	58898	2030	85413
Employment (Jobs)*	2000	60831	2030	76180

*if more than one forecast year, choose data from the forecast year for the Long Range Plan

18. List the current and forecast year(s) total demographics *of the area within the model cordon.*

Demographic	Current Year	Current Year Value	Forecast Year	Forecast Year Value
Population*	2000	1443539	2030	1963713
Households or Dwelling Units*	2000	574461	2030	830754
Employed residents*	2000	766363	2030	1270102
Employment (Jobs)*	2000	815088	2030	1223168

*if more than one forecast year, choose data from the forecast year for the Long Range Plan

Data Forecasts

19. What demographic and socioeconomic parameters are used in any portion of the model? Choose all that apply.

	Trip Generation	Trip Distribution	Mode Choice
Population	✓	✓	✓
Households	✓	✓	✓
Housing type/ condition			
Labor Force or workers	✓	✓	✓
Jobs or employment	✓	✓	✓
Vehicle Ownership	✓	✓	✓
Household Income	✓	✓	✓
Household Size	✓	✓	✓
Workers per Household	✓	✓	
Employment Density			
Population Density			
Household Density			
Area Type	✓	✓	✓
Parking Cost	✓	✓	✓
Walking/cycling suitability measure or index			
Other*			

*List all not shown in the box below

19A. For the demographics listed below, who performs the forecast?

Demographic	MPO (inhouse)	State	Consultant	Other*
Population	✓			
Households	✓			
Employment	✓			
Household Income	✓			
Vehicle Ownership	✓			
Other Parameters				

*Please specify in the box below

School Enrollment

19B. For the demographics listed below, what methods are used to prepare the regional forecasts?

Demographic	*Bottom-up Model##*	*Top Down Model@@*	*Woods and Poole or similar source*	*Don't Know*	*Other**
Population	☐	☑	☐	☐	☐
Households	☐	☑	☐	☐	☐
Employment	☐	☑	☐	☐	☐
Household Income	☐	☑	☐	☐	☐
Vehicle Ownership	☐	☑	☐	☐	☐

*Please specify in the box below

##"Bottom-up" means that forecasts are prepared for small areas (e.g. planning districts, political jurisdictions, traffic analysis zones, etc.) and then aggregated to yield regional totals.

@@"Top Down" means that forecasts are made for larger geographic units (e.g. entire State, sub-state planning districts, etc.) and the allocated to sub units such as political jurisdictions or local planning areas.

19C. For the demographics listed below, how are the data allocated to traffic analysis zones?

Demographic	*Negotiation*	*Model based on available area or holding capacity*	*Master Plan / Zoning*	*Based on current distribution*	*Other**
Population	☐	☑	☐		☐
Households	☐	☑	☐		☐
Employment	☐	☑	☐		☐
Household Income				☑	☐
Vehicle Ownership				☑	☐

*Please specify in the box below

20. What data sources are used for model development? These are the data used to explore functional relationships and estimate the model coefficients, not data used to validate the model.

	Trip Generation	*Trip Distribution*	*Mode Choice*	*Trip Assignment*
Decennial Census Summary File 1	☐	☐	☐	☐
Decennial Census Summary File 3	☐	☐	☐	☐
Census Transportation Planning package	☐	☐	☐	☐
Census public use micro sample	☐	☐	☐	☐
National Household (Travel) Survey - NHS				

or NHTS	☐	☐	☐	☐
Household travel (home interview) surveys	☑	☑	☑	☐
Stated preference surveys	☐	☐	☐	☐
Roadside Interviews	☑	☑	☐	☐
License Plate matching surveys	☐	☐	☐	☐
Cordonline surveys	☐	☐	☐	☐
Screenline surveys	☐	☐	☐	☐
Traffic Counts	☐	☐	☐	☐
Transit on-board surveys	☐	☐	☑	☐
Other*	☐	☐	☐	☐

*List all not shown in the box below

21. What year was the last household travel survey conducted? 1999

22. What was the method used for the household survey?

- ☐ Face-to-face interview
- Telephone interview
  - i. Previous Solicitation
    - ☐ 1. By Mail
    - ☑ 2. By Phone
    - ☐ 3. None
  - ii. Diary Provided
    - 1. Yes
      - ☑ a. Full trip recording
      - ☐ b. Reminders only
    - ☐ 2. No
  - iii. Diary returned by mail?
    - ☐ 1. Yes
    - ☑ 2. No
- ☐ Others (Please specify)

23. Were the household survey data:

- ○ Trip based
- ○ Activity based
- ◉ Other (Please Specify)

24. How many valid responses were obtained for the household survey (unlinked trips)?

Households	5555
Persons	13524

	Trips	52031

25.	**What percentage of households did this represent?** 76 %

26.	**Were the household survey data:**	
	◉	Weighted and expanded
	○	Used in Disaggregate form only
	○	Both

27.	**What year was the last stated preference survey conducted?** - Select One -

28.	**What was the method used for the stated preference survey?**

29.	**How many people were surveyed for the stated preference survey?**

30.	**What was the response rate for the stated preference survey?** %

31.	**What percentage of the total population did the stated preference survey represent?** %

Planning Issues and Model Uses

32.	**When was the Long- Range Plan updated?** 2004 **What is the name of the current version?** 2030 Transportation Plan

33.	**How often is the Long-Range Plan updated?**	
	○	More often than every three years
	◉	Every three years
	○	Every four or five years
	○	Every six or more years

34.	**When was the travel demand model set last updated? (Report year updated model set was first used).** Note: Please use judgment in responding to this question. By "updated" we do not mean minor adjustments such as subdividing a few TAZs or adjusting speeds on the network. We mean changing the functional form, coefficient values or rates for some component of the model; adding a new submodel (e.g. auto ownership) or something similar.	2004

34A.	**What componenets of the model were updated at that time? (check all that apply)**	
		Four Step Model
	☐	Trip Generation - Productions
	☐	Trip Generation - Attractions
	☐	Trip Distribution
	☐	Mode Choice
	☐	Highway Assignment

☐	Transit Assignment
☐	Post-processing for speeds
☐	Post-processing for design volumes
☐	Emissions Analysis
☑	*Conversion from Four Step to other model form*

34B.	**Is this most recently updated model set documented?**
◉	Yes
○	No
○	Partial

35. How many TAZs are in the modeled area? (i.e. excluding external stations, how many rows and columns are in the trip tables?) 1805

36. How many external stations are there? 72

37. How many links are in the highway network? 25000
(Count A->B and B->A, if 2-way roadway, as one (1) link. If divided roadways are coded A->B with reverse as C->D, count as two links. Estimate if exact count not available)

38. How many nodes are in the highway network? *(estimate if exact count not available)*
9983

39. How completely do the networks incorporate transportation facilities? Please check your best estimate of the percentage of the facility mileage coded in the network.

	100%	*75-99%*	*50-74%*	*25-49%*	*1-24%*	*0%*	*N/A*
Freeway	◉	○	○	○	○	○	○
HOV lanes	○	○	○	○	○	○	◉
Major arterial	◉	○	○	○	○	○	○
Minor arterial	○	◉	○	○	○	○	○
Collector	○	○	◉	○	○	○	○
Local street mileage	○	○	○	○	◉	○	○
Rail transit	○	○	○	○	○	○	◉
Express/regional bus	◉	○	○	○	○	○	○
Local bus	◉	○	○	○	○	○	○
Commuter Rail	○	○	○	○	○	○	◉

Model Validation

40. When was the current model validated? (specify year validation was completed) 2004

41. What was the validation year? (The year for which model "forecasts" were compared against observed data) 2000

42. How often is the model validated?

○	Every year or two
○	Every three years
○	Every four or five years
○	Every six or more years
○	Never
◉	Other (Please specify) 10 years with miny

43. What data sources are used for model validation?

	Trip Generation	Trip Distribution	Mode Choice	Trip Assignment
Decennial Census Summary File 1	☐	☐	☐	☐
Decennial Census Summary File 3	☐	☐	☐	☐
Census Transportation Planning package	☐	☐	☐	☐
Census public use microdata sample	☐	☐	☐	☐
National Household (Travel) Survey NHS or NHTS	☐	☐	☐	☐
Household travel (Home interview) surveys	☑	☑	☐	☐
Stated preference surveys	☐	☐	☐	☐
Roadside Interviews	☐	☐	☐	☐
License Plate matching surveys	☐	☐	☐	☐
Cordonline surveys	☐	☐	☐	☑
Screenline surveys	☐	☐	☐	☑
Traffic Counts	☐	☐	☐	☑
Transit on-board surveys	☐	☐	☐	☐
Transit Counts	☐	☐	☑	☐
Boardings and Alightings	☐	☐	☑	☐
Other *	☐	☐	☐	☐

*List all not shown in the box below

44. When the current model was validated which components were validated. Check all that apply.

☐	Final Model Results Only (e.g. counts vs. assigned volumes)
☑	Trip Generation (separately)
☑	Trip distribution (separately)
☑	Mode Choice (separately)
☑	Highway Assignment (separately)
☑	Transit Assignment (separately)

Trip Generation

45. What is the time period for the trip generation model?

◉	Total day
○	AM Peak period or peak hour* ***: Time*** ***AM to*** ***AM*** *(enter time in decimal format - i.e. 6:30 = 6.5)*

○	PM Peak period or peak hour* : ***Time*** _____ ***PM to*** _____ ***PM*** *(enter time in decimal format - i.e. 6:15 = 6.25)*
*Please specify any additional comments below	

46.	**What trip generation approach is used in the model?**
☐	Trip-based Productions and Attractions
☐	Trip Based Origins And Destinations
☑	Tour-based
☑	Activity-based
☐	Other (Please specify)

47.	**What trip types are represented in the trip generation models? Pick categories that most closely represent trip purposes in your MPO's process, even if names are slighly different. Choose all that apply.**
☑	Home based work
☑	Home based retail
☐	Home based non-retail (service)
☑	Home based school
☑	Home based College/University
☑	Home based other
☐	Non-home based
☑	Work based
☑	Trucks
☑	Commercial vehicles
☐	Taxis
☐	Other*
*Please specify in the box below Home based other = escorting, maintenance, discretionary, eating out (trip types)	

48. What unit of travel is used in the model?

Trip Type	***Vehicular trips***	***Motorized person trips***	***Total person trips***	***Tours***	***Other****
Home based work	○	○	○	●	○
Home based retail	○	○	○	●	○
Home based non-retail (service)	○	○	○	○	○
Home based school	○	○	○	●	○
Home based College/University	○	○	○	●	○
Home based other	○	○	○	●	○
Non-home based	○	○	○	○	○
Work based	○	○	○	●	○
Trucks	●			○	○

Commercial vehicles	◉			○	○
Taxis	○			○	○

*Please specify in the box below

49. What is the form of the production model?

Trip Type	*Cross-Classification*								*Regression*	*Other**
	Income	*Household size*	*Workers/HH*	*Auto/HH*	*Location*	*Density*	*Housing Type*	*Other**		
Home based work	☐	☐	☐	☐	☐	☐	☐	☐	☑	☐
Home based retail	☐	☐	☐	☐	☐	☐	☐	☐	☑	☐
Home based non-retail (service)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Home based school	☐	☐	☐	☐	☐	☐	☐	☐	☑	☐
Home based College/University	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Home based other	☐	☐	☐	☐	☐	☐	☐	☐	☑	☐
Non-home based	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Work based	☐	☐	☐	☐	☐	☐	☐	☐	☑	☐
Trucks	☐	☐	☐	☐	☐	☐	☐	☐	☑	☐
Commercial vehicles	☐	☐	☐	☐	☐	☐	☐	☐	☑	☐
Taxis	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

*Please specify in the box below

50. What is the form of the attraction model?

Trip Type	*Trip Rates*		*Mathematical function*	*Based on linear regression*	*Other**
	ITE	*Other*			
Home based work	☐	☐	☐	☑	☐
Home based retail	☐	☐	☐	☑	☐
Home based non-retail (service)	☐	☐	☐	☐	☐
Home based school	☐	☐	☐	☑	☐
Home based College/University	☐	☐	☐	☑	☐
Home based other	☐	☐	☐	☑	☐
Non-home based	☐	☐	☐	☐	☐
Work based	☐	☐	☐	☑	☐
Trucks	☐	☐	☐	☑	☐
Commercial vehicles	☐	☐	☐	☑	☐

*Please specify in the box below

51. Are productions and attractions balanced prior to trip distribution?

Trip Type	*Yes*	*No*
Home based work	◉	○
Home based retail	○	○
Home based non-retail (service)	○	○
Home based school	○	○
Home based College/University	○	○
Home based other	○	○
Non-home based	○	○
Other (Please specify)		

52. How are the productions and attractions balanced?

Trip Type	*Normalized to Productions*	*Normalized to Attractions*	*Average of Productions and Attractions*	*Other**
Home based work	☑	☐	☐	☐
Home based retail	☐	☐	☐	☐
Home based non-retail (service)	☐	☐	☐	☐
Home based school	☐	☐	☐	☐
Home based College/ University	☐	☐	☐	☐
Home based other	☐	☐	☐	☐
Non-home based	☐	☐	☐	☐
Other (Please specify)				

Trip Distribution

53. Does the model distribute:

Trip Type	*Person Trips*	*Vehicle Trips*	*Other**
Home based work	☑	☐	☐
Home based retail	☑	☐	☐
Home based non-retail (service)	☐	☐	☐
Home based school	☑	☐	☐
Home based College/University	☑	☐	☐
Home based other	☑	☐	☐
Non-home based	☐	☐	☐
Work based	☑	☐	☐
Trucks		☑	☐
Commercial vehicles		☑	☐

* Please specify in the box below

54. What time period impedances are used for the trip distribution model?

Trip Type	Total day	AM Peak period or peak hour*	PM Peak period or peak hour*	Mid-day or off-peak	Evening and night
Home based work	●	○	○	○	○
Home based retail	●	○	○	○	○
Home based non-retail (service)	○	○	○	○	○
Home based school	●	○	○	○	○
Home based College/University	●	○	○	○	○
Home based other	●	○	○	○	○
Non-home based	○	○	○	○	○
Work based	●	○	○	○	○
Trucks	○	○	○	●	○
Commercial vehicles	○	○	○	●	○

***AM Peak period or peak hour Times:** 6.5 **AM to** 9.5 **AM** *(enter time in decimal format - i.e. 6:30 = 6.5)*

***PM Peak period or peak hour Times:** 3.5 **PM to** 6.5 **PM** *(enter time in decimal format - i.e. 6:15 = 6.25)*

*Please specify any additional comments below:

Dest choice also has logsums from various time periods for various purposes -

55. What is the form of the trip distribution model?

Trip Type	Gravity Model	Destination Choice (Logit)	Intervening Opportunity	Fratar	Direct Demand	Other*
Home based work	○	●	○	○	○	○
Home based retail	○	●	○	○	○	○
Home based non-retail (service)	○	○	○	○	○	○
Home based school	○	●	○	○	○	○
Home based College/University	○	●	○	○	○	○
Home based other	○	●	○	○	○	○
Non-home based	○	○	○	○	○	○
Work based	○	●	○	○	○	○
Trucks	●	○	○	○	○	○
Commercial vehicles	●	○	○	○	○	○

*Please specify in the box below

56. What is the trip impedance measure?

Trip Type	Travel time over the highway network	Travel distance over the highway network	Combination of highway time and distance	Combination of highway and transit time	Logsum from mode choice model	Time plus cost over network	Other*

Home based work	○	●	○	○	○	○	○
Home based retail	○	●	○	○	○	○	○
Home based non-retail (service)	○	○	○	○	○	○	○
Home based school	○	●	○	○	○	○	○
Home based College/University	○	●	○	○	○	○	○
Home based other	○	●	○	○	○	○	○
Non-home based	○	○	○	○	○	○	○
Work based	○	●	○	○	○	○	○
Trucks	●	○	○	○	○	○	○
Commercial vehicles	●	○	○	○	○	○	○

*Please specify in the box below

logsum from time of day choice model

57. Are adjustment factors (K-factors or something similar) used in the distribution model?

Trip Type	*Yes – K-factors*	*Yes – time penalties*	*Yes – constants (in destination choice model)*	*Yes – other*	*No*
Home based work	☐	☐	☑	☐	☐
Home based retail	☐	☐	☑	☐	☐
Home based non-retail (service)	☐	☐	☐	☐	☐
Home based school	☐	☐	☑	☐	☐
Home based College/University	☐	☐	☑	☐	☐
Home based other	☐	☐	☑	☐	☐
Non-home based	☐	☐	☐	☐	☐
Work based	☐	☐	☑	☐	☐
Trucks	☐	☐	☐	☐	☑
Commercial vehicles	☐	☐	☐	☐	☑

58. To what percent of total TAZ to TAZ interchanges are K-factors applied?

Trip Type	*100%*	*75-99%*	*50-74%*	*25-49%*	*11-24%*	*5-10%*	*<5%*	*0%*	*N/A*	*Don't Know*
Home based work	○	○	○	○	○	○	○	○	●	○
Home based retail	○	○	○	○	○	○	○	○	●	○
Home based non-retail (service)	○	○	○	○	○	○	○	○	○	○
Home based school	○	○	○	○	○	○	○	○	●	○
Home based College/ University	○	○	○	○	○	○	○	○	●	○
Home based other	○	○	○	○	○	○	○	○	●	○

Non-home based	○	○	○	○	○	○	○	○	○	○
Other*	○	○	○	○	○	○	○	○	○	○

*For others, please describe below

58A. To what percent of total TAZ to TAZ interchanges are geographic barrier time penalties applied?

Trip Type	*100%*	*75-99%*	*50-74%*	*25-49%*	*11-24%*	*5-10%*	*<5%*	*0%*	*N/A*	*Don't Know*
Home based work	○	○	○	○	○	○	○	○	●	○
Home based retail	○	○	○	○	○	○	○	○	●	○
Home based non-retail (service)	○	○	○	○	○	○	○	○	○	○
Home based school	○	○	○	○	○	○	○	○	●	○
Home based College/ University	○	○	○	○	○	○	○	○	●	○
Home based other	○	○	○	○	○	○	○	○	●	○
Non-home based	○	○	○	○	○	○	○	○	○	○
Other*	○	○	○	○	○	○	○	○	○	○

*For others, please describe below

58B. To what percent of TAZ to TAZ interchanges are destination choice constants applied?

Trip Type	*100%*	*75-99%*	*50-74%*	*25-49%*	*11-24%*	*5-10%*	*<5%*	*0%*	*N/A*	*Don't Know*
Home based work	○	○	○	○	○	○	○	○	○	●
Home based retail	○	○	○	○	○	○	○	○	○	●
Home based non-retail (service)	○	○	○	○	○	○	○	○	○	○
Home based school	○	○	○	○	○	○	○	○	○	●
Home based College/ University	○	○	○	○	○	○	○	○	○	●
Home based other	○	○	○	○	○	○	○	○	○	●
Non-home based	○	○	○	○	○	○	○	○	○	○
Other*	○	○	○	○	○	○	○	○	○	●

*For others, please describe below

most districts to CBD; some district to district

59. If a Gravity Model is used, how is it applied?

Trip Type	*Singly Constrained (output attractions not forced to equal input attractions)*	*Doubly Constrained (output attractions forced to equal input attractions)*	*N/A*	*Don't Know*
Home based work	○	○	●	○
Home based retail	○	○	●	○
Home based non-retail	○	○	○	○

(service)				
Home based school	○	○	●	○
Home based College/University	○	○	●	○
Home based other	○	○	●	○
Non-home based	○	○	○	○
Other*	○	○	○	○

*For others, please describe below

Mode Choice

60. Is there a mode choice model?

Trip Type	*Yes*	*No*
Home based work	●	○
Home based retail	●	○
Home based non-retail (service)	○	○
Home based school	●	○
Home based College/University	●	○
Home based other	●	○
Non-home based	○	○
Other*	○	○

*For others, please specify

61. What is the form of the Mode Choice Model?

Trip Type	*Trip End*	*Trip Interchange*				*Other**
		Diversion curves	*Regression equations*	*Multinomial logit*	*Nested logit*	
HB Work	☐	☐	☐	☐	☑	☐
Other trip types	☐	☐	☐	☐	☑	☐

*For others, please specify

62. What modes are treated in the Mode Choice Model?

Mode	*HB Work*	*Other trip types*
Auto (generic)	☐	☐
Drive Alone	☑	☑
Auto Passenger	☑	☑
Two person auto	☐	☐
Two or more person auto	☐	☐
Three person auto	☐	☐
Three or more person auto	☐	☐
Four person auto	☐	☐
Four or more person auto	☐	☐
Transit (generic)	☐	☐

Premium transit (generic)	☐	☐
What modes are premium? i. Express or commuter bus	☐	☐
ii. Bus Rapid Transit	☐	☐
iii. Light Rail	☐	☐
iv. Heavy Rail	☐	☐
v. Commuter Rail	☐	☐
Transit by access mode *i. Walk to transit* a. Walk to local	☑	☑
b. Walk to express	☑	☑
c. Walk to premium	☐	☐
d. Walk to rail	☑	☑
e. Other	☐	☐
ii. Drive to transit a. Drive to local	☑	☑
b. Drive to express	☑	☑
c. Drive to premium	☐	☐
d. Drive to rail	☑	☑
e. Other	☐	☐
Local Bus	☑	☑
Express or commuter bus	☑	☑
Bus Rapid Transit	☑	☑
Light Rail	☑	☑
Heavy Rail	☐	☐
Commuter Rail	☑	☑
Walk	☐	☐
Bike	☐	☐
Other*	☑	☑

*For others, please specify

non-motorized=walk+bike

63.	**Is there a separate mode-of-access model?**
○	Yes
◉	No

64.	**For what conditions are bias constants, or similar adjustments, applied in the mode choice model?**	
	HB Work	***Other trip types***
By mode	☑	☑
CBD/Non-CBD	☐	☐
Geographic area (production or attraction)	☐	☐
Area-to-area		

(production and attraction)	☐	☐
Other*	☑	☑

*For others, please specify

income category, person type, joint tour, #

65. What impedances (travel times) are used for the mode choice models?

Trip Purpose	*Total day*	*AM Peak period or peak hour**	*PM Peak period or peak hour**	*Night and/or evening*	*Mid-day or off-peak*
Home based work	☐	☑	☐	☐	☑
Home based retail	☐	☑	☐	☐	☑
Home based non-retail (service)	☐	☐	☐	☐	☐
Home based school	☐	☑	☐	☐	☑
Home based College/University	☐	☑	☐	☐	☑
Home based other	☐	☑	☐	☐	☑
Non-home based	☐	☐	☐	☐	☐
Other**	☐	☐	☐	☐	☐

***AM Peak period or peak hour Times:** 6.5 **AM to** 9.5 **AM** *(enter time in decimal format - i.e. 6:30 = 6.5)*

***PM Peak period or peak hour Times:** 3.5 **PM to** 6.5 **PM** *(enter time in decimal format - i.e. 6:15 = 6.25)*

*Please specify any additional comments below:

**Please specify other trip purposes not listed in the box

Managed Lanes

66. Is the choice of toll road vs. non-toll road treated as a mode choice? ○ Yes ◉ No ○ N/A ○ Don't Know

67. Are the cost of tolls included in the following?

	Yes	*No*	*N/A*	*Don't Know*
Trip Generation	○	◉	○	○
Trip Distribution	◉	○	○	○
Mode Choice	◉	○	○	○
Trip Assignment	◉	○	○	○

68. Are HOV's separately assigned? ◉ Yes ○ No ○ N/A ○ Don't Know

Trip Assignment

69. What was the source of the data used for model validation?

Traffic Counts

70. For what time periods are highway trips assigned?

☐	Total day
☑	AM Peak period or peak hour*
☑	PM Peak period or peak hour*
☑	Night and/or evening
☑	Mid-day or off-peak

***AM Peak period or peak hour Times:** 6.5 **AM to** 9.5 **AM** *(enter time in decimal format - i.e. 6:30 = 6.5)*

***PM Peak period or peak hour Times:** 3.5 **PM to** 6.5 **PM** *(enter time in decimal format - i.e. 6:15 = 6.25)*

*Please specify any additional comments below:

71.	**Are transit trips assigned?**	◉ Yes	○ No	○ N/A	○ Don't Know

72.	**What assignment method is used to assign transit trips?**
○	Minimum time
○	Minimum weighted time
◉	Minimum impedance
○	Stochastic
○	Other (Please specify)

73.	**Are the time periods used for transit assignment the same as for traffic assignment?**
◉	Yes
○	No

74.	**Which method is used for traffic assigment?**
○	All-or-nothing
◉	Equilibrium
○	Iterative Capacity Restraint
○	Incremental Capacity Restraint
○	Other*

*Please list any comments below:

NOTE: IF MULTIPLE TRAFFIC ASSIGNMENTS, REPORT ONE HAVING SMALLEST CLOSURE TOLERANCE OR GREATEST NUMBER OF ITERATIONS

Closure Tolerance for "Equilibrium" Assignment 0.1 %

Number of Iterations to achieve Closure for Validation Year 16

Number of Iterations to achieve Closure for Forecast Year 20

Number of Iterations for "Iterative Capacity Restraint" Assignment

Number of Iterations for "Incremental Capacity Restraint" Assignment

75.	**Do you have different networks for different periods of the day?**			
	Yes	***No***	***N/A***	***Don't Know***

	Highway	●	○	○	○
	Transit	●	○	○	○

76.	For what percent of the links are traffic counts available for validation of forecast highway link volumes by functional class?								
		100%	*75-99%*	*50-74%*	*25-49%*	*1-24%*	*0%*	*N/A*	*Don't Know*
	Freeway	○	●	○	○	○	○	○	○
	HOV lanes	○	○	○	○	○	○	●	○
	Major arterial	○	○	○	●	○	○	○	○
	Minor arterial	○	○	○	●	○	○	○	○
	Collector	○	○	○	●	○	○	○	○
	Local street mileage	○	○	○	○	○	○	○	○

77.	How many transit passenger counts are available for validation of transit volumes by service type?								
		100%	*75-99%*	*50-74%*	*25-49%*	*1-24%*	*0%*	*N/A*	*Don't Know*
	Rail transit	○	○	○	○	○	○	●	○
	Express/regional bus	●	○	○	○	○	○	○	○
	Local bus	●	○	○	○	○	○	○	○
	Commuter Rail	○	○	○	○	○	○	●	○

78.	What speed data are available to check the speeds on links?
	None

79.	Are station boardings or transit route ridership figures available?	● Yes	○ No	○ N/A	○ Don't Know

80.	From the model validation, what is the percent root mean square error comparing traffic counts with the highway link volumes for all links with counts for each functional or volume class?	
	RMS Error Percentage	Comments
Freeway	18 %	
Expressway	%	included in major collec
Major arterial	22 %	
Minor Arterial	31 %	
Collector	41 %	41% major collector, 58
Local street	99 %	
Total-All link types	40 %	

Additional Questions

81.	Are non- motorized trips modeled?	● Yes	○ No	○ N/A	○ Don't Know

82.	Are truck trips modeled?	● Yes	○ No	○ N/A	○ Don't Know

83.	If truck trips are modeled, how are they modeled?

○	Growth Factors
●	Fratar
○	Synthetic O-D table
○	Other (Please specify)

83A.	**If truck trips are modeled, when was the truck model developed?**	2004

84.	**Is freight movement modeled?**	○	Yes	●	No	○	N/A	○ Don't Know

85.	**Is there feedback of highway and transit travel times to the following? (Check all that apply)**				
		Yes	***No***	***N/A***	***Don't Know***
	Auto ownership	●	○	○	○
	Trip Generation	●	○	○	○
	Trip Distribution	●	○	○	○
	Mode Choice	●	○	○	○
	Land use	○	●	○	○
	Please list any comments below.				

86.	**Are the travel model results post-processed for use by EPA Mobile Model or the California EMFAC model and for the preparation of mobile source emission inventories?**
	● Yes
	○ No

86A.	**For emissions modeling, do you use any of the following procedures to adjust assigned VMT to match HPMS?**		
	☐	Refine model calibration	
	☐	Adjust link volumes produced by the model	
	☑	Add VMT for local roads	
	☑	Other, please explain	Adjust emission results based on base year

86B.	**For emissions modeling, do you make any adjustments to VMT to reflect seasonal variations in traffic?**	
	●	Yes
	○	No

86C.	**For emissions modeling, do you use any of the following procedures to adjust the volumes and speeds that are output from the travel model?**		
	☐	Use existing model output volumes and speeds in conjunction with MOBILE or other emission model defaults	
	☑	Use locally derived time-of-day factors or other post-processing procedures to obtain hourly volumes and speeds	
	☐	Other, please explain	

86D.	**To what extent do your travel model procedures, related to emissions**

modeling, account for different vehicle types in the traffic stream?

- ( ) Traffic assignments are not stratified by vehicle type
- (•) Traffic assignments are stratified by vehicle type, but this stratification is not carried forward into the MOBILE or other emission model
- ( ) Traffic assignments are stratified by vehicle type, and this stratification is used separately in emissions calculations
- ( ) Other, please explain

87.	**Are you working toward any activity or tour-based approaches to replace the existing model?**	( )	Yes	( )	No	(•)	N/A	( ) Don't Know

88.	**Have any backcasting exercises been performed to verify that prior years can be properly replicated?**	( )	Yes	(•)	No	( )	N/A	( ) Don't Know

89. What are the best features of your models?

90. Which features of your models are most in need of improvement?

Time of running, and crashes due to software-hardware

91. What software package(s) is used for travel forecasting?

- [ ] EMME/2
- [ ] Transcad
- [x] TP+
- [ ] Tranplan
- [ ] CUBE/Voyager
- [ ] QRS II
- [ ] TMODEL
- [ ] VISUM
- [ ] TRANSIMS
- [x] Other (Please specify)

Please provide link(s) to website(s) with documentation of your models in the box below

Please provide comments on your experience with this survey

Survey Status

- [x] Survey Complete

Finish

Appendix B: Panel Questions

1. Which agency (or consultant) performs the travel forecasts for the long- range plan, TIP, and conformity? Is this done using a model?
2. Who prepares the regional forecasts for population, households, and employment? What methods are used for these forecasts?
3. How are forecasts of population, households, and employment allocated to subareas or zones?
4. When was the last home interview survey conducted? What was the method (e.g., CATI)? How many households were surveyed? What was the response rate? What percent of the total population is this? Are revealed preference or stated preference surveys used to gather information for model development?
5. How many zones are modeled? How coarse or fine is the grain of the zone structure?
6. How completely do the networks represent transportation facilities, e.g What fraction of freeway, major arterial, minor arterial, collector, and local street mileage is coded in network? Are HOV facilities explicitly coded in network? What proportion of rail transit, express/regional bus, and local bus routes are coded in network. Are bus transit facilities explicitly coded in network?,
7. Are vehicle ownership and household income inputs to the modeling process? If so, at what geographic level, and how are they forecasted?
8. What trip types are represented in the trip generation models? What is the form of the models? How are productions and attractions balanced?
9. What is form of the trip distribution model? How are productions and attractions converted to an O/D table?
10. What transit modes are modeled and what is the form of the mode choice model?
11. What time-of-day characteristics are represented for traffic assignment?
12. Which method is used for traffic assignment?
13. How is feedback of highway and transit travel times to trip generation, distribution, or mode choice accomplished?
14. How are the travel model results post-processed for use by the EPA Mobile Model or the California EMFAC model and for the preparation of mobile source emission inventories?
15. When was the model last validated, and when was the last Long Range Plan Forecast prepared?
16. How many traffic counts are available for validation of forecasted highway link volumes, by functional class? How many freeway and arterial counts are there per road-mile? What speed data are available to check link speeds? How many station boardings or transit route ridership figures are available?
17. From the last model validation, what is the percent root mean square error comparing traffic counts with highway link volumes for all links with counts and for each functional or volume class.
18. What features of the model are innovative or state of the art?
19. Are you working toward any activity or tour-based approaches to replace the existing trip distribution model? If so, have any backcasting exercises been performed to verify that prior years can be properly replicated.
20. How are non-motorized travel and freight movement modeled?
21. What are the best features of your models? Which features are most in need of improvement?

APPENDIX C: Summary of Selected Literature Review, January 2006

To assist in understanding the current state-of-the-practice in travel area forecasting used by Metropolitan Planning Organizations (MPOs), and to provide the committee with background on how others may have characterized either the state-of the practice or acceptable practice, a review was undertaken of previous applicable literature. The materials reviewed included both sources identified by the Committee in the Transportation Research Board's Request for Proposals on Determination of the State of the Practice in Metropolitan Area Travel Forecasting and other materials identified by the contractor. Literature detailing the state-of-the-practice for travel demand modeling was available from a variety of sources, primarily from or related to medium- and large-sized MPOs nationwide.

Literature addressing travel forecasting loosely falls into four broad categories: articles or reports that provide general overviews of the state-of-the-practice but tend to avoid judgments about the quality of these procedures (general guidelines); articles or reports that that discuss the procedures in use but offer judgments about the quality of these procedures and make recommendations for improvement (general critiques); comparison studies of the procedures of one MPO in relation to several peer MPOs (peer comparison); and expert reviews of specific MPO models (peer review). While the literature in each of these categories addresses the same topic—travel demand modeling procedures—the methods and aims of the categories of articles differ.

The first category of articles provides general guidelines or recommendations for MPOs to bring their procedures up to the state-of-the-practice. The reports reviewed in this group do not reflect the findings of any quantitative survey of MPOs but rather were developed by knowledgeable professionals based on their experiences working with MPOs. These articles provide examples of efforts to either broadly define the state-of-the-practice or make general recommendations to improve shortcomings in prevalent modeling techniques. The second category—critiques of the practice—focus on deficiencies, as seen by the authors, in the state-of-the-practice. These deficiencies tend to stress the structural inability of the models to deal with certain types of issues, particularly the lack of true behavioral analysis of traveler decision making and the relationships between the transportation system and the patterns of land development. In the third category, each article uses a peer comparison to evaluate the procedures of a specific MPO's travel demand model. These comparison studies use the practices of a small group of peers to establish general acceptable practices and then to determine if their specific model is adequate. The final category—peer-review articles—consists of professional and expert reviews of specific MPO travel demand models. These reviews do not depend on a direct comparison to peer MPOs' models, but rather rely on the expertise of representatives of peer MPOs and modeling professionals to evaluate their modeling procedures and make recommendations for improvements. Despite the different motivations authors may have had in producing their articles, each provides insight into the state-of-the-practice.

General Articles - Guidelines

Literature dealing with the state-of-the-practice in general terms tends to serve at least one of two purposes. First, it is intended to provide MPOs with guidance as to which specific procedures are current and acceptable. Second, it raises issues with aspects of prevalent procedures that need improving. Although no article claims to be able to provide definitive modeling procedures, literature dealing generally with the state-of-the-practice provides an overview of what authors have classified as state-of-the-practice, and the issues authors have identified with some procedures considered state-of-the-practice.

Boyce and Williams provide a comprehensive overview of both the history and the perceived current state of travel forecasting as of early in the first decade of the twenty-first century (1). The authors do not attempt to describe travel forecasting methods in great detail. Rather, they present a detailed history of the evolution of the four step modeling procedure. They note that the four-step process developed in the U.S. based largely on methods relying on empirical data and has gradually incorporated elements founded in more general principals. Notable examples are the use of discrete choice methods, especially nested logit, for mode choice and equilibrium assignment. The authors agree with a previous finding by the Hague Consulting Group that "…there is no generally accepted state of the art or state of the practice in travel forecasting but rather large classes of models and model systems, some at distinct stages of development and in a process of continued refinement." They argue that the trend in model development has been to ever greater incorporation of disaggregate techniques so that the detailed relationships between traveler and household behavior can be applied to the analysis of transportation system issues, such as response to congestion, time-switching, and costs. They do note that it is necessary to consider the costs and benefits of models at different levels of resolution and to maintain a balance between over-elaboration and misspecification. They also make a strong case for validation that addresses not only replication of an observed base-year condition but consideration of elasticity measures as they affect forecasts. Activity- and tour-based models are seen as topics showing considerable advances.

The final conclusion of Boyce and Williams is particularly noteworthy. From a very practical standpoint they state, that in the exercise of comparing the procedures available for travel forecasting "…nothing is obsolete until it is replaced by a model system fully tested in the arena of practice."

Focusing more on the details of travel demand modeling, Greig Harvey and Elizabeth Deakin prepared an overview of the state-of-the practice in *A Manual of Regional Transportation Modeling Practice for Air Quality Analysis* (2). This 1993 document prepared for the National Association of Regional Councils provides the most comprehensive overview of travel demand modeling state-of-the-practice of any of the literature. This manual was specifically intended to serve as a resource for MPOs evaluating the need for improving their transportation modeling procedures in order to meet the requirements of EPA guidance for mobile source air quality analysis. The authors focus on identifying and describing current acceptable forecasting procedures used to model travel demand and encouraging all MPOs to modernize their practices. They also highlight procedures that are not recommended. Although the authors suggest methodologies for applying model procedures, they stop short of attempting to set standards for modeling or prescribing a single modeling approach. Instead they emphasize that diversity exists between models for different regions because of the various regional attributes, such as transit importance, levels of congestion, concern about growth, and

complexity in urban and rural development patterns. Therefore, they believe that good modeling practice should be customized to the key issues and available resources of an area.

The authors describe what they identified as both basic and advanced practices for nine key modeling steps:

1. Regional Economic and Population Forecasts
   Use of regional economic and population forecasts published by the federal government is recommended. The authors refute the legitimacy of using trends-extended or "bottoms-up" forecasting. Advanced methods can be applied to expand on the federal forecasting, including demographic models, tracing industrial growth, life expectancy data, educational attainment based on economic levels, and employment rates. The authors state that ideally, these forecasts could be used to create both "high" and "low" forecasts, both of which would be analyzed.

2. Employment and Population Allocation
   Employment and population allocation approaches should be negotiated based on employment and population data and trends as well as information on land availability, land use occupancy, and zoning information. Allocations based on local aspirations are frowned upon. Advanced mathematical models using zone-level time series data on population, employment, land availability, and accessibility are also acceptable.

3. Network Descriptions
   Network descriptions are the basis of travel times and should be as detailed as possible, at a minimum including all facilities to the minor arterial or major collector level and encompassing routes that carry at least 85 percent of all interzonal traffic volume. The authors suggest expanding network descriptions to include additional detail such as rail and bus transit networks, HOV lanes, ramp meters, and intersection details.

4. Vehicle Ownership
   Vehicle ownership models predict the number of passenger vehicles owned by (or available to) households in a particular travel analysis zone or sub-area. Household data can be used to predict vehicle ownership, and basic practice dictates that income and household size are the primary variables determining the number of automobiles per household. Advanced practice also often includes consideration of variables such as licensed drivers, gender, labor force participation, housing type, employment density in residential zone, area type and density, and accessibility.

5. Trip Generation
   The most common trip generation technique is cross-classification because it is quantitatively superior to linear regression, but regression techniques may be useful if they are non-linear. Depending on the sophistication of the model, the modeler can calculate either person trips by vehicle or total person trips, both of which are acceptable. Total person trips are the more basic unit because a small number of economic and life-cycle factors appear to account for the bulk of variation, but they lead to more complex models in later steps.

6. Trip Distribution
   Acceptable modeling techniques include the Fratar growth-factor method for very basic models and the more common gravity model method. The gravity model technique is considered flawed because of inherent inaccuracy in the calibration procedure and requires the application of K-factors to account for these inaccuracies. Advanced models are based on the gravity model technique, but run more complex and encompassing disaggregate logit destination choice models, possibly including K-factors depending on the accuracy of the utility functions. The advantage of the logit models lies in their ability to account for a variety of zonal impedances regarding destination choice.

7. Mode Split
   The mode split is calculated via discrete choice multinomial logit or nested logit models. The logit model assumes individuals select the mode of travel based on characteristics of the mode, including dollar costs of travel and various weighted components of travel time. Multinomial logit models have problems when alternatives are closely related. Probit models can solve these problems, but software using this method is scarce. Nested logit is considered a preferred technique as it allows for multiple levels of choice (i.e. walk vs. transit vs. auto). According to the authors, walking and bicycling modes of travel are an integral component of the mode split step, but these options are considered by only a small number of metropolitan areas. Additionally, while research indicates that comfort, convenience, and reliability are critical variables to mode choice determination, these variables are rarely considered in most models.

8. Peaking Factors
   The application of peaking factors should be done based on data from specific facilities rather than based on a regional average for many roadways. Typically, application of the time-of-day factors (TODF) is completed either before the trip distribution or mode choice steps. Application of TODFs after mode choice is not recommended, except possibly in extremely congested models.

9. Trip Assignment
   The customary approaches include incremental capacity restraint and equilibrium assignment. The all-or-nothing method is not considered valid. Advanced software packages include more realistic speed estimates for congestion and queuing analysis techniques.

Beyond the nine model elements, the authors provide further recommendations for improving travel demand modeling. The inherent difficulty of creating an accurate model arises from beginning the process with unreliable interzonal travel time estimates. Therefore, an iterative process of re-running the trip distribution and mode choice modules can be undertaken until the initial and final travel time matrices show only minor differences. No standard model convergence criteria are stated, but when various alternatives are examined, key indicators should reach the same minimum level of convergence for all alternatives.

The authors also suggest using a variety of measures to validate the model, including estimated vs. measured volumes, vehicle-miles traveled, vehicle-hours traveled, congested speeds, travel times, and delay. Advanced techniques could further improve the model, such as

"Root Mean Square Error" (RMSE) calculations coupled with reasonable thresholds for the RMSE values. Acceptable error guidelines from FHWA advise that all measured counts should be within 5 to 10 percent of the sum of model estimates.

Finally, the authors advocate the use of accurate local survey data. They emphasize the importance of a document containing nationwide guidelines for all MPOs to use in carefully designing household travel surveys.

Harvey and Deakin's manual provides an understanding of the state-of-the-practice as of 1993. Many of the procedures identified and recommendations made in their manual remain true today. A more recent look at travel forecasting procedures goes beyond Harvey and Deakin's project. The report *Perspectives on Acceptable Practice for Travel Forecasting Procedures Used in Metropolitan Areas Subject to 40 CFR 93.122(b), Summary of Discussions of July 24 and 25, 200* prepared by BMI-SG, does not only review current modeling practices, but also attempts to determine minimal acceptable standards of practice (3). Although these reports are similar—they both generally identify the state-of-the-practice—the latter provides MPOs with more specific instruction on the necessary modeling procedures they should consider incorporating into their own models.

This 2003 report summarizes the findings of a panel of travel demand forecasting professionals regarding minimal acceptable standards of practice for meeting 40 CFR 93.122(b) (Conformity to State or Federal Implementation Plans of Transportation Plans, Programs, and Projects Developed, Funded or Approved Under Title 23 U.S.C. or the Federal Transit Laws) and establishes basic parameters to assist MPOs in travel forecasting. The document is structured to present a series of tables and descriptions of each component of the travel demand process and then list the basic standards of practice as well as both advanced and emerging techniques for MPOs to consider and to which they should aspire. The analysis is not based on formal studies of the failings or successes of travel demand forecasting in any specific settings but rather on the general experience of the group of professionals. Throughout, the report recognizes that MPOs will have different modeling requirements based on the transportation planning or analysis issues that are of importance in their specific regions.

The current standard of practice model relies on vehicle trips in the most basic models or motorized person trips in areas with or planning for significant transit, HOV, or ridesharing activity. Trip productions are generated at the household level, typically using cross-classification methodology, and trip attractions may be generated using either cross-classification or linear regression. Trip distribution and mode choice are developed using individual traveler data and then calibrated and assigned at the TAZ level.

Basic trip purposes consist of home-based work, home-based other, non-home based trips with truck, and external-external trips treated as separate market segments. Travel is modeled on a daily basis, preferably modeling travel in the peak period before mode choice allocations. Socio-economic factors affecting travel habits must be reflected in procedures for the trip generation and mode choice either by market segmentation or stratification of variables in the model functions. In areas with a significant transit presence or plans, separate models for mode choice and auto occupancy are required. Finally, zone-to-zone travel impedances must be in reasonable agreement with the travel times estimated from the final assigned traffic volumes. Therefore, evaluation of the input and final impedances, followed by adjustment and iteration, if necessary, is standard practice.

The report identifies standard practice for each of the following model components (which differ from Harvey and Deakin's nine model components) as constituting the current (2003) state-of-the-practice:

1. Trip Generation
   Based on rates developed from household surveys, trip productions are generated at the household level, typically using cross-classification methodology. Trip attractions are usually generated at the zone level using either cross-classification or linear regression for simpler data sets. Balancing or equalizing the total number of projected trip productions and attractions before trip distribution is considered standard.

2. Trip Distribution
   The state-of-the-practice in trip distribution is clearly the Gravity Model. Market segmentation matching the trip generation trip purposes is required and further segmentation by socio-economic groups, such as work trips stratified by income levels, is recommended. Highway travel time is the minimal standard for impedance and inclusion of transit time, at the least, is recommended. Use of a doubly constrained model for work trips in common and required. Single constraint for other trip purposes is acceptable. The use of K-factors to equalize estimated and observed trips is acceptable if limited to large-scale area-to-area movements for which independent data exist.

3. Mode Choice
   Mode choice models are not an absolute requirement of the travel demand modeling process for regions without significant transit usage. Therefore, mode choice models only apply to regions operating more advanced models with person trip capabilities. For the most rudimentary of these models, auto occupancy factors, by purpose, would suffice for acceptable mode choice practice. However, models examining strategies that affect auto-occupancy and transit usage should develop a mode choice model allocating trips into all possible motorized and non-motorized travel modes. Locally estimated impedance coefficients are preferred to borrowed values. Sufficient network detail representing access to transit within zones is also required.

4. Time of Day Models
   Basic practice requires at least the morning peak period, evening peak period, and off-peak period to be modeled. Household survey data are typically used to derive factors to convert from daily production-attraction trips to origin-destination trip tables by time period. Acceptable practice currently does not account for peak spreading.

5. Highway Assignment
   Acceptable practice requires some form of capacity restraint on the traffic network to re-compute assignment as links approach their capacity, but does not require equilibrium assignment specifically. Model calibration to examine resultant travel volumes and link capacities and determine accurate congestion speeds is a critical (and difficult) task. For regions with travel restrictions for certain subsets of traffic, the ability to analyze multiple trip tables simultaneously is necessary. Use of a standard volume delay function, or functions stratified by facility type, are good practice.

6. Land Use
   As the direction of travel demand modeling becomes more dependent on land use modeling, the use of local population and employment data and local agency travel forecasts based on these data are being phased out. Fully maintainable land use models integrated with the travel demand model are suggested to replace the current state-of-the-practice.

7. Highway Network
   In the model highway network, all roadways to the minor arterial level at a minimum should be included. Similarly, all regionally significant projects must be included, covering all principal arterial highways and fixed guideway transit facilities, at minimum. Initial travel time speeds for adjustment functions should be based on the uncongested, free-flow speeds, ideally obtained through travel time runs rather than roadway classifications by others.

8. Transit Network
   All regionally significant projects including fixed-guideway service and major bus routes must be included. Representation of the network must also include several transit-based time categories, such as walking drive access, in-vehicle, and waiting. Both base-year and forecast travel times can acceptably be based on transit agency operational information, but preferred practice is to relate forecast travel times for buses to the forecast highway speeds. Park-ride facilities must be included in the network representation, with trips assigned to the highway network.

9. Model Development and Validation
   In the absence of specially collected local household data, models may acceptably be based on the functional relationship in other metropolitan areas with limited calibration using local data from the CTPP and NHTS. Traffic counts from local highway agencies, HPMS, and transit ridership data should be used to validate results. Current standards only require reasonable correlation between observed count data and estimate traffic volumes. Documentation should include detailed discussion of the various model inputs and possible changes to those inputs as well as the validity of results when compared to observed data. Users' Guides are not currently required, but should be a priority for future models.

The emerging practice for travel demand models primarily involves tour-based modeling, which accounts for chaining of person trips to multiple destinations. These models allow for much greater detail derived from more comprehensive roadway and transit network attributes and the use of discrete choice logit models to be applied to the trip generation, trip distribution, and mode choice components. While basic models should show correlation to at least one socio-economic factor (income, auto ownership, etc.), sensitivity to a comprehensive list of socio-economic factors, land-use mix, pedestrian environment, and accessibility to jobs is a hallmark of more advanced choice models. Research into poorly understood areas such as peak spreading, trip chaining, and adaptive assignment of link volumes is hoped to improve detail-oriented

modeling capabilities and the validity of modeled results by improving correlation between estimated and observed traffic conditions.

Although not intended as a resource for MPOs in their transportation modeling efforts, Thomas Walker in *A White Paper on Metropolitan Planning Organization (MPO) Land Use, Transportation and Air Quality Modeling Needs in the New Federal Transportation Bill* also reported on current modeling practices (4). The study was conducted by the National Association of Regional Councils (NARC) in conjunction with the Delaware Valley Regional Planning Commission (DVRPC). These organizations conducted a national survey to ascertain current modeling practices.

The survey focused on three aspects of modeling required under the Intermodal Surface Transportation Efficiency Act (ISTEA) and the Clean Air Act: socioeconomic and land-use projection, travel demand forecasting, and mobile source emission calculation. The findings were used, in part, to help shape NARC's position on pending reauthorization legislation. Thirty-one regional planning agencies responded to the survey – 8 classified as large (over 500,000 population) and 23 classified as small. The report documents such factors as: forecasting responsibilities; socioeconomic and land-use forecasting procedures; travel demand forecasting procedures; mobile source emission estimation procedures; travel demand model validation; and, uses for travel forecasting model output. The report also documents the proportion of responding organizations planning specific improvements in land use modeling and transportation modeling.

General Articles - Critiques

Boyce and Williams address the general theory and structure of travel forecasting models, while the Harvey and Deakin, BMI-SG, and Walker articles all attempt to provide both general overview of the state-of-the-practice and specific details about the methods that constitute the practice. The last three articles are concerned specifically with providing MPOs with information to gauge whether their models are acceptable for air quality conformity. This is, in part, an indication of the importance that the requirement for conformity analysis and the subsequent EPA regulatory activity has had on spurring assessments of travel demand forecasting procedures. These articles also provided recommendations and advanced practices to varying degrees. Several other authors—while also concerned with the general state-of-the-practice—focused on specific problems and issues they identified with conventional travel demand modeling. Many of these authors also identify state-of-the-practice procedures, but primarily to establish problems with those procedures. These authors raise several important concerns with current travel forecasting, and suggest many solutions that go beyond the current state-of-the-practice. Addressing these concerns in future models will help improve the accuracy of travel demand modeling.

Robert Johnston's chapter, "The Urban Transportation Process," in *The Geography of Urban Transportation* provides an overview of the history of the travel demand modeling process (5). The history of the process helps to explain some of the conventions in currently used in travel models, which he believes are inadequate to accurately forecast travel demand.

Starting in the 1960's federal laws required a transportation planning process which resulted in the establishment of the Urban Transportation Modeling System (UTMS). The UTMS standardized the four-step modeling process: trip generation, trip distribution, mode choice, and route assignment. Under the original guidelines, MPOs established regions, subdivided into 100 to 2,000 zones comprised of census blocks or tracts. Networks were

designed by the MPO to represent all the major roadways and transit lines. Finally, the MPO conducted random household surveys within the model region to identify trips made in the region by time, mode, route, destination, and purpose. This data are then fed into the four-step process to model travel behavior in the region.

Generally, models were run on a 20-year horizon for facility planning and run for intermediate years with emissions reduction deadlines. The primary focus of the original models was to determine where congestion was growing and plan for future roadways to alleviate this congestion. In the 1970's and 1980's, modeling practice advanced statistically with the use of disaggregate discrete choice models for mode choice. By the 1990's, as a result of the 1990 Clean Air Act, air quality had become an important focus of the models' use. Requirements of the Clean Air Act led to advancements and increased complexity in the modeling structures regarding travel speeds, projections of land use in each zone, investigation of Transportation Control Measures (TCM), and consideration of socio-economic inequalities. The general result of the new policies was an advancement of the models run by large MPOs, with the medium-sized MPOs lagging behind.

The author believes that the current state-of-the-practice in travel modeling (2004) only crudely represents real-world conditions. He characterizes the problems with the state-of-the-practice for each of the four basic travel model steps as follows:

1. Trip generation is represented poorly because a large variety of trip types are ignored, especially for non-motorized travel, and land use and accessibility is not accounted for.
2. Trip distribution is rudimentary because trips are modeled individually (not sequentially), household income is not matched to job type, and many models do not feed speeds from the assignment phase back into the trip distribution.
3. Disaggregate models for mode choice are good, but smaller MPOs do not use them, or omit this step entirely, and non-motorized travel is often ignored.
4. Travel assignment is inaccurate because the road capacities and speeds are poorly represented, resulting in greater error for the final projections.

The author also suggests features for which new submodels should be created, including auto ownership, trip chaining, time of travel, location of land development, location of workplaces, and location of households. Various recommendations for expanding and improving the state-of-practice for travel demand models are also given.

As the foundation for the modeling process, the author advocates for a shift in planning policy and improved spending on the pre-analysis phase. He suggests the following improvements:

1. MPOs should view their objective as "maximizing accessibility" rather than simply "widening congested roadways."
2. Trip making should be viewed simply as a way to access activities, which would lead to policy initiatives encouraging mixed-use developments. Mixed-use developments inherently increase accessibility by conglomerating the types of activities (destinations) that are currently more spread out.
3. Expanding the list of alternatives that are modeled, particularly to include all transit alternatives, which would improve the MPOs' evaluation regional improvement.
4. Measures of comparative aggregate economic welfare should be included in modeling.

5. Data collection should be ongoing, including regularly conducting the household and company surveys and increasing land use data collection.

The author also recommends inclusion of a land-use model coupling forecasted land-use patterns with transportation facility changes, rather than the current judgmental process used to assign future land use. Trip generation should be expanded to include pedestrian and bicycle modes and as many trip making purposes as is feasible, including variables such as auto ownership, residential density, and residential parking costs.

Trip distribution should be run through "full-feedback" until all steps have the same travel speeds and volumes. Avoiding "full feedback" results in two problems:

1. Greater reported congestion, which may provide false justification for facility improvements
2. A model which is logically and legally indefensible

Additionally, destination choice distribution models are considered more accurate than the method of iteratively fitting trip tables. The discrete mode choice models used by most MPOs are good, but ideally should include non-motorized modes and land-use variables. Traffic assignment networks need to be "cleaned" to correct errors in link capacities and other attributes, for which accurate up-to-date data is extremely important.

The current trends in modeling include the micro-simulation of travel, goods shipment, households, and firms with land, developers, and floor space demand all represented. GIS-based management and display technology is growing. Both travel and land-use modeling is moving toward discrete time and space models with household coded by address and firms by block or tract.

Unlike the previous authors, Johnston is not looking to what is common practice to advise MPOs in their modeling endeavors. Instead he is critically examining common practices to evaluate if those practices are adequate to accurately predict travel. This approach is useful in directing MPOs and travel forecasting professionals toward components in models that need improvement, further study, or the development of new procedures.

Similar to Johnston, in their article "Integrated Urban Models for Simulation and Transit and Land Use Policies," Eric Miller, David Kriger, and John Hunt identified the need to better integrate land-use in transportation models (6). These authors provide guidelines for the implementation of integrated land-use transportation models in current practice and on a long-term horizon. Integration of a land-use model within transportation demand models is a result of recent legal requirements, advancements in the understanding of how land use affects regional transportation, interdependence of land-use and transportation policies, the importance of accurate transit forecasts, and the need to increase the role of economic decisions.

The authors frame their argument for the development of land-use transportation models in terms of the relationship between transit and land use. They list seven "urban form" factors that affect travel activity: residential density, transit supply, automobile ownership, socioeconomics, employment density, accessibility, and neighborhood design. The authors feel that the effects of transit supply, automobile ownership, socioeconomics, and employment density are all underestimated within current modeling practice and that these factors should be incorporated into land-use transportation models to a greater extent. Conversely, they argue that neighborhood design is overestimated to some extent and that peoples' trip-making activities are

far to complex and varied to be explained completely by neighborhood design. To complete their discussion of the land use-transit relationship, the authors list four attributes of transit's effect on urban form:

1. Fixed, permanent transit systems have the most significant effect.
2. Transit's effects are measurable only in the long-term.
3. Transit's effects on land and development markets (not land values) must be considered.
4. Transportation facilitates development but does not cause development.

The ideal integrated urban model should be based on sound theory and data; flexible enough to tailor to the needs and inputs of the individual MPO using it; and practical both to operate and present. The authors envision an integrated model that is sensitive to a wide range of land use and transportation policies and will be able to trace the direct and indirect effects of any of these policies through time and space. Moreover, they feel that this type of model is within reach of our current and emerging technologies.

The authors then begin an evaluation of existing cutting edge integrated models currently in use throughout the world. They list three well known models in the U.S. (ITLUP or DRAM/EMPAL, MEPLAN, and TRANUS), which are commercially available and established. Three others (MUSSA, NYMTCLUM, and UrbanSim) are at least practically operational and contain a significant market representation. A detailed comparison of the models revealed that all fall short of the ideal to varying extents because of excessive spatial aggregation and reliance on static equilibrium assumptions, overly aggregate household representation instead of individuals as trip-makers, and a lack of endogenous demographic and automobile ownership processes. Also, the authors specifically point to reliance on the four-stage model method as a shortcoming and suggest a new generation of integrated models will need to be developed to achieve the ideal model.

The first recommendation is a classification system of six various modeling capabilities (with the sixth representing the ideal model), which would allow MPOs to identify their current state and outline an appropriate plan for future development. The authors include a table of relatively specific benchmark capabilities, but the most accessible representation of this system is a classification table with the land use model capability levels along the Y-axis and levels of travel demand modeling along the X-axis, as shown below:

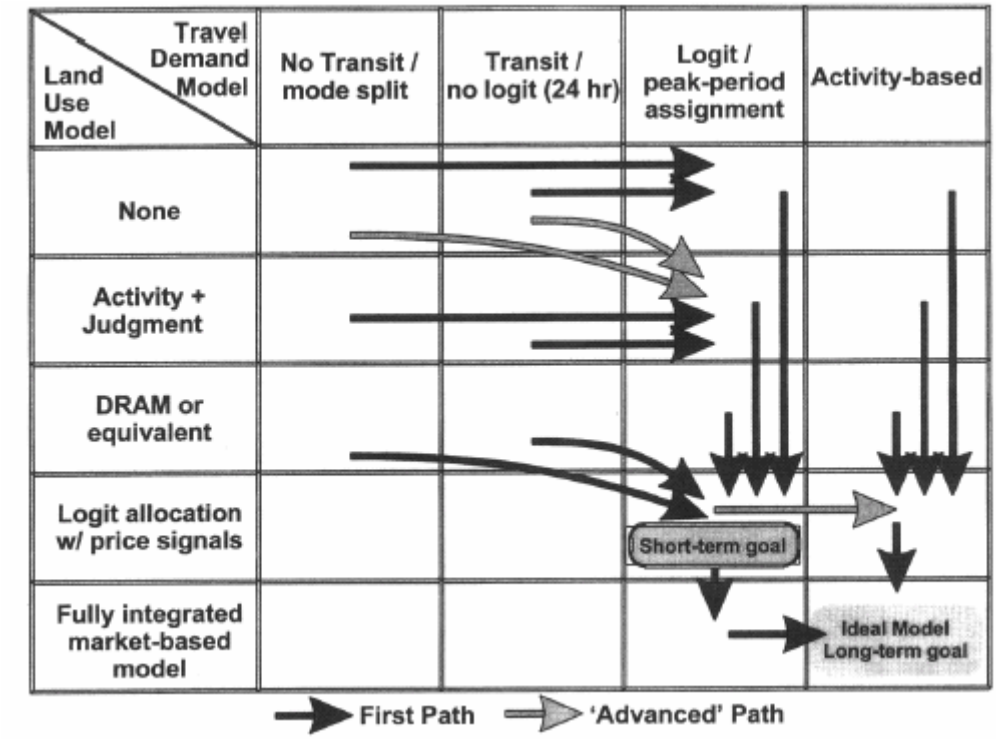

Figure 3: A taxonomy of transportation-land use modeling capabilities; TCRP Report 48, page 16.

The authors explain the appropriate state for an individual MPO depends on its size and needs, however they state that MPOs should sensibly reside along the major diagonal (upper left to lower right). They believe that MPOs with advanced travel demand models but little or no capability in land-use modeling cannot adequately forecast travel. The arrows designate recommended paths for improvement.

The authors recognize the financial and technical constraints many planning organizations face. They suggest that MPOs should only attempt to improve long-term modeling state in realistic, incremental steps. To improve models in the short term, the authors suggest taking the following steps:

1. GIS links are required, with the ability to disaggregate inputs.
2. Given the lack of a standard algorithm for modeling technique, acquisition of comparative descriptions and evaluations of other existing models is important.
3. Improved validation of modeling results, as well as validation of modeling results over time to compare new models to older versions, is recommended.
4. Improving the availability and quality of employment data is considered an extremely high priority by many forecasting professionals.
5. Improved feedback between land-use, transportation, and environmental models is required to allow modelers to scenario-test and, eventually, isolate individual feedback effects.

Importantly, the authors stress that the long-term goal of developing the ideal model will require specific dedication to a research and development program for model improvement, outside of the commitment to daily operation of the model. Practically, most MPOs should develop a solid travel demand model before attempting to develop any land-use model and

generally travel demand modeling capabilities should be upgraded before land use modeling capabilities. They extol the virtues of GIS as a cutting edge technology for future modeling and include an expansive list of other general recommendations for model improvement. The recommended state-of-the-practice mechanism includes a case study approach with "modeler-MPO partnerships" used to evaluate model cases and share feedback.

The National Cooperative Highway Research Program also focused on problems associated with one particular aspect of the modeling process in its report *Predicting Air Quality Effects of Traffic-Flow Improvements: Final Report and User's Guide* (7). In part, the report is concerned with the need to predict vehicle emissions due to capacity changes—both increases and decreases—in the transportation network, once again illustrating the key role that the need to forecast emissions has played in spurring efforts to improve transportation models. The ability to accurately predict the change a transportation facility improvement or management policy will have on vehicle emissions depends on incorporating such changes into a travel demand model. The challenge comes in incorporating these changes into the trip generation forecast. In the conventional four-step modeling process, trip generation is unaffected by price of travel, leaving the prediction unchanged as transportation capacity increases or decreases. The report presents examples of more advanced travel demand models—activity- and tour-based models—that incorporate transportation system changes into travel forecasts. These types of models can predict vehicle activity changes that result from minor changes to the built transportation network.

The report then presents a general overview of the state-of-the-practice as well as criticisms of prevailing travel demand and emissions forecasting procedures used by MPOs to evaluate changes in demand due to traffic-flow improvements. Although the report deals primarily with the incorporation of capacity changes into a model capable of predicting emissions, its review of the state-of-the-practice for general transportation modeling is still useful.

The report details the current demand-modeling procedures employed by seven leading MPOs. These MPOs use a range of practices classified from intermediate to relatively advanced. Although the report makes no judgment which travel demand modeling procedures are best, the list indicates the resources that might be available for an advanced methodology in forecasting travel. Each of these MPOs uses a travel demand model that is based on the four-step modeling procedure.

The report goes on to provide an overview of several criticisms that have been levied against conventional practice. While the critiques of travel demand modeling are not specific to the seven MPOs, they provide an overview of the general concerns and suggestions for improvement that other authors have raised regarding current practice. Citing the work of Deakin and Harvey, the report describes the shortcomings of current practice they identified: omission of key variables; lack of enough trip generation variables; inadequate representation of trip attractions; omission of transit and walking accessibility in trip distribution; lack of peaking information by trip type and market segment; simplistic representation of socioeconomic variables; and, simplistic characterization of non-work travel. Stopher points out further problems with the conventional travel demand models, including their inability to reflect changes in trip making per household; their lack of feedback; their failure to use land-use models; their aggregation errors with large zones; and, their inability to accurately predict real-world travel speeds. Feedback, or equilibration of travel times with the assumed travel times, is also identified as a major issue for travel models.

The report also includes the recommendations several authors made for improving current practice. Stopher and Fu identified several short-term improvements that they assert could improve the accuracy of conventional travel demand models. These improvements include factoring of daily trips to time of day immediately after the trip generation step; more precise capacities computed on a link-specific basis rather than on general capacity values, more realistic speed-flow curves that reflect a steeper drop in speeds when demand exceeds capacity and providing feedback on congested travel times to the trip distribution step. No studies or comparative data are included to support these assertions. Furthermore, Repogle recommends additional data collection, such as panel surveys, traffic counts, time and delay studies, supply inventories, pricing data, goods movement data, special generator data, and land development inventories among others. The report does not distinguish between these recommendations or suggest a priority in addressing the identified problems.

The report also addresses the limits most models face in forecasting non-motorized and truck travel demand. It gives an overview of two potential methods for modeling both non-motorized and truck travel. Only discrete choice and regional travel models for forecasting non-motorized travel are reviewed because these two approaches reflect the most advanced estimation techniques. For truck travel, the report discusses vehicle-based and commodity-based models. Examples of each of these models are provided, but no evaluation is made as to which is best.

Finally, the National Cooperative Highway Research Program recommendations for a new modeling framework that is capable of evaluating the influence of transportation control measures (TCM) on travel demand are presented (7). The first recommendation is to focus on the individual, the household, the vehicle, and the trip, rather than the aggregate group. This can be accomplished through the use of emerging activity-based modeling approaches. It is also recommended that instead of aggregating households by traffic analysis zone to predict the mean trip patterns for a group, forecasts should be based on random selection of individual persons or households and prediction of their individual travel patterns. Additionally, the use of incremental analysis that can compare the changes produced by specific strategies and better predict travel behavior rather than the absolute magnitude of travel is recommended. The use of traffic microsimulation can help obtain accurate modeling of congestion effects and to output vehicle operating mode predictions. Finally, the use of household travel survey data with stated preference data to support policy analyses.

The final article addressing the general state of transportation modeling was written by D.B. Hess. *Reconciling Incompatible Zone Systems in Metropolitan Planning* also pinpoints a problem with one particular component of travel demand modeling (8). The author conducted a survey of 346 MPOs in the United States to determine how the organizations typically convert spatial data between census zones and transportation analysis zones (TAZ), which are defined by incompatible boundaries. Based on feedback from 154 MPOs, the survey revealed that 60 percent of MPOs perform the procedure approximately once per year using highly error-prone methods. The author cites the lagging application of newer, advanced GIS technology and techniques within the planning organizations as a leading cause for the use of antiquated and inaccurate methods. The survey's results suggest that more advanced GIS training for planners and improved sophistication among the travel demand modeling community will be required to rectify this problem. Over the relatively short time since Hess's study, only three years, GIS techniques have become more widely adopted. Although sophisticated GIS software and experienced staff may not be resident in every MPO, an increasing number of agencies have

some GIS capability and almost all graduating planners or engineers have some GIS expertise. GIS methods are being rapidly adopted for transportation planning, modeling and other applications.

Peer Comparison Literature

The articles discussed above deal most broadly with the state-of-the-practice, addressing both what is considered the state-of-the-practice as well as recommendations for improving it. This literature can provide general guidance for an MPO looking to evaluate or improve its transportation model. The remaining articles all deal with the evaluation of a specific travel demand model in comparison to what is defined as the state-of-the-practice. These studies also provide insight into what different MPOs and travel demand modeling professionals have considered state-of-the-practice. Furthermore, these reports serve to identify the detailed operational problems that that practitioners often perceive in the, typically, four-step models as opposed to the more basic structural problems that are identified by researchers.

In these studies, the MPO under evaluation first establishes a group of peer MPOs. The modeling practices of this peer group are complied in an attempt to establish modeling norms for MPOs with similar characteristics. With this information, an MPO can compare its own modeling procedures to the procedures used by its peers to determine if its travel demand model is acceptable. This type of study also enables a MPO to learn about alternative and advanced modeling practices in use, which it can use to improve its model. Although such articles focus on particular models and small groups of peers, they address the state-of-the-practice, modeling issues and problems facing particular MPOs, and suggestions for improving models.

The Southeastern Wisconsin Regional Planning Commission (SEWRPC) conducted a comparison of its third-generation travel simulation models to the state-of-the-practice of travel simulation models of 10 peer MPOs throughout the United States (9). For the purpose of the study, a state-of-the-practice travel demand modeling method is defined as a procedure in widespread use in travel modeling. Ten MPOs were selected. The commission evaluated the structure and components of each MPO's travel demand models to assess its own models in relation to the state-of-the-practice.

The study focused on six components of a travel demand model. A review of the peer group found the following regarding travel modeling practices:

1. *Model Structure* – The travel demand models for all 10 MPOs as well as the Commission's third-generation model use a four-step trip-based model structure, which is the most widely used model structure and is the current state-of-the-practice.
2. *Classification of Travel* – All 10 MPOs and SEWRPC classify trips to determine the relative proportion a type of trip represents. This enables an MPO to focus its travel simulation modeling resources on modeling the types of trips that represent larger portions of travel. SEWRPC and the 10 MPOs all classify travel in three components—resident personal travel, commercial truck travel, and external travel—with a modeling procedure for each component.
3. *Trip Generation* –To forecast trip productions, 9 of the 10 MPOs use the cross-classification method either on its own or in combination with another method. The Commission's model uses a combination of cross-classification and growth factoring for its trip production model.

There is greater diversity in how the 10 MPOs forecast trip attractions. Four of the 10 MPOs use trip rates, one uses trip rates for only some trips and does not model the remaining trips, one uses a combination of trip rates and regression, three use regression methods, and one uses cross-classification. The Commission uses trip rates and growth factoring in its trip attraction model.

Travel simulation modeling is based on trip purposes. The 10 MPOs all use the following similar trip purposes with some variations: home-based work (HBW), hone-base shopping (HBS), home-based other (HBO), home-based school (HBS), and nonhome-based (NHB). The Commission's models are based on these same trip purposes with the addition of nonhome-based school (NHBS) trips.

The study found that in comparison to the 10 peer MPOs, the Commission's third-generation models are consistent with the state-of-the-practice for modeling trip productions, attractions, and trip purpose.

1. *Trip Distribution* – Eight of the 10 MPOs as well as SEWRPC use some form of the gravity model when modeling trip distribution.
2. *Mode Split* – Half of the MPOs use a single logit model to forecast the division between auto and transit trips, while the others use two models applied sequentially. The Commission's models use the latter approach, applying first a logit model to forecast the division between auto and transit trips and then employing a cross-classification model to forecast vehicle occupancy of auto trips.
3. *Traffic Assignment* – All 10 of the MPOs use a capacity-restrained, equilibrium assignment method to assign routes on the highway network over several periods of the day. The Commission uses the same procedure as the MPOs to conduct the assignment for nine periods.

Seven of the MPOs conduct the transit assignment by time of day, two MPOs perform a single daily assignment, and one does not assign transit trips. Six of the nine MPOs use a multipath assignment method while the other three use a shortest path method. The Commission's transit assignment model is a time-of-day assignment for four time periods and uses the shortest path method.

The study found that after a review of 10 peer MPOs' travel simulation models, the Commission's third-generation models are consistent with the current travel demand modeling state-of-the-practice. The study of other travel simulation models did reveal a number of potential refinements the Commission should consider for its future models. Although the Commission's model structure is consistent with the state-of-the-practice, the Commission should explore developing a tour- or activity-based model over the next 10 years. Additionally, the following refinements were recommended for the trip generation, distribution, and mode choice components of the model: stratification of non-home-based trips into work and non-work related trips; consider alternative destination choice models for trip distribution; and, incorporate choice of mode of transit access, consider inclusion of walking and bicycle trips, and consider nested or multinomial logit models for mode choice.

Although primarily a committee review, the Letter Reports of the Committee for Review of Travel Demand Modeling by the Metropolitan Washington Council of Governments (MWCOG) also use a peer comparison to provide an understanding of the state-of-the-practice. As a committee review, this report is similar to the final category of articles, panel reviews of

specific models. The letter reports relay a study by the Transportation Research Board committee convened to review MWCOG and the National Capitol Region Transportation Planning Board's (TPB) travel demand model, and the responses to the committee's findings by TPB. The exchanges between the committee and the MPO provide an example not just of what was considered state-of-the-practice, but also what changes an MPO made to its model in response to an evaluation. It is also beneficial because the dialogue delves into the criticism and justification of several specific components of the MWCOG/TPB model. The TRB panel based its recommendations, in part, on review of validation materials produced by MWCOG. The recommendations address not only the broad model structures but also details of model application. This latter point is important as it illustrates that the application of any model includes a host of detailed practices that often are not well documented.

The first letter report was written by Dr. David Forkenbrock (TRB) to Peter Shapiro (TPB) on September 8, 2003 (10.a). The TRB's Committee for Review of Travel Demand Modeling by MWCOG issued this first letter report as a performance review of the state-of-the-practice of travel demand modeling by the TPB of the MWCOG region. The report states that there are no widely accepted guidelines explicitly delineating the "best" practices or setting standards for the practice for travel demand modeling. However, the report cited eight primary findings regarding TPB's current travel demand model:

1. *The TPB travel model is based on the widely accepted four-step system and is typical in comparison to other MPO models.* According to the TRB committee, TPB's current model set, designated as the "COG/TPB Travel Forecasting Model, Version 2.1/TP+, Release C" and referred to as the Version 2.1/TP+ model, is "a translation of the MINUTP-based Version 2 model."16 Release C of the Version 2.1/TP+ model is considered representative of models used by other similar MPOs.

2. *As is common practice among many MPOs, TPB collects local household survey data for trip rates and lengths, which is preferable to using national data or travel surveys.* The 1994 Household Travel Survey was the primary source of trip information for TPB. TRB acknowledges that local survey data is the best source for accurate trip information, but suggest that national travel survey data could be used to cross-check the local information for accuracy.

3. *Base-year link volumes do not match observed traffic counts as closely as expected.* Validation of the model compared to observed data was conducted using RMSE statistics. TPB's model showed a year 2000 RMSE for all facility types of about 51 percent and TRB considered RMSE values for many TPB traffic volume classes to be only marginally acceptable. Similarly, the TRB committee found that the TPB model underestimated transit trips in the range of 5-8 percent and suggested a broader comparison of transit results than system-wide averages and cordon crossings.

4. *MWCOG's consensus-based method for projecting population and employment is consistent with other MPOs.* Despite the availability of computer-based land-use models, the TRB committee recognized the widely accepted practice for predicting future distributions of employment and households is a consensus-based approach among the constituent jurisdictions.

5. *TPB's inclusion of the home-based shopping trip (HBS) is commendable, but combining commercial and business trips is not advisable.* TPB estimates person trips in four categories: home-based work (HBW) home-based shopping (HBS), home-based other (HBO), and non-home based (NHB). The TRB committee disagrees with the combination of business and commercial light-duty trucks based on information from other MPOs suggesting that explicit modeling of commercial trips can correct underestimation of travel in models based on home interview survey data.

6. *The use of fixed bus speeds in TPB networks may misstate the influence of transit in estimates of future trip distribution and mode choice.* The TRB committee preferred a method for deriving transit (bus) link speeds based on algorithms connected to highway link speeds, as used by other larger MPOs.

7. *TPB's extensive use of adjustment factors in trip generation, trip distribution, and mode choice to enhance the match between simulated and observed base-year data undermines the fundamental behavioral logic of the four-step modeling process.* TPB uses factors ranging from 0.5 to 2.0 to account for production and attraction mismatches presumably resulting from minimal household data for some superdistricts. Additionally, the widespread use of K-factors in the trip distribution portion of the model appears unjustified given the limited number of factors (e.g. river crossings) that would justify their use. Finally, factors are used to adjust transit trips that could shift projected transit usage by five to ten percent. The TRB committee considers all of these factors to be unusual and presumes they are used simply to improve statistical fit between base-year data and simulations. The TRB committee feels these factors are subject to criticism in light of possible demographic, land-use, and transportation system changes.

8. *TPB's feedback of highway and transit times to trip distribution bypasses mode choice and is not typical of good modeling practice in regions with significant transit services.* The TRB committee states that current conformity requirements state that mode choice should be included in the feedback process when transit is considered to be a significant factor in satisfying travel demand.

Additionally, the TRB committee issued findings regarding the post-processing procedures used by TPB. These findings addressed the disaggregation of VMT, the estimation of hourly traffic for emissions estimates, and development of weighted emissions rates.

Ronald F. Kirby (TPB) provided an advance response to the TRB committee's first letter report on travel demand modeling in the Washington region (10.b). TPB lists a number of practices that it considers well established elements of the state-of-the-practice for travel demand models:

1. TPB's model is based on the "four-step representation of travel demand that is widely adopted in current U.S. practice.
2. TPB uses locally gathered household survey data to estimate trip rates and trip lengths, rather than using national data.

3. MWCOG uses a consensus-based method for projecting regional distributions of population.
4. TPB disaggregated VMT into detailed vehicle classes.
5. TPB uses weighted emission rates reflecting county-level travel patterns.

TPB also outlines the areas which it feels TRB will need to investigate further. They suggest that RMSE values should be improved and expanded based on information from larger and more complex metropolitan areas. TPB notes the difficulty in modeling transit usage for an area as large and complex as the Washington region. TPB recognizes that development of a specific model for light commercial travel is important and suggests that more light commercial travel data is required. However, in light of the scarcity of data regarding light commercial travel, they consider including these trips as part of the non-home based trip category to be acceptable. .

TPB advocates for the use of adjustment factors in trip generation, trip distribution, and mode choice to enhance the match between simulated and observed base-year data. They use a variety of adjustment factors, including K-factors for different trip types and matching estimated trip productions and attractions. They justify the use of these adjustment factors by citing the complexity of the model, especially regarding the need to account for the effects of the multiple state and city jurisdictions in the Washington area.

TPB uses a different speed feedback procedure that excludes mode choice. According to TPB, feeding speed data directly through mode choice results in unrealistic reductions in estimated levels for transit and HOV on priority lanes because overall person trip levels decrease significantly. TPB also uses a method for establishing time-of-day volumes by assigning 24-hour volumes to the links and then redistributing the daily volumes to hourly volumes using observed Washington region distributions.

An additional response to the TRB committee's first report was provided by TPB (10.c). This letter addressed the descriptions of proposed work elements for the TPB models development program to address the concerns raised by the TRB committee report, and advance the state of modeling practice in the metropolitan Washington region. TPB outlines steps that it is taking to improve their travel demand model's performance and correlation to observed data. Numerous detailed appendices address specific issues and concerns raised in the committee's report.

Short-term improvements include development of pre-existing transit sum-models, linking highway and transit speeds, and reviewing in- and out-of-vehicle weighting in transit paths. Explained in detail in the Appendices of the report, the basic improvements to the model including expanded transit validation, explicit truck models based on classification counts, working with the local transit agency on methods for linking bus speeds to highway speeds, minimizing the use of adjustment factors, inclusion of mode choice in the speed feedback iterations, and improving the post-processing procedures.

As the current model ages, TPB is looking to the next step in development of their travel demand model. In the long-term, TPB will focus on developing and nested logit model for the region, and expanding model capability. Among the features being considered are continuous development of an airport ground access model, tour- or activity-based surveys and trip generation techniques, and expanded detail in the travel analysis zones.

Reported in an appendix to the letter, TPB conducted a survey regarding current modeling practices at 11 MPOs for cities of similar size to Washington D.C.: Atlanta, Boston,

Chicago, Dallas/Fort Worth, Detroit, Houston, Miami, Philadelphia, Phoenix, San Francisco, and Seattle.

Of the responding MPOs, it was determined that most have modeled an area similar in size to their air quality non-attainment areas, directly linking the models to the air quality analyses. The TPB model is bigger than the Washington non-attainment area, which TPB feels improves the traffic assignment for the non-attainment area. However, this method relies on some outer non-TPB member jurisdictions which are more difficult to obtain and maintain data from and are often larger, which worsens goodness-of-fit validation.

While TPB's model uses four passenger vehicle trip purposes, most other MPOs use six or seven. Some use up to 11 passenger trip purposes for trip generation, but collapse the purposes to three to six categories for trip distribution and mode choice. Nearly all of the other MPOs use similar categories for commercial traffic to the TPB model, however a number of the other MPOs explicitly model light trucks in addition to medium and heavy trucks, the TPB standard.

TPB accounts for special generators by using a set of adjustment factors called p-mods and a-mods, which ensure estimated and observed productions and attractions match. Other MPO models also account for special generators and at least two of the other MPOs use p-mod and a-mod factors.

TPB, like nearly every other MPO, uses a gravity distribution model. Seven of the nine MPOs who responded use K-factors or similar adjustments to account for the various socio-economic forces at work in their model area. The San Francisco MPO applies a large number of K-factors to as many as 50 percent of their interchanges, as opposed to 9 to 20 percent for TPB.

TPB employs a sequential multinomial logit model, with separate models for each trip purpose. They also use jurisdictional level adjustment factors. By comparison, the Philadelphia MPO uses a binary probit model with inter-area-type penalties and factors to adjust auto occupancy. The TRB committee was unable to obtain detailed information from any other MPOs regarding mode choice factors.

TPB's model does not adjust bus speeds, but instead bases them on the most current bus schedule information, which they believe inherently incorporates link congestion. A majority of the peer MPOs change bus speeds based on link congestion.

TPB's validation of transit trips from their 1994 and 2000 models showed only three to five percent difference between observed and estimated transit trips. These results are consistent or better than the validation results achieved by most of the peer MPOs.

TPB uses a speed feedback method for the trip distribution and traffic assignment steps, but excluded the mode choice step except for the base iteration. Information from most other MPOs is unclear; however it appears at least four other MPOs include mode choice in their speed feedback processes.

TPB's use of the RMSE goodness-of-fit method for validating link volume results is shared by only three of the peer MPOs. Some of the other MPOs list RMSE values for separate portions of the network but do not compare regional highway link volumes assignments.

Another appendix detailed the procedure used by the Baltimore Metropolitan Council (BMC) to model commercial vehicle and truck travel. The BMC issued two reports outlining their procedures for creating separate commercial vehicle and truck models for the trip generation component of their travel demand model. Because of the difficulty in defining commercial vehicle travel or obtaining accurate truck data from surveys, a consultant hired by BMC developed a method for calculating trip tables for commercial vehicles and truck traffic

from available count data. The consultant then developed a model to calculate link-level volumes for commercial vehicles, medium trucks, and heavy trucks. Selected manual counts were conducted and a procedure dubbed "adaptable assignment" was used to verify the accuracy of the model.

Responding to criticism from the first TRB letter report, TPB offered a more detailed explanation of their use of adjustment factors throughout their model in an appendix. TPB cites the following causes of concern regarding the model's approximation of the model area travel network and uses these concerns to justify the application of their adjustment factors:

1. Underreporting from surveys which affect non-work person trip rates;
2. Aggregation error within the trip distribution and mode choice modules;
3. Limitation of explanatory variables with respect to the socio-economic and geographical variations of the Washington area and the presence of another nearby major metropolitan area (Baltimore);
4. Limited geographic scope of the Household Travel Survey.

According to TPB, modeling "noise" increases near the edges of a model network, prompting them to expand their network to include outlying non-TPB jurisdictions to improve the model's accuracy within the air quality non-attainment area. Adjustments, calibrated with data from the TPB-member jurisdictions, are required to better simulate network conditions. The following specific adjustments were applied:

1. Use of p-mod and a-mod factors in application of trip generation rates;
2. Use of time penalties to model income bias in the trip distribution;
3. Use of K-factors to account for historical patterns, special generators, and Baltimore influence;
4. Transit percent and car occupancy adjustments to ensure proper matching in the results of the disaggregate mode choice models.

In another appendix, TPB describes their feedback process, which involves four iterations known as pump-prime, base, first, and second iterations. The pump-prime iteration runs the entire model to create an initial set of traffic assignment-based highway "skims." These skims are re-run through the trip distribution and mode-choice models for the base iteration. Finally, using the skims from each previous iteration, the first and second iterations re-run the trip distribution and trip assignment steps, while holding constant the transit and priority facility/HOV trips produced by the mode choice model from the base iteration.

TPB tested its model results by running three additional iterations of the mode choice model to assess whether any changes resulted from using final highway speeds, as opposed to pump-prime speeds. Based on the test, TPB concluded that the number of estimated transit trips was lowered in the 2025 forecast. They consider two possible adjustments to their model based on this result: 1) the pump-prime trip distribution speed table could be updated for forecast years or 2) the model could be re-run with the three additional iterations to ensure speeds in the mode choice step are close to the final assignment speeds.

This response letter also includes an appendix written by Mark Moran, describing the methodology of modeling one specific category of special generator trips in the Washington-area travel demand model: airport trips. The complexity of ground-based airport trips in the

Washington area arises from the presence of three separate commercial airports: Washington National Airport, Dulles International Airport, and Baltimore-Washington International Airport (BWI).

The author conducts case studies to discern how airport travel is handled at seven different planning agencies, including Atlanta, Boston, Chicago, Los Angles, New York, Portland, and San Francisco. To model airport trips, all of these planning agencies utilize air passenger surveys for base data and then apply a discrete choice logit model with varying degrees of complexity, except for Chicago which does not specifically model any airport trips. The report contains extremely detailed case studies for the airport modeling procedures used in Atlanta, Los Angeles, Portland, and San Francisco. The authors recommend that TPB should emulate the airport models used by the Atlanta, Portland, and San Francisco MPOs. All three of these MPOs rely heavily on passenger survey data and have developed complex airport choice, ground choice, and calibration-estimation data sets.

Finally, TPB requests guidance from TRB on its plan to conduct a new household travel survey with a sample size of 10,000 to 15,000 households, more than twice the size of the original 1994 survey. TPB justifies its plan based on large survey conducted in Seattle and New York. TPB prefers one-day trip-based surveys, as opposed to multiple-day activity-based surveys, because they believe the response rate will be better, but they request input from TRB. TPB is also considering conducting an add-on sample that would track vehicles from 200 households using GPS equipment. This activity is based on a California survey technique and allows modelers to account for likely underreporting in the normal survey.

The TRB committee provided a response to the TPB's proposed elements of improvement for their travel demand model in a letter from Dr. David Forkenbrock (TRB) to Christopher Zimmerman (TPB) in May 2004 (10.d). Overall, the committee agrees with TPB's internal recommendation for improvement of their model in six primary areas: model validation, travel estimation for trucks and commercial vehicles, bus network representation, uses of adjustment factors, applications of feedback through mode choice in reaching final travel estimates, and procedures in post-processing.

Beyond these proposals, the TRB committee recommends that vehicle classification counts including truck and commercial vehicle representation be collected immediately and model development begin without waiting for count completion. The committee still considers TPB's use of adjustment factors to be excessive and recommends that TPB "aggressively" document the basis for their use of all adjustment factors. The committee notes that accepted feedback algorithms for obtaining convergence are available. TPB should develop post-processing procedures that maintain consistency with their four-step travel demand modeling procedures to improve the correlation between time-of-day link volumes within the modules.

Regarding the elements of the TPB report that requested TRB guidance, the committee offered a number of suggestions. They advocate surveys that incorporate selective sampling of stratified populations rather than simply sampling a larger population at greater financial cost. TRB recommends researching numerous discrete mode choice models to find the most flexible model based on the quality of the available input data. TPB should also monitor progress of "early adopters" of tour- and activity-based models to maintain current standards and good practice. The TRB committee could only offer general guidelines regarding zone sizes, recommending that the zones should be small enough to accurately model travel behavior but not too small to significantly increase data requirements. Finally, regarding expansion of the surveying effort, the TRB committee makes no firm recommendation regarding multiple day

surveys, except to evaluate costs in relation to potentially helpful data, and they do not generally recommend the use of GPS devices to track vehicles.

Ronald F. Kirby (TPB) responded to Dr. David Forkenbrock (TRB) regarding the TRB committee's second letter report on travel demand modeling in the Washington region in May 2004 (10.e). Kirby provided a list of planning improvements or justifications for TPB's current modeling methodology:

1. TPB maintains that it validates its model to equilibrium based on the needs of the data set, but concurs with TRB that additional model validation research could be helpful.
2. TPB has initiated new data collection to improve representation of light trucks in their model; however, TPB is doubtful that the TRB committee's recommended firm survey will provide sufficient response to justify its cost.
3. TPB is working with regional and local transit planning staff to improve their policy and planning focus in guiding the technical representation of future bus service.
4. TPB agrees with the TRB committee's recommendations that use of adjustments factors should be fully documented, continually re-examined, and minimized as much as possible. Coincidentally, TPB states that it is eliminating nine K-factors and dampened a number of other K-factors. TPB also explains that rather than use K-factors to approximate the effects of physical barriers, such as the Potomac River, time penalties stratified by trip purpose and income level were implemented using an iterative gamma trip distribution fitting technique.
5. TPB feels that allowing major variations in feedback speeds leads to unrealistic reductions in final transit and HOV speeds, but TPB agrees to investigate improved equilibrium algorithms to incorporate into the model.
6. TPB staff plans to increase their usage of observed time-of-day data in the model's post-processor, but the Washington-area time-of-day travel patterns are complex and may make this difficult to implement.

Regarding the questions or requests for guidance from TRB, TPB was reassured by the TRB committee's acknowledgement that travel forecasting relies heavily on the professional experience and judgment of its practitioners. TPB stresses that it plans to improve the quality of its model inputs, particularly more specific capacity and free-flow speeds, refined volume-delay functions, additional zone centroid connections, and improved estimates of employment by traffic analysis zones.

This extensive exchange between a review committee and an MPO illustrates that there is little consensus on what constitutes acceptable practice in travel forecasting and, more specifically, what constitutes acceptable performance in model validation. Lacking independent data against which the performance of individual elements of the model set may be judged, the assessment relies on review of the end products of the forecasting models (transit ridership and highway link assignments) and the professional judgments of the participants to assert the acceptability of aspects of widely used practices.

Peer Review Literature

Both the SEWRPC study and TRB committee report on MWCOG and TPB use comparisons to peer MPOs to establish their standing in relation to the state-of-the-practice. Since the two studies used a different set of peers, they each turn up unique information on how

they interpret the state-of-the-practice in their studies. These studies of small peer groups also turn up several similarities in modeling procedures. Each focuses on slightly different information in its evaluation of the state-of-the-practice and what aspects of the specific model need improving. These articles give a better understanding of not only the general state-of-the-practice, but also of how specific MPOs use that information to make model improvements. The final group of articles further demonstrates how MPOs have understood their models in relation to the state-of-the-practice. Similar to the letter reports about the Washington region, these studies are based on expert and peer panel reviews of specific models.

While many of these articles do not attempt to explicitly establish the state-of-the-practice in their studies, they all make criticisms and recommendations based on their interpretation of the state-of-the-practice. Therefore, their evaluations of specific models reveal additional information on the state-of-the practice. Since these articles all focus on a specific model, they also provide the opportunity to examine in depth the issues and problems facing models in use. These specific examples offer general lessons about acceptable modeling procedures and common modeling problems.

As part of an MPO evaluation from 1992 to 1994, the Volpe National Transportation Systems Center (Volpe) reviewed the travel demand models for several MPOs. During this time, Volpe headed a multi-agency panel tasked with analyzing the operation of travel models around the country and making recommendations for improvements. The panel reviewed the model of each MPO studied separately. The panel's findings on nine MPO travel models provide a broad overview of what the panel considered state-of-the-practice as of the early 90s, the shortcomings of various models, and the improvements required to make modeling procedures acceptable. By 2005 many of the findings are not longer relevant as the state of technology has changed and many of the recommendations of the Volpe panel have been implemented; others are still frequent recommendations in model reviews.

Common themes of the reviews of the mid-1990s were recommendation to:

1. Move from mainframe to desktop application systems
2. Do peak period, not just, 24-hour assignments
3. Collect new data, especially data on lesser used modes
4. Improve consistency among all aspects of the models
5. Use GIS techniques to manage data and conduct analyses
6. More feedback within the overall model chain
7. Develop methods to account for tolls
8. Develop land use models

The Volpe panel did find several MPOs' models to generally fall within the state-of-the-practice. The Sacramento Area Council of Governments (SACOG) was one MPO the panel found to use a travel demand model that represents the state-of-the-practice (11). It is interesting to note that although the Volpe review found the SACOG models to be consistent with the state-of-the-practice the agency has invested considerable resources in developing and applying more advanced techniques.

In addition to the work conducted by Volpe in reviewing MPO travel demand models, several other studies convened panels of travel forecasting professionals to assess the state of specific models. Similar to the Volpe project, these panels outlined the components of the

models under review and made recommendations to bring the model at least up to the state-of-the-practice. Since these reviews were all conducted after 2000, they are more reflective of the current state-of-the-practice and the recommendations for improvement that are now considered to be reasonable. One such panel review was assembled by the Ohio-Kentucky-Indiana Regional Council of Governments (OKI). OKI was interested in assessing its model's ability to address important planning issues and consistency with the state-of-the-practice.

Some of the existing OKI model features described by OKI staff are listed in the report (12). Trip purposes include home-based work, home-based university, home-based other, home-based school, non-home based, and external-internal. Independent variables used in the model steps include worker per household, person per household, automobile per household, and household area type. However, the model lacks a household auto ownership model which reflects household composition and does not forecast income. The highway path finding algorithm uses a weighted linear combination of time and distance (rather than just travel time) which, combined with multiple speed-volume functions, reduces the tendency to assign higher freeway volumes than observed counts. Additionally, the model converts truck volumes to passenger car equivalents. Among other functions, the model is designed to evaluate potential HOV lanes and public transit improvements.

Modifications to the model were made by a consultant in the previous two years. Primary among the modifications was the combination of the OKI region with the Miami Valley Regional Planning Council (MVRPC – Dayton, OH) region because of significant vehicular travel between the regions. As a result of the increased complexity involved in this conglomeration of regions, changes were made to the allocation of trips and trip production and attraction factors were introduced. A new nested logit mode choice model was developed for the combined regional model with transit mode choice occurring before access mode choice. Separate sets of models were developed for peak and off-peak periods.

The truck model is based on methods proposed in the Quick Response Freight Manual (13) which uses observed traffic counts to construct a base year table for light and heavy trucks. Discussion of truck model forecasts revealed a very aggressive forecast using a Fratar technique to estimate future trips and a productivity factor to estimate the daily rate of truck trips per employee.

The panel issues a number of findings regarding the state of the OKI travel demand model. The panel praises the melding of the OKI and MVRPC regions, but suggests new survey data should be collected, especially for the MVRPC region which lacks significant recent household data. Rather than relying on other agencies' forecasts, OKI should develop independent forecasts capabilities, including more detail stratifications for employment forecasts. The panel is concerned by a number of model attributes:

1. Overestimation of trip lengths in the trip distribution model
2. Inconsistency in the utility functions for mode choice and trip distribution
3. Use of trip generation factors
4. Use of significant K-factors
5. Presence of transit system specific factors in the mode choice utility functions

The panel recommends further analysis of these weaknesses and suggested that greater market stratification may be necessary to improve them. Other recommendations that address very specific aspects of model application include:

1. Use of passenger car equivalents in the trip assignment process
2. Allowing area type designations to change over time
3. Careful analysis how growth in work productivity is reflected in employment forecasts

These later recommendations again illustrate that model improvements come in many forms and that significant enhancement of conventional model structures is still viewed as reasonable.

Over the long-term, the panel recommends that OKI consider tour-based models generating person-trips by all modes. Some other suggested improvements include incorporating land-use factors and a density measure into the forecasting process; development of destination choice and automobile ownership models; income-based stratification in trip distribution and mode choice; and greater detail in demographic and employment data, and graphical presentation.

A report by a peer review panel of the Baltimore Metropolitan Council (BMC) provides another example of how transportation modeling professionals have assessed an actual model (13). The panel's report summarizes the expert opinions given to the BMC regarding both short- and long-term improvements to the Baltimore travel demand model. The existing Baltimore model uses the four-step travel demand forecasting process and is based on home interview data from 1993. Land use is forecasted at the TAZ level. The transportation network consists of both the highway and transit networks and also includes walk access. The model includes a substantial truck and commercial vehicle model based on linear regression from Lehigh, PA.

The trip generation model includes six trip purposes; cross classifies household size, vehicle availability, and density code; and trip attractions are identified only for motorized trips. The trip distribution uses a double constrained gravity model, executed twice. BMC's mode choice uses a nested structure accounting for ten modes. Different coefficients for transit and auto travel time are used to improve data fit. Finally, trip assignment is an equilibrium procedure for five different time periods. BMC faces challenges in validating results because the Maryland DOT conducts only a limited number of traffic counts within the city of Baltimore. BMC collaborates with the Maryland Department of the Environment to conduct post-process emissions modeling.

The review panel suggests improvements to the BMC model. The panel feels that establishment of an independent process to develop statewide and regional employment control details is an important step for Baltimore and Washington, DC. Ideally, the panel suggests that employment totals should be developed collectively for the BMC and Washington COG regions.

The panel also suggests a number of data improvements. They recommend an external trip survey (or origin-destination survey) be conducted for external-to-external trips, again ideally encompassing both the Baltimore and Washington regions. Additionally, the panel finds a lack of information on external commercial trips to the Baltimore port and suggests conducting a survey to improve this data specifically. They recommend treating BWI airport trips as person trips with transit options. Finally, the panel recommends that improved traffic counts in the city of Baltimore are required and suggests BMC may need to lead this effort if the State of Maryland is unwilling to improve its data.

The panel states that BMC should reconsider its peak period length, suggesting they consult temporal traffic and transit volume data to determine if their 4-hour peak period is too long. Additionally, the panel recommends that BMC include all trip purposes in their feedback

loops, develop convergence criteria, and run more feedback from assignment to distribution loops until convergence is achieved.

Finally, the panel lists a number of long-term improvement steps for BMC to consider. The panel advises BMC to avoid development of managed lane schemes because there is currently a lack of consensus on implementation; however, they suggest that BMC should analyze a few specific managed lane concepts such as truck-only and HOT lanes with varying congestion. Pertaining specifically to improve model operation in the long-term, the panel suggests implementation of consistent market segmentation between all of the model steps. They also believe improvement in the mode choice model is necessary, and suggest that BMC consult FTA guidance on use of IVTT and OVTT coefficients and less restrictive model calibration approaches. Additional general suggestions included improving BMC's understanding of the regional commuter market, improving the nesting structure to produce realistic results for major transit projects, and possibly adding more recent National Household Travel Survey data.

In addition to the other assessments present in the MPO travel demand modeling literature, a peer review panel advised the Denver Regional Council of Governments' (DRCOG) on strategies for employing an advanced model beyond the current state-of-the-practice (15). The report outlines DRCOG's interest in updating its travel demand model to a version more sensitive to the many development and transportation market and policy initiatives in the Denver region. To that end, DRCOG assembled a panel peer review in October 2003 to give recommendations on how to further develop their practices.

DRCOG has a long-term ambition, dubbed the Vision Phase, to implement a cutting edge travel demand model incorporating a land-use model, likely using UrbanSim, and integrating their land-use and travel model elements. They hope to diversify their depiction of household characteristics, probably based on a "synthetic population" method. They also want to create a more realistic trip generation and distribution system, possibly with tour-based generation and a destination choice model. They plan to upgrade to nested logit mode choice model from the current multinomial logit model. Ultimately, DRCOG wishes to run an extremely robust and thorough model with strong capabilities for forecasting the behaviors of all of the regions transportation elements and their interaction with one another.

The panel assembled by DRCOG generated an expansive list of state-of-the-practice procedures and recommendations pertaining to the development of an advanced DRCOG model. The panel listed a number of "basic" findings, heavily emphasizing integrated model design. They emphasized the importance of tailoring the model to policymakers' needs and maintaining focus on these needs to avoid getting too comprehensive. The panel mentioned model integration frequently, suggesting integrating model data with data from other organizations and maintaining consistent data groups and assumptions throughout the modeling process. They specifically mention having a strong and diverse data and GIS system and using computers to replace much of their handwork. They suggest striking a balance between aggregate and disaggregate data usage. The panel also recognized the risks in picking one modeling approach or system given changes and advancement in technology; however they advised DRCOG to confidently make a plan based on their best judgment. Some other broad recommendations for future model development included:

1. Sensitivity to price and behavioral changes

   a. Generally speaking, special surveys are needed for low-share alternatives, such as toll roads.
   b. Careful consideration of the various complicated personal travel costs is necessary to maintain a very robust and detailed model.
2. Modeling low-share modes
   a. Eliminate sparse model networks; use detailed basemaps such as TIGER to estimate trip distance, time for bikes, pedestrians
   b. Include model consideration of land-use characteristics affecting home location and mode choice, rather than just using trip length and cost.
   c. Improve detail for teleworking to include both self-employed and "classic" teleworkers.
3. Effects of development patterns on travel behavior
   a. Conduct research, starting with the Robert Wood Johnson Foundation and the CDC studies.
   b. To actually model choices, new types of data beyond revealed data will be required.
   c. Choose a direction for regional investments: creating land-use alternatives or modal choices.
   d. Determine a feasible level of detail for urban design inclusion, especially the land use model.
4. Effects of transportation system and system condition
   a. Thorough feedback of transportation conditions to the land use model is important but should be compared to policy-makers' expectations for land development patterns.
   b. System reliability is as important as average service level.
5. Ability to examine key policy choices
   a. Test the extremes of both land-use and transportation policy.
   b. The POM allows discussion of overall strategies and depicts the effects of policy choices.
   c. Create benchmark points, with accessible and bounded outputs, to generate information and visual outcomes; avoid error-prone, "on-the-spot" answers.
6. Improve validity and reliability
   a. The model should interpret results for policy-makers, most importantly giving a confidence level of the results (providing "error bands").
   b. Show "back-casts" as well as forecasts, to improve confidence in the model's results.
   c. Include traffic engineers and transportation system professionals in the development team.
   d. Research improvements to better model route choice (i.e., traffic path and assignment).
7. Ability to show environmental effects
   a. Tour-based models are more adept at showing environmental effects.
   b. Investigate the Edmonton model, which effectively links travel and environmental models, and the Portland model, which evaluates air pollution near roadways using recommended line-source modeling techniques.
   c. Meeting these myriad recommendations will help DRCOG to fully meet and in many cases surpass the state-of-the-practice.

Another publication dealing in part with an advanced modeling procedure was written by Leslie Jones about the Metropolitan Transportation Commission's (MTC) in the San Francisco area (16). Although the document is concerned primarily with the history and guidelines for travel demand modeling by Caltrans, it contains a brief description of MTC travel demand model. MTC's model, known as BAYCAST, is described as a state of the art forecasting system. BAYCAST was designed as an advanced trip-based model, expanding on the typical four-step model by including three additional steps: workers in household, auto ownership choice, and time of day choice models. BAYCAST is intended to operate primarily, but not exclusively, with MINUTP, TRANPLAN, and EMME/2.

Each of these reviews of an MPO's travel demand model by experts and professionals reveals the diversity as well as the similarities in how the state-of-the-practice is defined and how specific models measure up to it. Even in these cases where no state-of-the-practice standards are explicitly stated, the assessments of models expose the procedures that are acceptable and those that are not. Examining reviews of specific models also reveals common problems that MPOs face in executing their models. The combination of praise and criticism these models receive provides further evidence on the state-of-the-practice.

General Findings

Although there are numerous variations on travel demand models as well as on experts' opinions about what are the best modeling procedures, this literature review revealed several findings common to many of the cited studies and reviews. These findings are the most prevalent practices and frequent recommendations to improve procedures. It is also noteworthy that while the literature stretches back to 1993, much at the core of what is considered state-of-the-practice has remained the unchanged. While new variations of old techniques have developed, many models still employ the same general techniques that were used 15 years ago.

Boyce and Williams provide a thoughtful and practical overview addressing both the structural problems inherent in the standard four-step process and the practical difficulties of shifting to models sets based on a stronger theoretical paradigm.

Much of what Harvey and Deakin documented in 1993 remains true today. Models still face some of the same common shortcomings. For instance, many models have no trip generation variables beyond auto ownership and income; trip distribution models frequently omit consideration of transit and walking accessibility; and, models suffer from a lack of peaking information on trips by type and market segment. The exclusion of this type of information from travel models makes it difficult to accurately predict travel demand. The authors also voice several other concerns about model components that could influence a forecast's accuracy. In citing Stopher and Meyburg, they question the need for constants, k_{ij}, in the gravity model, which is the most prominent model used to predict trip distribution. Furthermore, they note that of all of the four steps in the travel forecasting process, traffic assignment has received the least critical scrutiny.

Beyond just listing potential problems with models, they also advise MPOs to follow certain approaches to achieve the best modeling results, which are also still relevant toady. Harvey and Deakin suggest that models incorporate population and employment allocations based on firm data analysis, rather than based primarily on the aspirations of localities, without consideration to market or political realities. Additionally, they state that bus in-vehicle travel times should be consistent with the travel times and delay in the highway network. The authors also caution that models are only as good as the data on which they are based, and there is a need

for urban areas to collect better data. Finally, they urge MPOs to incorporate advanced practices into their models when possible acknowledging, for example that models of the choice of the time of travel are not ready for mainstream regional modeling, but research has progressed far enough that the use of such models in advanced modeling practice would be desirable. Many of these sentiments were mirrored by authors of other reports and studies

Each of Harvey and Deakin's comments could have been taken from the report of a peer review of a model set conducted within the past few years. In general, there appears to have been increased adoption of the methodologies described by the authors as "Best Practice" since 1993. While a few agencies have adopted or are experimenting with techniques listed by Harvey and Deaken as "Advanced Practice," the categorization of those methods as "Advanced" is still, for the most part, correct.

Several common themes are found throughout the literature. In many cases professional and expert views align with what studies of MPO models identify as the state-of-the-practice. Most agree that the four-step models are flawed. Where there is disagreement is how these flaws are to be resolved or even if they need to be resolved. The researchers stress the need to adopt procedures based on stronger theoretical constructs and grounded in traveler behavior and discrete choice. Practitioners focus on incremental changes to detailed features to enhance the four-step models.

Based on this literature review, all or almost all MPOs use a gravity model to predict trip distribution while many reviews, particularly in complex areas, suggest that destination choice models would yield better forecasts or, at least, could account for a broader range of factors in developing forecasts. Related to this component of the modeling process, models using the gravity model all rely on adjustment factors (K-factors or others). Many reviewers of these models have commented that too many adjustment factors are generally used to predict travel demand. For the trip assignment step of the four-step model, most agencies use the equilibrium assignment technique. Unfortunately, no data on closure are reported in the literature. Few commentators of the general practice of travel demand forecasting address the detailed issued of the volume-delay functions applied in capacity sensitive assignment procedures, yet this is a frequent topic in peer reviews.

Concerns commonly raised include questions about the methods used to develop land-use and demographic forecasts and the allocations of regional totals to small areas. The way these forecasts are developed and allocated will influence how travel demand is ultimately predicted. Many articles also recommend that better data are collected and maintained to provide the most up-to-date information for use in models.

In addition to identifying common problems with the existing components of models, many authors spotted the same gaps in travel demand models. Most agencies have relatively crude methods for forecasting commercial truck travel based either on old models or some type of factoring. Furthermore, many models do not include non-motorized travel in their forecasts. Better incorporation of commercial truck and non-motorized transportation into travel demand models will, it is argued, enhance a model's ability to accurately predict travel demand. Another frequent recommendation in the reports and studies was for MPOs to move from trip-based to tour-based models or, more recently activity-based models. Although currently advanced practices, models of these types appear to be the future state-of-the-practice for its ability to more accurately represent the way people travel.

These general findings present a broad overview of many of the common travel demand practices and problems. Many of the authors identify similar practices that they find either

acceptable or unacceptable. Although none of these articles on their own or in combination offers a comprehensive definition of travel demand modeling state-of-the-practice, they do reveal individual interpretations and common understandings of the state-of-the-practice.

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Appendix D: Analysis of Responding vs. Non-Responding MPOs

Introduction

The web-based surveys were sent to 381 MPOs, 228 of which responded. While the response rate is high (over half of all MPOs and an even greater proportion of the largest MPOs responded), it is possible that in some ways those agencies that did not respond differ from those that did respond. Ideally, one would like to be able to compare the responses that would have been received from non-responding MPOs with those that were received from those that did respond. That, of course, cannot be done. However, some characteristics of all MPOs can be determined from other sources. Using these data from the FHWA MPO database, four aspects of possible differences between the responding and non-responding MPOs have been analyzed. These differences relate only to the MPOs and the areas which they serve; there is no information about the methods of travel forecasting used by responding or non-responding agencies.

Objectives

The overall objective of this analysis was to determine whether the responding MPOs were significantly different from the non-responding MPOs. The specific objectives of this analysis were to observe the differences by the following parameters:

1. Respondents vs. non-respondents by area (square miles)
2. Respondents vs. non-respondents by population/square mile
3. Respondents vs. non-respondents by MPO founding year
4. Respondents vs. non-respondents by region of the country

Graphical and statistical tests by each parameter were done to determine the differences for each parameter.

Graphical Analysis

Figure 1 shows the number of responding and non-responding MPOs by area (square miles) category. There is significant difference in the number of responses received from MPOs with an area of greater than 2,000 square miles and a moderate difference in response by MPOs with an area of less than 400 square miles. There seems to be equal representation by MPOs with an area between 400-2000 square miles.

Figure 1: Number of Responding and Non-Responding MPOs by Area (Square Miles) Category

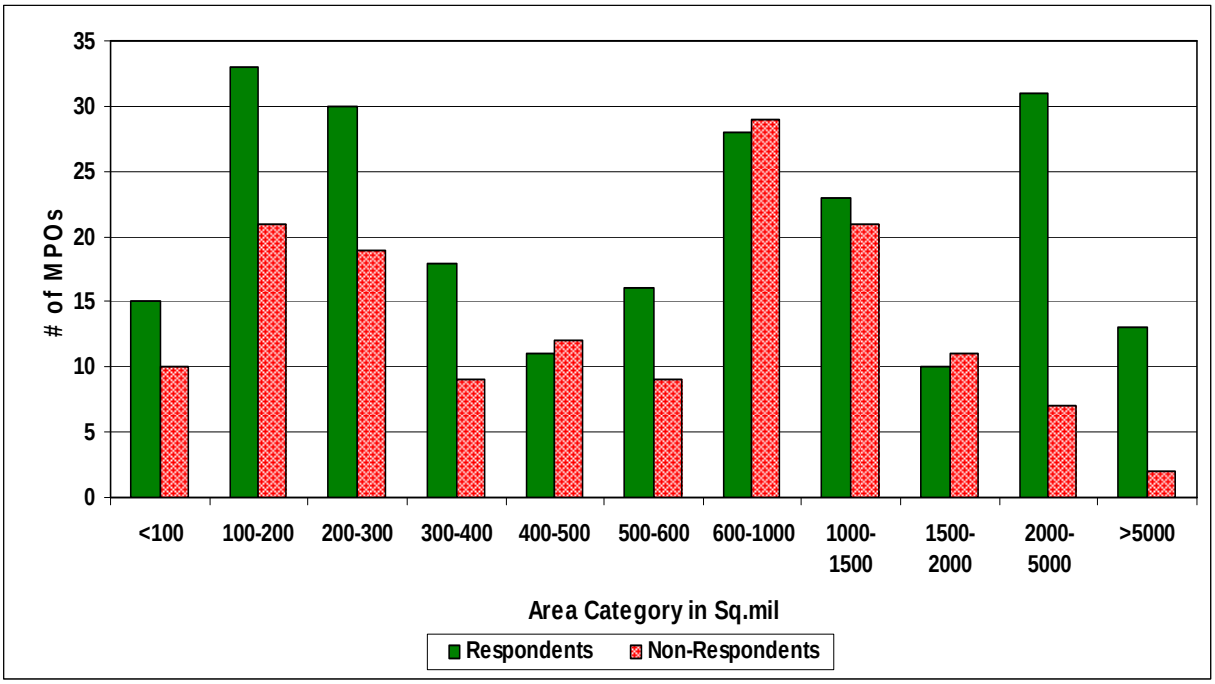


Figure 2 shows there is a responding MPOs are moderately more represented than non-responding MPOs, based on their population per square mile. MPOs in areas of greater population density were more likely to respond.

Figure 2: Number of Respondents and Non-Respondents by Population per Square Mile

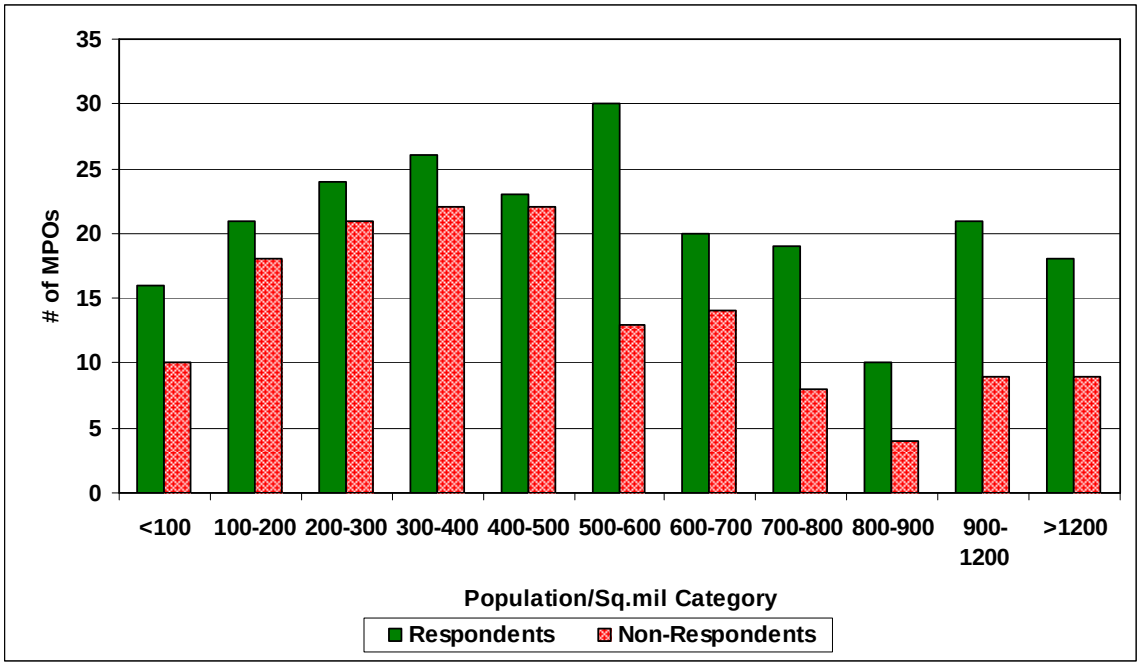


Figure 3 shows the MPOs of that have been in existence longer were most likely to have responded to the web-based survey.

Figure 3: Number of Respondents and Non-respondents by MPO Designation (Founding) Year

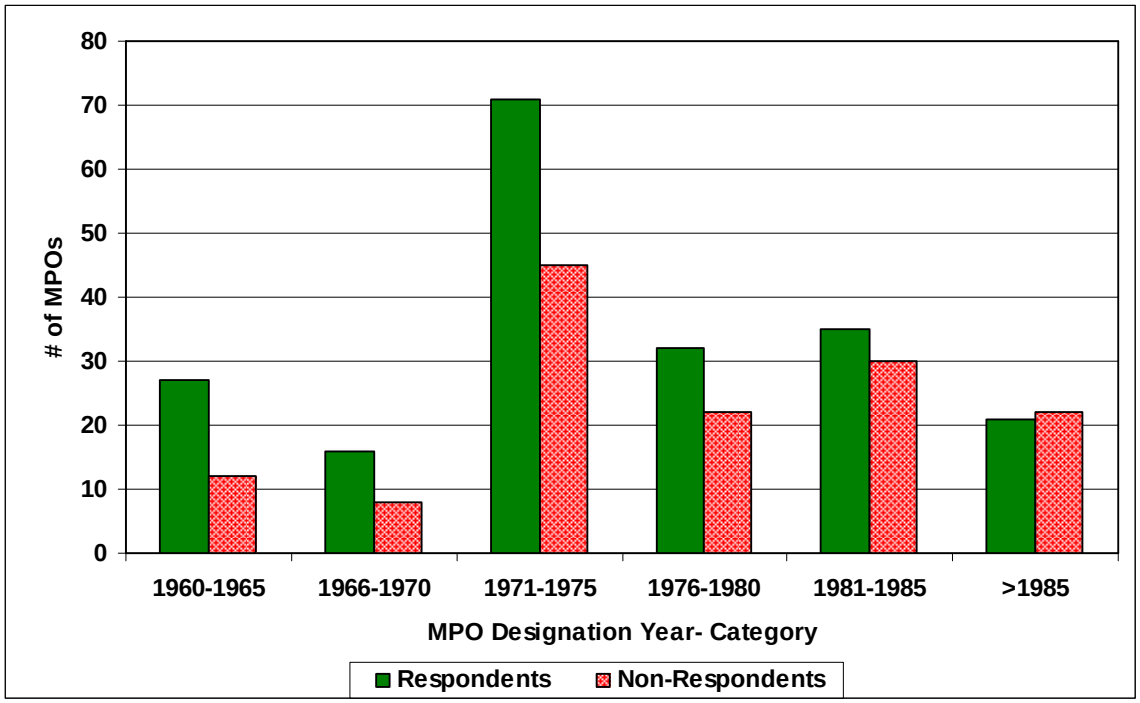
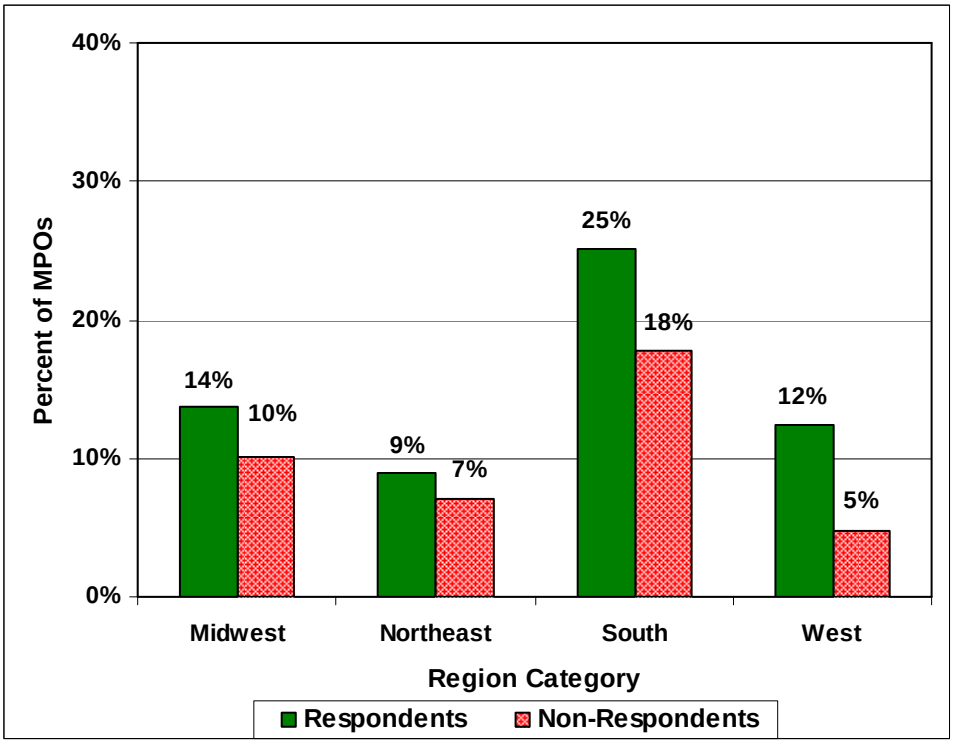


Table 1 summarizes the proportion of MPOs responding by region of the county. By inspection it is noted that the response rates for the Midwest, Northeast and South are quite similar – between 56% and 59%. Agencies in the West responded at a higher rate than the rest of the county. Figure 4 shows that all regions of the country were represented by both responding and non-responding MPOs in roughly equal proportions, though the South and West may be slightly over represented in the dataset.

Table 1: Percent of MPOs Responding by Region

Region	Percent Responding	Number of Agencies
Midwest	57.8%	90
Northeast	55.7%	61
South	58.6%	162
West	72.3%	162
Grand Total	60.3%	378

Figure 4: Percent Respondents and Non-respondents by Region of the Country



Statistical Analysis

Assessing the degree to which the agencies that responded to the survey differ from those that did not can also be assessed by testing for the statistical significance of the difference of the mean of the distributions of measures of the two groups. Table 2presents the results of this analysis. For each of the tested measures – years since designation of the organization as an MPO, population density and population – the data show that the difference is significant at the 95% level. This is to be expected since special efforts were made to obtain data from the largest MPOs, those serving areas with populations of one million or greater. These are the areas that have the greatest population and those that were designed as MPOs shortly after the legislation establishing the MPO process was enacted. For population density, a measure not tied so closely to the absolute magnitude of the population in an MPOs area, the difference is still significant but barely so.

Table 2: Statistical Tests of Difference between MPOs that Responded to the Survey and Those that Did Not Repond

Measure	Years since designation as an MPO			Population Density			Population		
	Did Not Respond to Survey	Responded to Survey		Did Not Respond to Survey	Responded to Survey		Did Not Respond to Survey	Responded to Survey	
Mean	26.935	29.010		494.6897	606.6858		292544	780893	
Standard Deviation	8.803	8.247		355.1823	682.922		367367	2192645	
Number of observations (n)	138	201		150	228		150	228	
Variance	77.485	68.020		244717.913	368067.686		1.3496E+11	4.80769E+12	
Degrees of Freedom			337			376			376
t-statistic ($\lvert t \rvert > 1.96$ implies significant difference between those that responded and those that did not)			-2.19			-1.97			-3.29

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