SPECIAL REPORT 288

METROPOLITAN TRAVEL FORECASTING

Current Practice and Future Direction

TRANSPORTATION RESEARCH BOARD
OF THE NATIONAL ACADEMIES

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

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Preface

Metropolitan planning organizations (MPOs) develop regional transportation plans and programs to accommodate mobility needs within their regions. This process is commonly performed with the assistance of computerized travel demand models that provide information on current and future transportation system operations.

In 2003, the Transportation Research Board (TRB) of the National Research Council (NRC) conducted a peer review of the travel demand modeling of the Metropolitan Washington Council of Governments' (MWCOG) Transportation Planning Board (TPB), the MPO for Washington, D.C. In the course of this review, it became apparent that little information is available to practitioners to assist them in making judgments about state-of-the-practice techniques for model development and application. Although the NRC committee that conducted the review was charged with assessing whether the modeling of the MWCOG TPB was state of the practice, the committee had to rely on its judgment in making this assessment, rather than on detailed information about how key technical issues are treated by the MPO's peers.

In this context, the Federal Highway Administration (FHWA), the Federal Transit Administration (FTA), and the Office of the Secretary of Transportation (OST) and TRB funded a new TRB study to gather information needed to determine the national state of practice in metropolitan area travel demand forecasting by MPOs and state departments of transportation (DOTs). The statement of task for this study comprised three main elements: (*a*) description of the current state of practice in metropolitan travel forecasting; (*b*) evaluation of the current state of practice, including any deficiencies; and (*c*) recommendations for improvement. This main report responds to each of these elements, although it emphasizes the latter two. In addition, a companion technical report commissioned for this study provides supporting detail on current MPO modeling practice, although the reader should not need to consult that report for a broad understanding of the committee's findings and recommendations. The detailed charge to the committee may be found in the appendix to this report.

To conduct this study, TRB formed a committee chaired by Martin Wachs, then director of the Institute of Transportation Studies at the University of California, Berkeley, and currently director of the RAND Corporation's Transportation, Space, and Technology Program. The 12 committee members brought to the study expertise in four broad areas: the relationship of travel forecasting to public policy and planning, the development of applied travel forecasting models, the application of travel forecasting models, and independent academic research on travel forecasting. In addition, committee members were expert in key areas of interest, including land use planning and modeling, air quality emissions estimates, transit modeling, and data collection and analysis.

The committee supplemented its own expertise by seeking technical guidance from three corporations that were responsible for much of the model development in U.S. metropolitan areas: PB Consult, Inc., Cambridge Systematics, Inc., and AECOM.

To gather the detailed information on travel modeling practice needed to respond to its charge, the committee employed a consulting firm, BMI-SG, Inc. (subsequently VHB, Inc.). The consultant conducted a web-based survey of modeling practice among all MPOs. Responding to this survey were 60 percent of all MPOs and 84 percent of those with a population exceeding 1 million. The consultant also conducted an extensive literature review, as well as in-depth interviews at 16 MPOs or state DOTs that perform modeling for MPOs in their state.

To be further advised on topics relating to the study, the committee requested and received at its meetings presentations from staff of FHWA, FTA, OST, the U.S. Environmental Protection Agency, the Association of Metropolitan Planning Organizations (AMPO), the American Association of State Highway and Transportation Officials' (AASHTO's) Standing Committee on Planning, Environmental Defense, and the TRB Committee on Transportation Planning Applications. Particular topics on which the committee asked to be briefed were FTA's New Starts program, FHWA's TRANSIMS modeling initiative, and FHWA's Freight Models Improvement Program. In addition, the committee held a joint meeting with the AMPO Travel Models Working Group to discuss the initial findings of the above web-based survey of MPO modeling practice.

The committee deliberated carefully as to the intended audience for its report. It concluded that the primary audience for this main report, with its findings and recommendations, should be those with a broad interest in metropolitan transportation planning, programming, and policy making, such as MPO policy board members. The committee was well aware that travel forecasting is a complex topic, with specialized concepts and language that may not be accessible to that primary audience. It therefore attempted to ensure that this main report would be largely nontechnical; where technical modeling terms are used, they are explained.

This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by NRC's Report Review Committee. The purpose of this independent review is to provide candid and critical comments that assist the authors and NRC in making the published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The contents of the review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. The committee thanks the following individuals for their participation in the review of this report: Elizabeth A. Deakin, University of California, Berkeley; Mark E. Hallenbeck, University of Washington, Seattle; Lester A. Hoel, University of Virginia; Charles E. Howard, Jr., Puget Sound Regional Council; Keith L. Killough, Southern California Association of Governments; Ronald F. Kirby, MWCOG; Frank S. Koppelman, Northwestern University; and T. Keith Lawton, Keith Lawton Consulting, Inc.

Although the reviewers listed above provided many constructive comments and suggestions, they were not asked to endorse the committee's conclusions or recommendations, nor did they see the final draft of the report before its release. The review of this report was overseen by Adib K. Kanafani, University of California, Berkeley, and C. Michael Walton, University of Texas at Austin. Appointed by NRC, they were responsible for making certain that an independent examination of the report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and the institution.

Jon M. Williams of TRB managed the study and drafted the final report under the guidance of the committee and the supervision of Stephen R.

Godwin, Director of Studies and Special Programs at TRB. Suzanne Schneider, Associate Executive Director of TRB, managed the report review process. Frances Holland and Amelia Mathis assisted with meeting arrangements and communications with committee members. Rona Briere edited the report, and Alisa Decatur prepared the edited manuscript. From the TRB Publications Office staff, Norman Solomon, Senior Editor; Jennifer J. Weeks, Editorial Services Specialist; and Juanita Green, Production Manager, assisted with the final report publication, under the supervision of Javy Awan, Director of Publications.

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The committee particularly acknowledges the contribution of Frank Spielberg, who, as principal investigator from VHB, led the gathering and interpretation of technical information, attended all committee meetings, and greatly helped the committee in shaping its findings and recommendations, with the assistance of Phillip Shapiro, the VHB co–principal investigator. Ramanujan Jagannathan and Srividya Vadlamani made substantial contributions to surveys of MPOs. David Anspacher and Richard Roisman contributed to data analysis and fact checking.

Principals from three national consulting firms provided the committee with valuable information on current technical practice. They were William Davidson of PB Consult, Inc., Thomas Rossi of Cambridge Systematics, Inc., and William Woodford of AECOM.

The committee supplemented its expertise with briefings at its meetings from federal, state, and local government officials and practitioners; public interest groups; and other interested parties. The committee thanks Edward Weiner, OST; Cynthia Burbank, Gloria Shepherd, Rolf Schmitt, Fred Ducca, Bruce Spear, and Brian Gardner, FHWA; Ron Fisher and Eric Pihl, FTA; John Davies, U.S. Environmental Protection Agency; Michelle Pourciau, D.C. Department of Transportation; Ron Milone, MWCOG; Jerry Faris, Chair of the TRB Committee on Transportation Planning Applications; Michael Replogle, Environmental Defense; Jennifer John, Metro Portland; Felix Nwoko, Durham–Chapel Hill–Carrboro MPO; and Mark Wilkes, Metro Planning Commission, Savannah, Georgia.

A number of associations were especially helpful to the committee in its information gathering and deliberations. In particular, the committee thanks the Honorable Rae Rupp Srch, President, DeLania Hardy, Executive Director, and Rich Denbow, Director of Technical Programs, AMPO; the Honorable James L. Kennedy, President, and Peggy Tadej, Director of Research, National Association of Regional Councils; and Debra L. Miller, Chair, AASHTO Standing Committee on Planning.

Contents

Summary Findings and Recommendations

Under federal law, metropolitan planning organizations (MPOs) are charged with developing transportation plans and programs to accommodate mobility needs for persons and goods within their regions. To this end, the MPOs estimate future travel demand and analyze the impacts of alternative transportation investment scenarios using computerized travel demand forecasting models. These models are used to estimate how urban growth and proposed facilities and the associated operational investments and transportation policies will affect mobility and the operation of the transportation system. Forecasts derived from these models enable policy makers to make informed decisions on investments and policies relating to the transportation system. In addition, MPOs in federally designated air quality nonattainment or maintenance areas have been given a central role in determining whether their regional transportation plans and programs conform to State Implementation Plans for meeting national air quality standards. Travel forecasting models play a principal role in this process as well.

STUDY CHARGE

The committee was tasked with assessing the state of the practice in travel demand forecasting and identifying shortcomings in travel forecasting models, obstacles to better practice, and actions needed to ensure the use of appropriate technical approaches. This report provides the requested assessment and recommendations for improvement and is designed for officials and policy makers who rely on the results of travel forecasting. A separate report commissioned by the committee is intended for readers with an interest in the technical details of current practice.

FINDINGS

The findings summarized below are based on surveys of MPO and state agency practice, a literature review, and the knowledge and judgment of the committee members.

Current State of Practice

The basic modeling approach at most MPOs remains a sequential four-step process by which the number of daily trips is estimated, distributed among origin and destination zones, divided according to mode of travel, and finally assigned to highway and transit networks. In smaller metropolitan areas, there may be little or no public transit, and the mode-of-travel step may be omitted, resulting in a three-step process. This basic approach has been in use since the 1950s and was originally intended to aid in decisions on the scaling and location of major highway and transit capital investments. Through the years, refinements and incremental improvements to this process have been made, but its basic structure has remained unchanged. A few metropolitan areas have adopted or are experimenting with the use of more advanced travel models based on tours of travel or the representation of human activity, unlike the four-step approach, which is based on single trips. These more advanced models can provide a better representation of actual travel behavior and are more appropriate for modeling policy alternatives and traffic operations. Other fundamental advances being used in a few places include joint transportation–land use models and the combining of travel demand forecasting with detailed traffic simulation models.

Although the four-step process is nearly ubiquitous, there are considerable variations in the completeness and complexity of the models and data employed. Smaller metropolitan areas with stable growth may use a simple version of the current models without a transit component or land use model, addressing travel only on the network of larger highways. Areas with more complex needs are likely to use more sophisticated four-step models, including combined transportation–land use models, or to adopt advanced techniques, such as activity-based models. Metropolitan areas such as San Francisco, New

York, and Columbus, Ohio, have implemented more advanced approaches. ***The committee finds that there is no single approach to travel forecasting or set of procedures that is "correct" for all applications or all MPOs. Travel forecasting tools developed and used by an MPO should be appropriate for the nature of the questions being posed by its constituent jurisdictions and the types of analysis being conducted.***

Shortcomings of Current Models and Modeling Practice

The demands on forecasting models have grown significantly in recent years as a result of new policy concerns. Existing models are inadequate to address many of these new concerns. MPOs are required by federal law to consider in their planning process how projects and strategies will affect a wide variety of policy concerns. Requirements specific to modeling include estimating motor vehicle emissions (which depends on estimating speeds and traffic volumes by time of day), estimating new travel generated by adding new capacity, evaluating alternative land use policies, and estimating freight movement and nonmotorized trips. In general, the conventional four-step models in use by most MPOs perform reasonably well in representing and forecasting aggregate system- and corridor-level travel demand. As the problems being studied become more disaggregate and more linked to individual behavior, however, the four-step process yields less satisfactory results.

Current models have inherent weaknesses. Most fundamentally, the processes that represent travel demand in the four-step model are not behavioral in nature; that is, they are not based on a coherent theory of travel behavior and are not well suited to representing travelers' responses to the complex range of policies typically of interest to today's planners and politicians. They also are unable to represent dynamic conditions for the transportation system. The conventional travel models make use of networks, both highway and transit, in which congestion is represented by averages over an extended period. These models cannot represent the conditions that would be expected or found by an individual traveler choosing how, when, and where to travel. ***As a consequence of these weaknesses, the following cannot be adequately represented:***

- **Time chosen for travel:** The conventional model structure is inherently incapable of accurate treatment of the choices travelers make in response to congestion and other indicators of system performance. Applications that depend on the ability of models to characterize and forecast travel by time of day include vehicle emissions, variable pricing toll strategies, variable work hours, convertible traffic lanes, and time shifting of travel in response to congested networks or road pricing.

• **Travel behavior:** Traveler behavior is currently represented in a highly aggregate manner. Factors influencing travel behavior—such as value of time and value of reliability—for different sectors of the traveling public are impossible to model with the four-step process. This makes it difficult to represent travelers' responses to changes in public policies, such as road pricing, telecommuting programs, transit vouchers, and land use controls.

• **Nonmotorized travel:** Many walking or bicycle trips take place or are affected by features wholly within a travel analysis zone and thus cannot be captured by the current models. One solution to this limitation is to code a much finer-grained zone system; however, doing so imposes a major burden of labor and computer processing. As a result, many MPOs do not model walking or bicycle travel. This makes it difficult to evaluate the impact of such initiatives as smart growth and transit-oriented development.

• **Time-specific traffic volumes and speeds:** The four-step process does not produce accurate, disaggregate estimates of time-specific volumes or speeds on specific routes. These estimates are needed to evaluate improvements in traffic operations, modes of access to transit stations, time shifting of travel in congested networks, and freight movement policies, as well as to calculate air quality emissions.

• **Freight and commercial vehicle movements:** The lack of robust, validated models with which to forecast freight movement and commercial truck activity is of great concern, especially since these vehicles have a disproportionate effect on emissions, traffic, and pavement wear. The reasons for this deficiency include a lack of data (since much freight movement begins or ends outside the metropolitan area) and a lack of information on the business demands that drive freight movements.

Shortcomings of conventional forecasts are also related to poor technical practice in the use of models. The committee notes that this problem is not particular to conventional models and will need to be addressed for advanced models as well. Examples of this problem include the following:

• **Inadequate data:** The survey conducted for this study found that many MPOs have inadequate data to support their modeling process. This is particularly true of hourly directional traffic counts to support model validation, current household travel data rich enough to support market segmentation or other disaggregate needs, and any useful origin–destination data on freight movement for use in specifying models of goods movement.

• **Optimism bias:** A number of studies have shown that forecasts for toll road and new transit projects are typically substantially higher than actual start-up patronage. This is true for projects undertaken 20 years ago as well as for more recent start-ups, although forecasts supporting requests for federal capital assistance for transit (Transit New Starts) have improved. These problems have drawn the attention of the Federal Transit Administration (FTA) and bond rating agencies.

• **Quality control:** Organizing a metropolitan travel forecasting process is a complex undertaking requiring detailed network coding, use of extensive traffic and passenger volume data, and proper integration of various models and submodels. Many opportunities to introduce errors arise. The best practice is to have a rigorous, formally defined quality control process, with independent assurance during each step. While some MPOs have such a process in place, many do not.

• **Validation errors:** Validating the ability of a model to predict future behavior requires comparing its predictions with information other than that used in estimating the model. Perceived problems with model validation include insufficient emphasis and effort focused on the validation phase, the unavailability of accurate and current data for validation purposes, and the lack of necessary documentation. The survey of MPOs conducted for this study found that validation is hampered by a dearth of independent data sources.

The committee believes that FTA is to be commended for taking steps to ensure quality in the travel forecasting methods used for major project planning. In particular, FTA initiatives to ensure the quality of New Start ridership, revenue, and cost information have been useful in uncovering weaknesses in model practice and form.

Obstacles to the Development and Application of Improved Models

Despite some obvious shortcomings of current travel forecasting models, change has been slow to come in comparison with, for example, the period 1950–1960, during which much of the current four-step urban transportation modeling system was developed. Advanced models exist that are more responsive than conventional approaches to a wider array of current issues, but there are also barriers to their widespread implementation. Obstacles to advances in modeling practice include preoccupation with the immediate demands of production, fear of legal challenges, and significant budget and staff limitations.

Insufficient evidence exists that advanced models can be implemented for a reasonable cost and will provide significant improvements over current practice. Although a number of agencies have begun to use tour- and activity-based models, many believe that these models are not fully ready for implementation. There are valid concerns about the costs associated with the new models and the amount of data needed to specify, calibrate, and validate them. Yet agencies that are using these advanced models are providing a growing body of evidence that they can successfully replace the current models used to perform basic MPO forecasting activities and address more complex policy and operational issues as well.

Intergovernmental relations have changed over time. Direct federal involvement in and funding for the development of models and associated training have gradually decreased. Responsibilities for model development have devolved to the states and MPOs, with private-sector support. At the same time, federal planning and related environmental requirements for states and MPOs have grown. Even as the federal government has greatly reduced its financial support for efforts at model enhancement, federal regulations have imposed additional requirements on the modeling process. Aside from recent significant federal investment in a complex microsimulation modeling package (TRANSIMS), MPOs and states have been on their own in developing models that can respond appropriately to these requirements.

Federal funding for MPO model development efforts has not grown commensurately with travel modeling and forecasting requirements and is severely deficient. The Travel Model Improvement Program (TMIP) has the potential to greatly facilitate the adoption of advanced modeling practices and the improvement of current practices. For the past several years, TMIP has been funded at $500,000 per year for all activities other than development of TRANSIMS. This is an inadequate amount to assist MPOs with meeting the federal requirements.

Although TRANSIMS was not evaluated for this study, the committee notes that it has provided an important bridge from the current practice of static, trip-based modeling to improved future practice. TRANSIMS receives about $2 million annually through the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) to support the development of new applications and to assist agencies with its deployment. This funding is not adequate for these purposes. By comparison, in the late 1970s and early 1980s, federal highway and transit agencies spent about $5 million a year on travel modeling, an amount that equates to about $15 million in current dollars.

To put this funding issue in context, SAFETEA-LU authorizes about $40 billion annually in federal support for highway and transit improvements, many of which are subject to metropolitan and statewide planning rules or other programmatic requirements, such as Transit New Starts. One would expect appropriate corresponding support for models used to provide critical information on how this large investment should be planned and implemented.

Recent Advances in Modeling Practice

Through the TRANSIMS initiative and other efforts by university researchers and consultants, advanced travel models are being developed that are based on a more comprehensive understanding of the activities of households and a more complete representation of network performance that accounts for the details of congested operations throughout the day. Such models have been implemented in a few places, where they appear to perform well.

Summary

The findings summarized above reveal that most agencies continue to use a trip-based three- or four-step modeling process that, while improved during the past 40 years, has remained fundamentally unchanged. These models have basic, documented deficiencies in meeting current modeling needs. There are also deficiencies in current practice—particularly data gaps—that will not be resolved by switching to more advanced models. The institutional environment for travel modeling has devolved much of the responsibility for the development of travel models to the states and MPOs, although the federal government retains a strong interest in the area. Advanced models that better meet the needs of MPOs have been developed and satisfactorily implemented by some metropolitan areas. There are, however, considerable barriers to fundamental change, including resource limitations, practitioners' uncertainty as to whether new practices will be better than those they replace, a lack of coordination among stakeholders, and inadequate investment in the development and transfer of new techniques. Accordingly, the pace of fundamental change in the field of travel forecasting has been very slow.

RECOMMENDATIONS

It is imperative that policy makers have the ability to make informed decisions about future investments and public policies for the transportation system. On the basis of the findings presented in this report, the committee concludes that current models and modeling practice are not adequate for many of the tasks to which they are being applied. **The committee therefore recommends development and implementation of new modeling approaches to demand forecasting that are better suited to providing reliable information for such applications as multimodal investment analyses, operational analyses, environmental assessments, evaluations of a wide range of policy alternatives, toll-facility revenue forecasts, and freight forecasts, and to meeting federal and state regulatory requirements.** The committee acknowledges evidence that current practice is also deficient in many respects and that introducing advanced models will not in itself improve that practice. **Therefore, steps must be taken to improve both current and future practice in metropolitan travel forecasting.**

The committee believes that the key to change and growth in these areas rests with the government agencies whose programs would benefit from accurate, reliable travel forecasts—MPOs, states, and the federal government. Each level of government has unique responsibilities and opportunities to assist in the needed transition to more advanced models and practice. Therefore, the policy recommendations that follow are organized by the level of government responsible for their implementation. Advanced models are not needed for all applications and may take some time to adopt where they are most needed. It is also imperative, therefore, to improve existing models and their use. The following suggestions and recommendations are based on the committee's judgment about how the fundamental recommendation made above can be accomplished.

Metropolitan Planning Organizations

The committee believes that MPOs would benefit from establishing a national metropolitan cooperative research program. Because models must suit local needs and contexts, it is important for MPOs to take a leadership role in their development, testing, verification, and application. Large costs are involved in both improving current and developing more advanced models. Rather than having these costs duplicated at each MPO, it would be beneficial to pool resources for such activities as enhancement of existing models, development of new models, implementation procedures, and staff training programs. Pooling of roughly $4 million to $5 million annually would allow MPOs to organize and conduct such a program. This fund could be created through the state transportation agencies that receive federal funds for MPOs or directly by the federal government. Another approach would be for MPOs with common needs to join in research and development studies of mutual interest. Regardless of the specific operating mechanism, pooling of research and development funds would be an efficient means of meeting MPO needs for model enhancement, development, and implementation. Under such an arrangement, the MPOs would be in direct charge of a substantial, ongoing fund that could be used for their own model research and development needs or for other research purposes as determined by the MPOs themselves.

MPOs should conduct formal peer reviews of their modeling practice. Independent peer review of modeling practice is essential given the complexity of the modeling enterprise and the need to assure stakeholders of the quality of travel forecasts. Such reviews have been an ongoing activity for many MPOs on an ad hoc basis, funded by TMIP.

Individual MPOs and universities could form partnerships to foster research on travel modeling and the implementation of advanced modeling practice. Universities and MPOs in California, Florida, and Texas have demonstrated the benefits of such partnerships for advancing the state of practice of metropolitan travel forecasting.

MPOs and other planning agencies should conduct reasonableness checks of demand and cost forecasts for major projects. This can be accomplished by comparing forecasts with similar operational projects. Another possible reasonableness test is the use of differing model inputs and assumptions to determine whether the changes in modeled results are realistic. The FTA Summit tool can also be employed for model checking.

MPOs experimenting with or fully implementing advanced modeling practices should document their experiences, including costs, advantages, drawbacks, and any transferable data or model components. Given the pressure on MPOs for timely completion of their work programs, this recommendation is most likely to be fulfilled if supported by the MPO research program or federal assistance.

State Transportation Agencies

States play a particularly important role in supporting smaller MPOs but should also be collaborating with larger MPOs within their borders. This collaboration could be accomplished through the following means:

- **Support for the development of the national MPO cooperative research program described above and other research related to MPO needs.** States could be partners in and beneficiaries of such a program. They could be active partners in garnering a small takedown of federal MPO funds and could provide supplemental support, perhaps through the National Cooperative Highway Research Program of the state departments of transportation.
- **Support for model user groups.** Such groups could provide a means for training, discussion of common issues, and purchase of modeling software for statewide use.
- **Evaluation, in cooperation with MPOs, of socioeconomic forecasts used for MPO modeling and forecasting.** A large amount of potential transportation forecasting error is associated with socioeconomic forecasts, including those for households, employment, and population.
- **Coordination with MPOs on statewide and metropolitan models and data needs.**

Federal Government

There is a historic precedent for a strong federal role in providing leadership and resources for the development and implementation of travel models and associated training. The need for this role is underscored by the considerable federal requirements that guide MPO planning activities. It is also in the federal interest to ensure that federal funds are being used to support the highest-priority needs for maintenance and improvement of the national transportation system. **The committee recommends that the U.S. Department of Transportation (USDOT), the Federal Highway**

Administration (FHWA), and FTA take the steps outlined below to assist in the needed improvements in practice.

Support and provide funding for incremental improvements to existing four-step (or three-step) trip-based models in settings appropriate for their use. This support would ensure that these models are adequate for the planning applications of many MPOs, that they can continue to be used as new planning needs arise, and that staff have the training necessary to use them.

Support and provide funding for the continued development, demonstration, and implementation of advanced modeling approaches, including activity-based models. MPOs with more challenging planning applications need resources and encouragement to implement advanced models. MPOs also require assistance in using case studies to document their experiences with new modeling approaches.

Continue to rely on TMIP as an appropriate mechanism for advancing the above recommendations, with funding necessary to support the program. To date, TMIP has supported a number of highly useful national activities to advance the state of practice in travel modeling. New funds would be used to help build MPO institutional capacity; develop and improve analytical methods derived from federal requirements; and support mechanisms designed to ensure the quality of technical analyses used to inform decision making and meet local, state, and federal program requirements. TMIP could also support MPO peer reviews, outreach activities, a handbook of practice (see below), training and capacity building, and state model users groups.

Continue support for the implementation of activity-based modeling and other advanced practices; considerably expand this support through deployment efforts in multiple urban areas. TMIP's TRANSIMS initiative has focused attention on the potential for activity-based modeling and travel simulation, and in particular has provided an essential component of these methods—the population synthesizer.

Increase funding to appropriate levels to support the federal government's role as a partner with MPOs and state transportation agencies. An annual investment in model development of 0.05 percent of the highway and transit capital program would amount to $20 million, comparable, in constant dollars, with the amounts spent 30 years ago. The committee recognizes that congressional authorization and additional funding would be required to support this level of assistance and encourages USDOT to seek such authorization and Congress to provide it.

Continue the federal MPO certification process, with a model checklist to provide MPOs with useful information on minimum expectations for their models. In addition, examination of the conduct and results of peer reviews (see the MPO recommendation on conducting such reviews) should be incorporated into the certification process. The resulting information could be the basis for an ongoing national compendium of the state of practice, thus continuing the work of the present study.

The committee recommends that in their planning guidance and planning regulations, USDOT, FHWA, FTA, and the U.S. Environmental Protection Agency allow MPOs substantial flexibility in their travel demand modeling practices, recognizing that one size does not fit all, and that unnecessary technical planning requirements could inhibit innovation and advanced practice.

Intergovernmental Cooperation

A large degree of intergovernmental cooperation is inherent in the metropolitan planning and travel forecasting process. The recommendations presented above recognize overlapping responsibilities of MPOs and the state and federal governments in such areas as research, implementation of improved travel models, staff training, data collection, and funding.

MPOs, state transportation agencies, and federal agencies should work cooperatively to establish appropriate goals, responsibilities, and means of improving travel forecasting practice. This cooperation could be accomplished through a steering committee of principal representatives from each of these levels of government that would meet regularly to set goals and an agenda for joint activities aimed at improving travel models and modeling practice.

A national travel forecasting handbook should be developed and kept current to provide salient information to those practicing travel demand forecasting. The current institutional environment for metropolitan travel forecasting is highly decentralized. Although the federal government establishes requirements for what must be accomplished through the metropolitan planning process, there is little guidance on the technical processes necessary to meet these requirements. No single source of information describes current or evolving practices for travel modeling and forecasting. The proposed handbook would fill this void by describing alternative best practices for addressing different travel markets and metropolitan needs, recognizing that differing approaches are needed according to the metropolitan context. It should also include extensive information on various ways to conduct quality control and model validation. Such a handbook would be an informational and evolving document, without prescriptive or regulatory implications.

Implementation of the handbook might be achieved through a national organization that brings together practitioners and researchers from agencies, consulting firms, and academia; the primary stakeholders would be those responsible for conducting metropolitan travel forecasting. Resources to support this effort might be derived from the proposed metropolitan cooperative research program, the National Cooperative Highway Research Program, the Transit Cooperative Research Program, and the federal government.

Studies should be performed to compare the performance of conventional and advanced models. Questions persist about the efficacy of advanced modeling practices and about whether they can provide improvements sufficient to warrant the time and expense associated with their development. This issue should be resolved through comparative studies using such techniques as time series, backcasting, and sensitivity analyses to evaluate the capability of conventional and advanced models to analyze simple and complex scenarios and to forecast future travel. The ability of advanced models to handle complex planning issues beyond the scope of current models should be evaluated as well.

MPOs, together with the federal government and the states, should examine in detail data requirements for validating current travel forecasting models, meeting regulatory requirements, and developing freight models and advanced travel models. This may include updating travel surveys, collecting information on freight flows, expanding traffic counts, and measuring traffic speeds. On the basis of these requirements, data collection needs should be documented, and strategies and sources of funding for the collection of such data should be identified.

1

Introduction

Every urban area in the United States with a population of 50,000 or more must have a metropolitan transportation planning process as a precondition for federal funding of transportation projects (23 USC 134 and 49 USC 5303). A metropolitan planning organization (MPO), designated by agreement between the governor and units of general-purpose local government representing at least 75 percent of the affected population, is responsible for leading this planning process. An MPO is a transportation policy-making body composed of representative local elected officials, representatives of public transportation agencies, and appropriate state officials.

OVERVIEW OF TRAVEL FORECASTING

A key element of transportation planning is the evaluation of alternative operating and capital investment strategies. This process requires estimates of current and forecasts of future travel on the surface transportation system, including highway, transit, nonmotorized, and freight modes. These travel forecasts are generally accomplished through computerized network simulations of the transportation system, known as travel demand forecasting models. Such models are highly complex and require as inputs extensive current information on roadway and transit system characteristics and operations, as well as current and forecast demographic information. Creating and operating the models requires a high degree of technical training and expertise.

Travel forecasting models are used to study proposed investments in the transportation system and to determine which of those investments will best serve the public's needs for future travel and economic development. The models are also used to evaluate the travel impacts of alternative land use scenarios. The model outputs are used as well to determine the air pollutants due to automobiles, trucks, and buses and thus the air quality impacts of proposed transportation projects.

The work of MPOs is under increasing scrutiny by stakeholders, including local elected officials, state transportation agencies, federal agencies with resource allocation and regulatory responsibilities, bond financiers, the business community, the environmental community, and the traveling public. Different stakeholders may propose or support differing transportation investments and outcomes, and travel forecasts provide them with important supporting information. Some MPOs have even faced legal action or the threat of such action against their transportation planning process based on the quality of their travel forecasts. According to a recent study, "Although travel demand models have been used in transportation planning for some four decades, there are few universally accepted guidelines or standards of practice for these models or their application" (TRB 2003). As a result, metropolitan area and project-level travel forecasts and the models that produce them often become the object of intense public debate, and agencies need to have a means of showing they are doing credible work.

Metropolitan travel forecasting models that produce reliable and broadly accepted forecasts allow elected officials to weigh the competing needs of stakeholders and make informed decisions about optimal investments of public funds. On the other hand, when models are supplied with inaccurate or out-of-date data, are poorly specified, or are not competently applied, they may produce poor forecasts that contribute to planning failures. Such failures include wasting public funds on transportation facilities that are over scale or not warranted at all, building facilities that are under scale and do not meet near-term demand, and conducting air quality planning that fails to achieve emission reduction targets. The consequences of planning failures include new passenger rail systems that are underutilized and therefore require unexpected funding for operations, new toll facilities that are underutilized and cannot meet operational costs and bonding debt service, freeway expansions that are completely congested a few years after opening, and the public health effects of air pollution. For these reasons, MPOs require the best available travel forecasting processes.

In the absence of practice guidelines, MPOs need information on the current state of travel demand forecasting to best satisfy federal, state, and local requirements; to provide elected officials with a sound basis for informed decision making; to assure interested stakeholders of the quality of the forecasting process; and to avoid the consequences of poor forecasts. Moreover, there is a growing consensus that metropolitan travel forecasting might be improved through and could benefit from the identification of current best practices for differing metropolitan settings and applications. This report is intended to respond to these needs.

REPORT ORGANIZATION AND APPROACH

Modeling and forecasting of metropolitan travel demand are founded on a set of complex and evolving technical tools and methods, often described in a highly specialized language. Metropolitan travel forecasting has the intended purpose of providing vital information to inform policy and programming decisions. The subject therefore holds great interest for both those engaged in the technical aspects of travel forecasting and those using the resulting forecasts for decisions on transportation capital investments and policies.

This report is intended for a broad audience of transportation planners, policy makers, and technical experts. It necessarily includes discussion of travel forecasting processes but at a conceptual level, using nontechnical language and explaining the meaning of technical terms that must be employed. The committee's findings and recommendations are summarized at the beginning of the report.

The remainder of the report provides a brief history and overview of metropolitan transportation planning and travel forecasting (Chapter 2); a description of the institutional framework for travel forecasting (Chapter 3); a review of the current state of modeling and forecasting practice derived from a literature review, a web-based survey, and interviews (Chapter 4); a discussion of the shortcomings of current forecasting processes (Chapter 5); a review of recent advances in the state of practice (Chapter 6); and a discussion of the pace of change and innovation. Chapters 2 through 6 conclude with a brief summary of the key findings and the committee's recommendations found in each chapter.

The committee also wished to meet the needs of those with a primary interest in the technical aspects of metropolitan travel forecasting, and much of the information gathered and distilled for this study may be of value to the technician. Therefore, the full consultant technical report on MPO modeling practices commissioned for this study has been provided as an electronic annex to this report, available at http://onlinepubs.trb.org/onlinepubs/reports/VHB-2007-Final.pdf (VHB 2007).

REFERENCES

Abbreviation

TRB Transportation Research Board

TRB. 2003. Letter Report from TRB Committee for Review of Travel Demand Modeling by the Metropolitan Washington Council of Governments. Transportation Research Board of the National Academies, Washington, D.C., Sept. 8. http://onlinepubs.trb.org/onlinepubs/reports/mwcogsept03.pdf.

VHB. 2007. *Determination of the State of the Practice in Metropolitan Travel Forecasting: Findings of the Surveys of Metropolitan Planning Organizations.* Transportation Research Board of the National Academies, Washington, D.C. http://onlinepubs.trb.org/onlinepubs/reports/VHB-2007-Final.pdf.

2

Forecasting Metropolitan Travel

The current practice of metropolitan travel forecasting and the relationships among the agencies that produce the forecasts are grounded in circumstances and events of the past 50 years. To understand the present state of practice, it is important to have some knowledge of the historical context in which metropolitan transportation planning and travel forecasting emerged.

HISTORICAL CONTEXT

Metropolitan Transportation Planning

America's cities lie within larger metropolitan regions that comprise a patchwork of local governments. The Boston metropolitan region, for example, includes 101 local governments; San Francisco, 111; and Chicago, 274. Each of these constituent towns, cities, or counties manages infrastructure and delivers administrative services within its jurisdiction. There are, however, matters of public interest that transcend the boundaries of local jurisdictions and require regional attention. The transportation system, economic development, and environmental quality are examples of such regional matters.

In the Progressive Era of the early 1920s, as America's cities grew, the concept of metropolitan regional planning emerged. Lewis Mumford and others founded the Regional Planning Association of America (RPAA) to promote a designed and controlled approach to managing the growth of cities. In the same decade, the Russell Sage Foundation funded the creation of a plan for the New York City region of New Jersey, New York, and Connecticut, and the New York Regional Planning Association was founded to implement the proposals in the plan. RPAA hoped that this New York City initiative would result in a comprehensive approach to regional land use planning, one that would lead to a rational distribution of population and economic growth. Instead, the emphasis was on the development of road systems and parks. This transportation-oriented model of regional planning would become prevalent throughout America (Gerckens 2002).

Following World War II, the federal government showed increasing interest in addressing urban issues through regional councils. The Housing Act of 1954 for the first time gave federal grants to councils of governments and other metropolitan planning agencies for work to address regional problems (Solof 1996). The Federal-Aid Highway Act of 1956 authorized construction of the multibillion dollar, 41,000-mile National System of Interstate and Defense Highways. The act included the Highway Revenue Act of 1956, which created the Highway Trust Fund to receive tax revenues dedicated solely to highway purposes (Weiner 1999). The transportation program thus initiated eventually resulted in more than 46,000 miles of Interstate highways, which were to have a huge impact on the landscape and economy of America and its cities. Means of planning the metropolitan infrastructure and operations of a new transportation system were needed. These means were provided first by the Housing Act of 1961, which allowed federal aid for "preparation of comprehensive urban transportation surveys, studies, and plans to aid in solving problems of traffic congestion, facilitating the circulation of people and goods on metropolitan and other urban areas, and reducing transportation needs." This was followed by the Federal-Aid Highway Act of 1962, the first federal legislation to require urban transportation planning as a condition for receiving federal-aid transportation funds in urban areas. According to this act:

> After July 1, 1965, the Secretary shall not approve under section 105 of this title any programs for projects in any urban area of more than fifty thousand population unless he finds that such projects are based on a continuing, comprehensive transportation planning process carried out cooperatively by states and local communities in conformance with the objectives stated in this section.

The act laid the foundation for the current metropolitan transportation planning process and led to the establishment of metropolitan planning organizations (MPOs) for every urbanized area in the country (Weiner 1999).

MPOs exist in an unusual stratum of governance. They are designated by agreement between a state governor (or governors in the case of multistate MPOs) and units of local government, a process mandated by the federal government through laws enacted by Congress and rules promulgated by the U.S.

Department of Transportation (USDOT). A designated MPO and an ongoing planning process are required for federal-aid funding to flow to transportation projects within metropolitan areas. MPOs are governed by policy boards comprising local elected officials and representatives of public transportation agencies and relevant state agencies. MPOs therefore represent a partnership among the federal government, state governments, and local governments, created to ensure that a continuing, comprehensive, and cooperative transportation planning process is in place in each metropolitan area.

MPO policy boards require support from a "staffing agency" to prepare planning documents, conduct studies and make forecasts, and provide logistical support for coordination with other groups. These staffing agencies may be regional planning agencies, councils of government, or in-house staff hired by the MPO policy board. In a few cases, state transportation agencies serve as the staffing agency for the MPO.

MPOs receive annual core funding from both the Federal Highway Administration (FHWA) and the Federal Transit Administration (FTA), often with state matching funds. Nationally, the federal share of this funding was $366 million in 2006, up from $161 million in 1992 (see Figure 6-1, Chapter 6).

Metropolitan Travel Forecasting

A connected national system of limited-access freeways was proposed prior to World War II. The Federal-Aid Highway Act of 1934 provided federal funds to the states for the conduct of survey research. The Federal-Aid Highway Act of 1938 directed the Chief of the Bureau of Public Roads (BPR, called the Public Roads Administration from 1939 to 1949) to investigate the feasibility of "toll superhighways" running from the east to the west and the north to the south of the United States. Supported by data collected by the states, BPR concluded that a toll road network was not viable but that a national network of expressways was needed. Traffic counts and travel surveys continued through the 1940s. These studies of volume and direction included information on origins and destinations gathered from license plate studies and driver interviews (Weingroff 2000). In 1944 the Public Roads Administration, working with the U.S. Bureau of the Census, developed a sampling technique for interviewing household members on their travel patterns, now known as a "home interview survey" (FHWA 1977). These means of collecting and organizing travel information are an important basis of today's metropolitan transportation planning process.

In addition to information on current travel patterns, a method for forecasting future travel was needed. One such method, developed by Thomas Fratar, employed factoring of origin–destination trip patterns to account for growth over time. This method, while still in use for certain applications, lacks an underlying theory and cannot account for future travel if there is none in the present. Other researchers explored the use of a "gravity model" approach to forecasting urban travel. The underlying assumption of the gravity model is that urban places will attract travel in direct proportion to their size (population and employment) and in inverse proportion to the distance between them. Alan M. Voorhees organized work on the gravity model into a comprehensive theory of urban travel, published as "A General Theory of Traffic Movement" (Voorhees 1956). The introduction of the gravity model into the travel modeling process allowed planners to forecast future travel on the basis of forecasts of population, households, and employment (Heightchew 1979).

Other basic modeling innovations were developed in the 1950s and 1960s as large cities such as Detroit, Chicago, Cleveland, Philadelphia, Washington, D.C., and New York undertook transportation studies to plan for major highway and transit capital investments, in particular the Interstate highway system. These innovations included a model for calculating the split between transit and highway travel (mode choice). Another problem was how to load travel onto a network; this problem was solved through the use of a "minimum path algorithm." Both travel-mode choice models and network loading procedures evolved through a series of improvements of increasing mathematical complexity. Perhaps the most important innovation was the adoption in the 1950s of IBM mainframe computers to store the large amount of information collected on travel and to run the various models needed to simulate and forecast metropolitan travel. Over time, the use of computers for travel forecasting has evolved into the present practice of using high-speed desktops running software supplied by commercial vendors.

As public ownership of and investment in transit increased in the 1960s and 1970s, more sophisticated models were developed to better represent transit and high-occupancy vehicle alternatives. By the 1990s, commercial transportation planning software for microcomputers had largely replaced federally supported transportation planning software for mainframes, but the commercial software retained similar modeling methods and approaches.

All the major technical innovations mentioned in this brief summary are in use for today's practice of travel forecasting. Home interview surveys and related information are used to estimate travel generated by households and employment sites (trip generation). The gravity model is used to determine how much travel will occur between places (trip distribution). In larger urban areas, a mode-choice model estimates transit trips and car occupancy. Minimum path algorithms are used to load travel onto highway and transit networks (assignment). Forecasts of future travel are made by using forecasts of future demographics. This entire process is termed "travel demand forecasting" or the "four-step process."

The metropolitan travel demand forecasting process was born of necessity in the postwar era during a time of major capital investment in inter- and intracity transportation systems. The process grew in a piecemeal manner as a linked chain of submodels, each designed to solve a particular problem associated with the ultimate goal—forecasting future travel to assist in planning the size and location of new and expanded highway and transit facilities. It is notable that these models, as they have evolved, are deterministic, providing point-estimate forecasts. This approach is acceptable for solving simple problems, such as whether a new freeway should have four or six lanes. More complex problems might benefit from probabilistic models, which would provide distributions of possible outcomes.

While the use of computerized, network-based travel models is not mandated by federal or state law, most MPOs operate such four-step models as an integral part of their planning process.

MPO PLANNING AND TRAVEL DEMAND FORECASTING MODELS

As noted above, federal regulations require that urban areas with a population of 50,000 or more either establish a new or join an existing MPO (FHWA 2007b). Urbanized areas with a population of 200,000 or more are designated transportation management areas (TMAs), and the MPOs that serve these areas have stricter requirements. The MPO planning process in a TMA must include a congestion management process to monitor and evaluate the performance of regional transportation facilities.

In 2006 there were 384 MPOs. The MPO and its policy board are charged with developing a metropolitan long-range transportation plan with at least a 20-year horizon and a short-range Transportation Improvement

Program comprising projects drawn from the long-range plan. In developing these transportation plans and programs, the MPO is to consider the following eight factors:[1]

- Economic vitality of the region;
- Safety of the transportation system;
- Security of the transportation system;
- Accessibility and mobility options;
- Environmental protection, energy conservation, and quality of life;
- Integration and connectivity of the system;
- Efficient system management and operations; and
- System preservation.

To discharge the above responsibilities, MPO staff must develop a transportation plan that reflects a 20-year forecast of future travel. This is commonly done with the assistance of computerized travel demand models that provide information on how urban growth and proposed facility and operational investments will affect the operation of the transportation system.

In addition, MPOs in federally designated air quality nonattainment and maintenance areas must determine whether their regional transportation plans and programs conform to state air quality implementation plans (SIPs) for meeting national air quality standards.[2] This transportation conformity evaluation requires MPOs to use forecasts for their Transportation Improvement Program and long-range plan to estimate traffic volumes and speeds, which become inputs to the Environmental Protection Agency's (EPA's) MOBILE model.[3] That model, in turn, provides estimates of future motor vehicle source emissions. These emissions estimates are used to determine whether the proposed transportation plan and programs will result in motor vehicle emission levels that are consistent with those established in state air quality plans and approved by EPA. Under federal "conformity" requirements, if the estimated emissions that result from future vehicle travel exceed the limits established in the SIP and transportation conformity cannot be determined, projects and programs may be delayed (FHWA 2007a).

[1] 23 USC 134(h)(1) and 49 USC 5303(h)(1).

[2] The Clean Air Act, last amended in 1990, requires the Environmental Protection Agency to set National Ambient Air Quality Standards (40 CFR Part 50) for pollutants considered harmful to public health and the environment.

[3] In California, EPA has authorized the use of the Emission Factor (EMFAC) model.

Travel demand models also play a significant role in FTA's New Starts and Small Starts program as a basis for project development and the environmental review process (e.g., preparation of the Environmental Impact Statement).

Travel demand forecasts produced by computer models are central to the statutory responsibilities of MPOs. The future is intrinsically clouded by uncertainty, and it is critical for MPOs to employ models and modeling practice producing the best possible forecasts of future travel for alternative scenarios.

The following key concepts underlie the most widely used travel demand forecasting procedures:

- Human activities are spatially separate, and travel is needed because of that separation. Travel consumes time, money, and resources, but it is necessary because of the need to reach activities that are not close by (Stopher and Meyburg 1975).
- Demand for travel is, thus, "derived." Except for certain recreational purposes, people do not demand travel for its own sake. Rather, they demand such daily activities as work, shopping, recreation, and education, and travel allows them to reach these activities (Meyer and Miller 2001).
- The analysis of travel is derived from microeconomic theory relating demand to supply in a market setting. *Travel demand* comprises the volumes of travelers flowing from one place to another. *Travel supply* includes the available transportation systems (highways, transit, bikeways, and walkways) and their operating features. *Price* in urban travel markets is represented by travel times or distances and travel costs. The most commonly used metropolitan travel forecasting models represent the interactions among demand, supply, and price in a combined regional travel demand model. More advanced modeling practice may require interfaces with separate supply models to provide detailed information on such transportation system characteristics as speeds, volumes, congestion, delay, and traffic by time of day. Some of these advanced approaches are discussed in more detail in Chapter 6.
- Travel demand forecasting is in done in two basic steps:
  1. Analyze demand for and supply of travel.
  2. Forecast demand for travel through association with forecasts for other variables, such as population, housing, employment, and automobile ownership.

Travel demand forecasting models in use by MPOs are sequential systems of component submodels, sometimes referred to as a "model chain" or "model set." In the present study, "model" refers to the complete system of model components unless otherwise noted. The entire process in a typical four-step model system is summarized in Chapter 4.

EXPANDED REQUIREMENTS FOR METROPOLITAN TRAVEL MODELING

MPOs today face a much broader and more complex set of requirements and needs in their travel modeling than they did in the 1960s and 1970s, when the primary concern was evaluating highway and transit system capacity expansions. Some of the most salient of these requirements and the demands they make on modeling practice are discussed below. Chapter 5 reviews the shortcomings of current models for meeting these expanded needs, and Chapter 6 reviews advances toward improved modeling practice.

Motor Vehicle Emissions and Vehicle Speeds

EPA's currently approved methodologies for estimating motor vehicle emissions[4] rely heavily on vehicle speeds, a factor to which emissions estimates are extremely sensitive (FHWA 2006). Modeled speed estimates in turn rely on accurate representations of capacity and validation against measures of congestion. Since congestion is a determinant of speed and changes with the time of day, time-of-day modeling is necessary. Currently, some MPOs model separate time periods, but this approach still does not yield a full representation of the continuous time shifting of trips due to changes in congestion levels. Moreover, current travel forecasting models are used primarily to produce estimates of vehicle and traveler volumes. Modeled speeds may not accord well with observed speeds and may need to be adjusted through a "postprocessing" procedure prior to being used as inputs to the MOBILE model. The production of accurate representations of vehicle speeds for emissions modeling using the current travel models is therefore a considerable challenge.

Induced Travel

The report *Expanding Metropolitan Highways* (TRB 1995) documented the finding that highway capacity expansions that reduce travel times induce new

[4] MOBILE6.2 model for areas outside of California and EMFAC within California.

travel on the improved highway facility. This occurs because improved travel times may encourage travelers to change their route, change the time they travel, switch from transit to driving, or make a trip they would not have made when the highway was more congested. The same report also noted that the then-current four-step travel models could not adequately measure induced travel. This finding is significant because it means that the models may underestimate the usage of new or widened highways.

To forecast volumes and emissions more accurately, some MPOs have decided to include the induced-travel effects of major capacity additions. The need for such expanded model applications has led to the development of household activity–based modeling, which starts with activity schedules, vehicle allocations, and the development of tours for each driver. Only a few large MPOs have developed activity-based models, but these models will become more common as the software and data issues involved become more tractable. Activity-based models are discussed in more detail in Chapter 6.

Land Use Policies

Many growing regions must consider options other than transportation capital improvements for addressing future mobility needs. Their MPOs therefore need to be able to model land use policies such as increases in overall density, urban growth boundaries, intensification around rail stations, and more mixed housing and employment. Models must be sensitive to these variables. Larger MPOs have respecified their models accordingly, adding the necessary variables in their trip generation and mode-choice model steps. They have also added an automobile ownership step that is sensitive to land use characteristics.

Nonmotorized Travel

The amount of nonmotorized travel (walking and biking) is affected by urban form (density and mix), road congestion, automobile ownership, and neighborhood amenability to walking and biking. As these characteristics change through time, the share of walking and bicycle trips changes as well.

Modeling of nonmotorized travel is a major issue for urban areas considering policies of smart growth and transit-oriented development to address future mobility needs and to reduce vehicle miles traveled and vehicle emissions. More broadly, nonmotorized travel can make up nearly 10 percent of the trips in a medium-sized or large urban region. Thus, a model that does not address these modes fails to account for a substantial market share of the region's travel.

Transportation Policies

Air quality nonattainment areas must pay increased attention to travel demand management as a means of reducing vehicle emissions. Travel demand management encompasses such policy measures as variable tolls, parking charges, and fuel taxes. Some regions are exploring such measures as a means of controlling traffic congestion or raising revenues to pay for highway and transit construction. These pricing policies place additional demands on modeling. For example, time-of-day responses to changes in tolls must be modeled to represent the effects of peak-period tolls. Doing so requires a detailed understanding of the value of time and behavioral responses to time-variable prices for different segments of the traveling public.

Cumulative and Secondary Impacts

The National Environmental Policy Act requires assessment of the impacts of new or expanded transportation facilities, which often includes the growth-inducing impacts of projects. Recent research has yielded estimates of the elasticity of development (permits per year) with respect to changes in driving speed and changes in freeway capacity (Cervero 2003). Methods for estimating induced land development impacts range from professional judgment to use of expert panels or formal models. Several MPOs and state departments of transportation have used expert panels, a practice that has been documented in published reports (FHWA 2003). Several other MPOs have used formal integrated "urban models" that combine land use and travel forecasting, and models that are stronger in their adherence to theory have recently come into use (Wegener 2005) and are discussed in the literature (Wegener 2004; Hunt et al. 2005). Several MPOs, such as that in the Sacramento region, are applying the newest land use models in conjunction with tour-based and activity-based travel models.

Environmental Justice

The human environment is a key consideration in the transportation planning and decision-making processes. Presidential Executive Order 12898 (*Federal Actions to Address Environmental Justice in Minority Populations and Low Income Populations*) was signed in February 1994. It requires agencies to account for and avoid disproportionate adverse impacts on low-income and minority households or disproportionate distribution of benefits. To implement this executive order, USDOT and FHWA and FTA have published program guidance specifying that MPOs should have processes in place for assessing the environmental justice impacts of transportation plan investments (USDOT 1997; FHWA and FTA 1999). These impacts can be analyzed with census household data or with more complete methods that include measures of traveler economic welfare by income class.

Economic Development

Some regions and states are becoming interested in how changes in the transportation system affect economic growth. Certain types of statewide and combined transportation–land use integrated urban models can produce performance measures for wages, land rents, and economic growth rates. Some MPOs are adding heavy-truck models, and larger MPOs are developing goods movement models, which provide more complete representations of total vehicle movements. Truck traffic is forecast to increase more rapidly than automobile traffic as a result of higher consumption of goods per capita, just-in-time manufacturing, and increased global trade.

Projecting changes in economic development requires that agencies undertake new modeling practices. But a travel model does not encompass the total economy, just personal travel. Urban models represent an opportunity to measure changes in the economy in much more inclusive ways. Metropolitan regions and states that use commodities movement models with a mode-choice step can obtain a more accurate version of the economic benefits of alternative transportation investments because these models represent the costs of goods movement more accurately. Some urban models can also project changes in total production for different economic sectors. Such a set of measures is useful in many cases. The 2004 Oregon Bridge Study, for instance, used this set of economic impact measures to determine priorities for bridge repair or reconstruction (Weidner et al. 2005). Many MPOs and a few states are developing urban models to represent future land use patterns more accurately but will also be able to use these models to obtain various measures of changes in economic development.

Planning for Emergencies

Travel models are increasingly being employed to plan evacuations due to natural disasters, to plan immunization programs, and to conduct risk assessments related to homeland security. The events of September 11, 2001, exemplify the need for these new modeling applications and, in turn, the need to develop new modeling practices and data that are appropriate for emergency planning.

Changes in Population

Demographic trends anticipated in the United States over the coming decades may have effects on travel demand and thus pose new challenges for modelers. These trends include the aging of the population, continued increases in population growth, and increases in immigrant populations (Little and Triest 2001):

- Those aged 65 and older will grow to 20 percent of the population by 2030. The increased older population will be located disproportionately in low-density areas, with attendant mobility, access, and road safety issues (Herbel et al. 2006).
- While U.S. population growth is expected to slow in the coming years, an overall increase of almost 25 percent is expected from 2005 to 2030. This growth will be highly concentrated in the south and west, particularly California, Texas, and Florida. New demand for transportation facilities will be especially acute in higher-growth areas, and certain types of travel modeling may be specific to these needs (PB Consult 2006).
- The Census Bureau has projected that new immigrants and their offspring will account for about two-thirds of U.S. population growth from 1998 to 2100. It is challenging to forecast and plan for the impacts of this population shift on urban development and travel demand (Little and Triest 2001).

Summary

The changes in demography, federal laws, and transportation policies discussed above have resulted in a need for models that are (*a*) more completely specified, to address more variables of interest; (*b*) more disaggregate in time, space, and categories of activities; and (*c*) better able to account for supply-side effects (traffic operations).

SUMMARY FINDINGS

The current practice of metropolitan travel forecasting and the relationships among the responsible agencies are grounded in circumstances and events of the past 50 years.

Following World War II, the federal government showed increasing interest in addressing urban issues through regional councils. The Housing Act of 1961 and the Federal-Aid Highway Act of 1962 laid the foundation for the current metropolitan transportation planning process and led to the establishment of MPOs for every urbanized area in the country. A designated MPO and an ongoing planning process are required for federal-aid funding to flow to transportation projects within metropolitan areas. MPOs are designated by agreement between a state governor (or governors in the case of multistate MPOs) and units of local government. This is a requirement of the federal government through laws enacted by Congress and rules promulgated by USDOT.

MPOs represent a partnership among the federal, state, and local governments, created to ensure that a continuing, comprehensive, and cooperative transportation planning process is in place in each metropolitan area. MPOs receive annual core funding from both FHWA and FTA, often with state matching funds. Nationally, the federal share of this funding was $366 million in 2006, up from $161 million in 1992. In 2006 there were 384 MPOs.

The MPO and its policy board are charged with developing a metropolitan long-range transportation plan with at least a 20-year horizon and a short-range Transportation Improvement Program comprising projects drawn from the long-range plan. The major technical innovations in use for today's practice of travel forecasting were developed in the 1950s and 1960s through transportation studies in such cities as Detroit, Chicago, Cleveland, Philadelphia, Washington, D.C., and New York. The entire process is termed "travel demand forecasting" or the "four-step process." While the use of computerized, network-based travel models is not mandated by federal or state law, most MPOs operate such four-step models as an integral part of their planning process.

The analysis of travel is derived from microeconomic theory relating demand to supply in a market setting. *Travel demand* comprises the volumes of travelers flowing from one place to another. *Travel supply* includes the available transportation systems (highways, transit, bikeways, and walkways) and the operating features of those systems.

Travel demand models, as they have evolved, are deterministic, providing point-estimate forecasts. This approach is acceptable for solving simple problems, such as whether a new freeway should have four or six lanes. Today, however, MPOs face a much broader and more complex set of requirements and needs in their travel modeling than they did in the 1960s and 1970s, when the primary concern was evaluating highway and transit system capacity expansions. They must now account for or evaluate such issues as the following:

- Motor vehicle emissions and vehicle speeds;
- Induced travel;
- Alternative land use policies;
- Nonmotorized travel (walking and bicycling);
- Transportation policies, such as congestion pricing;
- Cumulative and secondary impacts of transportation facilities;
- Environmental justice, or avoiding disproportionate adverse impacts on low-income and minority households or disproportionate distribution of benefits;
- Economic development;
- Emergencies due to weather, health, or threats to homeland security; and
- Demographic changes.

Changes in demography, federal laws, and transportation policies have resulted in a need for models that are (*a*) more completely specified, to address more variables of interest; (*b*) more disaggregate in time, space, and categories of activities; and (*c*) better able to account for supply-side effects (traffic operations).

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Abbreviations

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FTA	Federal Transit Administration
TRB	Transportation Research Board
USDOT	U.S. Department of Transportation

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3

Institutional Framework for Travel Demand Modeling

The federal government, state transportation agencies (STAs), and metropolitan planning organizations (MPOs) have historically shared responsibilities for developing travel demand models and making metropolitan travel forecasts. Initially, federal agencies took the lead in developing travel forecasting methods and software and were able to devote substantial staff and financial resources to this effort. Through time, these responsibilities have devolved to the states, MPOs, and the private sector. Following is a discussion of how the federal government, the STAs, and the MPOs work together to accomplish metropolitan travel forecasting.

FEDERAL GOVERNMENT

In the 1950s and 1960s, the Bureau of Public Roads (BPR) led the development of standardized computer programs for simulating and forecasting travel on urban highway networks. These models were essential to those conducting metropolitan transportation studies, who did not have the resources to develop their own programs. BPR staff also provided substantial assistance to state and local planners wishing to apply these new models, which collectively became known as PLANPAC (Weiner 1999). Indeed, during this period it was not unusual "for BPR employees to actually staff and run the Planning Survey operations for a state" (Mertz n.d.). Computer programs for transit planning were also developed in the mid-1960s by the U.S. Department of Housing and Urban Development, which had responsibility for the federal transit program. A new version of these programs was released by the Urban Mass Transportation Administration (UMTA) in 1973 as the Urban Transportation Planning

System (UTPS). In 1976, the Federal Highway Administration (FHWA) (the successor to BPR) decided to join UMTA in supporting the UTPS package.

UTPS was supported by the federal government as the standard set of programs for metropolitan travel forecasting from the mid-1970s to the late 1980s. Running the programs required an IBM mainframe computer, which most STAs and large MPOs either owned or could access. UTPS encompassed the primary submodels of the four-step process—trip generation, trip distribution, mode split, and traffic assignment. FHWA and UMTA provided software, training, and manuals for both basic and advanced practice in setting up and running the UTPS models. Users were responsible for establishing area systems, coding networks, providing local data, and calibrating the models to local conditions. In some states, such as Ohio, the STA assumed responsibility for setting up and running all the models (Ohio Department of Transportation 2006). In other states, the STA addressed the modeling needs of smaller MPOs, and the larger MPOs were self-sufficient. In still other states, the MPOs handled all their own modeling needs.

In the 1980s, advances in the storage capacity and speed of microcomputers allowed them to replace mainframe computers for running the travel forecasting models. Within a decade, the common practice evolved from modeling on mainframe computers to reliance on microcomputers, and while operating systems differed, the basic computational approaches to travel modeling remained the same. By 1989 FHWA and the Federal Transit Administration (FTA) had stopped providing user support for mainframe UTPS applications, and the transition to microcomputers was nearly complete. Responsibility for the development and operation of travel forecasting models had shifted from the federal government to STAs and MPOs, with support from the private sector and universities.

This devolution of modeling responsibilities and engagement of the private sector might have been expected to result in the emergence of new and improved modeling approaches and practices. In fact, as the survey of MPOs described in Chapter 4 shows, the basic practice of travel forecasting has changed little since the days of UTPS. The most significant advances have been in computer technology and such software enhancements as improved graphical displays and geographic information systems.

The federal government has not become a disinterested bystander with respect to metropolitan travel forecasting, however. A robust travel forecasting process with which to estimate travel impacts and facility needs is necessary to meet the requirements of federal laws, in particular the Clean Air Act, the National Environmental Policy Act (NEPA), and the recently enacted Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU).

FTA has taken a particular interest in the adequacy of travel forecasts. New Starts is a discretionary grant program, so FTA is careful to ensure that candidate projects compete on an equal basis. The projected ridership for projects under consideration and the associated benefits are key factors in FTA's evaluation. The agency carefully reviews the travel forecasting procedures employed to ensure that they are free of factors that would bias the results. In addition, SAFETEA-LU established a requirement that projects receiving funding under the New Starts program be the subject of before-and-after studies. Those studies are to document how the ridership achieved under the project compares with the forecasts made during project planning, thus establishing a formal and regular process for retrospective analysis of travel forecasts for major transit projects. FTA intends that the data collected and analyses performed in these studies contribute to improved travel forecasting procedures.

FTA has published guidance for New Starts that includes reporting instructions specific to travel forecasting procedures (FTA 2006). These instructions note a guiding principle: "to make sure that the travel forecasting approach does not bias the results in favor of any particular alternative." In keeping with this principle, FTA asks that the chief executive officer of an agency applying for New Starts funding certify in writing the adequacy of the technical methods employed, including use of the best available data and quality assurance reviews to identify and correct any large forecasting errors. In addition, applicants must use the FTA reporting tool Summit with the results of their travel forecasting model to calculate user benefits. Summit also imposes a rigor in quality control of travel forecasts by producing summary tables and color-coded maps that easily identify anomalies in travel patterns that highlight erroneous or illogical results in the travel forecasts.

There may be some risks in applying such a structured approach. For example, in the experience of the committee, agencies administering NEPA and New Starts requirements have sometimes interpreted them to mean that population and employment allocations must remain fixed throughout a multiscenario analysis. This restriction does not encourage the development and use of land use allocation models.

FTA and FHWA jointly conduct a certification of each transportation management area (TMA) at least every 4 years to ensure the adequacy of the transportation planning process. The TMA certification process includes a review of travel forecasting methods that typically assesses the following:

- Such factors as whether the MPO is currently applying for an FTA New Starts grant, air quality nonattainment status, planning for major projects that will increase highway capacity, local opposition to transportation plans, and threatened or actual legal actions that challenge the adequacy of travel forecasting methods;
- Measures of technical capability, including the training and experience of MPO staff, the adequacy of funding allocated for improving travel models, and peer review of travel forecasting methods; and
- Documentation of travel forecasting methods.

FHWA takes the lead for the Travel Model Improvement Program (TMIP), which comprises a number of activities designed to support metropolitan travel forecasting, including development of the TRANSIMS advanced model suite. These activities are discussed in Chapter 6.

STATE TRANSPORTATION AGENCIES

STAs are increasingly developing and using statewide travel forecasting models that can be applied in coordination with the metropolitan area models within the state. Statewide models can provide valuable information for use in metropolitan modeling, such as information on freight flows and long-distance passenger travel. This information is often difficult to obtain from within the metropolitan area.

A recent study (Horowitz 2006) reviews the current state of practice in statewide travel forecasting models. Currently, about half of the 50 states have such models operational or in development. These models have many uses, including statewide transportation planning, intercity corridor planning, economic development studies, and freight planning. Most follow the urban models closely in structure for forecasting of passenger travel. For freight forecasting, there is a trend away from truck models designed primarily to produce estimates of truck volumes on roadway segments toward models of commodity flows that permit analysis of a wider range of modal options for moving freight. Three states—California, Ohio, and Oregon—are implementing a new modeling paradigm that integrates economic activity and land use into the travel model.

In the future, statewide and metropolitan travel models may share common networks and zone systems and a common goal of seamless forecasting of the impacts of freight, passenger, and land use policies and major capital investments.

COMBINED EFFORTS OF STAs AND MPOs

Continuing federal interest notwithstanding, STAs and MPOs have assumed increased responsibility for model development and forecasting of metropolitan travel. To explore how STAs and MPOs work together in carrying out these responsibilities, the committee surveyed the 50 states at the outset of this study, in 2004. All 50 states, representing all 384 of the current MPOs, responded.

For purposes of reporting the survey results, MPOs were classified into three groups according to population, as shown in Figure 3-1. Just over half of the MPOs (55 percent) are in areas with populations of 50,000 to

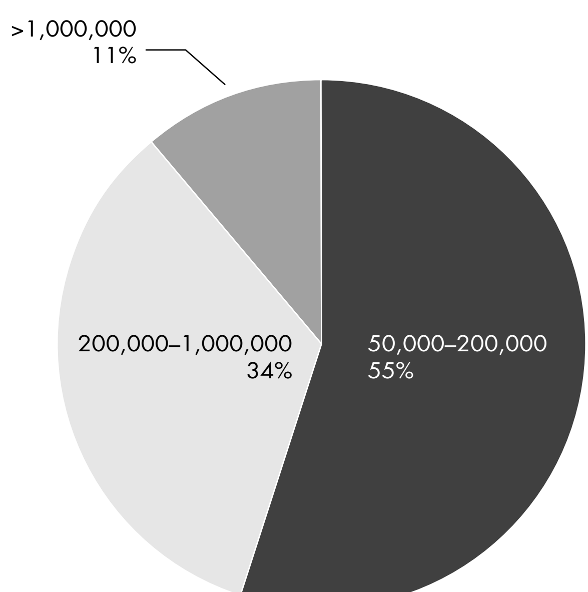

FIGURE 3-1 **MPOs by population.**

200,000, 34 percent in areas with populations of 200,000 to 1 million, and 11 percent in areas with greater than 1 million population.[1]

Sixteen states indicated that they provided MPOs with formal guidance for model development and forecasting. Some states, such as Florida and Kentucky, required that all MPOs use the same software. Some had formal guidelines, some had less formal minimum standards, and some provided training for MPO staff. In each case, there was a clear intent to achieve uniformity of practice and quality assurance of the modeling work being done by the MPOs. In addition, 14 states (Arkansas, Connecticut, Delaware, Georgia, Michigan, Montana, North Carolina, North Dakota, Ohio, Rhode Island, Texas, Virginia, Wisconsin, and Wyoming) performed model development and forecasting for many or all MPOs in the state. These states had direct control over the travel forecasting process. For the three categories of MPO by population size, the STAs and MPOs worked together in model development and forecasting as follows:

- *Population 50,000 to 200,000:* Under federal regulations, urban areas with populations of more than 50,000 must have a metropolitan transportation planning process that meets all legislative and regulatory requirements. However, those with populations below 200,000 and not in a nonattainment or maintenance area for ozone or carbon monoxide may be allowed to develop an abbreviated metropolitan transportation plan and Transportation Improvement Program. Figure 3-2 shows the breakdown of modeling and forecasting between states and MPOs for this class of small MPOs.
- *Population 200,000 to 1 million:* Urban areas with populations of more than 200,000 are designated by federal regulations as TMAs, and the MPOs that serve them are required to create and maintain a congestion management process in addition to carrying out the entire set of MPO responsibilities. Figure 3-3 shows the breakdown of modeling and forecasting between states and MPOs for these medium-sized MPOs.
- *Population exceeding 1 million:* These MPOs are likely to have more complex planning requirements and to account for multiple transit modes in their modeling processes. Figure 3-4 shows the breakdown of modeling and forecasting between states and MPOs for these larger MPOs. As might be expected, most (89 percent) did their own model development and forecasting with or without some STA assistance. Rhode Island and Virginia were

[1] While there are officially 384 MPOs, 381 were identified by this survey. By population range, they are as follows: 50,000 to 200,000, $n = 208$; 200,000 to 1 million, $n = 130$; more than 1 million, $n = 43$.

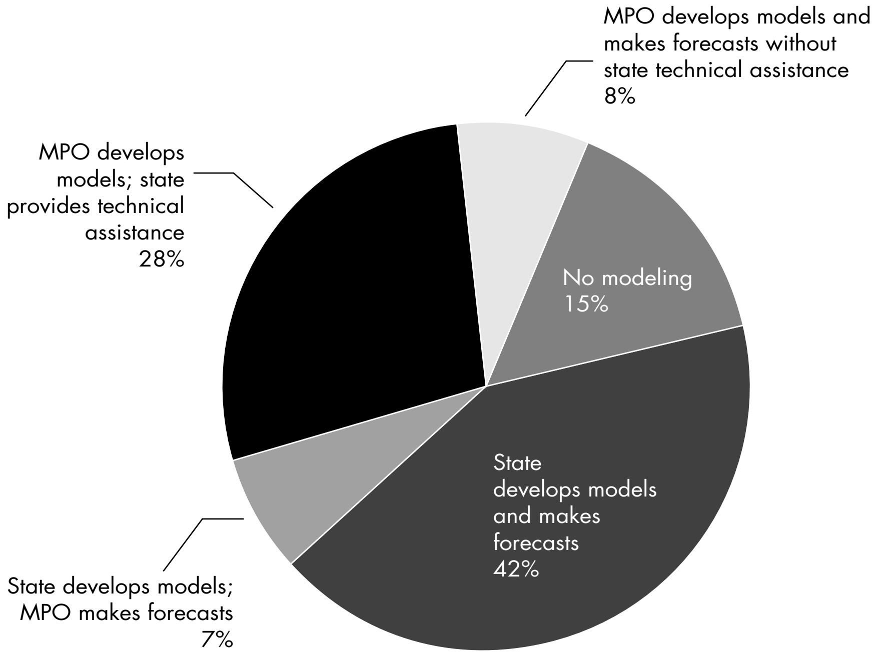

FIGURE 3-2 **MPOs with population 50,000 to 200,000.**

the only states with primary responsibility for modeling for large MPOs (for Providence and Hampton Roads).

An important finding of this survey is the extent to which STAs were directly involved in model development and forecasting, in particular for small and medium MPOs; of those small or medium MPOs that did modeling, the STA did all model development and forecasting for 37 percent. Another significant finding is that a number of states (16) provided MPOs with guidance aimed at standardizing modeling practice.

Another study identified 16 states in which STAs organize statewide MPO model user groups that meet regularly and provide such services as staff training, technology transfer, and pooled purchase of software licenses (FHWA 2007). In one state (New York), the MPOs and the state have entered into a shared-cost multiyear research and development program.[2]

[2] Overview of New York's Shared Cost Initiative. Personal communication (e-mail) from John Poorman to Jon Williams, March 28, 2006.

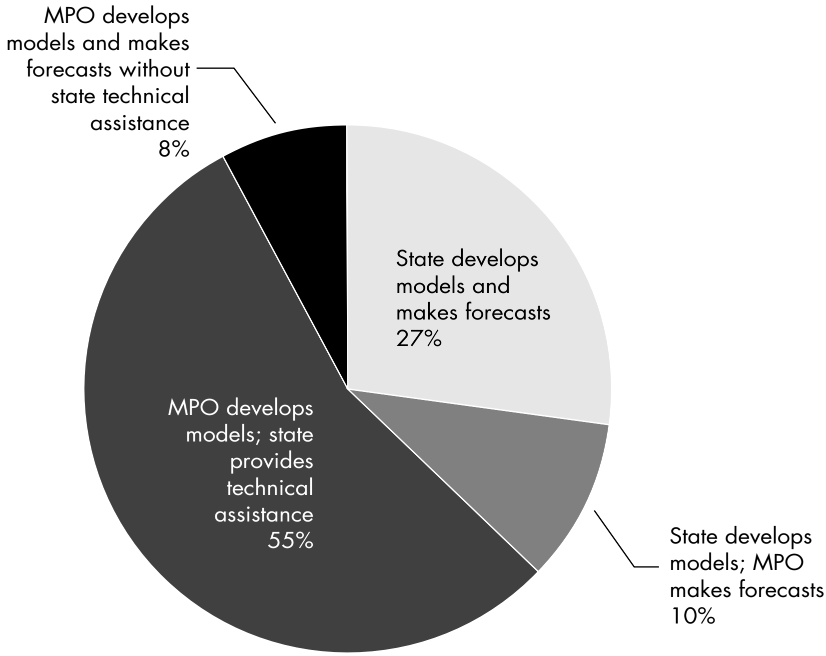

FIGURE 3-3 **MPOs with population 200,000 to 1 million.**

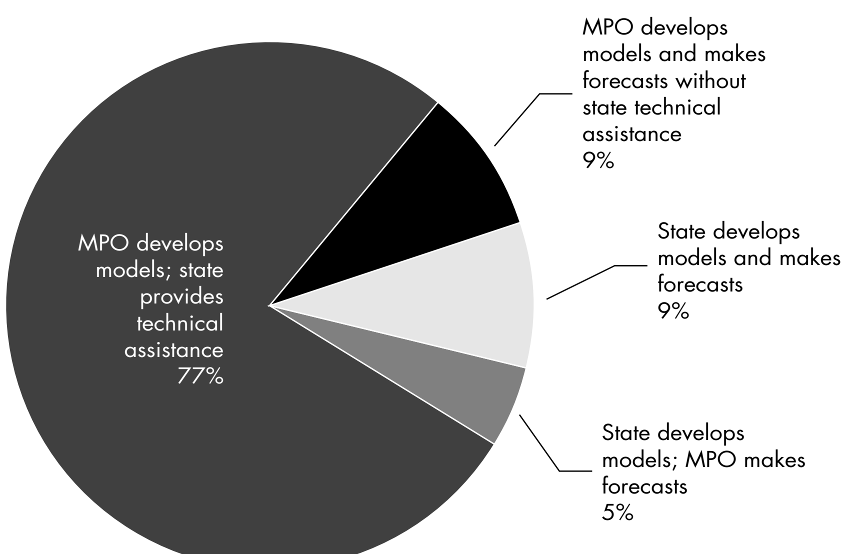

FIGURE 3-4 **MPOs with population exceeding 1 million.**

The federal government, the states, and the MPOs have a strong shared interest in the production of accurate travel forecasts to guide investments and operational planning. The public interest is best served by coordination of model development and implementation activities among these levels of government. This would be a natural role for the federal government and other national organizations. Chapter 6 explores how the research and development activities of the various levels of government and other entities could be better integrated.

SUMMARY FINDINGS AND RECOMMENDATIONS

The federal government, STAs, and MPOs have historically shared responsibilities for developing travel demand models and making metropolitan travel forecasts. Initially, federal agencies took the lead in developing travel forecasting methods and software and were able to devote substantial staff and financial resources to these efforts. Over time, these responsibilities have devolved to the states, MPOs, and the private sector.

Computer programs for transportation planning were developed in the mid-1960s. By 1973, they had evolved into UTPS, which required an IBM mainframe computer. The federal government provided software, training, and manuals for setting up and running the UTPS models. In some states, the STA assumed responsibility for setting up and running all the models. In other states, the STA addressed the modeling needs of smaller MPOs, and the larger MPOs were self-sufficient. In still other states, the MPOs handled all their own modeling needs.

In the 1980s, advances in microcomputers allowed them to replace mainframe computers for running the travel forecasting models. Within a decade, this shift had become commonplace. The basic computational approaches to modeling travel that had been used on mainframes were employed in the desktop versions that succeeded them. By 1989, FHWA and FTA had stopped providing user support for mainframe UTPS, and the transition to microcomputers was nearly complete. Responsibility for the development and operation of travel forecasting models had shifted from the federal government to STAs and MPOs, with support from the private sector and universities.

Despite this devolution of modeling responsibilities and engagement of the private sector, the basic practice of travel forecasting has changed little since the days of UTPS. The most significant advances have been in computer technology and such software enhancements as improved graphical displays and geographic information systems.

At the same time, the federal government retains an interest in metropolitan travel forecasting. FTA has taken a particular interest in the adequacy of travel forecasts. New Starts is a discretionary grant program, so FTA is careful to ensure that candidate projects compete on an equal basis. **The committee commends FTA for taking steps to ensure quality in the travel forecasting methods used for major project planning.**

FTA and FHWA jointly conduct a certification of each TMA at least every 4 years to ensure the adequacy of the transportation planning process; this includes a review of travel forecasting methods. **The federal MPO certification process, which, with a model checklist, provides MPOs with useful information on minimum expectations for their models, should be continued. In addition, examination of the conduct and results of MPO peer reviews should be incorporated into the certification process** (see Chapter 4).

TMIP, sponsored by FHWA, has the mission of supporting metropolitan travel forecasting. TMIP is discussed in detail in Chapter 6.

STAs are increasingly developing and applying statewide travel forecasting models, which may be applied in coordination with the metropolitan area models within the state. Statewide models have the potential to provide valuable information for metropolitan modeling practice. In the future, statewide and metropolitan travel models may share common networks and zone systems and a common goal of seamless forecasting of the impacts of freight, passenger, and land use policies and major capital investments.

STAs and MPOs often work together in travel model development and forecasting. The committee's survey of the states found that STAs were responsible for model development and forecasting for 42 percent of small, 24 percent of medium, and 3 percent of large MPOs. Other useful state activities in support of MPOs include establishing guidelines for standardizing modeling practice and forming statewide model user groups for such purposes as training and joint acquisition of computer software and hardware.

States play a particularly important role in supporting smaller MPOs but should also be collaborating with larger MPOs within their borders. The committee believes this can be accomplished in the following ways:

- **Support for the development of a national MPO cooperative research program** (described in Chapter 6);
- **Support for model user groups;**

• **Evaluation, in cooperation with MPOs, of socioeconomic forecasts used for MPO modeling and forecasting; and**

• **Coordination with MPOs on statewide and metropolitan models and data needs.**

This chapter has reviewed the institutional relationships among the federal government, the states, and the MPOs in developing travel models and making forecasts. These relationships have evolved over time, with the federal government playing a less prominent role. The next chapter presents information on the current state of travel forecasting practice.

REFERENCES

Abbreviations

FHWA	Federal Highway Administration
FTA	Federal Transit Administration

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4

Current State of the Practice

The committee obtained the information needed to categorize the current state of the practice in travel model development and forecasting from three sources:

- A review of the literature;
- A web-based survey of 381 metropolitan planning organizations (MPOs), 228 of which were represented by the responses received; and
- Interviews with staff at a sample of 16 agencies [MPOs or state transportation agencies (STAs) that provide travel forecasting services for multiple MPOs], designed to obtain more detailed information.

The literature review provided insights into the state of the practice as perceived by knowledgeable authors engaged in research on or the application of travel forecasting methods. The literature also notes many of the perceived shortcomings of current practice and suggests approaches for improvement. Such critiques tend to be of two types: those that question the basic paradigm on which current practice is founded and those that question specific aspects of implementation. The noted shortcomings are discussed more fully in Chapter 5.

The web-based survey provided a broad view of travel forecasting as it is practiced by MPOs of various sizes across the nation that deal with a wide variety of planning issues. Even with an extensive questionnaire, however, the survey could address only the general methods used by each agency. Follow-up interviews were therefore conducted with MPOs represented by committee members and with several agencies known to have implemented new procedures or to be active in relevant professional organizations. The survey and interview findings are summarized below. Additional detail is provided in the electronic annex to this report [available at onlinepubs.trb.org/onlinepubs/reports/VHB-2007-Final.pdf (VHB 2007)]. Information derived from the survey is descriptive of the methodology used and many of the details of its application. While this information documents the state of the practice, it does not reveal whether the models used produce accurate forecasts.

For both the web-based survey of all MPOs and the targeted interviews with selected MPOs, respondents were guaranteed confidentiality. Thus the information presented here is either in summary form (most of the web-based survey findings) or linked to an agency identified by number rather than name. Only when the information is generally available through a published source is reference made to a specific MPO.

WEB-BASED SURVEY

The web-based survey was structured to obtain information that would quantifiably describe the travel forecasting procedures of a broad sample of MPOs. The express purpose was to identify the state of the practice in travel demand modeling on the basis of the current practices of regional MPOs. The survey was designed to incorporate specific questions raised by the committee with regard to travel demand forecasting, as well as to provide an assessment and categorization of common modeling methods.

Initial versions of the survey were developed and pretested by two MPOs in May 2005. The final surveys were originally distributed to all MPOs in June 2005, and responses were received through December 2005. The committee made a special effort, with assistance from the Association for Metropolitan Planning Organizations (AMPO) and others, to obtain information from those MPOs classified as large (i.e., in areas whose population exceeds 1 million).

The survey was sent to 381 MPOs identified in databases obtained from the Federal Highway Administration (FHWA) and AMPO. In addition, each STA received an e-mail with a link to the survey and notification that a survey request had been sent to each of the MPOs in the state. STAs and regional MPOs were asked to coordinate and cooperate in responding to the survey. This was of particular importance for those states in which most of the travel demand forecasting work, including model development or application, is done by the STA. In these states, the STA completed and submitted the survey for each MPO. When the analysis data set was closed, responses reporting data for 228 MPOs had been received. These 228 represent 60 percent of the 381 MPOs to which the survey was distributed—84 percent of the 43 MPO areas with a population of more than 1 million (large), 57 percent of those with a population of 200,000 to 1 million (medium), and 57 percent of those with

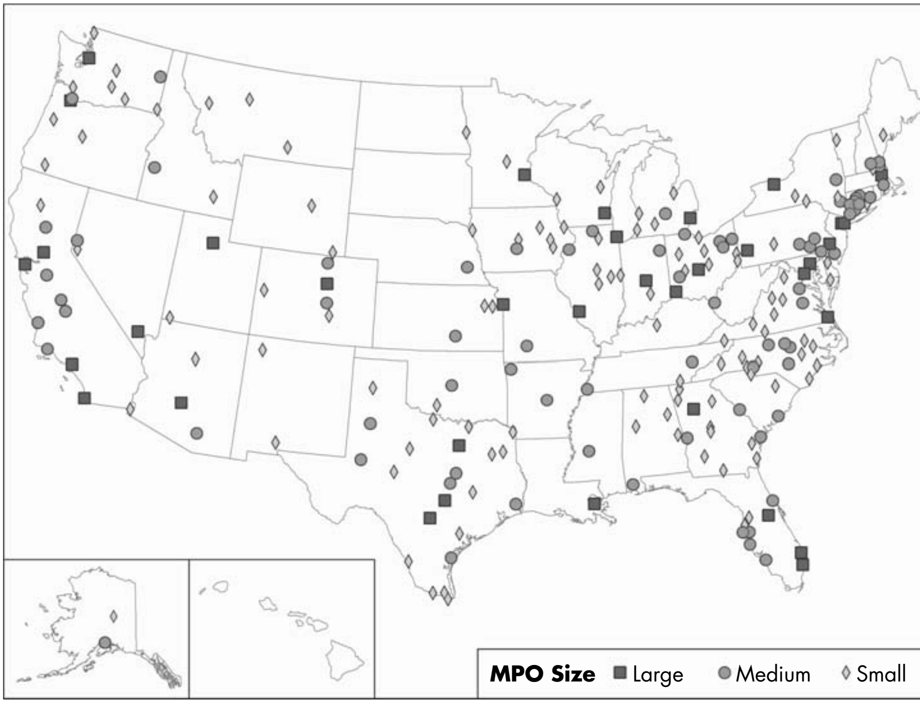

FIGURE 4-1 **MPOs from which responses were received.**

a population of less than 200,000 (small). Since not all questions were answered for each MPO, the number of responses was not the same for all questions.

Figure 4-1 shows the locations of the MPOs for which survey responses were received. All states except Hawaii are represented by the responses.

Following is a summary of the basic steps of the travel modeling and forecasting process as it is currently practiced at most MPOs, based on the survey results.

Input Data

Agencies make use of extensive input data in developing travel models and preparing travel forecasts. These data include the following:

- Traffic and vehicle classification counts, highway travel times and speeds, and results of traffic origin–destination surveys;

- Transit ridership and boarding counts;
- Roadway characteristics, such as functional classification, number of lanes, link distances, and intersection characteristics;
- Transit routes and schedules;
- Results of home interview surveys, including household characteristics and individual trips made by purpose, origin–destination, time of day, and mode; and
- Current and future estimates of small-area employment, population, and households, along with other socioeconomic characteristics, such as household income and vehicle ownership.

Some of these data are current, while some are forecast for future years. The committee's web-based survey found that almost all MPOs require forecasts of population, households, and employment as input to their travel forecasting process. About half also forecast one or more of the following: household size, automobile ownership, and income. In general, MPOs are responsible for preparing these forecasts, although they often obtain assistance from other state or local agencies and consultants.

Area System

The entire region is divided into travel analysis zones (TAZs) and sometimes larger districts, which usually can be related to U.S. census tracts. The number of TAZs in a region varies from several hundred to several thousand, depending on the region's size. All travel is assumed to be to or from these zones. Each zone has a "centroid," from which all traffic is assumed to start. The zone system is often mapped in a geographic information system (GIS) database.

The number of TAZs for MPOs that responded to the committee's survey is, on average, 280 for small MPOs, 870 for medium MPOs, and 1,760 for large MPOs. The average TAZ density is 0.9, 0.8, and 0.5 TAZs per square mile for small, medium, and large MPOs, respectively.

Networks

Highway and transit networks are a principal means by which the supply side of transportation is represented. It is in the "assignment" process (discussed below) that demand and supply are brought together.

The highway network is represented as individual, connected links between intersections. Usually all freeways, expressways, principal arterials, minor arterials, and feeder/collector routes are included. Data on roadway characteristics are associated with each link. Current highway networks range in size from 4,200 links for small MPOs to more than 20,000 for large MPOs.

The transit network (if there is one) is represented as routes for the various transit systems in the metropolitan area. Some of these routes run on the highway network and share highway links, while others are on their own right-of-way. Transit networks are typically more complex than highway networks because of the multiple modes involved and the need to consider operating frequencies and schedules. The vast majority of MPOs that have rail transit within their area include the entire rail network in their transit model. More than 80 percent of all MPOs and 90 percent of large MPOs include at least 75 percent of available express bus miles in their transit network. All of the large MPOs that reported having local bus service include at least three-quarters of the local routes in their network. In contrast, more than 60 percent of the small MPOs and 20 percent of the medium MPOs that reported having local bus service include less than three-quarters of local service miles in their network.

The networks are connected to the TAZs in the area system through "centroid connectors," which attach to the centroid at or near the center of each zone. Most networks are mapped and edited by using GIS software.

Trip Generation

The trip generation step involves estimating how many trips are expected to be made to and from each TAZ for various purposes, such as work, school, shopping, and commercial transport. As many as nine trip purposes are currently used in MPO models; smaller MPOs are more likely to use fewer purposes. The estimation procedure employs mathematical models that associate each purpose with demographic characteristics of the TAZ, such as population, households, employment, vehicle ownership, and income. Current information on these variables may be obtained from special household surveys or census reports; future information is derived from forecasts, as noted above in the discussion of input data.

Trip Distribution

The trip distribution process is used to determine the number of trips between each pair of zones. Most MPOs accomplish this with a "gravity model" that assumes the number of trips between zones is (*a*) directly related to the number of trips generated from each zone and (*b*) inversely related to the difficulty of travel between two zones, which is usually a function of travel time and cost. Gravity models may be insensitive to socioeconomic or geographic variables that influence travel behavior and consequently produce results that do not correspond to actual travel patterns. In this case, the interchanges between zones may be adjusted by using so-called K-factors. The extensive use of K-factors is not recommended because they interfere with a model's ability to predict future travel (Ismart 1990). Slightly fewer than 50 percent of all MPOs responding to the web-based survey reported using K-factors or a similar type of adjustment factor in their trip distribution model.

Another model used for trip distribution is called "destination choice." This type of model includes traveler characteristics (e.g., income, automobile ownership), travel conditions, and variables that influence the attractiveness of each destination (e.g., employment by job category, land use categories by square foot). The model can thus take into account differences in circumstances that influence travelers' destination choices and are poorly accounted for in a gravity model. Some believe that destination-choice models are superior to gravity models for determining trip distribution, provide more information for use in policy analysis, and may require the use of fewer K-factors to adjust trip flows (e.g., Deakin and Harvey 1994, 43). The committee's survey found that 11 MPOs are currently using destination-choice models.

Mode Choice

Mode choice is the allocation of trips between automobiles and public transit. Within automobile travel, there is further allocation between drivers and passengers; within public transit, there may be allocation among local bus, express bus, and various rail options. Some MPOs include bicycle and walking trips in their mode choice model. This modal determination is made on the basis of the trip's purpose, origin, and destination; characteristics of the traveler; and characteristics of the modes available to the traveler. More than

90 percent of large MPOs and 25 percent of small MPOs reported using a mode-choice model. More than half of large MPOs reported that representation of nonmotorized trips is part of their model set; few medium MPOs and almost no small MPOs model nonmotorized trips.

Assignment

Assignment is the allocation of trips to actual routes in the transportation network described above. The committee's survey showed that a number of small (8 percent) and medium (4 percent) MPOs use the "all-or-nothing" assignment method, which allows travel between zones to be assigned according to the least-time route without regard to congestion. Most MPOs (73 percent of small, 74 percent of medium, and 91 percent of large MPOs) use the more sophisticated "equilibrium" method, which accounts for congestion and delay in assigning travel to specific routes. This method may require a number of iterations to achieve stability.

In many smaller MPO regions, there is little traffic congestion, and transit service is minimal. For such regions, it is reasonable for MPOs to assign average daily (24-hour) travel, a method that requires the use of factors to represent probable morning and afternoon peak period demand and resulting congestion. More complex regions with traffic congestion and more extensive transit operations model travel by time periods within the day and account more explicitly for congestion effects on route choices. Among large MPOs, 75 percent assign travel for at least two and as many as five time periods, including a.m. peak period, p.m. peak period, midday, evening, and nighttime.

Feedback

Travel times are typically required to estimate trip distribution and mode choice; however, travel times depend on the level of congestion on routes in the network, which is determined only after trip assignment has been completed. Once congested travel times have been determined by the assignment process, these adjusted travel times should ideally then be fed back through the distribution, mode-choice, and assignment processes to produce more realistic estimates of travel. Feedback is a model feature required for metropolitan areas that are not in attainment of federal clean air standards.

The use of feedback has become more common as advances in computing power have enhanced the ability to iterate at reasonable time and cost. More than 80 percent of large MPOs feed back times to distribution and mode choice; 40 percent feed back congestion effects to forecasts of land use and automobile ownership.

Postprocessing for Emissions Calculations

Hourly link-specific traffic volumes and speeds must be calculated for use as inputs to the Environmental Protection Agency's (EPA's) MOBILE emissions model or California's EMFAC model. These detailed emission model inputs are not usually travel model outputs and so must be postprocessed after the model has been run.

Commercial and Freight Travel

The treatment of commercial and freight travel is one area in which most travel forecasting models need substantial improvement. The development of better models is hampered by a lack of data on truck and commercial vehicle travel both within and beyond the metropolitan area. Truck trips are modeled in some fashion by about half of small and medium MPOs and almost 80 percent of large MPOs; few MPOs have the ability to model all freight movement.

Movement Toward Advanced Models

About 20 percent of small and medium MPOs and almost 40 percent of large MPOs reported that they are exploring replacing their existing model with an activity- or tour-based model (see Figure 4-2). Three U.S. cities have implemented such advanced models, and eight others are in the design process (see Chapter 6). The committee's in-depth interviews with selected MPOs, however, revealed that many of them are satisfied with their current model and believe it is adequate for most planning purposes.

In the web-based survey, 70 percent of large and medium MPOs identified features of their models needing improvement. The most commonly cited improvement was developing a tour- or activity-based model.

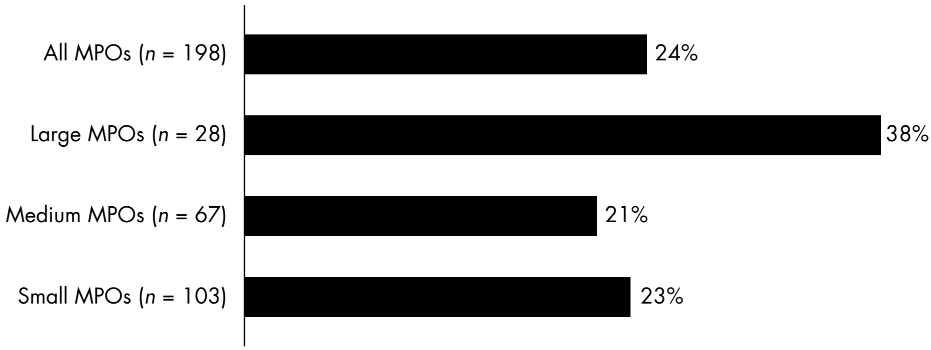

FIGURE 4-2 **MPOs considering activity- or tour-based models.**

MPO INTERVIEWS

The committee's in-depth data gathering, including interviews of key MPO staff and supplemental written documentation provided by selected MPOs, offers insights beyond those obtainable from the mere tabulation of survey data. While these efforts could not be of sufficient depth or detail to allow assessment of the degree to which the procedures used by any agency produce accurate or valid forecasts, they do offer a view of specific practices used or contemplated by at least some of the more active MPOs. Given the small number of in-depth interviews, the methods and procedures of these agencies cannot be viewed as average or representative of the practice of most MPOs; rather, they are a snapshot of what at least a few active agencies have undertaken.

After reviewing the web-based survey findings, the committee identified several topics on which it would be desirable to obtain further information through discussions with a number of MPOs. These topics included the following:

- Validation,
- Sensitivity analysis,
- Staffing and budget,
- Advanced practices,
- Barriers to improvement, and
- Perceived shortcomings of current methods.

The committee identified 16 MPOs or STAs as candidates for these discussions (see Table 4-1). These agencies were selected because there was

TABLE 4-1

Interviewed Agencies

In-Person Interview		Phone Interview	
Agency	Area	Agency	Area
East-West Gateway Council of Governments	St. Louis, Missouri	Atlanta Regional Commission[a]	Atlanta, Georgia
Mid-Ohio Regional Planning Commission	Columbus, Ohio	Chicago Area Transportation Study[a]	Chicago, Illinois
North Carolina Department of Transportation	North Carolina	Community Planning Association of Southwest Idaho	Boise, Idaho
Ohio Department of Transportation	Ohio	MetroPlan	Little Rock, Arkansas
Sacramento Council of Governments	Sacramento, California	MetroPlan Orlando	Orlando, Florida
Virginia Department of Transportation	Virginia	Metropolitan Transportation Commission[a]	San Francisco, California
		Metro	Portland, Oregon
		North Central Texas Council of Governments[a]	Dallas–Ft. Worth, Texas
		Pikes Peak Area Council of Governments	Colorado Springs, Colorado
		Regional Transportation Commission of Southern Nevada	Las Vegas, Nevada

[a]Agency was not interviewed in person but provided answers to the interview questions in written form.

some indication that they were 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 had developed or applied travel forecasting models for multiple MPOs within a state. The committee visited six of these agencies; the rest either were interviewed via phone or provided responses to a detailed questionnaire. Practices found by these agencies to be useful and to lead to better forecasts are likely to become more widely adopted and over time to be incorporated into the state of the practice. As noted above, to protect the identity of the responding agencies, the committee excluded specific agency names from the following discussion.

As is the case with the web-based survey information, more detailed information from the in-depth data gathering may be found in the electronic annex to this report.

Estimation, Calibration, and Validation

Model validation must be understood as one of four closely related processes—estimation, calibration, validation, and application. The correct conduct of these processes is crucial to the quality of model results.

- *Model estimation:* Information on actual travel is gathered by such means as household travel surveys and transit on-board surveys. Statistical estimation procedures are then used to create a model that can replicate the actual travel data.
- *Model calibration:* After the model has been estimated, it is calibrated so that predicted travel accords with observed travel on highway and transit networks.
- *Model validation:* After the model has been estimated and calibrated, it is validated to test its ability to predict future behavior. Validation requires comparing the model output with information other than that used in estimating or calibrating the model. The model output is compared with observed travel data, and parameters are adjusted until the output falls within an acceptable range of error. There are two superior (but not often performed) ways of checking model performance: (*a*) the historical method, in which a prior-year model is used to forecast current travel, which is then compared with actual current travel; and (*b*) backcasting, in which a current-year model is used to estimate travel for a prior year, which is then compared with actual travel in the prior year. Backcasting is used by 5 percent of all and 13 percent of large MPOs. (An example of the historical method is given in Chapter 5.)
- *Model application:* Although a model may replicate base-year conditions, the model forecasts for future-year conditions should be checked for reasonableness. The sensitivity of the models in response to system or policy changes may be used as part of the reasonableness check (FHWA 1997).

The committee's survey and interviews revealed that true validation is often hampered by a lack of independent data sources. Even the more active MPOs validate against much of the same data (for example, nonwork trip generation, trip distribution, and mode choice) used to develop their models. Moreover, there are no commonly agreed-upon standards for an acceptable range of error other than thresholds suggested by FHWA and STA guidance such as the Ohio Department of Transportation's *Traffic Assignment Procedures* (Giaimo 2001).

Sensitivity Analysis

As noted above, sensitivity testing is key to checking the reasonableness of travel forecasts. Formal procedures used for sensitivity analysis are described in the literature (Barton-Aschman Associates and Cambridge Systematics 1997). Two agencies interviewed for this study have begun changing some aspect of the system (e.g., inserting or removing employment and residential units in several zones, changing travel times) and then analyzing the forecast changes in trip making, trip distribution, mode shares, and network congestion. These agencies also remove links from the highway network to determine the impact on traffic volume on other highways in the network. In addition, specific aspects of the model may be tested, such as the sensitivity of mode choice to transit fares.

Such sensitivity testing is done in a small number of agencies, but the practice is not widespread. Agencies that do perform sensitivity analysis appear to do so on an ad hoc basis. The Federal Transit Administration's (FTA's) Summit tool has also been used for model checking.

Staffing and Budget

MPOs vary significantly in the number of staff devoted to travel forecasting. While the committee's web-based survey of MPOs did not request information on the size of travel forecasting staff, this was a topic of the in-depth interviews. Among the MPOs interviewed, the staff reported as working on travel forecasting ranged from one person part-time with support from the state agency to as many as seven working at least part-time on some aspect of the process. The agency typical of this group of MPOs has two or three staff involved in travel forecasting and spends \$150,000 to \$200,000 annually on model application. Another study found that MPOs with a population of less than 500,000 have an average of one full-time travel modeler on staff, while larger agencies average three full-time modelers. The same study found that virtually all MPOs believe it is either difficult or very difficult to hire experienced travel modelers (*Urban Transportation Monitor* 2006).

Typically, model development is specifically budgeted for when a major upgrade is undertaken. Most of the interviewed agencies reported using consultants for model development, but a few have budgets large enough to support staff that can devote at least some time to consideration or development of model improvements. Most of the agencies reported an increase in both staff and budget over the past 3 years.

Advanced Practices

Advanced practices include not only a major shift in the modeling paradigm from trip- to tour- or activity-based, but also incremental improvements to the four-step trip-based process. The interviews revealed several practices in use by the MPOs that have the potential for more widespread application. One of the agencies interviewed has an operational advanced model and five more are actively developing such models, while several others expressed an interest in doing so. Other agencies are less interested in the near-term implementation of advanced modeling practices and appear to be satisfied with their current models. In addition, some agencies appear to be interested in developing more effective truck models and special generator models.[1]

Obstacles to Improvement

Agencies interviewed cited a desire for tangible evidence that new procedures perceived as more complex or requiring significantly greater effort for development and application would yield forecasts notably better than those produced with currently accepted procedures. Other factors cited as impeding the adoption of advanced techniques were the unavailability of vendor-supplied software needed for implementation, a lack of sufficient staff to apply the new techniques, the difficulty of finding staff versed in the development and application of the techniques, and insufficient funds for the purpose. As noted,

[1] "Special generators" are developments such as airports, universities, shopping centers, and hospitals that place special demands on the transportation system.

some of the MPOs interviewed believe their current models are doing an adequate job for the issues they are asked to address.

Perceived Shortcomings of Current Methods

Many MPOs would like to have improved procedures for studying policy and land development issues and for addressing truck trips and freight movement. Agencies also recognize that current regional travel forecasting procedures are not capable of addressing some policy issues and fail to provide the detail often requested for design studies or impact analyses.

MATCHING THE MODEL TO THE CONTEXT

The committee finds that no single approach to travel forecasting or set of travel forecasting procedures is “correct” for all applications or all MPOs. Rather, travel forecasting tools developed and used by an MPO should be appropriate to the nature of the questions being posed by the constituent jurisdictions and the types of analyses being conducted. Using a simplistic model to analyze complex issues can lead to findings that do not properly reflect the likely traveler response patterns. Similarly, applying an overly complex method to more straightforward issues not only diverts resources that might have better uses but also creates an opportunity to introduce errors related to factors not directly applicable to the problem at hand.

Figure 4-3 illustrates how the modeling approach employed can be tailored to the issues being addressed. As the detail required to address a transportation issue increases, so, too, should the complexity of the analysis techniques. In a smaller metropolitan area experiencing little or no growth, with little transit, and having no air quality problems, a three-step model will likely be sufficient to determine the proper number of lanes for a new roadway. At the other end of the spectrum is a rapidly growing metropolitan area that is not in attainment of air quality standards, has severe congestion, and is planning to apply dynamic tolling for high-occupancy travel lanes on which there will also be bus rapid transit. In such an area, it will be desirable to have a travel forecasting process that (*a*) is sensitive to prices; (*b*) allows analysis of mode choice, time-of-day choice, and trip chaining; (*c*) permits detailed assessment of travel speeds by segment and time; and (*d*) incorporates sufficient

		Level of detail required for analysis: Aggregate ←→ Disaggregate					
	Typical transportation issues	Roadway sizing	Transit New Starts	Land use effects on mode choice	Air quality analysis/tolls	High-occupancy travel lanes, variable tolls	Corridor studies, peak spreading, saturated networks
		Transportation analysis methods					
Typical land use issues	Land use analysis methods	Three-step	Four-step	Five-step (automobile availability) with land use variables	Population synthesis	Household activity-based	Traffic microsimulation
Slow to moderate growth	Spreadsheets, geographic information systems	■	■				
Fast growth, growth impact analysis	Lowry-type accessibility-based models[a]		■	■			
Growth, housing costs, environmental justice	Real estate market models			■	■		
Economic development	Markets and input/output models			■	■	■	■
Economic development and environmental justice	Disaggregate business and residential location models			■	■	■	■

■ = Reasonable combination of models

[a] The Lowry-type accessibility-based model was first developed by Ira S. Lowry for Pittsburgh. Such models estimate the location and scale of (*a*) employment for basic industries and services whose clients are outside the region, (*b*) employment for retail activities serving the region, and (*c*) the resident population of the region (Chapin and Kaiser 1979).

FIGURE 4-3 **Matching the model to the context.**

information about travelers to support an analysis of disproportionate impacts on minority and low-income populations.

SUMMARY FINDINGS AND RECOMMENDATIONS

The information used by the committee to describe the current state of the practice in metropolitan travel forecasting was obtained from three sources: a review of the literature, a web-based survey that yielded responses representing 228 MPOs, and interviews of staff at a sample of 16 agencies (MPOs or STAs).

The basic modeling approach at most MPOs remains a sequential four-step process in which the number of daily trips is estimated, distributed among origin and destination zones, divided according to mode of travel, and finally assigned to highway and transit networks. Certain practices are common to most MPOs, while others differ according to local circumstances:

- *Common practice:* Forecasts of population, households, and employment are required as input to the travel forecasting process.
- *Differing practice:* About half of MPOs also forecast one or more of the following: household size, automobile ownership, and income.
- *Common practice:* The modeled region is divided into TAZs. The zone system is mapped in a GIS database.
- *Differing practice:* The number of TAZs in a region varies from several hundred to several thousand, depending on the region's size.
- *Common practice:* Transportation supply is represented through highway and transit networks mapped in a GIS database.
- *Differing practice:* Highway networks range in size from 4,200 links for small MPOs to more than 20,000 for large MPOs. The larger the MPO, the more likely it is to have complete representation of transit routes and service on the transit network.
- *Common practice:* Trip generation is used to estimate how many trips are expected to be made to and from each TAZ.
- *Differing practice:* Trips for different purposes, such as work, school, shopping, and commercial transport, are estimated. As many as nine trip purposes are currently used in MPO models; smaller MPOs are more likely to use fewer purposes.
- *Common practice:* Trip distribution—the process of determining the number of trips between each pair of zones—is accomplished primarily with a gravity model.

• *Differing practice:* Destination-choice models are used by 11 MPOs for trip distribution. Such a model can take into account differences in circumstances that influence travelers' destination choices, which are poorly accounted for in a gravity model.

• *Common practice:* Mode choice is the allocation of trips between automobiles and public transit. Within automobile travel, there is allocation between drivers and passengers; within public transit, there may be allocation among local bus, express bus, and various rail options.

• *Differing practice:* Some MPOs include bicycle and walking trips in their mode-choice model. More than 90 percent of large MPOs reported using a mode-choice model, while 25 percent of small MPOs reported using such a model.

• *Common practice:* Assignment is used to allocate trips to actual routes in the transportation network.

• *Differing practice:* Many smaller MPO regions have little traffic congestion and minimal transit service, and MPOs may assign average daily (24-hour) travel. More complex regions with traffic congestion and extensive transit operations model travel by time periods within the day to better account for the effects of congestion on route choice. Among large MPOs, 75 percent assign travel for at least two and as many as five time periods.

The committee's web-based survey and MPO interviews revealed a number of areas for improvement in metropolitan travel forecasting.

First, about 50 percent of all MPOs use K-factors or a similar type of adjustment factor in their trip distribution models. Extensive use of K-factors is not recommended because they interfere with a model's ability to predict future travel.

Second, most travel forecasting models are in need of substantial improvement to address commercial and freight travel. A lack of data on truck and commercial vehicle travel both within and beyond the metropolitan area is a major issue. Truck trips are modeled in some fashion by about 50 percent of small and medium MPOs and almost 80 percent of large MPOs. Few MPOs have the ability to model all freight movement.

Third, models are validated to test their ability to predict future behavior. Validation requires comparing the model output with information other than that used in estimating or calibrating the model. The model output is compared with observed travel data, and parameters are adjusted until the output falls within an acceptable range of error. Validation is often hampered by a lack of independent data sources, and many MPOs validate against much of the same data used to develop the models.

Fourth, sensitivity testing is a key to checking the reasonableness of travel forecasts. Such testing is currently done by only a small number of agencies. **The committee recommends use of these tests, which vary model inputs and assumptions to determine whether the changes in modeled results are realistic.** FTA's Summit tool can also be used for model checking.

Finally, in their responses, 70 percent of MPOs mentioned the most-needed improvements to their modeling processes. The most commonly cited improvement was a tour- or activity-based model. About 20 percent of small and medium MPOs and almost 40 percent of large MPOs reported that they are exploring the idea of replacing their existing model with a tour- or activity-based model.

MPO staffs recognize the limitations of their current forecasting procedures. Yet the agencies interviewed reported the following barriers to implementing advanced modeling practices:

- A lack of tangible evidence that new procedures would yield forecasts notably better than those produced with currently accepted procedures.
- The unavailability of vendor-supplied software needed to implement new techniques.
- Resource and staff limitations. Among the agencies surveyed, staff reported as working on travel forecasting ranged from one person part-time with support from the state agency to as many as seven working at least part-time on some aspect of travel forecasting. Another study found that MPOs with a population of less than 500,000 have an average of one full-time travel modeler on staff, while larger agencies average three full-time modelers. The same study found that virtually all MPOs believe it is either difficult or very difficult to hire experienced travel modelers.
- Some of the MPOs interviewed believe that their current models are doing an adequate job given the issues MPOs are asked to address.

The committee finds that no single approach to travel forecasting or set of travel forecasting procedures is "correct" for all applications or all MPOs. Travel forecasting tools developed and used by an MPO should be appropriate to the nature of the questions being posed by the constituent jurisdictions and the types of analyses being conducted. As the detail required to address a transportation issue increases, the complexity of the analysis techniques should also increase. **The committee recommends that in their**

planning guidance and planning regulations, the U.S. Department of Transportation, FHWA, FTA, and EPA allow MPOs substantial flexibility in their travel demand modeling practices, recognizing that one size does not fit all and that unnecessary technical planning requirements could inhibit innovation and advanced practice.

This chapter has presented information on the current state of the practice in metropolitan travel forecasting, including common practice, variations in practice, areas needing improvement, and reported barriers to improvement. The next chapter reviews in greater detail the shortcomings of current forecasting models.

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Abbreviation

FHWA Federal Highway Administration

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5

Shortcomings of Current Forecasting Processes

The four-step (or, in some cases, three-step) trip-based modeling process used by the vast majority of metropolitan planning organizations (MPOs) has evolved over a period of about 50 years. Originally conceived as an aid to developing transportation networks for large cites, the process was widely adopted to support planning for the urban segments of the Interstate highway system and to support the metropolitan planning requirements of the Federal-Aid Highway Act of 1962. Over the years, the procedures employed have been modified to address other planning questions and issues (e.g., air quality, transportation operations, Transit New Starts). While many projects have been planned and justified on the basis of data produced from models of this type, it has long been recognized that the process has many shortcomings.

Models used to forecast travel are critical in estimating likely impacts of investment and policy decisions, with the understanding that socioeconomic conditions over the forecast period may change in ways that cannot be predicted. Estimates of differences among alternatives may reasonably be regarded as more precise and reliable than overall forecasts since alternatives are likely to be equally affected by global changes. Travel forecasting introduces a reason-based rigor into the planning process that would otherwise be lacking. Given the inherent uncertainty in knowing the future, it is imperative that forecasting models themselves not introduce undue additional uncertainty.

Travel forecasting as practiced by MPOs is a type of systems analysis. It requires a set of environmental system inputs (small-area socioeconomic projections), specified alternative strategies to be evaluated (capital investments in new facilities or operational policies), models that describe relationships between the data inputs and strategies (the four-step travel forecasting models), and estimated consequences of each alternative strategy (such as forecasts of traffic, ridership, and travel times). Modeled outputs from an iteration of the process aid in redesigning alternatives to be examined in succeeding iterations. While this analytic forecasting process is logically and intuitively appealing, it has limitations and shortcomings. Critiques of the four-step process, of its ability to address the issues with which MPOs must deal, and of the forecasts obtained using the process are numerous:

- According to a report of the Transportation Research Board (TRB), "the state of knowledge and modeling practice are not adequate for predicting with certainty the impacts of highway capacity additions. In particular, the models are not well suited to the types of analyses and levels of precision called for by the conformity regulations. They were developed to address different questions and cannot be readily adapted to the task at hand" (TRB 1995, 224).
- A report of the National Cooperative Highway Research Program reviews the current state of the art for analyzing transportation control measures and concludes that "serious reservations exist concerning the accuracy of these results, the robustness of the underlying data, and whether the correct set of variables are captured in the model systems." The report recommends a new modeling framework consisting of the following modules: disaggregate and activity-based demand, household sample enumeration, incremental analysis, traffic microsimulation, and household travel survey data with stated preference data to support policy analysis (Cambridge Systematics 2001).
- Another TRB report suggests that "the available models are not suited to estimating the emissions effects of small projects or linking these effects with air quality" (TRB 2002).
- Meyer and Miller (2001) state: "While UTMS [the Urban Transportation Modeling System] has been employed . . . for almost 40 years, it has also been seriously criticized from many points of view for almost the same length of time. Most fundamentally, UTMS is not behavioral in nature; that is, it is not based . . . on a coherent theory of travel behavior." They suggest further that "the trip based approach to travel demand modeling is not well suited to representing . . . traveler responses to the complex range of policies typically of interest to today's planners (pricing, HOV and carpooling options, telecommuting, other [transportation control] measures, etc.)."

The following discussion of the shortcomings of current modeling practice is presented with the understanding that MPOs must use the best tools available to them in doing their work. Newer, advanced modeling tools may be available but beyond the resources of the agency or not yet proven in practice. This having been said, the weaknesses of current practice can be categorized as follows: (*a*) inherent weaknesses of the models, (*b*) errors introduced by modeling practice, (*c*) lack or questionable reliability of data, and (*d*) biases arising from the institutional climate in which the models are used.

INHERENT WEAKNESSES OF CURRENT MODELS

In general, as the detail required to address transportation issues increases, the complexity of appropriate analysis techniques must also increase (see Figure 4-3 in Chapter 4). The current four-step travel demand forecasting models are not well suited to applications that require the portrayal or analysis of detailed travel markets, decisions of individuals, effects of value of time and value of reliability, continuous time-of-day variations in travel, and goods movement. In particular, the current widely used four-step metropolitan travel demand forecasting process cannot adequately characterize the following (without the use of off-model adjustments):

- Road pricing;
- Time-specific policies, such as parking, work schedules, and scheduling of truck deliveries;
- Hourly speeds or traffic volumes;
- Improvements in traffic operations;
- Improvements or policies addressing freight movement;
- Nonmotorized travel;
- Peak spreading and highly congested networks; or
- Goods movement.

The inherent weaknesses of current models are discussed in more detail below.

Inability to Represent Individual Decisions

The aggregate models in general use today are limited by an inability to represent the detailed decision patterns of individuals or households easily. The conventional four-step trip-based models rarely attempt to associate traveler characteristics with trips being made. In some cases, market segmentation is used to incorporate information about the household characteristics of travelers—

typically income—throughout the steps of the modeling process. In theory, market segmentation could be used to account for other household or traveler attributes, but doing so is difficult in practice. A larger problem is the failure of the conventional models to consider the full range of choices available to individuals. In conventional models, the available choices are typically to make or not make a trip (trip generation), the destination visited (trip distribution), the mode used (mode choice), and the path taken (assignment). In reality, travelers have other choices, including making a trip at a different time or on a different day, incorporating a trip to fill one need into a trip to fill other needs, having a trip made by another member of the household or trip-making unit, or substituting communication for travel.

Lack of Sensitivity to Current Issues

Models can address only questions to which they are sensitive. If a quantity is not an independent variable included in the model, the model cannot be used to answer questions about the impact of a change in that variable on travel demand. Two examples illustrate this point—road pricing and goods movement.

Road Pricing

The summary of a 2005 Expert Forum on Road Pricing and Travel Demand Modeling notes that "the four-step modeling system does not capture behavioral responses to pricing options because pricing has dynamic, interactive effects that cannot be accommodated in a linear, static modeling system" (Schofer 2006, 10). A paper prepared for the forum identifies important modeling challenges:

- Accounting for reliability,
- Accounting for heterogeneity among users and their values of time, and
- Dealing with time-of-day variations and peak spreading.

These challenges can be addressed to some extent for a fixed-toll facility using a well-calibrated four-step modeling process, supplemented by local surveys and off-model adjustments. But "representing the full spectrum of pricing outcomes will require a shift to more advanced tools," such as activity- or tour-based models, microsimulation, and dynamic traffic assignment (Vovsha et al. 2005).

Considerable evidence reveals the shortcomings of travel forecasting models for predicting the performance of new toll facilities. The process for bond financing of new toll roads includes review and evaluation of proposed financial plans by a bond-rating agency. At the heart of financial planning is an "investment grade forecast" of the traffic and revenues the toll road will attract upon opening. In recent years, underperformance of new toll roads and consequent risk to investors have caused bond-rating agencies to take a hard look at these forecasts.

Standard and Poor's (S&P) has assembled a database of 104 international toll road, bridge, and tunnel case forecasts and actual experience of traffic and revenues. Analysis of this database shows what S&P calls "systematic optimism bias." For all case studies, toll road forecasts overestimated actual first-year traffic by an average of 20 to 30 percent. This situation does not improve for the second through fifth years after opening; the overestimates for these years are similar to those for the first year. If the database is arrayed as a ratio of actual to forecast traffic, the population is normally distributed in a bell-shaped curve, but the mean rests well below 1.0 at 0.77, underscoring the tendency toward optimism bias.

S&P also found that truck forecasts were considerably more variable than those for total traffic; for the ratio of actual to forecast traffic, the standard deviation for trucks was 0.33, compared with 0.26 for total traffic. The differential probably reflects the more primitive state of freight forecasting models. The variability in truck forecasts has consequences for toll roads, where trucks account for a larger share of revenues than other traffic (S&P 2005).

Another rating agency, FitchRatings, has also studied the toll road forecasting issue. While noting examples of start-up toll roads that have exceeded forecasts (e.g., 407, Toronto, Canada; Chesapeake Expressway, Virginia; Mid-Bay Bridge, Florida), FitchRatings cites many more projects for which traffic and revenues have been significantly below forecasts (e.g., Dulles Greenway, Virginia; E-470, Colorado; Foothill Eastern, California; Osceola Parkway, Florida; Pocahontas Parkway, Virginia; San Joaquin Hills, California; Garcon Point Bridge, Florida; Sawgrass Expressway, Florida; Southern Connector, South Carolina).

The skew toward overestimated forecasts suggests optimism bias (see the discussion below of biases arising from the institutional climate), but FitchRatings also points to "the use of regional travel demand models intended for other planning purposes and not necessarily appropriate for use to support the issuance of toll road debt" (FitchRatings 2003, 2).

Modeling challenges become considerably more complex for projects for which tolls charged vary by time of day. Several metropolitan areas are considering managed-lane projects in which the price for traveling on a facility could vary dynamically on the basis of usage of the facility. Implementing this approach could require forecasting demand and revenue for an existing freeway segment that is to be reconstructed, expanded, and subsequently operated as a toll road. As noted by Spear, however, "Virtually all of the road pricing models implemented to date have been used to analyze the travel demand and revenue impacts of static tolls (i.e., toll charges that remain constant over a fixed time period). Current four-step travel demand models cannot easily analyze the impacts of variable tolls (i.e., toll charges that are adjusted within a peak period to discourage overuse of the facility to maintain acceptable levels of service), because they do not specifically consider the temporal build-up and dispersal of traffic during peak period" (Spear 2006, 19).

Goods Movement

Freight has emerged as a major issue in the transportation community. Highways, railroads, and ports are running out of capacity to accommodate projected increases in the volume of goods to be moved. In an economy organized around fast and reliable delivery of goods, congestion becomes an important variable in the cost of business and in economic development (FHWA 2006).

Regional transportation plans and project analyses must address goods movement. Doing so is important not only from the perspective of mobility but also from an environmental and roadway design point of view. Given the nature of their fuel, size, and cargo, trucks are a source of significant nitrogen oxide and particulate emissions. Trucks also have a disproportionate impact on the road infrastructure.

As goods movement becomes an increasingly important concern for many regions, the lack of validated models of goods movement and truck activity is receiving greater notice. The recently instituted Freight Model Improvement Program is a partial response to this need (FHWA 2006). The number of truck trips (including commercial vehicles and trucks of all sizes) and resultant vehicle miles traveled (VMT) are growing at a rate more than twice that of trips made by personal vehicles in some areas. As congestion increases, the delivery of goods and services by truck throughout a metropolitan area is becoming more difficult and less reliable. This situation leads in turn to concerns regarding the economic vitality of businesses within an area.

The information and tools available to address goods movement, however, are severely limited. Truck count data, information on distribution patterns, and trip chain profiles are but a few areas in which the analyst faces data shortages. Characteristics of goods movement can vary by commodity, payload, time of day, and truck type. Furthermore, little is known about how businesses make decisions on freight logistics. Without a better understanding of freight activity and models based on data that reflect real-world logistics and distribution systems, planners cannot begin to assess, for example, how the performance of the transportation system would change if truck deliveries were limited to off-peak delivery times.

Failure to Deal with Uncertainty in Model Estimates

Most travel forecasting models produce a single answer, although the model is estimated, calibrated, and validated on the basis of data sets that are subject to many sources of error and uncertainty. The data used are based on sampling and include sampling errors, as well as other types of errors due to survey methodology. Errors also are made, for example, when data are aggregated and entered into databases. The models themselves may suffer from misspecification. When models are used for prediction, additional errors are necessarily introduced because the values of parameters in the future are always estimates and thus subject to error.

Some degree of error is unavoidable. Within reason, moreover, the presence of errors does not prevent effective applications. It is necessary and appropriate, however, to develop sampling and modeling strategies that are informed by the patterns in which errors occur and especially by understanding of the ways in which errors are propagated through sequences of models. Errors should be discussed in the course of normal practice; their influence understood and disclosed; and proper account taken of the variation that necessarily occurs in the use of models for forecasting purposes, particularly when forecasts are used to evaluate alternatives that differ only modestly or to produce point estimates of travel to meet regulatory requirements.

As noted, even though it is highly unlikely that all of the factors input to forecast travel demand will occur as projected, travel demand forecasts are typically presented as a single value (e.g., transit boardings, traffic volumes). Methodologies have been developed and in a few cases applied to associate a probable variance with each input factor and produce an expected error range for the final forecasts. Presenting model results with an estimate of error allows users either to derive a point estimate (midpoint of the confidence interval) or to use a range estimate (defined by the confidence limits). In either event, users will be more knowledgeable about the output of the model.

Inability to Represent Dynamic Conditions

The conventional travel demand models make use of networks, both highway and transit, in which impedances are averages over an extended period, do not reflect any uncertainty or unreliability, and are not representative of the conditions that would be expected or found by an individual traveler at the time a trip choice is made. Agencies are being asked to evaluate road pricing schemes in which tolls can vary rapidly over the course of a few minutes on the basis of levels of congestion. The regional travel demand models in use today can treat such variation only in an aggregate estimate, although some studies have used detailed simulation procedures to augment the forecasts derived from these models.

One barrier to including reliability as a variable in road pricing models is that traditional four-step travel demand models are designed structurally to work with average or mean values (e.g., average daily or average peak period travel volume) and not the variation about those mean values. Recent progress in the development and deployment of simulation techniques in traffic modeling suggests considerable promise for addressing variability in traffic congestion, but a much better understanding of the factors that influence traffic variability is needed as well. Moreover, as Spear notes: "Despite the potential importance of (travel time) reliability in road pricing (especially as a congestion mitigation strategy), there are few, if any, examples of operational travel demand models that explicitly include reliability as a variable" (Spear 2006, 19).

ERRORS INTRODUCED BY MODELING PRACTICE

Inadequate Validation Practices

A primary concern is the lack of sufficient data for proper validation of models after estimation of model parameters. The cost and difficulty of collecting data on both household characteristics and trip patterns limit the ability of model developers, MPOs, and others to validate an estimated or calibrated model. The size of household survey data sets is a particular issue. A data set may be of sufficient size and stratification to be used to identify proper functional forms and to estimate key parameters of most travel models, but the same data set often may not provide sufficient information for validation of geographic patterns beyond a rather gross level. This is particularly true for the trip distribution element of a four-step model. The U.S. census provides some independent information about the distribution pattern of work travel, but other than results of household travel surveys, there are no data against which nonwork trip distributions can be validated. [In the future, these travel data will be obtained in the annual American Community Survey (ACS) rather than the decennial census.]

Trip distribution modeling would benefit from new, more advanced procedures and more extensive data for model development and validation. Current gravity-type trip distribution models used by MPOs can often be flawed because of poor model calibration and application.

Even if the data collected in a household survey are considered adequate for validating the base-year application of a model, similar data are not available for validation as the model ages. As a result, validation may be based almost solely on the ability of the assigned volumes—the final step of the modeling—to accord with traffic counts or VMT. Even if there are sufficient counts to support valid comparison with assigned volumes, the counts provide no information about vehicle occupancy or trip generation, distribution, purpose, and length. Analysts have little quantitative guidance for making any needed adjustments to the model set. Too often the later steps in a modeling chain (e.g., mode choice, assignment) are manipulated in an attempt to correct for errors in earlier stages. As a result, the mode-choice stage of a sequential four-step model may be misestimated because it is attempting to correct for error in the generation and distribution models.

Rodier (2004) evaluated the official travel model of the Sacramento region for model error by running the 1991 model for 2000 with data from the actual 2000 observed travel survey, along with demographic and economic (employment) data, as inputs. In such a test, input error is eliminated, and only model error remains. Rodier found that trip generation was underprojected by 6 percent and VMT was overestimated by 6 percent as compared with actual counts. This test thus finds primarily model specification and model calibration error. The author also tested the accuracy of socioeconomic/land use projections made in 1991 for 2000. This test showed that trip generation was 2 percent higher and VMT 12 percent higher than counts and actual 2000 survey data. This type of test finds specification, calibration, and input errors, all acting together. The household and employment projections made in 1991 turned out to be 8 percent and 9 percent higher, respectively, than actual figures for the whole region and so were a major source of error. In both of Rodier's tests, errors were much higher for trip generation for the home–shopping trip purpose, and mode shares were the most incongruent for 3+ shared-ride trips and especially for walking trips. This is one of the most useful papers to date on modeling error using both historical forecasting and sensitivity tests. Very few MPOs conduct such exercises, but all MPOs should do so as part of model validation.

Failure to Maintain Consistency Among All Elements of a Forecast

The effects of a lack of consistency among the various elements of the modeling chain have often been overlooked. In some cases, this neglect has been due to a limitation of the model application software; in other cases, those developing or applying the model set are unaware of the potential problems. Scrutiny of forecasts made for Transit New Starts projects has demonstrated that a lack of consistency in generalized cost relationships (e.g., time, distance, tolls) among various elements of a model can lead to counterintuitive and likely incorrect results (AECOM Consult 2005).

There may be a disconnection between land use/growth forecasts and transportation plans. This disconnection relates to both the location and nature of the growth. Over the years, many MPOs have investigated the use of systematic procedures for forecasting the location of growth in households and employment. Some have implemented and are using formal land use models that account not only for attributes of the transportation system but also for other factors that are expected to affect location decisions. In many other agencies, however, growth projections are formulated by the component jurisdictions without regard for expected transportation system improvements or congestion. Reports of allocation of "forecasts by negotiation" are common.

Many agencies have begun to include in their model sets factors intended to reflect the influence of subarea development patterns, including density, activity mix, and design, on trip generation, distribution, and mode share. Given the small sample sizes of household surveys, most of these procedures are based on limited data. The impact of development patterns on travel is not yet well established, but agencies are in some cases being asked to consider these effects in formulating plans and evaluating projects.

In all but the most uncongested systems, the transportation network conditions assumed for purposes of initiating the forecasting process are not the conditions that would actually apply in view of the volumes of travelers and vehicles about to be forecast by the models. To compensate, it is common to feed back congested travel times from the forecast output to successive iterations of trip distribution, mode choice, and network loadings. As the modeled networks become more congested, feedback of this type becomes more important.

Use of Models Without Regard for Their Limitations

As noted earlier, travel models were originally developed for macro-scale regional planning. With many adjustments and new components, they have been adapted for the study of many other issues, including transit station boardings and projections of regional emissions. In the committee's experience, agencies have reported future-year facility volumes on the basis of data taken directly from the model outputs. Unless the models have been carefully restructured or estimated with the objective of addressing such issues, the resulting forecasts may not be valid.

Peer Review

Given the complexity of the modeling enterprise, it may be difficult to avoid altogether errors in modeling practice such as those catalogued above. Independent, rigorous, regular peer reviews of MPO models and practice are one means of reducing the incidence of these errors and assuring stakeholders of the quality of travel forecasts. Peer review has been ongoing for many MPOs on an ad hoc basis. The Federal Highway Administration's Travel Model Improvement Program has provided financial support for peer review of models as well.

LACK OR QUESTIONABLE RELIABILITY OF DATA

Models can be responsive only to factors that have been included in their specification. In some agencies, factors are omitted simply because data are insufficient to permit a valid specification. In other cases, factors are omitted because the agency did not anticipate the need to consider how variations in those factors might affect travel demand or because the agency did not have a way to forecast the factors. Examples might include household life cycle, family composition, age of family members, pattern of development, and toll charges.

The difficulties of obtaining sufficient data for model validation were discussed above. Even with limited data, however, application of a model to forecast or backcast between 2 years offers better validation than simply determining how well the model outputs match observations of a single base year. Validation of a forecast involves comparing the outputs a model developed in 2000, for example, to forecast traffic in 2005 with actual 2005 counts. Many agencies do this as part of routine model revalidation and updates. Unfortunately, validation of this type can be done only several years after a model has been developed. Backcasting can be performed as part of model development. An example of backcasting is the use of a model developed with data for 2005 in conjunction with known 2000 socioeconomic and transportation system data to backcast for 2000. This procedure is rarely done.

Reliability of Exogenous Forecasts

An inherent weakness of the aggregate trip-based modeling approach is reliance on demographic forecasts that are independent of the travel forecasting system. With few exceptions, travel forecasting procedures make use of data that are developed independently, often with no input from or feedback to transportation system attributes. These data—forecasts of population, households, and employment, both in total magnitude and as allocated to specific geographic subareas—are significant drivers of travel forecasts. Errors or uncertainties in these data may introduce errors of unknown magnitude into the travel forecasts. In metropolitan regions that are growing slowly or are stable, regional errors in demographic forecasts are likely to be small; in more rapidly changing regions, greater errors in demographic forecasts would be expected. There may be considerably more uncertainty in allocating regional demographic forecasts to subareas. If an area is undergoing steady or even dramatic growth, one can predict future regional population and employment with some confidence; where those people and jobs are going to go within the region is far more uncertain.

While some MPOs employ sophisticated demographic models and forecasts, others may use nonreplicable methods for projecting land uses. That is, the assumptions cannot be written down, and another entity cannot perform the same analysis with the same outcome. One needs to be careful to separate errors in variables input to a travel model from the model itself. Errors in demographic forecasts can lead to the incorrect location of trip origins and destinations, creating significant orientation errors in trip distribution and accessibility anomalies in transit forecasting.

Even with the most sophisticated demographic forecasting tools, it has been noted that "there is really no hope that a mathematical model can ever accurately predict the future, given the uncertainty in demographics, technological shifts, and social changes" (Hunt et al. 2001, 62).

Figure 5-1 and Table 5-1 show socioeconomic forecasts for six metropolitan areas made in 1980 for 2000. These forecasts, used by MPOs in travel forecasting for their long-range planning purposes, are compared with actual data

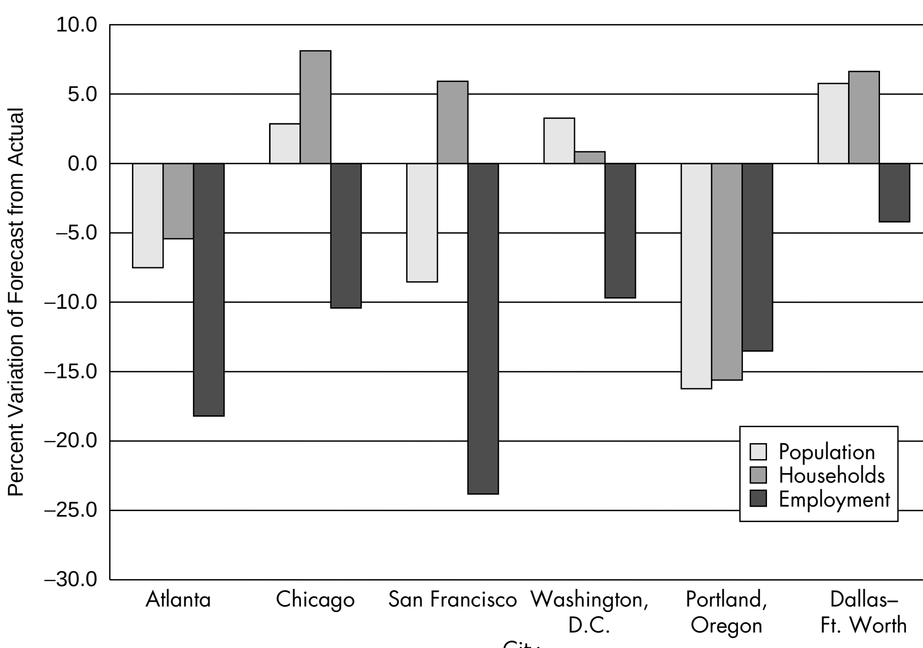

FIGURE 5-1 **Forecasts made in 1980 for 2000 metropolitan population, households, and employment versus actual data for 2000.**

TABLE 5-1

Forecasts Made in 1980 for 2000 Metropolitan Population, Households, and Employment Versus Actual Data for 2000 (in hundreds of thousands)

		Population	Households	Employment
Atlanta	Forecast	2,846	1,135	1,546
	Actual	3,077	1,200	1,890
	Difference	−231	−65	−344
	% Difference	−7.5%	−5.4%	−18.2%
Chicago	Forecast	8,323	3,143	3,873
	Actual	8,092	2,907	4,323
	Difference	231	236	−450
	% Difference	2.9%	8.1%	−10.4%
San Francisco	Forecast	6,205	2,612	2,860
	Actual	6,784	2,466	3,754
	Difference	−579	146	−894
	% Difference	−8.5%	5.9%	−23.8%
Washington, D.C.	Forecast	4,202	1,556	2,397
	Actual	4,069	1,543	2,654
	Difference	133	13	−257
	% Difference	3.3%	0.8%	−9.7%
Portland, Oregon	Forecast	1,499	588	803
	Actual	1,789	697	929
	Difference	−290	−109	−126
	% Difference	−16.2%	−15.6%	−13.5%
Dallas–Ft. Worth	Forecast	5,030	1,897	2,918
	Actual	4,756	1,779	3,046
	Difference	274	118	−128
	% Difference	5.8%	6.6%	−4.2%

Note: Atlanta—Atlanta Regional Commission; Chicago—Chicago Area Transportation Study; San Francisco—Metropolitan Transportation Commission; Washington, D.C.—Metropolitan Washington Council of Governments; Portland—Metro Portland; Dallas–Ft. Worth—North Central Texas Council of Governments.

for 2000.[1] Considerable variation between the 20-year forecasts and the actual situation in 2000 can be seen. These data are not displayed as a critique of demographic planning but to show the degree of uncertainty associated with such forecasts, regardless of how sophisticated the forecasting process in use may be.

For most cities, the greatest variation was between forecast and actual values for employment, which was significantly underpredicted for each of the six areas. It is instructive to note that the United States as a whole experienced a double recession in 1980–1981 (the period when these forecasts for 2000 were made) and that some parts of the country were particularly affected. Oregon, for example, lost 10 percent of its jobs during this recession, and it took 6 years to replace these jobs (Thompson 2004).

The uncertainty associated with socioeconomic forecasts raises questions about the validity of travel demand modeling that produces deterministic point estimates of future travel. A better use of travel models might be for analysis of outcomes of a range of transportation alternatives, considering different scenarios of future urban development. Such an approach would allow a city to best position itself for whatever policy makers believe the future may bring.

Future Data Challenges

The challenges of obtaining appropriate and sufficient data for modeling are magnified by such emerging issues as changes in lifestyle that affect the traditional methods used to conduct home interview surveys, changes in census products, and the need for data on daytime populations.

Collection of Travel Data

While MPOs today have data processing capabilities far superior to those applied in the original urban transportation studies, technological developments and other considerations have combined to make the methodology of home interview surveys more problematic. In-person (or in-home) interviews have become very expensive and difficult to conduct in many urban settings, and interviews are now conducted more commonly by phone or through self-reporting travel diaries. Both of the latter approaches are less likely to elicit comprehensive trip reports than in-person interviews. While automated computer-assisted telephone interviewing helps hold down survey costs, permits real-time checking for data inconsistencies, and allows respondents to

[1] Percent variation between actual and forecast data is calculated as (forecast – actual)/actual.

be prompted in the same way as during an in-person interview, telephone interviewing has disadvantages compared with the in-person approach.

The method used most commonly to select sample households for surveying is now random phone number selection, which limits the households in the sample to the subset with land-line telephone numbers. Changes in communications technology have made this method of selecting households even more questionable because many—typically those with younger persons—now depend solely on cellular phones, which cannot legally be contacted through automated dialing. Screening of calls with voice mail, answering machines, and caller identification has also reduced the effectiveness of phone interviewing. Moreover, contacting households by phone means that those whose members remain at home and can be contacted by phone are more likely to be sampled. Obtrusive telemarketing has an impact as well because many individuals will not respond positively to any phone solicitation, regardless of how well intentioned. Finally, in-person interviewing has the added advantage of enabling observation. Thus even if one does not interview the respondent, some information about the household can be assumed from observing the neighborhood, the type and condition of housing, the number of automobiles, and so on.[2]

Data from Census Products

The Census Bureau no longer intends to collect long-form data from a large sample of housing units during decennial censuses; however, roughly comparable long-form data will be available from the ACS (U.S. Census Bureau 2006). The ACS estimates will have higher standard errors than past decennial census long-form estimates because of smaller housing unit samples, even with 3- and 5-year sample accumulations. The ACS will provide transportation planners with intercensus-year data on households, persons, and commuters that previously were available only every 10 years. Introduction of the ACS will also affect the Public Use Microdata Samples and the Census Transportation Planning Package special tabulation of long-form data, which are extensively used by MPOs for model development (Eash 2005).

Data on Daytime Populations

Travel models are used for typical travel behaviors but are increasingly being used as well for planning of evacuations and relief efforts due to natural disasters, immunization programs, and risk assessments for homeland security. These

[2] Personal communication, J. Zmud to T. Palmerlee, March 8, 2007.

new purposes bring their own data needs. An example is the estimation of daytime population—the number of people who are present in an area during normal business hours. There are means of roughly calculating daytime populations from Census Bureau information on resident populations and workers commuting into and out of an area (U.S. Census Bureau 2007). The time of day at which commuting takes place complicates the calculation, especially for employment centers with a substantial number of shift workers. Further complication derives from the travel of such groups as students, tourists, and shoppers. Information sources on the various components of daytime populations are limited, posing a challenge for these new uses of travel demand models.

BIASES ARISING FROM THE INSTITUTIONAL CLIMATE

Forecasts of costs, traffic, and revenue are made for the purpose of assessing courses of action. They are used regularly in planning and designing transportation facilities and policies. The practice of using travel demand forecasts for policy assessment is based on the understanding that large capital investments and long-term commitments of public resources to operating and maintaining networks of facilities are always controversial. Objective analysis is needed to select wisely among alternative investment strategies. Both capital and operating costs of facilities are forecast during the process of planning networks of transportation facilities.

Forecasting often occurs in a politically contentious environment. Some communities desperately want facilities expanded to serve them; others organize in fierce opposition to certain projects or to particular design characteristics that are proposed. Some interest groups therefore wish to exaggerate the expected traffic on a planned facility, while others seek to minimize estimated use. Forecasts are needed to facilitate compromises among approaches advocated by different interest groups. Travel and cost forecasts should not be expected to avoid or resolve political differences or debates. Rather, they are intended to inform and facilitate debate and to contribute to rational decision making and compromise, especially in complex and politically charged situations. Forecasts are always subject to error and uncertainty, but they should be prepared honestly, data should not be falsified, and assumptions should be chosen on defensible and technical grounds and not because they favor certain outcomes over others.

Over the past 20 years, researchers have investigated the extent to which travel demand forecasts are objective or influenced by politics. In a well-known and controversial report, Pickrell (1990) argued that in the United States, the majority of a sample of rail transit projects he studied were forecast to have ridership levels higher than those actually achieved when the projects were completed, while the vast majority of those projects experienced higher capital and operating costs than had been forecast at the time funds were committed. Thus, actual costs per rider turned out to be much higher than had been forecast. Other authors, including Richmond (2005), have argued that the outcomes of such forecasts were politically inspired; for reasons that could be explained and understood in terms of consultants' behavior, they deliberately departed from reasonable expectations. Wachs (1990, 2001) examined forecasting for transportation projects as a complex phenomenon prone to both error and deliberate distortion.

The Federal Transit Administration (FTA) evaluated the performance of 10 projects in 1990 (including those in the Pickrell study) and 19 other new projects in 2003. It was found that in 1990, none of the 10 new starts (all rail projects) achieved even 80 percent of forecast ridership; only one exceeded 70 percent (Figure 5-2). By 2003, the accuracy of forecasting had improved. Of 19 new starts (again all rail), eight achieved 80 percent of forecast ridership.

Recently, a group of European scholars led by Professor Bent Flyvbjerg from the University of Aalborg has added fuel to the fire that has characterized this debate. This team studied hundreds of projects in many countries, including highways, rail projects, and bridges built over more than 50 years (Flyvbjerg et al. 2002, 2003, 2005, 2006). They found that costs are far more likely to be

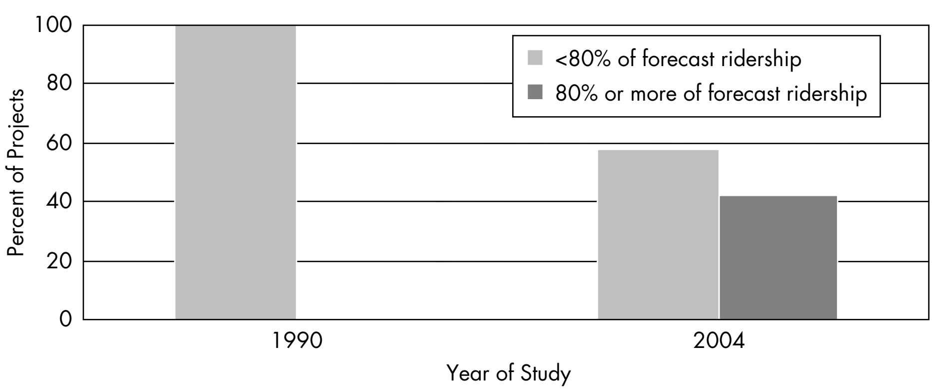

FIGURE 5-2 **New start rail transit forecasts and actual ridership, 1990 and 2004.**

underestimated than overestimated prior to construction, while patronage or use of facilities is far more likely to be overestimated than underestimated. If estimates are truly unbiased, overestimation and underestimation should be roughly equally likely. Of interest, the magnitude of forecast errors has not been declining over time. This suggests that, with some exceptions such as FTA New Starts, the performance of travel demand models and transportation cost estimates is not improving despite the efforts of many transportation researchers to improve the techniques employed. Forecast errors are also persistent across modes of transportation (roads and rail projects) and geography, though on average they are larger for rail than for highway projects.

The above findings can be interpreted in different ways, leading transportation researchers and analysts to suggest alternative courses for corrective action. The first course is to undertake deeper and continuing research to isolate the specific causes of divergence between forecasts and actual performance. Some have characterized the apparent optimism bias in forecasts as innocent and unsurprising. Facilities are less likely to be built, it is said, if their forecast costs are high and expected use is low, leading to the phenomenon of errors in one direction dominating facilities that have been built. Other research suggests, however, that optimism bias is hardly the result of innocence; in some cases, researchers have been able to document "strategic misrepresentation" in the form of "adjusted" coefficients and "refined" parameters from one model run to the next. It is, of course, quite possible that some of the observed divergence is unintentional while some is deliberate. The conduct of research on the causes of discrepancies between forecasts and actual performance is hindered by the fact that funds are rarely made available by public bodies in any country for follow-up analyses of the performance of forecasts after facilities have been built.

It is both necessary and possible to chart a responsible course by developing standards and procedures for evaluating forecasts of patronage, revenue, and costs in association with the planning of new transportation investment projects. The Department for Transport in Great Britain has issued a white paper on procedures for controlling optimism bias in forecasting (Flyvbjerg et al. 2004). Requirements that assumptions be reported and explained, that critical external peer review of forecasts be performed, and that standards for the use of data and the making of assumptions in forecasting be published are all helpful. In the United States, FTA is gradually developing a set of guidelines and procedures designed to ensure that best practices are routinely employed in forecasting for new starts of urban rail systems. These strategies would, at the very least, allow egregious deviations from objectivity and good practice to be recognized and criticized.

A second promising course of action is the development of "reference class forecasting," based on research that led to the awarding of the 2002 Nobel Prize in economics to Daniel Kahneman (Kahneman 1994; Lovallo and Kahneman 2003). Kahneman has argued that projects such as rail extensions, bridges, and highways should be evaluated on the basis of "outside" as well as "inside" views. That is, forecasts of patronage and costs should be placed within a range of variation established by previous projects of a similar class. If forecasts lie well outside a range thus established, they should be considered suspect and required to undergo further analysis. Several countries have applied these insights in developing guidelines for the evaluation of forecasts of traffic, revenue, and costs. While reference class forecasting holds promise, data limitations may make it impossible to obtain accurate representations of forecasts and actual results for previous projects to be included in the class. Moreover, cost overruns are often a function of changes in the scope of a project that evolve as a facility is being built. It is not clear how to account for this phenomenon appropriately in reference class forecasting.

The divergence between forecasts and the actual performance of transportation projects is a complex and multidimensional problem. While it is possible to state that forecasts *should* be as free as possible from deliberate distortion and misrepresentation, it remains difficult to prescribe mechanisms that can ensure this outcome.

SUMMARY FINDINGS AND RECOMMENDATIONS

The four-step or in some cases three-step trip-based modeling process is used by the vast majority of MPOs. The many shortcomings of this process have long been recognized. The weaknesses of current practice can be categorized as follows: (*a*) inherent weaknesses of the models, (*b*) errors introduced by modeling practice, (*c*) lack or questionable reliability of data, and (*d*) biases arising from the institutional climate in which the models are used.

Inherent Weaknesses of the Models

Critiques of the ability of the current modeling process to address the issues with which MPOs must deal are numerous. Most fundamentally, on the demand side, the process is not behavioral in nature; that is, it is not based on a coherent theory of travel behavior and is not well suited to representing travelers' responses to the complex range of policies typically of interest to today's planners. On the supply side, the process is unable to represent dynamic conditions. The conventional travel demand models make use of networks, both highway and transit, in which impedances are averages over an extended period, reflect no uncertainty or unreliability, and are not representative of the conditions that would be expected or found by an individual traveler at the time a trip choice is made. The issues that the current widely used metropolitan travel demand forecasting process cannot adequately characterize as a consequence of these deficiencies include the following:

- Road pricing, including high-occupancy travel lanes;
- Time-specific policies, such as parking, work schedules, or scheduling of truck deliveries;
- Hourly speeds or traffic volumes;
- Improvements to traffic operations;
- Nonmotorized travel;
- Peak spreading and highly congested networks; and
- Goods movement.

Poor representation of uncertainty is another deficiency. Most travel forecasting models produce a single answer, although the model is estimated, calibrated, and validated on the basis of data sets subject to sampling and other errors. There are many sources of error and uncertainty in travel demand forecasting, but end users of most travel forecasts would not be aware of these limitations.

Errors Introduced by Modeling Practice

A primary concern is the lack of sufficient data for proper validation of models after the estimation and calibration of model parameters. As noted in the previous chapter, validation is often hampered by a lack of independent data sources, and many MPOs validate against much of the same data used to develop the models. Too often the later steps in a model chain (e.g., mode choice, assignment) are manipulated in an attempt to correct for errors in earlier stages. Moreover, scrutiny of forecasts made for Transit New Starts projects has demonstrated that a lack of consistency in generalized cost relationships (e.g., time, distance, tolls) among various elements of a model can lead to counterintuitive and likely incorrect results.

Finally, travel models were originally developed for macro-scale regional planning. As new requirements have emerged, models have been used without regard to their limitations (with many adjustments and new components) for such purposes as forecasts of transit station boardings and projections of regional emissions.

To ameliorate errors introduced by modeling practice, **MPOs should conduct formal peer reviews of their modeling practice.** Independent peer review of modeling practice is essential given the complexity of the modeling enterprise.

Lack or Questionable Reliability of Data

Errors in demographic forecasts can lead to the identification of incorrect locations for trip origins and destinations, creating significant orientation errors in trip distribution and accessibility anomalies in transit forecasting. For example, considerable divergence is seen between 20-year forecasts of households, population, and employment and the actual situation 20 years later. These data show the degree of uncertainty associated with such forecasts, regardless of how sophisticated the forecasting process being used may be.

There are also a number of emerging data challenges. They include the collection of travel data and data from census products, and estimates of urban daytime populations.

MPOs, together with the federal government and the states, should determine data requirements for validating current travel forecasting models, meeting regulatory requirements, and developing freight models and advanced travel models.

Biases Arising from the Institutional Climate

Forecasts are always subject to error and uncertainty, but they should be prepared honestly, data should not be falsified, and assumptions should be chosen on defensible and technical grounds and not because they favor certain outcomes over others.

Over the past 20 years, researchers have investigated the extent to which travel demand forecasts are objective or influenced by politics. Particularly in the areas of new transit and toll-road start-ups, there is evidence of a systematic bias toward patronage forecasts that are substantially higher and cost forecasts that are substantially lower than the actual performance of completed projects. This phenomenon is known as "optimism bias." To guard against this type of bias, **MPOs and other planning agencies should conduct reasonableness checks of demand and cost forecasts for major projects.** This can be accomplished by comparing forecasts with the performance of similar operational projects.

Additional Recommendations

Policy makers must have the ability to make informed decisions about future investments and public policies for the transportation system. In reviewing the findings presented in this chapter, the committee concludes that current travel forecasting models and modeling practice are inadequate for many of the purposes for which they are being used. **The committee therefore recommends the development and implementation of new modeling approaches for forecasting demand that are better suited to providing reliable information for such applications as multimodal investment analyses, operational analyses, environmental assessments, evaluation of a wide range of policy alternatives, toll-facility revenue forecasts, freight forecasts, and federal and state regulatory requirements.** The committee acknowledges the evidence that current practice is also deficient in many respects and that introducing advanced models will not in itself improve practice. **Therefore, steps must be taken to improve both current and future practice in metropolitan travel forecasting.**

Conclusion

The focus of this chapter has been on the shortcomings of current travel forecasting models for their intended uses. The next chapter reviews opportunities for addressing these shortcomings and advancing the current state of the practice.

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Abbreviations

FHWA	Federal Highway Administration
S&P	Standard and Poor's
TRB	Transportation Research Board

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6

Advancing the State of the Practice

Incremental improvements can be made to the conventional travel models without changing their basic structure or approach to travel demand forecasting. Some metropolitan planning organizations (MPOs) and other agencies, however, are experimenting with or have adopted fundamental changes in travel modeling that may significantly expand the applications of current models (VHB 2006). Because many of these advanced modeling practices have been implemented only recently, there is no consensus yet that they should be widely adopted. Since these practices are tied more closely to household and traveler characteristics and behavior, they should in concept permit MPOs to address policy questions that cannot be treated with the conventional four-step models. Yet some practitioners remain unconvinced that their adoption is warranted in view of the perceived costs and difficulties associated with their implementation. This chapter addresses in turn improvements in four-step trip-based modeling; advanced modeling practices; the TRANSIMS system; experience with advanced practice; obstacles to model improvement; and model research, development, and implementation.

IMPROVEMENTS IN FOUR-STEP TRIP-BASED MODELING

Many improvements in the four-step process can be and have been made. Often these improved approaches become possible when application procedures are implemented in one of the several commercially available software packages. These approaches may be conceptually appealing and should contribute to better forecasts. Indeed, some of the approaches reported by agencies do lead to better replication of observed patterns; however, few if any systematic studies have demonstrated that they lead to better forecasts. The following are some illustrative improvements to the four-step process:

• *Improved measures of arterial congestion:* The "BPR (Bureau of Public Roads) curve" has been used for years to estimate congestion and delay. It yields good responses for freeways but has been viewed as lacking for arterial roadways, where intersection delay and queuing are major factors. Newer approaches now used by some MPOs estimate congestion on the basis of modeled delay at arterial intersections.

• *Inclusion of both highway and transit travel in trip distribution:* Trip distribution, the second step in the four-step process, involves allocating travel among analysis zones. In areas with significant transit use, it is thought that trip distribution patterns should reflect not only highway but also transit travel times and costs. A number of agencies have implemented distribution models with this feature.

• *Improved trip distribution models:* "Destination-choice" models are an alternative to gravity models. They take into account characteristics of both travelers and their possible destinations in allocating travel among analysis zones and reduce the need to use arbitrary factors to match traffic counts. Such models have been developed and applied by MPOs. In the early 1990s, destination-choice models were considered advanced practice; this remains true today. Deakin and Harvey (1994, 43) note that "the aggregate gravity-type model remains deeply ingrained in practice despite its apparent disadvantages."

• *Improved modeling of nonmotorized travel:* To incorporate bicycling and walking into the modeling scheme, some MPOs are introducing a high degree of spatial resolution into the model system since the measurement of small-scale accessibility is essential. One method that can be used for this purpose is to reduce zones to a size that can reflect meaningful walking distances between zones. Walking distances should be no more than 0.5 mile between zone centroids in the urban portions of the modeling area, where the walking and bicycling modes are most likely to be used. Another method is to use geographic information systems to measure accessibility from a zone centroid (e.g., number of retail employees within 0.5 mile, number of households within 10 minutes). With the ability to measure accessibility at a nonmotorized level, variables that potentially influence the decision to walk and bike can be identified. Examples of typical variables are accessibility to jobs, shopping opportunities, and households. Other relevant variables are household socioeconomic characteristics (e.g., automobile ownership, number of workers) and intersection density (i.e., ease of crossing streets). If the city or region has household survey data that capture travel information for all modes, models that address the full spectrum of travel options can be specified.

• *Improved sensitivity testing:* Models are used to project the responses of travelers and the transportation system to changes but have often been validated only on the basis of replication of observed conditions. Some MPOs, such as that of Las Vegas, have applied a technique that involves varying properties of the system (e.g., the population or employment in a zone, the capacity of a road) and examining the forecast response (Fehr & Peers 2005). While there is no way of ascertaining whether the forecast response is correct, analysts can assess whether it is reasonable or explainable given what is known about traveler behavior.

MPOs may undertake ambitious modeling improvement programs within the framework of their current methods. Tables 6-1 and 6-2 show a work program proposed by the Sacramento Area MPO to upgrade its land use and travel models to better represent user needs (DKS Associates 2001).

ADVANCED MODELING PRACTICES

It has been asserted that travel forecasting cannot be truly improved until the underlying paradigms reflect more fully the requirements and decision patterns of households, the interactions among the patterns of the various members of households, and household needs over more than a single day (McNally 1997; Boyce 2002). Travel models based on a more comprehensive understanding of the activities of households would better reflect the full range of trade-offs that affect whether to make a trip, what time a trip is made, the destinations visited, the modes used, and the paths selected. Also needed is a more complete representation of the supply-side network to account for the details of congested operations throughout the day. No one new modeling approach can address all these needs. Rather, a suite of related approaches, taken together, shows promise for greatly improving modeling practice. These approaches are referred to here as "advanced modeling practices" or advanced models.

The readiness of advanced models for wider application is the subject of debate among travel forecasters. Some practitioners argue that the benefits to be derived from the apparently more complex and data-intensive procedures

TABLE 6-1

Example Land Use Model Elements and Upgrades to Address User Needs: Sacramento Area Council of Governments

Element	Current Versus Upgraded Practice
Base-year population	Current practice: Track housing unit completions; apply vacancy rates. Tallied by SACOG minor zone. To address user needs: More detail on household structure (size, workers, life cycle, etc.) and location.
Base-year employment	Current practice: Track job locations by situs address and SIC code. Tallied by SACOG minor zone. To address user needs: More detail on location. Ideally, more detail on employment types.
Shifts in population demographics over time	Current practice: Allocate population growth to minor zone. Rule-based cross-classification to persons, workers, and income. To address user needs: Forecast detailed household characteristics on the basis of known characteristics and trends. More geographic detail needed.
Shifts in size and structure of economy over time	Current practice: Based on current development trends and land use policy (general plans). Constrained by population growth. To address user needs: Tied to changes in labor supply and the ability of the transportation and land use system to serve the needs of various industries.
Labor market—demand and supply	Current practice: Regional employment growth parallels (and is constrained by) regional household growth. To address user needs: Changes in employment tied to employment conditions (e.g., wages) and available labor in region.
Household relocation	Current practice: Not addressed. To address user needs: Minimally, allocations of new households should be based on household and area characteristics and on supply and demand by area. Ideally, "move" or "stay" decision for each household is based on household characteristics.
Firm/business relocation	Current practice: Not addressed. To address user needs: Minimally, aggregate allocation to zones, with floor space prices adjusted to clear the market. Ideally, "move" or "stay" decision based on firm characteristics.
Floor space prices	Current practice: Not addressed. To address user needs: Equilibrium with floor space demand by firms and households and area supplies.
Development of floor space	Current practice: Implied development of acreage based on acres/job rates. To address user needs: Simulation of development probability by parcel or grid cell, with consideration of floor space prices and vacancy.
Goods movement/ shipment logistics	Current practice: Simple truck model. To address user needs: Simulate shipment of goods at the firm/business level. Take account of industry characteristics.

Note: SACOG = Sacramento Area Council of Governments; SIC = Standard Industrial Classification.

TABLE 6-2

Example Travel Model Elements and Upgrades to Address User Needs: Sacramento Area Council of Governments

Element	Current Versus Upgraded Practice
Automobile ownership	Current practice: Cross-sectional automobile ownership model. To address user needs: Enhance current model with more detailed household data, linkages to other parts of model. Ideally, include vehicle type in model.
Tour/trip generation	Current practice: Trip-based. Limited use of accessibility variables. To address user needs: Day pattern model with logsum feedback from lower models. Some accounting for household characteristics.
Destination choice	Current practice: Trip-based destination choice, integrated with mode-choice model. To address user needs: Tour-based destination choice, with intermediate stops.
Mode choice	Current practice: Trip-based, with nonmotorized modes. To address user needs: Tour-based mode choice, with mixed-mode tours.
Time of travel	Current practice: Fixed factors. To address user needs: Time-choice model, sensitive to household characteristics and travel conditions.
Level of spatial detail	Current practice: Zone level for all. To address user needs: Some block-face level of detail needed (especially for nonmotorized travel).
Network simulation/ route choice	Current practice: Multiclass equilibrium for highway; shortest-path AON for transit. Nonmotorized travel not assigned. To address user needs: More classes needed, especially for transit. Ability to assign nonmotorized trips. Ideally, network microsimulation.
Application framework	Current practice: Zone-based enumeration by origin–destination, mode, purpose, and time of day. To address user needs: Person-based and firm-based enumeration, to track demographic characteristics with travel.
External and special trips	Current practice: Fixed matrices. To address user needs: Airport access model needed. Interregional travel keyed to growth in neighboring regions.

Note: AON = all-or-nothing assignment.

have not yet been demonstrated and may not be worth the effort. On the other hand, many members of academia and some others assert that advanced models have been implemented, that the major barriers to implementation have been resolved, and that the use of such models should permit agencies to develop better forecasts.

Following is a discussion of advances that go beyond the prevailing four-step modeling paradigm.

Improved Land Use Modeling

Planning agencies have been considering for years how best to reflect the interactions between transportation investment decisions and land development patterns. For a number of MPOs, various forms of land use models are now part of the routine process for analysis of growth, allocation of growth, and study of the land use impacts of alternative transportation investment programs. Miller et al. (1999) suggest that MPOs wishing to analyze land use–transportation interactions should consider adopting a land use model for their analyses.

Land use models have a long history of evolution and application in the United States and elsewhere. A recent innovation is the acceptance and use of "integrated urban models" that combine advanced land use and transportation models to better represent the interactions between transportation and land use. A variety of land use models are in operational use. While differing in their details and their relative strengths and weaknesses, they demonstrate that land use models can be applied successfully in practice. The models do, however, require significant investment in data assembly, model development, and technical support staff. Given the diversity of urban regions and associated planning needs, it is unlikely that a single standardized modeling methodology will emerge. The more likely scenario is that diverse methods will be employed that share common objectives (credible projection of future land uses) and principles (e.g., sensitivity to transportation system effects, appropriate treatment of real estate market processes). Miller et al. (1999) provide guidance for how to implement a land use modeling capability within an MPO or other agency concerned with undertaking integrated analysis of transportation and land use policies.

Tour-Based Models

Tour-based modeling recognizes that travelers may have multiple purposes and multiple stops within each trip—thus a "tour." This is a significant advance over the four-step trip-based approach, which aggregates trips from zone to zone according to such purposes as "home to work." Tour-based modeling has been applied by a few MPOs and can be an important step toward full activity-based modeling (VHB 2006).

Activity-Based Models

Activity-based models differ from previous travel forecasting methods in concept and structure. The approach recognizes the complex interactions between activity and travel behavior. The conceptual appeal is that the need and desire to participate in activities form the basis of the model. By emphasizing participation in activities and focusing on sequences or patterns of activity, such an approach can address complex issues (Bhat and Koppelman 2003). The differences between activity-based models and the current four-step approach include a consistent and continuous representation of time, a detailed representation of persons and households, time-dependent routing, and microsimulation of person travel and traffic. Activity-based models require more detailed information about population demographics than is available from surveys or the Census Bureau. "Population synthesizers" have been developed so that available data can be used to extrapolate synthetic populations that are statistically equivalent to actual populations. They can also apply land use data to locate all households relative to the transportation network (Hobeika 2005).

Regional-scale traffic microsimulation is an end product and major contribution of the federal TRANSIMS project (discussed below) and other activity-based models as well. The static assignment of current MPO models is replaced by a process that addresses such traffic effects as queuing and upstream effects of congested links. Motor vehicle emissions, for example, cannot be adequately estimated by static assignment outputs; microsimulation or dynamic network loading is needed.

Discrete-Choice Modeling

Travel decisions are made by individuals, not by traffic analysis zones (Domencich and McFadden 1975). While there can be benefits to aggregation when all aspects of decision processes cannot be accounted for, model results will be improved to the extent that model sets can more clearly represent both choices available to travelers and decision factors relevant to individual travelers. Discrete-choice methods have been used for many years for the development of mode-choice models and are increasingly used for the development of destination-choice models. Discrete-choice methods have not been widely used for the application of models. As synthetic populations are increasingly used for forecasting households, the use of discrete choice for model application will become more attractive.

Supply-Side Models

Advanced computerized traffic models that provide greater temporal and operational detail have been developed. They have the potential to be combined with conventional or advanced travel demand models, although properly integrating such advanced supply models with demand models may require coding a more detailed highway network that includes facilities carrying local traffic and intersection control information. Integrating transit supply and transit demand models poses a more challenging task because of the temporal variations in transit routes and schedules and the unavailability of transit at certain times of the day. Following are descriptions of two supply models that hold promise for integration with travel demand modeling.

Traffic microsimulation is the modeling of individual vehicle movements on a second or subsecond basis for the purpose of assessing the traffic performance of highway and street systems, transit, and pedestrians. Microsimulation can provide the analyst with valuable information on the performance of the existing transportation system and potential improvements. The past few years have seen a rapid evolution in the sophistication of microsimulation models and a major expansion of their use in transportation engineering and planning practices (Dowling et al. 2004). Traffic microsimulation can be combined with an activity-based travel demand model to provide a powerful tool for forecasting and analyzing supply-side transportation system and facility performance.

In addition to traffic microsimulation, methods for regional- or local-scale network dynamic traffic assignment applications have been developed. These software systems have the potential to predict where and when drivers will travel on the road network. They have great potential for operational planning, such as real-time intelligent transportation system applications. Issues exist in terms of how best to use the more aggregate, static outputs from the four-step equilibrium assignment as inputs to the more dynamic/micro models.

While dynamic assignment and traffic microsimulation are more realistic than current static equilibrium methods, they are also computationally far more expensive. Indeed, these models generally still cannot feasibly be applied at the full urban region level with a reasonable expenditure of computation time and resources. As progress is made toward greater use of activity-based travel models, as cost-effective computing power continues to increase, and as dynamic assignment methods that run more rapidly are developed, the gradual introduction of these methods into operational regional modeling is likely.[1]

TRANSIMS

Starting in 1992, the federal government undertook a pioneering model development project to advance the state of the practice of travel forecasting. The initial ground-breaking work on TRANSIMS was performed at Los Alamos National Laboratory. TRANSIMS is a computer-based system for simulating the second-by-second movements of every person and every vehicle throughout the transportation network of a large metropolitan area. It consists of multiple integrated simulations, models, and databases. By employing advanced computational and analytical techniques, it creates an integrated environment for analysis of regional transportation systems (Los Alamos National Laboratory 2007). TRANSIMS incorporates and integrates some of the advanced modeling practices detailed above, in particular population synthesis, activity-based modeling, and traffic microsimulation.

TRANSIMS was funded primarily by congressional appropriation and administered through the Federal Highway Administration's (FHWA's) Travel Model Improvement Program (TMIP). From 1992 to 2003, $38 million was spent on TRANSIMS, about three-quarters of which went to Los Alamos for basic research and development. After 2003, a 3-year hiatus occurred during which no funding was available for TRANSIMS development or implementation. The Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) allocates $2 million annually to TRANSIMS, some of which is to support implementation by MPOs and other operating agencies and some of which is to support TRANSIMS-related development activities.

TRANSIMS was originally field-tested in Dallas–Fort Worth, Texas, and Portland, Oregon. The work in Portland stopped during the hiatus in funding but is now being continued under SAFETEA-LU. SAFETEA-LU will also support two to three new deployments a year. Already funded are simulations of hurricane evacuation plans in New Orleans ($300,000, in cooperation with the Louisiana Department of Transportation and Development); a planning

[1] Personal communication, E. J. Miller to J. Williams, March 4, 2007.

study in Burlington, Vermont ($300,000, in cooperation with the Chittenden County MPO); and simulation of freight border crossings in Buffalo, New York ($500,000).

TRANSIMS technology is also being used for projects not funded through SAFETEA-LU. These include the following:

- Evacuation planning for Chicago, sponsored by the City of Chicago and Illinois Department of Transportation ($1.28 million);
- A congestion study for central New Jersey, sponsored by Rutgers University ($500,000);
- A study of street closings in Washington, D.C., near the White House, sponsored by FHWA ($1.5 million);
- A feasibility study for TRANSIMS in Atlanta, Georgia, sponsored by the Georgia Regional Transportation Authority ($50,000); and
- Linking of TRANSIMS with the UrbanSim land use and policy model, sponsored by the University of Vermont ($800,000).

TRANSIMS has not yet been implemented by any MPOs for use in their core travel forecasting activities. There are a number of reasons for this. First, the original software evolved in a research and development setting at a government laboratory. While suitable for use in that setting, it was not well adapted for general deployment. In addition, early versions required high-performance computers and the Linux operating system, which many agencies did not own or have access to. The user interface and system documentation were deficient and did not easily support applications. In addition, the capability to handle transit assignment through a time-sensitive network model has not been developed. As TRANSIMS has evolved from a research concept, public perceptions have been shaped by the problems associated with the initial start-up of this complex new technology. There was a perception among many practitioners that implementing TRANSIMS (or other activity-based models) might be an overwhelming task.

There have been some misconceptions about TRANSIMS as well. The extent and cost of necessary data collection, computer hardware requirements, and the complexity of implementation have been exaggerated. Implementing such a new model set does require more data, staff resources, and computing power than continuing to use existing technology, but it is demonstrably achievable (see "Experience with Advanced Practice" below). A number of improvements have made TRANSIMS more accessible and ready for implementation:

- Availability in a Windows environment;
- Hardware advances—the requisite computers can be purchased for $15,000 as of 2007;
- Improved documentation;
- Removal of restrictive licensing agreements and the move to an "open-source" environment; and
- Easier transition from the old to the new—in the Portland case study, ways of layering TRANSIMS methods over existing methods and data were discovered, thus creating a more tractable deployment path.

On the basis of its experience and knowledge, the committee believes that TRANSIMS provides an important bridge from the current practice of static, trip-based modeling to a future practice that better represents personal activity and dynamic traffic flow throughout the day. The groundwork provided by TRANSIMS research and development has materially assisted other model developers in moving toward highly disaggregate tour-based models and in particular has demonstrated the importance of fully representing the temporal dimension for both demand and supply. The committee believes that the federal government should continue TRANSIMS and other initiatives with the aim of developing advanced modeling methods that, once proven effective, can be transferred to practice by the most efficient means.

EXPERIENCE WITH ADVANCED PRACTICE

Questions remain about the wisdom of investing in advanced modeling practices. For example, is the advanced practice more than the agency really needs? Are the forecasts reasonable? Can the agency maintain the model set? The current state of knowledge is such that there can be no definitive answer to these questions, but the following discussion of field experience with advanced practice models should shed some light.

The following three agencies in North America have implemented advanced activity-based travel models and are using them in practice (VHB 2006):

- Mid-Ohio Regional Planning Commission (MORPC), Columbus;
- New York Metropolitan Transportation Council (New York City); and
- San Francisco County Transportation Authority.

Eight others are currently in the process of designing and implementing such models (Cervenka 2007):

- Atlanta Regional Commission,
- Denver Regional Council of Governments (DRCOG),
- Metropolitan Transportation Commission (MTC) (San Francisco Bay Area),
- North Central Texas Council of Governments (Dallas–Fort Worth),
- Portland Metro (Oregon),
- Sacramento Area Council of Governments,
- St. Louis East-West Gateway Council of Governments, and
- Tahoe Regional Planning Agency (Lake Tahoe, California and Nevada).

The growing interest in advanced modeling reflects an understanding that the current trip-based models are not well suited to analyzing the complex range of policy alternatives that are of interest to many urban areas (Meyer and Miller 2001). Activity-based models, in contrast, offer full incorporation of the time-of-day dimension, which permits modeling of differential time-specific tolling and parking policies and flexible working hours, as well as production of improved inputs needed for the Environmental Protection Agency's MOBILE model. Activity-based models also allow for detailed representation of segments of the travel market and portrayal of value of time for population segments. Travel response to demographic changes can also be accounted for. Finally, pairing an activity-based model with a traffic microsimulation model permits detailed analysis of improvements in traffic operations (Vovsha et al. 2005).

Following are four case studies of the implementation of advanced models.

Mid-Ohio Region Travel Demand Model

This new set of regional travel forecasting models for MORPC was completed in 2004. It is described as an advanced, multistep tour-based microsimulation model (Anderson and Donnelly 2005). The model features

> explicit modeling of intra-household interactions and joint travel that is of crucial importance for realistic modeling of the individual decisions made in the household framework and in particular for choice of the high occupancy vehicle (HOV) as travel mode. The original concept of a "full individual daily pattern" that constituted a core of the previously proposed activity-based model systems has been extended in the MORPC system to incorporate various intra-household impacts of different household members

> on each other, joint participation in activities and travel, and intra-household allocation mechanisms for maintenance activities.

The model also features

> enhanced temporal resolution of 1 hour with explicit tracking of available time windows for generation and scheduling of tours instead of the 4–5 broad time-of-day periods applied in most of the conventional models and activity-based models previously developed. (PB Consult 2005, 1)

As of January 2007, the prior, conventional model was no longer in use; the MORPC activity-based model had been estimated and validated and was in use for the long-range plan, air quality conformity, and transit alternatives. The work on transit alternatives included the North Corridor Transit Project, a likely candidate for the Federal Transit Administration's (FTA's) New Starts program. Because of the high standards set by FTA for travel demand modeling for New Starts, the performance of the MORPC model for this transit study was evaluated with some care (Schmitt 2006). The following are some findings concerning the model's performance for this study:

- Overall, the modeled trip distribution for work purposes appears to be as good as or better than that of comparable models used elsewhere in the United States.
- The model produced reasonable results for user benefits.
- The maps from the model were very good at explaining the benefits and disbenefits of the project.

MORPC was found not to be taking advantage of the increased functionality of the new model because of a need to catch up with a backlog of routine work, but it was reported that with the new model, the range of applications that could be addressed was considerably expanded (Anderson 2007).

New York Best Practices Model

Planning and data collection for this model were conducted in the 1990s, and the model was implemented in 2002. This is described as an activity-based model employing microsimulation to replicate the travel patterns of each person in the region using all modes of travel, including nonmotorized. The model covers 28 counties and has 3,600 transportation analysis zones. During 2002–2006, the model was used for air quality conformity analysis, major investment studies, analysis of the Transportation Improvement

Program and regional transportation plan, and the Manhattan area pricing study (Chiao et al. 2006).

Those using the model results for particular studies (Tappan Zee Bridge/I-270 Alternatives Analysis and Kosciuszko Bridge) reported either having no problems or being highly satisfied with the model results, which appeared to be intuitive and to provide an improved level of detail as compared with other models (VHB 2006).

San Francisco County Transportation Authority

The San Francisco County activity-based model was developed to provide more detailed and accurate information on traveler behavior with respect to destination choices, modal options, and time of day. The model focuses on travel in San Francisco County and combines input from the regional metropolitan commission for a complete portrayal of travel (Outwater and Charlton 2006). The model was used to provide forecasts for the New Central Subway light rail transit project and the alternatives analysis for the Geary Study. For the Central Subway project, the model was used to calculate user benefits for an FTA New Starts application; staff who worked on the application reported satisfaction with the model (VHB 2006). For another application, the San Francisco model was linked with traffic microsimulation software to estimate and portray network impacts of a bus rapid transit project (Charlton 2007).

Finally, in the development of the countywide transportation plan, the San Francisco model was applied to an equity analysis to estimate impacts on mobility and accessibility for different populations. Equity analyses performed by traditional models suffer from aggregation biases and limited data. The San Francisco microsimulation model makes it possible to estimate impacts on different communities according to gender, income, automobile availability, and household structure (Outwater and Charlton 2006).

DRCOG Activity-Based Model

This model is in the planning stages. It is of particular interest as DRCOG, the Denver MPO, conducted an extensive regional visioning process (Metrovision), after which the model features needed to support regional planning for the elements of Metrovision were determined. DRCOG concluded that, while activity-based modeling could not fully address all issues, it would be clearly superior to four-step modeling in many respects. Among the issues for which activity-based modeling was judged to be superior were the following (Sabina and Rossi 2006):

- Pricing and tolling analysis,
- Policies sensitive to time of day,
- Urban centers and transit-oriented development,
- Transportation project analysis, and
- Induced travel.

OBSTACLES TO MODEL IMPROVEMENTS

Despite recent demonstrated advances, the pace of change in travel demand forecasting practice through the years has not been fast. MPO staffs want to use travel forecasting tools that are consistent with the state of the practice and are appropriate for the issues the MPO must address. At the same time, they work within the constraints of time and budget, both of which must be directed to meeting current project planning needs as well as conducting any research activities. Following are some salient obstacles to adopting advanced modeling practices.

Cost

Cost is one potential barrier to the implementation of advanced modeling practices. The cost of implementing an activity-based model depends on a number of variables, including the size of the network, the extent of transit service, and the availability of activity information from a recent home interview survey. Another key issue affecting cost is the extent to which there is a continuous representation of time for traffic assignment. Information on implementation cost was sought informally from three agencies (MORPC, DRCOG, and MTC) and an experienced consulting firm. Respondents expressed costs primarily in a range representing both consultant and staff costs. The average of these total costs was $1 million to $1.4 million.

Technical Issues

In addition to cost, some agencies may have technical reasons for being reluctant to adopt advanced models. These include the following (Vovsha et al. 2005):

• Activity-based models provide probabilistic forecast results; different model runs with the same inputs produce different outputs. This has implications for meeting regulations that require point estimates of travel.

• Data are required from a large-sample home-interview travel survey (typically 4,000 to 5,000 households).

• It may be difficult to achieve reasonable computer run times given the complexity of the model.

Staffing and Training

As noted in Chapter 4, in many agencies, staff members with the skills required to develop and apply advanced practices are limited. Most small and medium MPOs have few staff members assigned to travel forecasting. These employees may have skills in applying the existing model but often lack training or experience in model development. Unless special efforts are made, many of these employees will not have exposure to or interest in new methods. For all MPOs, the transition from the old model to the new may be difficult to achieve given the demands on MPOs' technical staff for production and continuity of model results.

Institutional Issues

Another obstacle to model improvement activities by MPOs is aversion to changing the status quo. The committee believes there is institutional reluctance to suggest problems with existing models since projects planned using those models may be challenged not only in the public arena but also in lawsuits. Implementing a new modeling procedure may be viewed as an implicit admission that there were problems with the models previously used. Where planned projects exist over which some controversy remains, implementing a new procedure may open up the possibility that previous decisions will be challenged and that completed analyses will need to be reassessed in light of new forecasts. Procedures established for analyzing the conformity of an adopted transportation plan with air quality programs are another salient issue in considering the development of new models. Given the work involved in revising forecasts, agencies may be reluctant to change models once the model emissions budget within the state implementation plan has been established.

The committee believes that the interagency structure of planning within a metropolitan region may also be a barrier to change. In many metropolitan areas, local planning agencies, transportation providers, and state agencies may maintain their own travel forecasting models that use outputs from the regional model, or they may borrow the MPO's models for their own use. In such instances, significant MPO modeling enhancements might be viewed as a hindrance to ongoing work by other agencies, which are likely to be represented on regional transportation technical committees and the MPO policy board. This is not an insurmountable problem, but the need to build a consensus among all users of the MPO model and its outputs can be a significant complicating factor in efforts to introduce new modeling approaches.

Need for Tangible Evidence

The need for evidence has two facets. First, agencies may believe that their current models are adequate for current uses and have no evidence to the contrary. MPOs have rarely investigated the extent to which forecasts produced by their models have been valid. Time and funds for retrospective analysis are lacking. Periodic validation of a model set will reveal surface problems such as differences between assigned volumes and counts but will give no indication of where within the model set problems may reside. A true reassessment of the existing model set, from generation through distribution and mode choice to assignment, requires as many data as are required for model development, or more. Lacking such retrospective analysis that demonstrates a failure of current forecasting procedures, agencies are under little pressure to devote resources to the exploration or development of new procedures.

Second, proof that the advanced modeling practices are better than current practices is needed. Before undertaking major investments in new models, MPOs want tangible evidence that the new procedures will yield forecasts that are notably better than those produced with currently accepted procedures.

Overcoming Obstacles to Model Improvements

The committee's web-based survey showed that 70 percent of large and medium MPOs identified features of their models needing improvement. In the web-based survey, about 20 percent of small and medium MPOs and almost 40 percent of large MPOs reported that they are exploring replacing their existing model with an activity- or tour-based model. Three U.S. cities are known to have implemented such advanced models, and eight others are in the design process. While some MPOs are satisfied with the status quo, it is apparent that there is a growing willingness to adopt or at least explore advanced practices that may better serve MPOs with more complex needs. Some lead agencies clearly have found ways to overcome obstacles to improvement, and it is likely that with increased experience, better home interview techniques, and faster computers, these difficulties may be mitigated. Presumably with greater experience, the initial cost of model development will fall. A strong case can be made for the pooling of resources among MPOs for joint development, and for continued or increased federal support and leadership in advanced model development.

MODEL RESEARCH, DEVELOPMENT, AND IMPLEMENTATION

Activities aimed at advancing the state of practice through research and development take place at each level of government and through nongovernmental efforts as well. There is great potential for expansion and better coordination of this work.

Federal Initiatives

As noted in Chapter 3, the federal government has a strong interest in robust metropolitan travel forecasting to ensure that federal funds are being used to support top-priority needs for maintenance and improvement of the national transportation system and to meet the requirements of federal laws, in particular the Clean Air Act, the Clean Water Act, and the National Environmental Policy Act. As also noted in Chapter 3, FTA has taken a strong role in improving modeling practice.

TMIP has been sponsored by FHWA since 1992. Its mission is to "support and empower planning agencies, through leadership, innovation and support of travel analysis improvements, to provide better information to support transportation and planning decisions" (tmip.fhwa.dot.gov/about/mission.stm). The program has three goals:

- Help planning agencies build their institutional capacity to develop and deliver travel model–related information to support transportation and planning decisions;

• Develop and improve analytical methods (including TRANSIMS) that respond to the needs of planning and environmental decision making; and

• Support mechanisms designed to ensure the quality of technical analysis used to support decision making and to meet local, state, and federal program requirements (tmip.fhwa.dot.gov/about/goals_activities.stm).

A 2003 performance assessment found that TMIP had had a positive influence on short-term model improvements, leaving transportation agencies in a better position to address federal and state planning requirements. Specific activities have included the following:

• Enhancements to current models,

• Topical conferences and workshops,

• A newsletter (1,300 subscribers),

• A website with a library of literature on modeling topics (visited on average 1,500 times a day),

• An e-mail list that reaches a national and international audience (almost 900 members and 50 postings per month), and

• A travel model peer review program for which more than 20 agency reviews had been completed as of 2006.

Long-term model development has been accomplished through TRANSIMS, discussed above. The evaluation report notes: "While much has been accomplished, continuing outreach and additional research are needed to help advance the state-of-the-art with travel forecasting models" (Shunk and Turnbull 2003, 27).

In 2007, FHWA is providing TMIP staff support and, through the agency's research program, the primary funding for TMIP activities. TRANSIMS is funded separately by specific allocations [as it was previously under the Transportation Equity Act for the 21st Century (TEA-21)]. In the latter days of TEA-21, TMIP was funded at approximately $500,000 annually for all activities other than TRANSIMS. The same approximate level of funding has continued under SAFETEA-LU. Given the stated purposes of the program and the apparent need for such a national program to advance the state of practice in travel modeling, the committee finds this level of funding to be inadequate.

In the late 1970s and early 1980s, FHWA and the Urban Mass Transportation Administration (later FTA) spent about $5 million a year on travel model development and implementation, equivalent to about $15 million in current dollars. A strong federal role is needed to provide models and data development, assistance with implementation, training, and documentation. The resources currently being provided are insufficient to allow the federal government to assume this role in a meaningful way. The current authorized FHWA and FTA capital program totals about $40 billion. It would appear appropriate to make an annual investment of 0.05 percent, or $20 million, of this amount for the development and implementation of improved travel forecasting models.

State Initiatives

The states have their own national research program, the National Cooperative Highway Research Program (NCHRP), sponsored by individual state transportation agencies and the American Association of State Highway and Transportation Officials (AASHTO) in cooperation with FHWA. NCHRP was created in 1962 as a means to conduct research of interest to the states in acute problem areas that affect highway planning, design, construction, operation, and maintenance nationwide. Funding for the program is contributed by each state, drawing from federal State Planning and Research funds. Research topics are chosen annually by the AASHTO Standing Committee on Research. NCHRP conducts research on topics related directly to metropolitan travel forecasting. Examples are the completed *NCHRP Report 388: A Guidebook for Forecasting Freight Transportation Demand* and two efforts currently under way: NCHRP Projects 8-37, Standardized Procedures for Personal Travel Surveys, and 8-61, Travel Demand Forecasting, Parameters and Techniques.[2] In the past, NCHRP funding has been programmed to support specific TMIP activities.

Other Research and Development Initiatives

Other sources of funding and research to advance the state of practice in travel modeling include the national Transit Cooperative Research Program (TCRP), established with FTA sponsorship and funding in July 1992. The program has an independent governing board representing the transit industry—

[2] Updates *NCHRP Report 187: Quick-Response Urban Travel Estimation Techniques and Transferable Parameters: User's Guide.*

the TCRP Oversight and Project Selection Committee, which also selects research topics. TCRP has performed research that has contributed to advancing the state of practice in travel forecasting. Examples are the completed *TCRP Report 48: Integrated Urban Models for Simulation of Transit and Land Use Policies: Guidelines for Implementation and Use* and the in-progress TCRP Project H-37, Improving Travel Forecast Models for New Starts—Mode Specific Constants.

University researchers can also make substantial contributions to research and practice, working with MPOs and states. One example is the joint initiative of the University of Texas at Austin and the Dallas–Fort Worth MPO to demonstrate the Comprehensive Econometric Microsimulator for Daily Activity-Travel Patterns, an econometric activity-based modeling system. This work is being funded by the Texas Department of Transportation (Bhat et al. 2006). Another example is the University of California at Davis–Caltrans Air Quality Project, which since 1997 has been developing and implementing transportation-related air quality analysis tools and procedures that help regional, state, and federal agencies achieve improved air quality (aqp.engr.ucdavis.edu/). In Florida, there is a statewide Florida Model Task Force that commissions research projects from the state's universities to benefit all Florida MPOs (Florida Model Task Force 2007).

Consultants play a key role in technology transfer and application development. Notably, the three implementations of activity-based metropolitan models (San Francisco, New York, and Columbus, Ohio) have depended heavily on consultant leadership, and TRANSIMS also relies on consultant assistance for its current development and implementation activities.

Metropolitan Opportunities

The principal consumers of research and development in models for metropolitan travel forecasting are the MPOs (and states that perform model development and forecasting on behalf of MPOs). These operating entities are responsible for providing validated regional models for use in analyzing and forecasting changes in travel for alternative transportation investments and policies. As noted in Chapter 2, they are also faced with meeting expanded requirements for their planning programs.

Evaluation of which potential model enhancements can usefully be implemented is ultimately the MPOs' responsibility, funding to support improved or new models must be sought by individual MPOs, and implementation of new modeling practices must take place at the metropolitan level. Despite these considerable responsibilities, the MPOs currently have no national, collective means of identifying and directing the most appropriate research and development that would serve their needs or of funding such activities. Each MPO must find its own funding, data, consultant assistance, and trained staff for model development. To the extent that metropolitan areas have their own unique conditions, this may be appropriate. But there is also a strong case to be made for the economies of a pool-funded approach to modeling research and development that could benefit many or all MPOs.

Figure 6-1 shows federal funding from FHWA and FTA available from 1992 to 2006 to support the planning activities of all 384 MPOs. Funding levels are shown in both current and constant dollars, indexed to 1992. Since 1992, funding in current dollars has grown from $161 million to $366 million, an increase of 127 percent. If inflation is taken into account, the increase is to $287 million, or 78 percent.

Concurrent with this increase in MPO funding was an increase in the scope of MPO responsibilities, due mainly to expanded federal requirements. There was also steady growth in the number of MPOs as more urban areas reached

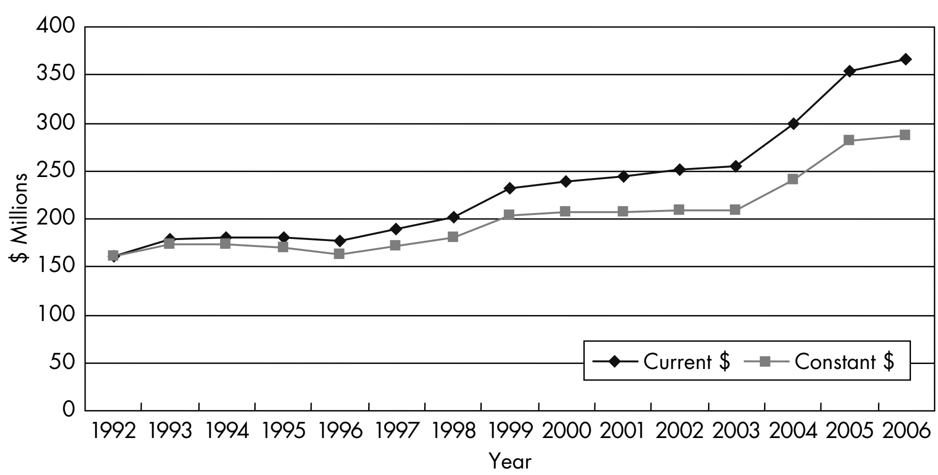

FIGURE 6-1 **Federal MPO funding, 1992–2006.** (Sources: FHWA 2006; FTA 5303 Apportionment Table, personal communication from Ken Johnson to J. Williams, April 24, 2006.)

the 50,000 population threshold. Nonetheless, $366 million is a substantial figure, and a modest takedown from this figure could support a national MPO research program, controlled by MPOs and dedicated to their research needs.

The New York State Association of Metropolitan Planning Organizations (NYSAMPO) has shown how such an initiative can work on a statewide basis. There are also national models for how entities with common research interests can benefit from pool-funded research: NCHRP for state transportation agencies, TCRP for transit agencies, the Airport Cooperative Research Program (ACRP) for airports, the National Cooperative Freight Research Program (NCFRP), and the Hazardous Materials Cooperative Research Program (HMCRP). A Metropolitan Planning Cooperative Research Program would give MPOs the lead in developing their own national research agenda and carrying out that agenda through a research program. The scale of such a program can be roughly estimated from that of the cited national programs, for which approximate annual funding is as follows:

- NCHRP, $33 million;
- TCRP, $9 million; and
- ACRP, $10 million;
- NCFRP, $3 million; and
- HMCRP, $1 million.

The administrative costs of these programs are roughly 25 percent. Assuming a Metropolitan Planning Cooperative Research Program wished to start 12 research and development projects a year and that these projects averaged $300,000 each, the cost of the program would be (12) ($300,000) (1.25) = $4.5 million.

This $4.5 million would represent 1.2 percent of total federal (FHWA and FTA) funding for MPOs ($366 million in 2006). Following the example of NYSAMPO, the smaller MPOs (those with populations of under 200,000) might be exempted from financially supporting the program, in which case the takedown would be greater for the larger MPOs. This fund could be created through the state transportation agencies that receive MPO funds or through the federal government.

Another approach would be for MPOs with common needs to join together for research and development studies of mutual interest. State transportation agencies often join together for such pool-funded research on topics of common interest. FHWA has a program to facilitate this type of pooled research, and MPOs are mentioned as possible participants (www.pooledfund.org/).

The project-by-project approach does not lend itself to creating an ongoing research program but may answer the needs of a group of MPOs with a common problem to address.

Regardless of the specific operating mechanism, pooling of research and development funds offers an efficient means of meeting MPO needs for model enhancement, development, and implementation. Another advantage is the possibility of leveraging funds through joint ventures with federal, state, transit, and other research programs. MPOs could be in charge of substantial ongoing funds, which could be used to satisfy their own model research and development needs or for other research and development purposes, according to their wishes.

The following are examples of what such pooled research might accomplish (Cervenka 2005):

- Rigorous examination of implemented (or estimated) advanced models, with sensitivity and validation tests;
- Exploration of data and parameters transferable from region to region;
- Development of universally estimated, locally calibrated models;
- Pooled acquisition of computer software and hardware; and
- Documentation of practice for shared-use applications.

An Integrated Approach to Research, Development, and Implementation of Advanced Models

Currently, elements of research, development, and implementation for travel models are diffused among local, state, and federal governments and other entities. Each of these entities has a definite and discernible role. The federal government takes the lead and bears the risk for high-payoff research that will benefit the nation and facilitates diffusion of advanced practices. Through their research programs, states sponsor advances that meet state and MPO needs and facilitate training and technology transfer through statewide model user groups. The transit industry has its research program in support of transit agencies, as well as means for technology transfer through such groups as the American Public Transportation Association. MPOs bear the responsibility for transferring travel model research into practice, a role that might be facilitated through a national program of application-oriented research funded and directed by MPOs.

These various elements of research, development, and implementation could be better integrated for the mutual benefit of all parties and achievement of the ultimate goal of improved travel forecasting models. This integration could be effected through a national travel forecasting steering committee. This committee could meet regularly to set goals and an agenda for joint activities to improve travel models and modeling practice, avoiding duplication of effort and ensuring that resources would be directed toward top priorities.

An activity associated with the national steering committee could be the development and production of a national travel forecasting handbook. Currently, no single source of information describes current or evolving practices in travel modeling and forecasting. Such a handbook could identify alternative best practices for addressing various travel markets and metropolitan needs. It would be an informational and evolving document, with no prescriptive or regulatory implications, and would reflect recognition that different approaches are needed according to the metropolitan context. Creation of the handbook might be directed by the travel forecasting steering committee and accomplished through a national organization that would bring together practitioners and researchers from government agencies, consulting firms, and academia. The primary stakeholders would be those responsible for conducting metropolitan travel forecasting. Resources to support the handbook might be derived from NCHRP, TCRP, the recommended Metropolitan Cooperative Research Program, and the federal government.

SUMMARY FINDINGS AND RECOMMENDATIONS

This chapter has addressed improvements in four-step trip-based modeling; advanced modeling practices; TRANSIMS; experience with advanced practice; obstacles to model improvement; and model research, development, and implementation.

Improvements in Four-Step Trip-Based Modeling

MPOs may undertake ambitious modeling improvement programs within the framework of their current models. Typical results are improved measures of arterial congestion, accounting for highway and transit in trip distribution, improved trip distribution models, improved modeling of nonmotorized travel, and improved sensitivity testing.

Advanced Modeling Practices

Travel models can be improved by being based on a more comprehensive understanding of the activities of households. Also needed is a more complete representation of the supply-side network to account for the details of congested operations throughout the day. No one new modeling approach can address these and other needs. Rather, a suite of related approaches, taken together, shows promise for greatly improving modeling practice. These approaches include improved land use modeling, tour-based models, activity-based models, discrete-choice modeling, traffic microsimulation, and dynamic traffic assignment.

There remain questions about the wisdom of the investment in advanced modeling practices. For example, are they more than the agency really needs? Are the forecasts reasonable? Can the agency maintain the model set? The current state of knowledge is such that there can be no definitive answer to these questions. For this reason, the committee believes that **MPOs experimenting with or fully implementing advanced modeling practices should document their experiences, including costs, advantages, drawbacks, and any transferable data or model components.** In addition, the committee recommends that **studies be performed to compare the performance of conventional and advanced models and to evaluate how well-implemented advanced models handle complex planning issues that are beyond the scope of current models.**

TRANSIMS

TRANSIMS is a computer-based system capable of simulating the second-by-second movements of every person and every vehicle through the transportation network of a large metropolitan area. It incorporates and integrates some of the advanced modeling practices detailed in this chapter, in particular population synthesis, activity-based modeling, and traffic microsimulation.

From 1992 to 2003, $38 million was spent on TRANSIMS, about three-quarters of which went to Los Alamos National Laboratory for basic research and development. TRANSIMS was originally field-tested in Dallas–Fort Worth, Texas, and Portland, Oregon. SAFETEA-LU will support two to three new deployments a year. TRANSIMS technology is also being used for projects not funded through SAFETEA-LU.

TRANSIMS has not yet been implemented by any MPOs for use in core travel forecasting activities. Some reasons for this include the software's having been developed in a research and development setting, its not being well adapted for general deployment, early requirements for high-performance computers and the Linux operating system, a poor user interface, and documentation that did not easily support applications. There has been a perception that implementing TRANSIMS (and other activity-based models) may be an overwhelming task. Yet a number of improvements have made TRANSIMS more accessible and ready for implementation. **On the basis of its knowledge and experience, the committee believes TRANSIMS has provided an important bridge from the current practice of static, trip-based modeling to an improved future practice. The federal government should continue funding TRANSIMS development and implementation at appropriate levels.**

Experience with Advanced Practice

Three agencies in the United States have implemented advanced, activity-based travel models and used them successfully for typical transportation planning applications. Users report satisfaction with the model results, and where analysis has been done, the results are described as reasonable and comparable with those from the prior, trip-based models. At least eight additional U.S. cities are actively planning for the introduction of advanced models.

Obstacles to Model Improvement

Obstacles to the adoption of advanced modeling practices include the following:

- Cost of implementation,
- Limited staff skills,
- Reluctance to suggest problems with existing models since doing so could cause projects planned on the basis of those models to be challenged,
- Reluctance to change models once the model emissions budget within the state implementation plan has been established,
- No analysis demonstrating a weakness of current forecasting procedures,

• The need for evidence that new procedures will perform better than the current ones, and

• The belief of some MPOs that their current models are doing an adequate job.

Model Research, Development, and Implementation

Activities to advance the state of practice through research and development take place at each level of government and through nongovernmental efforts as well. There is great potential for expansion and better coordination of this work.

Federal Initiatives

TMIP has been sponsored by FHWA since 1992. A 2003 performance assessment found that TMIP had a strong positive influence on short-term model improvements. Successes have included enhancements to current models, topical conferences and workshops, a newsletter, a website, an e-mail list that reaches a national and international audience, and a travel model peer review program. Long-term model development has been accomplished through TRANSIMS, discussed above.

The committee finds the current annual funding for TMIP ($500,000) to be inadequate. The committee calls on the U.S. Department of Transportation, FHWA, and FTA to take the following steps to facilitate the needed improvements in both models and practice:

• **Support and provide funding for incremental improvements to existing four-step (or three-step) trip-based models, in settings appropriate for their use.**

• **Support and provide funding for the continued development, demonstration, and implementation of advanced modeling approaches, including activity-based models.**

• **Continue to rely on TMIP as an appropriate mechanism for advancing model improvement.**

• **Increase funding to an appropriate level to support the federal government's role as a partner with MPOs and state transportation agencies in the development and implementation of improved models—an annual investment of approximately $20 million.**

State Initiatives

The states have their own national research program, NCHRP, sponsored by individual state transportation agencies. Funding for this program is contributed by each state. NCHRP conducts research on topics directly related to metropolitan travel forecasting.

Other Research and Development Initiatives

Other sources of funding and research support efforts to advance the state of practice in travel modeling. One example is TCRP. Consultants also play a key role in technology transfer and applications development. University researchers can make substantial contributions to research and practice, working with MPOs and states. **Individual MPOs and universities could form partnerships to foster travel model research and implementation of advanced modeling practice.**

Metropolitan Opportunities

The principal consumers of research and development in metropolitan travel forecasting models are the MPOs (and states that perform model development and forecasting on behalf of MPOs). Despite their considerable responsibilities, the MPOs currently have no national research program of their own. **The committee believes the MPOs would benefit from establishing a national metropolitan cooperative research program.** Because model applications must fit local needs and context, it is important for MPOs to take a leadership role in model selection, development, application, testing, and verification. Large costs are involved in both improving current models and developing more advanced models. Rather than duplicating these costs at each MPO, it would be beneficial to pool resources for such activities as model enhancement, new model development, implementation procedures, and staff training programs. MPOs nationally receive annual funding of $366 million. A takedown of 1.2 percent from this total would produce a program with a $4.5 million annual budget, which should be sufficient to start 10 to 12 research projects a year.

An Integrated Approach to Research, Development, and Implementation

Currently, elements of research, development, and implementation in travel modeling are diffused among local, state, and federal governments and other entities. **These levels of government should work cooperatively to establish appropriate goals, responsibilities, and means of improving travel forecasting practice. This cooperation could be accomplished through a national travel forecasting steering committee.** This committee could set goals and an agenda for joint activities aimed at improving travel models and modeling practice. **An activity associated with the national steering committee should be the development and production of a national travel forecasting handbook.** This would be an informational and evolving document, with no prescriptive or regulatory implications.

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Abbreviation

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7

The Pace of Change and Innovation

From 1955 to 1965, the basic components and practice of the current trip-based four-step travel demand forecasting process were developed and implemented in cities throughout the United States. Major studies of needs for urban highway and transit infrastructure were completed, regional transportation plans were formulated and adopted, and the design and construction of new highways and transitways commenced.

In 1973, a national conference was held in Williamsburg, Virginia, to discuss the future of metropolitan travel demand forecasting. As noted in the proceedings of that conference, travel forecasting procedures were developed and used to address the issues of the 1960s and support regional transportation plans necessary to design major transportation facilities. The proceedings went on to note that the major issues of the 1970s had changed and now included "demand responsive transit . . . parking policy, flow metering, exclusive lanes for buses, traffic control schemes, pricing policy, and vehicle exclusion zones." Other new issues included influencing demand to conserve energy and equitable treatment of different sectors of the population. What was needed, concluded the Williamsburg conferees, were policy-sensitive modeling tools to inform decision making. The conferees were confident that many of these tools had already been developed by using disaggregate modeling procedures and could be incorporated into practice in a 3-year time frame (HRB 1973, 1).

In 1979, a classic text, *Fundamentals of Transportation Systems Analysis,* assured readers: "While the conventional urban transportation planning models have serious limitations, a new generation of models is now being developed. These models encompass much improved demand functions and a sounder theoretical basis for explicit travel-market equilibrium analysis" (Manheim 1979, 33).

In 1982, a national conference on travel analysis methods for the 1980s was held in Easton, Maryland. The proceedings from this conference noted that "the gap between the state of the art and the state of the practice is considerably wider now than in the 1970s. . . . This has occurred while the state of practice has not improved appreciably." The state of the art for travel analysis, on the other hand, was "generally well-advanced and capable of dealing with issues likely to need attention in the 1980s." This was seen as particularly true because of the development of superior tools using disaggregate mathematical techniques and the adoption of methods from behavioral science. The only rub was that practitioners were not using these tools (TRB 1983, 3).

In the early 1990s, the National Association of Regional Councils commissioned Elizabeth Deakin and Greig Harvey to prepare a manual on travel modeling practice for air quality analysis. This initiative was occasioned by the Clean Air Act Amendments of 1990, which provided a regulatory impetus for accurate travel forecasts of the impacts of transportation policies and improvements on reducing automobile emissions and promoting clean air. The manual was based on a study of metropolitan planning organization (MPO) modeling practice at that time and served as a baseline for the present study of metropolitan travel forecasting practice in 2005. Deakin and Harvey found that "advances . . . in the development and application of land use and transportation forecasting technologies were made in the 1970s and '80s, but only a few MPOs had the resources at that time to implement these advances." As in the 1960s, 1970s, and 1980s, the MPO models used in practice were found to be generally incapable of adequately addressing parking policies, pricing strategies, improvements in traffic operations, and land use and urban design measures. Moreover, there were new air quality planning requirements for estimating link-specific hourly traffic volumes and speeds that were beyond the capabilities of any regional model (Deakin and Harvey 1994, 2).

In 2005, this committee undertook a comprehensive survey of current metropolitan travel forecasting practice (see Chapter 4). As in the 1970s, 1980s, and 1990s, with few exceptions, MPO travel forecasting models remained aggregate, trip-based, and structured into four sequential steps. The models remained reasonably well suited to estimating the scale and location of major capital improvements. In 2005, as has been true for the past four decades, these models could not provide accurate information to inform decision making on many transportation and land use polices or traffic operations projects. Improvements made to the modeling process since Deakin and Harvey's work were primarily the result of computer hardware (faster microcomputers with larger hard drives) and software (geographic information systems). These innovations allow more rapid computation and better portrayal of information, but not the information needed for contemporary decision making.

The practice of metropolitan travel forecasting has been resistant to fundamental change. Every 10 years or so there begins a cycle of research, innovation, resolve to put innovation into practice, and eventual failure to effect any appreciable change in how travel forecasting is practiced. This sobering assessment underscores the need to break out of this cycle, using the coordinated resources of each level of government in an alliance with academia and the private sector. It is time for a return to the creativity and willingness to innovate that were hallmarks of the early days in which travel forecasting was pioneered.

REFERENCES

Abbreviations

HRB	Highway Research Board
TRB	Transportation Research Board

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APPENDIX

Committee Statement of Task

This project will gather information and determine the state of the practice of metropolitan travel demand modeling by metropolitan planning organizations and state departments of transportation. The practice of interest includes such features of travel modeling as

- The size and scope of the transportation network and how it is represented;
- Population, employment, and land use forecasts and travel surveys and how they are generated and input into the modeling process;
- How key model details, such as trip purposes, are represented, including how light-duty and heavy-duty commercial vehicle travel are modeled;
- The nature, extent, and justification of model adjustments to fit unique local circumstances;
- How congestion on networks is represented and how it is used as an input to mode choice models;
- Techniques and measures used in model estimation, calibration, and validation;
- Postprocessing of travel demand modeling outputs to become inputs to emissions factor modeling;
- Feedback and model iterations;
- Induced travel demand;
- Staff capability and resources; and
- Unique conditions in individual areas.

The committee will commission a consulting firm to gather and synthesize information from MPOs and state DOTs. This work will be guided by the committee's judgment about appropriate information to collect and how the information should be presented. The committee will further guide the consultant by recommending a taxonomy of area types with similar modeling needs, considering such factors as population size, modal complexity, special needs such as recreation and through travel, and air quality attainment status. The committee may recommend a sampling plan associated with this taxonomy for data collection. The committee's findings will address modeling in each area type, within the limitations of the data.

In addition to overseeing the collection of information about current practice, the committee will respond to the following questions:

a. What models do MPOs currently use or have under development?
b. Are MPOs using multiple models for multiple purposes?
c. What are key similarities and differences among MPOs in the development and application of models, and what factors are associated with these differences? Factors to be considered may be from the taxonomy developed by the committee or from other sources.
d. Based on evidence collected by the consultant, what, if any, are the technical shortcomings in the models for their intended uses, such as technical analysis of the Transportation Improvement Program and the Long-Range Plan, emissions analyses, FTA New Starts analyses, and NEPA analyses?
e. What, if any, are the obstacles to appropriate applications of the models?
f. Any other questions or issues raised by the consultant's reporting.

Finally, the committee may identify actions needed to ensure that the appropriate technical processes are being used for travel modeling.

Study Committee Biographical Information

Martin Wachs is director of the Transportation, Space, and Technology Program at the RAND Corporation in Santa Monica, California. He retired at the end of 2005 from the University of California, Berkeley, where he was director of the Institute of Transportation Studies and held faculty appointments as professor of city and regional planning and of civil and environmental engineering. His research is in transportation planning and policy, including public transit systems and evaluation of alternative transportation projects. Recently, his writings have dealt with the relationships among transportation, air quality, and land use and with transportation finance. Dr. Wachs is a member and past chair of the Executive Committee of the Transportation Research Board (TRB). He has served on numerous committees appointed by the National Research Council (NRC) and chaired the Committee for the Evaluation of the Congestion Mitigation and Air Quality Improvement Program. He holds MS and PhD degrees in transportation planning from Northwestern University and a BS degree in civil engineering from City University of New York.

Laura L. Cove is manager of the Traffic Engineering Group for the Town of Cary, North Carolina. Before taking that position, she was manager of the Technical Services Group of the Transportation Planning Branch of the North Carolina Department of Transportation. This group is responsible for travel demand model development and applications for the 17 North Carolina metropolitan planning organizations (MPOs), including determination of conformity of transportation plans with air quality regulations. The group is also responsible for the department's traffic surveys. Ms. Cove has worked as assistant director for the Office of Strategic Planning at the Tennessee Department of Transportation and as an engineer for the Federal Highway

Administration division offices in Tennessee and North Carolina. She is a licensed professional engineer and holds MS and BS degrees in civil engineering from Clemson University.

Thomas B. Deen (Member, National Academy of Engineering) is a transportation consultant and former executive director of TRB, a position he held from 1980 to 1994. He is former chairman and president of PRC-Voorhees, a transportation engineering and planning consulting firm with clients worldwide. His research interests include intermodal planning of urban transportation systems. Early in his career, Mr. Deen was a pioneer in the development and application of computer-based modeling methods for analyzing urban transportation problems and designing urban transit systems. Initially, these methods were used in the planning of the Washington, D.C., Metrorail system; they have subsequently been used to plan and design transit systems throughout the world. After leaving his position with TRB, he served as chair of a panel appointed by the Governor of Maryland to make recommendations on the Intercounty Connector. He also served as vice chair of the NRC Committee on Transportation of Radioactive Waste, was chair of a panel investigating the Chesapeake Bay Bridge deck failure, and was cochair of a committee established to advise the Maryland legislature on a high-speed maglev system for the Northeast Corridor. He holds a BS degree from the University of Kentucky and a certificate from the Yale University Bureau of Highway Traffic.

George B. Dresser is a senior research scientist at the Texas Transportation Institute and is program manager for the transportation planning program. He has provided extensive planning and travel modeling services for the Texas Department of Transportation and many of the state's MPOs. He has particular expertise in modeling and forecasting mobile source emissions for air quality planning. He has taught courses in urban travel demand forecasting through the National Highway Institute. Dr. Dresser holds a PhD in civil engineering, an MS degree in statistics from Texas A&M University, and a BS degree in chemistry from the College of William and Mary.

Ronald W. Eash is currently a visiting scholar at the Transportation Center of Northwestern University. From 1977 to 2000, he was a senior technical manager at the Chicago Area Transportation Study, the MPO for metropolitan Chicago. In this capacity he was responsible for the implementation of regional travel forecasting models for northeastern Illinois. Features of these models include simulation of individual travel and mode choice decisions, incorporation of nonmotorized alternatives, and time-of-day traffic assignments for air quality conformity. He is a registered professional engineer in Illinois. He holds a master of urban planning and policy degree from the University of Illinois and MS and BS degrees in civil engineering from Northwestern University.

Robert A. Johnston is an emeritus professor in the Division of Environmental Science and Policy at the University of California, Davis. His major research interests are in the areas of land use plan implementation, open space and terrestrial habitat protection, transportation and land use modeling, and regional planning support systems. His geographic information system–based urban growth model is being used in 14 California counties. He recently undertook the Assessment of Integrated Transportation/Land Use Models for the California Department of Transportation, which involved reviewing and evaluating urban models for use by large California MPOs. He is currently on a team applying the PECAS urban model to all of California. Among Professor Johnston's publications are a chapter, "The Urban Transportation Planning Process," in *The Geography of Urban Transportation,* 2004; he coauthored "Comparisons from Sacramento Model Test Bed," which appeared in *Transportation Research Record: Journal of the Transportation Research Board, No. 1780,* in 2001. He holds an MA degree in planning from the University of Southern California; an MS degree in renewable natural resources from the University of Nevada, Reno; and a BA degree from Dartmouth College.

Eric J. Miller is Bahen-Tanenbaum Professor of Transportation Engineering and Planning at the University of Toronto, where he is also director of the Joint Program in Transportation. His research interests are modeling of transportation–land use interactions, microsimulation modeling, modeling of urban transport emissions and energy consumption, travel demand modeling using disaggregate choice models, travel demand survey methodology, transit route ridership analysis and forecasting, and simulation of transit route operations. He developed GTAMODEL, a multimodal regional transportation modeling system used by public agencies to forecast and analyze travel demand in the Toronto metropolitan area. He is leading a team of researchers from four universities in developing the Integrated Land Use, Transportation, Environment modeling system. Dr. Miller is coauthor of the textbook *Urban Transportation Planning* and *TCRP Report 48: Integrated Urban Models for*

Simulation of Transit and Land Use Policies: Guidelines for Implementation and Use. He is a member of TRB's Committee on Travel Demand Forecasting and its Task Force on Moving Activity-Based Approaches to Practice. He holds a PhD from the Massachusetts Institute of Technology and MASc and BASc degrees from the University of Toronto.

Michael R. Morris is director of transportation at the North Central Texas Council of Governments, which he joined as a transportation analyst in 1979. As transportation director for the MPO for Dallas–Fort Worth, he is responsible for analysis of the region's long-range transportation plan and Transportation Improvement Program to determine travel and air quality emission impacts of proposed capital and operational investments and public policies. Mr. Morris is a registered engineer in the state of Texas. He is a Policy Committee Member of the Association of Metropolitan Planning Organizations and a member of TRB's Executive Committee. Mr. Morris has served on the NRC Committee to Review EPA's Mobile Source Emissions Factor Model, the Committee for the Evaluation of the Congestion Mitigation and Air Quality Improvement Program, and the Committee on Air Quality Management in the United States. He holds a BA degree in environmental design and planning and an MS degree in civil engineering from the State University of New York, Buffalo.

Richard H. Pratt is the principal of Richard H. Pratt, Consultant, Inc. In this capacity, he has provided advisory and full project transportation planning services across the United States and internationally since 1985. He has been a vice president and head of the Systems Group at Barton-Aschman Associates and a project manager at Alan M. Voorhees & Associates, in charge of system planning studies for the Washington, D.C., Metrorail system. Throughout his career, he has worked on travel model development and applications for public and private agencies. His most recent work is as principal investigator for the Transit Cooperative Research Program project to prepare the updated third edition of the handbook *Traveler Response to Transportation System Changes.* Mr. Pratt is a registered engineer in the states of California and Maryland. He holds a BS degree in science from the California Institute of Technology and an MS degree in civil engineering from Northwestern University.

Charles L. Purvis is a principal transportation planner/analyst at the Metropolitan Transportation Commission (MTC), Oakland, California, and has been at MTC since 1981. He is responsible for travel model development and for regional and subregional forecasts of travel for the San Francisco Bay Area. He is also responsible for the analysis and use of data from household travel surveys and the decennial census to support transportation analysis activities. He has chaired or been a member of the TRB Committee on Urban Transportation Data and Information Systems since 1989 and has served as chair of the TRB Travel Analysis Methods Section since 2004. He has been a member of a number of National Cooperative Highway Research Program project panels, including Commuting in America III, Using American Community Survey Data for Transportation Planning, and Standardized Procedures for Personal Travel Surveys. He holds a BA degree in geography from California State University, Northridge, and a master of city and regional planning degree from Rutgers University.

Guy Rousseau is modeling manager for the Atlanta Regional Commission (ARC), the MPO for Atlanta, Georgia, which he joined in 1998. He is responsible for modeling the impact of regional transportation plan updates and Transportation Improvement Programs, coordinating the travel model with the DRAM-EMPAL land use model, modeling air quality emissions for conformity and attainment of clean air goals, implementing geographic information system applications, and obtaining data for the modeling process through household surveys and other studies. Before coming to ARC, he was a principal traffic engineer for the City of Atlanta Department of Public Works, with responsibilities for travel modeling and traffic simulation. Mr. Rousseau has also been a transportation modeler for the MPOs in Dayton, Ohio, and Tulsa, Oklahoma, and for Jefferson Parish, Louisiana. He is a member of the TRB Committees on Transportation Planning Applications, Metadata, and Travel Survey Methods, and a member of the TRB oversight panel for the Airport Cooperative Research Program's Airport Access Mode Choice Models. He has participated in the Federal Highway Administration's Travel Model Improvement Program peer review of metropolitan travel forecasting for the North Carolina Department of Transportation and for Memphis, San Diego, St. Louis, and Knoxville. He has undertaken doctoral studies in planning at the University of New Orleans and holds an MSCE degree from Laval University and a BSCE degree from the University of Montreal.

Mary Lynn Tischer is the director of the Commonwealth of Virginia's Multimodal Transportation Planning Office and was formerly adviser to the

Governor of Virginia. Previously, she was assistant director at the Arizona Department of Transportation, where she worked to improve the transportation planning process throughout the state and initiated the first comprehensive long-range plan in cooperation with the Arizona MPOs. She was director of the Office of System and Economic Assessment at the Volpe National Transportation Systems Center. From 1989 to 1997, she was director of the Office of Policy Analysis for the Virginia Department of Transportation. From 1975 to 1989, she held a number of positions at the Federal Highway Administration. There she performed statistical modeling and forecasting, provided technical assistance on modeling and data collection methods, and was an instructor in courses on planning methods. Dr. Tischer is cochair of the Transportation Research Record Publication Board, cochair of the Strategic Highway Research Program II Capacity Committee, and a member of the TRB Committees on Statewide Multimodal Transportation Planning and Performance Measurement. She has served on the editorial boards of a number of transportation journals, was a fellow of the Urban Land Institute, and chaired the Advisory Committee to the Federal Highway Administration's Travel Model Improvement Program. She holds a PhD in political science from the University of Maryland, an MA degree from American University, and a BA degree from Rosemont College.

Richard E. Walker is the Transportation Research and Modeling manager for Metro Portland, the MPO for Portland, Oregon. He manages all programs related to travel forecasting, including data collection, model development, and model applications. His areas of expertise include multimodal, freight, transit, and air quality conformity modeling. He has participated in the peer review of metropolitan travel forecasting models in Santa Cruz, Salt Lake City, Las Vegas, Anchorage, and Phoenix. In Oregon, Mr. Walker has chaired the Modeling Steering Committee and currently is the chair of the Modeling Program Coordination Committee. He is a member of TRB's Committee on Transportation Planning Applications and its Task Force on Innovations in Freight Transportation Modeling. He holds a BS degree in civil engineering from Montana State University.

METROPOLITAN TRAVEL FORECASTING

Current Practice and Future Direction

Metropolitan planning organizations (MPOs) develop regional transportation plans and programs to accommodate mobility needs within their regions. The process is commonly performed with the assistance of computerized models that provide information about current and future transportation system operations. This study assesses the models currently in use for metropolitan travel forecasting.

The study committee concludes that the travel forecasting models are not adequate for many of today's planning and regulatory requirements. The committee recommends the development and implementation of new modeling approaches that provide more reliable information and that are better suited to current requirements for travel forecasting. Steps also are recommended to improve current modeling practice. The committee believes that the MPOs, states, and federal government agencies that would benefit from accurate, reliable travel forecasts hold the key to change and growth in this area.

Also of Interest

Traveler Behavior and Values 2006
Transportation Research Record: Journal of the Transportation Research Board, No. 1985, ISBN 0-309-09995-1, 272 pages, 8.5 x 11, paperback, 2006, $67.00

Statewide Travel Forecasting Models
National Cooperative Highway Research Program (NCHRP) Synthesis 358, ISBN 0-309-09765-7, 116 pages, 8.5 x 11, paperback, 2006, $36.00

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