NCHRP

SYNTHESIS 364

NATIONAL
COOPERATIVE
HIGHWAY
RESEARCH
PROGRAM

Estimating Toll Road Demand and Revenue

A Synthesis of Highway Practice

TRANSPORTATION RESEARCH BOARD
OF THE NATIONAL ACADEMIES

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Estimating Toll Road Demand and Revenue

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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

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FOREWORD

By Staff
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Highway administrators, engineers, and researchers often face problems for which information already exists, either in documented form or as undocumented experience and practice. This information may be fragmented, scattered, and unevaluated. As a consequence, full knowledge of what has been learned about a problem may not be brought to bear on its solution. Costly research findings may go unused, valuable experience may be overlooked, and due consideration may not be given to recommended practices for solving or alleviating the problem.

There is information on nearly every subject of concern to highway administrators and engineers. Much of it derives from research or from the work of practitioners faced with problems in their day-to-day work. To provide a systematic means for assembling and evaluating such useful information and to make it available to the entire highway community, the American Association of State Highway and Transportation Officials—through the mechanism of the National Cooperative Highway Research Program—authorized the Transportation Research Board to undertake a continuing study. This study, NCHRP Project 20-5, "Synthesis of Information Related to Highway Problems," searches out and synthesizes useful knowledge from all available sources and prepares concise, documented reports on specific topics. Reports from this endeavor constitute an NCHRP report series, *Synthesis of Highway Practice.*

This synthesis series reports on current knowledge and practice, in a compact format, without the detailed directions usually found in handbooks or design manuals. Each report in the series provides a compendium of the best knowledge available on those measures found to be the most successful in resolving specific problems.

PREFACE

This synthesis reports on the state of the practice for forecasting demand and revenues for toll roads in the United States. The synthesis focused on the models that are used to forecast the demand for travel. It also considered the application of these models to project revenues as a function of demand estimates. Goals included: developing a profile of the current state of the practice in toll road demand forecasting; identifying technical modeling issues that affect the accuracy, effectiveness, and reliability of the forecasts; and making recommendations for research to improve the state of the practice. The report is intended to serve as a resource for state departments of transportation (DOTs), metropolitan planning organizations, tolling authorities and operators, potential investors, bond rating agencies, and consultants who prepare models and forecasts on behalf of DOTs and other toll facility owners.

A survey was distributed to various state DOTs, toll authorities, bond rating agencies, and bond insurance agencies in the United States. A literature search was undertaken to identify relevant research reports, papers, and other publications for review.

David Kriger, Suzette Shiu, and Sasha Naylor, iTRANS Consulting, Richmond Hill, ON, Canada, collected and synthesized the information and wrote the report. The members of the topic panel are acknowledged on the preceding page. This synthesis is an immediately useful document that records the practices that were acceptable within the limitations of the knowledge available at the time of its preparation. As progress in research and practice continues, new knowledge will be added to that now at hand.

CONTENTS

ESTIMATING TOLL ROAD DEMAND AND REVENUE

SUMMARY

Throughout the United States, traditional public-sector funding sources for transportation projects are becoming less able to meet the growing demand for highway infrastructure. The shortfall affects the construction of the highway, as well as its operation, maintenance, and expansion. As a result, state departments of transportation are increasingly seeking alternative methods, such as toll facilities, of financing for new highway projects, with a greater reliance on private-sector sources.

For toll facilities to be financially viable and/or attractive to potential investors (public–private partnerships, etc.) in the future, the facility must be seen to be able to generate sufficient revenue from operations to cover debt service cost, and potentially other project and maintenance costs over the lifetime of the facility. This requires a reliable and credible forecast of the expected revenues, which are functions of the estimated traffic demand and toll rates for the facility. However, in the past, industry experience in the toll demand forecasts upon which these are based have been quite varied, in that demand (and the accompanying revenues) has ranged from overestimated in many cases to occasionally underestimated. In addition, the accuracy of *when* specific levels of demand are projected to occur has been mixed, with problems being particularly acute in the short-term facility ramp-up period. The resultant variations have had significant impacts on both the actual revenue streams and on the facility's debt structuring and obligations. This has led to concerns among facility owners and the financial community (which rates and insures and/or invests the bonds that are issued for the facility's implementation) about the accuracy, reliability, and effectiveness of the demand forecasts upon which the revenue projections are based.

The purpose of this synthesis is to report the state of the practice in demand forecasting models that are used as the basis of revenue forecasts for toll roads in the United States. The synthesis profiles the current state of the practice in toll road demand and revenue forecasting, through a literature review and a survey of practitioners. It identifies the technical modeling issues that affect the performance of the forecasts and how these have been treated in current and emerging practice. The synthesis also develops checklists and lists of questions that practitioners (owners, proponents, and financial backers) can use to improve the state of the practice. Finally, recommendations for future areas of research are identified. The synthesis focuses on the state of the practice in the United States; however, it also references international practices where applicable.

A total of 138 survey questionnaires were distributed to either state departments of transportation, toll authorities, bond rating agencies, and bond insurance agencies. Responses were received from 55 agencies (40%), of whom 25 completed the first two parts and 13 the entire questionnaire.

CHAPTER ONE

INTRODUCTION

CONTEXT

Throughout the United States, traditional public-sector funding sources for transportation projects are unable to meet the growing demand for new highway infrastructure and maintain an aging infrastructure. Motor fuel taxes—the primary source of transportation finance in the United States—have not kept pace with the demand for travel and, in turn, for capital investment, owing to inflation, improved fuel efficiency, and increased vehicle usage (*1*). The shortfall can lead to economic impacts on highway construction, as well as its operation, maintenance, and expansion. As a result, some state departments of transportation (DOTs) and transportation authorities are relying increasingly on tolling as an alternative means of financing new and expanded highway infrastructure. A related problem is the need to improve the management and utilization of existing facilities, because many of the urban centers that require additional capacity to relieve congestion have limited space for expansion.

With budget shortfalls and an increasing demand for roadway facilities to alleviate the congestion problems that are common to many highways, state DOTs are turning to user-based fees or tolling as a means of financing roadway improvements and expansion and managing growing traffic demand for both interurban and urban facilities. The Texas DOT, for example, has determined that any new highway project in the state must be evaluated as a toll road (*2*).

As state DOTs turn to tolling, increasing attention is being focused on the performance of the underlying revenue forecasts and the projected ability of the facility to service debt. This is because the performance of the revenue forecasts, which are derived largely from forecasts of traffic demand, has varied among projects. In some cases, the lower-than-anticipated revenues were addressed through alternative sources of revenue to pay debt service, such as other toll roads, gas taxes, or government guarantees, or, where available, through sufficient reserve funds. This ensured that no struggling project was entirely dependent on traffic revenues for debt payment. As a result, between 1985 and 1995, forecasting errors or inaccuracies, which were known to exist, did not result in a single default in payment or any serious payment difficulties with new toll road projects in the United States (*3*).

However, concern has since been expressed that these alternate sources of revenue may not be available to protect more recent projects or even future projects. For example, the privately held Dulles Greenway in Virginia went into default in 1996, as a result of toll revenues being less than projected (achieving only 20% of projected revenues in 1995, its first year of operation, and still only 35% of projected revenues in its fifth year). Other toll roads have also struggled; for example, revenues from the Southern Connector in South Carolina have been sufficient to cover operating costs but only a portion of the debt service, because traffic projections have not been met (just over half of the projected demand was realized in its third year of operation). Similarly, traffic on the Pocahontas Parkway located southeast of Richmond, Virginia, has been just under half of the projected demand in its second year of operation. One result is that the credit ratings for the bonds for both facilities were lowered (*4*). The Foothill/Eastern toll road in Orange County, California, was refinanced in 1999 (*3*). Contributing factors to the financial problems of the Pocahontas Parkway and the Foothill/Eastern toll roads (and others) have been attributed to various inaccuracies in the demand and revenue forecasts, which included the unanticipated affects of a recession, actual ramp-up volumes being less than projected, and the expected extension of a connecting road not occurring (*5*).

For toll facilities to be financially viable and/or attractive to potential investors (public–private partnerships, etc.) in the future, the facility must be seen to be able to generate sufficient revenue from operations to cover debt service cost and potentially other project and maintenance costs over the lifetime of the facility, as well as providing a reasonable return on equity. This requires a reliable and credible forecast of the expected revenues, which are functions of the estimated traffic demand and toll rates for the facility. However, industry experience in tolling forecasts and the associated recoverable benefits historically have been quite varied, in that demand (and the accompanying revenues) has ranged from frequently overestimated to occasionally underestimated. Also, the accuracy of *when* specific levels of demand are projected to occur has been mixed, with problems being particularly acute in the short-term facility ramp-up. The resultant variations have had significant impacts on both the actual revenue streams and on the facility's debt structuring and obligations. This has led to concerns among facility owners and the financial community (which rates and insures and/or invests the bonds that are issued for the facility's implementation) about the accuracy, reliability, and effectiveness of the demand forecasts upon which the revenue projections are based. In addition, the growing use of Intelligent Transportation Systems and other technologies provides DOTs with the ability to implement variable pricing, HOT (high-occupancy toll) lanes, and other innovations that require a greater level of accuracy in the depiction of demand and revenues.

It is of critical importance that the forecasted toll revenue targets be accurate, based on the ability of the toll road to achieve its forecasted traffic targets, if debt service on bonds or a return on equity for private operators are to be paid (*6*). The fiscal feasibility of new toll road projects, or the revenue side of the benefit–cost relationship, is based on models that forecast traffic demand. Therefore, the reliability, accuracy, and effectiveness of these forecasts are important, because they are critical in determining the credit quality of the projects.

Accordingly, to maximize the prospects of a project's financial viability—that is, the likelihood that the forecasts match the actual revenues—it is necessary to look at the early stages of the process; namely, the models that are used to forecast travel (traffic) demand and their resulting successes or failures to improve the forecast results. To understand the reasons for unrealized traffic demand forecasts, it is necessary to review not only the model as a whole, but to separate it into its constituent structure, inputs, calibration, and application and examine the underlying assumptions that drive the forecasts. This synthesis explores the subject in a manner that takes into account viewpoints and experiences from both the engineering and planning communities and the financial community.

PURPOSE AND SCOPE

Purpose

The purpose of this synthesis is to report the state of the practice in toll road demand forecasting models that are used as the basis of revenue forecasts for these facilities. The synthesis had four specific goals:

- Develop a profile of the current state of the practice in toll road demand forecasting through a survey of the forecasting community and a literature review.
- Based on this profile, identify the technical modeling issues that affect the accuracy, effectiveness, and reliability of the forecasts.
- Make recommendations regarding ways to improve the state of the practice.
- Identify areas for potential future research.

Subject

This synthesis focused on the models that are used to forecast the demand for travel on tolled facilities and their reliability. It also took into account the application of these models to project revenues as a function of the demand estimates. Several different aspects of the models were considered.

- Purposes of toll demand forecasting (i.e., how they differ from other travel demand forecasts).
- Methods for forecasting toll facility demand and revenues, ranging from simple sketch-planning tools to investment grade studies; also taking into account how these have changed over time.
- Products provided from forecasting, and how they were used.
- Input data used, such as surveys, and data sources and key assumptions.
- Methods of estimating the value of time.
- Treatment of different horizon years, with particular attention to short-term (ramp-up) forecasts.
- Peer review procedures.
- Comparison of forecasts with the actual experience.
- Comparison of the accuracy and effectiveness of various toll facility demand and revenue forecasting methods.
- Variables associated with forecasting successes and failures, such as the type of proposed investment (i.e., stand-alone projects or expansions to existing projects), financing methods, modeling techniques, etc.
- Assessment of risk for demand and revenue forecasts.
- Transparency (i.e., availability and understanding of detailed information on modeling procedures, the underlying assumptions, etc.).
- Innovative techniques used to improve the quality of forecasts.

Scope

Given the subject, the scope of what was included in this synthesis is defined by the following:

- Tolled roads and highways and related infrastructure, including bridges and tunnels. In practice, these facilities generally have limited access; that is, they generally are not accessible from adjacent properties.
- HOT lanes (i.e., limited access lanes that provide free or reduced cost access to qualifying high-occupancy vehicles (HOV), but also provide access to other paying vehicles that do not meet the occupancy requirement).
- Road-based traffic forecasts for the aforementioned facilities; typically light vehicles (i.e., personal automobiles, vans, pick-up trucks, or motorcycles) and heavy vehicles (typically trucks), but potentially including commercial, fleet, or service vehicles and public transit buses (i.e., road-based transit, but not including rail that operates in mixed traffic).
- Urban as well as interurban tolled facilities.
- Different types of facility ownership.
- Different types of toll collection, pricing schemes, level of service and capacity differences, etc. Distinctions were noted where they were appropriate to the forecasting

process (e.g., the incorporation of bias factors regarding the type of toll collection).
- Toll roads and highways anywhere in the United States, although experiences elsewhere could be considered if they were deemed relevant to the situation in the United States.
- Different types of proposed investments, ranging from network-wide feasibility planning studies to facility-specific forecasts.
- Forecasts up to 30 years old (although virtually the entire literature addressed facilities that were 20 or fewer years old), with a focus on the most recent experience to appropriately represent the prime objective of the state of the practice.

The following topics were beyond the scope of the synthesis and so were not included:

- Non-tolled roads and highways of any kind.
- Transit-only infrastructure or facilities for other modes of transportation.

Study Process

The synthesis focused on the *practice* as opposed to academic or theoretical considerations, although the latter were noted if they were relevant. The synthesis is based on information that was acquired either through a review of the literature or by means of a web-based survey of state DOTs, toll authorities and their consultants, bond rating agencies, and bond insurance agencies. Thus, the synthesis considered the perspectives of both the engineering and planning communities (the builders and owners) and the financial community (the financial backers), assembling factual information as well as opinions and interpretations.

Where appropriate, information from actual cases was used to illustrate the different approaches: these were drawn from the literature or the survey.

Finally, it is important to note that this synthesis focused on the *technical* aspects of the state of the practice in modeling. It was not intended to be judgmental with respect to the policies of individual states, tolling authorities, bond rating agencies, or any other parties, or how these organizations have used the resultant forecasts.

ORGANIZATION

This synthesis is organized into five chapters. The remainder of chapter one describes the balance of the report, identifies the intended audiences for the synthesis, and presents various definitions for terms that are used in the text.

Chapter two describes the methods used for the literature review and for a survey of practitioners. This chapter is not intended to be a detailed discussion, but rather presents an understanding of how the information was gathered and any caveats or comments that may be associated with the information.

Chapter three is the core of the synthesis. It begins by describing the state of the practice and the emerging developments in travel demand forecasting, and then describes the applications to toll road traffic and revenue forecasts. The chapter then describes the problem at hand by documenting and commenting on the "performance" of toll facility forecasts and the reasons for this performance. The discussion is based on the information collected in the literature search and in the survey of state DOTs, toll authorities, bond rating agencies, and bond insurance agencies. Although the state of the practice largely reflects that of the United States, practices elsewhere also are considered, where appropriate.

Taking into account the identified problems and how others have addressed them, chapter four synthesizes the state of the practice in terms of "checklists" and indices that practitioners can use to identify and account for the relevant issues and needs when they develop and apply travel demand models for toll road traffic and revenue forecasts.

Chapter five offers conclusions drawn from the findings and makes suggestions for future research in the area of toll road demand and revenue forecasting. A list of references, a bibliography of sources, and a glossary of selected terms are also included.

Four appendixes complement the synthesis. Appendix A describes the development and administration of the survey, as well as the response to the survey. Appendix B is a copy of the original survey as sent to practitioners. Appendix C tabulates the survey results. Appendix D describes the characteristics of the toll facilities that were included in the chapter three comparison of projected and actual revenues.

AUDIENCES

This synthesis is intended to serve as a resource for several types of organizations.

- State DOTs, which are in various stages of considering, planning, implementing, and operating tolled facilities, either within the organization specifically, through a dedicated authority, and/or some type of arrangement with a private-sector owner. The DOTs also set policies (pricing, funding, enforcement, etc.) and are responsible for other competing or complementary transportation infrastructure.
- Metropolitan planning organizations (MPOs), which are responsible for planning an urban area's long-range transportation plan, within which a tolled facility must be planned, and for gaining a consensus on priorities for

funding and implementation (if federally funded projects; not required for privately funded).
- Tolling authorities and operators, who are charged with the actual planning, implementation, financing, operation, maintenance, and expansion of a specific facility.
- Potential investors, who might provide the financial backing for the facility.
- Bond rating agencies, which must assess the underlying credit quality of the bonds.
- Bond insurance agencies, which underwrite the bonds.
- Consultants, who prepare the models and the forecasts on behalf of the DOTs and facility owners.
- Academia and researchers, who might seek ways to improve the modeling process, algorithms, structure, inputs (e.g., through improved quality control or risk management), and the application of the actual model.

Although it is based largely on practice in the United States, it is expected that the synthesis also would be of interest to audiences outside the country for adoption to local needs, and because of the growing involvement of foreign financiers (and their consultants) in owning and operating facilities in the United States. Finally, it is important to note that the broad list of audiences in the synthesis requires that both the technical modeling community and those who benefit from or participate in the use of these models are addressed.

DEFINITIONS

This section identifies and explains key travel demand forecasting and modeling terms. Explanations of other terms (e.g., HOT lanes) are provided only if they are pertinent to travel demand and revenue forecasting.

Alternative definitions may exist for some of these terms; the definitions presented here represent how the terms were understood in the context of this synthesis. These definitions are complemented by a glossary of terms found at the end of the report.

- Congestion pricing (or value pricing)—Use of pricing as a means of managing traffic, through the imposition of a premium fee to road users who choose to drive during peak periods, such as rush hour or holiday weekends. Tolls vary according to the level of congestion; for example, higher tolls are charged during peak hours of operation or peak direction of travel (*7*). (See also variable pricing.)
- Critical review (or audit or second opinion)—Process by which an independent review is conducted of the toll demand and revenue forecasts, the model on which these are based, and the input data and assumptions. This is distinguished from a peer review, which is conducted during the calibration and development of the model, thus providing input to the actual development of the model (and not necessarily examining any resultant forecasts). (The terms are used loosely and interchangeably in practice).
- Feasibility study—Examination of the feasibility of implementing a proposed toll facility or a network of toll roads. It is generally not used as the basis for funding, but rather as the basis for determining whether the subject warrants further investigation. The feasibility study might test alternate facility or network configurations, different assumptions of other competing routes or modes, demographic and economic forecasts, etc.
- High-occupancy toll (HOT) lanes—Limited access roads that provide free or reduced-cost access to qualifying HOVs, but also provide access to other paying vehicles that do not meet the occupancy requirement. By using price and occupancy restrictions, the number of vehicles that travel in these lanes can be managed (*8*).
- Investment grade traffic and revenue forecast—A more detailed estimate of the traffic demand and revenues for a specific proposed facility. The term is used in different ways in the practical literature (which may reflect, in part, some of the observed problems regarding reliability, accuracy, and credibility of the forecasts). However, a general definition that has been accepted in the financial community is that an investment grade traffic and revenue forecast represents a forecast that can form the basis for credit ratings, financing approval, and the sale of capital markets debt.
- Ramp-up period—Time for traffic volumes to reach their full potential, without considering growth, after the opening of a new toll facility. The ramp-up period, which can last for several years, is the time it takes for users to become aware of the new toll road, change their travel patterns accordingly, and recognize the potential time-savings of using the new toll road (*9*).
- Revealed preference survey—Quantitative survey of observed travel behavior in the study area. These surveys record how people actually travel over a certain time period (e.g., a 24-h period on a "typical" weekday) or at a certain point in time. The surveys capture the trip origin and destination, its purpose (e.g., the home-to-work commute and going shopping), the mode used and, in some cases, the start and end time of the trip. Related questions are also often asked (e.g., whether the driver paid for parking or whether a transit rider could have used a personal vehicle). The surveys can be conducted with a representative sample of homes in an urban area, generally by face-to-face interview, telephone, or mail (household origin–destination survey, capturing all the trips made by household members over a period of time), by interviewing drivers "intercepted" along a road or highway of interest (the interview typically covers the current trip), goods movement surveys (of truck drivers and dispatchers, etc.), and so on.
- Risk assessment—Quantitative or qualitative estimation of the incidence and magnitude of an adverse effect on a given population (*10*). In the context of toll

road revenue forecasts, this often refers to the values of various inputs (e.g., forecasts of population or of the value of time); assumed configurations of the transportation network, such as the timing of planned competing routes or modes; or the treatment of specific components of the forecasting process (e.g., the methods used to estimate ramp-up traffic). It also can refer to inherent uncertainties in the modeling process and structure.

- Risk management—Uses the results of a risk assessment to develop options for addressing or mitigating the identified risk, and subsequently evaluating and implementing these options (*10*). In the context of toll road revenue forecasts, this could refer to the development of alternate scenarios (e.g., a range of population projections) or sensitivity tests to be run in the model to test the variability of the toll road demand with regard to alternate scenarios.
- Stated preference survey—Survey that attempts to quantify how travelers would behave in a situation that is new to them. These surveys are typically used to estimate the value of time for proposed toll facilities, which generally cannot be captured in revealed preference surveys. (Thus, a revealed preference survey provides a general quantification of the distribution, magnitude, and characteristics of a region's or corridor's travel activity; whereas a stated preference survey is used to estimate the impact of the imposition of pricing on the routes that the travelers who generate this activity would take.) Stated preference surveys are designed to present different options to respondents; for example, to determine not only the value of time but also how their perceptions of that value would vary by time of day (i.e., by congestion level).
- Value of time (VoT)—Monetary value given by travelers to travel time. VoT is used in the forecasting process to relate how the value of tolls influences route choice (i.e., the driver's decision to use the tolled facility rather than a non-tolled alternate route). VoT varies by individual, trip purpose, mode, average income levels, or time of day.
- Variable pricing—User charge that varies by time period as a way to manage travel demand and reduce congestion. This is the basis of congestion pricing. Such fees are higher during peak periods when the congestion is most severe and lower during off-peak periods when there is minimal congestion. This concept is similar to many services, such as telephone service, electric utilities, and airlines that use time-variable pricing to encourage more efficient use of system capacity and allow users to save money by shifting their consumption to off-peak periods (*11*).
- Willingness to pay (WTP)—Value of time that accounts for how much travelers value different attributes of the proposed facility, as opposed to simply its availability. The average WTP can be greater than the actual value of time, and can vary by time of day (i.e., as congestion increases). The WTP can reflect drivers' expectations of what the tolled facility offers, such as improved safety and reliability.

CHAPTER TWO

METHOD FOR LITERATURE REVIEW AND SURVEY

This chapter describes the derivation of the information upon which this synthesis was based. The information was gathered in two separate tasks: a literature review and a survey of practitioners. The tasks were conducted in parallel, seeking similar information.

LITERATURE REVIEW

The literature review began with a search for any resources that had the potential for further review. An online search was conducted using traffic resource websites and search engines to gather available electronic resources. This was followed by contact with representatives of different DOTs, toll authorities, bond rating agencies, and bond insurance agencies, as well as with academics, to request resources from the search that were not available online. The agency representatives were also asked to provide any other sources of information (e.g., published reports, journals, and articles), as well as the names of any other individuals or organizations that might provide further assistance.

The literature review and sources of data focused primarily on U.S. practice and experience. However, there are several international projects that have come into existence within the last 10 years in North America and in Europe. These are relatively state of the practice and provide the added benefit of being completed studies with tangible results (e.g., the Highway 407 Electronic Toll Highway in Canada). In such cases, resources were also compiled based on international project experience.

Relevant publications and reports were located by various search methods including, but not limited to, the following five sources of information:

- Online Transportation Research Information Service (TRIS);
- The state of the practice survey;
- Contacts from the DOTs, toll authorities, bond rating agencies, and bond insurance agencies (including members of the topic panel);
- The consultant's internal library; and
- The Travel Model Improvement Program (TMIP-L) Digest.

TRIS Online is the web-based version of the TRIS database. It provides links to full text and to resources for document delivery or access to documents where such information is available. These may include links to publishers, document delivery services, and/or distributors. It is the largest and most comprehensive source of information on published transportation research on the Web. TRIS Online provides access to more than 500,000 records (at the time of this synthesis) of published transportation research through a user-friendly searchable database. Sources of information found through TRIS included published articles and journals, and academic literature, as well as conference papers and presentations.

The state of the practice survey, Estimating Toll Road Demand and Revenue, asked respondents to forward copies of any reports that might be of interest or relevance to the synthesis. Several of the respondents included traffic and revenue studies, rating agency reports, or earnings reports, which were added to the literature database.

Contacts at the DOTs, toll authorities, bond rating agencies, and bond insurance agencies provided hard copies or electronic versions of various reports where possible (i.e., feasibility studies, risk assessment studies, traffic and revenue studies, etc.). They also provided information as to where online publications could be found.

The consultant's internal library was an important source of reports, including traffic and revenue studies, travel pricing strategies, highway finance theory, and practice research. It was also a secondary source for published articles on practice of toll roads with respect to modeling, revenue, forecasting, and more general topics such as electronic toll and traffic management.

Another secondary (although noteworthy) source used for acquiring literature and data was through a TMIP-L Digest discussion group, which is used by many modelers in the United States and elsewhere to raise technical issues. Some of the participants were contacted with respect to information or opinions expressed regarding toll road forecasting and modeling in this forum. They were asked to clarify or amplify these opinions and provide information and data.

SURVEY OF PRACTITIONERS

A web-based survey was sent to four types of organizations throughout the United States: state DOTs, toll authorities, bond rating agencies, and bond insurance agencies. The survey included both the "traditional" transportation community (the first two types) as well as the financial community (the last two types). This diversity in the survey group was intended to capture the viewpoints and experience of the forecasting and modeling process from as many participants involved in the process as possible.

Participants were given the option of answering directly online through a web-based survey program (Websurveyor) or completing a hard copy of the survey that was included in the e-mail as a pdf, which could be returned to the consultant by mail or by fax. A pilot test of the content, structure, and format was conducted before the survey launch.

The survey was divided into three self-contained sections (designated as Parts I, II, and III). This made the survey more "respondent friendly," to specifically target areas of interest in the modeling and forecasting process.

Part I determined the type of agency that was responding to the survey and who from that agency was completing the questionnaire. It also asked them to discuss their philosophy, in terms of their use of tolling technologies, what type of facilities were tolled, etc.

Part II pertained to the forecasting model itself and its variables. This section was answered either by the original respondent, if the responding organization performed the modeling and forecasting in-house, or could be forwarded to a consultant or the agency that actually developed or applied the model for the original responding agency. This section requested that the respondent describe in detail the type of model used and the parameters of the model in terms of inputs, structure, modeled trip purpose, calibration techniques, validation checks, etc.

Part III asked the respondent to discuss a specific example of a toll road traffic demand and revenue study carried out by the responding organization. Again, if the original respondent did not perform the actual analysis, the survey could be passed to a consultant or outside agency responsible for the study. The purpose of this section was to determine the results of the previously described model (Part II) and whether there were major or minor problems with the analysis, whether they were identified, how and if they were corrected, etc.

In sum, 138 surveys were sent to different organizations. There were 55 respondents, for a response rate of 40%. Of these, 29 declined to complete the survey or completed only Part I of the survey, because they did not currently or plan to own or operate toll roads. The remaining 26 respondents completed Part II, with 13 of these completing the entire survey.

CHAPTER THREE

TOLL ROAD FORECASTING: STATE OF THE PRACTICE

This chapter documents the state of the practice in travel demand forecasting for toll revenues. It begins by describing travel demand models (the basis of the toll road traffic forecasts), how they have evolved generally and specifically for toll road forecasting, and how the models relate to revenue forecasts. The specific problem of the performance of these models in toll road applications is illustrated by a comparison of projected and actual revenues from several facilities and a discussion of the factors that influence performance. Current and emerging practices in the treatment of these factors are then described, based on the literature search and survey.

TRAVEL DEMAND FORECASTING MODELS, APPLICATIONS, AND EVOLUTION

This section briefly reviews the practice of travel demand forecasting models and how these models and their applications have evolved over the last several decades. The purpose is to provide a context for the ensuing discussion, at a level of detail and at a perspective that are appropriate to the discussion of toll road traffic forecasts. The discussion is not intended to replicate the many existing texts on forecasting [to which the reader can refer for further details—see, for example, Meyer and Miller (*12*)].

Overview of Travel Demand Forecasting Models

The demand for travel is a derived demand. People travel (and goods are shipped) as a function of human activities. These activities are commonly represented in a travel demand forecasting model as demographic, socioeconomic, and land-use variables (e.g., population, employment, and jobs).

Travel demand also is shaped by, and shapes, the transportation network. The "supply" of transportation services—the different modes, their relative costs (time-wise and money-wise, temporally and financially), and the relative ease of accessing one location versus another—determine how the demand uses the transportation network. Similarly, forecasts of demand define the required supply of transportation services (how many lanes of road at what capacity, where bus routes are needed, etc.).

Many medium- and most large-size urban areas in the United States, and around the world, use a travel demand forecasting model, albeit with various approaches and to varying degrees of detail and sophistication. In the United States, MPOs use models to develop long-range transportation plans. Consistent with this plan, a transportation improvement program must identify a list of projects proposed over a 20-year (or longer) period. The program also must identify priorities for the next 3 years (and must account for all federally funded projects over that time) and must be updated every 2 years. In addition, as a basis for improving urban air quality, federal regulations require that long-range transportation plans be consistent with air quality objectives and targets (*13*).

The so-called "four-step" modeling process represents the most commonly used formulation for travel demand forecasting models (*12*). The process has been used for several decades in the United States and around the world. Figure 1 presents a *generic* outline of the main inputs, processes, and outputs of this travel demand modeling paradigm. The individual elements are described here (*14*).

Inputs

- Zone definition. The urban area is divided into small spatial analytical areas, similar in concept to census tracts. Generally, traffic zones are defined by homogeneous land uses (residential neighborhoods, central business districts, industrial areas, etc.), major "traffic generators" (universities, hospitals, shopping centers, airports, etc.), or geographic boundaries (rivers, railways, etc.).
- Land-use inputs. These are defined for each traffic zone in terms of population, employment, floor space, etc.
- Transportation network. This normally includes the major road and highway network (typically, all roads except local streets), as well as the public transport network (bus routes, subways, light rail, commuter rail, etc.). These are defined in terms of a link-node network. The network can be refined to differentiate between HOV lanes, bus lanes, truck routes, routes with restricted access, etc. The network also can account for tolls. Traffic zones are represented as "centroids" (a single point each on the map), and are linked to the main network by means of "centroid connectors."
- Observed travel characteristics. This is measured typically by origin–destination (travel characteristics) surveys. These provide a quantitative portrait of travel characteristics in a city, typically on a weekday.

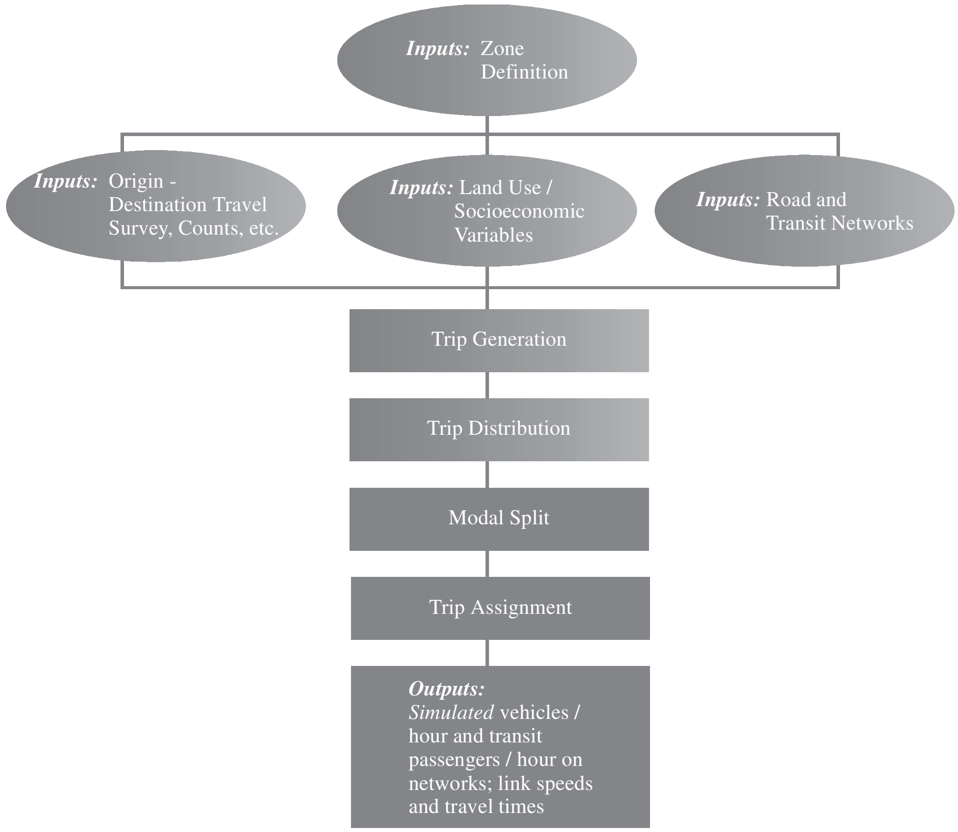

FIGURE 1 Outline of travel demand modeling process (traditional "Four Step" paradigm).

> Traditional origin–destination surveys are "revealed preference" surveys—that is, they observe how people actually behave. However, these have proved limited as predictors of conditions that do not exist currently in a specific city: particularly the use of a new transit technology (notably, rail) where none currently exists, and the willingness to use a tolled highway where tolls are currently not in place. "Stated preference" surveys attempt to quantify and predict such behavior. Counts of vehicles and their occupants by type of vehicle, at various points through the road and transit networks, are also important inputs. Other inputs include link/intersection (node) travel times and speeds. All of these observed conditions are used to calibrate the model.

Some urban areas are beginning to conduct "activity"-based surveys, which provide a more precise depiction of travel characteristics within the context of a household's daily activities. In comparison, the origin–destination survey focuses on these travel characteristics alone.

Process

The four steps of the process comprise:

- Trip generation—where the total numbers of trips that start and end in each zone are calculated as a function of the different land uses in each zone. The calculations take into account different trip purposes, which again are represented by land uses (e.g., the daily home-to-work commute is commonly represented by population or dwelling units at the home end and by the number of jobs at the work end).
- Trip distribution—where the generated trip ends are distributed among all zones. The distribution is conducted as a function of the zonal land uses (e.g., home-to-work trips would not be distributed to zones where there is no employment) and the characteristics of the transportation network (i.e., a function of the relative accessibility of a zone, which is measured as a function of travel time–congestion and cost–transit fares, parking charges, road tolls, etc.). Different calculations are made for different trip purposes to take into account their different behaviors. The products of this step are expressed as matrices of trips for different purposes (e.g., stating that there are 100 trips for purpose "x" from zone *i* to zone *j*).
- Modal split—where the distributed trips are allocated to the different available travel modes. Typically, the allocation is between automobiles and public transport; however, some models further differentiate among public transport modes (including park and ride), between HOV (i.e., automobiles in which there are two or more occupants) and SOV (i.e., automobiles in which the only occupant is the driver), and

nonmotorized modes (pedestrians and bicyclists). Different calculations may be made for different trip purposes, again to account for their different behavior; however, these are subsequently combined by mode for the next step.

A common formulation is the logit function, which simulates the traveler's utility according to out-of-pocket cost, door-to-door travel time, and other attributes of modal choice (such as trip distance, proximity of the transit stop to the workplace, in-vehicle comfort, the number of transfers required, and so on). Other, simpler formulations include diversion curves or factors. Different formulations may be applied to different trip purposes. Typically, the resultant matrices for a given mode are combined for all purposes, resulting in a matrix of all automobile driver trips, all transit passenger trips, etc. The survey of practitioners indicated that the inclusion of modes varied. All respondents (i.e., those that had completed all three parts of the survey) indicated that passenger vehicles were modeled; however, not all differentiated between SOV and HOV modes of travel. Most of these respondents included trucks and commercial vehicles as mode choices, and about half of these included transit in the model. The methods for mode choice modeling included logit (or similar) and other factors. Some of the respondents using assignment-only models calculated modal choice exogenously.

- Trip assignment—where the trips for each mode are loaded onto, or assigned to, the respective transportation network(s). This is a translation of demand, which is expressed as the number of trips by mode x (for all purposes combined) between zone i and zone j, into automobile traffic volumes on a given road link and ridership on a bus route, etc.

  Of interest to this synthesis is the treatment of automobile driver trips [which are equivalent to automobile *vehicle* trips (i.e., there is only one driver per vehicle)]. There are several algorithms for assigning automobile vehicle trips. The "equilibrium assignment" is a common technique. This process allocates traffic to links so as to minimize the cost of the automobile or transit traveler between his or her origin and destination; where "cost" is commonly defined as travel time (minutes) and, in some models, with a monetary cost expressed in terms of time (i.e., value of time). The latter allows for the impact of tolls or other pricing mechanisms on the driver's choice of route. Equilibrium is achieved when, between the current and previous iterations, no driver (i.e., vehicle-trip) can improve his or her travel time by switching routes. In contrast, the so-called "all-or-nothing" assignment algorithm does not account for the build-up of volume or cost, and assumes that all link speeds (typically, the posted or free-flow speed) remain fixed without regard to the actual volume on each link.

Outputs

Volumes by link and ridership numbers are the main outputs of the model, along with travel times and speeds across the transportation network by link. These outputs can be used in turn to identify costs, fuel consumption, and air pollutants, as well as revenues on a tolled facility.

Comments on Modeling Process

It is important to note that the aforementioned modeling process is not prescribed; that is, there is no one single or standard modeling process or universal method. Keeping in mind the different perspectives and uses of toll road demand forecasting, some comments are in order.

- Commonly, MPOs and other transportation planning authorities focus on simulating peak-hour travel on the transportation network—that is, the time of day at which the transportation system carries its maximum volume. Normally, this occurs during the morning or afternoon commuter peak periods. However, the model may simulate different time periods, ranging from 24-h travel on a typical weekday to a peak period or a peak hour within that period. Factors may be used to derive peak-hour matrices from 24-h or peak-period matrices; however, in the absence of these factors or of direct modeling of the peak hour or period, the use of sophisticated algorithms (such as the equilibrium assignment technique) is effectively precluded.

  In contrast, toll road revenue forecasts typically require annual estimates of demand. Therefore, forecasts from the aforementioned peak-hour models must be extrapolated. This requires the development of factors for different time periods, which can include the peak period, daily, weekly, monthly/seasonally, and ultimately, annually. Factors may be developed according to observations of traffic volumes or trends (e.g., 24-h traffic counts, by hour) or other sources. However, the use of factors maintains the status quo, does not account for temporal changes (peak spreading) or mixes in the traffic composition, and may require special additional factors or assumptions to account for travel on weekends or holidays. Some models have addressed this by simulating several time "slices" during the day (e.g., the a.m. peak hour, a midday hour, and the p.m. peak hour).
- Some models emphasize certain steps more than others, or the models may not include some steps or have combined others, or some parts of the process may be modeled exogenously. For example, the Quèbec (Canada) Ministry of Transportation's urban models for Montrèal and other cities focus on the trip assignment step, using trip matrices that are derived directly from comprehensive high-sample, origin–destination surveys. Modal shares and demand forecasts are developed exogenously to the assignment model, although

trip generation and trip distribution typically are not modeled. The point is that the treatment of a (nominally) common modeling process varies among transportation planning authorities, which differences in turn necessarily are carried through in the treatment of toll demand forecasting. As a result, the comparability of toll demand forecasts and their performance may be limited.

- Truck and commercial traffic is generally considered to be an important market segment for many toll roads. However, relatively few urban models simulate these trips explicitly. Some urban areas have developed truck models, which may or may not be integrated within the primary urban passenger travel model. A common treatment for including truck or commercial traffic is to factor the resultant automobile forecasts on each link according to the observed proportion of trucks or commercial vehicles in the observed traffic mix (according to traffic counts). Although this provides a simple technique for capturing the "full" mix of traffic on a particular facility, on its own it provides no way to account for tolling, other changes to the transportation system, or changes in demand. Moreover, the truck peak hours in many urban areas do not coincide with that of the dominant automobile peak hour.

Evolution of Models

The modeling process has evolved since the development of the four-step modeling process during the 1950s and 1960s. At that time, models were applied primarily to the planning of major transportation facilities (mainly highways) to accommodate rapid post-war urban growth. The four-step process is still the dominant formulation in urban travel demand models (*12*, p. 289). However, several concerns have encouraged the development of new techniques.

- The ability of the process to address current planning needs, which have evolved from the planning of new highways to meet forecasted demand to better managing that demand (e.g., through other modes as well as traffic management).
- Inconsistencies among the four steps have been identified with respect to their formulation, parameter values, costs, and variables (*15*). These inconsistencies have led to questions regarding their depiction of traveler behavior. In addition, the four-step process treats travel choices as independent choices, whereas in reality they are not mutually exclusive. For example, the decision to make a trip in the first place (generation) may be a function in part of the availability of a particular mode (modal split). Some models have addressed this by combining steps [e.g., trip distribution and modal split (*15*) or the trip generation, distribution, and modal split (*14*)].

  Other models have attempted to address this more simply by introducing feedback loops among the steps [i.e., which is not inherent to the four-step process (*16*)]—notably, the travel times that result from the trip assignment are fed back to trip distribution to provide a more realistic depiction of the "true" travel times between zones, with the distribution–modal split-assignment process then iterating several times until an equilibrium is reached.
- Similarly, there is inadequate feedback between the travel demand forecasting model and its land use inputs. The implication is that the changed travel patterns can affect the distribution, magnitude, and type of development over time (e.g., an expressway extension that improves accessibility to a new suburb), which in turn affects the characteristics of travel demand. Efforts in different U.S. cities and elsewhere to develop integrated land use and transportation models have been documented (*17*). In addition, several techniques have been used to forecast these land use inputs (*18*): the importance for toll road demand forecasting is that there is no consistency in modeling technique; this time for key inputs.
- Forecasting methods can be divided into two broad groups: macro-analytical methods, which are based on zonal averages, and micro-analytical methods, which are based on individuals and households. The four-step process is in the first group. Because of their low cost and technical simplicity, macro-level forecasts remain popular; however, it is precisely these two reasons that lead to questionable and inaccurate results (*18*). In contrast, micro-level forecasts can predict impacts with more detail and accuracy.

More generally, the development of micro-level forecasting capabilities also addresses the behavioral inconsistencies identified previously (simultaneous choices, lack of feedback, etc.), through the use of activity-based models. This approach treats travel as being derived from the demand for personal activities, so that travel decisions become part of an individual's broader activity-scheduling process. In turn, activities are modeled, rather than only trips. The basic travel unit is a tour, which is defined as "the sequence of trip segments that start at home and end at home" (*19*). This allows for a more consistent and inclusive treatment of the individual's decisions (when, where, why, and how to travel); links these decisions for all of an individual's trips over the course of the day, allows the decisions to be analyzed in the context of the decisions of other members of the households, and, allows for consideration of lifestyles (e.g., "commuting" by Internet) (*12*). The resultant chain of decisions means that higher-level decisions are fully informed about lower-level decisions (i.e., decisions are "nested") (*20*). Emerging methods also allow the simulation of an individual's activities dynamically, meaning that this micro-level treatment eliminates the need for zonal aggregations, allows the heterogeneous (travel) characteristics of the population to be analyzed, and has the potential to generate "emergent behavior" (i.e., behavior is not explicitly "hard-wired" into the model, based on its calibration to conditions at a particular point in time) (*12*).

- Methods to model time-of-day choice are emerging. This refers to the relative lack of consideration of temporal considerations in demand modeling—that is, the traveler's choices are related to choices regarding the time of day in which the trip is made. Time-of-day choice can be expressed in terms of the time "slices" that are modeled; the days that are modeled (e.g., weekday versus weekend or holiday); peak spreading (i.e., the allocation of trips between the peak hour or half-hour and the peak "shoulders," as the expansion of the duration of the peak period over time); and time-of-day choice modeling [i.e., the explicit modeling of the time at which the traveler starts his or her trip in order to arrive at a destination within a desired "envelope" (e.g., between 8:45 and 9:00 a.m. every morning)].

The aforementioned need to develop improved factors for expanding peak-hour volumes to yield annual revenues is one manifestation of the importance of time-of-day modeling to toll road demand estimation. Also important is its potential to depict more accurately a traveler's response to congestion: rather than switch routes (to an uncongested toll road), the driver may advance or delay the start time of his or her trip to a less congested time of day (or simply not travel).

Where time-of-day choice is considered in practice, the most common consideration has been peak spreading. One peak spreading model accounted for congestion when determining the proportion of a.m. peak-period vehicle traffic. It was hypothesized that "the total congestion for a trip is a primary reason for peak spreading rather than the congestion of, possibly, one link," thus establishing the need to account for congestion throughout the network in addition to trip purpose and trip distance. In other words, the advantages offered by a toll facility must be considered in the context of its impacts on overall network congestion. Although the model predicted the flattening of the a.m. peak period as congestion and trip length increase, it assumed that a constant duration of the peak period (in this case, 3 h). That is, the proportion of daily travel that occurs in the 3-h peak period was assumed to remain stable over time (which may not be appropriate in all cities or for toll roads, especially as the duration of peak period grows or off-peak traffic volumes increase). The report concluded that both trip purpose and trip distance, in addition to congestion, were important parameters in a model that predicts peak spreading (*21*).

A more recent analysis concluded that the use of dynamic traffic assignment (such as equilibrium assignment) models as a means to predict the impact of new infrastructure should account for departure time choice in addition to route choice. The resultant model took into account the need for travelers to arrive at their destination, for particular trip purposes (e.g., going to work, to classes, or to an appointment), at a particular time, which in turn determines their departure time. Each traveler has a preferred departure and arrival time, any deviation from which (owing to congestion) causes disutility. The dynamic traffic assignment models time choice simultaneously with route choice (*22*). Another emerging development is the use of "equilibrium scheduling theory," which simulates departure time choice modeling in the context of an equilibrium network model. This approach models the build-up and decay of travel times during the peak periods, taking into account the disutility of arriving before or after a preferred arrival time window (*23*).

- Network micro-simulation models have come into use as tools to simulate the dynamics of traffic along corridors and networks. Whereas the travel demand forecasting models simulate average speeds for an hour's slice of traffic, these models use micro-simulation techniques to represent traffic flows microscopically through a network as a series of individual vehicles and tracks each vehicle's progress at a finite resolution, which is typically one second or less. This logic permits considerable flexibility in representing spatial variations in traffic conditions over time and allows for the analysis of such traffic phenomena as shockwaves, gap acceptance, and weaving. The importance of network micro-simulation models to toll road demand forecasting lies in the emergence of managed lanes as tolled options in several cities; specifically, in their ability to simulate the dynamics of individual lanes and the diversion of drivers between lanes.

Network micro-simulation models provide a more detailed approach by taking into account the transient effects on speed and acceleration as the vehicle travels on a road network. By modeling vehicle kinematics (instantaneous speed and acceleration) on a road network, more reliable estimates of vehicle energy consumption and emissions result.

Typically, micro-simulation traffic models are applicable only to sub-networks of larger urban areas. This is a result, in part, of the required level of detail necessary of model inputs and the subsequent strain these requirements place on computing capabilities. The dynamics of individual vehicles are defined in terms of the number of departures from each origin–destination pair, the determination of vehicle speed based on car-following logic, and requirements for lane changing. The speed of the vehicle along that first link, as well as any subsequent links, is updated at discrete time intervals typically between 0.1 and 1.0 s. Each update reflects the distance headway between the vehicle in question and the vehicle immediately preceding this vehicle; whereas the exact speed for any given distance headway is based on a link-specific, car-following relationship. Beyond the speed restrictions, which arise from the above car-following logic, a vehicle's progress can also be delayed at traffic signals, ramp meters, queues, and/or other bottlenecks. The effects can be time-varying and may vary both spatially and temporally, which permits the replication of shock waves within the model. When a vehicle travels down a particular link, it may make discretionary lane changes to maximize travel freedom (speed). Conversely, mandatory lane changes may be required owing to the prevailing network geometry and routing behavior (*24*).

In sum, these developments provide opportunities to improve the overall state of the practice in travel demand forecasting, as well as that of toll road demand forecasting. However, many of these developments are emerging: there is only a very small number of practical applications of activity-based models in the United States (*20*) and few applications of time-of-day choice modeling. The TRANSIMS initiative of the federally funded TMIP also can be expected to affect transportation planning practice (*13*). Conversely, network micro-simulation models are well-established in transportation planning practice, with several recent managed lane applications.

Methods for Modeling Toll Road Demand

No state-of-the-art consensus exists among transportation researchers and practitioners regarding the best methods for achieving traffic and revenue forecasts (*25*). This mirrors the general application of models in transportation planning practice. Methods being used today can still be categorized primarily by incremental or synthetic analysis, both of which the transportation planning community has been using. The choice of analytical method varies, based on the method that is used to develop origin–destination trip tables for a given time period, trip purpose, and travel market segment (*25*).

A review of the state of the practice for value pricing projects in several U.S. cities identified the following five categories of modeling procedures (*20*). Although the review primarily addressed forecasts for managed lanes, the categorization is applicable more generally to toll road demand forecasts.

1. Modeled as part of an activity-based model—The state of the art in demand modeling allows for the inclusion of pricing into the decision hierarchy. A combination of revealed and stated preference surveys could be used as the basis, with the stated preference data allowing for the modeling of choices that do not yet exist. Only Portland, Oregon, a pioneer in the development of activity-based models, has applied this type of model to the subject (i.e., to an analysis of value pricing). The practical use of activity-based models in transportation planning is only now emerging and represents a significant effort (*20*). Only one respondent to the survey of practitioners indicated the use of an activity-based model, which was applied to a toll bridge.
2. Modeled within the modal split component of a four-step model—Automobile trips on a tolled or non-tolled road are considered as distinct modal choices, with separate modal split functions for work (or work-related) and non-work trip purposes (given the corresponding differences in values of time). The advantage of this approach is that out-of-pocket costs can be modeled explicitly, because travelers' utilities are "directly affected by the value of tolls and so are the respective modal shares"—that is, the approach ensures "robustness" in the results. The approach also can be expanded to trip distribution modeling, because the impedance incorporates the impact of tolls more explicitly. The ability to incorporate stated preference data into revealed preference data, as a means to account for nonexistent facilities, again was noted (*20*). Phoenix, Arizona, and Sacramento, California, were cited as examples of urban areas that have used this approach. The Phoenix [Maricopa Association of Governments (MAG)] model distinguishes between the SOV trip and the HOV trip. Because MAG allows vehicles with only two occupants to use its HOV lanes, the tolled/non-tolled choice is included only in the utility function of the SOV trips. The function includes a travel time savings term that is equivalent to the difference between tolled and non-tolled travel time. MAG's trip distribution model was being updated to account for these impedances (*20*).

   The analysis for the Minneapolis–St. Paul managed lane system (MnPASS) incorporated tolled SOV trips as a modal choice into the regional model. Values of time were developed for two trip purposes (home-based work and other trips), both classified by three automobile availability categories (number of vehicles per household, which had been found to be a determinant of value of time) and whether the trip was destined to the central business district (again, found to be a determinant). The basic values were adapted to this model from previous local studies or from experience elsewhere, given that the time frame available for the analysis precluded the collection of new data. The revised modal split function was used to screen alternative network configurations. For the purpose of the analysis, the resultant revised impedances were *not* implemented into the trip distribution component, to allow the alternatives to be compared on a common basis. In other words, although behaviorally the tolls (i.e., the revised impedances) would affect trip distribution (given the appropriate feedback loops), it was felt that the impacts would be small when compared with the ability to compare alternatives (*26*).

The MnPASS study used value-of-time data from an evaluation of the impacts of the Riverside Freeway (SR-91) tolled express lanes in Orange County, California. Based on observations from 3 years of operation (after the express lanes opened in 1995) and from traveler surveys, the evaluation found that gender (female) was a strong determinant of the use of the facility, with other factors [high income, middle age, higher education, and commuting to work (i.e., work or work-related)] also being indirect factors (indirect in that they determined the willingness to purchase an electronic transponder, without which drivers were unlikely to use the express lanes). Logit choice models were developed according to these factors (*27*). The SR-91 evaluation identified several important determinants of managed lanes—gender, income, age, education, and trip purpose. Although the mix of determinants and their values might vary by location, there is (for example) an observed correlation between travelers' income and the likelihood of using toll roads, with higher-income travelers more likely users than lower-income travelers (*20*).

The importance of considering time-of-day impacts was underscored by a recent study of the impacts of the Port Authority of New York and New Jersey's time-of-day pricing scheme, which it introduced in March 2001. The study found that 7% of passenger trips and 20% of truck trips changed behavior because of the new pricing scheme. The percent share of peak shoulder trips for both trucks and automobiles also increased during weekdays (*28*).

The modeling of toll demand as part of modal split requires that the generalized cost impedances (i.e., impedances that account for monetary values—such as tolls—as well as travel times) are fed back from trip assignment to trip distribution and modal split. The process iterates until a stable equilibrium is achieved; that is, when there are no significant differences in the impedances between two iterations (*29*).

3. Modeled within the trip assignment component of a model—This approach applies a diversion of trips within the trip assignment; that is, after (or in the absence of) demand modeling. It assumes that trip distribution and modal shares (not differentiating between tolled and non-tolled automobile trips) remain unchanged in the absence of feedback loops.

There are two general methods for modeling traffic diversion in trip assignment: The first translates the monetary toll into a time equivalent through the use of values of time. The equivalent times are then incorporated into the model's volume-delay functions, which—using the equilibrium assignment technique—are used in turn to allocate trips among different paths according to travel time, capacity, and congestion. Queuing and service time at toll plazas similarly can be incorporated into the function. (In essence, the tolls and plaza times are added as "penalties" to the modeling of actual travel time.) Values of time can be derived for different trip purposes, income levels, etc. (*25*).

The second method uses diversion curves as the basis for toll forecasts. This commonly takes the form of a logit function, which calculates the propensity to use a tolled facility (the facility's share of traffic) as a function of the relative cost or travel time between the tolled and non-tolled route (i.e., for each origin–destination path that could use the tolled facility). The slope on the S-shaped diversion curves represents the elasticity of demand with respect to the relative cost or travel time using the tolled road. The elasticity of demand is related inversely to the value of time or willingness to pay. The shape of the curve can be determined in two ways: using observed data (in which case the value of time is implicit) or from a statistically estimated logit function based on revealed and/or stated preference survey data. The curves can be fitted according to different trip purposes and vehicle occupancies. The diversion curve is applied to the relevant trip table (for a given purpose, income group, automobile occupancy, time period, etc.) to derive tolled and non-tolled trip tables. These then are assigned to the network to yield both updated impedances (and the process is repeated until an equilibrium is reached) and, ultimately, estimates of revenues (*25*). The primary benefit of using diversion models to estimate toll road demand is that they can be applied to an existing four-step model, without having to recalibrate it. However, the shape of the curve, and the data upon which it is based, generally are held as confidential or proprietary and so are not available to other users (*29*).

A variation is the use of a dual minimum path (equilibrium) assignment, which develops two sets of paths for each origin–destination pair: one using the tolled facility (where applicable) and one without the tolled facility. A proportion of the total trips between each zonal pair is assigned to each network path, according to the relative respective total costs, which can include vehicle operating costs as well as travel time costs and the costs of tolls (*2*).

An example of the second method (diversion) is provided by a traffic and revenue forecasting study for a proposed toll highway near Austin, Texas. A logit model was developed for several trip purposes, based on a stated preference survey. The utility functions for the work-related trip purposes were found to be sensitive to traveler income. The tolling diversion logit model was incorporated into the trip assignment component of an updated regional travel demand model. The model took into account different payment options (cash, cash plus electronic, and electronic only). The development of the logit model also accounted for toll road bias (the negative propensity to use a tolled road) and an electronic toll collection bias (the increased likelihood of using a tolled facility, owing to the convenience associated with electronic toll collection). Both terms largely offset each other, with the toll road bias found to be common in regions that had no prior experience with tolling (*30*). It should be noted that the assignment impedances were not fed back to the trip distribution and modal split models; that is, the trip origins and destinations were assumed not to change under traffic diversion. The survey of practitioners indicated that both methods were used.

4. Modeled as a post-processor—This approach can be used either within the framework of a four-step model or exogenously using the output of the four-step model. Washington, D.C., and San Diego, California, provided examples of the former, in which assigned volumes are diverted (i.e., after trip assignment) from general purpose lanes to managed lanes according to the excess capacity available in the latter. An example of the latter is provided in Minneapolis–St. Paul, in which the outputs of the regional model were input to the FHWA's Surface Transportation Efficiency Analysis Model to calculate costs and tolls as part of a pricing study. The procedures are operationally simple to implement; however, they are not sensitive to changes in traveler behavior (*20*).
5. Model as a sketch planning method—These are quick response tools that are used for project evaluation. Examples include the FHWA's Spreadsheet Model for Induced Travel Estimation, which estimates induced traffic (as a result of faster facility travel speeds, traffic diverted from other facilities, destinations, or modes) as a function of elasticities of demand with respect to travel time, with price and demand equilibrated as part of the procedure. A modified version is the Spreadsheet Model for Induced Travel Estimation-Managed Lane, which uses a pivot-point logit model to estimate changes in travel demand according to changes in travel time and tolls as well as improved transit service. The "model is relatively simple to implement and can be considered a reasonable tool for the initial screening of alternatives or in situations where results of formal travel models are not available." The FHWA's Sketch Planning for Road Use Charge Evaluation model also uses a pivot-point mode choice model to estimate changes in mode (i.e., managed lanes) and the associated revenues, costs, and travel time delays (*20*).

   The Texas Transportation Institute has developed a spreadsheet-based Toll Viability Screening Tool. The spreadsheet provides a way to assess the economic viability of a proposed tolled facility in advance of the need for a more detailed traffic and revenue forecast. It does so by assessing the potential variability of the initial demand, by subjecting various input parameters to a triangular distribution function (similar to a normal distribution)—that is, to a distribution that measures the likelihood of their occurrence. As input, the tool requires daily traffic volumes, toll rates, and assumed diversion. Results (revenues) are expressed as net present values. The tool also supports a risk analysis of the results, taking into account the distribution, which allows sensitivity tests of the inputs, which are the most important (*31*).

   Some survey respondents reported using a spreadsheet model to estimate travel demand for short-term (i.e., annual) revenue forecasts of an established toll facility, such as a bridge or tunnel for which travel demand was stable and dependable historical data were available. A review of literature indicated that this was a common practice. For example, Florida DOT's Annual Report on its Enterprise Toll Operations stated that for older, established toll facilities its forecasts were developed based on actual traffic and revenue performance, with adjustments for population growth and anticipated future events (such as new infrastructure) (*32*).

The survey of practitioners did not demonstrate any consistent or dominant treatments of the types of choices that were modeled or how they were modeled. This appears consistent with the practice of travel demand modeling in general. This is supported by research that summarized the treatment of pricing in seven models at major cities across the United States, which found that no two of the seven models treated the subject in exactly the same manner (*33*).

It is important to note that there is no fixed or standard process for determining which type of model must be used. Rather, the object is to ensure that the method meets the need. This was corroborated by the survey, which indicated that a range of model types was used. For example, one respondent to the survey, a state DOT, noted that it used two different models for two concurrent studies. One study was determining the impacts of an impending change in the toll rate on an existing bridge. The second study was for a proposed HOT lane. The first study used a semi-modeling approach with implied elasticity, using different values of time for the toll bridge users. The respondent found this method to be effective, given the known travel characteristics of the existing toll bridge users. The second method was fully model-based, using a combination of a traditional four-step travel model and a network micro-simulation model. This combination was chosen to capture the significant impact of small changes in traffic volumes on the HOT lane compared with the regular lanes.

Finally, it should be noted that practitioners appear to have responded to the specific needs of forecasting for toll roads. For example, the survey of practitioners indicated that various combinations of time periods were modeled; most of the cited travel demand models covered the weekday off-peak periods in addition to the (more typical) peak periods. In certain cases, nighttime and weekend periods were also modeled to reflect the type of facility (i.e., the weekend model for areas of high recreational use). A small number of respondents incorporated time-of-day choice into their models or used peak spreading models. More commonly, practitioners relied on factors from other sources (e.g., from traffic counts or from the local MPO) to address time choice, whereas others did not include time choice at all.

Evolution of Decision-Making Environment

Concerns regarding the reliability, accuracy, and credibility of travel demand forecasts are not new. A 1989 U.S.DOT study compared projected and actual ridership and costs for 10 heavy- and light-rail transit projects in 9 U.S. cities. The study found that the actual ridership for each of the 10 projects was significantly below the projections, whereas the actual costs were higher than the projected costs in 9 of the 10 projects. The projected ridership (i.e., benefits) and costs were used as the basis of investment decisions and of applications for federal government funding (*34*).

Although the study addressed only forecasts for transit, it is relevant to toll road demand and revenue forecasts because it received widespread attention in the transportation community and also because it anticipated many of the issues that have since been identified in toll road forecasts. Hence, it provides an important context for the discussion of how the decision-making environment has evolved. For example, the study explained the need for the community to understand the accuracy of the ridership and cost forecasts in three ways: the transit projects represented the largest investment ever in public works in each of the nine cities, local officials in other cities where rail projects were contemplated would also rely on similar projections to make their own decisions, and local officials typically used similar analytical processes for other public investments. To this end, the study found that these "mistakes" in ridership estimates could not be explained by differences between projected and actual values of the determinants of ridership: land use inputs (which differed little from the actual), network configurations, assumed feeder bus configurations, or downtown parking prices (which tended to be lower than those modeled). Each of the 10 projects was selected among several alternatives. The study noted that although the accuracy of the forecasts for the rejected alternatives could not be evaluated, for almost all of the projects the divergence between the projected and actual ridership and costs of the selected alternative was greater than the entire range of the ridership and costs of all the alternatives that were compared (which made it "extremely unlikely that a rail project would have prevailed in the presence of more reliable forecasts"). Rather, the study attributed the differences to the structure and nature of federal transit grant and fund programs (effectively favoring high-capital transit investments), which provided little incentive to local decision makers "to seek accurate information in evaluating alternatives." The result was a "bias" or "optimism" for rail transit (*35*).

These differences (and those in other areas of public policy) demonstrate a "serious ethical problem" in the use of forecasts, with occurrences noted in which modelers had been directed by their superiors (including local elected officials) to "revise" their ridership forecasts upwards, to "gain federal [financial] support for the projects whether or not they could be fully justified on technical grounds. Forecasts are presented to the public as instruments for deciding whether or not a project is to be undertaken; but they are actually instruments for getting public funds committed to a favored project." The goal of "exaggerated forecast[s] of demand and the cost underestimates" may be to "[get] the project built rather than honestly evaluating its social benefits" (*34*).

Forecasts have not become more accurate over time. In a multinational statistical analysis of 183 road projects (tolled and non-tolled) completed between 1969 and 1998, the "forecasts [appeared] to become more inaccurate toward the end of the 30-year period studied" (*36*). More recent forecasts were found to be more comprehensive than older studies; however, "this greater depth has not yet appeared to improve the accuracy of the forecasts." Newer forecasts did appear to respond to earlier concern; for example, by incorporating better methods to forecast ramp-up volumes. However, "whether this increased scrutiny has actually led to more accurate forecasts remains to be seen" (*3*).

The role of private provision of public services (such as privately owned tolled roads) continues to evolve. Although not specifically directed at the reliability of traffic and revenue forecasts, an article about "intellectual dishonesty" in the ongoing debate may provide some context. For example, the toll revenues for a (hypothetical) bridge that is operated by a private company must cover its capital, operating and maintenance costs, as well as depreciation, which reflects the eventual need for rehabilitation or reconstruction as a result of wear and tear. Its toll rates must be set sufficiently high to cover these costs. Because the company accounted for annual depreciation costs when it issued its debt to construct the bridge (which presumably has been paid off by the time major reconstruction is required), a one-time debt allows the construction of a bridge that "can presumably last forever." In contrast, public authorities in the United States are not required to account for depreciation, which means—for the same tolled bridge—its toll rates could be much lower. However, it must issue new debt when the bridge is reconstructed (i.e., the public authority inevitably must account for depreciation, but does so in terms of a "perpetual debt"). This means that the public authority's bridge seems "less expensive," because its lower toll rates ultimately have transferred the debt from its actual users to future generations (*37*). The relevance to this synthesis is that the public's expectations and inappropriate understanding of the real costs of public services may affect the choice of toll rates and, in turn, traveler behavior (which may not be captured properly by the forecasting models or the data upon which they are based).

A 1989 court case in the San Francisco Bay area claimed that state and regional planning authorities had not sufficiently met their obligations to reduce air pollution in their transportation plans. Much of the resultant findings focused on the adequacy and use of the regional travel demand forecasting model in predicting air quality impacts. In particular, it took a much more "literal" interpretation of model forecasts than had planners historically (i.e., given the planners' understanding of the models' limitations owing to errors in calibration, data input, or validation). A subsequent TRB study found that the "analytical methods in use are inadequate for addressing regulatory requirements" (such as air quality conformity analysis) (*13*). The relevance to this synthesis is that the concerns about model inaccuracies and performance that this court case identified, which preceded the TMIP and which, in part, the TMIP was intended to address, mirrors and anticipates similar concerns regarding the performance of toll demand and revenue forecasts.

RELATIONSHIP BETWEEN DEMAND AND REVENUE FORECASTS

Revenue forecasts are dependent on travel demand forecasts and the assumptions on which the travel forecasts were based. Critical assumptions include local growth policies, the magnitude and distribution of future land uses, the intensity of development, projected economic growth, changes in traffic patterns, drivers' willingness to pay tolls, and new competing roads in the transportation network. The level of uncertainty in revenue forecasts is proportional to the level of uncertainty in travel demand forecasts.

Revenue forecasts are also dependent on the tolling technology, toll rate structure and schedule, and the stratification of the toll road users (i.e., according to payment classes). Tolling schemes could include discounts for electronic tolling or multipass users, higher tolls for heavy vehicles, or variable tolls based on time of day or section of toll road used. Increases in toll rates can also affect the demand, especially as some authorities have elected to increase toll rates more sharply than projected to quickly generate revenues in the short term (when the projected demand had not materialized).

As noted, the travel demand forecasts are commonly developed for a weekday peak hour or peak period for several modeled horizon years. Conversion factors are then applied to generate daily and yearly traffic volumes. Revenue is estimated by multiplying the forecast volumes by the toll amount, taking into account different toll rates for vehicle type, potential toll evasion, discounts, and other facility-specific factors. With each assumption, a degree of error is introduced into the revenue forecast. Another layer of complexity is added when a schedule of predetermined toll rate increases is applied to the traffic forecasts.

In travel demand forecasting, the future year forecasts (20- to 30-year horizon) are more important and critical for long-term planning decisions. However, for revenue forecasts, the initial years of operation are crucial in terms of assessing and managing financial risk. This is because the risk for default is typically at its highest during this period, which is also referred to as the ramp-up period (*9*). During the ramp-up period, traffic volumes may be significantly lower than forecasted as drivers slowly become aware of the toll facility and its potential for saving time and/or convenience, or if population or employment growth along the facility corridor (i.e., the potential market) is also less than forecasted.

PERFORMANCE OF TOLL ROAD DEMAND AND REVENUE FORECASTS

Sources of Information

This section compares the projected and actual revenues for several facilities. However, to understand and interpret the comparison, it is important first to understand the sources upon which the information was based.

The projected and actual revenues were derived from different sources. Projections are commonly provided by the original traffic and revenue studies for the individual facility. The study is typically conducted several years before the facility's opening date, as the basis for securing funding for the planned facility.

The actual traffic and revenue studies proved difficult to obtain for three reasons:

- An accessible single or universal source or database of these traffic and revenue studies does not exist. Members of the financial community, such as bond rating agencies, do have access to a database of financial offerings, which include traffic and revenue studies; however, access is available only by subscription. Moreover, the database is not exhaustive.
- With some exceptions, facility owners generally were not willing to provide their traffic and revenue reports, which they considered proprietary or confidential.
- Some authorities have updated their traffic and revenue forecasts, in the face of poor performance (projected versus actual) and given the availability of observed traffic and revenues. The new forecasts replace the original study (meaning also that newer models or forecasting methods may be used, as well as newer data)—that is, a series of forecasts may be available for a given facility. In general, the new forecast produces much closer results in the subsequent years. Accordingly, the authorities use the updated study as a comparison with actual revenues, which in turn often demonstrates a much better performance than the original traffic and revenue study would indicate.

Other authorities prepare simplified projections of annual revenues. These are based on an extrapolation of the previous year's (or years') revenues, using growth factors that were developed from observed growth trends (e.g., in traffic volumes) without recourse to a travel demand forecasting model.

Information on the "actual" revenues generally was more readily available. Annual toll revenue statistics generally were accessible from annual reports or directly on the owner's website. However, there is considerable variation as to the amount of yearly data that each owner provides. For example, some owners report only the most recent year, whereas others provide information for several years. Most authorities reported only the three most recent years, with only a few providing information for up to 10 (or more) years. That is, information for older facilities (i.e., pre-2000) was not readily accessible.

The different sources, and the difficulty in procuring the different pieces of information, also suggest that the comparability of the projected and actual revenues for a given year may be limited. The definition of a "year" may vary between the projection and the actual (e.g., the definition of the fiscal year may reflect that of the owner rather than of the facility; and some facilities may have begun operation part way through the owner's fiscal year).

In summary, the comparison was derived from four types of sources:

- Comparisons of actual and projected revenues, prepared by various bond rating agencies.
- Financial offering statements for individual facilities, which include the traffic and revenue projections for the facility. These statements are circulated within the financial community by subscription to a central commercial service.
- Financial statements or reports, prepared by individual authorities (owners). Generally, these were found on the respective authority's website. In most cases, only the actual revenues were provided, although a small number of websites also compared these with the projected revenues. Of the four types of sources, only this one is available to the general public.
- Traffic and revenue forecasts, provided by individual facility owners that responded to the survey of practitioners.

It is important to note that several sources were used to compile the information for some facilities described in this synthesis. This is important for three reasons: First, as noted in the footnotes to Table 1, in some cases the reporting methods varied from year to year. Second, multiple sources of information, and different performance results, were sometimes provided for a given facility and year. Third, although the actual performance information was provided, for some facilities the corresponding projected performance was not available.

Comparison of Projected and Actual Revenues

Table 1 summarizes the performances of 26 different toll highways throughout the United States. The table compares the actual revenue collected as a percentage of the revenue that was projected in traffic and revenue forecasts. The facilities are listed according to the year in which the facility opened (between 1986 and 2004). The results are presented, where available (or where applicable; some of the facilities opened too recently to have an established performance history), for the first 5 years of operation. The table identifies the owner and the state in which the facility is located. Appendix D presents brief descriptions of the individual facilities.

It should be noted that other facilities were also investigated; however, they were not included because of insufficient data and information.

Table 1 demonstrates considerable variation in performance, ranging from a low of 13.0% for the Osceola County Parkway in Year 1, to a high of 152.2% for the George Bush Expressway, also in Year 1. The table also shows that there is little consistency, as follows:

- The results do not improve with newer facilities, which might have been expected given that the state of the practice in modeling generally is improving. The performance does not necessarily improve for a given authority [i.e., even as a history of models and forecasts is built up by (or for) a given authority, the performance does not necessarily improve as a new facility is planned].
- There is little consistency by year within a given facility, although the performance for some facilities improves when traffic and revenue forecasts are updated, based on actual in-operation performance. (The most recently opened facilities are too new to have recorded data for any but the initial year or two).
- Most of the results demonstrate an underperformance (actual is lower than projected), albeit with some notable exceptions. However, the under/overperformance may vary within a given facility by year.
- At least some of the results reflect updated forecasts (although the existence of updates may not have been noted in the source material). This is corroborated by the survey of practitioners: In response to poor initial performance, some respondents indicated that their model was recalibrated or the model networks were reconfigured; the demand forecasts or the revenue fore-

TABLE 1
ACTUAL REVENUE AS PERCENTAGE OF PROJECTED RESULTS OF OPERATION

Authority/Facility	Year of Opening	Year 1	Year 2	Year 3	Year 4	Year 5
Florida's Turnpike Enterprise/Sawgrass Expressway (*6*)	1986	17.8%	23.4%	32.0%	37.1%	38.4%
North Texas Tollway Authority/Dallas North Tollway (*6*)	1986, 1987	73.9%	**91.3%**	**94.7%**	**99.3%**	**99.0%**
Harris County Toll Road Authority (Texas)/Hardy (*6*)	1988	29.2%	27.7%	23.8%	22.8%	22.3%
Harris County Toll Road Authority (Texas)/Sam Houston (*6*)	1988, 1990	64.9%	79.7%	81.0%	83.2%	78.0%
Illinois State Toll Highway Authority/ Illinois North South Tollway (*6*)	1989	**94.7%**	**104.3%**	112.5%	116.9%	115.3%
Orlando–Orange Expressway Authority/ Central Florida Greenway North Segment (*6*)	1989	**96.8%**	85.7%	81.4%	69.6%	77.1%
Orlando-Orange Expressway Authority/ Central Florida Greenway South Segment (*6*)	1990	34.1%	36.2%	36.0%	50.0%	NA
Oklahoma Turnpike Authority/ John Kilpatrick (*3*)	1991	18.0%	26.4%	29.3%	31.4%	34.7%
Oklahoma Turnpike Authority/ Creek (*3*)	1992	49.0%	55.0%	56.8%	59.2%	65.5%
Mid-Bay Bridge Authority (Florida)/ Choctawhatchee Bay Bridge (*38,39*)	1993	79.8%	**95.5%**	**108.9%**	113.2%	116.7%
Orlando-Orange Expressway Authority/ Central Florida Greenway Southern Connector (*6*)	1993	27.5%	36.6%	NA	NA	NA
State Road and Tollway Authority (Georgia)/GA 400 (*3*)	1993	117.0%	133.1%	139.8%	145.8%	141.8%
Florida's Turnpike Enterprise/ Veteran's Expressway (*3*)	1994	50.1%	52.9%	62.5%	65.0%	56.8%
Florida's Turnpike Enterprise/ Seminole Expressway (*3*)	1994	45.6%	58.0%	70.7%	78.4%	70.1%
Transportation Corridor Agencies (California)/Foothill North (*3*)	1995	86.5%	**92.3%**	**99.3%**	NA[1]	NA[1]
Osceola County (Florida)/Osceola County Parkway (*3*)	1995	13.0%	50.7%	38.5%	40.4%	NA
Toll Road Investment Partnership (Virginia)/Dulles Greenway (*3*)	1995	20.1%	24.9%	23.6%	25.8%	35.4%
Transportation Corridor Agencies (California)/San Joaquin Hills (*3*)	1996	31.6%	47.5%	51.5%	52.9%	54.1%
North Texas Tollway Authority/ George Bush Expressway (*3*)	1998	152.2%	**91.8%**	NA	NA	NA
Transportation Corridor Agencies (California)/Foothill Eastern (*3*)	1999	119.1%	79.0%	79.2%	NA[1]	NA[1]
E-470 Public Highway Authority (Colorado)/E-470 (*3*)	1999	61.8%	59.6%	NA	**95.4%**[2]	NA[3]
Florida's Turnpike Enterprise/Polk (*3*)	1999	81.0%	67.5%	NA	NA	NA
Santa Rosa Bay Bridge Authority (Florida)/Garcon Point Bridge (*42,43*)	1999	32.6%	54.8%	50.5%	47.1%	48.7%
Connector 2000 Association (South Carolina)/Greenville Connector (*3*)	2001	29.6%	NA	NA	NA	NA
Pocahontas Parkway Association (Virginia)/Pocahontas Parkway (*44,45*)	2002	41.6%[4]	40.4%	50.8%	NA	NA
Northwest Parkway Public Highway Authority (Colorado)/Northwest Parkway (*46,47*)	2004	60.5%	56%[5]	NA	NA	NA

Sources are cited in parentheses.

Notes: Bold type reflects actual within 10% of projected. NA = traffic and revenue report not available or not provided.

[1]For these years, the Transportation Corridor Agencies combined the revenues (earnings) for the two facilities (Foothill North and Foothill Eastern). Accordingly, the individual performance for the two facilities cannot be calculated.

[2]Data reflect updated traffic and revenue study (*40,41*).

[3]Incomplete information (missing November and December).

[4]This is approximated owing to construction delays that only allowed the facility to be open for one-quarter of the expected full year.

[5]Projected performance for the 2005 fiscal year (*48*).

casts were revised. Other responses included revisions to the financial schedule, changes to the staging or timing of the project, or the implementation of annual updates and peer reviews. On the other hand, several respondents noted that the forecasts were accepted and used as is (i.e., no impact).
- Even with the availability of updated forecasts, only a small number of projections are within 10% of the actual revenues. These are indicated in bold type in the table.

Comparison of Projected and Actual Traffic

It should be noted that Table 1 and the preceding discussion compared projected and actual revenues, as opposed to traffic. However, a multi-national review of 183 tolled and non-tolled roads found significant inaccuracies in the traffic projections as well (*36*).

Another study compared the traffic forecasts for 104 tolled facilities around the world. The comparison found considerable variability in the performance of the traffic forecasts for the first year (during ramp-up), ranging between 15% and 150% of actual performance. On average, the forecasts overestimated Year 1 traffic by 20%–30%. This "optimism bias" (error) was not reduced for subsequent years; rather, a mixed performance profile resulted. The mean projected versus actual performance ranged between 0.77 and 0.80 over the first 5 years of operation.

The comparison disaggregated the forecasts according to vehicle type, and found that the variability in traffic forecasts was "consistently higher" for trucks than for light vehicles (generally, private automobiles). This reflected the greater difficulties in predicting the trucking community's response to tolls, given the variability in type and size of trucking operations. The significance is that trucks commonly pay higher tariffs than private vehicles, meaning that their contribution to revenue forecasts can be "significant," out of proportion to their volumes.

The comparison also noted the relative lack of tolled facilities that are more than 5 years old. This reflects "the innovative nature of the sector and that operational project-financed infrastructure concessions are a relatively recent phenomenon. A significant number of highway concessions globally still remained in design or under construction" (*49*).

The difficulty in tracking the performance of the forecasts over time was also noted, given "the common practice of preparing revised or rebased forecasts for toll facilities whose predicted use departs significantly from expectations. In such instances, credit surveillance documentation may fail to report the original forecasts" (*49*).

The analysis also compared four different forecasts for the same tolled facility. All of the forecasts represented "base-case forecasts"; that is, they were modeling the same situation but used different forecasting assumptions. The four forecasts varied between 26% (for the Year 5 forecast) and 255% (Year 35), with a steady increase in the interim.

> Very different projections of asset use result from relatively small divergence among the model input assumptions. . . . Traffic forecasts, particularly in the medium to longer term, can remain very sensitive to marginal parameter changes within the modeling framework, even though these parameter values are drawn from an entirely plausible range. In terms of assessing the reliability of future project cash flows, rigorous sensitivity testing clearly has a pivotal role to play in such cases (*49*).

Explanation of Performance

A second study assessed the performance of all but two of the toll facilities that are summarized in Table 1 (*3*). [The two exclusions were the Choctawhatchee Bay Bridge in Florida (Mid-Bay Bridge Authority) and the Northwest Parkway in Colorado (Northwest Parkway Public Highway Authority)]. The performance of each was assessed in the first 5 years of operation. All of these were start-up facilities.

Whereas Table 1 considered the facilities chronologically, to determine whether more recent forecasts presented any improvement in performance (as noted, no pattern was apparent), this assessment categorized the facilities according to several characteristics; location within the urban area, degree of integration with the existing road network, corridor income levels (i.e., the income levels of the drivers who would use the facility), time savings offered by the facility (i.e., the extent of congestion in the competing network and the availability of "competitive" non-tolled alternatives), value of time (e.g., the value of time would be highest in congested corridors traveled by high-income drivers), projected traffic growth (also related to the reliability of the demographic and economic forecasts upon which the forecasts were based), and the extent of development in the area served by the facility.

The categorization resulted in four groups, although some overlap was noted:

1. High congestion, suburban areas;
2. Outlying roads of metropolitan areas;
3. Developed corridors, parallels of existing roads, and/or faulty economic forecasts; and
4. Least developed areas.

The general findings are summarized in Table 2. The table does not list the individual performances for each facility, because the values differ from those listed in Table 1. However, the table demonstrates a decreasing performance according to the order of the four categories. In essence, improved performance resulted under the following conditions:

TABLE 2
PERFORMANCE BY CATEGORY

Group	Authority/Facility	Characteristics	Performance	Explanation
1. High congestion, suburban	Three facilities: • State Road and Tollway Authority (GA)/GA 400 • North Texas Tollway Authority/George Bush Expressway • Illinois State Toll Highway Authority/ Illinois North South Tollway	• Well-developed urban/ suburban part of large metropolitan area • Higher corridor income • Substantial corridor traffic • High value of time • Good connections to facility • No competitive non-tolled alternatives • Modest projected traffic growth	Approximated or exceeded projections	• Moderate toll rates • Very rapid adjustment of traffic patterns following opening • Moderate traffic growth in first 2–3 years, then growing more slowly
2. Outlying	Seven facilities: • Oklahoma Turnpike Authority/John Kilpatrick • Oklahoma Turnpike Authority/Creek • Florida's Turnpike Enterprise/Veteran's Expressway • Florida's Turnpike Enterprise/Seminole Expressway • Florida's Turnpike Enterprise/Polk • Transportation Corridor Agencies (CA)/Foothill North • Orlando–Orange Expressway Authority/ Central Florida Greenway North Segment	• Less established traffic patterns • Less integral to the existing network • These were partial beltways • Usually serving above-average income areas, but with less-established development patterns • Further from employment centers • Moderate-to-high toll rates (although usage inelastic because drivers already accustomed to paying tolls)	Mean ranged between 61% and 67% of forecasts, on average, with considerable variation	• Substantial forecast revenue growth (35% average over first 4 years) • Forecast error appears to result from overestimation of initial base period usage (high ramp-up rates)

(continued)

- Location within well-developed parts of a large metropolitan area, with established traffic patterns.
- Location within high-income corridor, with resultant high values of time.
- Well-connected to the road network.
- Few or no reasonable choices for non-tolled alternative routes.
- High savings in time offered by the facility.
- Rapid driver acceptance of the new facility, with moderate ramp-up traffic growth and subsequently slower growth.
- Moderate projected growth (i.e., appropriate accounting for economic conditions; notably, through appropriate consideration of the labor force, the aging of the population, and productivity).

A third analysis of the poor performance of start-up roads identified four types of explanatory reasons (*5*):

1. Model input risk, which was exemplified by the use of regional travel demand models that had been developed for other purposes and that assumed land use and socioeconomic forecasts that were appropriate for regional planning, but were not "sufficiently conservative" to support debt service; a "steady-state" forecast that does not account for "the very real likelihood" of economic fluctuations; weekend or truck traffic patterns that varied significantly from comparable experience; and differences in actual values of time compared with estimates.

The survey of practitioners found that few travel demand models had been created and calibrated specifically for a toll facility study. The survey revealed that only 15% of the models were developed specifically for the subject toll facility study and another 31% had been calibrated for a previous toll facility study. The remainder of the survey respondents indicated that the selected model was based on an existing model that had been calibrated for other purposes. At the same time, survey respondents also reported that the use of a model from a previous toll or non-tolled study yielded the most accurate results.

TABLE 2
PERFORMANCE BY CATEGORY (*Continued*)

Group	Authority/Facility	Characteristics	Performance	Explanation
3. Developed corridors	Five facilities: • Harris County Toll Road Authority (TX)/Hardy • Harris County Toll Road Authority (TX)/Sam Houston • Transportation Corridor Agencies (CA)/Foothill Eastern • Transportation Corridor Agencies (CA)/San Joaquin Hills • Santa Rosa Bay Bridge Authority (FL)/Garcon Point Bridge	• Corridors with more developed or already established traffic patterns • Usually constructed in large metropolitan areas or active tourist areas • "Solid" projected time savings • Moderate projected revenue growth	Mean ranged between 51% and 60% of forecasts, on average, with considerable variation	• Impacts of nearby non-tolled alternatives underestimated • Overestimated time savings • Overly optimistic economic forecasts • Failure to account for recessions • Overestimated corridor growth rates • High toll rates • Limited history of toll use in area • Unusual ramp-up problems • Expansion of competing non-tolled network
4. Least developed	Eight facilities: • E-470 Public Highway Authority (CO)/E-470 • Toll Road Investment Partnership (VA)/Dulles Greenway • Osceola County (FL)/ Osceola County Parkway • Orlando–Orange Expressway Authority (FL)/Central Florida Greenway South Segment • Orlando–Orange Expressway Authority (FL)/SR-417 • Florida's Turnpike Enterprise/Sawgrass Expressway • Pocahontas Parkway Association (VA)/ Pocahontas Parkway • Connector 2000 Association (SC)/ Greenville Connector	• Specific traffic generator serving as project basis (e.g., airport) • Located in undeveloped area • Toll road expected to stimulate development • High revenue growth rates • Assumed periodic toll rate increases	Mean ranged between 29% and 51% of forecasts, on average, with considerable variation	• Insufficient existing traffic congestion • Overestimated time savings or value of time • High ramp-up growth rates, due to overestimated base period usage • High subsequent growth rates

Source: Muller and Buono (*3*).

2. Ramp-up risk, with recent methods based on the use of other operating facilities as proxies, but with "spotty" results.
3. Event and political risk, for which were cited external factors such as the unforeseen construction or expansion of competing roads (San Joaquin Hills toll road), cancellation or postponement of expected expansions to the connecting network (Foothill Eastern), or the inhibition of expected development (which would have generated demand for the toll road) by a moratorium on servicing (Garcon Point Bridge). The slowdown in air travel after the September 11, 2001, terrorist attacks affected the forecasts for the E-470 toll road in Denver.

Political pressures were cited as influencing factors, given that transportation authorities exist in a political environment and this existence can depend on the support of elected officials (*25*). The challenge of evaluating projects that were generated initially for political reasons was noted. Business motivations were also seen as influencing factors, with politically connected business leaders seen as generating support for toll projects that might not otherwise have been considered (*25*).

Another exogenous event was the development of competing routes or the failure to anticipate network improvements such as feeder roads or highway interchanges. In some situations, noncompetition agreements have been developed that specify that other government agencies will not build competing facilities within a certain protected geographic area. However, the agreements have not always been implemented.

Survey respondents cited several exogenous factors that influenced the performance of the forecasts. All of these concerned the actual conditions under which the facility operated or was implemented. These factors included the actual operations and system reliability (e.g., actual congestion levels, operating speeds, and incidents); impact of the tolling technology on actual (recorded) traffic volumes (e.g., owing to unreadable license plates); violation rate; staging of the facility (or of other facilities); and changes in policy, mandate, legislation, ownership, etc.

4. Model error, which reflected the inherent variability in models regardless of how well the model was calibrated and validated [i.e., the forecasts can never replicate the (eventual) actual traffic]. Although a model's average error might be small, the average "may mask a problem, which when compounded within the model and over time, may severely skew results. This is an issue that is not discussed in an adequate level of detail in traffic and revenue reports." The analysis further noted that the "simultaneous manifestations" of two or more of these problems contributed further to the poor model performance, with the forecasts "[amplifying] the negative variance between projected and actual traffic levels."

Finally, the survey of practitioners found that no single modeling factor influenced the performance of respondents' forecasts. Respondents cited as factors the model structure; the process used to expand the modeled time periods to annual forecasts; the calibration process, coverage, and precision; "control" over how the model outputs were used, analyzed, or interpreted; the lack of transparency/opacity in the modeling and forecasting process; and the validity (i.e., appropriateness) of the model for financing purposes.

TREATMENT OF SPECIFIC FACTORS AFFECTING FORECAST PERFORMANCE

Drawing on the preceding discussion of the performance of the forecasts and the underlying reasons, this section examines the treatment of specific factors that were identified as part of the scope of the synthesis, in the literature, and by practitioners.

Demographic and Socioeconomic Inputs

There are two relevant issues. The first concerns the use of long-range demographic and socioeconomic forecasts (so-called land use inputs to the model) that may reflect an MPO's planning policy (i.e., as the source for these inputs) as opposed to market trends. Recent toll road demand and revenue forecasts have responded to these concerns by modifying these assumptions to account for input scenarios that were more conservative and that took into account historical trends and a more realistic assessment of likely future growth (*5*).

An example is provided by a recent (2003) traffic and revenue forecast for the Transportation Corridor System (the Foothill/Eastern Transportation Corridor and the San Joaquin Hills Transportation Corridor), in which the local MPO land use forecasts were reviewed and refined in several ways: an update to the forecasts according to actual development that had occurred in the 5–6 years since the MPOs had prepared them; a review of job and household growth rates according to a variety of national, state, and regional third party sources; interviews with developers, realtors, and other related interests to identify issues that would affect future development and the regulatory environment in the study area; detailed field studies of 50 "focus areas" to identify current and potential development capacity and constraints to development; and the identification of candidate areas for redevelopment and infill development at higher (than originally forecasted) rates in the long term. Forecasts for different categories of employment were revised according to recent trends, and forecasts for residential development accounted for such variables as recent changes in prices. Overall, revised short- and long-term land use forecasts were developed (*50*). The impact of the refined land use forecasts is not yet clear, given the recentness of the study. Although the actual revenue growth rates for 2003–2004 and 2004–2005 were greater than the projections (8.7% versus 4% and 9.7% versus 4%, respectively), a July 2004 increase in toll rates might have affected the results (*51*).

The second issue is the lack of consideration of the impact of short-term economic fluctuations on travel demand. The impact of optimistic economic projections on traffic projections was noted in several studies. The national recession of 1990–1991 affected the use of the first two segments of the Central Florida Greenway, which had opened in 1989 with first-year projections just slightly below actual, but with poorer results for the next two years (over the course of the recession). A "drag" from the recession was considered to have affected toll roads in Oklahoma City and Tulsa, Oklahoma, which opened just after the recession. Local economic impacts, such as the collapse in oil prices and the subsequent sharp regional economic downturn of 1986, left economic growth in the Houston area well below projections, with corresponding impacts on the Hardy and Sam Houston toll road revenues. Even when regional economic activity was close to the original projections, the performance of some tolled facilities still fell short, because economic activity within the immediate corridor did not meet projections (e.g., the Sawgrass Expressway in Florida) or the expected build-out of residential areas was slower than expected (e.g., the Seminole

Expressway toll road, also in Florida) (*6*). Practitioners have begun to consider the impact of short-term economic changes. The aforementioned Transportation Corridor System forecast took into account a "recession scenario," which considered a "double dip" of below average job gains in the immediate term, followed by job losses for the next two years, then by a modest recovery and a recessionary dip in the seventh year. These inputs were used as part of a sensitivity test of the demand and revenue forecasts (*50*). Another observer commented that "supply-driven" land use forecasts (meaning forecasts that take into account factors such as growth in the labor force, demographics, and productivity) provided more stable results than did "demand-driven" inputs (such as forecasts of population and jobs). The pending retirement of the "baby boom" generation was also seen to have an impact on the demand for travel. As an example, this observer cited the 1999 Foothill Eastern refinancing study, which preceded the aforementioned Transportation Corridor System study. This study accounted for a more stagnant labor pool after 2010, which in turn generated "far less" growth in the long-term traffic and revenue forecasts (*3*).

A related issue concerns the ability to understand the travel characteristics of the users of a proposed facility. With reference to improving the performance of transit ridership forecasts, one observer proposed bringing the forecasting horizon closer to the present, which "would reduce the range of developments that can cause projections to go awry, such as changes in the local economy or evolution of travel patterns in response to geographic redistributions of employment and population." An "extreme variant" would be to predict ridership under current demographic and travel conditions, "which would isolate the increased ridership attributable to improved transit service from that owing to demographically induced growth in overall travel demand." This "opening-day" ridership would be used as the basis for the evaluation of alternatives, rather than long-range forecasts (*35*). Although the analytical horizon for toll road demand and revenue forecasts clearly cannot be shortened, a current-year or very-short-term toll demand forecast based on a hypothetical immediate opening of the facility would allow analysts and users to differentiate the demand that would result from the network improvement and that would result from assumed demographic or economic growth. Further analyses could test the impact of the facility, with and without tolls, again in the short-term, to isolate the impacts of tolls. In other words, although these short-term forecasts might have limited use in the development of absolute estimates of revenues, they would be valuable in grounding and interpreting the long-range forecasts (i.e., to provide a reference against which to compare that proportion of forecasted long-term facility traffic that would use the facility whether or not the toll is in place or independent of assumed growth).

Travel Characteristics

The availability of appropriate data and the quality of these data were noted in the literature and in the survey as one of the major sources of potential forecasting inaccuracies (*25*). These data include such variables as traffic counts, network characteristics, travel costs, land use, and employment. Inappropriate base year data can result in model validation errors, which in turn affect all subsequent applications and forecasts. In practice, these data, which are the foundation of the forecasts, were found to be subject to substantial numbers of measurement and processing errors (*25*). Similar problems were found with forecast inputs such as land use: The model may accurately reflect the assumed or calculated inputs; however, if the assumptions are erroneous, then the accuracy of the forecast will suffer (*52*).

Current data collection practices are well-established. They include origin–destination surveys, trip diaries, activity-based surveys, stated preference surveys, traffic counts, travel time data, and speed surveys. Surveys of existing socioeconomic and transportation system characteristics are required for calibration. However, one observer noted that what was once a standard part of transportation planning is not usually undertaken to the same degree in contemporary planning studies (*25*). The Minnesota DOT model update noted earlier used two previous studies (one local and one from California) as sources of information, given the lack of data (*26*).

Another observer noted the need for caution in the use of "imported" data to address gaps: "without great care and considerable experience, significant errors can be introduced into the modelling framework through inappropriate importation of model parameters." Other factors relating to data included the role of uncertainties and potential sources of error introduced by sampling [in surveys]. The appropriate categorization of travel markets in terms of their individual values of time and willingness to pay was also noted, with income levels and time sensitivity (i.e., trip purpose) being important determinants. The ability to save time was the most important determinant of whether or not a private automobile driver chooses to use a toll road, whereas truck drivers also took into account the impact on vehicle operating costs (i.e., that a toll road's "competitive advantage" for trucks must be measured both in terms of time savings and the ability to save on fuel costs and reduce vehicle wear and tear). Similarly, the importance of "who pays" also was noted, as was the difficulty in modeling this influence. Finally, assumptions regarding growth in vehicle ownership (also related to growth in Gross Domestic Product and income) were noted as influences on traffic demand in general (*53*).

These findings generally were corroborated by the survey of practitioners. Respondents cited the values used for value of time, willingness to pay, and other monetary values as influences on the performance of the forecasts. Other influences included assumptions regarding land use forecasts or future network configurations, with some respondents distinguishing public and political influences in these assumptions; availability, appropriateness, or sufficiency of the data, models, or analytical processes; environmental or economic development considerations; and economic climate. Overall, respondents recommended collecting more or better data to improve travel demand forecasting results.

Value of Time and Willingness to Pay

The treatment of the ability and willingness of potential users to pay was cited as a key performance factor both in the literature and by practitioners. Values of time can be differentiated by purpose, mode, and/or vehicle class. Willingness to pay is a variation of value of time that accounts for how much travelers value different attributes of the toll facility, such as safety and reliability.

The valuation of travel time is based on two underlying principles (*54*). The first principle states that time is valuable because people can associate it directly with results, such as making money or participating in a leisure activity—that is, the time spent in travel could be devoted instead to other activities. The second principle assumes that time can have an additional cost over and above that associated with the first principle; for example, travelers might find it undesirable to have to walk, wait for transit, travel on a crowded bus, or drive in congested conditions. As a result, "the value of saving time may vary, depending on both the purpose of travel, which affects the possible alternative uses of time, and the conditions under which it occurs."

The measurement of the *perceived* value of a driver's travel time yields the value of time. This influences a driver's decision to use a toll road. Values of time vary from region to region, and what is assumed for one forecast may not be transferable to another forecast. The value of time is a function of a driver's purpose (where work trips are more valuable than discretionary trips), income, and personality.

The value of time is used to convert the monetary toll to time. This allows the monetary value to be incorporated into the model's generalized cost function. As described earlier in Methods for Modeling Toll Road Demand, this is incorporated into the calculation of route diversion (within or post-trip assignment), which in turn may be fed back to other parts of the modeling process. Two-thirds of the models reported in the survey of practitioners incorporated value of time, 10% used willingness to pay, and another 10% used both. One model incorporated travel time and travel cost in its mode choice utility equations.

The choice and derivation of the values used for this determination are the subject of considerable debate in the literature. The U.S.DOT has developed a guidance document on the subject. Its purpose was to establish "consistent procedures" for use by the department in its evaluation of travel time changes that would result from transportation investments or regulatory actions. The guidance stated clearly that locally derived data should be used to forecast demand on individual facilities (*54*).

The guidance reviewed the factors that are associated with the value of travel time. For trips made during work or when the traveler could vary his or her work hours, the guidance noted that "the wage paid for the productive work that is sacrificed to travel" could be used to represent value of time. The value of time for other (personal) purposes can be represented by some fraction of the wage rate. Thus, the hourly income (before-tax wage rates, including fringe benefits) could be used as a "standard against which their estimated value of time is measured." As well, higher income has been associated with higher values of time, meaning that toll roads that operate in higher-income areas should experience greater patronage (and support higher toll rates) (*3*). The guidance developed tables that expressed the values of time (and "plausible ranges") as percentages of hourly incomes, categorized by local and intercity travel, business (work-related) or personal trip purposes, and mode (surface modes taken together and air travel). A separate category was developed for truck drivers. A 2003 revision retained the method, but updated the actual hourly incomes (*55*).

For toll road demand and revenue forecasts, the value of time generally has been assumed as a single value to represent an average characteristic for a given study area (*25*). However, researchers have recognized that the use of an average value of time masks the heterogeneity among travelers, notwithstanding the existing categorizations of time values by purpose. Recent research examined the preferences of users of the SR-91 toll lanes (California) by analyzing different revealed and stated preference survey data sets. The research concluded that values of time and the value of reliability were high, although the values dropped for very long distances. However, these values contained considerable heterogeneity: to this end, the research examined the impacts of the time of day at which the trip was made, flexibility of arrival time, gender, age, household size, occupation, marital status, and education. The research highlighted differences in the data; for example, drivers with higher incomes were more responsive to the toll, according to the revealed preference data (i.e., according to how they actually behaved), but not according to the stated preference data. Finally, the data were used to develop a pricing policy model, which took into account the utilities calculated for the individual factors (as a means of illustrating the importance of accounting for heterogeneity in estimating the value of time) (*56*).

Other researchers identified problems in the application or development of values of time, as compared with the findings of empirical studies of what travelers were actually willing to pay. These included (*57*):

- Trip assignment models that simulated route choice (i.e., diversion under tolls) using travel time values that had been derived from empirical studies of mode choice.
- Application of values of time to choices whose attributes were quite different from those that were used to calculate the value of time (e.g., comfort, convenience, and status).
- Relationships between values of time and other influencing variables (notably, income), which were assumed to

develop over time in ways that were inconsistent with other evidence. [Other empirical studies have suggested that the value of time increases over time, but not proportionately with income levels (*57*)].

- Values of time that were calculated from stated preference methods, which must be based on very-short-term (i.e., immediate) preference structures, but whose resultant values are applied to models that reflect behavior that takes some years to evolve.

The researchers found that in cases where an average value of time represented a skewed distribution of values, there was a tendency to overestimate the revenue, and underestimate the impact of a toll, because for a given mean value of time (i.e., for the value of time that was used in the demand and revenue forecast) there was a smaller number of individuals who were prepared to pay the toll. To address this, the researchers recommended the establishment of a relevant set of purpose-specific, time value distributions; determining a way to address these distributions in forecasting demand; "growing" the values over time; accounting for the time values of automobile passengers (in addition to those of the driver); and establishing methods to convert disaggregated (heterogeneous) values of time into a single trip value that is appropriate to the specific project under consideration.

The impact of tolls on shifts in driver behavior over time is beginning to be understood, as a history of toll facilities develops from which both static conditions and changes over time can be observed. In addition to addressing the relative paucity of data on the subject (given the relative newness of tolled facilities), historical data are important because driver behavior can change over time: this, in turn, affects the forecasts that commonly retain base year rates, modeled relationships, and parameter values through all horizon years. This was demonstrated by recent research on the Lee County, Florida, variable pricing program, which found that shifts in traffic volumes varied over time, with the long-run (3–5 years) relative elasticity of demand being lower than that of the short run (1 year or less). The research also found that several demographic, socioeconomic, and travel behavior factors affected facility use over time. Drivers who were commuting, were full-time employees, had more persons in their households, had a postgraduate degree, and were between 25 and 34 years old were found to be more likely to have increased their use of the facility. Retired drivers and those with lower incomes were less likely to use the facility (*58*).

Two of the studies cited previously also commented on the use of stated preference surveys as the basis of valuating time (*57* and C. Russell, personal communication, Sep. 20, 2005).

Stated preference surveys attempt to measure the value of time by presenting hypothetical options to respondents to quantify how toll rates would affect driver behavior. They are widely used in toll demand and revenue forecasts. Stated preference surveys for toll demand forecasting are generally in three parts: (1) background information on a recent trip in the study corridor, (2) a set of stated preference experiments, and (3) demographic information. The background information provides revealed preference data about an actual trip, as well as baseline data to customize the stated preference scenarios. The variables of interest are determined and ordered into a series of scenarios that is presented to respondents as part of the experiments: the scenarios are designed so as to allow the subsequent estimation of the respondents' relative preferences for each of the tested variables. Diversion (multinomial logit) models and values of time in turn are calculated from these estimates. Travel time, toll cost, and income typically are included as attributes, with values of time calculated by trip purpose (work and non-work) and separately for automobiles and trucks. Stated preference surveys in areas that do not have tolled facilities have tended to result in low values of time, because respondents express their "anti-toll road sentiment." In areas that have existing toll roads and severe peak-period congestion, respondents have tended to overestimate their values of time. In either case, the calculated values of time may have to be recalibrated to reflect actual conditions more reasonably. The availability of electronic toll collection (as opposed to cash collection) may also influence the value of time, in that electronic toll collection users may be less aware of and, therefore, less sensitive to the total toll paid on a trip (*2*), at least in the short term. Another practitioner has noted that the importance of understanding what (average) values of time derived from stated preference surveys represent; namely, they are proxies for several attributes (comfort, safety, convenience, reliability, etc.) and that all the models derived from these data assume that the respondent has perfect knowledge at the time of his or her decision making (C. Russell, personal communication, Sep. 20, 2005).

The need for accurate ordering of preferences in the scenarios has been noted by some researchers, who examined the applicability of stated preference surveys, and the methods used to estimate values of time from them, for toll demand analysis. The research surveyed a nationwide sample of respondents on their preferences of 13 alternatives that described the "essential elements of a commute," including congested and uncongested travel times, travel cost (usually, a toll), and an indication of whether or not trucks were allowed on the road. The researchers then used the resultant preferences to calibrate different formulations of the diversion model. They found that the ordering of the preference scenarios was important and that the choice of model formulation gave "very different ratings" for the same data. Finally, the research found that the willingness to pay estimates were relatively low and did not vary much among drivers, which implied "that the average commuter does not appear willing to pay much to reduce automobile travel time." The research noted that the distribution of willingness to pay was fairly limited, meaning that few travelers (in the sample) were willing to pay considerably more than the average toll. The research concluded that "extreme caution should be used in estimating stated preferences based upon respondents' ratings" (*59*).

Finally, one study noted the "growing body of empirical evidence that travelers value reliability as an important factor in their tripmaking decision." Reliability generally reflects the day-to-day variability in expected journey times, owing to nonrecurrent congestion such as incidents, weather, construction, and so on. Reliability is considered important in variable-priced HOT applications, where tolls are adjusted according to traffic volumes, to maintain a specified level of service. Therefore, average travel times on HOT lanes may be only slightly reduced from those on non-toll lanes; however, the day-to-day fluctuations in travel time variability are reduced significantly. Reliability can be critical for travelers with fixed schedules (such as individuals with daycare pick-ups or those going to the airport), and is not necessarily correlated with the traveler's general value of time. However, there remain few (if any) operational demand models that account for reliability in traveler values of time or that measure the value of reliability, because of a general lack of data: this reflects the few examples of operational toll roads using variable pricing from which empirical data can be drawn (*29*).

Tolling "Culture"

An international review of toll road traffic and revenue forecasts demonstrated better performance for countries that had a "history" of toll roads, compared with those for which road tolling was new. In "countries with a history of tolling, consumers can be observed making choices about route selection, effectively trading off the advantages against the costs of using tolled highway facilities. The consumer response can therefore be more readily understood by forecasters preparing predictions for new or extended facility use." In contrast, in countries where tolling is new, there are no revealed preference data on consumer behavior, which "leaves forecasters more reliant on theoretical survey techniques and assumptions about how drivers may respond to tolls" (*60*). The existence of a tolling "culture" also affected the ramp-up forecasts, with there apparently being "little transferability of experience between projects (particularly those in different countries). Ramp-up tends to be project-specific" (*53*).

Other influences on traveler choice included the conveniences that toll roads offered or were seen to offer. Improved safety was cited as an influence that would attract drivers to a "perceived" safer highway, such as one with fewer trucks (*61*). Commuters also valued reliability, and travelers may be willing to pay for predictability of travel time, especially for time-sensitive activities. The type of toll collection was cited as a third influence on drivers' route choice (*61*).

Truck Forecasts

The treatment of truck forecasts was the subject of an analysis that found that the variability associated with such forecasts was consistently higher than that for light vehicles. Although truck traffic typically comprises a relatively small portion of the traffic mix, they commonly pay two to five times and sometimes as high as 10 times the respective car tariff and so their contribution to total revenues can be significant. The choice by trucking firms to use toll roads was also found to depend on, among other factors, the size of the firm, with independent owner–operators (that dominate some trucking sectors) being "very sensitive" to tolls (*49*).

Ramp-Up

The ramp-up period reflects a toll facility's traffic performance during its early years of operation. This period may be characterized by unusually high traffic growth. The end of the ramp-up period is marked by annual growth figures that have (or appear to have) stabilized and that are closer to traffic patterns that have been observed on other, similar facilities. The ramp-up period reflects the users' unfamiliarity with a new highway and its benefits ("information lag"), as well as a community's reluctance to pay tolls (if there is no prior tolling culture) or to pay high tolls (if there is a history). The performance of the facility during ramp-up is particularly important to the financial community, because the "probability of default is typically at its highest during the early project years" (*9*).

As the initial year forecasts in Table 1 indicated, the ramp-up performance has been problematic and inconsistent. One analyst noted that the consideration of ramp-up forecasts had three dimensions (*9*):

- Scale of ramp-up (i.e., the magnitude of difference between actual and forecasted traffic).
- Duration of ramp-up (from opening day to beyond 5 years).
- Extent of catch-up [i.e., having experienced lower-than-projected usage at the time of the facility's opening, to what extent could observed traffic volumes catch up with later year forecasts? The significance of catch-up volumes, according to one analyst, was that "projects with lower-than-forecasted traffic during the first year operations also tend to have lower-than-forecasted traffic in later years (referring to toll and non-tolled roads, as well as transit and inter-urban rail) (*62*)].

In other words, the conditions that define ramp-up were specific to each project, given that the factors that influenced ramp-up also varied (e.g., signage and marketing, the tolling culture, and the availability of competing free routes).

Another analyst noted that until recently ramp-up has largely been ignored. Subsequent efforts have considered ramp-up; however, these have tended to be based on the use of other facilities as proxies. However, as more facilities have opened, actual operations and influencing factors could be observed. An inverse relationship between time savings and ramp-up has been observed, such that greater time savings appeared to correlate to a shorter ramp-up (*5*). As an example, another analyst noted that the estimates of time savings for the Hardy and Sam Houston toll roads in the Houston, Texas, area were very different, with the Hardy saving less than 5 min per average trip and the Sam Houston saving more than 10 min. "At some level, this would indicate that the basic need for the Sam Houston was probably greater" (which was demonstrated by the significantly better performance of the Sam Houston toll road; see Table 1). Also, income levels along the Sam Houston corridor generally were higher than those in the Hardy corridor (meaning that the value of time would be higher for the former) (*6*).

In the absence of extensive observations, however, one analyst proposed the use of "revenue-adjustment" factors for ramp-up forecasts. These varied according to the expected duration of the ramp-up period, the extent to which the initial observed volumes would have to catch up (i.e., whether the initial volumes were less than projections, and by how much), and the source of the toll demand and revenue projections (meaning that those commissioned by banks appeared to be more accurate than those of others, such as the sponsor; with the former group "typically referred to as 'conservative' forecasts" and used as the base case in financial analyses). The factors were derived from a comparison of the performance of 32 tolled facilities around the world. The factors ranged from a 10% reduction to first-year revenues for facilities with a two-year ramp-up and no catch-up required, according to a bank-commissioned forecast, to a 55% reduction to first year revenues for facilities with an eight-year ramp-up and initial volumes 20% less than projected, according to forecasts commissioned by others (*9*). However, it should be noted that although they mask considerable variation, the averages of the actual versus projected results listed in Table 1 improve over time, from 59% in the first year to 70% in the fifth year.

An alternative treatment was to recognize the potential for an extended ramp-up by accounting, in the forecast, for the market served by the facility; the duration was assumed to be extended if the facility was "development dependent" and could also be shortened if it was in a built-up area. The starting point (base forecast) also could be reduced according to experience on other nearby facilities. This allowed the "inability to accurately predict a key factor [to be] balanced by very conservative assumptions" (*5*).

Time Choice Modeling

The need for models that more accurately capture the differences in travel patterns by time of day, day of week, and even season was identified by the financial community. The object is twofold: first, to account more explicitly for the temporal variation in composition of trip purposes, origins and destinations, and vehicle types, including (in addition to peak-hour travel) the off-peak, midday, night, and weekend (*5*). This would replace the common use of factors to expand peak-hour models to daily and then annual traffic volumes for purposes of revenue forecasting. It also would replace the use of 24-h models, from which estimates of hourly traffic volumes must be derived (typically using factors) as the basis for forecasting diversion under tolls; some MPO models, which are used as the basis for toll road demand and revenue forecasts, simulate only daily traffic; see, for example, "Tyler Loop 49—Level 2 Intermediate Traffic and Toll Revenue Study" (*63*). Research on the impacts of variable pricing in Lee County, Florida, found that shifts in trip start times changed over time; that is, long-run elasticities of demand were lower than short-run elasticities (*58*).

The second object is to add and integrate time-of-day choice with mode and route choice. The Florida Turnpike Enterprise provides an example of how time-of-day choice was integrated with modal and route choice. It has relied on what it considered best practice in its toll-forecasting procedures for periodic updates of traffic and revenue forecasts, as well as for the planning, design, and economic feasibility assessment of proposed new facilities (*33*). A basic nested logit approach was used to describe travel behavior for mode, route, and time of day, with the following choices (*33*):

- Mode: automobile, drive alone; automobile, two occupants; automobile three plus occupants; bus; and rail.
- Route: tolled or non-tolled roads.
- Time of day: desired travel time or time-shifted trip.

Sixteen statistically estimated nested modal choice models were developed from survey data. These models incorporated four time periods and four trip purposes. The models also included specific decision tree hierarchies for transit and occupancy classes. Four specific time periods were modeled: a.m. peak, p.m. peak, midday, and nighttime.

Risk

The need to address risk and uncertainty more comprehensively was cited by the financial community and by researchers. At the same time, the survey of practitioners indicated that only a small number of respondents conducted a risk assessment, with most of the remainder verifying their results through judgment or reality checks and others not doing any verification.

Many assumptions and variables must be interpreted and relied on to complete a traffic and revenue study. The ability to ensure exactness and accuracy in all of these is limited for representations of existing conditions as well as forecasts. A common treatment has been to address uncertainty through the simple use of conservative assumptions or ranges. However, this was not always possible, as indicated by some survey respondents, who noted the impact on the accuracy of forecasts of exogenous factors such as public or political inputs, land use, and network assumptions. For example, when uncertainties existed about whether a particular competing road would be constructed, it had been the practice to conservatively assume the competing road would be completed if it was expected to have a negative impact on the toll facility. If it was not expected to affect the toll project, it was then assumed not to be in place (*61*).

The literature indicated that sensitivity analyses on key variables was common practice, such as the area growth rate, value of travel time, planned toll rates, and other variables that were region-specific or that had shown a high degree of variability in the past. The SR-520 Toll Feasibility Study for the Washington State DOT provides an example. The purpose of the toll feasibility study was to determine the revenue potential and traffic impacts of tolling a replacement bridge on SR-520. To quantify uncertainty, two tolling objectives were modeled to "bookend" the upper and lower bound of the reasonable toll possibilities within the corridor (*64*). However, respondents to the survey of practitioners recognized that sensitivity analysis might not be sufficient, because just over half of the respondents stated the need to conduct more risk assessment in the forecast process. A risk analysis process can evaluate thousands of different scenarios to quantify the probability of a "range of potential outcomes" (*65*).

In other words, it is important, first, to ensure that risk assessment is incorporated explicitly into the forecasting process and, second, to make the distinction between the assessment of risk and other indirect treatments of uncertainty (such as judgment or sensitivity analysis). The first is related, in part, to the inclusion of an appropriate and complete set of assumptions and inputs, and in part to ensuring that model makers and users of the model outputs all understand the implications of alternative choices or influences (whether qualitatively or quantitatively).

The second requires a proper understanding of the roles of the different treatments of uncertainty. For example, some financial analysts have commented that sensitivity analysis does not adequately reveal the range of possible outcomes in a toll road forecast (*65*). Instead, a range of possible outcomes could be explored, based on Monte Carlo simulation and the probability not only of the variables acting as individual occurrences but in combination with each other based on their respective probability of occurrence (*65*). Another treatment is offered through "reference class forecasting," which uses the experiences of past projects to help statistically identify the probability of given inputs occurring at a particular value (*36*).

Toll road demand and revenue forecasts have given little or no consideration to the possibility of a series of events occurring simultaneously (*65*)—for example, if economic growth recedes, oil prices spike, and a large development that was scheduled to be in place at the time of the opening of the toll road is cancelled. Traditional sensitivity analysis typically took each of these assumptions and varied them one at a time; however, these assumptions often varied by arbitrary amounts. A further problem was that in reality, rarely, if ever, did these assumptions vary from actual outcomes one at a time (*65*).

Financial analysts have noted that the simultaneous occurrence of several vulnerabilities contributed to toll roads generating lower-than-expected traffic levels and, accordingly, toll revenues (*5*). Although risk analysis has been incorporated into some analyses, one analyst noted that many project uncertainties were external to the traffic model environment. Because these uncertainties may not be fully captured in the model probability analysis, the model outputs must also be interpreted within the framework of the risk analysis (*60*).

The National Federation of Municipal Analysts (NFMA) is comprised mainly of research analysts, who are responsible for evaluating credit and other risks with respect to municipal securities. NFMA has worked with nonanalyst professionals in various sectors to develop recommended best practice guidelines for certain markets, including the toll road demand and revenue forecasts. In these guidelines, NFMA has attempted to account for the likelihood that there are many possible outcomes if future events do not follow the projected assumptions that are predicted in the model. Given the large number of input variables required in the modeling process, NFMA found that the results of forecasts can be significantly influenced by changes in these inputs (*65*). Simplistically, by applying the appropriate background data inputs to the toll forecast, a model could produce a traffic and revenue forecast that is most likely to occur, often called a base scenario. Whereas a single best statistical estimate may be desired by some, there are limitations to a single expected outcome.

A proposed mitigation strategy is the assignment of a probability distribution to all inputs, or at least to those inputs identified as most influential to the process. Each individual variable, with its own probability distribution, can be fluctuated simultaneously. This capability supports a better approximation of reality then can be obtained, because in practice variables do not generally change one at a time but concurrently with varying rates of change (*65*).

NFMA's best practices guidelines developed a disclosure requirements list with respect to creating a range of possible outcomes for traffic and revenue studies. The list included the following:

- Creation of a no-build traffic forecast (including truck and congestion analysis) for the study area, without the toll road.
- Creation of a baseline traffic and revenue forecast (as per standard practice).

- Sensitivity analysis while simultaneously varying toll road inputs simultaneously (the following list is a guide only, but it should be used as the minimum standard):
  – Population growth,
  – Employment growth,
  – Personal income growth,
  – Toll elasticity by consumers, and
  – Acceleration of planned transportation network.
- Debt service analysis with toll road project sensitivity analysis.

A risk analysis using the Monte Carlo technique was applied to several factors that were used to develop traffic and revenue forecasts for a proposed toll road linking Hong Kong with nearby industrial areas in southern China. The risk analysis found that whereas variations in the forecasts of population had insignificant impacts on the traffic and revenue forecasts, the impacts of variability in the trip generation were very large, with standard deviations of the forecasts being of the order of double (or more) than the base forecasts. Variations in the estimated diversion rates to the facility and in the toll rate also were found to be significant. From these findings, the authors pointed out that the impacts of variability and uncertainty in these factors can influence the traffic and revenue forecasts, and noted that "if the effects of varied key assumptions and scenario options are not examined, the real optimal rate of return could be missed" (*66*).

One risk analysis consultant noted that the determination of risk should not focus on a single outcome but should explore a range of possible outcomes (D. Bruce, personal communication, March 4, 2005). This process first determines the degree of risk in each input variable by developing probability distributions for all variables. Risk analysis is carried out by allowing all the underlying variable estimates to vary simultaneously, which can be done using simulation techniques such as the Monte Carlo technique. The risk and uncertainty in the underlying input variable is then translated into a probabilistic, risk-adjusted forecast of output variables such as traffic levels, toll rate, revenue, and debt service coverage. Finally, the variables that drive risk, that is to say the variables that have the greatest influence on the forecast, are identified.

Bias

The existence of "optimism bias" in transportation projects has been noted by some observers. "It is in the planning of such new efforts [referring to projects in a city 'for the first time,' where 'none existed before'] that the bias toward optimism and strategic misrepresentation are likely to be largest" (*36*). Another analysis noted the influence of bias on the performance of forecasts, with "systematic optimism bias" cited as a "distinguishing feature of toll road forecasts." The analysis recommended that "base case forecasts should be adjusted to take account of any suspected optimism bias." Bias was differentiated from "general error" in modeling, with the performance of traffic forecasts for tolled and non-tolled roads generally being "very similar." The update also suggested the need to consider distributions in error (*67*). On the other hand, in a project for which multiple bids are assessed competitively, the forecasts that are used as the basis of financing, and which are available to the financial community, are those of the winner: the forecasts for the unsuccessful bids generally will project lower revenues (D. Johnston, personal communication, Aug. 17, 2005).

The literature review uncovered no formal methods or guidance to address optimism bias in toll road demand and revenue forecasts. However, the British Department for Transport recently developed a guidance document on procedures to address optimism bias in transportation planning (*68*). Although this document addressed the cost side (for both roads and public transport), its approach could inform any future discussion of optimism bias in demand forecasting. The guidance document noted that transportation projects always must be considered "risky," as a result of long planning horizons and complex interfaces. It was theorized that optimism bias resulted from a combination of the structure of the decision-making process and how the decision makers were involved in the process. Optimism bias was not an unknown or imaginary phenomenon; rather, it was a logical product of the participants involved, their interests, the framework for conditions for funding, and the resulting incentive structure they encounter.

The causes of optimism bias were grouped into four categories: technical, psychological, economic, and political. Technical causes included the long-range nature of the planning horizons and that often the project scope and ambition level can change during the development or implementation of the project. Psychological causes were explained by a bias in the mental make-up of the project promoters and forecasters who can all have reasons to be overly optimistic in the approval stage—for example, engineers want to see things built and local transportation officials are keen to see projects realized. Economic causes were demonstrated by the argument that if the project went forward and was implemented, then more work was created for the industry; and if the participants were involved directly or indirectly, there could be an affecting influence. Finally, political causes were seen as influencing the perceived optimism bias in terms of interests, power, and the prevailing institutional setting that surrounded decision making on transportation projects.

Project appraisers were seen to have demonstrated a tendency to be overly optimistic. To address this bias, appraisers should make explicit, empirically based adjustments to the estimates of a project's costs, benefits, and duration. These adjustments should be based on data from similar past projects and adjusted for the unique characteristics of the project.

Optimism bias uplifts were introduced as methods of combating optimism bias in the decision-making process. They were established as a function of the level of risk that the British Department for Transport was willing to accept regarding cost overruns in transportation projects. The general principle was that the lower the level of acceptable risk, the higher the required uplift. The optimism bias uplifts should be applied to estimated budgets at the time of the decision to build.

To minimize optimism bias, preliminary findings indicated that formal and informal rules aimed at changing the established culture should be applied. The following four benefits to applying optimism bias uplifts to budgets were identified:

- Emphasis on establishing realistic budgeting as an ideal while eliminating the practice of overoptimistic budgeting as a routine.
- Introduction of fiscal incentives against cost overruns.
- Formalized requirements for high-quality cost and risk assessment at the business case stage.
- Introduction of an independent appraisal process.

Model Validation

Model validation and model calibration are not the same: Calibration demonstrates how the model (and its individual components) *replicates* observed historical data, whereas validation proposes to demonstrate how "reasonably" the model's functional forms and parameters *predict* actual observed behavior. It was noted earlier (Explanation of Performance) that the inherent model error in toll road demand forecasts was not addressed, and often masked, by existing model validation that demonstrated base year forecasts "near 100% to actual traffic" (*5*). A thorough evaluation of toll road demand and revenue forecasts was found to comprise three steps: technical quality and merits of the forecasting process, interpretation and professional judgment on forecast results, and risk analysis and sensitivity analysis on key input variables (*25*).

A "major criticism of transportation demand models is the general lack of concern for, and effort put into, the validation phase of [model development]." Time, budget, and data constraints in "typical" practice contribute to this lack of concern; however, "the improvement in predictive capabilities of transportation demand models and in the credibility of these models with decision makers, rests to a large extent on the analyst's ability to validate the procedures used." Three general approaches to model validation are described here (*12*):

- Reasonableness checks of parameters and coefficients—for example, checking whether or not a particular value is within an expected range or has the correct sign. The objective is threefold: to ensure that the model does not violate theoretical expectations and, if it does, to identify the source of the error (the model or the expectation); to ensure that the model does not exhibit any "pathological tendencies"; and to ensure that it is internally consistent (meaning that its outputs do not violate any assumptions used to generate them).

  Reasonableness checks of the model outputs also can help the user determine whether the forecasts are reasonable. For example, the projected market for a proposed tolled facility should be verified to ensure that it is reasonable. Readily available techniques, such as a select link assignment, could be used. [This technique isolates which travelers (as measured by trip origins and destinations) are projected to use a particular facility. The technique then could be used to determine how this subset of travelers would behave under changes in network configuration—for example, with or without tolls, or with or without the facility in place]. However, one consultant noted that many traffic and revenue studies do not always include this (simple) verification, or a demonstration of the time advantages offered by the proposed facility (C. Russell, personal communication, 2005).
- A rigorous test of a model's predictive capabilities is provided by using the model to predict demand for a time period other than that used for the model calibration; this assumes the availability of (at least) a second set of observed data. The use of the model to predict some historical condition can be instructive; for example, in identifying the need to better account for unforeseen influences (such as conditions of economic stagnation).
- When data for multiple time periods are not available, an alternate (but more restricted) test involves the random splitting of the "one-period" data into two sets. One set is used for calibrating the model, which is then used to predict the second set's demand. This allows the model's predictive capability to be validated against an independent set of data, although the validation is limited by the lack of temporal difference between the two sets.

The temporal, budgetary, and data constraints posed to model validation were cited by another traffic and revenue consultant as fundamental reasons for inaccuracies in toll road demand and revenue forecasts. In particular, basic data were often old, incomplete, or unreliable because of limits to sample size; in turn, this implied that the models that were developed from these data were subject to "substantial error" (D. Johnston, personal communication, Aug. 17, 2005).

Peer Reviews

Peer reviews are processes in which external experts (i.e., in modeling) can provide technical guidance and advice to the proponent's team during the course of the development of the data, models, and forecasts. Peer reviews have been a part of the toll demand and revenue forecasting process in the past, but on a very limited basis and at a very small scale (*5*). Accordingly, the value of the peer review process has been somewhat limited to date, because the process must be continuous to show any improvement or advancement of techniques. To benefit from this process, detailed reports must be prepared and independent meetings conducted with bond rating agencies to discuss the extent of the review and the results achieved (*5*).

The requirements vary for peer reviews for models in U.S. transportation planning practice. The approaches of FTA, FHWA, and TMIP are described here.

- FTA has specific requirements and standard review procedures for forecasting as part of its New Starts discretionary grant program. These review procedures were implemented to enable FTA to evaluate and rate grant applications on an unchanging, unbiased level. Projects seeking New Starts funding must first pass a locally driven, multi-modal corridor planning process, which has three key phases; alternatives analysis, preliminary engineering, and final design. The list of evaluation criteria includes operating efficiencies (e.g., operating cost per passenger mile) and cost-effectiveness (e.g., the incremental cost per hour of transportation system user benefits) (*69*).
- FHWA allocates funding on a formula basis; meaning that states and MPOs do not have to compete on a project-by-project basis for funding. As a result, the same degree of standardization is not required of forecasting procedures as in FTA's New Starts program. However, FHWA does provide technical assistance to state DOTs and to MPOs in an attempt to ensure that the travel demand forecasts used are credible and based on proper planning practice. Three types of assistance are provided (B. Spears, personal communication, Aug. 18, 2005):
  - A checklist of questions that help FHWA, state DOT, and MPO staff understand what is required of the model. FHWA staff is encouraged to ask these questions during the triennial certification reviews that are conducted with those MPOs with populations of more than 200,000.
  - The creation of a peer review team, whose responsibility is to review the forecasting process and make recommendations for improvement. These teams typically include from four to eight travel modelers from other agencies, MPOs, state DOTs, academia, or consulting firms, who meet with local planners for one or two days of review.
  - The revision of travel forecasts used in specific project documents, such as transportation plans, conformity determinations, and environmental studies.

  If a peer review is convened, then several pieces of information and documentation must be made available to the team, including an inventory of the current state of transportation in the area, key planning assumptions used in developing the forecasts, and descriptions of the methods used to develop forecasts of future travel demand (*70*).
- In addition to its core methodological research, TMIP reviewed ways to improve existing modeling processes. To this end, a peer review panel recommended several types of improvements to the practice of travel demand modeling, including the peer review process. The relevant recommendations are summarized here (*71*):
  - Land use should be integrated into multiple stages of the travel demand model, and the integration of land development patterns into the models is paramount.
  - Understanding and incorporation of freight-based activities into travel demand modeling, because it can require specialized surveys, and their effect on traffic.
  - Migration to activity-based or tour-based modeling to be conducted only with ample funding, resources, and proper documentation; otherwise, it is recommended to improve the existing trip-based models.
  - Agency creation of coordinated data collection strategies and standardization guidelines for regional modeling.
  - Improvement of data quality by supplementing existing data sources with specialized add-on surveys. This can help to complete data sets that are incomplete as a result of low survey participation or inadequate funding.
  - Consistency checks undertaken throughout the modeling process.
  - Model should be designed to be flexible enough for a variety of toll and HOV modeling policies to be evaluated.
  - Micro-simulation modeling can be used for more detailed modeling of areas that have unusual characteristics or that are highly diverse.
  - Consideration of time-of-day variables, despite current modeling difficulties.
  - Agency pooling of resources and sharing of their experiences through best practice publications.
  - High-quality documentation of the components of and assumptions in agency and region travel demand models.

One example of the successful use of a peer review, as part of an overall process, was provided by a toll authority that responded to the survey of practitioners. This authority has used its travel demand model for several studies, including feasibility, policy, investment-grade forecast, design, review or audit, and state environment analysis studies. For the analysis of the toll facility feasibility study, the existing model was updated and enhanced. The success of the forecasting has been attributed to the regular refinement of the MPO model (upon which its model is based) over a 10-year period. The demand and revenue forecasting process has a built-in critical peer review process. The toll authority has taken a proactive approach in updating and enhancing a specific aspect of the model on an annual basis; revalidating the model annually using traffic counts, origin–destination surveys, speed and/or travel time surveys, and land use inputs and network characteristics. The toll authority noted that it has recently received a rating upgrade on its revenue forecasts.

There are no formal requirements for peer reviews in toll road traffic and revenue forecasts, although the bond rating community has called for more and improved reviews (*5*). Financial backers do conduct their own "stress tests" of the revenue and financial forecasts. In addition, as part of its project oversight and credit monitoring, The Transportation Infrastructure and Innovation Act, the federal credit assistance program for major surface transportation projects, requires a project's senior debt to have the potential to achieve an investment-grade bond rating. It also requires the development of an ongoing oversight and credit monitoring plan for each project, which includes a risk analysis, and requires that traffic and revenue forecasts be updated and monitored (*72*).

In comparison, the general practice in Europe is to conduct three sets of forecasts: the grantors of the concession (the governments); the facility sponsors (proponents); and the financial backers (lenders, investors, and/or auditors) (C. Russell, personal communication, 2005). The governments' forecasts are normally considered to be overly optimistic, because they are used to develop long-range policies and plans. The proponents' forecasts are usually the most extensive, although they do not always provide the best results because they are dominated by the model. The financial forecasts (audits) are usually smaller efforts that are intended to review the proponents' forecasts (although more substantive efforts may follow if the review identifies fundamental problems). The audit relies on sensitivity tests, spreadsheet modeling, and stress testing: at the end of the process, the auditors also must assume responsibility for the forecast.

The proponents pay for their forecasts as well as those of the financial backers. As a result, the proponents try to control the latter's audit. Some proponents now bring the auditors into the process early, before the lenders are appointed; this puts some pressure on the auditors, but also provides an opportunity for them to suggest improvements early in the process and—by the proponents who have put forward their case—allows issues generally to be understood.

Conversely, in some places the use of two or more independent forecasts for proponents "has been dropped because (at double the cost) it confuses the audience," with the result that—in a "tight bidding timeframe" much effort is wasted determining who is right, rather than exploring the key risk issues and refining one approach (D. Johnston, personal communication, 2005).

CHAPTER FOUR

CHECKLISTS AND GUIDELINES TO IMPROVE PRACTICE

This chapter identifies checklists and guidelines that could be used to improve the state of the practice in toll demand and revenue forecasting. Whereas the preceding chapter reviewed practices in specific topics, the checklist and guidelines could provide a framework within which these topics can be addressed. Three examples are taken from the literature. They comprise a checklist, guidelines, and an index: the checklists and guidelines constitute lists of questions and issues that should be addressed in a toll road demand and revenue forecast, whereas the index provides a way to organize and understand the factors and parameters that influence the forecast. All are aimed at helping the facility owner, proponent, and financial analyst (and their modelers) to better understand the process and identify questions that should be asked in the development of toll road demand and revenue forecasts.

CHECKLISTS AND GUIDELINES FOR MODELS

Federal transportation planning legislation requires that each MPO develop a transportation plan as part of its planning process (*70*). A transportation plan requires forecasts of future demand for transportation services that are usually arrived at by using travel demand models. Of specific interest to the toll demand and revenue forecasting community should be the documentation and access to the planning assumptions and forecasting methods used in the travel demand modeling process. FHWA has compiled a checklist for travel demand forecasting methods, mainly with the purpose of providing a certification review team with an overview of travel forecasting methods used by MPOs. Specific examples of important planning assumptions included in the checklist are:

- Population change (should be compared with past trends and with statewide demographic control totals).
- Employment change (should be compared with past trends and with statewide economic growth control totals).
- Regional distribution of future population, employment, and land use.
- Demographic change (including automobile ownership, household income, household size, and multi-worker households).
- Travel behavior change (including telecommuting, trip chaining, and Internet shopping).

Specific examples of important forecasting methods included in the checklist are:

- Last model revision (i.e., when were new variables, new algorithms recalibrated with new data?).
- Model specification (i.e., choice of model, specification of key model coefficients).
- Calibration data (what data were used; e.g., National Household Travel Survey or Census Transportation Planning Package).
- Local survey (how was the survey conducted, what type of control?).
- Model validation (what year and data source was the model validated against?).
- Size of network.
- Number of zones.
- Non-home-based travel (e.g., freight commercial services and tourists).

One analyst identified a list of recommended enhancements, from the perspective of the financial community, which would make the results more acceptable and more likely to qualify for investment grade status. The recommendations included (*5*):

- Incorporation of a range of possible outcomes given the low probability that the base case forecast will exactly match the likely outcome.
- Further study and greater validation of value of time as an input in forecasting models.
- Further study and greater validation of the ramp-up effect on start-up toll road facilities.
- More detailed truck traffic analysis as the higher revenue margin created by trucks is an important component of a forecast, especially when trucks are projected to be a significant fraction of traffic.
- Incorporation of the risk and reward of electronic toll collection with respect to violations and toll evasion against faster throughput, ease of use, and revenue recovery through penalties.
- Enhance the investors understanding of the exposure to modeling while highlighting risk in the final product (i.e., enhancing the validation process by validating more than one year, full disclosure of model limitations, etc.).

In a review of the performance of 14 toll road projects, another financial analyst identified the key variables and inputs that he believed have had large repercussions, both positively and negatively, on toll road demand and revenue forecasts (*6*).

One key variable was economic activity. Although national economic trends were relevant, the economic activity within the region and project corridor had a greater impact. An example of this is in Harris County, Texas, where a sharp downturn in oil prices in 1986 left economic growth in the region well below the projected levels. Particularly hard hit was the downtown business district, the primary end destination for many vehicles that were projected to use the toll road, which caused the forecasted traffic demand to be considerably lower than was projected.

An input that was constant in all the successful forecasts was the use of 30% or less as projected revenue growth over the first 5 years of operation. This low projection explicitly captured the high initial demand of the road with no need for toll increases. In contrast, where a very high revenue growth rate was assumed at the start of the project, it indicated a dependency on the growth of these routes to meet the forecasted revenue. If these growth rates were not met, the lost revenues were not easily recaptured in the following years; indeed, the forecast continued to lag behind initial projections.

Other inputs and variables that appeared most crucial in the model forecasting process were time saved, the cost of travel, and the ability or willingness to pay of potential users. In summary, the most successful forecasts generally had accurate or even conservative economic forecasts with moderate anticipated growth levels. These toll roads were built in corridors that were fully developed and where congestion already existed. Another factor was that the corridor income levels were above the regional levels and time savings were in excess of 5 min.

GUIDELINES SPECIFIC TO TOLL ROAD FEASIBILITY STUDIES

The Texas Turnpike Authority (TTA), a division of the Texas DOT, provides an example of recommended guidelines for conducting traffic and revenue studies in support of toll feasibility analyses (*73*). The key goals of the guidelines were to outline the traffic and revenue reporting requirements, improve the consistency of assumptions, and improve quality assurance. Four levels of analysis were proposed (*74*):

- Conceptual—determines the potential for a toll road project to support bonds. (Expected durations of each type of study were provided and they are listed here as an indication of the level of effort and detail. The conceptual level had an estimated duration of 1–4 weeks.)
- Sketch—project-specific estimate of costs, demand, and revenues (6 weeks duration).
- Intermediate—refines the previous analysis, including a tolling plan. It is expected that demand projects would be derived from a travel demand model (4–6 months duration).
- Investment grade—“extensive and detailed” analysis “to determine its value in anticipation of proceeding to the bond market” (12–18 months duration).

The guidelines recommended a forecast period of 40 years beyond the opening date of the project. The following inputs should be taken into account (*73*):

- Average daily tolled and non-tolled volume,
- Weekday toll transactions,
- Gross annual revenue,
- Tolled length,
- Number of lanes being tolled,
- Truck percentage,
- Opening year automobile and truck toll rate,
- Toll increase increment,
- Period between toll increase, and
- Equivalent revenue days.

The guidelines noted that a lack of consistency on key assumptions affected the comparability of options. Accordingly, to help ensure consistency and improve comparability, the following parameters should be considered (*73*):

- Phased improvement or system implementation scenarios; that is, each tolling point should change in response to the addition of new tolled segments.
- The definition of the study area should encompass those transportation facilities that could influence the candidate toll project. Route classification and lane configurations of competing facilities should also be considered.
- Toll diversion assumptions, including general toll attraction and composite toll attraction. Composite toll attraction includes ramp-up, electronic toll collection, toll rate adjustments, and toll utilization.
- Toll transactions estimates are required for all four of the study levels described previously.
- Traffic growth constraints should be considered, owing to the long time frame (40 years) of the forecast. Constraints could include highway corridor capacity, competing toll facilities, economic development, etc.
- Trip rate equivalence or toll equity, which considers the average toll rate paid by the user traveling all possible origin–destination paths on the facility. The toll rates should fall within an acceptable toll rate ratio.

The TTA has prepared a series of brochures related to tolling, including a “Toll Feasibility Analysis Guide,” which summarized the four levels of analytical studies and their main characteristics (*74*).

Another TTA document noted that the major bond rating agencies looked for the following topics to be addressed as part of toll road demand and revenue forecasts (*2*):

- Land use and demographic assumptions, including population and employment information;
- Highway network and alternative routes that are both feeding the project or competing with the project;
- Weekday versus weekend traffic;
- Review of travel demand parameter assumptions;
- Trip-making characteristics;
- Truck percentage and generated revenue, because of the impact trucks can have on toll revenue;
- Peak-period versus off-peak management, especially in managed lane or congestion pricing projects;
- Value of time;
- Ramp-up period;
- Violation rate;
- Toll rates and increases;
- Point estimate forecasts; and
- Economic and political risk.

TRAFFIC RISK INDEX

One financial analyst developed a Traffic Risk Index to assess and compare the risk associated with a given traffic and revenue forecast according to 10 facility attributes. Most of the attributes are divided into subattributes. A notional scale of from 0 to 10 assessed the risk for each attribute, with higher values reflecting increasing inherent uncertainty. Descriptions are provided for each extreme to help illustrate the range of risk that would be considered for the particular subattribute. For example, the fourth attribute, "forecast horizon," refers to near-term forecasts as having the least degree of uncertainty and long-term ("30+ year") forecasts as having the greatest uncertainty. The Index was described as a "starting point for considering toll-project traffic uncertainty in a logical and consistent manner. The Index also represents a checklist that can be used to examine project-specific uncertainties and prompt appropriate enquiries (allowing the analyst to draw his or her own conclusions about the likely reliability of the resultant forecasts)" (*9*). The means of assessing the risk are determined by the user, who also can tabulate or weight the results at his or her discretion. The Index is reproduced in Table 3.

SUMMARY OBSERVATIONS

Four observations are useful in summarizing the checklists, guidelines, and indexes.

- Each attempts to introduce consistency and a systematic approach to developing traffic and revenue forecasts.
- However, neither method nor the application of the lists, guidelines, or indexes is specified or prescribed; rather, these are left to the discretion of the user.
- A large range of attributes is described.
- The types of attributes that are considered varies according to the perspective: The user (i.e., financial) community's lists and indexes generally describe the conditions and environment within which the traffic model and forecasts are developed, as well as on the assumptions and inputs, whereas the modeling community focuses on the model specification methods.

TABLE 3
TRAFFIC RISK INDEX

<table>
<tr><th>Project Attribute</th><th>0</th><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th><th>8</th><th>9</th><th>10</th></tr>
<tr><td>Tolling regime</td><td colspan="6">• Shadow tolls</td><td colspan="5">• User-paid tolls</td></tr>
<tr><td>Tolling culture</td><td colspan="6">• Toll roads well established—data on actual use are available</td><td colspan="5">• No toll roads in the country, uncertainty over toll acceptance</td></tr>
<tr><td>Tariff escalation</td><td colspan="6">• Flexible rate setting/escalation formula; no government approval</td><td colspan="5">• All tariff hikes require regulatory approval</td></tr>
<tr><td>Forecast horizon</td><td colspan="6">• Near-term forecasts requirement</td><td colspan="5">• Long-term (30+ year) forecasts</td></tr>
<tr><td>Toll facility details</td><td colspan="6">• Facility already open</td><td colspan="5">• Facility at the very earliest stages of planning</td></tr>
<tr><td></td><td colspan="6">• Estuarial crossings</td><td colspan="5">• Dense, urban networks</td></tr>
<tr><td></td><td colspan="6">• Radial corridors into urban areas</td><td colspan="5">• Ring roads/beltways around urban areas</td></tr>
<tr><td></td><td colspan="6">• Extension of existing road</td><td colspan="5">• Greenfield site</td></tr>
<tr><td></td><td colspan="6">• Alignment: strong rationale (including. tolling points and intersections)</td><td colspan="5">• Confused/unclear road objectives (not where people want to go)</td></tr>
<tr><td></td><td colspan="6">• Alignment: strong economics</td><td colspan="5">• Alignment: strong politics</td></tr>
<tr><td></td><td colspan="6">• Clear understanding of future highway network</td><td colspan="5">• Many options for network extensions exist</td></tr>
<tr><td></td><td colspan="6">• Stand-alone (single) facility</td><td colspan="5">• Reliance on other, proposed highway improvements</td></tr>
<tr><td></td><td colspan="6">• Highly congested corridor</td><td colspan="5">• Limited/no congestion</td></tr>
<tr><td></td><td colspan="6">• Few competing roads</td><td colspan="5">• Many alternative routes</td></tr>
<tr><td></td><td colspan="6">• Clear competitive advantage</td><td colspan="5">• Weak competitive advantage</td></tr>
<tr><td></td><td colspan="6">• Only highway competition</td><td colspan="5">• Multi-modal competition</td></tr>
<tr><td></td><td colspan="6">• Good, high-capacity connectors</td><td colspan="5">• Hurry up and wait</td></tr>
<tr><td>Surveys/ data collection</td><td colspan="6">• “Active” competition protection (e.g., traffic calming, truck bans)</td><td colspan="5">• Autonomous authorities can do what they want</td></tr>
<tr><td></td><td colspan="6">• Easy to collect (laws exist)</td><td colspan="5">• Difficult/dangerous to collect</td></tr>
<tr><td></td><td colspan="6">• Experienced surveyors</td><td colspan="5">• No culture of data collection</td></tr>
<tr><td></td><td colspan="6">• Up to date</td><td colspan="5">• Historical information</td></tr>
<tr><td></td><td colspan="6">• Locally calibrated parameters</td><td colspan="5">• Parameters imported from elsewhere (another country?)</td></tr>
<tr><td></td><td colspan="6">• Existing zone framework (widely used)</td><td colspan="5">• Develop zone framework from scratch</td></tr>
<tr><td>Users: private</td><td colspan="6">• Clear market segment(s)</td><td colspan="5">• Unclear market segments</td></tr>
<tr><td></td><td colspan="6">• Few key origins and destinations</td><td colspan="5">• Multiple origins and destinations</td></tr>
<tr><td></td><td colspan="6">• Dominated by single-journey purpose (e.g., commute, airport)</td><td colspan="5">• Multiple-journey purposes</td></tr>
<tr><td></td><td colspan="6">• High-income, time-sensitive market</td><td colspan="5">• Average/low-income market</td></tr>
<tr><td></td><td colspan="6">• Tolls in line with existing facilities</td><td colspan="5">• Tolls higher than the norm extended ramp-up?</td></tr>
<tr><td></td><td colspan="6">• Simple toll structure</td><td colspan="5">• Complex toll structure (local discounts, frequent users, variable pricing, etc.)</td></tr>
<tr><td></td><td colspan="6">• Flat demand profile (time-of-day, day-of-week, etc.)</td><td colspan="5">• Highly seasonal and/or peak demand profile</td></tr>
<tr><td>Users: commercial</td><td colspan="6">• Fleet operator pays toll</td><td colspan="5">• Owner–driver pays toll</td></tr>
<tr><td></td><td colspan="6">• Clear time and operating cost savings</td><td colspan="5">• Unclear competitive advantage</td></tr>
<tr><td></td><td colspan="6">• Simple route choice decision making</td><td colspan="5">• Complicated route choice decision making</td></tr>
<tr><td></td><td colspan="6">• Strong compliance with weight restrictions</td><td colspan="5">• Overloading of trucks is commonplace</td></tr>
<tr><td>Micro-economics</td><td colspan="6">• Strong, stable, diversified local economy</td><td colspan="5">• Weak/transitioning local/national economy</td></tr>
<tr><td></td><td colspan="6">• Strict land use planning regime</td><td colspan="5">• Weak planning controls/enforcement</td></tr>
<tr><td></td><td colspan="6">• Stable, predictable population growth</td><td colspan="5">• Population forecast dependent on many exogenous factors</td></tr>
<tr><td>Traffic growth</td><td colspan="6">• Driven by/correlated with existing, established, and predictable factors</td><td colspan="5">• Reliance on future factors, new developments, structural changes, etc.</td></tr>
<tr><td></td><td colspan="6">• High car ownership</td><td colspan="5">• Low/growing car ownership</td></tr>
</table>

Source: Bain and Wilkins (*9*).

CHAPTER FIVE

CONCLUSIONS

This chapter presents several conclusions and observations derived from the study. The chapter closes with suggestions for further methodological and procedural research on toll road demand and revenue forecasting taken from the literature and the survey of practitioners.

The survey of practice and the literature corroborated and detailed several issues of concern, most of which had been identified in the scope for this synthesis. Several conclusions were reached.

- Many of the problems that had been identified with the performance of traffic and revenue forecasts were related to the applications of the models, less so to methods and algorithms. In particular, assumptions regarding land use, network inputs, values of time, and other inputs; the process of reviewing models and their results; and the treatment of uncertainties and risks were most often cited in the literature in explaining why the performance problems occurred.

  It is noteworthy that much of the literature that describes these problems in the context of toll road demand and revenue forecasts comes from the financial community, rather than the transportation modeling community. This suggests a disconnect between the two communities; the latter being the "traditional" users (and developers) of the models and the former representing the new users. The financial community's concerns also parallel those of other new users, such as those involved in air quality conformity analysis, which suggest that the state of the practice in travel demand modeling has not kept pace with the issues that the models now must address. The disconnect is exemplified in different ways; for example, in the use of risk analysis (incorporating a range of outcomes) and stress tests (which assess extreme and multiple "shocks"); neither of which has been widely applied to transportation planning. Another example is the treatment of the impact of short-term economic recessions on long-range demand forecasts, which is starting to be considered. A third example is the more explicit understanding of the role of different economic influences, such as gender, age, and occupation, on toll road choice.

  It is also incumbent upon the new users to understand how the models work and how to interpret their results, as well as their inherent limitations; and it is equally incumbent on the developers of the models and their data to provide this understanding. One traffic and revenue study reviewed for this synthesis noted that "professional practices and procedures were used in the development of the traffic and revenue forecasts included in this report" as a preface to its overview of the modeling process, which was brief and did not provide many details. Doubtless this is true; however, the ensuing documentation provided very little information that could help analysts understand the input or modeling assumptions, let alone address the questions posed in the preceding chapter's checklists. On the other hand, some traffic and revenue studies provided considerably more explanation of the modeling procedures and, especially, of the input assumptions and how they were derived.
- Nonetheless, improvements in both aspects (application and method) are required to address the performance of the models in traffic and revenue forecasts.
- Although the application of state-of-the-art methodological improvements into common practice—such as activity-based models and network micro-simulation—should be expected to improve the state of the practice, it is likely that these alone will not improve the performance of traffic and revenue forecasts.

  Notwithstanding, several methodological improvements might be made. Two important improvements to the travel demand modeling process are time-of-day choice modeling and the modeling of commercial and truck traffic. The understanding of traveler behavior when faced with tolls continues to evolve and must be better understood; that is, a more comprehensive understanding of the actual determinants of choice are required, including values of time and willingness to pay when confronted with different factors (such as the toll collection method). The explicit incorporation of risk and uncertainty in all aspects of the modeling process also is needed, as is consideration of inputs and outputs in terms of ranges rather than as absolutes.

  It could be argued that each of these areas requires further research and development before it can be implemented properly (e.g., the literature indicates that time-of-day choice modeling is an emerging topic). Conversely, it also could be argued that simplified (or better) methods already exist for accounting for each topic and would represent an immediate improvement to the forecast if considered (assuming, of course, that assumptions and methods are treated transparently).

Finally, more generally, a basic prerequisite to any toll demand and revenue forecast (and to the ability to account for any of the previously cited improvements) must be the ability to model the four components of travel (generation, distribution, mode choice, and route choice) as a starting point.

- According to the literature, questions regarding the performance of the models and forecasts have been posed mainly by the financial community, rather than by the transportation modeling community (with some notable exceptions). The latter community has focused on improving the methodological basis of modeling and its underlying data, as demonstrated by the extensive literature and research on the topic. However, as suggested in the previous point, this emphasis has not generally rectified the performance problems. In other words, this suggests that there is a disconnect between the developers of the models and their users, with the latter having evolved from the traditional decision makers to those with different or more rigorous decision-making criteria.
- In turn, this suggests that those in the transportation community who are making investment decisions regarding tolled facilities do not always know which questions to ask of their modeling and forecasting efforts—in other words, the analytical and modeling capabilities available to them have not always kept pace with the needs. This was demonstrated by the large number of explanations that were cited in the literature and in the survey as causes of performance failures. In some cases, the explanations were contradictory; in particular, the financial community cited application as a key problem, whereas survey respondents cited model method as the problem. This can be explained in part by the relative newness of toll roads in some parts of the country and the corresponding lack of a long-term performance history. It also can be explained by the changing nature of the tolled facilities, in which parts of a facility (i.e., individual lanes) are now being tolled: this changes the analytical requirements significantly. The problem is exacerbated by the "confidential" or "proprietary" nature of the forecasts and methods that are developed for toll roads, and also by "optimism bias" on the part of the sponsor, local elected officials, or other advocates of the proposed toll road.
- Observers have remarked, informally, that there is no standardization in the toll road demand and revenue modeling and forecasting processes. Also, they have questioned whether such standardization could be promoted in the community. Given that this mirrors a similar lack of standardization in travel demand modeling in general, as noted, that the state of the art in modeling continues to evolve, and that there are several different and valid techniques (e.g., as in toll diversion modeling), it may be more appropriate instead to do two things. First, standardize the terminology or at least list and categorize the different definitions for key terms; and second, develop a commonly used set of questions and attributes that should be considered. As an example of the first, there is no single, commonly understood definition of what is meant by an "investment grade" traffic and revenue forecast: it may be more appropriate instead to develop a list of how different organizations understand, interpret and use this term. An example of the second is the Texas Turnpike Authority's guidance (see chapter four), which provides a practical treatment that perhaps could be reviewed for general application across the United States, taking into account the different perspectives of the owners, sponsors, and financial community. The Traffic Risk Index similarly provides a useful starting point for elaborating on the specific questions that should be asked (more precisely, the variables that should be taken into account and their impacts) in the development of toll road demand and revenue forecasts.

  In their own right, standardizing and understanding the terminology will not improve the process and results of traffic and revenue forecasts. However, these improvements will encourage practitioners and owners to understand more clearly the objectives and requirements of decision makers and financial sponsors, and ensure in turn that the components of the forecasting process are more responsive to these needs.
- Several observers have noted that "you get what you pay for." In other words, in the United States, sufficient resources have not been devoted to procuring the required data or to updating older data, or to calibrating models to the level of detail that is required. The general practice in Europe, for example, is to prepare three sets of forecasts. This clearly requires an investment on someone's part. Intuitively, better data, more detailed models, and multiple forecasts should improve model performance. Similarly, it is intuitive that a stronger role for peer review should improve the performance; however, the literature review did not uncover any evaluations or specific assessments of the effectiveness of the peer review process for modeling in general.
- It should also be noted that the comparisons in the literature focused primarily on the *revenues* as opposed to the *demand* (i.e., the traffic and its composition). The literature noted that revenue performance could be affected by changes in toll rates or by drawing on reserves, or other means; in other words, by actions that are not related directly to demand. Therefore, at least some of the available information does not accurately reflect the outputs of the travel demand model and, accordingly, the linkage between the demand forecasts and the revenue performance is not always completely direct or explicit. Accordingly, there is a need to measure the performance of the travel demand models in their own right, specifically examining how well the toll road demand models simulate each class of vehicle and traveler.

The research literature cited in this synthesis largely focused on methodological issues; notably, the understanding of the variables that affect the traveler's decision to use a toll road, consideration of probability distributions to describe these variables as a means of analyzing and managing risk, development of time-of-day choice models, simulation of value of time and the role of stated preference surveys in estimating value of time or on the development of value-of-time models based on historical data that are now becoming available. The need for continued research in these areas was inherent in the literature, with specific recommendations for research comprising the following.

The financial community and practitioners made several explicit recommendations for further research.

- Improve understanding of the impact of electronic toll collection (more generally, the type of tolling collection) on value of time.
- Incorporate risk analysis into the demand forecasting process, accounting for multiple possible inputs and outputs.
- Account for the impacts of changed economic conditions (notably, recessions and lower than expected initial demographic and economic growth).
- Improve the understanding of and the methods for estimating value of time and ramp-up, including the impact of existing congestion and expected development on travel demand and on toll road demand specifically.
- Improve the treatment of trucks and commercial vehicles in toll road modeling.
- Improve the validation of the travel demand models.
- Develop a more improved understanding of the factors and assumptions that are used to develop the demand models and of the criteria that are used to assess their performance and calibration.

A 2005 review of the practice of modeling road pricing by Spears made the following five recommendations for research.

1. Document case studies of transportation planning agencies that have incorporated road pricing in their travel models to provide details "concerning changes in model structure, data requirements, value-of-time parameters, calibration and validation considerations, and specific application results from other modeling efforts."
2. Compile and synthesize current and past empirical research on value of time and value of reliability, then compile the existing research on value of time into "an application-oriented document that provides travel modelers with reasonable ranges for [value of time], classified by income level, trip purpose, or other relevant parameters," and includes practical guidance on value-of-time adjustments (such as the impact of electronic toll collection). A similar compilation of the more limited research on value of reliability was also recommended, as well as the identification of priority areas for additional research and data.
3. Encourage data collection on travel behavior on road pricing projects. Funding for such projects should account for additional empirical data collection (notably, on value of time and value of reliability), as well as for an independent evaluation of the project.
4. Conduct basic and applied research to incorporate time-of-day and peak spreading models in current travel demand models to address the "principal limitation" in current travel demand models; that is, "the way in which they distribute daily trips by time-of-day." New methods or models are needed to allow for more precise resolution of daily trip distributions (by the hour or half-hour), perform efficient multiclass assignments over multiple time periods, and allow for a systematic shift of trips between adjacent time periods to reflect peak spreading.
5. Conduct basic research to better understand and measure the influence of traffic congestion (and the underlying factors that influence congestion on a day-to-day basis) on travel time variability. Archived operational traffic data exist to explore this relationship, although they have been largely unused for this subject.

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GLOSSARY

All-or-nothing assignment—assignment approach in which all travel demand for each origin–destination pair is assigned to the shortest time path based on uncongested travel times.

Barrier toll road—has one or more toll plazas that form a barrier across the roadway to prevent free passage. Motorists are required to pay a toll to continue, and the system usually includes large mainline toll plazas and small toll plazas at on and off ramps.

Closed barrier toll—a system that does not allow motorists to enter the roadway network without first paying a fee. Generally a payment or a ticket is issued at the entry and exit points in the roadway network.

Electronic toll and traffic management (ETTM)—the use of two-way electronic communications between moving vehicles and roadside sensors for the purposes of toll collection and other traffic management functions.

Electronic toll collection (ETC)—the use of automatic electronic vehicle identification, such as transponders, for non-stop toll collection.

Equilibrium assignment—a trip assignment algorithm that takes into account the build-up of volume and the ensuing changes in trip time when allocating trips to links. From the traveler's perspective, the assignment simulates the driver's desire to minimize overall his or her travel time (i.e., his or her travel costs) between a particular origin and destination by switching paths. Equilibrium occurs when the travel time on all possible paths for a given origin–destination is equal—that is, the driver no longer can improve his or her overall trip time by switching paths. Equilibrium is achieved, usually after several iterations, when the difference in overall travel time (i.e., in generalized cost) summed over all trips and all origin–destination pairs is very small, between the current and previous iterations (i.e., is within specified absolute and/or percentage differences).

Feed-back loops—part of the iterative modeling process where at the completion of the travel demand assignment, the resulting travel times or costs are fed back into trip generation, trip distribution, or mode split steps. The next iteration takes into account these travel costs for each origin–destination pair and recalculates the travel demand.

Goodness of fit measures—used to validate models. Commonly used measures include the following:

Absolute comparison of the absolute difference between modeled flow and observed flow, on a given link or across a screenline.

Relative comparison of difference between the modeled flow and the observed flow. That is, modeled flow divided by observed flow, with the comparison typically expressed as a percent.

GEH statistic combines the absolute and relative comparisons. It accounts for two types of error: that associated with the simulated flow (reflecting the fit of the model) and that associated with the observed flow (through data collection errors and the day-to-day variability of traffic).

The statistic is defined as:

$$\text{GEH} = \sqrt{\frac{(\text{observed flow} - \text{simulated flow})^2}{0.5 \times (\text{observed flow} - \text{simulated flow})}}$$

The GEH is properly a goodness of fit measure, rather than a statistical test. It is intended to give a quick indication of how well the model is working. It can, and normally is, applied to all model links for which observed counts are available.

R^2 is the correlation coefficient of the best-fit regression line of a plot of the modeled flows versus observed flows. This measure is commonly used to compare flows across a number of links, whether or not they are part of the same screenline or route (for example, all arterials in an urban network for which traffic counts are available). Correlation coefficients closer to 1.0 indicate a better goodness of fit.

Open barrier toll—a system that allows motorists to enter the roadway network at certain locations without immediate payment prevents the motorist from proceeding past certain points, unless a fee is paid. It can use electronic toll collection, which offers drivers the ability to pay tolls without stopping.

Open road tolling—a system with no physical toll booths. All tolling is conducted by the identification of vehicles passing under a gantry at each individual tolling point. Tolls are collected by one of two methods including electronic toll collection or video license plate identification system.

Shadow toll—a payment and revenue process where instead of charging the user directly, businesses, land holders, or government agencies reimburse the private investor by accounting for the number and type of vehicles using the road, therefore allowing the private sector to invest the capital and the beneficiaries of the toll road to pay per the usage of the facility by the public.

Stress test—used to assess the financial stability of a project (or of a portfolio of projects). The process revalues the project's financial performance according to a different set of assumptions in the face; for example, of unforeseen "shocks." Most asset markets lack a history of returns that provide sufficient information about the behavior of markets under extreme events: stress tests complement traditional financial forecasting models by testing how the project's value changes in response to "exceptional but plausible" changes in the underlying risk factors. In addition to testing "market risk" [such as toll revenues less than projected], the process also examines credit risk (losses from borrower defaults) and liquidity risks (illiquidity of assets and depositor runs). Several techniques have been developed in recent years.

Violation rate—a measure of the vehicles that are illegally evading the tolls compared with the number of vehicles using the tolled facility. Examples of toll evasion include, but are not limited to, the following: screening of license plates, using HOT lanes without the proper number of people, or using improper electronic pass with an unregistered vehicle.

APPENDIX A

Development and Administration of Survey

OVERVIEW OF METHOD

A survey was conducted regarding the practice of toll facility demand revenue estimates. This survey of practitioners was sent to four specific agency types: state departments of transportation (DOTs), toll authorities, bond rating agencies, and bond insurance agencies. The first two types represent the traditional developers and users of traffic forecasts. The inclusion of the financial community (the latter two types) was intended to capture the viewpoints and experiences of the forecasting and modeling process from as many participants involved in the process as possible.

Participants were given the option of answering directly online through a web-based survey program (Websurveyor), or completing a hardcopy of the survey, which was included in the e-mail as a pdf (in which the survey form could be returned to the consultant by mail or fax).

SURVEY OF PRACTICE

Survey Development

The survey was conducted over a two-month period in April and May 2005. Before the survey was distributed, it was necessary to establish a comprehensive outline and to test the survey to ensure that it was as accurate and target-specific as possible.

During the initial stages of the survey design, it was determined that the survey should be completed by several different types of agencies that are involved in the toll road demand and revenue estimating process. A logical way to construct the survey was to structure the questions as close-ended as possible, to provide a clear indication of what was being asked and to help in the summary process. Therefore, most of the questions were asked with a selection or list of answers and the respondent was instructed to select a single answer, or as many answers as applied, depending on the question. However, given the nature of the subject, a standard set of answers likely would not always have covered all possibilities. Therefore, for every question there was also the option of selecting "Other," with space provided to allow expansion of the respondent's answer.

The research team developed a survey focusing on state-of-the-practice applications and techniques. Specifically, important information that was targeted for acquisition was:

- Who is the respondent to the survey?
- What types of modeling processes are being used?
- What variables are being modeled?
- How are the models being calibrated and validated?
- Are there specific case studies or examples?
- What is the respondent's experience with the model forecasts?

The survey was divided into three self-contained sections (designated as Parts I, II, and III). This made the survey more "respondent friendly," to specifically target areas of interest in the modeling and forecasting processes.

Part I determined the type of agency that was responding to the survey and who from that agency was responding. It also requested a discussion of their philosophy, in terms of their use of tolling technologies, what type of facilities was tolled, etc.

Part II pertained to the forecasting model itself and its variables. This section was answered either by the original respondent, if the responding organization performed the modeling and forecasting in-house, or it could be forwarded to a consultant or the agency that actually developed or applied the model for the original responding agency. This section asked the respondent to describe in detail the type of model used and the parameters of the model in terms of inputs, structure, modeled trip purpose, calibration techniques, validation checks, etc.

Part III asked the respondent to discuss a specific example of a toll road traffic demand and revenue study carried out by the responding organization. Again, if the original respondent did not do the actual analysis, the survey could be passed to the consultant or outside agency responsible for the study. The purpose of the final section was to determine the results of the previously described model (Part II) and whether there were major or minor problems with the analysis, whether they were identified, how and if they were corrected, etc.

A pilot survey session with one respondent was conducted to assess the usability and readability of the survey before distribution to all participants. The pilot participant remotely completed the survey while speaking his/her thoughts out loud over the telephone to the research team. Issues were identified related to the clarity of the survey and its ability to extract the desired information. Minor modifications were made to the survey following the pilot survey session. Subsequently, the survey was sent to state DOTs, tolling authorities, bond rating agencies, and bond insurance agencies throughout the United States.

Contact names and e-mail addresses of the DOTs were provided by TRB, for the toll authorities by the International Bridge, Tunnel, and Tolling Association (IBTTA), and for the bond rating agencies and bond insurance agencies through the Topic Panel and other individuals. In accordance with the scope of the synthesis, the survey was directed to respondents in the United States, although it was also sent to three Canadian provincial/territorial ministries of transportation and one Canadian tolling agency that had been included in the IBTTA list. Two follow-up reminders were sent at regular intervals to those who had not yet responded. Two methods of completing the survey were provided for the practitioner. The first was to complete the survey online through a commercial online survey host (Websurveyor). The second option was to allow the practitioner to complete the survey by hand on a hard copy. To this end, a pdf version was included in the initial e-mail. The survey could be returned by mail or fax. Support was provided throughout the process by means of e-mail correspondence, as well as a toll-free telephone number distributed with the survey.

Upon review of the survey responses, follow-up telephone interviews were initiated with respondents where additional information was required or to clarify unclear or contradictory responses. Moreover, if the survey indicated an exceptional toll modeling practice, then further details were sought to document the techniques and methodology.

Discussion of Survey Response

Two unexpected problems were encountered. These constitute important findings in their own right; however, they also affected the results of the survey and the subsequent analysis.

Several respondents indicated that they used relatively straightforward spreadsheet programs to generate forecasts. It should be observed that these practices of modeling were used to forecast short-term travel demand and revenue for existing toll facilities that have been in operation for many years. Simple modeling techniques were designed to forecast short-term annual demand and revenue for operations and maintenance, based largely as an extrapolation of previous years' experience, or by using elasticity factors.

There was also an issue pertaining to the compatibility of Parts II and III of the survey. In Part II, respondents were asked to describe the application of their model and the data to a *specific* demand and revenue forecast of their choice. This focus on a single model, application, and forecast was intended to avoid confusion among those respondents that had several models, applications, or forecasts. Most respondents selected the newest model and its use in a recent toll road feasibility study, generally ensuring that only the latest modeling techniques (the state of the practice) were described. However, in Part III, the respondents were asked for their experiences with actual toll road demand and revenue; specifically, how it related to the model described in Part II. Because many respondents had chosen their newest project for Part II, they were unable to provide corresponding state-of-the-practice responses to Part III.

This raised an interesting point in general, namely that the state of the practice in toll road demand and revenue forecasting is difficult to capture definitively, because the latest methods are still unproven or at least there are few actual performance data to substantiate whether the new modeling techniques are more or less successful than previous techniques. Because of the required lengthy lead time before the completion of the design and construction of toll roads, the only models with enough data to be able to determine their successes and failures are 10 or more years old. Accordingly, a caveat must be placed on what actually constitutes the state of the practice insofar as the results of the modeling process itself are concerned, because some of the new techniques are still in their infancy and the old techniques are being changed and updated.

Of the 138 surveys that were sent, there were 55 respondents, for a response rate of 40%. The corresponding rates of return by agency are found in Table A1. Of the 55 surveys

TABLE A1
RATE OF RETURN BY AGENCY

Agencies	No. of Surveys Sent	No. of Surveys Returned	Rate of Return (%)
State DOTs	56	29	52
Tolling authorities	70	21	30
Canadian authorities	4	3	75
Bond rating agencies	3	2	67
Bond insurance agencies	5	0	0
Total	138	55	40

returned, 10 were e-mail responses indicating that the state did not own or operate, or was not planning to own or operate, a toll road.

Question I.1 of the survey asked respondents to indicate their interest or mandate in toll road facilities by selecting one of the following five options:

- We are currently or plan to be an owner/operator
- Bond rater/insurer
- Travel forecasting or other consultant/independent reviewer
- None planned or expected
- Other.

Of the remaining 45 survey respondents, 19 indicated that they were neither planning nor expecting to own or operate a toll road, and therefore did not complete the remainder of the survey. Of the remaining 26 respondents, three selected "other" (see Appendix B for detailed responses) and one of those respondents indicated that he/she could not answer the survey.

In summary, there were a total of 25 completed responses to the survey. Of these, 23 completed Part I (two bond rating agencies that responded were directed to skip Part I, and also skipped Part II), 13 respondents completed Part II, and 13 respondents completed Part III. Tables A2 and A3 summarize in more detail which types of agencies completed Part II and Part III, respectively.

Of the total number of respondents, only 23 (42%) indicated that they were currently or planning to be an owner or operator of a toll road facility. Table A4 shows the percentage for all respondents.

A complete summary of the survey results is provided in Appendix C.

TABLE A2
RESPONDENTS COMPLETING PART II

Agencies	Completed Part II
State DOTs	3
Tolling authorities	9
Canadian authorities	1
Bond rating agencies	0
Bond insurance agencies	0
Total	13

TABLE A3
RESPONDENTS COMPLETING PART III

Agencies	Competed Part III
State DOTs	2
Tolling authorities	8
Canadian authorities	1
Bond rating agencies	2
Bond insurance agencies	0
Total	13

TABLE A4
SUMMARY OF RESPONSES TO QUESTION I.1 OF SURVEY

Agencies	No. of Respondents That Currently or Plan to Be an Owner/Operator	No. of Survey Respondents	Percentage
State DOTs	7	29	24
Tolling authorities	15	21	71
Canadian authorities	1	3	33
Bond rating agencies	0	2	0
Bond insurance agencies	0	0	0

APPENDIX B
Survey Questionnaire

TRANSPORTATION RESEARCH BOARD
of the National Academies

April 7, 2005

The Transportation Research Board (TRB) is preparing a Synthesis on "Estimating Toll Road Demand and Revenue." This is being done for the National Cooperative Highway Research Program, under the sponsorship of the American Association of State Highway and Transportation Officials in cooperation with the Federal Highway Administration. The objective of this Synthesis is to provide an overview of state DOT and other highway facility owner's practices, recent literature findings, and research-in-progress addressing the subject topic.

David Kriger of iTRANS Consulting Ltd. is preparing this synthesis report under contract to TRB. To assist Mr. Kriger, *we request that you complete the attached survey or forward it to the most appropriate person(s) in your agency.* The report will serve as a resource to all states and has the potential to improve methods and technologies for estimating demand and revenues for planned toll roads. This is a very timely topic, and your agency's response to the survey is extremely important to this study. Please note that, while lengthy, the questionnaire is mostly multiple choice.

Please have the completed questionnaire and any supporting materials returned to Mr. Kriger by April 22, 2005.

The questionnaire has been provided in two formats:

1) As a web-based questionnaire that can be filled out and returned on-line, in multiple sessions if needed.
2) As a PDF file that can be printed, filled out, and faxed or mailed (*this information can be found at the end of the survey*).

If additional time or information is needed to complete the questionnaire, please contact Mr. Kriger at 888-860-1116, or me at 202-334-3245. Thank you for your assistance.

Jon Williams
Manager, Synthesis Studies
Transportation Research Board
500 Fifth Street, NW
Washington, DC 20001
phone: 202-334-3245
fax: 202-334-2081
email: jwilliams@nas.edu

Estimating Toll Road Demand and Revenue

Thank you for participating in our survey on the state of the practice in estimating toll road demand and revenue. Please complete survey by **April 22, 2005**.

The survey is divided into three parts:

- Part I asks you to provide some background information regarding your organization's interest and/or mandate in toll road demand forecasting.
- Part II asks you about your organization's travel demand forecasting models for toll road traffic and revenue forecasts and about the data and assumptions that support the models and forecasts.
- Part III asks how the model outputs have been used for toll road studies and financing, and about your experiences with the performance, accuracy, and effectiveness of the tolling forecasts.
- Parts IV and V are identical to Parts II and III, respectively. They are provided should you wish to describe more than one specific model application.

Important note: For cases in which a consultant or someone outside your organization prepared the model or forecasts, please complete Part I (background information) before asking the consultant or outside organization to complete Parts II and III.

Documentation. To support our research, we seek copies of relevant reports: For example, reports and documents that describe your travel demand forecasting model, its calibration, the underlying data upon which the model is based, the tolling forecasts for which it has been used, reviews and audits of the model and/or forecasts, and any other information that you see as being relevant.

Contact Information

The following information is needed to help us ensure that our survey has covered a broad range of perspectives. We also might need to follow-up with you for clarifications of your responses. Please be assured that your contact information will be kept strictly *confidential* and will not be disclosed to outside parties.

Name: ____________________

Title/Position: ____________________

E-mail: ____________________

Telephone Number: ____________________

Organization: ____________________

Department/Group: ____________________

Location (City/State): ____________________

Part I. Background information

I.1 What is your organization's interest and/or mandate in toll road facilities? Please check (✓) one box only.

- ☐ We are currently or plan to be an owner/operator (→ *please go to Question I.2 below*)
- ☐ Bond rater/insurer (→ *please go to Section II*)
- ☐ Travel forecasting or other consultant/independent reviewer (→ *please go to Section II*)
- ☐ None planned or expected (→ *please go to the end of the form and submit your survey*)
- ☐ Other (*please explain*): ______________________________

I.2 What types of tolled facilities does your organization currently or plan to own or operate? Please check (✓) all boxes that apply.

Facility Type	Current		Planned	
	Own	Operate	Own	Operate
Urban expressway				
Rural or intercity expressway				
HOT lane				
Bridge or tunnel				
Urban arterials				
Rural arterial highways				
Other (*please explain*): ________________				

I.3 What tolling technologies are used or are planned? Please check (✓) all boxes that apply.

Tolling Technologies	Currently Used	Planned
Traditional toll plaza (manual toll collection only)		
Toll plaza with combination of manual and electronic toll collection (EZPass, FasTrak, etc.)		
Fully electronic toll collection (transponder, record license plate)		
Other (*please explain*): ____________________		

I.4 What sources of financing were used or are planned for the construction of these toll road facilities? Please check (✓) all boxes that apply.

Source of Financing	Currently Used	Planned
Federal government (all sources)		
State government		
Local/county/district government		
Public–private partnership		
Private sector		
Bond financing		
Other (*please explain*): ________________________________		

I.5 For what purpose(s) are the generated revenues used or planned? Please check (✓) all boxes that apply.

Use of Generated Revenues	Currently Used	Planned
Facility construction		
Facility operation and maintenance		
Expansion of existing facility		
Other roads or highways		
Public transit		
Debt service on bonds		
General tax revenues (not specific to the facility)		
Other (*please explain*): ______________________________		

I.6 What are the current or planned toll structure and rates for your toll roads?

Toll Structures	Currently Used	Planned
Point toll (e.g., expressed as $/trip)		
Distance toll—fixed (e.g., expressed as $/mile)		
Distance toll—variable (e.g., expressed as $/mile)		
Other (*please explain*): _______________________________		

I.7 What is your organization's role in or use of toll road demand and revenue forecasts? Please check (✓) all boxes that apply.

- ☐ Prepares travel demand (traffic) models/forecasts
- ☐ Prepares or collects the data that are used for the travel demand models/forecasts
- ☐ Conducts peer reviews or critical reviews
- ☐ Uses the travel demand forecasts to prepare revenue forecasts or conduct a financial analysis
- ☐ Uses the travel demand forecasts to approve or ensure funding
- ☐ Other (*please describe*): ____

I.8 If your organization does not prepare its own toll road demand forecasts internally, who provides the forecasts for your use? Please check (✓) all boxes that apply.

- ☐ Consultant (→ ***Please have your consultant complete Part II and Part III.***)
- ☐ Regional MPO/COG
- ☐ State DOT

Other (*please identify*): ____

Part II. State of practice in travel demand forecasting models for toll road demand and revenue forecasts

The questions in Part II ask you to describe the application *of your models and data to a* specific *demand and revenue forecast or study of your choice.*

Examples of the scope of applications are: system-wide feasibility or policy studies, forecasts for new facilities, forecasts for extensions or widenings of existing facilities, forecasts for HOT lanes, etc. The applications could have been used for concept studies, feasibility studies, policy studies, investment grade forecasts, design forecasts, critical reviews or audits, etc.

Some organizations have developed models or forecasts for more than one application. If so, please use the most recent/up-to-date application when answering the questions below. If, for any reason, the most recent application is not a good example of the state of the practice in your organization, please pick a more appropriate example and briefly explain your selection.

II.1 Please describe the specific application for which the model was (or is to be) used.

Facility or study name: ____

Date of study or forecast: ____

Organization that prepared the study or forecast: ______________________________

(Expected) year of facility opening: ______________________________

Horizon year(s) for which forecasts were prepared: ______________________________

Location—state/county/city/town: ______________________________

Description of facility (facilities)—urban/rural, type, length, number of lanes, cross section (e.g., rural expressway, 35 miles, 6 lanes divided): ______________________________

Toll structure (point or distance toll, variable or fixed, breakdown of rates): ______________________________

II.2 To what type of analysis was the model applied? Please check (✓) all boxes that apply.

- ☐ Conceptual plan/feasibility study
- ☐ Policy study
- ☐ Alternatives analysis
- ☐ Investment grade forecast
- ☐ Design forecast
- ☐ Critical review or audit
- ☐ Risk assessment analysis
- ☐ Other (*please describe*): ______________________________

II.3 Please describe the following basic characteristics of your travel demand forecasting model. Please answer all questions and/or check (✓) all boxes that apply. (*Please also provide any relevant documentation that describes your model.*)

- Software used for the model: ______________________________
- Area covered by model: _____ ☐ square miles _____ ☐ acres

  ☐ other (*please define*): ______________________________
- Population covered by model: ______________________________
- Base year of calibration: ______________________________

II.4 Please describe the characteristics of your model's networks and zone system.

- Number of traffic zones: _______________
- Number of network links: ______________
- Number of network nodes: _____________

II.5 Please describe the types of links (tolled and not tolled) in your model's networks.

Please check (✓) all boxes that apply.

Not Tolled	Tolled
☐ Expressways	☐ Expressways
☐ Arterial roads or highways	☐ Arterial roads or highways
☐ Collector roads	☐ Collector roads
☐ Local roads	☐ Local roads
☐ Transit network	☐ Other: ___________
☐ Other: ___________	

II.6 Please describe the modes that are modeled. Please check (✓) all boxes that apply.

☐ Single-occupancy passenger vehicles (SOV)

☐ High-occupancy passenger vehicles (HOV)

☐ Vehicles in commercial use (e.g., repair vans, taxis, courier trucks, etc.)

☐ Trucks (light and heavy)

☐ Emergency/military vehicles

☐ Buses (transit, commuter, school, intercity, etc.)

☐ Passenger rail (light rail transit, commuter, intercity, etc.)

☐ Other (*please describe*): ____

II.7 Please describe the time periods modeled. Please check (✓) all boxes that apply.

☐ Weekday AM peak hour/half-hour/period

☐ Weekday PM peak hour/half-hour/period

☐ Weekday other peak hour

☐ Weekday off-peak hour

☐ Weekday 24 hour

☐ Weekend

☐ Other (*please describe*): ____

II.8 Please indicate how the peak hour is derived. Please check (✓) one box only.

- ☐ Modeled directly in demand model (no factors)
- ☐ Factors or percentages applied to trip tables before assignment
- ☐ Other (*please describe*): ______________________________

II.9 Please describe the model structure. Please check (✓) one box only.

- ☐ Traditional four-step (generation, distribution, modal split, assignment)
- ☐ Trip assignment only (no demand modeling, or demand is forecast externally to the model)
- ☐ Activity-based modeling
- ☐ Other (*please describe*): ______________________________

II.10 Does the model have feedback loops? Please check (✓) one box only.

- ☐ Yes—assignment impedances are fed back to distribution and/or modal split for ____ cycles
- ☐ Yes—other (*please describe*): ______________________________
- ☐ No feedback loops

II.11 Please describe the trip purposes modeled. Please check (✓) all boxes that apply.

- ☐ Work (commute)
- ☐ Work-related
- ☐ Out-of-town business trip
- ☐ School/education
- ☐ Shopping
- ☐ Leisure/recreation
- ☐ Personal business (e.g., medical appointment)
- ☐ Serve passenger (pick up/drop off)
- ☐ Other (*please describe*): ______________________________

II.12 Please describe the formulation of the modal split model (methods for mode choice modeling). Please check (✓) all boxes that apply.

- ☐ Logit or similar

- ☐ Diversion curve
- ☐ Factors
- ☐ Other (*please describe*): ________________________________
- ☐ No modal split model

II.13 Please describe the formulation of the trip assignment model (methods for route choice modeling). Please check (✓) one box only.

- ☐ Equilibrium assignment
- ☐ All-or-nothing
- ☐ Capacity restraint
- ☐ Other (*please describe*): ________________________________

II.14 Please describe the methods used for time choice modeling. Please check (✓) all boxes that apply.

- ☐ Peak spreading model
- ☐ Time choice model
- ☐ Arrival/departure time choice model
- ☐ Factors (e.g., peak to 24-hour factors) from surveys, traffic counts, or other sources
- ☐ Other (*please describe*): ________________________________
- ☐ No time-of-day choice models

II.15 Please describe the tolling costs that are modeled.

- ☐ Value of time: [please check (✓) all boxes that apply]
  - ☐ By mode ☐ By vehicle class ☐ By purpose
- ☐ Willingness to pay: [please check (✓) all boxes that apply]
  - ☐ By mode ☐ By vehicle class ☐ By purpose
- ☐ Other (*please describe*): ________________________________

Willingness to pay: the value of time that accounts for how much travelers value different attributes of the proposed facility, as opposed to its mere availability. Typically, willingness to pay is greater than the value of time. Reasons that have been put forward to explain the higher value include the assumed safety and convenience that the new facilities would provide.

II.16 Are variable tolls modeled? Please check (✓) one box only.

- ☐ Yes
- ☐ No

II.17 How are tolls taken into account in trip assignment (route choice)? Please check (✓) all boxes that apply.

- ☐ Generalized cost in volume-delay function
- ☐ Diversion curves
- ☐ Other (*please describe*): ______________________________

II.18 Was this model calibrated specifically for this analysis? Or was it adapted from another model? Please check (✓) all boxes that apply.

- ☐ New model was calibrated specifically for this toll demand and revenue forecast
- ☐ Model was updated/enhanced from an existing model that was calibrated for previous toll demand and revenue forecasting studies
- ☐ Model was updated/enhanced from an existing model that was calibrated for other purposes (e.g., LRTP, TIPs, etc.)
- ☐ Existing model was used as is without special adaptations
- ☐ Other (*please describe*): ______________________________
- ☐ Don't know

II.19 Are there any special or innovative features related to this application, not otherwise described above?

II.20 What data were used to calibrate or validate your model? Please check (✓) all boxes that apply.

Data	Calibration	Validation
Origin–destination survey		
Activity- or tour-based survey		
Stated preference survey		
Traffic counts		
Speed/travel time surveys		
Land use inputs		
Network characteristics		
Other (*please explain*): ______________________		

II.21 What tests were used to validate the base year model assignment results? Please check (✓) all boxes that apply.

- ☐ Comparison of ratios of simulated and observed volumes at screenlines, cutlines, cordons, etc.
- ☐ Statistical tests (R^2, RSME, GEH, etc.) comparing simulated and observed link volumes
- ☐ Comparison of simulated and observed travel times or speeds on links, facilities, corridors, etc.
- ☐ Other (*please describe*): ______________________________
- ☐ No tests/don't know

II.22 Please indicate how your model and/or toll road forecasts have been verified. Please check (✓) all boxes that apply.

- ☐ None/not done (→ *please proceed to Part III*)
- ☐ Judgment/reality check (e.g., comparison with older forecasts)
- ☐ Statistical verification
- ☐ Risk assessment
- ☐ Sensitivity tests of key parameters or inputs
- ☐ Use of ranges of forecasts
- ☐ Independent audit/critical review
- ☐ Other (*please describe*): ______________________________

II.23 Were changes, corrections, or improvements recommended for the model or the forecasts as a result of the verification?

- ☐ Yes (*please explain*): ______________________________
- ☐ No

II.24 Were these recommendations implemented?

- ☐ Yes—all
- ☐ Yes—some (*please identify*): ______________________________
- ☐ No—not implemented in current model or forecasts
- ☐ Planned for implementation in future model and forecasts

II.25 Have the results of your forecasts been accepted by the intended audience/decision makers?

- ☐ Yes, unconditionally
- ☐ Yes, with qualifications or conditions (*please explain*):

  ____

- ☐ No (*please explain*): ____

II.26 Were network micro-simulation models used in the development of demand and revenue forecasts (e.g., for a HOT lane)?

- ☐ Yes
- ☐ No

II.27 What other type(s) of models were used for this application? Please check (✓) all boxes that apply.

- ☐ Land use/economic forecasting model (*what software?*) ______________________
- ☐ Traffic operations model (*what software?*)______________________________
- ☐ Other (*please explain*): ____
- ☐ None

Part III. Experience with toll road demand and revenue forecasts

The questions in Part III refer to the application *you described in Part II.*

III.1 Please describe how your toll road demand forecasts have compared with actual demand conditions or with the expected performance of your facility.

Ramp-up forecasts versus actual conditions	☐ Traffic forecasts overstated by ______% ☐ Traffic forecasts understated by _______% ☐ Traffic forecasts within 5%
Medium-term (5–10 years) forecasts versus actual conditions (if available to the application you are describing)	☐ Traffic forecasts overstated by ______% ☐ Traffic forecasts understated by _______% ☐ Traffic forecasts within 5%
Long-term (>10 years) forecasts versus actual conditions (if available to the application you are describing)	☐ Traffic forecasts overstated by ______% ☐ Traffic forecasts understated by _______% ☐ Traffic forecasts within 5%

III.2 What impact did the differences (if any) identified in question III.1 have on the forecasts or on the use of the forecasts? Please check (✓) all boxes that apply.

- ☐ Model was recalibrated/model networks were reconfigured
- ☐ Demand forecasts were revised
- ☐ Revenue forecasts were revised
- ☐ Financing schedule was revised
- ☐ Performance indicators changed/new indicators implemented
- ☐ Tolling structure or rates were changed
- ☐ Project costs changed
- ☐ Staging or timing of project was revised
- ☐ Project postponed or cancelled
- ☐ Policies revised/new policies adopted
- ☐ Other (*please describe*): ______________________________
- ☐ No impact (forecasts accepted and used as is)

III.3 What factors influenced the performance of the forecasts identified in Question III.1? Please check (✓) all boxes that apply.

Inputs:

- ☐ Assumptions regarding land use or future base network configurations on parallel/competing routes or modes
- ☐ Availability, appropriateness, or sufficiency of data, models, or analytical capabilities
- ☐ Values used for value of time/willingness to pay and/or other monetary values
- ☐ Public and political inputs regarding land use and network assumptions
- ☐ Environmental or economic development considerations

Modeling:

- ☐ Model structure
- ☐ Process of expanding modeled time periods to annual forecasts
- ☐ Transparency/opacity in the modeling and forecasting processes
- ☐ Calibration process, coverage, and precision
- ☐ Some modes were not modeled (e.g., trucks) or were not modeled well
- ☐ “Control” over how the model outputs were used, analyzed, or interpreted

Operations:

- ☐ Staging of proposed toll facility (or other facilities)
- ☐ Actual operations and system reliability (e.g., congestion levels, operating speeds, frequency of incidents, etc.)
- ☐ Impact of tolling technology on actual traffic volumes (e.g., unreadable license plates)
- ☐ Violation rate
- ☐ Changes in policy, mandate, legislation, ownership, political environment, etc.

☐ Other (*please describe*): ______________________________

Additional Comments:

III.4 What recommendations do you have to improve the usability, accuracy, reliability, and credibility of travel demand models and forecasts for estimating toll revenues and for financing? Please check (✓) all boxes that apply.

- ☐ Improve transparency in the modeling and forecasting processes (so that decision makers are better informed)
- ☐ Improve methods for travel demand forecasting modeling
- ☐ Collect better or more data as the basis for model calibration or to monitor conditions
- ☐ Provide better training for modeling and planning staff
- ☐ Find better ways to tie modeling process to organizational/facility business or financing plan
- ☐ Conduct more risk assessments in forecasts
- ☐ Conduct more critical reviews and audits
- ☐ Other (*please describe*): ______________________________

III.5 What recommendations from previous forecasting applications did this model (for this specific application) already incorporate? Please check (✓) all boxes that apply.

- ☐ Improved transparency in the modeling and forecasting processes (so that decision makers were better informed)
- ☐ Improved methods for travel demand forecasting modeling
- ☐ Collected better or more data as the basis for model calibration or to monitor conditions
- ☐ Provided better training for modeling and planning staff
- ☐ Found better ways to tie modeling process to organizational/facility business or financing plan

- ☐ Conducted more risk assessments in forecasts
- ☐ Conducted more critical reviews and audits
- ☐ Other (*please describe*): ______________________________

III.6 Which of these recommendations do you plan to implement in your models or in your next application? Please check (✓) all boxes that apply.

- ☐ Improve transparency in the modeling and forecasting processes (so that decision makers are better informed)
- ☐ Improve methods for travel demand forecasting modeling
- ☐ Collect better or more data as the basis for model calibration or to monitor conditions
- ☐ Provide better training for modeling and planning staff
- ☐ Find better ways to tie modeling process to organizational/facility business or financing plan
- ☐ Conduct more risk assessments in forecasts
- ☐ Conduct more critical reviews and audits
- ☐ Other (*please describe*): ______________________________

III.7 What factors would prevent you from implementing these improvements? Please check (✓) all boxes that apply

- ☐ Lack of financial resources
- ☐ Lack of staff
- ☐ Lack of time
- ☐ Don't know how to go about it
- ☐ Not in our mandate
- ☐ Other priorities
- ☐ Other (*please describe*): ______________________________
- ☐ None

III.8 Are there other models that were used for other applications that you would like to describe?

- ☐ Yes (→ *please go to complete Parts IV and V*)
- ☐ No (→ *please go to Question III.8*)

Are there any other comments that you would like to make, either on topics that have not been addressed earlier or to amplify or clarify what you have already said?

Reminder: To support our research, we seek copies of relevant reports: For example, reports and documents that describe your travel demand forecasting model, its calibration, the underlying data upon which the model is based, the tolling forecasts for which it has been used, reviews and audits of the model and/or forecasts, and any other information that you see as being relevant.

The survey is now complete.

Please submit the survey by **fax** toll free at 1-888-618-4981 or by **mail** at the following address:

iTRANS Consulting Inc.
100 York Boulevard, Suite 300
Richmond Hill, ON L4B 1J8 Canada

Thank you!

Please repeat Parts IV and V if you have other models that were used for other applications that you would like to describe

Part IV. State of practice in travel demand forecasting models for toll road demand and revenue forecasts

Examples of the scope of applications are: system-wide feasibility or policy studies, forecasts for new facilities, forecasts for extensions or widenings of existing facilities, forecasts for HOT lanes, etc. The applications could have been used for concept studies, feasibility studies, policy studies, investment grade forecasts, design forecasts, critical reviews or audits, etc.

Some organizations have developed models or forecasts for more than one application. If so, please use the most recent/up-to-date application when answering the questions below. If, for any reason, the most recent application is not a good example of the state of the practice in your organization, please pick a more appropriate example and briefly explain your selection.

IV.1 Please describe the specific application for which the model was (or is to be) used.

Facility or study name: ______________________________

Date of study or forecast: ______________________________

Organization that prepared the study or forecast: ______________________________

(Expected) year of facility opening: ______________________________

Horizon year(s) for which forecasts were prepared: ______________________________

Location—state/county/city/town: ______________________________

Description of facility (facilities)—urban/rural, type, length, number of lanes, cross section (e.g., rural expressway, 35 miles, 6 lanes divided): ______________________________

Toll structure (point or distance toll, variable or fixed, breakdown of rates): ______________________________

IV.2 To what type of analysis was the model applied? Please check (✓) all boxes that apply.

- ☐ Conceptual plan/feasibility study
- ☐ Policy study
- ☐ Alternatives analysis
- ☐ Investment grade forecast
- ☐ Design forecast
- ☐ Critical review or audit
- ☐ Risk assessment analysis
- ☐ Other (*please describe*): ______________________________

IV.3 Please describe the following basic characteristics of your travel demand forecasting model. Please answer all questions and/or check (✓) all boxes that apply. (*Please also provide any relevant documentation that describes your model.*)

- Software used for the model: ______________________________
- Area covered by model: ___ ☐ square miles ☐ acres

  ☐ other (*please define*): ______________________________
- Population covered by model: ______________________________
- Base year of calibration: ______________________________

IV.4 Please describe the characteristics of your model's networks and zone system.

- Number of traffic zones: ________________

– Number of network links: ______________

– Number of network nodes: ______________

IV.5 Please describe the types of links (tolled and not tolled) in your model's networks.

Please check (✓) all boxes that apply.

Not Tolled	Tolled
☐ Expressways	☐ Expressways
☐ Arterial roads or highways	☐ Arterial roads or highways
☐ Collector roads	☐ Collector roads
☐ Local roads	☐ Local roads
☐ Transit network	☐ Other: ___________
☐ Other: ___________	

IV.6 Please describe the modes that are modeled. Please check (✓) all boxes that apply.

☐ Single-occupancy passenger vehicles (SOV)

☐ High-occupancy passenger vehicles (HOV)

☐ Vehicles in commercial use (e.g., repair vans, taxis, courier trucks, etc.)

☐ Trucks (light and heavy)

☐ Emergency/military vehicles

☐ Buses (transit, commuter, school, intercity, etc.)

☐ Passenger rail (light rail transit, commuter, intercity, etc.)

☐ Other (*please describe*): ____

IV.7 Please describe the time periods modeled. Please check (✓) all boxes that apply.

☐ Weekday AM peak hour/half-hour/period

☐ Weekday PM peak hour/half-hour/period

☐ Weekday other peak hour

☐ Weekday off-peak hour

☐ Weekday 24 hour

☐ Weekend

☐ Other (*please describe*): ____

IV.8 Please indicate how the peak hour is derived. Please check (✓) one box only.

- ☐ Modeled directly in demand model (no factors)
- ☐ Factors or percentages applied to trip tables before assignment
- ☐ Other (*please describe*): ____

IV.9 Please describe the model structure. Please check (✓) one box only.

- ☐ Traditional four-step (generation, distribution, modal split, assignment)
- ☐ Trip assignment only (no demand modeling, or demand is forecast externally to the model)
- ☐ Activity-based modeling
- ☐ Other (*please describe*): ____

IV.10 Does the model have feedback loops? Please check (✓) one box only.

- ☐ Yes—assignment impedances are fed back to distribution and/or modal split for ____ cycles
- ☐ Yes—other (*please describe*): ____
- ☐ No feedback loops

IV.11 Please describe the trip purposes modeled. Please check (✓) all boxes that apply.

- ☐ Work (commute)
- ☐ Work-related
- ☐ Out-of-town business trip
- ☐ School/education
- ☐ Shopping
- ☐ Leisure/recreation
- ☐ Personal business (e.g., medical appointment)
- ☐ Serve passenger (pick up/drop off)
- ☐ Other (*please describe*): ____

IV.12 Please describe the formulation of the modal split model (methods for mode choice modeling). Please check (✓) all boxes that apply.

- ☐ Logit or similar
- ☐ Diversion curve
- ☐ Factors
- ☐ Other (*please describe*): ____

☐ No modal split model

IV.13 Please describe the formulation of the trip assignment model (methods for route choice modeling). Please check (✓) one box only.

☐ Equilibrium assignment

☐ All-or-nothing

☐ Capacity restraint

☐ Other (*please describe*): ____________________

IV.14 Please describe the methods used for time choice modeling. Please check (✓) all boxes that apply.

☐ Peak spreading model

☐ Time choice model

☐ Arrival/departure time choice model

☐ Factors (e.g., peak to 24-hour factors) from surveys, traffic counts, or other sources

☐ Other (*please describe*): ____________________

☐ No time-of-day choice models

IV.15 Please describe the tolling costs that are modeled.

☐ Value of time: [please check (✓) all boxes that apply]

☐ By mode ☐ By vehicle class ☐ By purpose

☐ Willingness to pay: [please check (✓) all boxes that apply]

☐ By mode ☐ By vehicle class ☐ By purpose

☐ Other (*please describe*): ____________________

Willingness to pay: the value of time that accounts for how much travelers value different attributes of the proposed facility, as opposed to its mere availability. Typically, willingness to pay is greater than the value of time. Reasons that have been put forward to explain the higher value include the assumed safety and convenience that the new facilities would provide.

IV.16 Are variable tolls modeled? Please check (✓) one box only.

☐ Yes

☐ No

IV.17 How are tolls taken into account in trip assignment (route choice)? Please check (✓) all boxes that apply.

- ☐ Generalized cost in volume-delay function
- ☐ Diversion curves
- ☐ Other (*please describe*): ____

IV.18 Was this model calibrated specifically for this analysis? Or was it adapted from another model? Please check (✓) all boxes that apply.

- ☐ New model was calibrated specifically for this toll demand and revenue forecast
- ☐ Model was updated/enhanced from an existing model that was calibrated for previous toll demand and revenue forecasting studies
- ☐ Model was updated/enhanced from an existing model that was calibrated for other purposes (e.g., LRTP, TIPs, etc.)
- ☐ Existing model was used as is without special adaptations
- ☐ Other (*please describe*): ____
- ☐ Don't know

IV.19 Are there any special or innovative features related to this application, not otherwise described above?

IV.20 What data were used to calibrate or validate your model? Please check (✓) all boxes that apply.

Data	Calibration	Validation
Origin–destination survey		
Activity- or tour-based survey		
Stated preference survey		
Traffic counts		
Speed/travel time surveys		
Land use inputs		
Network characteristics		
Other (*please explain*): ____________________________		

IV.21 What tests were used to validate the base year model assignment results? Please check (✓) all boxes that apply.

- ☐ Comparison of ratios of simulated and observed volumes at screenlines, cutlines, cordons, etc.
- ☐ Statistical tests (R^2, RSME, GEH, etc.) comparing simulated and observed link volumes
- ☐ Comparison of simulated and observed travel times or speeds on links, facilities, corridors, etc.
- ☐ Other (*please describe*): ____________________
- ☐ No tests/don't know

IV.22 Please indicate how your model and/or toll road forecasts have been verified. Please check (✓) all boxes that apply.

- ☐ None/not done (→ *please proceed to Part III*)
- ☐ Judgment/reality check (e.g., comparison with older forecasts)
- ☐ Statistical verification
- ☐ Risk assessment
- ☐ Sensitivity tests of key parameters or inputs
- ☐ Use of ranges of forecasts
- ☐ Independent audit/critical review
- ☐ Other (*please describe*): ____________________

IV.23 Were changes, corrections, or improvements recommended for the model or the forecasts as a result of the verification?

- ☐ Yes (*please explain*): ____________________
- ☐ No

IV.24 Were these recommendations implemented?

- ☐ Yes—all
- ☐ Yes—some (*please identify*): ____________________
- ☐ No—not implemented in current model or forecasts
- ☐ Planned for implementation in future model and forecasts

IV.25 Have the results of your forecasts been accepted by the intended audience/decision makers?

- ☐ Yes, unconditionally
- ☐ Yes, with qualifications or conditions (*please explain*):

  ____

☐ No (*please explain*): ____________________

IV.26 Were network micro-simulation models used in the development of demand and revenue forecasts (e.g., for a HOT lane)?

☐ Yes

☐ No

IV.27 What other type(s) of models were used for this application? Please check (✓) all boxes that apply.

☐ Land use/economic forecasting model (*what software?*) ____________________

☐ Traffic operations model (*what software?*)____________________

☐ Other (*please explain*): ____________________

☐ None

Part V. Experience with toll road demand and revenue forecasts

The questions in Part V refer to the application *you described in Part IV.*

V.1 Please describe how your toll road demand forecasts have compared with actual demand conditions or with the expected performance of your facility.

Ramp-up forecasts versus actual conditions	☐ Traffic forecasts overstated by ______% ☐ Traffic forecasts understated by _______% ☐ Traffic forecasts within 5%
Medium-term (5–10 years) forecasts versus actual conditions (if available to the application you are describing)	☐ Traffic forecasts overstated by ______% ☐ Traffic forecasts understated by _______% ☐ Traffic forecasts within 5%
Long-term (>10 years) forecasts versus actual conditions (if available to the application you are describing)	☐ Traffic forecasts overstated by ______% ☐ Traffic forecasts understated by _______% ☐ Traffic forecasts within 5%

V.2 What impact did the differences (if any) identified in question III.1 have on the forecasts or on the use of the forecasts? Please check (✓) all boxes that apply.

☐ Model was recalibrated/model networks were reconfigured

☐ Demand forecasts were revised

☐ Revenue forecasts were revised

☐ Financing schedule was revised

☐ Performance indicators changed/new indicators implemented

☐ Tolling structure or rates were changed

☐ Project costs changed

☐ Staging or timing of project was revised

☐ Project postponed or cancelled

☐ Policies revised/new policies adopted

☐ Other (*please describe*): ____

☐ No impact (forecasts accepted and used as is)

V.3 What factors influenced the performance of the forecasts identified in Question III.1? Please check (✓) all boxes that apply.

Inputs:

☐ Assumptions regarding land use or future base network configurations on parallel/competing routes or modes

☐ Availability, appropriateness, or sufficiency of data, models, or analytical capabilities

☐ Values used for value of time/willingness to pay and/or other monetary values

☐ Public and political inputs regarding land use and network assumptions

☐ Environmental or economic development considerations

Modeling:

☐ Model structure

☐ Process of expanding modeled time periods to annual forecasts

☐ Transparency/opacity in the modeling and forecasting processes

☐ Calibration process, coverage, and precision

☐ Some modes were not modeled (e.g., trucks) or were not modeled well

☐ "Control" over how the model outputs were used, analyzed, or interpreted

Operations:

☐ Staging of proposed toll facility (or other facilities)

☐ Actual operations and system reliability (e.g., congestion levels, operating speeds, frequency of incidents, etc.)

☐ Impact of tolling technology on actual traffic volumes (e.g., unreadable license plates)

- ☐ Violation rate
- ☐ Changes in policy, mandate, legislation, ownership, political environment, etc.

Other (*please describe*): ______________________________

Additional Comments:

V.4 What recommendations do you have to improve the usability, accuracy, reliability, and credibility of travel demand models and forecasts for estimating toll revenues and for financing? Please check (✓) all boxes that apply.

- ☐ Improve transparency in the modeling and forecasting processes (so that decision makers are better informed)
- ☐ Improve methods for travel demand forecasting modeling
- ☐ Collect better or more data as the basis for model calibration or to monitor conditions
- ☐ Provide better training for modeling and planning staff
- ☐ Find better ways to tie modeling process to organizational/facility business or financing plan
- ☐ Conduct more risk assessments in forecasts
- ☐ Conduct more critical reviews and audits
- ☐ Other (*please describe*): ______________________________

V.5 What recommendations from previous forecasting applications did this model (for this specific application) already incorporate? Please check (✓) all boxes that apply.

- ☐ Improved transparency in the modeling and forecasting processes (so that decision makers were better informed)
- ☐ Improved methods for travel demand forecasting modeling
- ☐ Collected better or more data as the basis for model calibration or to monitor conditions
- ☐ Provided better training for modeling and planning staff
- ☐ Found better ways to tie modeling process to organizational/facility business or financing plan
- ☐ Conducted more risk assessments in forecasts
- ☐ Conducted more critical reviews and audits

☐ Other (*please describe*): ______________________________

V.6 Which of these recommendations do you plan to implement in your models or in your next application? Please check (✓) all boxes that apply.

☐ Improve transparency in the modeling and forecasting processes (so that decision makers are better informed)

☐ Improve methods for travel demand forecasting modeling

☐ Collect better or more data as the basis for model calibration or to monitor conditions

☐ Provide better training for modeling and planning staff

☐ Find better ways to tie modeling process to organizational/facility business or financing plan

☐ Conduct more risk assessments in forecasts

☐ Conduct more critical reviews and audits

☐ Other (*please describe*): ______________________________

V.7 What factors would prevent you from implementing these improvements? Please check (✓) all boxes that apply

☐ Lack of financial resources

☐ Lack of staff

☐ Lack of time

☐ Don’t know how to go about it

☐ Not in our mandate

☐ Other priorities

☐ Other (*please describe*): ______________________________

☐ None

Are there any other comments that you would like to make, either on topics that have not been addressed earlier or to amplify or clarify what you have already said?

Reminder: To support our research, we seek copies of relevant reports: For example, reports and documents that describe your travel demand forecasting model, its calibration, the underlying data upon which the model is based, the tolling forecasts for which it has been used, reviews and audits of the model and/or forecasts, and any other information that you see as being relevant.

The survey is now complete.

Please submit the survey by **fax** toll free at 1-888-618-4981 or by **mail** at the following address:

iTRANS Consulting Inc.
100 York Boulevard, Suite 300
Richmond Hill, ON L4B 1J8 Canada

APPENDIX C

Summary of Survey Responses

Part I. Background information

I.1 What is your organization's interest and/or mandate in toll road facilities? Please check (✓) one box only.

	Responses*
We are currently or plan to be an owner/operator	21
Bond rater/insurer	2
Travel forecasting or other consultant/independent reviewer	0
None planned or expected	19
Other (*explanation below*):	3

*Note: There were also 10 agencies who responded by e-mail citing various reasons why they were unable to complete the survey at the time it was sent. A total of 45 agencies submitted the survey.

Comments related to the three respondents who selected "Other":

1.	[A state DOT] is planning a feasibility study
2.	[A responding DOT] proposed merger with [a tolling authority]
3.	[A state DOT] is working to determine the feasibility of tolling, but there is not have enough detail to answer these questions

I.2 What types of tolled facilities does your organization currently or plan to own or operate? Please check (✓) all boxes that apply.

Facility Type	Currently Own	Currently Operate	Plan to Own	Plan to Operate
Urban expressway	8	7	11	11
Rural or intercity expressway	2	2	6	5
HOT lane	0	0	2	2
Express toll lane	2	1	1	1
Bridge or tunnel	8	8	6	4
Urban arterials	0	0	2	2
Rural arterial highways	1	1	2	2
Other (*explanation below*):	3			

Comments related to the three respondents who selected “Other”:

1.	*Currently Own*—Toll supported bridges
2.	*Not Stated*—[A tolling authority] currently operates 90 centerline-meters
3.	*Not Stated*—3 toll bridges, including 2 at the border

I.3 What tolling technologies are used or are planned? Please check (✓) all boxes that apply.

Tolling Technologies	Currently Use	Plan to Use
Traditional toll plaza (manual toll collection only)	5	1
Toll plaza with combination of manual and electronic toll collection (EZPass, FasTrak, etc.)	13	10
Fully electronic toll collection (transponder, record license plate)	2	7
Other (*explanation below*):	4	

Comments related to the four respondents who selected “Other”:

1.	*Not Stated*—Study only at this time
2.	*Not Stated*—We also have coin machines
3.	*Not Stated*—High-speed electronic toll collection lanes are used
4.	*Plan to Use*—Open road tolling

I.4 What sources of financing were used or are planned for the construction of these toll road facilities? Please check (✓) all boxes that apply.

Source of Financing	Currently Use	Plan to Use
Federal government (all sources)	7	9
State government	7	11
Local/county/district government	4	5
Public–private partnership	4	7
Private sector	1	0
Bond financing	15	11
Other (*explanation below*):	8	

Comments related to the eight respondents who selected “Other”:

1.	*Plan to Use*—Any funding sources will be explored
2.	*Currently Used*—Development impact fees
3.	*Not Stated*—State funds for some [rights-of-way] and [for maintenance]
4.	*Not Stated*—Project conceived as public–private partnership, but rejected in favor of bonds

5.	*Currently Used*—Excess revenues
6.	*Currently Used*—Toll revenue
7.	*Plan to Use*—Development impact fees
8.	*Plan to Use*—Blank

I.5 For what purpose(s) are the generated revenues used or planned? Please check (✓) all boxes that apply.

Use of Generated Revenues	Currently Use	Plan to Use
Facility construction	10	11
Facility operation and maintenance	15	13
Expansion of existing facility	9	8
Other roads or highways	2	4
Public transit	2	2
Debt service on bonds	14	12
General tax revenues (not specific to the facility)	1	1
Other (*explanation below*):	1	0

Comments related to the three respondents who selected "Other":

1.	*Currently Used*—Operations and investment for other [a tolling authority] facilities through consolidated bonds
2.	*Not Stated*—Bond proceeds other roads and open space
3.	*Not Stated*—Public partnership projects

I.6 What are the current or planned toll structure and rates for your toll roads?

Toll Structures	Currently Use	Plan to Use
Point toll (e.g., expressed as $/trip)	11	6
Distance toll—fixed (e.g., expressed as $/mile)	3	3
Distance toll—variable (e.g., expressed as $/mile)	2	4
Other (*explanation below*):	8	

Comments related to the eight respondents who selected "Other":

1.	*Not Stated*—[A state DOT] has no toll facilities
2.	*Not Stated*—Per axle toll
3.	*Not Stated*—Probably a mixture
4.	*Not Stated*—Variable structure

5.	*Not Stated*—Barrier system ~ 0.1 per mile
6.	*Not Stated*—Under study at this time
7.	*Not Stated*—Too early in development stage to determine
8.	*Currently Used*—Time of day and class of vehicle

I.7 What is your organization's role in or use of toll road demand and revenue forecasts? Please check (✓) all boxes that apply.

	Responses
Prepares travel demand (traffic) models/forecasts	8
Prepares or collects the data that are used for the travel demand models/forecasts	9
Conducts peer reviews or critical reviews	5
Uses the travel demand forecasts to prepare revenue forecasts or conduct a financial analysis	14
Uses the travel demand forecasts to approve or ensure funding	10
Other (*explanation below*):	7

Comments related to the seven respondents who selected "Other":

1.	Manage and review consulting studies
2.	Revenue forecast and bond financing
3.	Policy and master plans
4.	Procures travel demand and finance analyst consultant services
5.	Use traffic and revenue studies to establish financial feasibility of proposal project
6.	Sell bond in the financial market
7.	Revenue forecasts are based on historical receipts

I.8 If your organization does not prepare its own toll road demand forecasts internally, who provides the forecasts for your use? Please check (✓) all boxes that apply.

	Responses
Consultant	13
Regional MPO/COG	2
State DOT	1
Other (*explanation below*):	3

Comments related to the three respondents who selected "Other":

1.	A consultant will do eventually

2.	Not yet determined; likely a consultant
3.	N/A

Part II. State of practice in travel demand forecasting models for toll road demand and revenue forecasts

II.1 Please describe the specific application for which the model was (or is to be) used.

The following information was needed to help us ensure that our survey has covered a broad range of perspectives. We also needed to follow-up with respondents for clarifications of responses. In the survey the respondent was assured that the answers to this question would be kept strictly *confidential* and would not be disclosed to outside parties. Therefore no responses are provided for this question.

II.2 To what type of analysis was the model applied? Please check (✓) all boxes that apply.

	Responses
Conceptual plan/feasibility plan	3
Policy study	2
Alternate analysis	6
Investment grade	6
Design forecast	3
Critical review or audit	2
Risk assessment analysis	1
Other (*explanation below*):	6

Comments related to the six respondents who selected "Other":

1.	Operating budget
2.	State environmental analysis
3.	RTP/ITP
4.	Operating revenue forecast
5.	Project year 2005 yearly volumes at the seven toll plazas
6.	Toll revenue and demand forecasting for existing facilities

Note: RTP/ITP = regional transportation plan/intermodal transportation plan.

II.3 Please describe the following basic characteristics of your travel demand forecasting model. Please answer all questions and/or check (✓) all boxes that apply.

	Software Used for the Model	Area Covered by the Model	Population Covered by the Model	Base Year of Calibration
Response #1	MINUTP	6-county [state] metro region	~ 2.5 million	2000
Response #2	TranPlan		5.3 million	2000
Response #3	Transcore proprietary and Excel	Vehicles per minute		
Response #4	TranPlan	4,700 square miles	1.8 million	1997 calibrated annually for [a tolling authority]
Response #5	Cube Voyager	3,968 square miles	3.8 million	2000 calibration/ 2005 validation
Response #6	Microsoft Excel	N/A	N/A	2004
Response #7	TranPlan	6,288 square miles	3.2 million	2001
Response #8	TranPlan	65 square miles	9.2 million	2003
Response #9	Microsoft Excel	[Two] counties bordering toll plaza		1998–2004
Response #10	Econometric models estimated in reviews and operationalized in Microsoft Excel	1,500 square miles	18 million	2003 (updated annually)
Response #11	EMME/2	2,750 square miles	4,306,700	1995
Response #12	EMME/2	9,000 square kilometers (3,745 square miles)	5.5 million	1996
Response #13	EMME/2	4,200 square miles	2.5 million	2000

II.4 Please describe the characteristics of your model's networks and zone system.

	No. of Traffic Zones	No. of Traffic Links	No. of Network Nodes
Response #1	437	[No response]	[No response]
Response #2	3,043	55,000	20,000
Response #3	1	7	7
Response #4	2,036	27,501	12,575
Response #5	1,740	40,000	30,000
Response #6	0	1	0
Response #7	953	17,400	6,300
Response #8	3,378	35,000	25,000

Response #9	No formal model	No formal model	No formal model
Response #10	[No response]	8 toll plazas	[No response]
Response #11	986	61,000 one-way	15,000
Response #12	1,700	40,000	12,000
Response #13	2,600	10,309	18,836

II.5 Please describe the types of links (tolled and not tolled) in your modelís networks. Please check (✓) all boxes that apply.

Type of Links	Not Tolled	Tolled
Expressways	9	10
Arterial roads	9	1
Collector roads	9	0
Local roads	7	0
Transit networks	3	0
Other (*explanation below*):	7	

Comments related to the seven respondents who selected "Other":

1.	*Not Stated*—HOV
2.	*Tolled*—Bridge
3.	*Not Stated*—[State] 400 only tolled facility
4.	N/A
5.	*Tolled*—Bridge tunnel
6.	*Tolled*—Bridges and tunnels
7.	*Not Tolled*—Interstate (limited access)

II.6 Please describe the modes that are modeled. Please check (✓) all boxes that apply.

	Responses
Single-occupancy passenger vehicle (SOV)	9
High-occupancy passenger vehicle (HOV)	7
Vehicles in commercial use (e.g., repair vans, taxis, courier trucks, etc.)	4
Trucks (light and heavy)	8
Emergency/military vehicles	0
Buses	5
Passenger rail	3

Other (*explanation below*):	3

Comments related to the three respondents who selected "Other":

1.	Airport
2.	All vehicle types listed above are forecasted, but distinct models are used to project revenue-paying autos, buses, light trucks, and heavy trucks.
3.	Passenger cars with no specified vehicle occupancy

II.7 Please describe the time periods modeled. Please check (✓) all boxes that apply.

	Responses
Weekday AM peak hour	9
Weekday PM peak hour	8
Weekday other peak	2
Weekday off-peak	8
Weekday 24 hour	5
Weekend	2
Other (*explanation below*):	7

Comments related to the seven respondents who selected "Other":

1.	Weekday night period
2.	Peak season weekday
3.	Aggregate monthly
4.	Entire 365 day year
5.	All time periods broken out for each vehicle-type forecast; however, distinct models by time period are factored by relevant activity data to arrive at time-of-day forecasts.
6.	Midday (9 a.m.–3 p.m.) and nighttime (6 p.m.–6 a.m.)
7.	Nighttime (NT)

II.8 Please indicate how the peak hour is derived. Please check (✓) one box only.

	Responses
Modeled directly in demand model (no factors)	3
Factors or percentages applied to trip tables before assignment	4
Other (*explanation below*):	5
Non-response	1

Comments related to the five respondents who selected "Other":

1.	Peak hour not modeled
2.	Factors applied to daily assignment
3.	N/A
4.	Provided by MPO
5.	Percentage applied to peak period to get peak hour

II.9 Please describe the model structure. Please check (✓) one box only.

	Responses
Traditional four-step (generation, distribution, modal split, assignment)	4
Trip assignment only (no demand modeling, or demand is forecast externally to the model)	3*
Activity-based modeling	1
Other (*explanation below*):	5
Non-response	0

*Note: One respondent to this option (trip assignment only) commented that the "MPO provides trip tables obtained from the regional model."

Comments related to the five respondents who selected "Other":

1.	Traditional four-step plus toll diversion
2.	Projection
3.	Existing volumes, growth rate, estimated increase/decrease due to specific development or detour
4.	Econometric model for traffic projection by vehicle type and facility type
5.	Non-traditional four-step with toll trips as mode choice

II.10 Does the model have feedback loops? Please check (✓) one box only.

	Responses
Yes—assignment impedances are fed back to distribution and/or modal split for cycles	6*
Yes—other	0
No feedback loops	7
Non-response	0

*Note: Two respondents that selected the first option commented as follows: (1) "1 cycle for mode share only," and (2) "Yes—other → Mode Choice."

II.11 Please describe the trip purposes modeled. Please check (✓) all boxes that apply.

	Responses
Work (commute)	7
Work-related	7
Out-of-town business	2
School/education	6
Shopping	7
Leisure/recreation	6
Personal business (e.g., medical appointment)	5
Serve passenger (pick up/drop off)	2
Commercial vehicles (i.e., trucks, etc.)	2
Other (*explanation below*):	8

Comments related to the eight respondents who selected "Other":

1.	Home-base other, non-home-base, air [passengers]
2.	Home-base other/non-home-base other
3.	Major tourist centers are special generators
4.	N/A
5.	Work/business-related and non-work/other
6.	None
7.	All trip purposes are modeled by vehicle type (auto, bus, light truck, heavy truck) for each crossing
8.	Non-home-based non-work (NHBNW), home-base other (HBO)

II.12 Please describe the formulation of the modal split model (methods for mode choice modeling). Please check (✓) all boxes that apply.

	Responses
Logit or similar	6
Diversion curve	0
Factors	4
No modal split model	3*
Other (*explanation below*):	3

*Note: One respondent to the fourth option (no modal split model) commented that "Assignment based on vehicle trip tables."

Comments related to the 3 respondents who selected "Other":

1.	N/A
2.	Trip tables provided by MPO
3.	Revealed preference (origin–destination) survey

II.13 Please describe the formulation of the trip assignment model (methods for route choice modeling). Please check (✓) one box only.

	Responses
Equilibrium assignment	8
All-or-nothing	1
Capacity restraint	1
Other	2
Non-response	1

Comments related to the two respondents who selected "Other":

1.	N/A
2.	Capacity and time-value of motorists to select nearby toll bridge or further free bridge

II.14 Please describe the methods used for time choice modeling. Please check (✓) all boxes that apply.

	Responses
Peak spreading model	1
Time choice model	1
Arrival/departure time choice model	0
Factors from surveys, counts, or other sources	6
No time-of-day choice models	4
Other (*explanation below*):	2

Comments related to the two respondents who selected "Other":

1.	N/A
2.	Mode choice is run by the MPO

II.15 Please describe the tolling costs that are modeled.

	Value of Time*	Willingness to Pay*	Other*
Mode	4	0	0

Vehicle class	4	2	2
Purpose	4	2	1

*Note: One respondent who did not select any option commented "N/A."

Comments related to the three respondents who selected "Other":

1.	*Vehicle Class*—Automobiles have choice to use lightweight bridge in some cases. Trucks generally do not have a nearby alternative.
2.	*Vehicle Class*—By vehicle class. Toll and fuel prices are controlled for in the econometric model.
3.	*Purpose*—Travel time, travel cost, and income modeled as mode choice utility equations classified by trip purpose and time of day.

II.16 Are variable tolls modeled? Please check (✓) one box only.

	Responses
Yes	3
No	10
Non-response	0

II.17 How are tolls taken into account in trip assignment (route choice)? Please check (✓) all boxes that apply.

	Responses
Generalized cost in volume-delay function	4
Diversion curve	5
Other (*explanation below*):	3

Comments related to the three respondents who selected "Other":

1.	N/A
2.	Generally following existing automobile choice from existing data
3.	Toll elasticities are estimated from observed response to toll changes and variable pricing.

II.18 Was this model calibrated specifically for this analysis? Or was it adapted from another model? Please check (✓) all boxes that apply.

	Responses
New model was calibrated specifically for this toll demand and revenue forecast	2

Model was updated/enhanced from an existing model that was calibrated for previous toll demand and revenue forecasting	4
Model was updated/enhanced from an existing model that was calibrated for other purposes (e.g., LRTP, TIPs, etc.)	6*
Existing model was used as is without special adaptations	1
Don't know	0
Other (*explanation below*):	1

*Note: One agency that selected the third option commented “[Toll Authority] revalidates annually.”

Comments related to the one respondent who selected “Other”:

1.	NTTM model is supported by information provided by the MPO

II.19 Are there any special or innovative features related to this application, not otherwise described above?

Response #1	Incorporated toll diversion curves into previously calibrated model
Response #2	The [state] toll facilities model is used to address queuing and delay at plazas
Response #3	Toll diversion model
Response #4	Trip reduction/consolidation factors due to tolling existing free bridge crossing
Response #5	The model is updated periodically to account for the behavioral changes in the [state] metropolitan area.
Response #6	This is the sixth annual projection completed. After the end of the year, actual toll volume is compared with projected toll volume revenue for the year, and growth rates are adjusted accordingly.
Response #7	The model allows scenario development/sensitivity testing of economic variables and assumptions regarding electronic payment utilization. A separate value pricing model has been developed that allows for estimation of traffic/revenue impacts of pricing changes by vehicle class, hour, method of payment, and crossing.
Response #8	A major shortcoming of a planning-level regional model is that traffic operations on each link operate independently of every other link. That is, there is a certain level of delay associated with a link that results from the traffic volume and link capacity only. The reality of external influences such as traffic from merging roadways or downstream blockages are not reflected in the regional model since queuing impacts from these situations are an important component of travel delay along the expressway during peak hours, it was necessary to modify link capacities in those areas where queue buildup is significant.
Response #9	Auto trips split into toll and non-toll components by trip purpose and time of day in the mode choice step

Note: Nine of 13 respondents to Part II answered this question.

II.20 What data were used to calibrate or validate your model? Please check (✓) all boxes that apply.

Data	Calibration	Validation
Origin–destination survey	5	7
Activity- or tour-based survey	2	1
Stated preference survey	3	3
Traffic counts	8	10
Speed/travel time surveys	3	9
Land use inputs	2	6
Network characteristics	3	6
Other (*explanation below*):	2	3

Comments related to the five respondents who selected "Other":

1.	*Calibration*—Electronic toll collection perception
2.	*Calibration*—Characteristic of toll users
3.	*Validation*—Toll impedance
4.	*Validation*—Electronic toll collection perception
5.	*Validation*—Characteristic of toll users

II.21 What tests were used to validate the base year model assignment results? Please check (✓) all boxes that apply.

	Responses
Comparison of ratios of simulated and observed volumes at screenlines, cutlines, cordons, etc.	10
Statistical tests (R sq., RSME, GEH, etc.)	7
Comparison of simulated and observed travel times or speeds on links, facilities, corridors, etc.	8
No tests/don't know	2
Other (*explanation below*):	3

Comments related to the three respondents who selected "Other":

1.	*K* factors adjusted to reflect origin–destination
2.	Compared actual vs. projected volumes from previous study
3.	Sensitivity analysis

II.22 Please indicate how your model and/or toll road forecasts have been verified. Please check (✓) all boxes that apply.

	Responses
None/not done	5*

Judgment/reality check	8*
Statistical verification	2
Risk assessment	2
Sensitivity tests of key parameters or inputs	7*
Use of ranges of forecasts	1
Independent audit/critical review	2
Other (*explanation below*):	2

*Note: One respondent to the first, (none), second (judgment), and fifth (sensitivity tests) commented that "Tolling not in place yet."

Comments related to the two respondents who selected "Other":

1.	Validated against existing conditions
2.	Observed traffic

II.23 Were changes, corrections, or improvements recommended for the model or the forecasts as a result of the verification?

	Responses
Yes (*explanation below*)	5
No	3
Non-response	5

Comments related to the five respondents who selected "Yes":

1.	[No response]
2.	The model is updated periodically
3.	Econometric models were respecified when realistic out-year forecast growth rates were not achieved by vehicle type. Quarterly forecasts are now being developed to refine annual forecast errors and improve on variance reporting throughout the year.
4.	[No response]
5.	Model refinements in validation

II.24 Were these recommendations implemented?

	Responses
Yes—All	4
Yes—Some (*explanation below*)	1
No—Not implemented in current model forecasts	0
Planned for implementation in future models and forecasts	0

Non-response	8

Comments related to the one respondent who selected "Yes—Some":

1.	Additional data are needed for high-speed electronic toll collection

II.25 Have the results of your forecasts been accepted by the intended audience/decision makers?

	Responses
Yes, unconditionally	7*
Yes, with qualification of conditions	1
No (*explain*)	0
Non-response	5

*Note: One respondent to the first option commented that "Bonds have been rated on 3 occasions."

II.26 Were network micro-simulation models used in the development of demand and revenue forecasts (e.g., for a HOT lane)?

	Responses
Yes	0
No	8
Non-response	5

II.27 What other type(s) of models were used for this application? Please check (✓) all boxes that apply.

	Responses
Land use/economic forecasting model (*software used listed below*)	2
Traffic operations model (*software used listed below*)	1
Other (*explanation below*):	3
None	1

Comments related to the six respondents who selected "Land Use/Economic Forecasting Model" or "Traffic Operations Model" or "Other":

1.	*Land use/economic forecasting model*—Proprietary
2.	*Traffic operations model*—HCM for the environmental studies
3.	*Land use/economic forecasting model*—DRAM/EMPAL
4.	*Other*—Independent economic review

5.	*Other*—National/regional economic forecast variables from Global Insight and Economy.com
6.	*Other*—A logit modeling software

Part III. Experience with toll road demand and revenue forecasts

III.1 Please describe how your toll road demand forecasts have compared with actual demand conditions or with the expected performance of your facility.

	Traffic Forecasts Overstated	Traffic Forecasts Understated	Traffic Forecasts within 5%
Ramp-up forecasts vs. actual conditions	1	0	7
Medium-term (5–10 years) forecasts vs. actual conditions	0	1	4
Long-term (>10 years) forecasts vs. actual conditions	0	0	2
Corresponding ramp-up percentage	50%	—	—
Corresponding medium-term percentage	—	24%	—
Corresponding long-term percentage	—	—	—

III.2 What impact did the differences (if any) identified in Question III.1 have on the forecasts or on the use of the forecasts? Please check (✓) all boxes that apply.

	Responses
Model was recalibrated/model networks were reconfigured	2
Demand forecasts were revised	2
Revenue forecasts were revised	2
Financial schedule was revised	1
Performance indicators changed/new indicators implemented	0
Tolling structures or rates were changed	0
Project costs changed	0
Staging or timing of project was revised	1
Project postponed or canceled	1
Policies revised/new policies adopted	0
No impact (forecasts accepted and used as is)	7*
Other (*explanation below*):	2

*Note: One respondent to the eleventh option (no impact) commented "Facility not tolled yet."

Comments related to the two respondents who selected "Other":

1.	Annual updates and peer reviews
2.	Anticipated revenues are used to determine upcoming revenues. If revenues are overstated, some projects may be postponed.

III.3 What factors influenced the performance of the forecasts identified in Question III.1? Please check (✓) all boxes that apply.

Inputs:

	Responses
Assumptions regarding land use or future base network configurations on parallel/competing routes or modes	5
Availability, appropriateness, or sufficiency of data, models, or analytical capabilities	4
Values used for value of time/willingness to pay and/or other monetary values	6
Public and political inputs regarding land use and network assumptions	2
Environmental or economic development considerations	2
Other (*explanation below*):	1

Comments related to the one respondent who selected "Other":

1.	Economic climate

Modeling:

	Responses
Model structure	4
Process or expanding modeled time periods to annual forecasts	4
Transparency/opacity in the modeling and forecasting processes	1
Calibration process, coverage, and precision	2
Some modes were not modeled (e.g., trucks) or were not modeled well	0
"Control" over how the model outputs were used, analyzed, or interpreted	2
Other (*explanation below*):	1

Comments related to the one respondent who selected "Other":

1.	Validity of models for financing purposes

Operations:

	Responses
Staging or proposed facility (or other facilities)	2

Actual operations and system reliability (e.g., congestion levels, operating speeds, frequency of incidents, etc.)	4
Impact of tolling technology on actual traffic volumes (e.g., unreadable license plates)	4
Violation rate	3
Changes in policy, mandate, legislation, ownership, political environment, etc.	1
Other	0

Additional Comments:

Response #1	Consideration of the factors above were among the reasons the [state toll road] forecast has been successful [factors checked included inputs table (first three responses reading from top to bottom), modeling table (the first four and the six responses), operations table (first four responses)].
Response #2	Not a standard link–node model (only check the 1 and 3 responses reading from top to bottom of the inputs table)

Note: Two of 13 respondents to Part III answered this question.

III.4 What recommendations do you have to improve the usability, accuracy, reliability, and credibility of travel demand models and forecasts for estimating toll revenues and for financing? Please check (✓) all boxes that apply.

	Responses
Improve transparency in the modeling and forecasting processes (so that decision makers are better informed)	4
Improve methods for travel demand forecasting modeling	8
Collect better or more data as the basis for model calibration or to monitor conditions	8
Provide better training for modeling and planning staff	5
Find better ways to tie modeling process to organizational/facility business or financing plan	3
Conduct more risk assessments in forecasts	7
Conduct more critical reviews and audits	4
Other (*explanation below*):	1

Comments related to the one respondent who selected "Other":

1.	More direct relationship to economic factors that determine travel demand

III.5 What recommendations from previous forecasting applications did this model (for this specific application) already incorporate? Please check (✓) all boxes that apply.

	Responses
Improve transparency in the modeling and forecasting processes (so that decision makers were better informed)	3
Improve methods for travel demand forecasting modeling	4
Collect better or more data as the basis for model calibration or to monitor conditions	6
Provide better training for modeling and planning staff	2
Find better ways to tie modeling process to organizational/facility business or financing plan	1
Conduct more risk assessments in forecasts	1
Conduct more critical reviews and audits	2
Other (*explanation below*):	2

Comments related to the two respondents who selected "Other":

1.	Simplicity
2.	More direct relationship to economic factors that determine travel demand

III.6 Which of these recommendations do you plan to implement in your models or in your next application? Please check (✓) all boxes that apply.

	Responses
Improve transparency in the modeling and forecasting processes (so that decision makers were better informed)	1
Improve methods for travel demand forecasting modeling	5
Collect better or more data as the basis for model calibration or to monitor conditions	7
Provide better training for modeling and planning staff	1
Find better ways to tie modeling process to organizational/facility business or financing plan	2
Conduct more risk assessments in forecasts	4
Conduct more critical reviews and audits	1
Other	0

III.7 What factors would prevent you from implementing these improvements? Please check (✓) all boxes that apply

	Responses
Lack of financial resources	5
Lack of staff	1
Lack of time	4
Don't know how to go aboutit	0
Not in our mandate	1
Other priorities	5

None	2
Other	0

III.8 Are there other models that were used for other applications that you would like to describe?

	Responses
Yes	0
No	10
Non-response	3

Are there any other comments that you would like to make, either on topics that have not been addressed earlier or to amplify or clarify what you have already said?

Response #1	The adaptation of the MPO models for use by this agency has been refined over a 10-year period. The forecasts results are review monthly against actual reviews. This application has been brought before the rating agencies on numerous occasions and forecast review have not been a bond rating issue as the forecasts are consistently 2%–5% lower than actual. The agency recently received a rating agency upgrade on the strength of the last bond presentation and the appropriately conservative nature of the revenue forecasts. The process of forecasting revenues benefits from a built-in peer review process and rigorous annual updates used for the traffic engineers annual revenue forecasts. These forecasts are used to set the agencies annual operating budget. Every year, a specific aspect of the model is focused on. Examples include sub-area land use updates, new data on high-speed electronic toll collection performance, or updates to remain consistent with the regional transportation models.
Response #2	[A tolling authority] does not employ a computer-based travel demand and forecasting model. Rather, we perform manual projections and analysis to support our current operations and possible changes to toll structure.
Response #3	Most of this survey does not apply directly to [bond rating agency], and we have experience working with forecasts generated by too many different models to address the problems we have had with each of them individually, but I think that most of the recommendations in this survey would be helpful for most if not all of the forecasts we have worked with, especially for start-ups.
Response #4	Part II asks for details on "state-of-the-practice" travel demand forecasting models. Part III asks for ramp-up, medium and long-term model results of the same model described in Part II. These parts are in conflict. Traffic and revenue forecasts leading to project decisions are prepared years before those projects are chosen, designed, and constructed. The required lead time is easily 10 years. So to be able to answer Part III, the survey asks us to pick a model application that is at least 10 years and most likely +20 years old. Models of such lineage cannot be considered as "state-of-the-practice" by any stretch of the imagination. We have chosen to respond to Part II with what we consider to be our most advanced model development (i.e., our state-of-the-practice) achievements. The traffic and revenue forecasts produced in this manner are for projects that have no traffic history simply because they are still in production. Therefore, we are unable to provide corresponding "state-of-the-practice" responses for Part III.

Note: Four of 13 respondents to Part III answered this question.

Other comments were made by respondents who only completed Part I or Part II of the survey. These are documented here:

Response #5	[State DOT] is presently in the process of selecting consultants to perform toll feasibility studies for three locations. We do not now have any toll facilities owned/operated by the state.
Response #6	We are new. We would like a copy of the results when complete if possible.
Response #7	[A state DOT] has only three toll facilities: [three bridges]. Our statewide travel demand model has not recently been used to forecast traffic over these crossings. Traffic forecasts for future studies at proposed new border crossings will probably be the subject of special contracts, and will probably not be sensitive to the impact of toll rates, since there are no untolled alternatives to the crossings: Our statewide model contains no provision for testing toll alternatives or making toll-road forecasts, other than to change the impedance on links proposed as toll routes. It has never been used for this purpose. No toll-road projects are under study in Michigan, and none are foreseen.
Response #8	No consultant performing toll forecasting at this stage of the project
Response #9	[State] toll roads were built in the 1950s, 60s, and 70s. Of the 10 constructed, tolls remain only on 2. There have been discussions involving the future use of tolls on existing facilities and also on project tolls; however, no detailed analysis has been undertaken at this time.
Response #10	[State] is planning on owning/operating a toll facility with [a state DOT] when they either get funds to complete their portion or when state law allows them to own/operate a toll facility.

APPENDIX D

Characteristics of Recorded Toll Roads

Authority/Tollway	Description
Florida's Turnpike Enterprise/ Sawgrass Expressway	• New 23-mile outer loop road in Broward County with an original toll per mile rate of 6.5 cents. There was no projected toll increase (2).
North Texas Tollway Authority/Dallas North Tollway	• 5.1-mile extension to existing 9.8-mile tollway in Dallas/Colin counties with an original toll per mile charge rate of 7.1 cents. There was no projected toll increase (2).
Harris County Toll Road Authority/Hardy	• New 21.7-mile road with an original toll per mile rate of 9.2 cents. There was no projected toll increase (2).
Harris County Toll Road Authority/Sam Houston	• New 27.5-mile outer loop road with an original toll per mile rate of 7.6 cents. There was no projected toll increase (2).
Illinois State Toll Highway Authority/Illinois North South Tollway	• New 17-mile road in Dupage/Will counties with an original toll per mile rate of 5.7 cents. There was no projected toll increase (2).
Orlando–Orange Expressway Authority/Central Florida Greenway North Segment	• Initial 5.1-mile part of beltway in East Orlando with an original toll per mile rate of 9.9 cents. There was a projected toll increase in the second year (2). Toll rate reduced and new beltway segment added in year 4, which were not in the original forecast (1).
Orlando–Orange Expressway Authority/Central Florida Greenway South Segment	• Additional 7 miles of beltway in east Orlando with an original toll per mile rate of 7.1 cents. There was no projected toll increase (2). New beltway segments added in years 4/5, which were not part of the original forecast (1).
Oklahoma Turnpike Authority/ John Kilpatrick	• New 9.5-mile north partial outer loop in Oklahoma City with an original toll per mile rate of 8.0 cents. There was no projected toll increase (1).
Oklahoma Turnpike Authority/ Creek	• New 7.0-mile southern bypass in Tulsa with an original toll per mile rate of 7.2 cents. There was no projected toll increase (1).
Mid-Bay Bridge Authority (FL)/Choctawhatchee Bay Bridge	• Choctawatchee Bay Bridge connects the Niceville area in the vicinity of White Point with Destin peninsula near Piney Point, in Okaloosa County. The project was scheduled to open in October of 1993, but opened 3 months early (14,15).
Orlando–Orange Expressway Authority/Central Florida Greenway Southern Connector	• 21-mile beltway in South Orlando with an original toll per mile rate of 9.5 cents. There was no projected toll increase (2).

Authority/Tollway	Description
State Road and Tollway Authority (GA)/GA 400	• New 6.2-mile road in north Atlanta/Fulton counties with an original toll per mile rate of 7.8 cents. There was no projected toll increase (1).
Florida's Turnpike Enterprise/ Veteran's Expressway	• New 15-mile expressway in northwest Hillsborough County with an original toll per mile rate of 8.3 cents. There was a projected toll increase in year 5; however, the proposed toll increase was postponed (1).
Florida's Turnpike Enterprise/ Seminole	• 12-mile north segment of eastern Orlando beltway with an original toll per mile rate of 12.5 cents. The proposed toll increase in year 5 was postponed (1).
Transportation Corridor Agencies (CA)/Foothill North	• 7.4-mile southern extension of existing Portola and Antonio parkways in Orange County with an original toll per mile rate of 13.3 cents. There was a projected toll increase in year 7. A new beltway segment was added in years 4/5, which was not part of the original forecast and therefore the data from years 4/5 was marked as NR (nor reported) due to incompatibility (1).
Osceola County (FL)/Osceola County Parkway	• Extends 12.4 miles east–west of the Florida turnpike from Osceola to Reedy Creek (Disney World) with an original toll per mile rate of 12.1 cents. There was a projected toll increase in year 3 (1).
Toll Road Investment Partnership (VA)/Dulles Greenway	• 14 miles in Loudon County, Northern Virginia, near Dulles Airport. An original toll per mile rate of 12.0 cents was used and there was a projected toll increase in year 4: toll rate increased in years 4/5 (1).
Transportation Corridor Agencies (CA)/San Joaquin Hills	• 14 miles that travels Costa Mesa to San Juan Capistrano; bypass of El Toro Y on I-5. An original toll per mile rate of 13.8 cents was used and there was a projected toll increase in year 4 (1).
North Texas Tollway Authority/George Bush Expressway	• 30.5 miles in the northern half of Dallas metropolitan area with an original toll per mile rate of 10.7 cents. There was no projected toll increase (1).
Transportation Corridor Agencies (CA)/Foothill Eastern	• 15-mile extension of existing Foothill North project and extension of Route 91 near Riverside County, connecting I-5 and I-55. An original toll per mile rate of 18.0 to 21.7 cents was used and there was a projected toll increase in year 3 (1).
E-470 Public Highway Authority (CO)/E-470	• 46 miles in the eastern perimeter of Denver; short segment coming off of I-25 in southeast Denver. An original toll per mile rate of 14.0 cents was used and there was a projected toll increase in year 3 (1).
Florida's Turnpike Enterprise/ Polk	• 25 mile partial loop around Lakeland/Winterhaven with an original toll per mile rate of 11.1 cents. There was a projected toll increase in year 5 (1).

Authority/Tollway	Description
Santa Rosa Bay Bridge Authority (FL)/Garcon Point Bridge	• 7.5 miles of roadway, plus 3.5 miles of bridge in Pensacola for a total of 11 miles. An original toll per mile rate of 16.1 cents was used and there was a projected toll increase in year 5 (1).
Connector 2000 Association (SC)/Greenville Connector	• I-85 bypass extending 16 miles from I-85 to I-385 in Greenville, South Carolina. The project opened early and the year 1 data represents the first 9.5 months, annualized for 2002. An original toll per mile rate of 9.5 cents was used and there was a projected toll increase in year 3 (1).
Pocahontas Parkway Association (VA)/Pocahontas Parkway	• Route 895 Connector extends from the current eastern terminus of Chippenham Parkway (SR-150) at I-95 to a connection with I-295 southeast of Richmond International Airport. It would include a major high-level bridge across the James River and improved access to Richmond International Airport and the overall I-64 corridor (18,19).
Northwest Parkway Public Highway Authority (CO)/ Northwest Parkway	• The Northwest Parkway extends about 11 miles southwest from the northern terminus of E-470 at I-25 to the intersection of 96th Street and SH-128 in the Interlocken area of Broomfield, Colorado (20,21).

Abbreviations used without definitions in TRB publications:

AAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI–NA	Airports Council International–North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	Air Transport Association
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S.DOT	United States Department of Transportation