Background and Purpose of the Forum

Road pricing has become increasingly attractive as a source of revenue to renew and expand highway infrastructure, as a revenue stream that can bring private money to public infrastructure investments, and as a mechanism for managing traffic congestion and its impacts. The growing gap between transportation infrastructure needs and available revenues is an important motivation. The availability of reliable vehicle identification technologies (i.e., RFID tags) is a key facilitator. The success of pricing schemes in a variety of cities around the world suggests that experience supports theory, and such favorable outcomes can build social and political support.

Forecasting traveler responses to pricing is a challenge because of the large errors in both demand and cost estimates associated with infrastructure projects in general, and transportation facilities in particular. Forecasting errors are at best embarrassing, and at worst may result in substantial financial losses. The market for accurate forecasting has expanded beyond government agencies now that private money is being invested in road systems. The private sector demands forecasting accuracy because of the risk of real money losses. At the same time, private investors seem better able than government to address and accommodate forecast uncertainty.

In parallel with the growing U.S. and worldwide interest in road pricing and private financing, the state of the art in travel behavior modeling has advanced considerably in the past two decades. New, behaviorally-based tools, more theoretically sound and more complex than traditional tools, have been the subject of much research, some development, and somewhat less implementation.

For all of these reasons, it was particularly timely to bring together experts in road pricing and demand forecasting to assess where we are and where we should go to enhance the ability to plan, predict, and make decisions about road pricing schemes. The specific intent of this conference was twofold:

- To provide a setting for travel demand modelers to share experiences representing road pricing in forecasting models, and
- To develop ideas for needed research in this field.

Overview of the Discussion Papers

The forum was focused around five discussion papers:
Spear points out that three firms dominate the market of providing investment grade forecasts in support of privately financed road pricing schemes. The approaches used tend to focus at the corridor level around a specific facility and predict route and sometimes mode shifting in response to road pricing. This can involve the use of traditional models or specialized diversion curves that are dependent on good estimates of the value of travel time. Spear’s research priorities include well-documented case studies, ways to assess the value of reliability (travel time consistency) as well as travel time, and improved ways to model user-system dynamics.

Zmud discusses data requirements for pricing analyses from the perspective of a broad history of road tolling and the motivations for it. She reminds us of the importance of understanding the audiences for pricing studies and their different needs. She focuses on data needs, recognizing that models and data evolve together, and each can be a constraint on the other. She distinguishes between the needs for policy analysis (emphasizing political and public acceptance and thus the need for attitudinal data), strategic decisions about the allocation of benefits and costs, and tactical financial planning for specific facilities. Zmud advocates conducting planned experiments, collecting before-after data, and developing locally accurate measures of the value of time and reliability. She identifies a need for data standardization to promote shared use and meta-analyses.

Pendyala’s paper focuses on specific modeling tools available to represent behavioral response to road pricing schemes, linking emerging models to specific pricing-driven behaviors. He posits that past forecasting errors may be attributable to flaws in underlying (4-step) models, as well as to overly optimistic assumptions about system performance and traveler response. He advocates tour-based demand models to accommodate trip reorganization within a tour; activity models to reflect the range of traveler adaptations to price structures that vary in time and space; dynamic traffic assignment to capture time varying route choice behaviors; and microsimulation for representing road conditions – including effects of toll collection methods – more accurately. He offers examples
of such models as indicative of the potential to advance the state of the practice. Like Zmud, he supports formal experimentation, data collection, analyses, and model formulation – learning from experience and building the knowledge base.

Kriger points out that since private money has begun to flow into public roadways, financial feasibility analysis has become an increasingly important function for travel demand forecasting, and the financial community has become our new partner in the highway planning and investment field. He offers a brief critique of the 4-step process in such applications and lists some of the more promising models and methods for forecasting toll road demand. He emphasizes the need to focus on the behavioral responses to pricing, to represent the effects of time of day more realistically, and to consider the impacts of pricing on commercial vehicles. Consistent with other papers prepared for this conference, Kriger underscores the importance of good estimates of value of time, which may vary with characteristics of the traveler, the trip, and time of day.

Kriger recognizes the importance of anticipating the nature and uncertainties associated with the toll facility startup period, advocates stress tests to explore worst case outcomes, and suggests the use of Monte Carlo techniques to take advantage of historical information on outcome uncertainties to guide decisions.

He offers a comprehensive checklist for practitioners engaged in toll facility revenue forecasting to support development and application of methods as well as interpretation of results. It includes questions on the decisions to be made, expected markets, available models and data, scenario assumptions, validity of value of time estimates, assumptions about the startup period, land use, the economy, and risk management techniques.

Kriger concludes with the suggestion for industry-wide guidelines on data and forecasting methods for use in toll financing studies; this parallels Zmud’s proposal for data standards to promote consistency and shared learning.

Vovsha, Davidson, and Donnelly identify the most important planning needs associated with different pricing strategies and link these to the most promising models and methods. In line with the other papers, they advocate tour and activity based models, dynamic traffic assignment, and microsimulation as the tools of choice. They remind us of the behavioral importance of price levels and fee collection schemes, and of the impacts of subsequent demand changes on travel time and reliability. They offer a classification scheme for pricing forms, and assess the degree to which the 4-step and more advanced approaches to modeling are responsive to expected behavioral outcomes.

This paper identifies important modeling challenges, specifically, accounting for reliability; considering the heterogeneity of users and their values of time; and dealing with time of day variations and peak spreading. They identify these basic approaches for modeling responses to pricing: use of generalized cost (time +
money + reliability) in assignment models; use of binary choice models to describe traveler choice of toll facilities; and modeling use of tolled facilities as an additional option in the hierarchy of alternatives. They conclude that the best contemporary starting point for toll facility evaluation is a well-calibrated, advanced regional modeling system. This can be enhanced with additional local surveys, including state preference data, to modify forecasts. However, representing the full spectrum of pricing outcomes will require a shift to the more advanced tools identified by all of the authors.

Presentation of each paper was followed by a discussion by panel of experts including public agency modelers and planners, consultants in transportation modeling, academic researchers, and specialists in revenue forecasting and financial feasibility studies. An integrated interpretation of the papers, panels, and discussions is presented below.

Interpretation of the Forum

This conference revealed a lack of confidence in our current demand forecasting methods and their application in the context of a growing need for the information produced by those methods, and yet no indication of a commitment to invest in better forecasting tools. It was reported that, “Congress doesn’t consider transportation planners to be experts...” Investors and their advisors give forecasts of revenues for proposed toll-financed facilities a 25% “haircut” to guard against excessive optimism that may have been common in past predictions. It was said that “we are using less data now,” and we heard reports that budget cuts threaten key data sources such as the Commodity Flow Survey and the National Household Travel Survey. At the same time, we heard that in some applications the state of the practice in travel forecasting is well behind the state of the art. Together, these points suggest a need for investments in and improvements to methods for forecasting traveler responses to road pricing and the feasibility of tolled facilities.

Still, projects get done, investors are able to make choices, and private money comes to the table in increasing amounts, along with private scrutiny at a level seemingly higher than the skepticism applied to strictly public choices. There is an active market for risk analyses to manage the uncertainty in forecasting. This seems healthy; if the demand models don’t get it right, we can prepare for them to get it wrong, anticipate the errors and, where necessary and appropriate, capitalize them in the marketplace.

Financiers appear to have confidence in the revenue forecasts of only a few consultants, who use proprietary techniques not subject to the scrutiny of peer review and publication. Thus, even if these consultants do get it right, the rest of the profession does not benefit from their special expertise. The tools used by these consultants are concerned not only with making forecasts more accurate,
but also with finding ways to protect investors from the consequences of large forecasting errors.

This conference was made more useful by the presence of some inside forecasters, along with advisors to the investment community who have been anointed to go behind the curtain to examine the proprietary forecasting methods for their clients. While we did not come away with any proprietary tools, we have a general sense of approaches used to make and assess private forecasts, to treat forecasting uncertainties, to make use of the experiential knowledge base, and to manage financial risks. The use of subjective probabilities, meta-analysis of many outcomes in the knowledge base, and Monte Carlo techniques to utilize historical information on forecasting errors offer ways to use available knowledge to test and improve the accuracy of demand and revenue forecasts. Indeed, mainstream transportation planning and decision making would also benefit from the regular and systematic application of such methods of risk management.

Still, a fundamental message is that we need better – more responsive and more accurate – forecasting tools to support:

- Facility and policy design decisions – what should we do, for whom, when should we do it and at what level?
- Impact evaluation, including effects on congestion and throughput, equity, the incidence and importance of suppressed trips, development outcomes, and the implications for environmental quality and energy consumption;
- Financial feasibility analysis and forecasts of return on investment (ROI) required by risk sharing owners.

Better forecasts will not always be correct, but they should protect us against the most serious errors – financial loss for private investors, social loss to the public when the performance is deficient or the impacts too onerous, and political loss to decision makers associated with failure. The penalty functions for forecasting errors are asymmetrical: an ROI too low is worse than one that is too high; impacts too high are worse than impacts too low. This may tell us where to look for trouble, though the asymmetries may conflict for different outcomes and stakeholders.

Forecast quality is a function of several factors:

\[
\text{Forecast Quality} = f(\text{data, models, modelers, } \varepsilon)
\]

While models are key to forecasting, both models and data must advance together to improve the state of the art (see Figure 1). A solid underlying concept – a model – is important to guide data collection. The concept itself usually comes from data collected earlier.
Data to identify, quantify, and model the impacts of existing pricing schemes are essential to understanding behavioral relationships and building the next generation of models. The right data are clearly necessary to drive contemporary forecasting tools, whether traditional or innovative.

To be useful, data must be salient – describing a stimulus-response situation that is similar to the forecast case. In the context of this conference, stimulus-response means before-after data showing behavioral reactions to changes in pricing and/or some other factor, collected in a setting that is the same as, or similar to, the application setting. Useful data must also be timely (recent – the context has changed radically in the past decade) and detailed (i.e., behavioral). Data must capture the complexity of travel choices; for example, in response to price changes, travelers may change modes, times of travel, routes, trip chains, destinations, activity patterns, and in the long run, auto ownership and location. And we should collect pricing information – price paid as well as attitudes and willingness to pay – in travel surveys.

While good data are important, it can be difficult to secure the resources to collect it. Sometimes decision makers are not interested in before-after data because they do not want to pay to measure their mistakes, but that is the kind of data we need to build the foundation for better forecasts. The Service and Methods Demonstration program of the Urban Mass Transportation Administration was a programmatic approach to data collection that is worth emulating.

Economies achieved by cutting back on thoughtful data collection can viewed as deferred debt: the absence of good data will amplify future forecasting errors, which may be manifest as direct costs or discouraged investment. As a community, we should look for and highlight examples of the value of quality data in decision making to build the case for experimentation and data collection.
Models with realistic fidelity are essential to produce accurate forecasts. Traveler decision processes are complex, dynamic, and iterative, and thus it is not logical to expect models to be simple. In this context it is increasingly difficult to defend continued use of the static 4-step travel demand forecasting process. For example, individuals’ value of time varies with personal and household situational factors. Time of day is a key variable in the response to time-varying road pricing schemes. These and other characteristics of the decision process are likely to lead us to activity- and tour-based models, dynamic traffic assignment, and microsimulation. In the long term, road pricing can be expected to produce land use impacts, which calls for advanced location modeling.

Some conference participants argued that it is easy to adopt and apply these new models, but change is difficult, and we are not all equally prepared for it. For some practitioners, and in some settings, converting to state of the art forecasting tools sensitive to the outcomes of road pricing and other policies will be a major challenge. The federal government does not mandate particular tools – a policy that probably encourages innovation and reduces the likelihood that an entire fleet of models and subsequent decisions may suddenly face recall. Still, some participants at this conference felt that more objective guidance about choice and application of models would help, though that might need to come from a TRB policy study or from recommendations by other professional organizations.

Demonstration projects where pricing is introduced and behavioral responses are measured and analyzed can serve as a test bed for evaluating existing methods, provide a foundation for developing better tools, and accelerate innovation in travel forecasting. To promote widespread adoption, new forecasting tools need to be proven in more pedestrian settings, not just in those MPOs at the cutting edge of methodology. These activities will require resources in an era when support for new tools is slim.

The modelers are also important contributors to forecast quality. Their experience and credibility bring wisdom and creativity to their work and influence the quality certification that goes along with the forecast. It has been argued that a good modeler has a greater impact on decisions that the model results alone, for the modeler brings experience, perspective, and judgment to bear on the numbers. The modeler adds the Bayesian twist that amplifies the value of the model. Thus, no matter how accurate the models become, there will always be room at the table for an experienced modeler, and as road pricing advances, experience in that application will become especially valued.

The error term listed in the conceptual quality equation reminds us that no forecast will be perfect, and we will always need ways to anticipate errors and manage the associated risk. Human behavior and its variations are too complex to expect perfection in travel forecasts.
Areas of Agreement

Although the forum did not define a formal consensus, there was good agreement on several key points:

- Road pricing is becoming more common for a variety of reasons.
- Accurate forecasting of behavioral responses to pricing schemes is important to plan, to ensure financial feasibility, and to draw private money into public infrastructure.
- Forecasting for pricing is complicated because tolls can influence many aspects of travel behavior.
- The 4-step modeling system does not capture behavioral responses to pricing options because pricing has dynamic, interactive effects that cannot be accommodated in a linear, static modeling system.
- Specialist forecasters have developed a variety of tools for predicting traveler response to road pricing schemes. While the methods are proprietary, it appears that they rely on fairly traditional tools, adapted with special data collection efforts and experience with other projects, and challenged with a range of assumptions to identify likely risks.
- There are forecasting models available that should provide better results because they are differently sensitive to factors involved in road pricing. These are:
  - Activity-based travel models that consider intra-household activity choices and scheduling that may be affected by pricing;
  - Tour-based models that account for trip chaining that may result from road pricing schemes;
  - Microsimulation that captures pricing effects on level of service that result from demand changes and delays caused by the toll collection process;
  - Dynamic traffic assignment that considers the temporal dynamics that occur when road pricing is based on time of day and/or congestion levels.
- Those tools are at various stages of practical application. Some are available for immediate use; others require more work to advance them into practice. Some of this work is research. Some is testing, accumulation of experience, and education.
- All of this requires resources:
  - Additional money
  - Skilled (trained) modelers
  - Better data – more detailed, more timely, including attributes of travelers, values derived from behavior (time, reliability), stated preferences and attitudes toward tolling.
Transition Paths

The transition path to new and better forecasting tools that balance realistic complexity with ease of use should be considered explicitly. For example, we might consider this evolutionary sequence:

1 - 3 years: In the near term, as a profession, we should work toward extending the application of state of the art tools, e.g., activity based modeling and dynamic traffic assignment. This can happen through professional organizations such as the Transportation Research Board, The American Planning Association, and the Association of Metropolitan Planning Organizations. The discussion needs to extend to organizations more closely tied to decision makers, such as AASHTO and the National Association of Regional Councils. This road pricing forum, and the upcoming TRB conference on Innovative Travel Modeling (May, 2006), are examples of settings for identifying opportunities to bring state of the art tools to the practice.

These organizations and activities should encourage the application and careful documentation of more advanced models in practical planning settings. Applications should not be limited to testing pricing schemes, because the objective is to move these models into routine practice so that they are more readily applied to road pricing and other options.

One limitation, of course, is that organizations and individuals further from the start of the art are less likely to participate in these events and applications. The training programs of the USDOT Travel Model Improvement can be used to reach out to these practitioners, as can continuing education programs at universities around the country.

The perspective of financial analysts should be included in this effort by engaging those professionals in transportation activities and organizations. Experts from this field have made real progress in the use of existing tools with enhanced data, and, perhaps more importantly, they can teach us something about risk management that will make it feasible, if not easier, to make decisions in the face of uncertainty. Specifically, risk management is a way to cope with uncertainty in forecasting when it cannot be readily reduced with more sophisticated models.

To grow better theory and models, we need better data on traveler behavior, preferences, and valuation of time and reliability. Such data can be gathered in routine surveys collected by MPOs, and some of it can come from larger scale efforts such as the NPTS. Data describing behavioral dynamics in the context of price and service change will be most useful for model calibration and valuing time and reliability. Therefore, it will be important to establish a before-after data collection program around pricing experiments, thus building the knowledge base to improve the quality of forecasts.
Finally, we should promote discussion of ethical issues in forecasting through professional forums and more frequent peer reviews to drive out intentional or careless bias in predictions.

3 – 10 years: The intermediate term should see the growing use of truly dynamic, integrated models, TRANSIMS and its derivatives, that better reflect the complexity of traveler decisions. We need federal guidance and resources to promulgate such tools, just as we did to move the 4-step modeling system into practice. That 4-step process should enter phased retirement, saved for specialized uses and historical expositions. The Portland TRANSIMS application will provide a foundation for further advancement of this simulation model, and that effort should be completed and documented. Other applications are planned or underway, and they, too, should be documented to encourage wider use of such model systems.

Beyond 10 years: We need to begin investing now in the long term development of NEXTSIMS, a household-activity based modeling system that is lighter, smaller and faster than TRANSIMS, supporting rapid application in new places through the use of generic and parametric activity databases, stronger understanding of model and parameter transferability, and automated network coding. This new class of models should be built on behavioral theory grown from the expanding knowledge base of before-after studies. The intellectual resources are in place to accomplish this. It is now necessary to guide and support them. Just as in the case of TRANSIMS, this next generation of models will not grow of its own accord, although the seeds for it are in place in the work on activity models and dynamic traffic assignment now underway.

All of this will take additional, directed resources for data collection, model development, field testing, and documentation. We should view this not simply as a way to achieve significant improvements in travel forecasting, but as a pathway to innovative options, including road pricing and other policy initiatives, and as a way to support more informed transportation investment choices. This will take a concerted effort of public and private interests, modelers and practitioners, to achieve real advances in both the tools of forecasting and the ways in which we apply them.