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Information Requirements for Transportation Economic Analysis

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Preface

In March 1997, the Transportation Research Board (TRB) and the Bureau of Transportation Statistics (BTS) sponsored a conference on information needs to support state and local decision making into the 21st century. That conference addressed the matter of data requirements generally, and recognized the need for future specialty conferences and workshops to address data requirements for specific aspects of transportation decision making.

The conference described in these proceedings, "Information Requirements for Transportation Economic Analysis," was one of several activities growing out of the 1997 event. This conference was sponsored by TRB and BTS in cooperation with the American Association of State Highway and Transportation Officials and the Association of Metropolitan Planning Organizations.

This report was prepared by Miriam Roskin, Roskin Consulting, on behalf of the Conference Steering Committee, and was reviewed and approved by that committee. The report was then reviewed by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the National Research Council's Report Review Committee. The purpose of this independent review was to provide candid and critical comments to identify areas in which the report could be improved and to ensure that it has met institutional standards for objectivity, evidence, and responsiveness to its charge. The review comments and draft manuscript remain confidential to protect the integrity of the process.

Thanks are due to the following individuals for their participation in the review of this report: Cameron Gordon, American Council on Intergovernmental Relations; Lester A. Hoel, University of Virginia; John P. Poorman, Capital District Transportation Committee, Albany, New York; and Ronald W. Tweedie, New York State Department of Transportation. Although the reviewers have provided constructive comments and suggestions, responsibility for the content of this report rests with the authoring committee and the institution.

The conference sponsors extend special thanks to the following individuals for their contributions to the conference: Alan Pisarski, consultant, for moderating the conference plenary sessions; Curtis Wiley, Fannie Mae, for his leadership as the first chair of the Conference Steering Committee; and Miriam Roskin, for her invaluable assistance in writing and producing these conference proceedings.

Contents

OVERVIEW

Conference Summary 3

Findings of the Conference Steering Committe 9

Introduction: Addressing a Tripartite Dilemma 12

KEYNOTE REMARKS

Transportation Conditions: A Top Concern of the Public 17
David Winstead

Importance of Transportation Information: Canada's Experience 19
Roger Roy

SETTING THE STAGE

Recent Developments in Economic Information 25
Transportation Satellite Accounts and Capital Stocks Accounts, *Barbara M. Fraumeni*
Rate of Return and Productivity Studies, Commodity and Passenger Flow Data, and American Community Survey, *Rolf Schmitt*
Economic Analysis at the State, Metropolitan, and Project Levels, *Alan E. Pisarski*

Relevance of Economic Analysis for Decision Making 30
Importance of Communicating Research Results, *John W. Fuller*

Why Information Matters 32
West Virginia: A Rural Point of View, *Samuel Bonasso*
Getting the Message Across About Transportation and Economic Development, *Dennis Lebo*

KEY TOPICS ADDRESSED BY WORKING GROUPS

Producing the Findings 37

How Levels of Transportation Investment Affect Economic Health 38
Presentation, *Randall W. Eberts*
Working Group Findings

Economic Evaluation for Decision Making on Transportation Projects,
Programs, and Policies 41
Presentation, *Randall J. Pozdena*
Working Group Findings

Estimation of Revenues from Use Charges, Taxes, and Other Sources of Income 44
Presentation, *David Gillen*
Working Group Findings

Proposed Research Statements

Responses 49
Marlon Boarnet
Hank Dittmar
Pete Hathaway
Kevin Heanue

Texts 53
Group 1: Levels of Investment and Economic Health
Group 2: Economic Evaluation
Group 3: Revenue Forecasting

Resource Papers

Strategies for Measuring Productive Highway Capital Stocks 71
Barbara M. Fraumeni

Information for Transportation Economic Analysis: State of the Art
and Relevance for Decision Making 93
John W. Fuller

How Levels of Investment in Transportation Affect Economic Health 97
Randall W. Eberts

Selecting Public Transportation Projects: Informational Requirements 114
Randall J. Pozdena

Estimating Revenues from User Charges, Taxes, and Fees:
Identifying Information Requirements 128
David Gillen

Appendix A: Steering Committee Biographical Information
and Committee Liasons 150

Appendix B: Conference Participants 152

Overview

Conference Summary

Findings of the Conference Steering Committee

Introduction: Addressing a Tripartite Dilemma

Overview

Conference Summary

In August 1999, participants of the Conference on Information Requirements for Transportation Economic Analysis convened over 3 days to identify gaps in the data and analytic tools needed to support economic analysis as related to transportation investment and to develop research proposals designed to fill those gaps. The opening day of the conference featured presentations by economists, transportation analysts, and policy makers on the theory and practice of economic analysis and its usefulness to decision makers. The second and third days of the conference revolved around participatory workshops. Six separate working groups deliberated over three questions:

1. What is the appropriate level of investment in transportation to encourage economic health?
2. How should projects be prioritized within a multimodal transportation program?
3. How much revenue is likely to flow from user charges, tolls, and other sources?

At the conclusion of its deliberations, each working group developed a list of research proposals, which it then presented to the conference as a whole.

Keynote Remarks

The conference opened with a dinner speech, in which David Winstead, former secretary of the Maryland Department of Transportation, affirmed the importance of transportation investment to the state of the economy, both nationally and at the state and local level. Several other policy makers echoed this theme, but they also noted that it is impossible to make a persuasive case concerning the linkage between transportation spending and a sound economy in the absence of credible economic analysis.

Roger Roy, director general of economic analysis for Transport-Canada, spoke at a luncheon on the second day of the conference. He discussed the following specific questions that have emerged during the 20-year evolution of Canada's major transportation:

- The impact on the transportation system if a new change is introduced or, alternatively, if the status quo is maintained;
- The benefits and costs of proposed changes to the system;
- The effects of a policy or program after it has been put in place;
- Which investments to make, how to set priorities, and where to invest;
- Which parties should make investment decisions, set prices, and manage, build, and maintain transportation infrastructure;
- The capital and operating costs of the transportation system, and how they can be reduced;
- How these costs should be recovered, and from whom;
- The level of charges necessary to achieve self-sufficiency;
- The institutional arrangements needed to manage transportation infrastructure;

- The impact of transportation on the environment;
- The safety of the transportation system and how to improve it;
- The costs of accidents and who pays those costs;
- The costs of accident prevention and, again, who pays those costs; and
- The reliability and efficiency of the transportation system.

Mr. Roy pointed out lessons learned from the Canadian experience, including the importance of information and analysis for influencing decision makers, and the difficulty of obtaining good information.

Setting the Stage

Economic Issues and Recent Developments in Economic Information

Transportation Satellite Accounts and Capital Stocks Accounts: Summary of Presentation by Barbara Fraumeni, Bureau of Economic Analysis

Transportation satellite accounts measure supply-side inputs to transportation, such as fuels, drivers, and trucks, for approximately 500 industries. The accounts concern themselves exclusively with businesses' use of transportation services, and they do not consider personal or governmental use of cars. These accounts provide a way to estimate the value of both for-hire and in-house business transportation services in the U.S. economy. On the basis of data from 1992, the transportation satellite accounts show that the supply of transportation services added about $313 billion, or 5 percent, to the gross domestic product.

Although transportation satellite accounts measure transportation's contribution to the economy as a whole, they do not deal with the value of existing infrastructure. Analysts quantify existing assets through construction of capital stock accounts. The most common way to quantify capital stocks is through the perpetual inventory method, which adds current-year expenditures to the value of the prior year's assets, adjusted for those assets' deterioration over time. Conference participants learned of two approaches for measuring capital stocks: a simpler strategy in which the rate of deterioration is represented by a constant factor; and a more complex strategy in which the analyst develops a unique, localized factor to adjust for the decline in a given set of assets' productive capacity. (The simpler approach is described in Barbara Fraumeni's paper in the "Resource Papers" portion of these proceedings. The more complex approach may be available at the website http://www.fhwa.dot.gov/reports/phcsm/index.htm.)

Commodity and Passenger Flow Data: Summary of Presentation by Rolf Schmitt, Bureau of Transportation Statistics

The value of transportation to the economy as a whole can be assessed not only by observing the supply of transportation services and capital assets but also by looking at the demand for these services and assets. The movement of people and goods—and by extension, the demand for transportation services—is the subject of the Commodity Flow Survey and the American Travel Survey, both spearheaded by the U.S. Department of Transportation's Bureau of Transportation Statistics.

The Commodity Flow Survey collects and disseminates data on domestic freight shipments in terms of distance, origin and destinations, and modes of transportation. It considers both the volume and the value of commodities transported, which is important because shipping can look very different depending on whether one asks about tonnage or dollar values. The survey breaks down some information, such as the value of truck shipments, by state, but even more disaggregated data would be useful. In particular, more data on the location at which commodities enter and exit the United States would be valuable, especially given the growing importance of international trade.

The American Travel Survey focuses on long-distance passenger travel habits. The survey polled 80,000 households for trip information: origins, destinations, modes of transport, and reasons for the trips. The survey found that Americans are traveling more and further, making about 1 billion long-distance trips in 1995, which accounts for about 25 percent of all travel in the United States. As with the Commodity Flow Survey for freight movement, the American Travel Survey provides excellent statistical information on the busiest routes for long-distance personal travel. Thus, the American Travel Survey can be especially enlightening for policy makers interested in the geographic characteristics of passenger transportation.

The Vehicle Inventory and Use Survey (VIUS) is conducted every 5 years by the U.S. Census Bureau to determine miles traveled, type of business, and industry served for trucks. It is hoped that VIUS will be expanded to include automobiles and buses.

Economic Analysis at State, Metropolitan, and Project Levels: Summary of Presentation by Alan E. Pisarski, Consultant

As state and local decision makers examine the merits of transportation investment, they now have access to a broader array of supporting data and analysis than ever before. Research published by the American Association of State Highway and Transportation Officials and the National Governors Association substantiates the public's implicit understanding of the linkage between transportation and the economy. The findings that derive from transportation satellite accounts, capital stock accounts, the Commodity Flow Survey, and the American Travel Survey also are very useful. Much of the information that is national in scope has been supplemented by more localized studies. For example, the Chicago Federal Reserve Bank and transportation agencies in Maryland and Wisconsin recently looked at the impact of transportation on their own regional economies. Today, decision makers regularly put these studies to productive use, and thus it appears that an abundance of research activity in the past 10 years is starting to pay off.

Like other sectors, transportation is starting to operate in a new economic context, dominated by just-in-time delivery, a global economy, more specialized labor requirements, an explosion in niche markets, new communications options, and unprecedented growth in personal travel and tourism. The shifting nature of the economy presents a fresh challenge to researchers and analysts. Ongoing research efforts that keep pace with this changing environment can be expected to inform policy makers' choices concerning transportation investment.

Relevance of Economic Analysis for Decision Making

State departments of transportation have attempted to inject economic analysis into the transportation decision-making process for several decades now. However, the job of communicating complex analytic information to those who are in the position of putting it to practical use has been and remains a challenge.

In light of this challenge, John Fuller of the University of Iowa presented five hypotheses concerning strategies by which transportation economists and statisticians might maximize their effectiveness. First, he urged that top priority be given to communications. Second, he stressed the importance of communicating with technical staff within state departments of transportation and metropolitan planning organizations, as these people are often in the best position to apply a message to local conditions and communicate effectively to top-level decision makers within their organizations. Third, case studies and other illustrative examples provide one of the best mechanisms for communicating in an effective way. Fourth, Dr. Fuller proposed the need for organizational changes within state departments of transportation in order to emphasize technical competency and raise the profile of economic analysis. Fifth, decision makers themselves must take responsibility for being accessible and seeking out the best technical advice when facing decisions with a substantial economic component.

Why Information Matters

Two transportation policy makers presented their perspectives on how economic information supports investment decisions at the state level. They also discussed the additional types of information that could further improve the decision-making process, including e-commerce, the impact of inland waterways on rail and highway capacity needs, and performance measurement of existing infrastructure. The value of case studies and anecdotal information was cited.

Samuel Bonasso, secretary of the West Virginia Department of Transportation, discussed the application of economic analysis to transportation decisions from the perspective of a state that remains largely rural. West Virginia has had a long history of using highway projects within the Appalachian Regional Highway System to stimulate economic development. Certain counties have emerged from a distressed economic condition during the past 30 years, and as might be expected, the more successful counties are precisely those in which improved transportation infrastructure has supported greater accessibility to and from other parts of the country.

Dennis Lebo of the Pennsylvania Department of Transportation provided several examples of how data concerning the linkage between economic health and transportation investment had informed the legislative decision-making process in Pennsylvania. Although the arguments for transportation investment have always been persuasive, analysts and policy makers must now begin to factor several new considerations into the case for transportation investment. First, congestion is becoming as important a consideration as accessibility, especially as traffic levels become severe enough to deter companies from locating in certain areas. Second, the global economy and the growing significance of international trade is an increasingly relevant concern even for inland states, and this in turn raises new questions associated with freight mobility. Third, communicating the results of economic analysis in a compelling fashion should remain a high priority, particularly given the complicated legislative landscape seen in so many states. And finally, the deterioration of existing infrastructure suggests that states need new information specific to the performance of existing assets as opposed to the costs and benefits of brand-new facilities.

Key Topics

How Levels of Transportation Investment Affect Economic Health

Summary of Presentation by Randall W. Eberts, W. E. Upjohn Institute

Until recently, most inquiries concerning the impact of transportation investment on the economy adopted a broad view, concerned principally with linkages occurring at the national level. Many of these studies arrived at different conclusions, but generally speaking, there appears to be a consensus view that transportation makes a positive but difficult-to-measure contribution to economic health.

The question of transportation's impacts on state and local economies is at least as important, for so many important investment decisions are made at subnational levels. Thus, it is encouraging to find that more analysis is now taking place at the state and local level. However, a number of methodological challenges makes it especially difficult to assess the relationship between transportation investment and economic health when focusing on a specific investment decision in a specific part of the country.

There are several ways in which the current state of the practice could be improved, particularly at the state and local level. For example, the current perpetual inventory approach to estimating existing assets would be vastly improved by the development of methods to recognize attributes of existing infrastructure, such as traffic flow, reliability, safety, volume, lane miles, grades, and functional types. As another example, researchers might wish to explore the relationship between outputs and outcomes in order to explore the impact of outputs, such as lane miles, on outcomes, such as reliability, safety, the economy, and the environment.

Proposed Research Projects

Two working groups developed a combined list of 10 research proposals related to determining the impact of transportation investment on economic health:

- Development of comprehensive input data for measuring transportation infrastructure capital stocks,
- Development of expanded measures of transportation systems,
- Exploration of the correspondence between the economic benefits of highway investment and road user taxation,
- Assessment of transportation's role in encouraging development in economically depressed areas,
- Measurement of transportation outcomes and improvement of the efficiency of data collection,
- Synthesis of economic linkage case studies,
- Identification of the network effects of highway improvements,
- Linkage of commodity flow data to establishment-level data to measure transportation system utilization,
- Estimation of the impacts of network externalities, and
- Analysis of counties' and states' provision of highway services.

Economic Evaluation for Decision Making on Transportation Projects, Programs, and Policies

Summary of Presentation by Randall J. Pozdena, ECONorthwest

When facing an investment decision, one of the most productive ways to choose among competing alternatives is through a decision hierarchy that interrelates policy objectives, programs, and individual project alternatives. In this idealized model, the first step is to identify the policy objectives and related selection criteria that should govern the decision. The second step is to establish programs with goals that support these policy objectives; these programs determine the array of individual projects from which to choose. The third and final step is to use a rigorous project selection methodology in order to make a final investment decision.

Political and social goals always will affect the decision-making process, and it is unrealistic to expect that a mechanistic approach to project selection always will prevail. However, good information and rigorous analysis can help remove some of the political constraints to sound decision making, particularly if economic analysis helps to illuminate some of the costs imposed by gamesmanship and politically driven decision-making practices. This is especially true today, as shortcut analyses and ex-post-facto project justifications can truly impair economic efficiency when considering incremental improvements to an existing transportation system.

As one applies the decision hierarchy to a particular investment dilemma, the most typical way to examine the relative merits of alternative investments is benefit-cost analysis. In performing benefit-cost analysis, the most important factors are to make sure to count everything worth counting and to ensure that the measurements are accurate. Though economists have been applying benefit-cost analysis to investment problems for years, there remains room for improvement. In particular, the state of the practice could be improved through research on better ways to convert the value of externalities to dollar amounts, to estimate who bears the benefits and costs, and to assess how transit providers and the freight industry respond to changes in demand for their services.

Proposed Research Projects

Three working groups assigned to the topic of economic evaluation developed 13 research proposals:

- Obstacles to implementing benefit-cost analysis: issues and solutions;
- Development of best practices for benefit-cost analysis and a standardized reporting template;
- Improvement of estimates of travel-time value for passengers and commodities;
- Development of expanded information on travel behavior and the demographic characteristics of households;
- Improvement of the integration of transportation system modeling and evaluation models;
- Development of a methodology to disaggregate elasticities;
- Identification of primary conditions and determinants for success in implementing congestion pricing;
- Management of risk in the transportation investment decision-making process;
- Development of improved methods for estimating the distribution of benefits and costs from transportation projects among population subgroups and for compensating affected groups;
- Development of a methodology for generating complete sets of alternatives;
- Development of strategies for allocating resources across modal programs;
- Monetization of transportation externalities; and
- Assessment of the impact of project financing choices on project decisions.

Estimation of Revenues from Use Charges, Taxes, and Other Sources of Income

Summary of Presentation by David Gillen, University of California, Berkeley

Fuel tax receipts and motor vehicle registration fees account for more than three-quarters of the total revenues available to spend on highway investments. Many states and local governments align future expenditure levels with anticipated revenues, meaning that receipts and expenditures tend to track quite closely with one another.

Although revenues tend to be quite stable from one year to the next at the national level, significant annual fluctuations are common at the state level. Fuel tax and registration fee receipts can vary by 25 percent or more from one year to the next, which can make it difficult for decision makers to set spending targets.

The quality of both available data and modeling techniques must be improved so that economists can better understand the dynamics underlying such volatile revenue streams. For example, to predict fuel tax revenues, analysts need better ways to measure relevant input variables, such as vehicle miles traveled and fuel efficiency, as well as the attributes of those variables. In particular, it would be helpful to have a better understanding of commercial vehicle miles traveled, as most research to date has focused on passenger vehicles. Better analytic tools are needed as well, and particularly ones that can anticipate behavioral responses to changes in fuel prices and other relevant factors. Also, as states look to new types of revenue streams, such as tolls and impact fees, policy makers will begin to demand better forecasts of future receipts deriving from these alternative mechanisms for financing transportation infrastructure.

Proposed Research Projects

The working group assigned to the topic of revenues forecasting developed seven research proposals:

- Development of an information base of current revenue forecasting efforts,
- Improvement of estimates of state-level vehicle miles traveled for passenger vehicles and commercial trucks,
- Development of a generic starting point model for forecasting state fuel tax revenue,
- Examination of the implications of alternative revenue instruments for highway financing,
- Examination of Bureau of Transportation Statistics products' role in improved revenue forecasting,
- Assessment of the impact of evolutionary vehicle and information technology on revenue forecasting, and
- Examination of the revenue gains and cost savings attributable to shifts in the point of fuel taxation.

Response to Proposed Research Statements

A "firing line" of four transportation experts spoke at the conference's closing plenary session. The members of this panel did not participate in the conference working groups but came at the end to listen to each working group's presentation of proposed research statements and offer an outside assessment of what they heard.

The first panelist was Marlon Boarnet of the University of California at Irvine. He approved of the working groups' minimal focus on research to identify the proper level of transportation investment nationwide; Dr. Boarnet noted that in his view, new federal funding authorizations are at about the right level. Rather, he said, questions of the "right" level of investment are far more compelling at the project level. Dr. Boarnet also assigned a lesser priority to efforts to ascribe dollar values to the nation's capital stocks; far more important, he said, is research to determine the value of the actual service provided by different types of transportation assets. Dr. Boarnet made two additional suggestions. First, he suggested that research to analyze the migration of people and capital in response to investment levels was very important. And second, he praised the research statement addressing the distribution of costs and benefits for given transportation investments. He noted that most project-related debates revolve around who wins and who loses, and he suggested that the bitterness of this debate could be mitigated by a full accounting and potential compensation of those people who bear the greatest costs.

Hank Dittmar of the Surface Transportation Policy Project spoke next. First, he applauded the working groups' attention to freight and goods movement and proposed further work to look specifically at the intersection of goods movement, information movement, and personal travel. Second, Mr. Dittmar emphasized the need for further work on travel decision making at the household level. Third, he affirmed the importance of research on local economic development projects. Noting that this is an area beset by wishful thinking, he emphasized that road projects have a better chance of achieving local economic development objectives when included as part of an overall regional economic development plan. Finally, Mr. Dittmar urged work to assess what role true economic analysis—as opposed to the spurious claims of project proponents—plays in the project selection process. Mr. Dittmar closed his remarks with a call to bolster informal networks of practitioners in the field of transportation economics, with special attention to including those practitioners from state department of transportation division offices, smaller metropolitan planning organizations, and transit agencies.

Pete Hathaway, chief deputy director of the California Transportation Commission, first discussed his agency's need for a better understanding of the marginal benefits of alternate statewide levels of investment in transportation, noting that this type of research promised to be very valuable in weeding out unfounded boosterism. Mr. Hathaway also called for a closer examination of the relative benefits of alternate types of investment, so that, for example, one could conduct a head-to-head evaluation of new construction versus rehabilitation, or a comparison of a carpool lane, a mixed-flow lane, and a high-occupancy toll lane. As his final recommendation, he urged consideration of supply-side responses in the freight transportation area, to determine, for example, how truck traffic reacts to high congestion on usual routes. Mr. Hathaway assigned lesser priority to research on the valuation of externalities, arguing that this issue simply never will be resolved in the political arena. And, concurring with Dr. Boarnet, Mr. Hathaway suggested that studies to calculate the value of transportation capital stocks also were of a lesser priority. Mr. Hathaway closed his remarks with a call for better communication of technical information to the layperson.

The fourth and final speaker, transportation consultant Kevin Heanue, stressed that questions concerning the cost of not investing in transportation are at least as important as questions concerning the benefits of investing. He concurred with Dr. Boarnet's view that we currently enjoy a relatively good balance between transportation funding and needs at the national level, but he argued that significant investment deficiencies still exist at the metropolitan area. Turning to the question of valuing the externalities associated with transportation investment, Mr. Heanue argued that past research focused too much on the cost side and too little on the benefit side. He urged that future research remedy this imbalance by attending closely to estimates of the benefits of specific transportation projects. He went on to say that even when benefits are registered, the traditional practice of economic analysis tends to discount those benefits away. Mr. Heanue noted that for transportation projects, all capital costs are incurred up front, whereas the benefit stream is spread out over time. This means that choosing an excessive rate by which future dollars are discounted to present-day values will devalue most of the project's benefits while still recognizing all of the up-front costs. He also said it would be useful to supplement the traditional analytic practices with a more future-oriented approach. Under this alternate approach, one would look forward 20 or 30 years, consider what would be needed to make a city function efficiently, and ultimately work one's way backward to today's investment requirements rather than starting with current-day conditions and forecasting forward. In closing, Mr. Heanue urged greater attention to operations. Currently most economic analysis work focuses on investment in new facilities and maintenance; Mr. Heanue recommended that equal consideration be given to the benefits of investment in operational improvements such as ramp metering and road pricing.

After the final plenary session, the Conference Steering Committee met to develop findings and recommendations based on the proceedings of the conference. Their conclusions are presented in the following section, "Findings of the Conference Steering Committee."

Overview

Findings of the Conference Steering Committee

Immediately following the final plenary session, the Conference Steering Committee convened to develop consensus conclusions on the outcomes of the conference. The agenda for this meeting centered on a discussion of the conference and development of consensus findings in four areas:

1. Priority research needs for transportation economic analysis, to be phrased as research statements;
2. Opportunities for applying recent national advances in economic information to issues of special concern to states and metropolitan areas;
3. Future activities to advance both research on and the application of economic information and analytic tools; and
4. Other recommendations.

This summary of the Steering Committee's consensus findings addresses each of these issues in turn.

Research Needs

The Steering Committee reviewed more than 30 research proposals that had emerged from the working groups, as shown in the "Key Topics Addressed by Working Groups" section of these proceedings. The committee considered whether to trim the list of recommended proposals and/or place the proposals in a priority order. After some discussion, the members of the Steering Committee concluded that each research proposal would have value to some part of the transportation community, and the committee did not want to bias the research selection process. Therefore, it concluded that all proposals should be presented without priority, for consideration by the National Cooperative Highway Research Program (NCHRP), the Bureau of Transportation Statistics (BTS), the Federal Highway Administration (FHWA), and any other organizations that might sponsor such research.

The full text of all proposed research statements generated during the conference and subsequently approved by the Steering Committee appears in the "Proposed Research Statements" section of these proceedings. Each statement is divided into four standard elements: problem statement, proposed work to be performed, cost estimate, and projected duration. At the close of the discussion concerning the research statements, the Steering Committee authorized the Transportation Research Board (TRB) to refer the final compilation of proposed research projects to organizations deemed to be potential sponsors and/or funders of the proposed research. It was also suggested that organizational elements of the American Association of State Highway and Transportation Officials (AASHTO), such as the Standing Committee on Planning, the Special Committee on Economic Expansion and Development, and the Standing Committee on Research, might serve as the principal liaisons to potential funding sources.

Application of National Advantages to States and Metropolitan Areas

Members of the Steering Committee concurred that maximizing the utility of recent national advances in data collection and analysis to the state and local level deserved greater emphasis. Several members remarked on the conferees' strong stated support for the Commodity Flow Survey (CFS), the American Travel Survey (ATS), and the Nationwide Personal Transportation Survey (NPTS). The Steering Committee as a whole recognized the value of these efforts and urged their continuation and, in some cases, expansion. In particular, several Steering Committee members noted that potential linkages among the findings generated by CFS, ATS, and NPTS ought to be explored. Several other members of the Steering Committee noted that it would be useful to introduce information on imports and exports into CFS.

Other comments centered on the need to perform an ongoing review of the kinds of information generated by the Highway Performance Monitoring System, the Highway Economic Requirements System, and the Transit Economic Requirements Model to ensure that they respond to the needs of analysts at the state and local level.

Finally, several Steering Committee members observed that traditionally, conferences on data and analysis had progressed under the assumption that data needs at the state, metropolitan, and local level were identical. Alan Pisarski asked the Steering Committee whether it would recommend any specific actions to ensure that metropolitan, county, and local governments get the kinds of information they need. Members of the Steering Committee noted that several of the research statements developed by the working groups dealt directly with the issues of state and local governments' data needs. Examples included investigations into

- The impact of transportation investment on economic development at the local or neighborhood level (see "An Assessment of Transportation's Role in Encouraging Development in Economically Depressed Areas," p. 54);
- The development of working collaborations between different jurisdictions to ensure an integrated approach to data collection (see "Measurment of Transportation Outcomes and Improvement of the Efficiency of Data Collection," p. 55);
- The network-wide effects of transportation improvements so that national cost impacts derived from CFS could be assigned at the state and project levels (see "Identification of the Network Effects of Highway Improvements," p. 56); and
- The application of Bureau of Transportation Statistics publications and products (e.g., CFS, ATS, and NPTS) for the use of transportation revenue forecasters at the state and local level (see "An Examination of BTS Products' Role in Improved Revenue Forecasting," p. 67).

The Steering Committee then proposed several future activities to promote a greater understanding of state and local governments' data needs, including, for example, the development of a network of state transportation economists and an inquiry into differentiating among the global, national, state, and local benefits that accrue from a project. These and other proposed future activities are summarized in the following section.

Future Activities: Further Research and Practical Applications for Economic Information

Members of the Steering Committee worked together to develop a list of future activities that would further research and application of new economic information and analytic tools. Following the discussion, the Steering Committee agreed to the following consensus items:

- Develop a database of literature on economic analysis as applied to transportation investment. This database would comprise studies dealing with the use of economic analysis and describing various analytic techniques. The content of the database likely would include one-page descriptions of all relevant NCHRP projects and other reports, analyses, and studies. As part of this exercise, it would be helpful to check which recommendations appearing in those reports have been implemented, and why or why not.
- Promote a synthesis to compile information on the various methods of measuring capital stocks, including capital accounts, state economic accounts, and satellite accounts. The synthesis also would highlight changes in the Government Accounting Standards Board's reporting standards and generally accepted accounting principles and describe how these changes will affect the inputs to various capital stock measurements.
- Develop an inventory that identifies economic competency within state government. This inventory would disclose where the economic function is housed within the state departments of transportation and other elements of state government, document economic skill levels at both the state department of transportation and metropolitan planning organization levels, and describe how analytic work at the state level is used at the metropolitan and local level.
- Promote the creation of a network of state transportation economists. This institution, which could be lodged in AASHTO, would help state transportation economists identify and exchange information with their peers in other states. TRB's standing economics committees also could be helpful in promoting peer-to-peer exchange.
- Promote an inquiry into analysts' approaches to differentiating among the global, national, state, and local benefits that accrue from a project. The basis for this in-

quiry derives from the concern that a proposed project's broader benefits may be missed if the scope of the benefit-cost analysis is limited to the project's immediate vicinity.

- Convene a conference focused on the quantification of costs and benefits. Some members of the Steering Committee proposed a separate conference to deal exclusively with the quantification of benefits, given the view that the cost side of benefit-cost analysis traditionally has received greater emphasis. Other Steering Committee members noted that any future conference geared to benefit-cost analysis ought to pay particular attention to the costs and benefits of no-build alternatives, given the view that the cost of the no-build, or do-nothing, alternative is another neglected area of inquiry.
- Perform an ongoing review of the Highway Performance Monitoring System and the National Transportation Database.
- Revisit the way in which financial information is reported in the FHWA publication *Highway Statistics* and in the National Transportation Database, and recommend changes if necessary.

Other Recommendations

The members of the Steering Committee closed their discussion with several observations and recommendations concerning this and future conferences. The members agreed to the following points:

- The proceedings for this conference should describe the individual working groups' general approach to discussing and subsequently developing responses to the questions posed to them, in addition to providing information on the conclusions they drew. (Note: a description of the standard practice employed by the six working groups appears later in this document.)
- The diversity of the audience invited to this particular conference was beneficial. In particular, members of the Steering Committee thought the conference and the working groups were strengthened through the presence of individuals from all levels of government as well as the private sector. A few members of the Steering Committee felt it would have been better to have even greater participation by chief executive officers and other top-level officials from both the public and private sectors.
- It was very helpful for all conference attendees to have received the four resource papers prepared for this conference (i.e., papers by Randall W. Eberts, John W. Fuller, David Gillen, and Randall J. Pozdena) well in advance of the conference itself. Members of the Steering Committee observed that the attendees' opportunity to read the papers beforehand appeared to have elevated the quality of discourse during both the plenary sessions and the meetings of the working groups.
- The "firing line" at the end of the conference—at which four outside experts were invited to respond to the proposed research statements as presented by the working groups—worked well.
- Given the great amount of materials that the working groups were expected to produce, it would have been helpful to have more computers and, especially, printers available for their use during the breakout sessions.

OVERVIEW

Introduction: Addressing a Tripartite Dilemma

This August 1999 conference focused on data needs specific to economic analysis. The key topics covered in this conference revolved around a tripartite dilemma facing state and local transportation decision makers. If decision makers are to invest in transportation infrastructure, they need to understand how levels of investment in transportation affect economic health. Once they understand this mechanism, they then need to establish a planning process that will lead to a set of investments that will best yield the desired economic and social returns. And finally, once these investments are selected, they must be paid for, meaning that decision makers must have a reasonable understanding of the financial resources available now and into the future.

For the purposes of this conference, the Transportation Research Board (TRB) distilled this combined dilemma into three distinct analytic issues:

1. What is the appropriate level of investment in transportation to encourage economic health?
2. How should projects be prioritized within a multimodal transportation program?
3. How much revenue is likely to flow from user charges, tolls, and other sources?

Conference-goers addressed these issues and questions together, in plenary sessions and in smaller working groups assigned to the individual topics. To prepare conference participants for their work, five resource papers were written and distributed prior to the conference; they also were presented at the conference. These are contained in the "Resource Papers" section of these proceedings and may be available electronically at the following website: www.itsamac.com/~nsjfoster/TRB/99Irvine/index.nclk.

A principal output of the conference was a list of proposed research projects that might be pursued by sponsors of research initiatives. To arrive at this final combined list of recommendations, each breakout group addressed three related questions, as shown in Figure 1. After the conference, the Steering Committee met to make recommendations on research needs, applying recent national advances in economic information to state and local needs, and future activities to further research and apply economic information and analytic tools.

The conference opened with an evening address by David Winstead, formerly of the Maryland Department of Transportation and currently a partner with the law firm of Wilkes, Artis, Hedrik & Lane. A 3-hour plenary session took place the following morning, dealing with the construction of transportation capital stock accounts, the new transportation satellite accounts, rate of return and productivity studies, commodity and passenger flow data, the American Travel Survey, and the relevance of economic analysis for decision making at the state and local level. Following this plenary session, the conferees broke into a total of six working groups. Two of these groups focused on the first issue, related to the impact of levels of investment on economic health. Three groups focused on the issue of economic evaluation. One group focused on the issue of revenue forecasting.

In the remaining 2 days, conference-goers alternated between meetings within their working groups and sessions with the group as a whole. During these larger meetings, spokespeople for the individual working groups

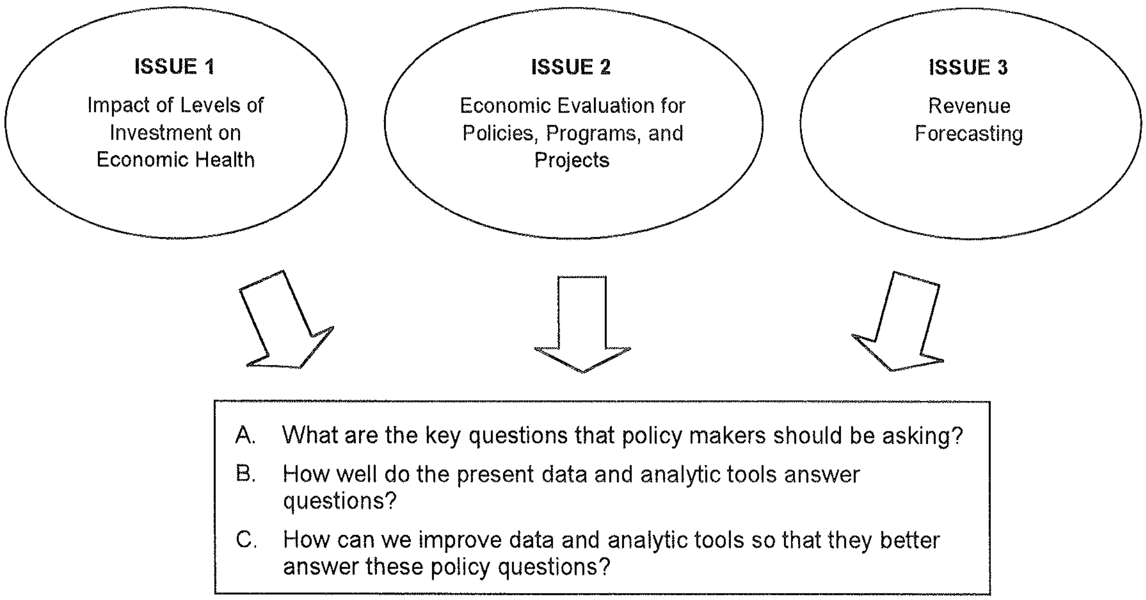

FIGURE 1 The conference's three analytic issues, broken out to address three related questions.

reported findings and conclusions to date. The conferees also enjoyed a luncheon address by Roger Roy, director general for economic analysis, Transport-Canada.

The conference closed with each working group recommending approximately six proposed research projects. A panel of four outside observers commented on the proposals.

Immediately following the conference, the Conference Steering Committee met to review the proposed research statements. The Steering Committee compiled a final list of recommendations emerging from this conference, reflecting both the recommendations of the six working groups and the Steering Committee's own observations. The section of these proceedings entitled "Conference Findings" presents the conclusions reached by the Steering Committee. Appendix A to these proceedings provides biographical information on all members of the Steering Committee.

Keynote Remarks

Transportation Conditions: A Top Concern of the Public

Importance of Transportation Information: Canada's Experience

KEYNOTE REMARKS

Transportation Conditions: A Top Concern of the Public

David Winstead, *Wilkes, Artis, Hedrick & Lane; formerly of the Maryland Department of Transportation*

In my judgment, the public has a much greater thirst for information on transportation and the economy today than ever before. This is for one fundamental reason: the public is more frustrated than ever before about transportation conditions, and especially traffic congestion.

When I started at the Maryland Department of Transportation (DOT) in 1995, the Baltimore Sun papers polled the citizens of Maryland about their top 15 concerns. The need for better highways ranked 15th, and better transit service ranked 14th.

Yet, in May 1999, a number of media outlets were pointing to congestion as a major concern. Indeed, a recent poll showed that 34 percent of 7,000 voters in the Washington, D.C., metropolitan area ranked transportation congestion as their top concern. Only 27 percent of those surveyed ranked taxes as a priority. So this is why data and information on the importance of mobility, capacity, and, by extension, transportation investment are of greater interest to the public than ever before. This is particularly true in the major metropolitan areas and urbanized states.

I was asked to talk about three questions this evening. First, what are some of the pertinent arguments that the American Association of State Highway and Transportation Officials (AASHTO) made to Congress leading up to enactment of the Transportation Equity Act for the 21st Century (TEA-21)? Second, what are some of the data needs that we have generated in Maryland? And third, what are some of the positives and negatives related to the availability of relevant data?

On the first question, I will describe some of AASHTO's efforts. In 1995, AASHTO's economic committee joined with the organization's communication group to develop a communication program. The purpose of this program was to assist state DOTs in their efforts to advance the reauthorization debate, particularly through educating elected leaders and the public about the importance of increased transportation investment and the need to move the Highway Trust Fund off-budget.

Three major publications resulted from this effort, including "Transportation Driving a Thriving Economy." We used these publications during the 1997 and 1998 efforts toward reauthorization and I believe that they were part of the reason that we were successful in getting the national governors, chambers of commerce, labor groups, and the construction industry behind the cause.

Information on return on investment was particularly useful during the debate. We compared the rate of return from investing the $70-plus billion surplus in the Highway Trust Fund back into highway investments versus into domestic spending cuts. We found a 14 percent annual return on investment associated with putting those funds into highway and transit investments, versus only an 8 or 9 percent return associated with domestic spending returns through a domestic tax cut.

That finding, combined with many others, was very important both in leading to the record levels of investment achieved in TEA-21 and in halting threatened raids on the Highway Trust Fund.

Now let me turn to some of the work we have done in Maryland. In 1996 we undertook an economic impact assessment of transportation investments in Maryland. Our objectives were not only to educate the public but also to generate support for a revenue increase that could be sought during the upcoming year 2000 legislative session. The document we produced considered both the short-term and long-term economic impacts that flow from transportation investment.

The findings were quite compelling. For example, the study found that the state's $933 million investment in transportation between 1991 and 1996 generated 24,000 full-time jobs, almost $3 billion in Maryland's output of goods and services, and over $206 million in state tax revenues. The study also found that the average dollar spent by Maryland on highways between those years reduced costs borne by private industry by 17 percent, primarily due to savings in the movement of goods and services.

This study, which was done by Towson State University, estimated an annual rate of return on investment of 17 percent. The study concluded that highway investment was responsible for 10 percent of the annual growth in productivity in Maryland between 1982 and 1997. The report has now hit the desks of the transportation and construction industry, and I think it will play a major role in the coming 6 months as part of the effort to raise the gas tax and replenish the trust fund in Maryland.

I will wrap up with a few thoughts on the positives and negatives of current information on transportation and the economy. One positive is that we are now getting very good data. Also, these data tend to be translated into very usable information. Good brochures are especially useful, as they are easily understood by and available to the general public.

On the negative side, I had great frustration during my years with the Maryland DOT in applying benefit-cost analysis to different modal transportation choices. I realize that much of the research to be discussed here will concern intermodal trade-offs, but at Maryland, we could never find a way to legitimately evaluate, for example, an auto-terminal investment in the Port of Baltimore versus a high-occupancy-vehicle lane on Route 50.

Also, communication across disciplines continues to be a weakness. I encourage all who are the custodians of this information to align yourselves with other organizations. I'm pleased, for example, to see that the Association of Metropolitan Planning Organizations is a cosponsor of this conference. Getting together with the leadership of the environmental community and sharing an understanding of the importance of transportation investment to quality of life, productivity, and competitiveness is terribly important as well.

In closing, I would like to note that the need for information on the economic impacts of transportation investment is constant. Research and analysis should not only be performed according to the cycles of revenue increases or periodic reauthorizations of the transportation program. Good analysis is always needed.

KEYNOTE REMARKS

Importance of Transportation Information
Canada's Experience

Roger Roy, *Transport-Canada*

In the remarks made at this conference, speakers have linked transportation information requirements to the decision-making process. That link is a very important one. Transportation information is needed by numerous stakeholders including policy makers, shippers, carriers, and, of course, the general public.

Those of us in the transportation field face decisions that tend to be linked to some fundamental questions. These questions deal with predicting or determining

- The impact on the transportation system if a new change is introduced or, alternatively, if the status quo is maintained;
- The benefits and costs of proposed changes to the system;
- The effects of a policy or program after it has been put in place;
- Which investments to make, how to set priorities, and where to invest;
- Which parties should make investment decisions, set prices, and manage, build, and maintain transportation infrastructure;
- The capital and operating costs of the transportation system, and how they can be reduced;
- How these costs should be recovered, and from whom;
- The level of charges necessary to achieve self-sufficiency;
- The institutional arrangements needed to manage transportation infrastructure;
- The impact of transportation on the environment;
- The safety of the transportation system and how to improve it;
- The costs of accidents and who pays those costs;
- The costs of accident prevention and, again, who pays those costs; and
- The reliability and efficiency of the transportation system.

We have to remind ourselves that no answer to any of these questions can resolve the issue for once and for all. We live in a dynamic world, a world of continuous change. As changes happen in all sectors of activities, the transport sector, with its derived demand, is dragged into this spiral of changes. This need for constant review means ongoing analysis, ongoing research, and ongoing information requirements.

The role and importance of analysis in transportation has been and will continue to be of capital importance to the legislative process. I would like to use Canada's experience of recent years to illustrate this point.

In 1967, the National Transportation Act was adopted in Canada. This act consolidated economic regulation of transportation under one single agency: the Canadian Transport Commission. However, policy-making functions stayed with the national Department of Transport. Then in 1987, three pieces of legislation were adopted: a new National Transportation Act, the Motor Vehicle Transportation Act, and the Shipping Conference Exemption Act. Each of these moved us toward a deregulated framework for each mode of transportation.

Then came the 1990s, bringing more reforms. Four driving forces behind these reforms stand out: the recession of the early 1990s, the findings of a royal commission on national passenger transportation, the findings of a review commission examining national transportation legislation, and the government's efforts to control its fiscal deficit.

Just look at the reforms Canada saw in the 1990s:

- The implementation of a national airport policy (1994) that commercialized the major federally owned airports.
- The announcement in 1995 of a national marine policy with the objective to commercialize Canada's port system and the St. Lawrence Seaway.
- The termination of the major freight transport subsidy programs of the federal government.
- The Canada Transportation Act of 1996, which fine-tuned the rail deregulation of our rail system.
- The privatization of CN, Canada's largest rail carrier.
- The privatization of the air navigation system.
- The adoption of the Canada Marine Act in 1998, which provided legislative authority for the commercialization of the Canadian portion of the St. Lawrence Seaway system.
- The introduction of public-private partnership approaches to finance transportation projects. The most famous example of such a partnership is Highway 407 in Ontario. But there are other examples as well, such as the Confederation Bridge linking the Prince Edward Island province to the mainland, and a highway in the province of Nova Scotia.

Lessons Learned

What are the lessons learned from all these changes? The first lesson is that the findings of research commissions can have lasting impacts. Consider the legacy of the transportation framework proposed by the Royal Commission on National Passenger Transportation. Under this proposed framework, users pay the full costs of transportation; competition and market forces provide viable and efficient carrier services. Infrastructure investments are made only when benefits exceed costs. The role of government is defined as one of policy making and of setting and enforcing standards. The influence of this framework is undeniable when one considers the 1990s' commercialization of the airport and port systems, privatization of the air navigation system, and termination of subsidy programs.

The second lesson to draw is the importance of analysis and information in influencing decision makers. Each legislative change was preceded by extensive analysis. These analyses supported a better understanding of the issues confronting the Canadian transportation industry, the transportation system as a whole, and the regulatory and legislative framework.

The third lesson has to do with the speed at which changes have taken place. The legislative changes of 1967 came after a very long period. Twenty years later, in 1987, three pieces of legislation were changed the same year. But subsequently, it took only 10 years to revisit and amend virtually every piece of national transportation legislation. The new reality is a dynamic environment in which the rapidity of changes in the marketplace indicates the need to fine-tune legislation more frequently.

The fourth lesson is Canada's introduction of "institutionalized monitoring." The National Transportation Act of 1987 included an annual comprehensive review requirement, equivalent to a program evaluation. Now, those tasked with producing these annual reviews curse them. But one has to admit that they support broader availability, accessibility, and circulation of information on the transportation system. The reports add transparency to policy making and promote better decisions.

The last lesson from the Canadian experience centers on the difficulty of obtaining good information. Under the 1987 legislation, we allowed stakeholders to provide the needed monitoring information on a voluntary basis. However, this voluntary approach failed to create a reporting "culture" among certain stakeholders. Subsequently, when we introduced regulations to define a new reporting scheme, we faced undeniable resistance. We use legislative and regulatory reporting requirements to obtain data, but we have no built-in incentives to stimulate reporting, as you do in the United States. This lack of incentives is increasingly problematic because some stakeholders report inconsistently or provide poor information. Such behavior is not penalized in any way, and thus, indirectly, we end up penalizing those who rigorously and consistently submit good data.

Transportation Challenges

Let me now turn to the transportation challenges we face in Canada, some of which you also have in your country, and present the implications of these challenges for information requirements.

In Canada, maintenance of our transportation system is one of our greatest challenges. This is especially true in our low-density areas; in these locations, maintenance is especially costly on a per capita basis and difficult to justify in a commercial decision-making setting. In the current context of pressures to reduce taxes and government expenditures, this challenge is particularly acute. From the perspective of information requirements, detailed information on all elements of the transportation system is important if one plans to focus on strategic maintenance expenditures.

The next challenge is to improve the existing transportation infrastructure. Because needs change over time, many parts of the transportation system require periodic investment. A broad spectrum of information is required to assess these needs.

Another challenge concerns the expectations of the transportation system's users. Users now place as much or more importance on the quality and efficiency of service as they do on the cost of the service. Carriers' performance is linked, in turn, to the transportation system. So performance of the system must be monitored in order to strategically schedule changes to the system to optimize results. Information is a key to successful intervention. I should add here that the dawning of the global economy implies that information requirements are not limited by borders. As globalization changes trade patterns, information must be accessible across borders.

Another challenge is to develop our transportation system in a manner consistent with the goal of sustainability. Sustainability has three pillars:

- Economic and financial sustainability, which implies an efficient use of resources and proper maintenance of assets in order to make transport more cost-effective and continuously responsive to changing demands;
- Environmental and ecological sustainability, which requires us to take fully into account external effects of public or private transport decisions; and
- Social sustainability, which concerns the equitable distribution of the benefits of improved transportation to all segments of the community.

We have only barely started to identify the types of transportation information needed to address these sustainability issues. For example, work on climate change discloses the limits of current information on transportation activities by equipment type, energy consumption information, and integrated modal activities. The need to allocate costs fairly indicates the need for advances in total cost accounting and methodologies for allocating costs to different categories of vehicles.

New Initiatives

In January of this year, Canada took an important step toward filling one of our major data gaps when we launched a new Canadian vehicle survey. This survey will allow annual estimates of vehicle kilometers for the entire road vehicle fleet, including trucks and buses, stratified by characteristics of the vehicles, the drivers, and the trips.

We also are in the process of starting a major research project to adapt analytical tools to some of the challenges that I alluded to earlier, such as sustainability. The intent is to create an intermodal transport efficiency model, which will integrate three models: (*a*) a general equilibrium model, with transportation more explicitly defined than in a traditional general equilibrium model, including a spatialization of activities; (*b*) a modal accounting system, similar to the transportation satellite accounts developed in the United States but also with some social cost components to capture costs related to the environment and safety; and (*c*) a component that deals with the performance of our assets. This research initiative is to take five years.

In closing, I would like to stress that the nature of our information requirements cannot be dissociated from the nature of the transportation challenges we face. It is certain, however, that our information requirements will demand that we view transportation through a wider lens that both looks into the future and beyond borders. And all the while, we must remember that every piece of information at our disposal comes at a cost to those who must collect and report it.

Setting the Stage

Recent Developments in Economic Information

Relevance of Economic Analysis for Decision Making

Why Information Matters

SETTING THE STAGE

Recent Developments in Economic Information

TRANSPORTATION SATELLITE ACCOUNTS AND CAPITAL STOCKS ACCOUNTS

Barbara M. Fraumeni, *Bureau of Economic Analysis, U.S. Department of Commerce*

Transportation Satellite Accounts

I will start with the transportation satellite accounts. They are a joint product between the Bureau of Transportation Statistics (BTS) and the Bureau of Economic Analysis (BEA). These accounts intend to answer the question of how important transportation is to the U.S. economy. The general framework looks at the use of "own-account" (or in-house) transportation and for-hire transportation for some 500 industries. It emphasizes business use; currently it covers neither the personal use of cars, nor the use of cars and other transportation forms by the government, nor the use of capital assets such as highways. Those can be quite significant.

The satellite account shows inputs to transportation, such as fuel, drivers, trucks, and so forth. You also can use the transportation satellite account to show the impact of some change in final demand for a product on the demand for transportation. For example, you can ask, if there is an increase in the demand for fruit, how will that ripple through the economy in terms of an increased demand for transportation generally and for an individual component of transportation more particularly?

The satellite account also helps you get at the importance of transportation in light of the rest of the economy. So how important is it? The answer is that across all industries transportation contributes about 5 percent of gross domestic product (GDP). This 5 percent has two parts. For-hire transportation accounts for 3 percent and own-account transportation accounts for approximately 2 percent of GDP. And in response to a question from the audience, it is exactly correct to interpret this to mean that if there were no transportation, GDP would fall by 5 percent.

Now, I do understand that the figure of 10.7 percent is floating out there. However, that figure is not really correct. When we focus on the supply side and seek to isolate transportation's value-added impact as an input to the economy, 5 percent is the correct figure to use. The methodology we used for deriving the 5 percent figure ensures that all inputs to GDP summed together add up to 100 percent. In contrast, if you used a gross output (as opposed to value-added) approach and thus derived the 10.7 percent figure, you would end up with a sum that equals about 200 percent of actual GDP. By focusing on value-added, we can legitimately compare transportation to all the other industries in the economy.

Now, a problem with the analysis I have just discussed is that the data feeding into it date back to 1992. The good news is that by approximately the summer of 2000, we will release a 1996 annual update of the transportation satellite accounts.

Capital Stock Accounts

Now, let us switch gears and talk about how to calculate capital stocks for highways. I have developed two strategies: a simple one and a complicated one.

Sometimes it is really going to be worthwhile to do the more complicated strategy, but let us start with the simple strategy. It is just a formula, as follows:

$$KS_y = \text{capital outlay}_y + [(1 - 0.0202) * KS_{y-1}]$$

There is one magic number that you need to know to be able to work with the simple strategy: 0.0202. It is the crucial piece in the construction of a capital stock when you use the perpetual inventory method, which is what almost everyone uses. The preceding formula shows that the capital stock in a given year depends upon the capital outlay in that year plus how much capital stock you already have. However, the capital stock you already have must be adjusted because of retirement and a decline in efficiency, and that is the 0.0202 factor: the rate of deterioration. In plain language, this is the decline in the potential productive capacity of any asset over time. And for this number, the 0.0202 factor is pretty good, as it derives from multiple empirical analyses.

Beyond the 0.0202 deterioration factor, what else do you need? Two pieces: You need a deflator. BEA uses a deflator that is essentially the same as the construction cost index from the Federal Highway Administration, which is very easy to get. Second, you need a benchmark, which is to say a starting point. That is the one thing for which there is not a totally obvious answer. You might choose, for example, the starting point of 1950, and then estimate the efficiency of the existing highway components. Even if you do not have a perfect benchmark, use a benchmark.

That is it for the simple strategy. Why would you want to use the more complicated strategy? Mainly because your particular region may not resemble the country as a whole. The paper I have prepared (available for download at www.itsamac.com/~nsjfoster/TRB/99Irvine/index.nclk) gives you a blueprint about how you can use the more complicated approach. A series of five Excel spreadsheets will soon be available for download from that same site, so that if you want to try your hand at the more complicated strategy, you do not have to type in all the numbers. This approach includes divisions by local, state, and interstate outlays and splits by right-of-way, new construction, reconstruction, pavement grading, structures, and so forth. The fat paper considers a $1,000 capital outlay in 1960 and provides a step-by-step example, showing exactly what you would do under the more complicated approach.

Finally, in response to a comment from the audience, I concur that capital stock measures, in and of themselves, reveal only part of the story. What is really useful is information on the services provided by those existing assets. We have very minimal information on the service provided by our capital stocks, and that is an inquiry that very much needs to take place.

Anyone who is a glutton for punishment should read the full 125-plus-page report ("Productive Capital Stock Measures," prepared by Barbara Fraumeni on behalf of the Federal Highway Administration and available for download at http://www.fhwa.dot.gov/reports/phcsm/index.htm). But I recommend looking at the strategy paper, which is only 11 pages. (Please see the "Resource Papers" section of these proceedings for the full text of the 11-page paper.)

Rate of Return and Productivity Studies, Commodity and Passenger Flow Data, and American Community Survey

Rolf Schmitt, *Bureau of Transportation Statistics, U.S. Department of Transportation*

I am going to talk about data on physical transportation activity, including commodity flows, passenger movement, and vehicle use. These data feed national economic accounts, can be used to translate those accounts to the state and local level, and provide key variables for use in project evaluation and revenue forecasts.

Transportation is an enabler of economic relationships, and transportation activity is a reflection of those relationships. The enabling role of transportation is obvious but not well measured. Someone asked earlier this morning whether a complete cessation of transportation services would cause the economy to decline 5 percent or disappear. The satellite account shows that transportation services contribute 5 percent to the economic activity of the nation; however, without transportation the steel produced in the Midwest would be worthless to the consumers of steel in the East, South, and West. Our economy would not disappear, but it certainly would be much smaller. Transportation allows local economies to link with one another, and the resulting flows of goods, people, and vehicles indicate how important those linkages are.

Our traditional view of transportation activity often focuses on the volumes of activity on each link in the network rather than on the areas being connected. The resulting images are very strong indications of hubs of activity, but they are not always an accurate reflection of underlying economic relationships. Moreover, when we consider volume rather than the value of the items being transported, we get a distorted view. When one considers tonnage moved by rail, it appears that the economic heart of America is Wyoming, but most of the tonnage is low-value coal rather than high-value manufactured goods.

A different picture emerges when we look at value. When we consider the value of imports and exports at the nation's many international gateways, America has multiple economic hearts. This view also demonstrates that intermodalism is more than a wish; indeed, the top three gateways in 1996 were a port (Long Beach), an airport (John F. Kennedy in New York), and surface crossings (the rail and highways bridges at Detroit).

Commodity Flow Survey

An intermodal world is not easily measured by a carrier-based, mode-specific survey. As a consequence, the Bureau of Transportation Statistics and the Census Bureau turned to shippers to measure commodity flows by all modes. The Commodity Flow Survey (CFS) asks basic questions of about 100,000 shipping establishments: What did you ship? Where did it go? How did it get there? How much did it weigh? How much was it worth?

CFS does not ask for distance, but it turns the reported origins and destinations into distance through network models and network databases developed primarily by Oak Ridge National Laboratory. The network databases are published as a BTS data product every year as the National Transportation Atlas Database.

CFS was conducted first in 1993, and the second edition covering 1997 was to be released at the TRB annual meetings in January 2000. CFS reports will include state-to-state and metropolitan-area-to-metropolitan-area flows of commodities by type of commodity, modes used, value, weight, and other shipment characteristics. This is the most complete view of shipments by all modes, and the only nationwide source of data on where trucks carry commodities.

Using the Oak Ridge models, BTS has produced a picture of commodity movements by truck that demonstrates the importance of interstate commerce. This picture shows the ton miles of shipments by truck within, from, to, and through each state. The within-state shipments are a minority of the value or ton miles except for the corner states. The shipments to and from each state represent that state's trading relationships with other states. The through-shipments represent the traffic that affects the state's highways but not necessarily the state's economy.

CFS is the biggest data source of its kind, but it does not cover everything. One of the gaps is imports, for which we must turn to the transborder surface freight transportation data established by BTS through the Census Bureau. Foreign trade data are disaggregated by mode used at the border crossing, to show, for example, where commodities carried by truck go through or to each state. It is based on foreign trade data.

Foreign trade data, at best, is an attempt to measure economic activity, but at worst it tends to measure paperwork geography. Because of the way in which customs data are filed and developed, you can get some weird things in here. For example, the first time we published these data, we showed a small but not inconsequential amount of live animals entering the United States by pipeline. That problem was quickly fixed. However, we do still have a significant number of trucks from Canada entering the United States in Dallas, Texas. There is a little gap in there between Texas and the nearest spot in Canada. That is obviously where the paperwork was filed. BTS will explore ways to fix this problem in a study required by Section 5115 of the Transportation Equity Act for the 21st Century (TEA-21). This problem is worth fixing since international trade may account for about 10 percent of the ton miles of what moves on U.S. highways. The percentage could be much higher for some states.

International trade is important as a transportation issue and as an economic development issue for each state. If we can improve the quality of data on the domestic movement of foreign trade for national transportation policy purposes, then states and metropolitan areas will get a much better picture of their international trading partners as an incidental byproduct. This is not a modest challenge. Trade data agencies are responsible for national balance of payments and thus care about getting the country right rather than the states. Federal trade agencies generally do not care about the balance of payments between Missouri and France, but only the United States and France.

Even if we get the right state, we do not necessarily know where in the state imports originate or exports are destined. And we often know the value, but not the weight. BTS will deal with the latter problem by creating value-to-weight tables for each commodity captured in CFS.

My greatest concern with using transportation statistics as a proxy picture of the economy is our tendency to use ton miles as the measure of transportation. Although ton miles is commonly used, particularly as an indicator of consumption of transportation resources, the measure can skew our perceptions. The 1993 CFS reveals that shipments over 1,000 miles account for only 2 percent of the tons shipped, 10 percent of the value of all truck-carried shipments, and a quarter of all ton miles. How could only 2 percent of the tons account for 25 percent of the ton miles? It takes one shipment moving 1,000 miles to equal 100 shipments each of the same size moving only 10 miles. Should shipments of fewer than 100 miles, representing nearly 80 percent of the tons and over 40 percent of the value, be given less weight than the 2 percent of tons and 10 percent of value that go more than 1,000 miles? The arithmetic is correct, but the perception of importance and the implications for economic activity may be overexaggerated by ton miles.

One challenge of this forum is to consider ways to turn these types of data into useful information for state and local decision makers.

American Travel Survey

Let me turn briefly to the passenger side. BTS conducted the American Travel Survey in 1995, asking 80,000 households where did they go on trips to places more than 75 miles away, how did they get there, why did they go, and a bunch of other things.

For trips of more than 100 miles, the survey revealed some obvious flows, such as the Northeast Corridor between Washington and New York, and also a few surprises, such as Los Angeles to Las Vegas.

From an economic standpoint, this information tells two stories: the tourism story and the services story. Tourism is the classic view, but the services view is perhaps more interesting, particularly because it is so poorly measured in general. Services are typically seen as the growing part of the economy, and business travel between regions reflects the service-based economic linkages of those regions.

Vehicle Inventory and Use Survey

Vehicle activity enables and reflects economic activity. The private trucking component of the Transportation Satellite Account described by Barbara Fraumeni was estimated from the Truck Inventory and Use Survey, which now has been renamed the Vehicle Inventory and Use Survey (VIUS) on the hope that it will be expanded to include automobiles and buses. VIUS is conducted by the Census every 5 years, and it is based on a sample of registered vehicles. Questions on miles traveled, type of business, and industry served provided data on physical characteristics that were linked with economic characteristics to determine the added value associated with private trucks.

The impact of changing costs and the role of transportation in the economy is even bigger from a household perspective. Dr. Fraumeni pointed out that transportation services contribute about 5 percent to GDP. This is a view from the supply side, which can be thought of as the business perspective. If transportation is measured from the perspective of final demand (what households consume, what governments spend, and what is in inventories), transportation accounts for about 11 percent of GDP. Much of the difference is in household spending, which is tracked by the Bureau of Labor Statistics through its Consumer Expenditure Survey. This survey shows that almost 20 percent of household expenditures are for transportation, much of which goes into personal-use vehicles.

Conclusion

Should we be content with these national statistics, or should we try to bring these statistics to the state and local levels? Abraham Lincoln, the father of transportation, implied a positive answer when he said in an 1848 speech while a member of Congress, "Statistics shall save us from doing what we do in the wrong places."

The question of place is made complicated by the tendency of major cities to be located at the edge of states. Economic areas often fail to respect state lines. Indeed, our country is organized economically, yet we administer much of our transportation system by political jurisdiction. We have to figure out how to accommodate this apparent mismatch in our data and in our actions.

Economic Analysis at the State, Metropolitan, and Project Levels

Alan E. Pisarski, *Consultant*

The public has an implicit understanding of the value of transportation and its role in economic development. Moreover, we all recognize that transportation operates in a new economic context, dominated, for example, by just-in-time delivery and a global economy. The American Association of State Highway and Transportation Officials, the National Governors Association, and others have documented the central role of transportation in both of these aspects of the new economy. Research efforts over the past decade have underscored the importance of transportation to the economy, and we are on the verge of a high payoff from this research.

Many organizations have performed research and published materials that provide a solid, quantitative basis for the public's general understanding of the linkage between transportation and the economy. At the national level, the Federal Highway Administration (FHWA) has published the results of research on industry cost savings from highway investments. At the state level, David Winstead reported how the Maryland State Highway Agency has looked closely at the impacts of the state highway system on the state economy. Also, the Wisconsin Department of Transportation has looked at similar questions. The Chicago Federal Reserve Bank has performed studies of economic linkages in the Midwest. And, as Barbara Fraumeni discussed, the Bureau of Transportation Statistics together with the Bureau of Economic Analysis have developed a transportation satellite account that documents transportation's impact on the gross domestic product.

But these examples are just the beginning. We can look forward to FHWA's construction of capital stock accounts for highways, expansion of FHWA's cost savings research to cover the passenger side, and work from the American Public Transit Association concerning the economic impacts of transit systems. And one of the most exciting prospects is for new applications of the Commodity Flow Survey and American Travel Survey to specific projects. For example, during the great Wilson Bridge debate in Washington, D.C., CFS and ATS were used to show the scale and impact of that bridge in the national economy. Two percent of the value of everything in America that moves by truck crosses that bridge each year; that type of information can be very powerful in informing investment decisions related to individual projects.

Current research also explores additional aspects of the new economy, including industry cost reductions, synergy between regions and niche markets, and personal travel and tourism. For example, the Federal Reserve Bank's research analyzes the transport and industrial characteristics that contribute to the Midwest's comparative advantage. The analysis finds that significant levels of trade are occurring not only between but also within industries. It also finds that industries are highly motivated to seek out high-quality but low-cost inputs. It also reports that the keystone of this new economy lies in communications and transportation, particularly given the transportation system's role in broadening the total "marketshed" in which firms can search for suppliers.

Above all, the future is going to be dominated by increased "niche-iness," such that an understanding of the economy will depend, more than ever, on an understanding of small markets that are difficult to measure. This new world will make immense demands on our descriptive capabilities, both statistically and analytically, and from a transportation perspective, this applies to both freight and passenger movements.

So what does this brave new world look like? Certainly transportation and GDP are, and will remain, aligned. More consumption will occur per capita, and more passenger travel will occur per unit of GDP. On the freight side, we will see fewer ton miles per unit of GDP. This does not necessarily mean less freight, but rather a world in which shippers produce and transport ever more valuable commodities. This focus on high-value commodities suggests that shippers will be more tolerant of relatively high-cost transportation. Indeed, modern communications and modern transportation, with its great speeds, has nearly destroyed distance. The issue, instead, is time.

On this last point, and in response to a comment from Dr. Robert Martinez in the audience, I recognize that from another point of view, the reliability of freight delivery can trump the issue of the time it takes to deliver the product. As Dr. Martinez says, in the coming years the real challenge facing freight providers—and by extension, the transportation system—will be reliability. Indeed, if freight providers could guarantee shippers 100 percent reliability in on-time deliveries, the shippers (and recipients) would likely register far less concern about time-in-transit.

Finally, we also need to take the new population into account. We will have skilled workers, but they will be in great demand and at a premium. The population will be older. At the same time, the big question will center on who will be immigrating here, and where they will locate. The question of location ties closely to the matter of communications, because we are looking at a population that can live and work almost anywhere. What lies ahead? An affluent, but challenged, society. We already have a lot of high-payoff research in hand. We must use it, expand it, and apply it to the transport challenges we face in the coming years.

SETTING THE STAGE

Relevance of Economic Analysis for Decision Making

THE IMPORTANCE OF COMMUNICATING RESEARCH RESULTS

John W. Fuller, *University of Iowa*

A number of years ago the Wisconsin Department of Transportation (DOT) hired me as a newly minted Ph.D. economist. The department decided that it needed an economist, and the task of that economist would be to explain to the engineers how economic analysis could be used in decision making. I proceeded to undertake what I think was one of the true fiascoes of my professional life. I translated all my marvelous economic theory into a course that covered rates of return, time valuation, and social costs. Many of these topics were still fairly new at that time, in the late 1960s.

The response to the course?

"How is this helpful? What are you telling us that we can put to use? Do you have a manual for us with lookup data?" No, it does not really operate that way.

"Well, can you help justify my project?" Well, no, that is not exactly what I am trying to do.

"Can you get me project approval? Can you work through the political mechanisms to make sure that my project is the one that comes forth?" Well, again, no.

So, although the project engineers were ultimately polite, there really was not much that a young Ph.D. economist full of economic theory could do to be of assistance. Fortunately, times have changed. Even though today's questions are not really any different, I think we have a great deal more information and a better opportunity to explain the usefulness of economic analysis to people who are in the position of putting economic analysis to practical use.

This is indeed a fortunate period of time. We currently enjoy an extremely healthy economy, with budget surpluses not only at the national level but also within virtually every state. However, to maintain and improve our economic situation presents a major challenge. It is a challenge that is intensified by globalization of the economy and the fact that we had a trade deficit of $170 billion just in 1998.

In preparing this presentation, I found it instructive not only to read the papers specifically prepared for this conference but also to look back at a little report on transportation issues that the General Accounting Office (GAO) published in early 1993. It listed the issues that GAO considered most important to the country. The very first issue that it listed underscored the imperative of wise investment in transportation.

GAO's statement built on the Intermodal Surface Transportation Efficiency Act of 1991 landscape, which included the creation of the U.S. Department of Transportation's Bureau of Transportation Statistics and Office of Intermodalism, both designed to seize emerging technological opportunities in the field of making wise investments.

The imperative for wise investment has not diminished in importance since 1993, and it is, if anything, greater today than it was then. I would like to point out a significant corollary, focusing on the importance of clear communications in the fields of economic analysis and investment decision making.

Surely we need stronger, more detailed data and better analysis procedures. However, I do not know that we need to improve the state of the knowledge so much as we need to translate that knowledge into language that people in state DOTs and metropolitan planning organizations (MPO) can use.

I will now suggest several hypotheses:

First: Top priority ought to be given to communications.

Second: Although it is important to communicate to interest groups, chief executive officers, legislatures, city councils, mayors, and the like, it is especially important to communicate with those at the technical level within state DOTs and MPOs. Those at the technical level are best equipped to sort through research findings and put them to work. Those with the technical expertise can then apply those findings to their unique local circumstances and share their knowledge with decision makers and interest group representatives.

Third: Communication is very greatly aided by examples and case studies. Case studies and examples are the rhetoric that resonates with people who can effect changes to transportation and investment policy.

Fourth: We probably need some organizational changes and some institutional strengthening within the state DOTs. It appears to me that the last decade has seen a diminution of many organizations' technical competency. What's more, it seems that those who deal with economic matters have been shunted aside to secondary roles instead of being truly useful advisers to decision makers. Thus, I submit that one of the key things we need to do is to improve communication channels within agencies and perhaps review the priority accorded to investment responsibilities.

Fifth and final: Decision makers must take responsibility for being accessible and for seeking out the best technical advice on economic questions. Clearly, economic considerations are only part of the story and should be balanced with other matters, but surely we should not neglect to allocate our resources appropriately and support the goals of our society properly through our expenditures.

Let me conclude by returning to my first hypothesis and underscore that the communication of our research results is at least as important as the generation of those results in the first place.

Setting the Stage

Why Information Matters

West Virginia: A Rural Point of View

Samuel Bonasso, *West Virginia Department of Transportation*

I am presenting a rural viewpoint. West Virginia, with 1.8 million people, is wholly within Appalachia, a region defined by the U.S. government. The Appalachian Regional Commission was established in 1965 to stimulate economic development. As part of its mission, it constructed the Appalachian Regional Highway System, which to this day is the only highway system ever created by the U.S. government with the sole purpose of stimulating economic development.

Between 1965 and today, the number of counties within West Virginia that are deemed distressed, as measured under federal criteria, has declined significantly. And it is no coincidence that counties located along the state border—that is, those that are accessible to neighboring states—represent the counties that are better off today than was the case in 1965. So there is ample evidence that highway investment has stimulated economic development in this region.

Nonetheless, those of us in rural areas still have a lot of questions specific to our situation, and I would like to present you with some of those questions.

Are the transportation, social, political, economic, and investment criteria for mountainous and rural regions comparable to the criteria for urban regions? Should they be? The roads here are definitely more expensive to build than they are in Kansas, and this holds true in all the mountainous regions of our country.

To what extent should population issues drive our transportation investments? We might take a look at where the people in West Virginia live. Fully half of the people in our state live in the border counties, surrounded by a sea of economic prosperity in Virginia, Pennsylvania, Maryland, and Ohio.

Might urban sprawl be addressed through the repopulation of small-town America? Thanks to communications technology, it is now a lot easier for people to work in smaller places today than it ever has been.

What does the rise of e-commerce imply for transportation requirements? In my own view, I suspect that e-commerce will reduce transportation requirements to the same extent that it has reduced the amount of paper that we must deal with each day: that is, not much at all. Indeed, the impact of e-commerce on transportation will likely be dramatic because transportation will have to take up the role of distributor, warehouser, and retailer.

And finally, coming from an inland state, I wonder whether expanded investment in inland waterways can become a source of new capacity for the highway and rail system. I also wonder what kind of information is needed to arrive at a response to that question.

In closing, I cannot resist giving you a West Virginian's definition of "pork." It is simply money spent by somebody else, somewhere else.

Getting the Message Across About Transportation and Economic Development

Dennis Lebo, *Pennsylvania Department of Transportation*

We have already talked a lot about the relationship between transportation and economic development. But it is not something new. In 1875, James Eads, a self-taught engineer who designed the first bridge to cross the Mississippi at St. Louis, described the relationship very plainly. He said, "The keynote of our nation's prosperity is founded in the simple words 'cheap transportation.' These words should be stamped upon the stripes of our national banner and thrown to the breeze from every farmhouse, mill, and factory throughout the commonwealth."

Those were pretty bold words back then, and they are just as true today. But the message is not quite as easy today as it was back then, when building new highways opened up vast new areas of the country. Clearly we are not in that situation of seemingly limitless expansion anymore.

Back in 1982, Tom Larson was secretary of the Pennsylvania Department of Transportation (DOT). He got five revenue increases in 8 years, which was a very remarkable feat. Most significant was what we called the billion-dollar bridge bill. In 1982 it was relatively easy to make an argument for that level of investment. Pennsylvania had a lot of bridges in bad shape. The economic arguments about being able to get trucks across bridges, to get goods to market, and to have a vibrant economy came very easily. The billion-dollar bridge bill was an easy sell.

But let me fast-forward through to a couple of years ago. Getting a revenue increase in Pennsylvania for transportation purposes was not nearly so easy. It involved one-on-one negotiations with dozens of legislators. These negotiations really exemplified the need for more information and the ability to communicate analytic findings.

I would like to point out a few of the supporting considerations that we in Pennsylvania are factoring into the case for transportation investment.

The first is a three-part factor: traffic, traffic, traffic. If congestion becomes too bad, a given company will not locate in our state. So, much of our work at Pennsylvania DOT focuses on identifying who pays and who benefits from reduced congestion, trying to strike a deal whereby beneficiaries will pay for at least part of that investment, and ensuring that proposed improvements do in fact reduce congestion as promised.

Second is the global economy. Transportation is an important component in any kind of trade, including foreign trade. Our governor recently signed an agreement between the Ports of Pittsburgh and Guadalajara. In fact, Mexico is now Pennsylvania's second leading foreign trade partner, after Canada.

Third is the need to communicate the results of economic analysis, as has already been mentioned by other speakers. Leaders always need ammunition to be able to sell the things that they are proposing. Selling the message demands information that is easily digestible and compelling. To this end, I would emphasize the need not only for streams of data, but also for case studies and anecdotal information, as suggested earlier by John Fuller.

Fourth is performance. One of our constant struggles is the need to maintain what we have. So, we must ask ourselves how far we can let a road or bridge deteriorate. Information that focuses specifically on the performance of existing infrastructure as opposed to new infrastructure is very important, and relating that performance to the vibrancy of our economy is critical, as well.

To close, I would like to respond to a comment from the audience concerning the cost of data collection. As I just mentioned, we in Pennsylvania are looking to make investment decisions on the basis of performance goals. This performance-driven approach demands that we collect more data on how our infrastructure performs, as opposed simply to how much infrastructure we have. So it is important that we have the right data, but we are acutely aware that performance measures and supporting data come at a cost.

Key Topics Addressed by Working Groups

Producing the Findings

How Levels of Transportation Investment Affect Economic Health

Economic Evaluation for Decision Making on Transportation Projects, Programs, and Policies

Estimation of Revenues from Use Charges, Taxes, and Other Sources of Income

KEY TOPICS
Producing the Findings

Randall W. Eberts, Randall J. Pozdena, and David Gillen prepared resource papers at the request of the Transportation Research Board (TRB) in advance of the conference. Every person attending the conference received a copy of each resource paper several weeks before the conference began. This background reading ensured that the working groups could launch into pro- ductive discussion immediately.

The resource papers addressed the conference's three key topics:

- The impact of levels of transportation investment on economic health;
- The application of economic analysis in evaluating transportation policies, programs, and projects; and
- The practice of forecasting revenues from transportation use charges, taxes, and other sources.

Following presentations by the authors of these research papers, six working groups, of 8 to 15 members each, addressed these topics. Two groups dealt with the first issue, three groups dealt with the second, and one dealt with the third. Each group applied three standard questions to its issue and responded to those questions in turn:

1. What questions should policy makers be asking?
2. How well do existing data and analytic tools answer those questions?
3. How can we improve data and analytic tools to answer the questions? (Develop research statements.)

Each group had a facilitator, and the conference sponsors had provided each facilitator with some suggested strategies for a successful brainstorming session. Whereas each group ultimately developed a specific approach that worked best for its own members, all groups employed similar methods for generating and then cataloging responses to the three assigned questions.

Generally speaking, each group used the applicable resource paper prepared for this conference as a point of departure. In addressing each question, groups began with a general roundtable brainstorming session, recording each of the ideas generated. Following the brainstorming session, groups held an open discussion to combine or refine the proposed responses. Finally, individual members of the working group voted for the responses they considered best. The group's facilitator then compiled the five or six top vote-getters into a brief presentation for the conference as a whole, and each group wrote out detailed research statements.

The following pages summarize the groups' responses to Questions 1, 2, and 3. For the sake of simplicity, we combine findings in cases in which multiple working groups were assigned to an individual topic.

KEY TOPICS

How Levels of Transportation Investment Affect Economic Health

PRESENTATION

Randall W. Eberts, *W. E. Upjohn Institute for Employment Research*

Note: The full text of the resource paper prepared and circulated by Mr. Eberts in advance of the conference appears in the "Resource Papers" section of these proceedings.

My interest in the areas of economic development and transportation dates back to the early 1970s, when I was a graduate student at Northwestern University. One of my professors suggested that for my dissertation, I go around to all 256 communities in the Chicago metropolitan area and ask them about how much infrastructure they have and what condition it is in. Well, no one had ever done that before, and I quickly found out why.

After I got my degree, I got a National Science Foundation grant to put together capital stock measures for metropolitan areas around the country. In recent years, however, the emphasis has shifted to the macronational level. I am very pleased that with this conference and others, we are getting back to the state and local level, which is where so many important decisions are made.

The questions that I posed in my paper all relate to the state and local level. We might ask, for example, how transportation investment increases value by creating new jobs, increasing personal income, improving environmental quality, enhancing quality of life, and perhaps even improving low-wage workers' access to jobs.

More specific questions at the national and state levels might address the effects of additional highway spending on economic development. At the local level, one might ask how a local freight facility, expansion of a regional airport, or an additional lane might boost the local economy.

Can we answer these questions very well? I would give us a fairly low score, especially for questions focused at the state and local level; on a scale of 1 to 10, I think we are around a 2 or a 3. We can do much better.

We don't have very good information, but we do know that broadly speaking, transportation investment makes a positive but small contribution to economic health. Many estimates find that the contribution of public investment to productivity is about a quarter of that which derives from private investment.

Most studies to date focus on the correlation between transportation infrastructure and economic activity over a long period of time. These analyses can be accomplished using a production function or a cost function.

Turning first to the production function, consider the following formula:

$$Q = f(K,L,M,G)$$

In this formula, Q represents output, measured as value-added. Output is a function of private capital (K), labor (L), materials (M), and government-provided infrastructure (G).

In contrast, the cost function formula looks like this:

$$C = h(Q, P_k, P_m, W, G)$$

In this formula, the cost (C) of producing a certain amount of output is a function of the amount of output (Q), the price for capital (P_k), the price for materials (P_m), the price for labor, expressed as the wage rate per hour (W), and government-provided infrastructure (G).

What's the difference between these functions? Production functions by themselves look at the technical relationship between outputs and inputs. Cost functions add in the demand for inputs through inclusion of the price variable. Thus, the cost function adds another dimension to the relationship.

But either way, we need to understand that this analysis occurs within the regional growth process. Thus it is important to anchor these relationships within some type of spatial context. However, most studies haven't yet done this, largely because the analysts don't have the detailed data necessary to make that spatial correspondence.

Once we have that regional process in mind, grounded again in some spatial context, we then can ask about transportation's effect. Transportation can play several roles. First, as a direct input it can affect output directly. Second, we can look at transportation's ability to help us produce more efficiently if we hold labor, materials, and all other inputs constant.

I would now like to walk through some of the shortcomings I perceive with the state of the practice as we currently know it:

- Most studies rely on capital stock estimates that are calculated using the perpetual inventory method that Barbara Fraumeni discussed earlier. The problem with this approach is that it does not recognize attributes. For example, the perpetual inventory method treats a dollar of highway investment in Montana the same as it does a dollar of highway investment in New Jersey, but we all know that this is not the case because of differences in terrain, climate, and construction costs.
- In a related matter, we have very little information with which to respond to more detailed questions about the contribution of specific attributes of a given highway segment to economic development. This is an especially serious problem because the highway system is so mature, meaning that most investment today entails changes to these attributes rather than construction of major new segments.
- Most studies include commodity flows—that is, where goods are coming from and where they are going. When looking at a national study that focuses on a given industry, we can make some inferences knowing that certain industries are concentrated in certain parts of the country. But still, most studies bundle all highway infrastructure in the whole country within the production function. It is important that we begin to separate out infrastructure that does not pertain to the activity or industry on which we are focusing.
- Current analyses also have a number of econometric problems associated with correlation and causation. Is infrastructure causing output, or is output driving additional demand for infrastructure?
- It is also important to capture network effects. Some studies are now trying to look at infrastructure in just one state and then layer that information onto data concerning infrastructure in the neighboring state. Certainly neighboring infrastructure has an impact. But does this type of layering really help refine the analysis?
- We also need to take a closer look at outputs versus outcomes. By outputs, I mean those services produced by transportation facilities, such as highways or rail. Outputs can be measured as traffic flows, reliability, or safety. By outcomes, I mean the effects of these outputs on the economy or environment. Outcomes are measured as the number of jobs created, changes in personal income, changes in gross domestic product, or air or noise pollution. If we look only at facility characteristics, such as lane miles, we're getting only part of the story. We need to understand how these outputs affect outcomes, such as reliability, safety, the economy, and the environment. And again, each of these depends on where a given facility is located.
- We need better ways to calculate the cost of providing transportation infrastructure. Although cost is embedded in the perpetual inventory method, cost is not explicitly considered anywhere else.
- Finally, it would be helpful to have a more comprehensive regional growth model, encompassing not just production and cost functions, but also the whole regional growth process. This links to the final proposal appearing at the end of my paper, which urges a working collaboration among agencies so that we can collectively maintain and improve the data that measure these various dimensions.

Working Group Findings

Susan Binder of the Federal Highway Administration and William Black of Indiana University led the two groups assigned to the issue of investment levels' impact on economic health. The findings of these groups appear below.

Key Questions

- What are the full benefits and costs of transportation?
- Are there significant costs or benefits not being captured?
- Who bears the costs and enjoys the benefits?
- Can transportation address social issues such as sprawl and spatial mismatch of jobs?
- How should network effects be estimated (including creation of new networks and enhancements to existing systems)?
- What will this mean for jobs and income?
- Can transportation benefits be compared to other products of public investment? How can this information be used to guide investment decisions?
- How do we evaluate the performance of the transportation system and its individual components?
- How does transportation help our major industries?
- How can one link macro- and microanalyses? Can individual benefit-cost analyses be aggregated up to a macrolevel approach?
- What institutional forms and financing arrangements for delivering transportation will maximize net benefits?

Sufficiency of Data and Analytic Tools

- Consumer benefits are not adequately measured. In particular, it is difficult to isolate the benefits that accrue to nonusers.
- The data collected on functional or jurisdictional grounds often are inconsistent. They should be better aligned.
- We need better forecasts of economic conditions, both regionally and nationally.
- Measures of outcomes need to be expanded to include complementary public service investments.
- It can be difficult for analysts to obtain access to archived data (e.g., older metropolitan travel surveys).
- Existing measures of congestion do not adequately reflect delay on existing metropolitan or statewide networks.
- It would be helpful to see a segment-based measure of reliability.
- The National Passenger Transportation Survey provides good national data, but it is not currently flexible enough to support metropolitan planning and transportation modeling.
- With respect to vehicle stocks and travel patterns, it is difficult to distinguish business versus personal use.
- We lack good data on the value of privately owned capital to transportation service.
- With respect to behavioral choice models, these analytic tools could do a better job of showing the effect of pricing on consumer and producer behaviors.
- With respect to commodity flow models, we do not have a good understanding of imports or traffic on bridges. These kind of data would complete the local picture of freight movements and their importance to the economy.
- Regional forecasting models are not well developed and their usefulness is impaired by the fact that data are not available at the substate level.

Research Needs

- Development of comprehensive input data for measuring transportation infrastructure capital stocks;
- Development of expanded measures of transportation systems;
- Exploration of the correspondence between the economic benefits of highway investment and road user taxation;
- Assessment of transportation's role in encouraging development in economically depressed areas;
- Measurement of transportation outcomes and improvement of the efficiency of data collection;
- Synthesis of economic linkage case studies;
- Identification of the network effects of highway improvements;
- Linkage of commodity flow data to establishment-level data to measure transportation system utilization;
- Estimation of the impacts of network externalities; and
- Analysis of counties' and states' provision of highway services.

KEY TOPICS

Economic Evaluation for Decision Making on Transportation Projects, Programs, and Policies

PRESENTATION

Randall J. Pozdena, *ECONorthwest*

Note: The full text of the resource paper prepared and circulated by Mr. Pozdena in advance of the conference appears in the "Resource Papers" section of these proceedings.

My paper is about the transportation decision-making process—the process by which we plan for, select, and implement transportation projects in the public sector. This process can be viewed as the public-sector analogue of the process that the private sector uses to choose from among competing investments.

However, the private sector has the advantage of having a singular objective: to maximize profit. It enjoys the benefits of a winnowing process in which economically unproductive projects are very quickly taken out of the mix. We don't always have that luxury in the public sector. So, we have to have to develop analytic processes that are more complex and more time-consuming. The paper I prepared for this conference focuses on the information requirements for selecting transportation policies, programs, and projects within the public sector.

My paper and my remarks revolve around a simple decision hierarchy. Within this hierarchy you set clear policy objectives and evaluation criteria. You then set up programs that align with those objectives and meet those criteria. The programs are used to develop candidate projects. Finally, you apply a rigorous selection methodology to those candidate projects. Above all, it is important to articulate objectives and evaluation criteria at the front end of the process and then carry those objectives and criteria throughout the hierarchy.

Of course, all this takes place in a bath not only of data and analysis, but also of political and social goal-seeking. Thus, many projects are selected through a shortcut process, which is not always a healthy thing. Shortcut analyses and ex-post-facto project justifications actually were not too bad in our nation's early years. If you knew you needed to span the Golden Gate or cross the East River, you could make small errors relative to the project's large benefits and really not impair economic efficiency very significantly. But now we must concern ourselves with the margins. In this day, we are more likely to make relatively large errors on a project's incremental benefits unless we do the analysis with more rigor.

There is an old joke about lawyers, that 99 percent of lawyers give the rest of them a bad name. I think the same is true about the transportation decision process: it is not perfect in the main, but it still has kernels of good judgment. Moreover, we can understand how it can be improved by looking at the idealized process.

Certainly you have to respect political reality, because this is the world in which we live. Still, my own feeling is that a lot of the constraints on analysis that are attributable to political demands could be removed if we better understood the opportunity costs that they impose. I truly believe that information and analysis can help remove some of the political constraints that we otherwise take for granted.

As we move through the decision hierarchy from policy, to programming, to project selection, we must face a myriad of measurement issues. The main thing is to make sure that we count everything worth counting. This is really the sum total of the various research statements I have included at the end of my paper. These research statements deal with such things as

- The inadequate characterization of transit supply responses within the urban transportation context,
- How to better monetize transportation externalities,
- How to better integrate system modeling and evaluation, and
- How to deal with distributional issues related to who pays for and who benefits from a given improvement to the transportation system.

I am sure that this conference's working groups will come up with many more.

Working Group Findings

Abigail McKenzie of the Minnesota Department of Transportation, Anthony Rufolo of Portland State University (Oregon), and Terry Gotts of the Michigan Department of Transportation led the three groups assigned to the issue of economic evaluation for transportation decision making. The findings of these groups follow.

Key Questions

- Have all policy and project options been considered? For example, have all engineering design alternatives and modal alternatives been considered? Has the potential role of pricing and privatization been considered? What impact do existing legislation and, notably, earmarking have on the decision? What are the tradeoffs between system preservation and enhancement?
- Have all potential effects of the proposed project been evaluated (e.g., congestion, environmental effects, user benefits, land-use patterns, business development, job creation)?
- Does the proposed project produce net gains to society as a whole? Within those net gains, who benefits? Who defines the benefits? What is the nature of the perceived benefits? Who bears the costs and why? How, if at all, can we compensate those bearing a disproportionate share of the costs?
- How well did prior decisions work?
- How do we ensure that the analysis is credible?
- What share of resources should be directed to data gathering, analysis, and monitoring?
- Is there a clear, well-defined policy that reflects societal values? Can I defend and justify my program?
- How should we allocate resources among modes (highways, public transit, intercity rail, ports, etc.) and nontransportation projects?
- How should we finance transportation investments? Does the choice bias future decisions?
- How do we monetize (value) benefits whose natural units are not dollars?
- How do I rank projects?
- What alternatives can achieve program objectives?
- How do we factor risks (and uncertainty) in outcomes into the decision-making process?
- What is the internal rate of return for a project and its alternatives?
- What is the interaction/synergy between projects?
- How do we consider factors such as environmental justice?
- What are the limitations on data and analysis?
- Which impacts are benefits, which are costs, and which are double-counted?
- What problem does the proposed project solve and how will we know if it does so?
- What policies and goals are supported? How do we know? Who cares?
- How do we choose among potential beneficiaries?
- Was economic analysis part of the analysis? What weight should be given to it?
- How do you evaluate system preservation versus enhancement?
- How does one make comparisons across modes?
- Does added capacity increase economic development?
- When should benefit-cost analysis be done?
- How reliable are our estimates of road users' costs?

Sufficiency of Data and Analytic Tools

- In generating alternatives, it is difficult to discern interactions among individual projects.
- We need improved information on how to monetize benefits with natural units other than dollars (e.g., environmental impacts, travel time).

- We need improved travel demand forecasts, and we need to improve our understanding of travel behavior (especially nonpeak). In the same vein, we need to disaggregate elasticities by submarkets. Also, detailed trip/tour characteristics by demographic group are needed to disaggregate benefits and costs.
- As noted by Randall Pozdena, we need a better understanding of proposed projects' impact on networks and businesses. We also need a better understanding of freight and transit supply responses to changing conditions and more fine-grained data on freight movements.
- We need a better method for measuring sprawl.
- We need better information on how technology and changes to existing policy will affect future demand.
- There is little reliable information on the effectiveness of transportation demand management and other strategies.
- Estimates of user benefits from capacity improvements are often based on inaccurate baselines.
- "Costs" may not include all applicable costs, such as the opportunity cost of right-of-way.
- Inaccurate myths are frequently used in policy discussions, such as the notion that each transit ride represents reduced auto use.
- The system effects of individual decisions are neither well modeled nor well evaluated.
- It would be helpful to see how risks and uncertainty might be factored into the decision-making process and how uncertainty affects the results.
- Monitoring is hampered by a lack of baseline (i.e., benchmark) data (speed, safety, travel time, volumes, etc.). We need to keep regular tabs on how estimated costs compare to actuals.
- We lack honest auditors, accreditation, or other methods of certifying the analytic process. We also need updated guidance on how to perform economic analysis. Automated tools to support benefit-cost analysis would be helpful.
- It is unclear how willing policy makers are to commit resources to data and analysis, particularly given the uncertainty concerning the payback from investing in better information and analysis.
- Analysts lack good information on travel-time values by commodity group and trip purpose.
- Data are needed for quantifying the benefits of system preservation; the effect of given improvements on the cost of operating a vehicle; and the relationship among transit infrastructure, amenities, and benefits.

Research Needs

- Obstacles to implementing benefit-cost analysis: issues and solutions;
- Development of best practices for benefit-cost analysis and a standardized reporting template;
- Improvement of estimates of travel-time value for passengers and commodities;
- Development of expanded information on travel behavior and the demographic characteristics of households;
- Improvement of the integration of transportation system modeling and evaluation models;
- Development of a methodology to disaggregate elasticities;
- Identification of primary conditions and determinants for success in implementing congestion pricing;
- Management of risk in the transportation investment decision-making process;
- Development of improved methods for estimating the distribution of benefits and costs from transportation projects among population subgroups and for compensating affected groups;
- Development of a methodology for generating complete sets of alternatives;
- Development of strategies for allocating resources across modal programs;
- Monetization of transportation externalities; and
- Assessment of the impact of project financing choices on project decisions.

KEY TOPICS

Estimation of Revenues from Use Charges, Taxes, and Other Sources of Income

PRESENTATION

David Gillen, *University of California, Berkeley*

Note: The full text of the resource paper prepared and circulated by Mr. Gillen in advance of the conference appears in the "Resource Papers" section of these proceedings.

Randall Eberts talked about what we should be doing. Randall Pozdena said how we should be evaluating our options among infrastructure alternatives. And now I am going to talk about how we pay for our choices.

The earlier discussions concerning capital stocks are also important to this discussion, because that is really what this revenue forecasting is about. Indeed, in the past decade, we have witnessed a dramatic shift from a supply-side world to a demand-side world, or at least a world in which one must recognize what the value of the demand side looks like. This is essential for revenue forecasting, as revenues are driven by demand for the product, which is, in this case, transportation infrastructure services.

If you look at highway finance you find that the majority of revenue (54 percent) comes from fuel taxes. About 24 percent of total highway revenue comes from registration fees. How difficult can it be to predict revenues and thus set expenditure targets? Can you not just predict how much fuel and how many vehicle registrations are projected and arrive at some pretty good numbers? Why is this a problem?

My analysis of registration fee revenues nationwide revealed very little variability over time. But the story is very different when one considers individual states, and this is true for both registration fee and fuel tax revenues. Consider Louisiana. Between 1994 and 1995, both registration and fuel tax revenues went up about 1.7 percent. Between 1995 and 1996, they went up 27.6 percent. Between 1996 and 1997, they went down 18.5 percent. If you gear spending to anticipated revenues, you will take on some significant political and economic risk if your cutoff point keeps going up and down, year in and year out. I should note that Louisiana is not unique in these huge fluctuations; Montana, North Carolina, and Pennsylvania all display this same type of variability.

What is going on here? The vehicle miles traveled (VMT) cannot be changing all that much. The fuel efficiency of the fleet is not changing all that much. Can our measurements really be that bad? I think that there are really three questions that one should be asking:

- First, if the models are good, are the data bad?
- Second, if the data are all right, are the models bad?
- And third, what are we to do about other types of transportation-related revenues? States' reluctance to increase gasoline taxes is redirecting interest toward tolls and dedicated taxes. How we are going to integrate those new revenue streams into our forecasting models?

How does one go about looking at questions like these? Well, you might start out by looking at the formula for fuel tax revenues: revenues are simply the product of fuel price times quantity sold. The quantity sold is in turn a function of how far one drives and how fuel-efficient the vehicles are. So then the question becomes, how accurate are VMT measurements and how accurate are the fuel efficiency measurements of the vehicle stock?

When you look at input data, and particularly VMT measurements, they really are not all that good. Some states have permanent traffic detectors, but those detectors are generally in older areas of town and thus ignore newer, growing areas where there may, in fact, be more traffic. Also, these trip detectors don't tell you anything about the attributes of the trips, and, as we know from the preceding presentations, attributes matter.

As for models, those currently used to estimate travel patterns and fuel efficiency are relatively simple. They merely produce accounting identities and reflect nothing about behavioral patterns. So, you cannot understand how an increase in world fuel prices affects VMT, for example.

I conclude that we certainly need better measures of the relevant variables and more insightful modeling of the structural forms. We really must figure how things fit together and derive the reduced forms.

We also need some better econometric techniques. We appear to be in the midst of a shift away from needs studies and toward an emphasis on making optimal investments. This implies an analytic process that more closely resembles a private-sector mentality, and that in turn suggests a new approach to estimation.

In closing, I will list the research statements that appear in my paper:

- First, we need better estimates of VMT and particularly of the attributes of VMT. How long are the trips? Where are they taking place?
- Second, we need some sort of generic model that the states could adapt to their own particular circumstances.
- Third, we need some development of commercial VMT. To date, almost all work has focused on passenger trips, and almost none on commercial movements.
- Fourth and finally, we need a study that looks at new financing mechanisms and how they are integrated both institutionally and practically into the construction of revenue capital requirements.

[Note: Mr. Gillen's remarks led members of the audience into a general discussion concerning the differing time periods over which revenue forecasting can take place. Robert Martinez noted that revenue forecasting can be viewed in two ways: first, as a tool for projecting one's ability to meet cash-flow demands 1 or 2 years into the future; and second, as a tool for planning long-range capital investments. Mr. Martinez added that when serving as Virginia's secretary of transportation, he found that the state was quite capable of projecting short-term revenues for cash-flow purposes, but that the real problem came when one attempted to look significantly further into the future. Dennis Lebo of the Pennsylvania Department of Transportation and Samuel Bonasso of the West Virginia Department of Transportation agreed that short-term revenue projections within their states were quite reliable, but that accuracy in long-term projections was problematic. All three further agreed that although short-term forecasts of state-level revenues were quite reliable, federal funding levels from one year to the next were notoriously uncertain and represented one of the greatest challenges to state-level decision making.

[Mr. Gillen responded that in his view, revenue forecasts cannot look more than 3 to 5 years into the future with any level of accuracy. He added that even these 3- to 5-year forecasts tend to be questionable and demand improvements to causal models and a better understanding of behavioral relationships.]

Working Group Findings

Christopher Mann of the Southeast Michigan Council of Governments led the discussions of the working group assigned to the issue of revenue forecasting. In contrast to the other groups, the group dealing with revenue forecasting elected to examine Questions 1 and 2 (key questions policy makers should be asking and the sufficiency of existing data and analytic tools) together. The group chose to do so because members felt that policy makers who rely on revenue forecasts for policy-making purposes ought to have an understanding of the foundation for those forecasts. In particular, the members of the group felt that policy makers need to know how robust the forecasting model and input data are. Policy makers also need to understand the risk of a forecast being off by 10 or 20 percent and the implications of that margin of error.

The specific findings of this working group follow.

Key Questions and Sufficiency of Data and Analytic Tools

- Current status: Who is doing what? What data are used and what are their limitations? What are the purpose and use of these data?
- Given that states and larger metropolitan planning organizations have different levels of expertise in revenue forecasting, how do we network with other states? How might we encourage information sharing and mentoring?
- How accurate are the data currently being collected?
- How is nonuser fee revenue—for example, receipts from local option taxes, tax increment financing districts, and other alternatives—forecast?
- What do forecasters need to improve accuracy?
- How will transportation and information collection technology affect our ability to forecast revenue?

Research Needs

- Development of an information base of current revenue forecasting efforts,
- Improvement of estimates of state-level VMT for passenger vehicles and commercial trucks,
- Development of a generic starting point model for forecasting state fuel tax revenue,
- Examination of the implications of alternative revenue instruments for highway financing,
- Examination of Bureau of Transportation Statistics products' role in improved revenue forecasting,
- Assessment of the impact of evolutionary vehicle and information technology on revenue forecasting, and
- Examination of the revenue gains and cost savings attributable to shifts in the point of fuel taxation.

Proposed Research Statements

Responses

Texts

Proposed Research Statements
Responses

Marlon Boarnet, *University of California at Irvine:*

I think that the proposals presented this morning were excellent. I suppose the next step is to prioritize the individual proposals. In addressing this question of prioritization, I want to make three points.

First, a lot of the discussion still seems to implicitly or explicitly focus on the overall impact of the transportation system on the health of the macroeconomy. I believe that it is time to recognize that we can now say somewhat definitively that we are at about the right level of investment. Today's best empirical studies suggest that the marginal effects of additional investment at the macro level are not as big as was thought 10 years ago. Thus, to my mind, we do not face an analytic crisis when pondering big questions such as how big the Transportation Equity Act for the 21st Century ought to be. Rather, the important questions today tend to center on specific projects. For example, what are the merits of a given highway widening project, or a new link, or a repaving project, or an airport expansion? What would that specific project do for a local or regional economy? Would it benefit one economy and disadvantage another? National findings are statements of averages, and they say nothing about whether individual investments are wise or useful.

My second point concerns the extent to which we should continue to refine our measurement of transportation infrastructure stocks. In my judgment, further attention to capital stocks is probably a mistake. Instead, we need to concentrate on the services produced by transportation infrastructure. That is, we now need to take the next step and assess the *value* of the services that our existing capital stocks produce, including the geographical impact of those services and their impact across different groups of people.

Along the same lines, I think it is important to understand how factors of production, including people and capital, migrate in response to different investments. That is quite a technical issue, but it is very important.

My third point centers on the communication issue. To what extent do we need to better communicate to the public? Certainly communication is vital. But as earlier mentioned, oftentimes certain groups of people might not want to know the answer. In response, we may wish to view the large federal role in transportation as a bully pulpit to elicit "better" behavior from state and local authorities. The federal government could play almost a standard-setting role in terms of how one evaluates projects.

In closing, I should mention that I was especially struck by one proposal that seemed to pull these elements together very nicely. It is the proposal concerning improved methods for understanding the distribution of benefits and costs and for compensating affected people. Now, I realize that there is some difference of opinion concerning the merits of this proposal. But let me explain why I singled it out. I like that proposal because it implicitly has a project focus. It tries to elicit the effects of individual projects. And it tries to get at the main topic we debate in the political arena, 9 times out of 10. Most of the transportation debates I have observed seem to revolve almost completely around who wins and who loses. One reason why these debates rage so fiercely is that we really do not compensate people at all. Take, for example, the issue of local airport expansion. There are definitely individuals who think that their businesses will greatly benefit from the expansion of a given airport. But there are people who live under the flight path who are equally convinced that they will be greatly disadvantaged.

I submit that if we compensated these folks, much of the debate would not be so fierce. We have the beginnings of technical tools to figure out how to effect such compensation. Now, the political challenge would be intense. But a consideration of compensation would, I think, refocus the debate in a way that could ultimately be more fair. It also would provide a mechanism for resolving conflicts in a new way. It could move us beyond conceptual arguments of dueling studies and toward a real dollar-value assessment: the amount to be paid to those who are harmed. And if we find out that this is more than we think the project is worth, it would provide a more realistic litmus test on whether one should move forward.

Hank Dittmar, *Surface Transportation Policy Project:*

In our business, economic analysis is used most often by project proponents or opponents for the following purposes: (a) to justify decisions or points that they have already reached, (b) as wallpaper to cover holes in problems with their projects, or (c) as a rhetorical tool to argue for a desired legislative outcome. And so, an underlying topic on which this conference ought to focus is how to differentiate true economic analysis from the spurious economic claims of project proponents. Indeed, one of the key problems we face is that those spurious and unsubstantiated economic claims are fully integrated into the political decision-making process.

It is troubling that so little data are collected on the decisions that we do make. The Surface Transportation Policy Project has been doing some research on the availability of traffic forecasts and travel time savings data on costly road projects. Our findings are unsettling: for five of the eight big projects we studied, we have been unable to unearth any data that I would deem worthy of putting in a report.

With regard to the research statements proposed today, you need to recognize that there is not very much money available to fund this kind of study. The research budget of the Federal Highway Administration (FHWA) is fully earmarked. There is heavy competition for National Cooperative Highway Research Program funds. So I urge you all to narrow the list down to just three or four very compelling projects and push hard for those few.

As for research priorities, I applaud the attention the group has paid to freight and goods movement. It also would be nice to see a study of the intersection of goods movement, information movement, and personal travel, particularly in terms of how they are beginning to substitute for and complement one another. Similarly, I did not see a lot of discussion about travel decision making at the household level. That involves not only household trip selection, but also decisions concerning the purchase of a car, how household transportation budgets affect economic well-being, and how that has changed over time.

I also want to vote for questions that concern local economic development projects. There is a lot of research that shows that unless a road project is part of an overall regional economic development plan, the road is not going to do much. Case-study work is an appropriate way to get at this question, and it is critical in order to get rid of some of the wishful thinking that we see.

It also would be nice to see a project that took a detailed look at the project selection process to determine what role, if any, economic data or benefit-cost analysis plays. If we want to have better decision making, we need to look at how that decision making takes place. Again, this analysis is probably best suited to some case studies in a few places. This would be a difficult project because the topic is inherently political. Perhaps it would be best to choose some older projects, so that you are not goring any recent oxen. But I think it is very important, because if we want to design a technology transfer process, we need to understand the process into which we are trying to inject that technology.

Finally, if I were to pick the No. 1 thing we need to do, it would be to bolster informal networks. It appears that informal networks today tend to be dominated by the same groups of elites who attend these conferences. It would be nice to supplement these networks with individuals at state department of transportation (DOT) division offices, the smaller metropolitan planning organizations (MPOs), and transit agencies. These are the folks who are really on the front lines.

Pete Hathaway, *California Transportation Commission:*

The agency that I represent, the California Transportation Commission, has three responsibilities that are germane to this discussion. First, we are the agency that estimates the funds and approves the projects that go in the state transportation program. Second, we provide policy advice to both our legislature and our governor and his administration. And third, we serve as a forum in which MPOs and the state DOT try to reach consensus or accommodation for the various policies and projects that they want to pursue.

I want to commend you all for the list of very practical research proposals. I want to spend my time highlighting those that seem more useful from the standpoint of my agency, and which ones seem less so.

Three research proposals appearing either in the resource papers or in the previous presentations really stand out for me. First, it is very important for us to learn more about the marginal economic benefits of various levels of investment in transportation overall. We in California have a real-life example that demonstrates the importance of this question. We are currently looking at a proposal for $4 billion of general obligation bonds. The political process tossed us a 25 percent portion of the proceeds until or unless we can prove that we need something different. I sure would like to know how to demonstrate a lot of value for that investment.

In the same vein, we also need some consistency of information in this arena to weed out boosterism. Consider, for example, a current dilemma we face in Northern California. The City of Chico is a city of 100,000. It has a good state university that specializes in high technology. It has a large labor force. Yet it also has some of the worst unemployment in the state. This is probably because Chico is 50 miles from the nearest freeway. So we are proposing to spend $400 million developing a freeway corridor that will go to Chico, in order to bring Chico into the state's mainstream economy. Is that an effective strategy? We do not have a clue.

Second, we should examine the relative economic benefits within the transportation sector for resource allocation. As an example, my commission is currently reviewing a proposal to provide Caltrans with $1 billion for rehabilitation. The problem is that we do not know the marginal value of rehabilitation versus improvements to the existing system. Most regional agencies, for political reasons, are not going to contest the decision to focus on rehabilitation, though a few have begun to come forward, albeit meekly, to request that some of the funding go to improvements, too.

Third, we need to be better positioned to evaluate multiple projects, considering, for example, a carpool lane, versus a mixed-flow lane, versus a high-occupancy toll lane.

Among the research statements that I consider important, but maybe less so, are studies on the valuation of externalities and travel time. Consensus on these matters is possible among economists, I suppose, but I do not think it is possible in the political arena. Different people think externalities are of different importance and of different worth.

It is interesting that no one brought out Randy Pozdena's proposal to look at the supply-side responses of transit. I think that is a good one, but I am even more interested in the supply-side responses in the freight transportation arena. There is a freeway in Southern California that carries 35,000 trucks a day. If the congestion gets bad, where are they going to go? We definitely would like to know, for the sake of the rest of the system.

Finally, I would put lesser priority on studies that are aimed at calculating the value of transportation stock. This may be useful information in the political arena and for economists, but we at the Transportation Commission do not need it. Similarly, I view more research about revenue forecasting as a lower priority. We in California really do not have a problem with forecasting fuel tax revenues; we tend to be accurate within plus or minus 10 percent, which is acceptable to the commission, unless we are chronically wrong in one direction all the time. I do agree, however, that we need better ways to forecast the alternative revenue sources that are now coming into play.

As a final point, I agree that we need better ways to translate technical information to the layperson and the political decision maker. I do not know that this communication issue is really a research subject, but it certainly is a basic need that arises at the end of the research trail.

Kevin Heanue, *Transportation Consultant:*

Let me offer a few opening remarks on the topic of transportation investment and economic health. Almost all transportation project evaluations focus on the benefits of investing. I believe that a look at the cost of not investing is equally important. I agree with Marlon Boarnet's comment that we seem to have a relatively good balance between overall transportation investment and needs or requirements at the national level. However, in individual metropolitan areas, and certainly along some key corridors, there are significant transportation deficiencies. Not investing in areas with transportation deficiencies results in a decline in system performance and also can result in the loss of jobs, population, and other opportunities. I did not see that any of the groups called for research on the costs associated with underinvestment or of not investing in overcoming transportation deficiencies.

Turning to the topic of economic evaluation, I heard a number of suggestions about improving travel models. I believe that the TRANSIMS group already is working on many of these problems. I hope that the TRANSIMS models when fully developed will resolve some of the issues that have been raised.

As for putting transportation externalities in monetary terms, I am concerned that we have overemphasized the cost side. Knowledge of transportation benefits at the project level remains relatively weak. We generally consider only travel time saving. Research and practice give considerable attention to both direct and external costs of transportation facilities. But knowledge remains extremely crude on the benefits side. The proposals put forth today were rather neutral on the topic of costs and benefits. I see a need to remedy the imbalance evident in past research and practice in this area.

Let me now turn to some thoughts prompted by the resource papers. Randy Pozdena talked about the controversy in the field of economics over the value of time and the use of interest (or discount) rates. I would like to underscore the importance of looking at present value and discounting in a more realistic way. Some of you were bemoaning the fact that we do not see more benefit-cost analysis. I would argue that conventional benefit-cost analysis is perhaps not the best way to look at transportation investments. At the least, we ought to structure the analysis in light of an understanding that the benefits are very real, despite the fact that they are occurring well into the future.

A dollar today is worth a dollar. But 50 years out, a dollar of transportation benefits is credited, in today's terms, as worth only 9 cents or 2 cents, depending on whether you are using a 5 percent or 8 percent discount rate. At 20 years out, the period of all project analysis, a dollar of benefits is worth 38 cents in today's terms if one uses a 5 percent discount rate and only 21 cents if you use the 8 percent rate. The choice of a discount rate makes a big difference when analyzing transportation projects, because all capital costs are incurred up front, while the benefit stream is spread out over time. If we choose too high a discount rate, we end up discounting away most of the benefits, while still recognizing all of the costs. By the time the future period has arrived, it is no longer possible to advance the project because development has occurred on the right-of-way.

As an illustrative anecdote, I remember the day that FHWA stopped requiring benefit-cost analysis on interstate projects. That was the day that Frank Turner was told that one of the key interstate facilities in Washington had a benefit-cost ratio of 0.39. Mr. Turner was crestfallen, for he had never come across an interstate project that did not have a benefit-cost ratio greater than 1.0. What was going on? Well, the issue was that we were now trying to fill gaps in the system, and these gaps tended to occur in dense urban environments where the costs of acquisition and construction were very high. Some of these urban projects just would not pay for themselves.

In my view, we have cities that are overbuilt relative to their transportation system. We must recognize that we have to subsidize transportation, be it highways or transit, in order to provide adequate service. And yet the economic tools we use treat transportation investment in a manner that requires the benefits to be accrued in the short term.

In the Washington, D.C., area, the Capital Beltway and the Metrorail system are both more than 20 years old. They are the backbone of the region's transportation system. When they were evaluated back in the 1950s and 1960s, the benefits they bring today would hardly enter the benefit/cost calculation since discounting would make today's benefits irrelevant.

It is critical that we acknowledge that transportation improvements will have an impact on our children's children. We need to treat far-off impacts with respect. We should not eliminate discounting, but we might look at changing the parameters of the analysis. I think we can still use discount rates and economic evaluation, but we must acknowledge that one cannot expand a transportation system if our analysis simply starts today, forecasts out 20 years, and tries to justify the investment on that basis. Instead, I think you have to jump ahead 20 or 30 years, ask yourself what will make a city function in an efficient manner, and then work backward.

Finally, I would like to see more emphasis on operations. Intelligent transportation systems deal with the tremendous efficiency that can be gained by keeping traffic moving at the point at which capacity is maximized. The traveling public and some transportation professionals do not realize how inefficient it is to allow a few extra vehicles to congest, and thus degrade, the operation of a highway facility flowing at capacity and optimum speed. Those few extra vehicles not only drop speed but also significantly reduce the number of vehicles the facility can accommodate. Ramp metering is part of the answer, as is pricing. And yet most of the discussion these days seems to focus on investment in new facilities and maintenance. I would urge that future research in economic analysis give equal consideration to the benefits of investment in operations.

Proposed Research Statements

Texts

Group 1: Levels of Investment and Economic Health

Development of Comprehensive Input Data for Measuring Transportation Infrastructure Capital Stocks

Description of Research Problem

Most studies of the impacts of highway investment use either a production function approach or a cost function approach. Both approaches require measures of productive highway capital stock; capital stock measures also are needed for other transportation modes at national, state, metropolitan, and local levels. This creates a need for a comprehensive set of transportation infrastructure capital stock measures. However, past and current capital stock measurement efforts are greatly hampered by a lack of data on investment levels, service life, and retirement and deterioration patterns, stratified both by type of asset and by location. Given that the most widely used method of capital stock measurement requires these data as inputs, building such a data set is the first step toward more current capital stock measures and more reliable and detailed studies of the impact of public investment in transportation infrastructure.

Work To Be Performed

This research project will produce a comprehensive set of input data for measuring public transportation infrastructure capital stock for all transportation modes and at all important geographical levels. It will require efforts in data collection, data integration, and statistical analysis. More specifically, it will involve building the following data components:

- A set of time series data on public investment in transportation infrastructure. The time series in this data set will not only have to span a sufficiently long period of time but also need to be sufficiently specific to address important substructures within each type of asset. Because the time period often extends far back into history, extensive review of data sources and data extrapolations may be required.
- Data on service lives by asset types, subcomponents of assets, and locations. This may require a survey of state and local transportation planners or engineers. Estimates based on analytical methods also may have to be explored.
- Data on retirement patterns. For transportation infrastructure, reconstruction and abandonment are equivalent to retirement. Retirement patterns are not incorporated in most of the previous transportation infrastructure capital stock measurements. Building reliable data on retirement patterns, however, may require data collection and extensive statistical analyses.
- Patterns of efficiency decline. For productive capital stock, it is important to understand how efficiency declines over time in order to capture how the infrastructure capital loses its productive capacity over time.

Cost estimate: $600,000

Development of Expanded Measures of Transportation Systems

Description of Research Problem

Transportation systems have been constructed primarily using the perpetual inventory method and crude physical characteristics, such as lane miles of highways. These measures do not capture system use; output of transportation systems including traffic flow, reliability, safety, and volume; and characteristics of transportation systems including grades and functional types. Such measures are fundamental for estimating the relation between transportation systems and economic health, which can be used by state and local decision makers. Omitting these characteristics from highway capital stock and highway capital input measures and from the analysis could lead to significant biases in the estimation of the effect of highways on economic activity. The lack of these measures also precludes state analysts from obtaining estimates specific to their states.

Work To Be Performed

This initiative proposes to improve the measures of transportation systems that are typically used in estimating the effect of transportation on economic outcomes. Highway capital input estimates that incorporate these elements, and that are consistent with the relationship among system characteristics, outputs, and outcomes, will be pursued. This effort will be comprehensive in that it includes the several major types of transportation systems, including highways, rail, air, and water shipping. An effort will be made to collect data so that it can identify facilities at specific locations (such as highway corridors) and so that it can be aggregated to various levels depending upon need. Geographic information systems will be explored as a means to organize this information. The primary products of this research are measures of highway capital stock at the state and local levels that incorporate the characteristics of local areas.

Cost estimate: $750,000

Exploration of the Correspondence Between the Economic Benefits of Highway Investment and Road User Taxation

Description of Research Problem

Empirical studies of the effects of highway investment on the commercial sector of the U.S. economy reveal significant differences in productivity benefits across industry sectors. In other words, the marginal benefits of infrastructure investment are not uniformly distributed across the production sectors. For a variety of reasons, some industries benefit more from road improvements than others, and this unequal distribution of benefits of road investment raises important public policy issues about the efficiency and fairness of current road user taxation. Road user taxes largely are based on the public cost of highway provision and repair imposed by different types of vehicles. This means that tax levels tend to vary in accordance with vehicle characteristics. Because different products can be carried in similar vehicles and will be subject to similar tax contribution, some shippers may be required to pay more for the road system than they receive in benefits, and vice versa. In effect, the incidence of road user taxation is independent of the benefits of infrastructure received.

Work To Be Performed

Through an econometric analysis of the distribution of benefits and social welfare, this research will evaluate the extent to which the current system of road user taxes may have unintended economic consequences. Specific questions to be addressed will include the following:

- Does the current system of vehicle taxation result in interindustry cross subsidies?
- To what extent do road taxes alter industry-specific net benefits and social welfare?
- How do road charges affect the flow of producer benefits over time and in different locations?
- Do variations in road taxes across political jurisdictions affect industry benefits?

Cost estimate: $200,000

Assessment of Transportation's Role in Encouraging Development in Economically Depressed Areas

Description of Research Problem

There are pockets of economically depressed areas where the rate of unemployment is chronically high, and there is little, if any, business or manufacturing activity taking place. Usually such areas can provide a good supply of labor (albeit typically unskilled), but due to a lack of job opportunities, this labor supply remains underused. Very often a high percentage of the resident population of such areas is on one form of public assistance or another. These economically underdeveloped pockets exist even in the most prosperous states or regions, such as, for example, the greater Los Angeles metropolitan area. Rural areas provide more instances of economically depressed areas, usually with a high degree of seasonal unemployment. To add to the problem, these areas generally do not enjoy good political representation and thus fail to capture the attention of the public sector. In addition, the risks and the cost of doing business in these areas usually are greater than the private sector might want to assume. These facts contribute to a persistent cycle of underdevelopment.

The research question is whether provision of transportation facilities and services might be able to help such areas. Industrial location publications confirm that more than 90 percent of industrial locations are on four-lane facilities. At the same time, it is recognized that transportation might not be the only, or even the major, factor in the process of economic development. However, transportation might be able to act as a catalyst to attract other spurs to economic development.

Given the pressure that many state departments of transportation (DOTs) face from local governments eager to attract or retain a specific firm or industry, these DOTs need new tools and methodologies to assess quickly the total public benefits of these proposed improvements.

Work To Be Performed

This research project will identify economically depressed areas and assess their transportation needs. The analysis then will explore the extent to which improved transportation infrastructure could support development in these areas and/or attract other spurs to economic development. This work would be supported by case studies that demonstrate exemplary analytic practices that can be duplicated elsewhere.

Beyond identifying strategies for assessing the economic benefits of transportation investment within localized areas, additional objectives of this research are (*a*) to create a national agenda for a microeconomic development program, and (*b*) to provide a rationale for directing some growth away from the high-growth areas and toward areas where growth can be more easily accommodated without the undesirable side effects.

Cost estimate: one state study, $500,000; several states, $1 million

Measurement of Transportation Outcomes and Improvement of the Efficiency of Data Collection

Description of Research Problem

Monitoring the long-term effects of transportation system investment on economic health requires a well-conceived approach to data collection, dissemination, and analysis. It further requires a substantial body of data to measure the outputs derived from transportation facilities funded by given investments and the outcomes of these investments. Additional data and analytic methods will be required to assess the linkages among investment, output, and outcome and to determine both the short-term and long-term effects of these investments on the economic health of cities, regions, states, and the nation.

The ability to sustain the level of data collection required by this new emphasis on linking the effects of transportation investment to the economic health of various jurisdictions will depend upon a much more highly coordinated and collaborative method of data collection and integration than has heretofore been practiced within the transportation planning community. In addition to incentives and resources that traditionally have been embodied in the uniform planning work programs of metropolitan planning organizations, regional planning agencies, economic development agencies, and the data collection functions of the states and federal agencies, new ways must be found to establish uniform collection, measurement, reliability, and transferability of information on economic and transportation system performance. Current data collection efforts may provide some, but not all, of the quantifiable measures that may be needed for future investment and economic analysis.

The interdependence of economic linkages between jurisdictions and regions (which may or may not be adjacent to each other) and the need for a seamless hierarchy of data that deals with the movement of people and goods across existing political boundaries will render current data collection practices obsolete within just a few years. Thus, the ability to sustain a long-term data collection strategy and ongoing and effective use of these data depends upon a much higher level of coordination among the governmental agencies, private-sector representatives, and other stakeholders as they collect and archive comprehensive, reliable, and usable economic performance data for transportation systems.

Work To Be Performed

This research proposal intends a two-tiered approach to establish a working collaboration among all entities with an interest in developing the data resources needed to assess the relationship between economic health and transportation (and other infrastructure) investments. The first tier of this study is basic research on the current state of practice in data collection and utilization that is related to measures of performance, output, and outcomes of the transportation system, pertaining to economic health at different jurisdictional levels. This research will examine the kinds of data that are currently collected, and how these data support the analytical requirements for quantifying and linking economic activity and transportation system performance. Assessed will be issues related to the transferability of economic and performance data between jurisdictions, unique data collection requirements, current and best practices for collection of economic and system performance data, and new data, as well as the long-term requirements for data to support programmatic assessment (including postproject monitoring).

The second tier of this study will provide the forum through which various jurisdictions responsible for collecting economic and transportation system performance data can develop the collaborative mechanisms to implement a program designed to meet data collection needs associated with a more directed and focused transportation investment program. In addition to establishing forums, workshops, and collaborative discussions to involve local, state, and federal agencies, as well as private corporations and nongovernmental stakeholders, this project will establish a key role for the university transportation centers as conveners and repository institutions. Systematic collaboration between jurisdictions, with significant emphasis on resources and agency missions, will enable all participating organizations to commit to long-term involvement in integrated data collection efforts.

Cost estimate: $1.5 million

Synthesis of Economic Linkage Case Studies

Description of Research Problem

There has been significant economic research completed at all levels of government (national, regional, state, and local). Due to the vast amount of information collected so far, it is likely that many policy makers and technical analysts are unaware of the full extent of the available literature. As a result, analysts may duplicate previous work and deal with difficult study design issues that already have been researched, thus delaying application. Even though more detailed evaluations specific to a given investment dilemma or location may eventually be needed, an understanding of the commonalties across jurisdictions and past approaches to problem solving can inform local decisions. Moreover, analysts will be better positioned to focus their annual research budget when they possess a better understanding of what work already has been done.

Work To Be Performed

This project will center on a comprehensive review of economic research conducted to date. On the basis of the identified anecdotal or other localized research findings, this project will develop generalized findings and identify gaps for further research. The objective is to inform decision makers of key linkages between transportation and economic health and present this information so that it can be applied to similar circumstances, with findings arrayed across a variety of transportation considerations and geographic conditions. Location-specific conditions might include rural and urban areas and local economies typified by agricultural production or severe traffic congestion.

Cost estimate: $250,000

Identification of the Network Effects of Highway Improvements

Description of Research Problem

Individual highway links, when properly connected to each other, form highway networks that carry people and goods from any place to any other place. It is generally recognized that new highway projects can result in improvements in connectivity or other performance of the overall network, which, in turn, results in changes in transport costs and accessibility. However, these network effects generally are not measured, although they should be considered in any evaluation of the merits of a highway project. The objective here will be to create a methodology for measuring highway network effects and to identify how they should be included in project evaluation.

Work To Be Performed

Although individual states could undertake measuring the network effects of various improvements, it would be far more efficient if this were done for all states at one time. With the use of a geographic information system, the accessibility of all major cities in the United States will be derived using a standard travel-time metric that can be translated into dollars based on the Commodity Flow Survey's interstate flows. The system created should be capable of assessing the national reductions in cost attributable to construction of a new network link, and these should be assignable to each state as well as each project. The addition of more network detail and personal travel for states or metropolitan areas will give a better assessment of these network effects, which will vary with scale of analysis and obviously the scale of the project.

Cost estimate: $250,000 to $1 million depending on the level of network detail

Linkage of Commodity Flow Data to Establishment-Level Data To Measure Transportation System Utilization

Description of Research Problem

The primary purpose of transportation systems is to move goods and people. However, studies of the effect of transportation systems on economic activity have not taken into account the movement of goods. For example, with few exceptions, it is assumed that all highways are used with the same level of intensity, which is definitely not the case. From a business perspective, the value of highways or rail depends upon the destination of their shipments. The Commodity Flow Survey shows that manufacturing establishments at the individual level and aggregated within broad industry classifications use highways with different levels of intensity. Thus, productivity estimates depend upon the extent to which businesses use highways.

Work To Be Performed

This project will build from a study already begun at the Center for Economic Studies, the Census Bureau, that has started to construct information showing where and by what mode establishments ship goods. This will be accomplished by merging the microfiles of the 1992 Commodity Flow Survey with the establishment-level records of the Census Bureau's Longitudinal Research Datafile (LRD) files. In this way, information about commodity flows can be linked to business outcomes (such as employment change, output growth, and productivity growth). Particular emphasis is placed on collecting establishment-level data that can be obtained from the Census Bureau's LRD files and from state ES202 files. These data are then merged with the transportation systems data so that spatial correspondence between the users of transportation systems and the outcomes of businesses that use these systems can be established.

The proposed research will extend the Center for Economic Studies' existing effort to more recent data as well as establish historical files so that estimates of the relation between systems and outcomes can be measured more precisely. Moreover, to date the focus of the project has been on highways. In contrast, this effort will extend the analysis to other modes of transportation. The files generated under this research project should be shareable and accessible to other researchers as much as possible.

Cost estimate: $700,000

Estimation of the Impacts of Network Externalities

Description of Research Problem

Improvements in the quality of transportation services and networks shift the demand curve for transportation. More frequent service and reductions in the variability of travel time, for instance, have more of an effect than simply saving travel time, reflected by moving along the conventional demand curve. These service quality improvements are themselves functions of travel demand. The objective of this research is to understand those shifts and determine how to include them in micro- and macroanalyses.

Work To Be Performed

This study will, for both passengers and freight markets, quantify how service frequency and reliability vary with the size of the market. It then will estimate how demand depends on these characteristics in addition to travel time and cost itself. The magnitude of these network externalities then will be considered endogenously within project evaluations.

Cost estimate: $100,000

Analysis of Counties' and States' Provision of Highway Services

Description of Research Problem

Highway facilities are provided by state, county, and city levels of government. Different states have different mixes of this provision. There is a basic lack of understanding of the effects that organizational structures have on the provision of transportation/highway services. The proposed research will use case studies and econometric data to examine the economies of scale of having such services and operation provided by various levels of government. The secondary impact of this research will be to find the most efficient form, and thereby decrease the cost of providing capital stocks and services, and increase transportation output, leading to improved vitality.

Work To Be Performed

The research will examine both the maintenance and capital costs (expenditures), the output (lane miles of roads by functional classification and ownership), and a quality measure (e.g., Highway Performance Monitoring System data for roughness index) of these activities as performed by city, county, and state highway departments. Characteristics of the states and counties (size, population, usage, density, etc.) will be taken into consideration. The approach will be to gather data for the 50 states as well as the counties within these states where such data are available and to assemble a national database. Case studies will examine the impacts of changing organizational approaches, such as outsourcing road maintenance and other forms of privatization.

Cost estimate: $300,000

GROUP 2: ECONOMIC EVALUATION

Obstacles to Implementing Benefit-Cost Analysis: Issues and Solutions

Description of Research Problem

State departments of transportation and other organizations responsible for transportation planning and programming have experienced numerous problems in using benefit-cost analysis. These include the following:

- Lack of familiarity with the tool,
- Perceived lack of uniformity,
- Perceived lack of reliability,
- Perceived or actual cost of implementation,
- Reluctance to rely upon a single statistic, and
- Difficulty in obtaining consensus on appropriate categories of benefits and costs.

Improvements to the state of the art of conducting benefit-cost analysis will have little value without first overcoming these and similar obstacles to implementation.

Work To Be Performed

This research project will include the identification, description, and analysis of actual obstacles experienced by agencies attempting implementation at both the project and system levels. Specifically the research will include the following elements:

- *Survey of current and former practitioners.* The researchers will survey state and regional transportation planning organizations to identify those that have both successfully and unsuccessfully implemented benefit-cost analysis. They will select a representative cross section for more detailed analysis.
- *Case studies.* The researchers will develop case studies of benefit-cost analysis. These case studies will focus on the identification of specific political, administrative, fiscal, and technical problems faced by the agencies. The case studies will include an analysis and description of these obstacles. In the case of successful implementation, the case studies will describe how the obstacles were overcome.
- *Conclusions and recommendations.* The researchers will identify lessons learned and recommend techniques to overcome obstacles. Examples might include improved communication, education and training, or database development.

Cost estimate: $250,000

Development of Best Practices for Benefit-Cost Analysis and a Standardized Reporting Template

Description of Research Problem

Benefit-cost analysis frequently is practiced on an ad-hoc basis. Even similar methodologies include very different benefits and costs. For example, benefit-cost analyses performed by different analysts but for comparable highway projects may or may not include factors related to air quality, loss of habitat, or economic development opportunities, and analysis frequently has little guidance to follow when choosing whether to include such factors.

The utility of benefit-cost analysis also can be hampered by the manner in which the findings are reported; results are typically published as either dense, lengthy reports or alternatively, a single number. Neither of these forms of reporting imparts information very usefully. The result is that decision makers as well as the public at large frequently misuse, misinterpret, or wholly misunderstand the analytic results.

In sum, the practice of benefit-cost analysis is so complex and subject to so much dispute that some practitioners are discouraged from its use because it can be so costly to undertake and the results do little to inform a decision.

An analysis of best practices for benefit-cost analysis coupled with the development (and subsequent use) of a standardized template for reporting the results of an analysis could support improved decision making in a variety of ways. The principal objectives of this project are to ensure consistency across multiple analyses and demystify an important tool for investment decision making.

Work To Be Performed

Phase I will center on research concerning best practices for benefit-cost analysis and preparation of a handbook detailing the findings. The work will be accomplished through the following steps:

1. Identify all reasonable current benefit-cost analysis practices, including selected international experiences.
2. Evaluate the identified practices. Organize them into categories of application (such as by mode: intelligent transportation systems, highway, transit, multimodal, etc.) and rank them within each category.
3. Provide case studies for the top-ranked practices for each category.
4. Prepare a handbook describing the best practices and include case studies as appendices to the manual. This handbook should build on the guidance appearing in the American Association of State Highway and Transportation Officials *Red Book*.

Phase II will involve development of a reporting template through two tasks, as follows:

1. Building on the Phase I findings concerning best practices, perform site visits throughout the country to determine the types of information that decision makers and analysts find most useful in selecting projects. Entities interviewed must represent all levels of government and the private sector, and each entity should have project selection as one of its major responsibilities. This task also will address these decision makers' views on the most effective way to communicate and display information.

2. Set up a reporting template of approximately three to five pages. This template should encourage consistency in reporting as well as full disclosure of the analytic assumptions and principal levers on the ultimate findings. To this end, it might include such items as assumptions, the composition of the benefits and costs by type, the analysis's time horizon, the discount rate, a sensitivity analysis, the composition of beneficiaries by demographic or geographic group, and the allocation of costs and risks to these beneficiaries. It also will be desirable for the template to show baseline conditions and projected outcomes and to provide blank spaces for a future back-check of actual results versus projected outcomes.

Cost estimate: $300,000

Improvement of Estimates of Travel-Time Value for Passengers and Commodities

Description of Research Problem

Travel-time savings are a stated objective for many transportation projects. These savings typically account for a major share of a proposed transportation project's benefits; there is an assumption that transportation improvements improve productivity for industry by lowering transportation costs and they improve safety, comfort, and reliability for personal travel. Current estimates of the value of travel time are fairly imprecise, consisting primarily of broad averages that do not necessarily relate to the mix of users or travel conditions in a corridor for which a project has been proposed. Detailed information is lacking on the values placed on travel-time savings by different individuals, under different circumstances, by shippers of different commodities, and the like.

Travel time is a cost of travel, composed of two main parts: opportunity cost and disutility. Opportunity cost pertains to the degree to which preferred activities are precluded or constrained, such as reading, sleeping, working at a computer, or conversing. Disutility consists of discomfort, anxiety, impatience, and frustration. To the extent that these vary from one travel experience to another, they should be recognized in the valuation of travel time. The value of travel time is the sum of these two components, and it is intended to measure the user's willingness to pay to reduce the time spent in travel.

Little is known about how the value of travel time varies by opportunity cost or disutility factors. Opportunity cost is clearly related to the wage rate, but there are reasons for avoiding making large distinctions on that basis. Trip purpose—such as shopping, recreation, or work—is a breakdown frequently used in modeling, but theory suggests that people shift their time between activities so as to equilibrate them at the margin; hence, the purpose of the trip is not an important determinant of the value of the user's time. Explicit pricing mechanisms such as tolls help to reveal users' values for travel time, but little is gained without knowledge of the personal characteristics of those making choices.

This research project will estimate travel-time values associated with various modes (air, rail, transit, and auto), users (commercial and industrial categories as well as personal travel), and conditions (comfort, uncertainty, etc.). These results should be generalizable to other corridors or projects with common characteristics.

Work To Be Performed

Phase I will focus on a review of current literature and provide a survey of existing estimates of the value of travel time. This should include estimates of the value that individuals place on travel-time savings, differentiated across categories of individuals, types of trips, and types of time savings for specific trips, such as waiting time versus line-haul time for transit trips. It also should include estimates of the value of travel-time savings and variance in time for shippers by type of trip, type of commodity, time of day, and so on.

For individual travelers, the researcher next will develop a classification system to allow for more precise estimates of the effect of travel-time savings by geographic area, time of day, purpose of trip, length of trip, and demographic characteristics. Similar estimates are to be developed for freight movement by type of commodity, geographic area, length of trip, mode of trip, and purpose of trip.

Next, the researcher will determine methods to evaluate the impact of changes in travel time by various demographic groups based on income, race, gender, automobile availability, and location; for commercial and noncommercial transport; and for other characteristics, as determined necessary.

Finally, the researcher will design a work plan for subsequent work, including a strategy to improve as many of the above estimates as possible. This strategy should be discussed with and approved by the project review committee and a research design approved.

Phase II will build on the results from Phase I. The researcher will design and conduct a combination of revealed-preference and stated-preference surveys or experiments to generate empirical estimates of travel-time values for the full range of user types and travel conditions. Because stated-preference instruments are considerably more costly to implement than most revealed-preference techniques, as much information as possible should be extracted from existing surveys and "natural" experiments in which travel time and money are being traded off. Data obtained from these surveys should be related to mode, facility location, current operating level, and area demographic characteristics. Data obtained from freight carriers should be related to facility type, industry, and area economic profile.

Cost estimate: Phase I, $75,000 to $150,000, depending on the research design; Phase II, $1 million to $1.5 million

Development of Expanded Information on Travel Behavior and the Demographic Characteristics of Households

Description of Research Problem

The available Census of Transportation and Public Use MicroData Sample (PUMS) household census data provide only the most rudimentary basis for understanding how travel behavior varies with the demographic characteristics of households. The PUMS data, for example, do not provide trip length or place-of-work information. Neither source provides substantive nonwork trip-making information or information about whether drivers have the option of free or fee parking. Consequently, it is difficult to build models that can be used to predict the differential response (and, thereby, the benefits enjoyed) by households of various incomes or other important demographic characteristics. Assembly of such information has been left to individual MPOs whose purposes and resources for assembling these kind of data are limited. Even MPOs in large, complex regions such as the San Francisco Bay Area continue to rely on old and incomplete travel behavior surveys.

Work To Be Performed

This initiative will involve conducting a comprehensive survey of households, either through a large national sample or through a series of regionally focused samples. Data on trip information (trip origin, destination, mode, time and length, etc.) will be linked to detailed information on household characteristics [income, family structure, car ownership, out-of-pocket operating expenditures, workplace type(s), parking options, etc.]. Modern transportation demand modeling argues that the surveys should use a tour orientation rather than a trip orientation. This way, the linking of trip purposes (such as the after-work shopping that is done on the commute trip home) can be better examined. A national sample will permit some comparisons of behavior across regions, but regional surveys can be used to develop demand models for the surveyed regions.

Cost estimate: $4 million to $8 million for a national sample; $350,000 to $1 million for each regional sample

Improvement of the Integration of Transportation System Modeling and Evaluation Models

Description of Research Problem

Very capable multistep transportation planning models have been developed in the past 5 years. Both trip- and tour-based travel demand models are tightly integrated with trip distribution and network assignment models such as EMME/2. The tools for using the information from such models for project or policy evaluation purposes, however, are rudimentary. The elements of such evaluation models exist in such decision support models as STEAM and SPASM. But the integration between the typical four-step model operated by regional transportation planning and evaluation models is weak, with the result that few transportation planning processes produce economic impact measurements.

Work To Be Performed

This initiative will analyze the interface characteristics of the prominent transportation planning model suites and the available evaluation models. The interface characteristics include the form, dimension, content, and format of the output of transportation planning models and the analogous input requirements of the available evaluation models. The research will identify the compatible and incompatible aspects of various pairs of planning and evaluation models and discuss the best modeling suites for analyzing particular types of transportation improvements. It also will recommend enhancements to the existing models and develop intermediate models to better link the planning and evaluation models.

Cost estimate: $500,000

Development of a Methodology To Disaggregate Elasticities

Description of Research Problem

Travel demand elasticities are essential for project evaluation, especially in cases in which improvements (or their absence) will have a significant impact on the generalized price of travel. ("Generalized" means that time and other costs are translated into a common quantitative measure, presumably dollars, and "price" means the cost to the user.) Elasticities determine the magnitude of incremental consumer surplus from induced travel or induced demand. Travel demand models can sometimes provide suitable information for especially large projects, but rarely for average projects.

For highway travel, demand elasticities typically are calculated in terms of vehicle miles of travel. Currently available empirical estimates primarily are based upon components of travel cost, such as fuel price, parking cost, tolls, and time. All are aggregate, in that they net out shifts within travel markets such as route diversion and temporal diversion. Few are converted from the component elasticity to total (i.e., vehicle) elasticities. Most are ambiguous about the time period to which they apply, whether short run or long run, and no variation by market segments (such as household characteristics or trip purpose) is recognized.

For transit travel, suitable elasticities may be calculated in terms of passenger boardings or passenger miles. With better estimates of the value of travel time spent in waiting, in-vehicle, and access times, separate elasticities are not necessary, but confirmation of these conversions will be useful, particularly since both elasticities and travel-time valuations are lacking at present.

The output of the research could be described as either a multidimensional matrix of elasticity ranges broken down by various application contexts, or a set of algorithms that transforms basic (aggregate?) elasticities into those applicable in a specific context defined by the values of the parameters. The major dimensions of application that need to be addressed are

- Short-run versus long-run elasticities (land use and investment);
- Peak versus off-peak versus all-day elasticities (temporal diversion);
- Facility versus corridor versus regional elasticities (route diversion);
- Variations by market segment (schedule flexibility, demographic characteristics); and
- Cross elasticities across modes (transit, high-occupancy vehicle, automobile, and other modes).

Work To Be Performed

The intent of the research in these areas is to fill out our understanding of travel demand elasticities through the following tasks:

1. Review previous empirical studies and syntheses of studies (metastudies).
2. Based on where the gaps appear to be, design a set of empirical studies, selecting from the following analytic techniques: econometric (statistical) models, controlled experiments, survey research, and stated-preference experiments.
3. Gather the necessary data, using necessary means to collect that data (household surveys, intelligent transportation system technologies, existing data sources, stated-preference experiments).
4. Conduct an analysis from these studies and then synthesize these results with previous evidence.

The result will be a report that comprehensively documents the set of elasticities that is sensitive to the factors listed above.

Cost estimate: $1 million

Identification of Primary Conditions and Determinants for Success in Implementing Congestion Pricing

Description of Research Problem

Urban highway congestion is a growing problem, spreading from traditional urban areas into suburban areas. When congestion is recognized as a "major" problem, pricing is sometimes considered as a solution, but it seldom is given extensive consideration and rarely implemented. We believe this is due to the lack of adequate consideration and communication of the incidence of benefits and costs to the affected drivers. Attributes that determine public acceptance also are to be considered, but the emphasis of this research is on actual benefits and operational considerations rather than marketing.

Work To Be Performed

The researcher will perform the following tasks:

- Document travel, economic, and social conditions indicated by implementation experience domestically and internationally. (Examples of acceptance include Norway; Sweden; Singapore; SR91 in Orange County, California; Houston; and Lee County, Virginia. Examples of rejection include San Francisco; Boulder, Colorado; Bangkok; and Hong Kong.) The researcher should include information on traffic volumes, projected and actual travel-time savings from implementation, and projected and estimated costs to those negatively affected.
- Highlight overall process and practices used in implementation.
- Document specific conditions and factors under which projects were implemented.
- Document specific conditions and factors under which project implementation was unsuccessful.
- Synthesize/summarize conditions under which proj-

ects were successfully implemented and produce recommendations/strategies for successful implementation in U.S. cities based on "conditions" data, including highlighting benefits to society, as well as programs to compensate those who lose from the implementation project.

Cost estimate: $300,000

Management of Risk in the Transportation Investment Decision-Making Process

Description of Research Problem

Economic evaluation methods (e.g., benefit-cost analysis) are well developed for providing information on the desirability or worth of investments in transportation improvements. However, many evaluations result in estimates of program or project outcomes that are uncertain, and they result in risky investment decisions. Risk, in this case, is the possibility of suffering harm or loss. Surprisingly absent in public-sector transportation decision making is the awareness that private businesses are experiencing a revolution in their approach to risky investment decisions that goes well beyond the application of net present value or expected value approaches. This revolution, called the options approach to risk analysis, brings to investment decisions the insight that there is an inherent *value in option-creating actions* (by resolving uncertainty, enabling flexibility, or uncovering new relevant information) and a *cost associated with exercising options* (irreversible commitments of resources and time). The options approach moves investment decision making from simply choosing whether or not to build a project to a regime that considers a range of possible decisions, with the potential value of each decision measured in terms of its option-creation value and irreversible commitment cost. Practitioners of the options approach have developed a powerful set of analysis tools that help to structure risky projects as a series of option-creating steps that preserve flexibility and maximize the ultimate benefits from investments in transportation.

Work To Be Performed

This research initiative will build on the work in two recent research papers on the options approach to evaluating transportation investments. These are the only known applications of the new approach to public-sector transportation planning and decision making. The theoretical work in these papers on optimizing investment decisions using options that involve timing, flexible options, and gathering additional information and data will be extended to case studies of actual transportation investment decisions. Decisions on projects that have been built or implemented with negative results will be revisited and analyzed using the tools of the options approach. With the benefit of hindsight, the potential benefits of the approach, had it been applied, will be calculated to illustrate the power of the approach to mitigate risk, and to develop insights and lessons for its application. Prospective decisions on risky transportation investments also will be analyzed as case studies to make recommendations on these investments, including additional options for these investments. The research will develop guidelines for the application of the options approach to transportation investments, and recommendations for when it could be applied with the greatest benefit in mitigating the riskiness of transportation investments.

Cost estimate: $600,000

Development of Improved Methods for Estimating the Benefits and Costs from Transportation Projects Among Population Subgroups and for Compensating Affected Groups

Description of Research Problem

The aggregate benefits and costs of transportation projects typically can be estimated using relatively well-documented procedures. In contrast, the distribution of a project's benefits and costs among specific subgroups of the affected population is not often explicitly estimated as part of benefit-cost analysis, and often it is treated as an "afterthought" even where it is addressed. Analysts conducting benefit-cost evaluations of proposed transportation projects will be greatly aided by a clearly defined set of procedures for identifying the specific groups likely to be affected by each project, as well as for estimating and documenting the incidence of its benefits and costs among those groups.

In addition, decision makers selecting from among proposed projects will be aided by the availability of realistic mechanisms for compensating specific groups on whom a project imposes significant net costs. These mechanisms will enable decision-making officials to develop widespread political support for projects that affect specific population subgroups disproportionately but nevertheless promise to generate large *total* benefits.

Work To Be Performed

The necessary work will be performed in three separate phases:

Phase I will consist of a survey of published literature that describes methodologies for estimating and documenting the distribution of costs and benefits generated by investment projects. Particular attention will be paid to identifying methods that are readily usable or easily adaptable for use in the evaluation of transportation projects in particular. In addition, Phase I will include a survey of proposed or successfully implemented methods for compensating specific subgroups of the population that are likely to bear large net costs from transportation projects.

Phase II will entail a survey of current practice in estimating and documenting the distribution of transportation project costs and benefits, and in developing mechanisms to compensate disproportionately affected groups. One purpose of this phase of the proposed research is to develop a compendium of "best practice" measurement techniques, analytic methods, and related procedures for estimating the incidence of benefits and costs generated by transportation projects and for documenting and presenting their estimated distributions. Another purpose is to describe mechanisms that have been or might potentially be used to compensate specific population subgroups that are identified as likely to bear costs from a transportation project that significantly exceed the benefits they receive. This compendium should include specific examples of useful methods for estimating and documenting the distribution of transportation project benefits and costs, as well as of actual or proposed mechanisms to compensate groups bearing disproportionate costs from such projects.

Phase III of the proposed research will document the examples of "best practices" identified in Phase II in a format that can be widely distributed among both analysts conducting evaluations of proposed transportation projects and political officials required to select from among competing projects. This documentation should include specific, detailed examples of transportation project evaluations that can serve as models for how to estimate and document the distribution of the project's benefits and costs. It also should include transferable examples of mechanisms that can be used to compensate groups that disproportionately bear the costs from a project, as a means of broadening political support for its implementation.

Cost estimate: $500,000

Development of a Methodology for Generating Complete Sets of Alternatives

Description of Research Problem

There are currently no tools or data sets that enable a decision maker to quickly verify that all alternatives have been considered when selecting a solution to a perceived transportation problem. These alternatives will include traditional transportation solutions as well as innovative nontransportation strategies (land-use changes, zoning changes, business locations, school locations, tax policy, etc.). Similarly, there is presently no tool or mechanism to encourage project designers to look outside of traditional highway and engineering solutions to solve problems.

Work To Be Performed

This initiative will involve conducting a literature search, a best practices search, and a comprehensive survey of senior transportation, economic development, community affairs, and business leaders to identify potential strategies to be incorporated into one or more checklists. The checklist will be used by project managers to confirm to executive management that a reasonable set of alternatives has been considered when recommending their preferred alternative for the project.

The findings of this work effort will be subject to a peer-review analysis. The results of the review will be followed by a workshop of decision makers to determine if the information is complete and to make it usable and relevant in their state and local process. The proceedings of the workshop will be available to all Transportation Research Board members.

The refined checklist then will be used by several agencies on a pilot basis for a period of 6 months to 1 year. Follow-up interviews will be conducted to determine the usefulness and relevancy of the survey in their decision making. The checklist then will be further refined and made available nationwide.

The checklist will serve two purposes: First, it will force project designers to look outside the typical engineering solutions and build relationships with and bridges to nonengineering professionals when analyzing the problem. Second, it will enable decision makers to verify that all alternatives have been considered and to buttress their support of the project and their ability to justify the project.

The final product will be a checklist showing the set of alternatives for consideration as options to improve the relevance and relationship of the selected project to the policy that one is attempting to support.

Cost estimate: $150,000 to $200,000

Strategies for Allocating Resources Across Modal Programs

Description of Research Problem

Elected officials and other policy makers have long struggled with how to objectively evaluate the relative merits of investments in different modal programs such as highways, public transportation, intercity rail, ports, and so forth.

To date, only subjective analyses have been available, sometimes facetiously referred to as "data-free analysis." Although it may not be possible or practical to develop a totally quantitative method to base allocation of resources across modal programs, better objective tools and data are needed to at least support this process. Research is needed to determine how this can be done.

Work To Be Performed

The desired product is a set of tools and models and the identification of required data sources (and their costs) that could be used to support policy makers in the allocation decisions described above.

Citizen and elected-official participation in the use of the tools and models will be critical. The tools and models must be general enough to be applicable to different jurisdictions.

Cost estimate: $800,000

Monetization of Transportation Externalities

Description of Research Problem

Environmental and other external effects of transportation are looming increasingly large in transportation planning decisions. Such information is often not included in a monetized form in cost-benefit analyses. Some information in this area is available, but it often has limitations. For example, the available meta-analyses (i.e., pooled analysis of past studies) and literature reviews of transportation externalities have produced results that suggest a wide range of plausible values. Also, these studies have focused on the results of past studies without getting into how the analysis was conducted.

When evaluating transportation projects in a cost-benefit framework, the failure to include monetizable information often results in the undervaluation (or ignoring) of nonmonetizable costs and benefits. It also can cause the project selection process to be handed over to a multicriterion analysis. This may introduce more subjectivity in project evaluation than is warranted. For project-level analysis, information is needed on the *marginal* effects of the transportation improvements and the monetary values of these impacts. However, currently, the only credible information available is estimates of average national values of various external effects, such as health impacts of emissions, noise damage, accident costs, and public service costs.

For project-level analysis, information is needed on the marginal monetary values of externalities; however, for program- and policy-level analysis, *average* values may be appropriate. However, analyses at the program or policy level seldom consider monetary values of externalities. Analysts need better guidance in order to encourage the consideration of externalities in program and policy evaluation.

Work To Be Performed

This research project will develop methods to assist transportation analysts in estimating external effects and monetary values of externalities for use in project-level, program-level, and policy-level economic analysis. This research ought to focus on impacts at the margin, recognizing that although national averages may be useful for preliminary planning purposes, more detailed analysis requires the analyst to develop values specific to the context in which analysis is being done. To supplement this consideration of marginal monetary impacts, the researcher also will be expected to use meta-analysis methods to clarify the reasons for the large range of values in certain key areas of external impact and identify the relationship (linear or nonlinear) between transportation activity and externalities.

The product of this research will be a handbook or template that guides the analyst in developing monetized values for each of the external cost categories. The research will yield ways to better incorporate analysis of externalities in transportation project analysis as well as in program and policy development.

Cost estimate: $500,000

Assessment of the Impact of Project Financing Choices on Project Decisions

Description of Research Problem

The impact of a choice of financing mechanism for solving a particular transportation problem may far outlive the problem itself. For instance, a state may choose to fully obligate its interstate maintenance funds before its other federal-aid highway funds because the federal share for the interstate maintenance program is 90 percent instead of 80 percent. This choice may lead to a situation in which preservation work is delayed on facilities of a lower functional classification, ultimately requiring total reconstruction of the route instead of capital preventive maintenance or resurfacing, at a cost differential of 5:1. As another example, the choice may be made to add a lane to an interstate route instead of implementing parallel bus service in order to relieve congestion, again for the sake of a higher federal contribution. The result is that the maintenance of the additional lane becomes a long-term committed cost, whereas operation of the bus service is not permanent.

Work To Be Performed

The work first will involve conducting a national survey of state governments and MPOs, or a series of regional focus groups, or a combination of both. The survey will be expected to yield a list of instances in which the state DOT or MPO has learned that such an early decision of funding source has biased subsequent project-level decisions. The second phase will be for the investigator to choose up to 20 such cases to investigate further through on-the-spot interviews at the DOT or MPO. The interviews will be designed to

- Document the original cost of the alternative chosen,
- Estimate the cost of the alternative(s) not originally chosen,
- Estimate the 20-year life-cycle cost of the originally chosen project,
- Estimate the 20-year life-cycle costs(s) of the project(s) not chosen, and
- Compute the net present value of the differential costs incurred or avoided through the original choice of projects.

The deliverable will be a report of the case studies of the cases chosen with their resulting cost and construction experiences.

Cost estimate: $500,000

GROUP 3: REVENUE FORECASTING

Development of an Information Base of Current Revenue Forecasting Efforts

Description of Research Problem

The practice of revenue forecasting by state agencies is not well documented. Specifically, there is a paucity of information regarding the importance of revenue forecasting in individual states, who does the forecasting (e.g., the state department of transportation or the revenue administration), how it is done, and what data are used. Additionally, we have little information on the similarities of the models and methods used, the data collection efforts, and how the availability of data may constrain the forecasting process. It appears that states have not examined what they can learn from other states in terms of the types of models, data measurement, and what might be transferable.

It is essential that a comprehensive survey of state agencies precede efforts to develop improved measures of vehicle miles traveled (VMT) or other variables to forecast revenues or to develop new revenue forecasting models. The focus of this research will be to better understand the current practice of revenue forecasting among states and to determine what lessons can be learned to direct future research.

Work To Be Performed

This is a two-phase research project in which the information collection will be the focus of Phase I and the development of a "Primer on Highway Finance and Revenue Forecasting" will be the research focus of Phase II.

Phase I will undertake a comprehensive survey of state agencies and a sample of MPOs responsible for highway revenue forecasting to gather information on a number of factors. These factors include identification of who is responsible for revenue forecasting, what methods and models are used in revenue forecasting, what data forecasters rely on and where they are housed, how accurate are the models, and how accurate they need to be. The purpose of this inquiry is to better understand the differences and similarities across states.

Although the major thrust of this research will focus on highway finance, the research also should explore the practice of forecasting in other modes, particularly aviation. An important aspect of this investigation is to examine the institutional arrangements that are used to ensure information transfer across agencies responsible for revenue forecasting.

The product of the research effort in Phase I will be a report containing (*a*) the results of the information survey, (*b*) an assessment of what the common elements are and where they may be transferable, and (*c*) a set of recommendations regarding the direction of subsequent research efforts.

Phase II of the research will develop a "Primer on Highway Finance." The primer will describe the basic process for highway finance, addressing such matters as where the money comes from and how it is collected and distributed. The primer will identify the structure of taxes, which states use different instruments, and what issues are associated with the tax device. It also will evaluate each tax instrument using established public finance criteria (e.g., efficiency, adequacy, and administrative burden). The primer is intended to be user friendly with visual exhibits wherever possible such as charts and graphics. It is designed to be an easy read with accessibility by a broad audience.

This research project will build on information from Phase I. It will include an analysis and review of the state efforts that offer commonality and potential integration. It also will contain a review of federal funding sources and how these are shared among the states. The central thrust is to describe what goes on with highway finance today, perhaps including some history of legislation and its evolution, but with an emphasis on current legislation and policy. The audience for this primer will include policy makers; administrators; legislators and their staffs;

and possibly members of private-sector organizations, such as underwriters, credit rating agencies, and financial advisors.

Cost estimate: $250,000

Improvement of Estimates of State-Level VMT for Passenger Vehicles and Commercial Trucks

Description of Research Problem

Available estimates of state-level VMT for both passenger vehicles and commercial trucks are inadequate and require significant improvement. A number of states measure VMT only in a limited number of locations and for a limited number of years, with estimates for the intervening years interpolated from values for the years in which VMT is measured. Similarly, local estimates of VMT are expanded to the entire state based sometimes on data collected on a relatively limited—and certainly older—part of the system. States need to invest more in collecting information on three attributes of VMT—the number of miles, the location of the miles, and the average trip length—as well as perhaps on the type of traffic by vehicle type.

The research into structural models of VMT for light vehicles has not carried over into commercial-vehicle VMT. We need a better understanding of how trucking (both private and for hire) is used by different industries. We find, for example, that VMT between Canada and the United States has increased since the North American Free Trade Agreement was signed. A major source of this VMT are industries specializing according to their competitive advantage and industries adopting strategies that place specific product production in specific locations (e.g., the automobile sector). As economic activity shifts between countries and among states, we can expect more truck VMT and a potentially significant redistribution of activity. Trucking registration fees present another set of challenges for revenue forecasting since regulations governing registration can lead to gaming behavior by trucking firms. As rules change, forecasting becomes more difficult.

Work To Be Performed

Estimates of VMT can be obtained from three sources: (*a*) surveillance, (*b*) household surveys, and (*c*) odometer readings. The research will involve activities in all three areas:

- There is an increasing number of modern surveillance techniques and surveillance locations. A prime example is the prominence of freeways that are equipped with cameras. One element of this research project will explore alternative surveillance technologies for collecting data. Each technology will be evaluated in terms of cost and accuracy. Once a technology is selected, a time series of VMT data, including trip length and vehicle counts, will be collected.
- The second source of data for improving VMT estimates is household surveys. Total VMT can be obtained from the current Nationwide Personal Transportation Survey (NPTS) by combining information from different files. It also is possible for urban areas (and perhaps states) to use NPTS to obtain more detailed information at the subnational level by increasing the sample size in a given area. These survey data will yield information on household behavior.
- The third source for VMT information is odometer data. Odometer data can be collected in those states that inspect vehicles on an annual basis. From this source, it is possible to construct a data set that provides VMT information by number, age, and type of vehicle. The unit of observation will be the vehicle. This research on VMT will build upon VMT research being performed by the Federal Highway Administration (FHWA).

On the basis of this analysis of three sources of VMT data, this research project will achieve multiple objectives. It will identify the approach that is cost-effective yet maintains data quality. It will provide a basis for comparison across methods. It will offer different behavioral units from the three sources and this will flow naturally into the improved modeling project discussed below.

This project also will develop several new modeling approaches. The first is a model of truck use at the firm level to provide estimates of both the number of vehicles as well as the use of vehicles in the private trucking segment. A second model will examine two issues: the decision to use for-hire rather than private trucking, and the amount of for-hire trucking to use. An integral part of this modeling effort is to develop an understanding of how different industries use more or less trucking and how the distribution of economic activity affects the level of VMT. Furthermore, the researcher will need to examine the growing role of intermodalism in the movement of freight and the implications of this development for truck VMT.

Cost estimate: $750,000

Development of a Generic Starting Point Model for Forecasting State Fuel Tax Revenue

Description of Research Problem

The argument has been made that the models now in use in many states are simplistic whereas in other states they are relatively sophisticated. The variance in modeling design and forecasting reliability is reasonably high. It is desirable to develop a generic forecasting model that could serve as the basis for all states to develop forecasts. States will have the opportunity to augment the basic model to meet their particular needs and circumstances.

Work To Be Performed

The gap is large between what is used now in the forecast of state revenues and what we have earlier argued is a desirable full structural model. To close this gap in a meaningful yet practical way, the following should be done: Set out the full structural model to ensure the causal relationships are well understood and then step down to a manageable reduced-form model. The manageability of the reduced-form model will be dictated to a significant degree by the availability of data. The gap between the structural and reduced-form models will provide the states with information on the type of data they should be collecting to augment their revenue forecasting models.

The structural model might take the form of estimating two relationships, the amount of travel (measured in terms of VMT) and the fuel efficiency of the fleet, and using an accounting identity for total fuel consumption. This will provide the requisite information to forecast fuel tax and registration fee and other fee revenues. The appropriate behavioral unit is probably the individual household, in which case the system determines annual VMT per household rather than total annual VMT. It also will require household-level data, which are difficult and expensive to come by. Therefore, that estimate model using annual time-series data at the national or state level, rather than household-level data, could be used, albeit with some concerns for aggregation bias. The model could be calibrated on national data and then provided to each state, which could recalibrate the model if it so desired, or the parameter estimates for the national-level model could be used to forecast revenues.

Cost estimate: $400,000

Examination of the Implications of Alternative Revenue Instruments for Highway Financing

Description of Research Problem

The traditional approach to highway finance and the use of conventional taxes and fees such as vehicle registration fees and fuel taxes provide the basis for our current forecasting models and information base used to guide investment decisions and operations management. However, revenue forecasters' information needs may be changing as alternative financing instruments are developed and a more businesslike approach typifies infrastructure management. States' legislators also are enabling local governments to earmark funds for specific purposes. Revenue streams also are being tied to specific investment projects.

There is a need to explore how changes to methods of financing transportation projects will affect institutional relationships, forecasting approaches, and informational requirements. For example, if a broad-based carbon or energy tax were adopted, revenues might flow into a general revenue fund rather than be earmarked for transportation purposes. Highways, transit, and other modes of transportation will compete with other government demands for funding.

Work To Be Performed

The purpose of this research is to explore the far-reaching implications of changes in the structure of highway finance. This research project will examine the jurisdictional, financial, and economic consequences of three potential changes to revenue sources. The three changes to be explored are (*a*) the movement to allow local governments to use traditional revenue sources to fund specific projects (e.g. bonds, sales taxes); (*b*) the movement away from fuel taxes and toward economy-wide carbon or energy taxes; and (*c*) the move to rely more heavily on road tolls and road pricing.

Cost estimate: $350,000

Examination of Bureau of Transportation Statistics Products' Role in Improved Revenue Forecasting

Description of Research Problem

The accuracy of revenue forecasts from fuel taxes, registration fees, and other charges depends heavily on our ability to predict the level and mix of transportation activities in each state. Existing transportation-related data and information do not fully support the needs of state departments of transportation to estimate revenues from fuel taxes, fees, and user charges. Existing comprehensive data sets may be useful for this purpose, but they have not yet been fully used for revenue estimation purposes. Specifically, data derived from sources such as the Commodity Flow Survey (CFS), American Travel Survey (ATS), and Nationwide Personal Transportation Survey (NPTS) have not been explored for their potential use in supplementing existing data sets. The issue for this research project is how Bureau of Transportation Statistics-sponsored products such as CFS, ATS, and NPTS, as well as other data, can be used to improve the quality of revenue forecasting. The further question is whether and how CFS, ATS, and NPTS can be improved or modified to collect data and information that might fill these gaps.

Work To Be Performed

This project will review existing revenue forecast tools and data used by each state DOT. Some information may be made available from a separate research study of the data and structure of existing data sets such as CFS, ATS, and NPTS. Based on the findings of the data needs for improving state revenue forecasts, the researcher will design methods that would use existing CFS, ATS, and NPTS data for the purposes of forecasting revenues from fuel taxes, fees, and other user charges. The report will make recommendations about changes to the CFS and ATS survey questionnaires to make data collected useful for revenue forecasting in the various states.

Cost estimate: $200,000

Assessment of the Impact of Evolutionary Vehicle and Information Technology on Revenue Forecasting

Description of Research Problem

Technology for collecting data on transportation system use is expected to continue to expand. Developments in vehicle technology, particularly related to vehicle navigation systems and alternative fuels, will have a significant impact on revenue generation and estimation. Current revenue forecasting models rely heavily on the ability to identify vehicle use (through such measures as VMT) and the type of fuels used. Relevant technologies are changing rapidly, with, for example, alternative fuels being explored as a legitimate technology to mitigate the impact of fossil fuels on the environment. California and several Northeastern states have mandated the use of such fuels. By the same token, intelligent transportation systems in various forms have the capability or potential capability to collect data on vehicle use and movements, whether nationwide or within metropolitan areas. As technology changes, it will be imperative for the transportation community to identify and monitor these rapid changes.

Work To Be Performed

This research project will explore the impact of new technologies in two basic areas: data collection technology and vehicle technology. Technologies in both of these areas will lead to changes in the method by which revenues are collected and distributed. New data collection technologies, for example, are expanding in a manner that will allow the detailed tracking of transportation by various vehicle types. The introduction of new vehicle technology, such as vehicles operating using alternative fuels that currently are not taxed, may have an impact on total revenues. It will be necessary for the researcher to anticipate the dynamics of this technology and anticipate the fiscal impacts on traditional revenue sources for transportation. This research project will determine the potential of technology to improve the efficiency of current data collection and facilitate the collection of expanded data elements.

Cost estimate: $400,000

Examination of the Revenue Gains and Cost Savings Attributable to Shifts in the Point of Fuel Taxation

Description of Research Problem

There is growing evidence from 18 states indicating that a shift in the point of fuel tax collection from the retail level to the rack (wholesale) level can lead to a significant increase in the amount of revenue collected. This finding implies that there is a significant amount of revenues being lost through evasion. A study performed by FHWA 10 years ago bolsters this inference; the study showed significant reductions in evasion when purple dye was added to diesel fuel.

Work To Be Performed

This research project will undertake a survey to describe the methods used to collect fuel tax revenue, the collection points, and how these might differ across fuel types. The investigation will span all modes of transportation. The project also will undertake an analysis of those states that have shifted their point of taxation and document the revenue gains from these shifts, how administrative costs may change, and what added costs are imposed on collection agencies when the point of sale is shifted. The analysis should provide some insight into the key features of those states that were able to gain the most from the shift in point of taxation. The impact of a shift in the point of collection may, for example, depend on industrial mix or some other economic factors. It also may be related to macroeconomic variables. Therefore, this research project will reveal whether it will or will not pay for a state to shift the point of taxation, and whether or not this is a change that all states should undertake.

Another important part of this study is to document the process by which the legislative change took place in those states that have shifted the collection point. This can be accomplished through using two or three detailed case studies of the process of legislative change. This might serve as a blueprint for other states to follow.

Cost estimate: $180,000

Resource Papers

Strategies for Measuring Productive Highway Capital Stocks

Information for Transportation Economic Analysis: State of the Art and Relevance for Decision Making

How Levels of Investment in Transportation Affect Economic Health

Selecting Public Transportation Projects: Informational Requirements

Estimating Revenues from User Charges, Taxes, and Fees: Identifying Information Requirements

RESOURCE PAPER

Strategies for Measuring Productive Highway Capital Stocks

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The Federal Highway Administration (FHWA) recently released a report describing an 18-month project to construct productive highway capital stocks (*1*). As few researchers will be able to undertake a project of such magnitude and many will not have time to read the full report, this paper summarizes the methodological concepts and techniques needed to measure productive highway capital stocks and outlines two shortcut measurement strategies.

This paper begins by briefly outlining the difference between productive and wealth capital stock. The sidebar on page 74 continues this conceptual discussion with particular reference to efficiency patterns. Next, the perpetual inventory method (PIM) is presented, as both measurement strategies call for its use. The strategies, whose description is the central core of this paper, are based on the findings and analysis in Fraumeni (*1*). The simplest strategy for measuring productive capital stock is described first, followed by a description of a more complicated and more time-consuming strategy. Reasons are given for why and in what circumstances the more complicated strategy should be followed. Either of these strategies can be applied to stock measurement at different administrative or geographic levels, for example, metropolitan, regional, local, state, and interstate. (In this paper, "state" refers to state-administered roads excluding interstates and "local" refers to all roads except for state-administered roads and interstates.) The more complicated strategy allows for the introduction of information specific to the particular project being undertaken. Tables 1–6 (pp. 82–88) list all data from Fraumeni (*1*) that might be needed to pursue the more complicated strategy. Table 7 (p. 89) shows how to calculate productive capital step by step using the information from Tables 2–6. The final topic covered is benchmarking, a necessary component of almost any effort to construct a capital stock. A list of definitions is given in the sidebar on page 72.

PRODUCTIVE VERSUS WEALTH CAPITAL STOCK

This theoretical section is included for two reasons: (*a*) wealth capital stock is the preferred measure in some cases, and (*b*) many researchers who should have used productive capital stock in fact employed wealth capital stock (*1*, pp. 12–19, 32–34).

Productive capital stock is the appropriate concept for estimating the productivity of capital stock or measuring the contribution of capital stock to economic growth. Wealth capital stock is the appropriate measure of the market value of capital and could be used in a balance sheet not using the book value convention. Wealth capital stock estimates give a sense of the future whereas productive capital stocks concentrate on the situation at a certain point in time. Both types of capital stock are adjusted for efficiency decline or the decline in the potential productive services of an asset still in use as it ages. Productive capital stock is adjusted for current and past declines in efficiency. Wealth capital stock in addition is adjusted for future declines in efficiency. Aside from a discount rate needed in the calculation of wealth capital stocks, the information needed to calculate the two different types of capital stock is identical. As a con-

DEFINITIONS

Capital is a durable asset. The convention is that any asset expected to last at least one year is called capital, and if an asset is expected to last less than one year it is termed a consumption good.

Capital outlay is a synonym for investment (see definition below).

Capital stock is a measure of how much capital you have at a particular point of time, for example, December 31, 1997.

Depreciation is the change in the value of an asset associated with aging.

Deterioration is the decline in the potential productive services of an asset as it ages. Deterioration includes the effects of efficiency decline or decay and retirements.

Economic life is the number of years that the benefits from an asset are at least as great as the cost of keeping the asset in service.

Efficiency decline is the decline in the potential productive services of an asset still in service as it ages.

Efficiency pattern, profile, or curve is the pattern, profile, or curve showing an asset's potential productive services as it ages. They reflect the efficiency decline of an asset still in service. Pattern, profile, and curve are synonyms.

Geometric deterioration. With this, the rate of deterioration is constant in every period. The rate of deterioration, δ, is as follows: $\delta = R/T$, where R is the estimated declining balance rate and T is the average service life of the asset. With geometric deterioration, the rate of deterioration is equal to the rate of depreciation.

Investment, a flow measure, is the addition to the capital stock over a particular time period, for example, from January 1, 1997, through December 31, 1997. Investment is a synonym for capital outlay.

Net capital stock is the sum of capital outlay minus deterioration (productive concept) or the sum of capital outlay minus depreciation (wealth concept).

One-hoss-shay. With this, there is zero deterioration until the asset is retired.

Perpetual inventory method. Under this method, capital stock is estimated by summing up capital outlay to produce gross capital stock or by summing up capital outlay and reducing the resulting total by an estimate of asset deterioration to produce net capital stock.

Productive capital stock is the capital stock that has been adjusted for the effects of deterioration, for example, efficiency decline and retirements. Productive capital stock is a net capital concept.

Retirements are assets withdrawn from service.

Service life is the number of years that an asset is kept in service or in use.

Wealth capital stock is the capital stock evaluated at its market value.

NOTE: Several of the definitions come from J. E. Triplett's Concepts of Capital for Production Accounts and for Wealth Accounts: The Implications for Statistical Programs, a paper presented at the International Conference on Capital Stock Statistics, Canberra, Australia, March 10-14, 1997. Others come from *System of National Accounts, 1993,* Commission of the European Communities, International Monetary Fund, Organization for Economic Co-operation and Development, United Nations, and World Bank, in Brussels, Luxembourg, Paris, New York, and Washington, D.C., 1993. The remainder are the sole responsibility of the author.

sequence, although this paper does not describe how to construct wealth capital stocks, all of the required input to such a calculation except for the discount rate is given in Tables 1–6.

Economists favor the lightbulb example to explain the difference between the two types of capital stocks. Assume a lightbulb is capable of shining for 12 months. At any point in time over that 12 months, until the bulb stops shining, it is 100 percent productive, as the intensity of light is constant. If one sold the lightbulb after 6 months of use, however, a rational buyer would only be willing to pay approximately half of the original purchase price. In stock measurement, at the 6-month point, a productive capital stock of the lightbulbs is approximately double the wealth capital stock.

The sidebar on page 74 continues this conceptual discussion with particular reference to efficiency patterns. Included is a discussion of the difference between an efficiency pattern for one asset versus a group of assets and the difference between productive capital stock and wealth capital stock under different deterioration assumptions.

Perpetual Inventory Method

Under the perpetual inventory method, capital stock is estimated by summing up investment and reducing the resulting total by an estimate of asset deterioration to produce net capital stock. [The terms "investment," "capital outlay," and "capital expenditures" are synonyms. "Capital outlay" is the term used in *Highway Statistics* (2), so it is used subsequently in this paper.] Under the simplifying assumption of a constant (geometric) rate of deterioration, δ, the general equation for the PIM is

$$\text{Capital stock}_{\text{year}} = \text{capital outlay}_{\text{year}} + (1 - \delta)\ \text{capital stock}_{\text{year}-1}$$

where "year" is the current year and "year – 1" is the previous year. Deterioration is the decline in the potential productive services of an asset as it ages. It includes the effects of efficiency decline and retirements. Retirements are assets withdrawn from service. The notion of retirements for highways is somewhat different from that for many other assets, as highways are not typically withdrawn from service or thrown away, rather components of them undergo major treatments. Pavement "retirement" occurs when a major treatment such as reconstruction, restoration, and rehabilitation or a major (not light) resurfacing is undertaken.

As information on capital outlays is typically available at best beginning in 1921 and frequently not until the post-World War II era, the use of PIM also requires a benchmark or starting point for the calculations. Benchmarks are discussed in a later section.

Capital stocks should be generated in real or constant dollars so that comparisons can be made across time. The easiest methodology is to deflate capital outlay before it enters into the PIM equation. Appropriate highway capital outlay deflators are available from the Bureau of Economic Analysis (BEA) on a computer disk (*3*) or in a printed volume (*4*). The BEA deflators used in Fraumeni (*1*) are listed in Table 6 (p. 88).

Simplest Approach to the Measurement of Productive Capital Stock

The simplest approach to the measurement of productive capital stock is to use the geometric rate of depreciation from the forthcoming BEA fixed capital benchmark study. The convention of using the term "deterioration" in conjunction with productive capital stocks and the term "depreciation" in conjunction with wealth capital stocks is followed in this paper. Depreciation is defined as the change in the value of an asset associated with aging.

Although BEA estimates wealth capital stocks, wealth stocks are identical to productive capital stocks when a geometric rate of depreciation is used. With a geometric rate, the rate of depreciation is equal to the rate of deterioration; therefore the stocks are equal to each other (*5,6*). If this simplest strategy is used, only total capital outlay on highways is needed, as well as a benchmark and a deflator.

The new BEA geometric rate of depreciation, which is equal to the rate of deterioration δ in the capital stock formula, is .0202. This rate is calculated from the formula $\delta = R/T$, where R (= .91) is the declining balance rate for structures and T is the service life (= 45) (*7*). The geometric rate of depreciation is being revised upward because two studies—the Fraumeni FHWA study (*1*) and a recent study by Beemiller of BEA (*8*)—concluded that the average service life for highways, including all components of a highway, is substantially lower than that previously used by BEA (*9*). If an asset's service life is lower than previously thought, then it also must be true that the asset "wears out" (declines in efficiency) at a faster rate than previously thought.

The result of the higher rate of depreciation/lower service life will be to bring the post-benchmark BEA highway capital stocks into closer alignment with the Fraumeni highway capital stocks. Figure 1 shows the current BEA highway capital stock versus the Fraumeni estimates of the same. Although differences will remain between the two series, following BEA's methodology is a defensible and simple strategy to approximate productive highway capital stocks at the national or subnational level. Although a rough estimate of the revised BEA stocks was calculated, an exact comparison of the

Efficiency Patterns

A lightbulb is a special case of an asset as it follows what is called a "one-hoss-shay" pattern of decline in efficiency. Unlike a lightbulb, most assets decline at least somewhat in efficiency—for example, light intensity in the lightbulb case—before the end of their useful life.

It is important to think about the case of a group or sample of assets, because even a small town has more than one road. Looking at a sample of assets gives you a different picture than looking at one asset. The efficiency profile for a group of assets differs from the efficiency profile for one asset whenever assets "retired" (in this case, the lightbulb burns out) at different points of time.

With 20 lightbulbs, suppose that the lightbulbs burn out according to Table S-1.

One lightbulb declines in efficiency according to the one-hoss-shay pattern, as shown in Figure S-1, but the efficiency decline of the group of lightbulbs diverges from the one-hoss-shay pattern. This example could be complicated even further by looking at assets of different vintages, for example, capital outlays made in different years.

The difference between productive and wealth capital stocks depends upon the pattern of how assets decline in efficiency or are retired over time. The difference between measured productive and wealth capital stocks is greatest when assets decline in efficiency according to a one-hoss-shay pattern and all assets are retired at the same age. Introducing different retirement ages and different patterns of deterioration reduces the differences in the measures. With a geometric rate of deterioration, assets deteriorate at a constant rate. With a geometric rate, the difference between estimates of productive capital stocks and wealth capital stocks is the least; in fact, productive and wealth capital stocks are identical.

There are a variety of deterioration patterns in the Fraumeni (*1*) productive capital stocks. Grading is most closely approximated by a one-hoss-shay pattern. Pavement follows a pattern that is not one-hoss-shay, varying from reasonably close to a one-hoss-shay pattern to clearly substantially different from a one-hoss-shay pattern, for example, interstates versus local roads. Structure deterioration is approximated by a geometric pattern following the Bureau of Economic Analysis, as very little is known about structures.

TABLE S-1 Example of Lightbulbs Burning Out, in Total of 20

Age of Lightbulb in Months	*Number Burned Out by Month*	*Number Remaining by Month*
0	0	20
1	0	20
2	0	20
3	0	20
4	0	20
5	0	20
6	0	20
7	0	20
8	0	20
9	1	19
10	2	17
11	3	14
12	8	6
13	3	3
14	2	1
15	1	0

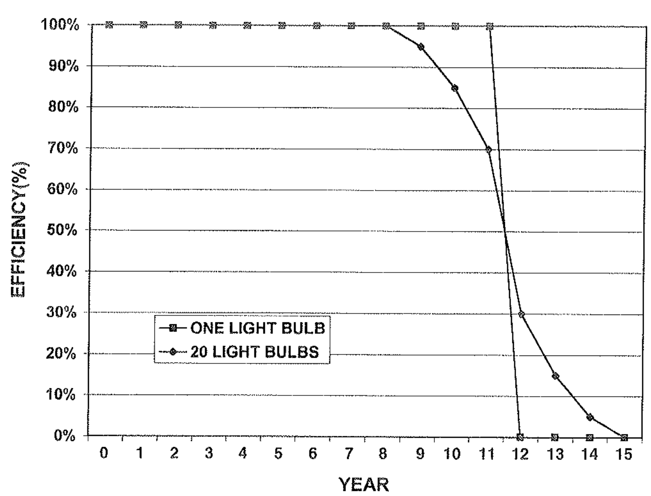

FIGURE S-1 Efficiency of one lightbulb versus 20 lightbulbs.

two series awaits the generation of the new benchmark BEA series.

A More Complicated Approach

A more complicated approach to the measurement of productive highway capital stocks is to use detailed results of Fraumeni (*1*). In order to do this, one needs to separate capital outlay by administrative level—interstate, state (i.e., noninterstate), and local (all other highways)—and by component—right-of-way, grading, pavement, and structures (*1*, pp. 69–71, 73–74). In addition, capital outlay should be separated into new construction and reconstruction versus all other ("other" refers to other than new construction and reconstruction capital outlay) (*1*, p. 72).

One tactic in the absence of information at this level of detail is to employ Table 4 information. For example, if the percentage split between new construction and reconstruction and other is unknown, the Table 4 splits can be used.

Given the substantial additional detail required to implement this strategy, it makes sense to ask, "Why bother?" The simplest approach previously described does not necessarily reflect the changing composition of capital outlay even at the national level. There are at least two sources of changes in the composition of capital outlay. One is the changing distribution of capital outlay among interstate, state, and local administrative levels; Figure 2 shows the changing percentage of interstate, state, and local capital stock for selected years. The second is the changing distribution of capital outlay between new construction and reconstruction versus other capital outlay; Figure 3 shows how the percentage of new construction and reconstruction capital outlay varies across time and by administrative level. Table 3 documents how the distribution of pavement, grading, and structures components of highways differs significantly between new construction and reconstruction versus other. The Table 3 numbers are generated from numbers underlying the 1997 Cost Allocation Study (found in unpublished worksheets by Arthur Jacoby). These 1997 numbers are given in Fraumeni (*1*, p. 73).

Figure 3 and Table 3 both demonstrate the importance of attempting to identify capital outlay for new construction and reconstruction versus other. If the composition of capital outlay changes, then the service life and the deterioration profile of the resulting aggregate capital stock will change. As noted previously, in the geometric case, the rate of deterioration δ, which is equal to the rate of depreciation, is equal to R/T, where R is the declining balance rate and T is the service life. Therefore, when the service life changes, the deterioration rate and the deterioration profile of the capital stock change.

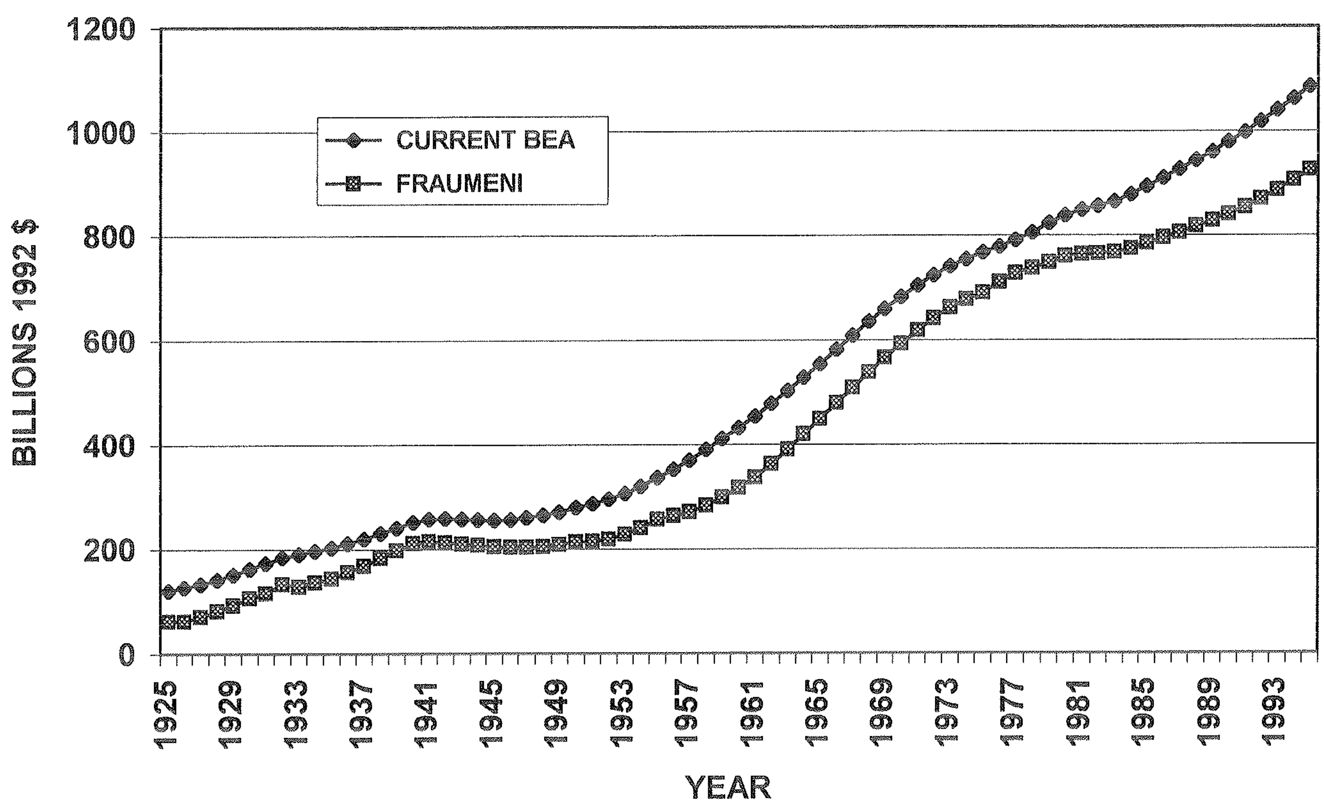

FIGURE 1 Fraumeni vs. current BEA capital stock, 1925–95.

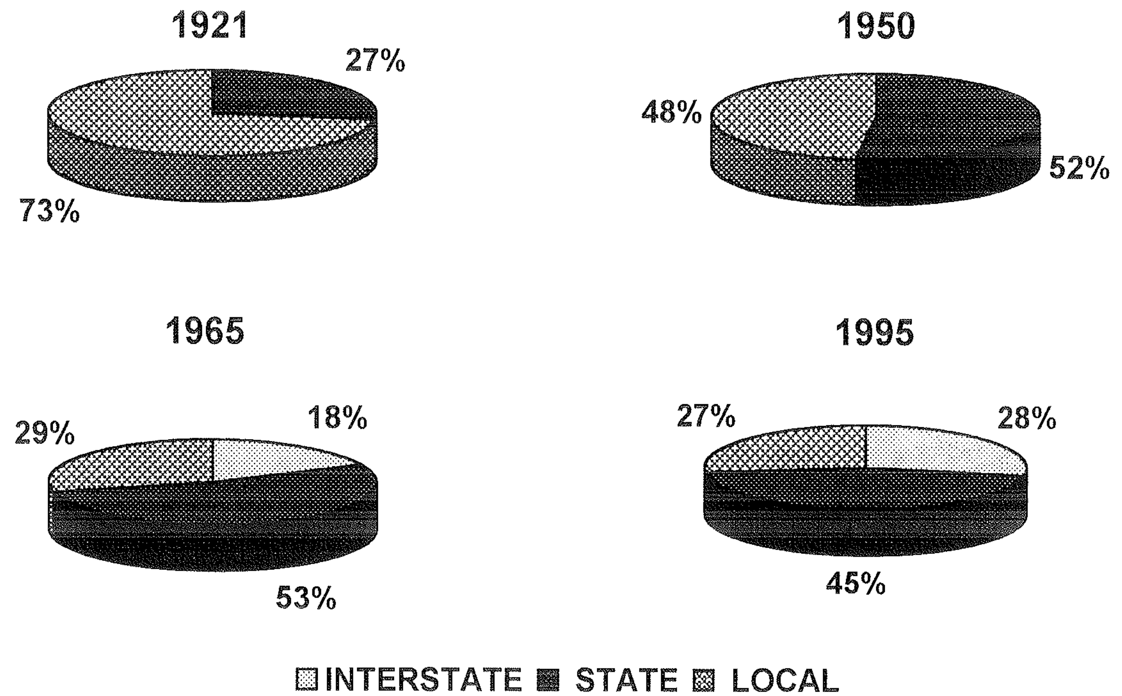

FIGURE 2 Type of capital split—interstate, state, and local.

In addition, the use of the BEA national geometric rate of deterioration in constructing capital stock for subnational units will not reflect significant differences among subnational regions and the nation in the composition of capital outlay and the resulting capital stock. Subnational regions can have different types of highways. For example, primarily rural states have relatively more miles of rural roads compared to primarily urban/suburban states.

Even within the more complicated approach, there are various levels of complexity. As noted earlier, a researcher can insert specific information about the particular highway stock being estimated or use all of the percentage splits and efficiency profiles from Fraumeni (*1*) given in Tables 1–6—or a strategy in between.

For example, if a researcher knows something about the composition of capital outlay by administrative level, this information can be used in combination with the percentage split between new construction and reconstruction versus other capital outlay from Fraumeni (*1*). This section, in conjunction with Table 7, is a guide to the use of the more complicated strategy. Table 7 uses the example of a $1,000 capital outlay in 1960 to demonstrate the use of the Fraumeni results (*1*) with the Tables 2–6 spreadsheet data as inputs. Clearly, the use of the more complicated approach depends upon the research effort that can be expended and whether anything is specifically known about the productive capital stock being measured.

The exposition of the more complicated strategy follows the order of the Tables 2–6 spreadsheet tables. Table 1 lists the contents of Tables 2–6.

Table 2: Percentage Right-of-Way Is of Capital Outlay

It is useful to split expenditures for right-of-way (ROW) from other types of capital outlay because ROW does not deteriorate—either you have it or you do not (*1*, pp. 70–71). ROW expenditures are added directly to the productive capital stock and remain at their full value forever. The spreadsheet data in Table 2 show that ROW expenditures as a percentage of capital outlays including ROW have varied over time and by administrative level. The capital outlay weighted average reflects the distribution of capital outlay by administrative level at the national level and may or may not be appropriate to use for particular subaggregates.

Table 3: Percentage Split of Capital Outlay Less ROW Among Pavement, Grading, and Structures

As the three major components of a highway have different deterioration patterns, it is important if possible to identify the different types of capital outlays (*1*, pp. 73–75). In Fraumeni (*1*), pavement, which represents the largest capital outlay category, is deteriorated according to efficiency profiles developed from American Asso-

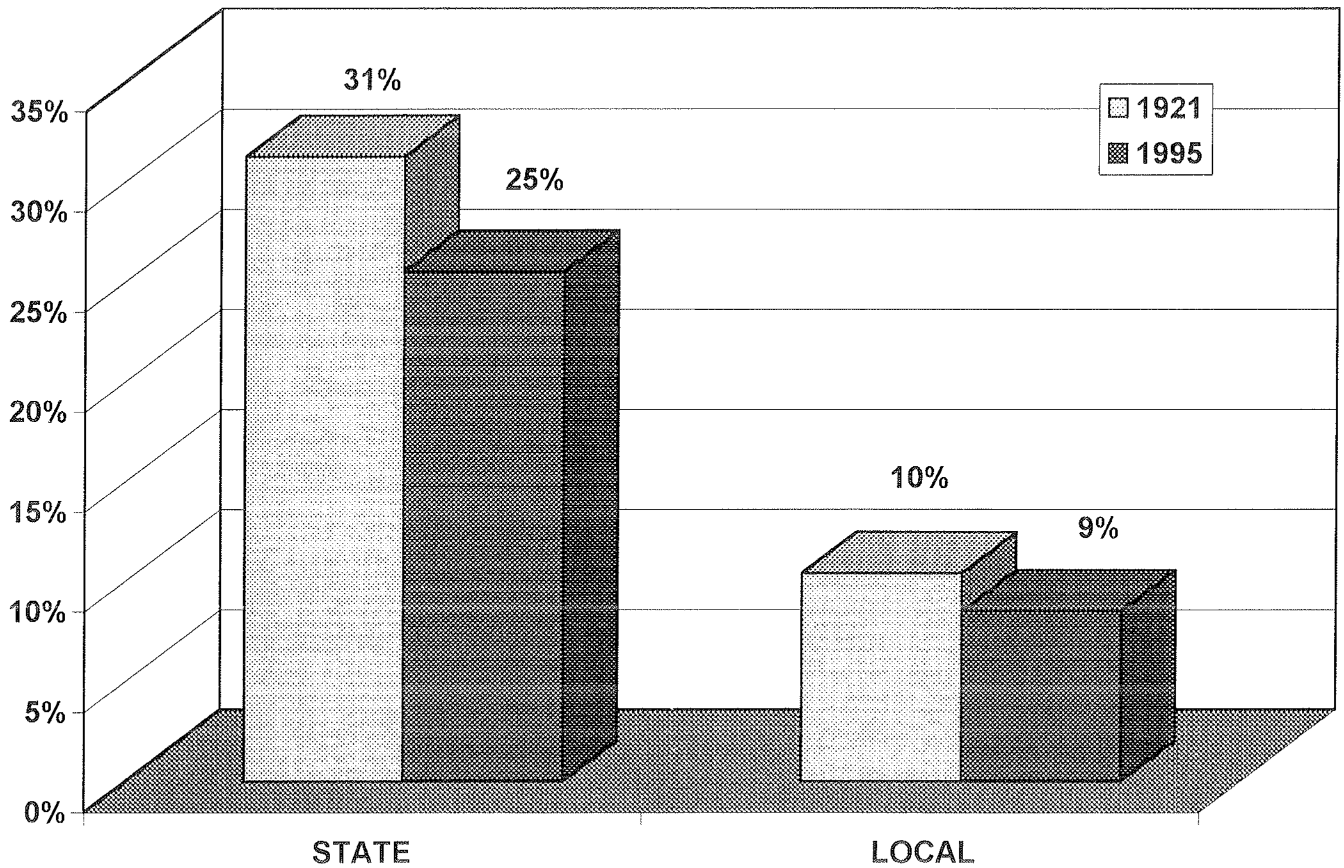

FIGURE 3 **Percentage new construction and reconstruction is of total capital outlays.**

ciation of State Highway and Transportation Officials pavement deterioration curves adjusted for time cost and operating cost (*1*, pp. 77–84). The service life of pavement is 20 years. Grading is deteriorated according to a one-hoss-shay pattern, with an assumed life of 80 years (*1*, pp. 25, 27, 46, 73–75, 82–83). This means that any capital outlay for grading made after 1915 enter the productive capital stock in the same way that ROW enters the productive capital stock, as the capital outlay is not retired until after 1995. These expenditures are added directly to the productive capital stock and remain at their full value for 80 years. Structures, which are mainly bridges, are assumed to deteriorate at a geometric rate of .0182 (*1*, pp. 46–47, 82–84). This rate is calculated from the formula $\delta = R/T$, where R (= .91) is the declining balance rate for structures and T is the service life (= 50), as the service life for most government buildings is 50 years (*7*). It was determined that highway structures are more comparable to government buildings than to any other type of asset covered by BEA.

As would be expected, the percentage of capital outlays, less ROW, for grading and structures is higher for new construction and reconstruction than for other. Accordingly, the percentage of capital outlays, less ROW, for pavement is lower for new construction and reconstruction than for other.

In spite of the fact that retirement patterns can significantly affect the efficiency pattern of a group of assets, as demonstrated in the sidebar on Page 77, it is assumed that all grading and pavement are retired at the same time as nothing is known about actual retirement patterns. A differential retirement pattern already is subsumed into a geometric rate of deterioration, so it is not assumed that all structures have the same service life.

A simple arithmetic average across the three administrative levels is included in the Table 3 spreadsheet for the percentage split of capital outlay less ROW among pavement, grading, and structures. Simple averages are used in the spreadsheets instead of capital outlay weighted averages when the information is reasonably similar across aggregated categories.

Table 4: Percentage of Capital Outlay Including ROW That Is New Construction or Reconstruction

As the percentage split of capital outlay among pavement, grading, and structures is different for new construction and reconstruction versus other, to fully capitalize on the information in the previous category, capital outlay must be split between new construction or reconstruction and other. As the new construction or reconstruction versus other percentages by administrative level are quite different, a capital outlay weighted average is given in the Table 4 spreadsheet (*1*, pp. 27, 42–45, 72).

Table 5: Pavement Efficiency Profiles

As capital outlay on pavements is the largest capital outlay component, a significant amount of time was spent in the development of the pavement efficiency profiles (*1*, pp. 77–82, 118–128). An efficiency profile is constructed for each of four initial capital outlay years—1921, 1941, 1961, and 1981—for state and local. There are only two initial years for interstates—1958 and 1978—as construction of the interstate system did not begin until 1956. For intermediate years, the prior initial year is used; for example, capital outlays made in 1921–1940 all use the 1921 initial-year deficiency profile. Figure 4 shows that there is a significant difference between the curves by administrative level. Figures 5 through 8 show the curves by administrative level by initial capital outlay year. A comparison of Figure 7 to Figure 8 demonstrates that axes' scale can significantly impact on the perception of similarity of curves. Figures 5 through 8 demonstrate that it is reasonable to use a simple arithmetic average to construct efficiencies by administrative level that could be used for any initial capital outlay year.

Table 6: BEA Capital Outlay Deflators

Current dollar or nominal capital outlay should be deflated by the BEA capital outlay/investment deflators as only constant dollar capital outlay and capital stocks can be compared across time. BEA deflators are available in Table 6 and in the downloadable website version. More recent versions of these deflators are available from the sources cited earlier.

Benchmarks

Even if capital outlay is available from 1921, as was true in the Fraumeni study (*1*), a benchmark is needed. Some parts of long-lived components of highways, such as grading, put in place during the 1920s are probably still

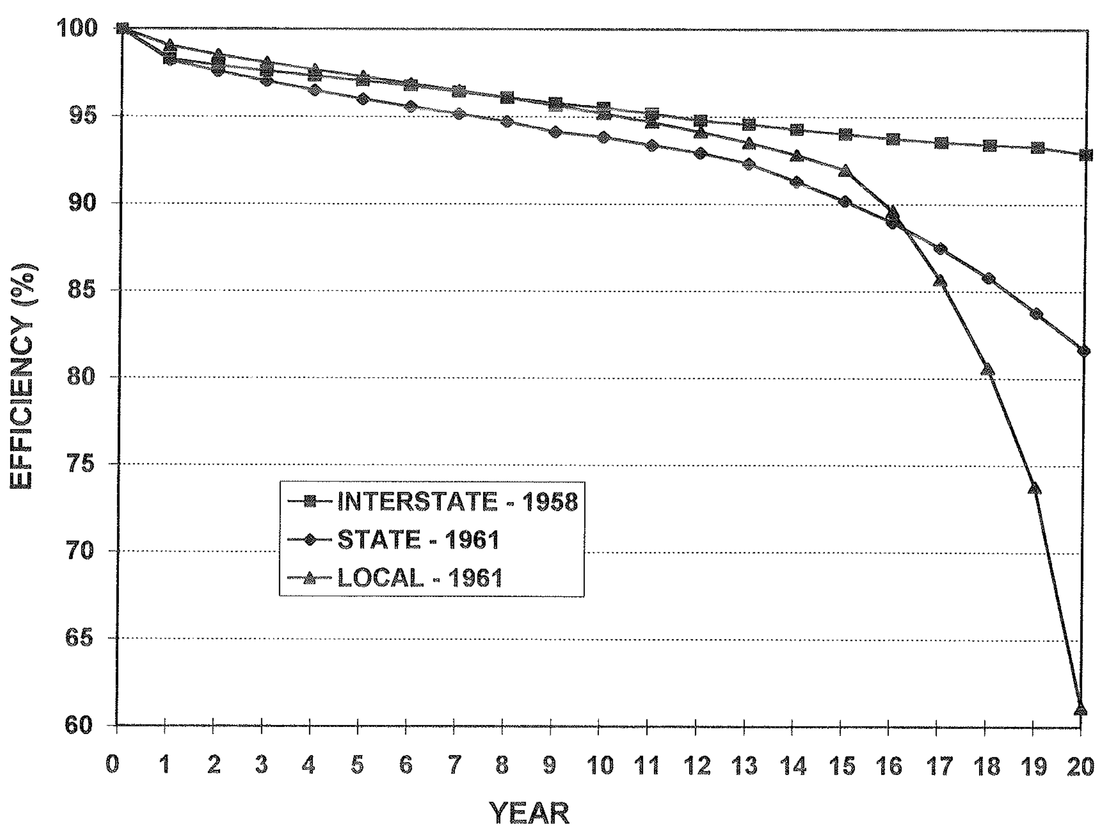

FIGURE 4 Efficiency curves.

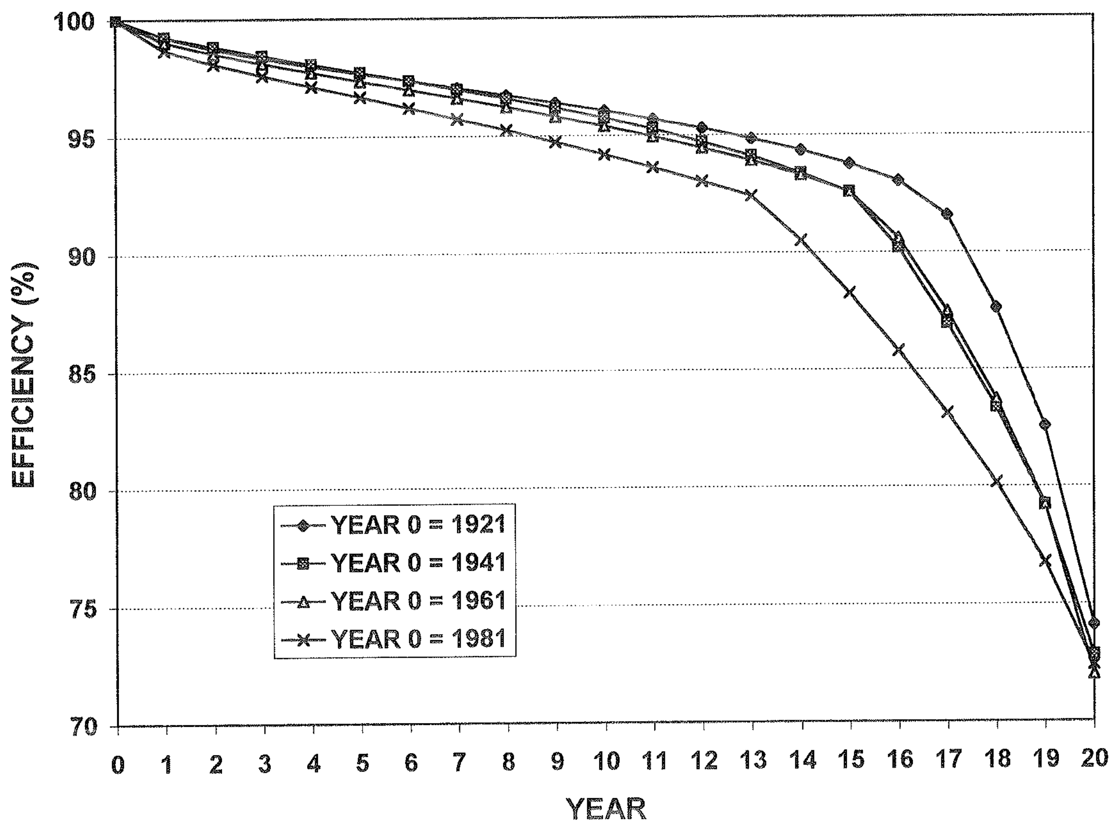

FIGURE 5 Local efficiency curves.

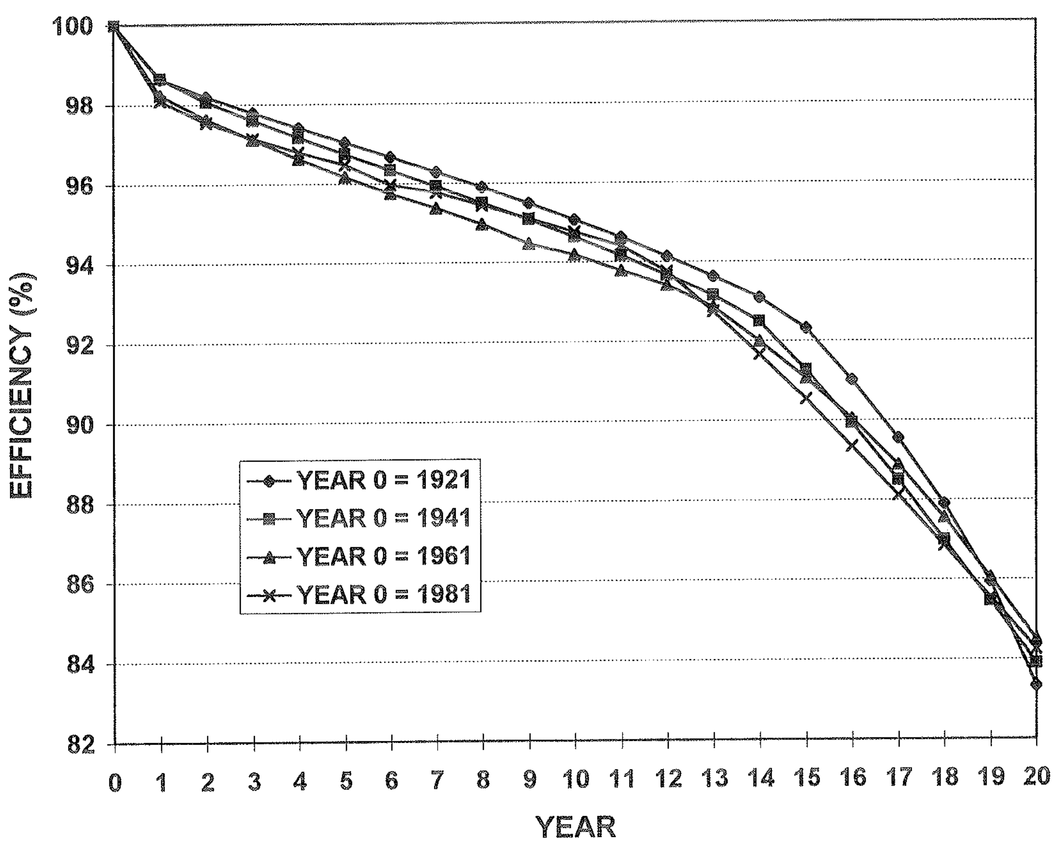

FIGURE 6 State efficiency curves.

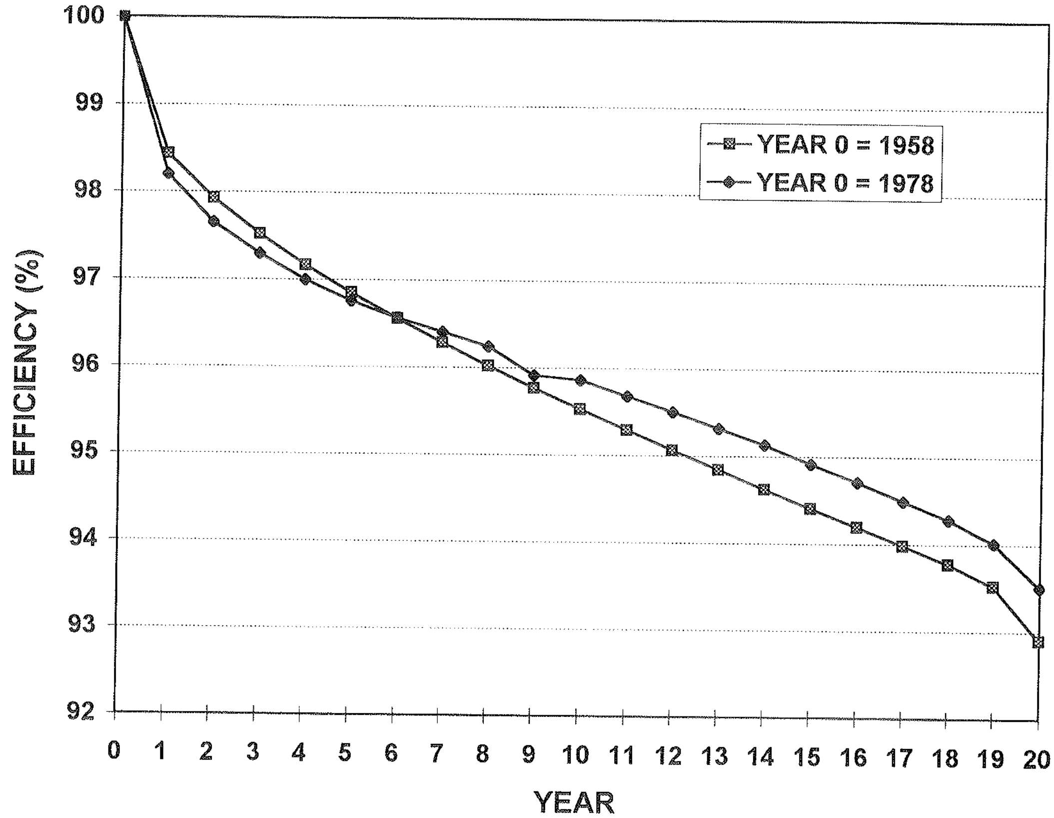

FIGURE 7 Interstate efficiency curves.

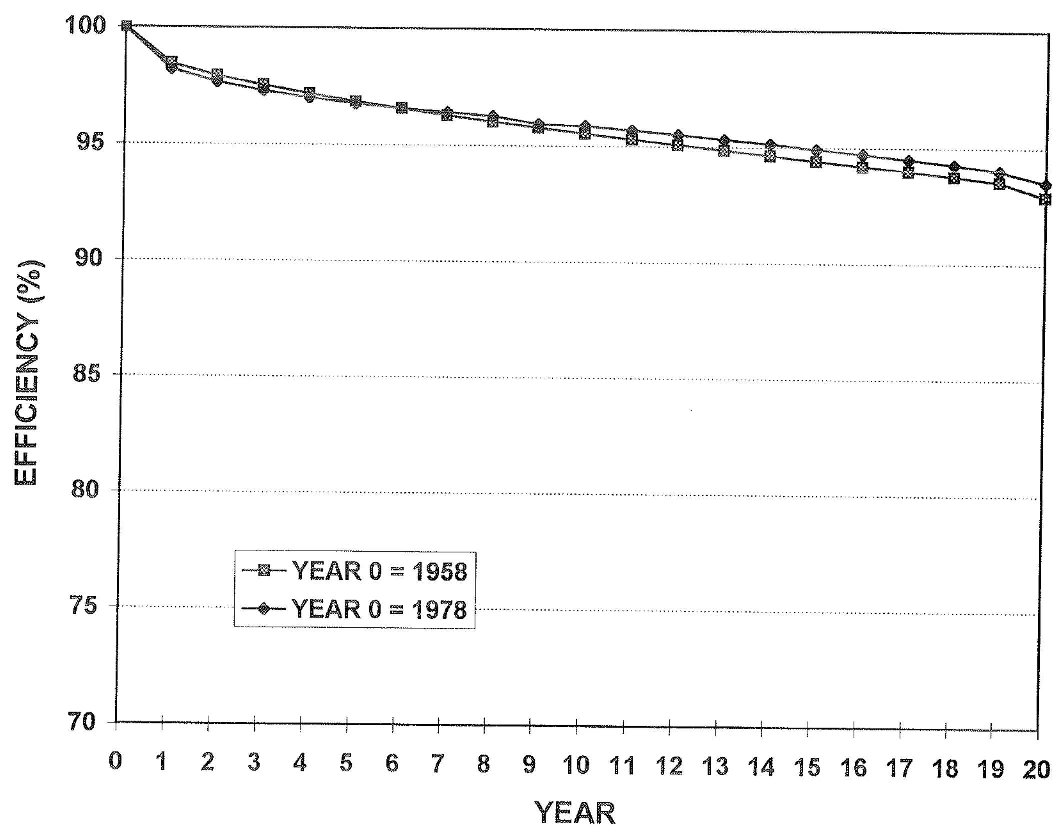

FIGURE 8 Interstate efficiency curves.

a productive part of highways during the post-World War II period. Figures in Fraumeni (*10*) show how the lack of a benchmark in 1931 significantly affects productive capital stock estimates even until the 1990s.

If national estimates are being calculated, then benchmarks can be directly lifted from the Fraumeni study (*1*). For an example, if capital outlay is available from 1958, the constant dollar U.S. capital stock benchmark is $270.799 billion (this number comes from the downloadable data set at www.fhwa.dot.gov/reports/phcsm/index.htm).

This and any benchmark stock deteriorate in years subsequent to 1958, its year of use, so a decision needs to be made about how to handle this. The easiest way to deal with benchmark deterioration is to employ a geometric rate for the benchmark stock. However, if the object is to construct national estimates, the Fraumeni (*1*) estimates could be used directly, so the relevant question is the benchmark strategy for subnational levels.

Several individuals have given considerable thought to benchmarking capital stocks (*1*, pp. 12–15, 23–26, 32–34, 75–76). Unfortunately, all strategies to estimate benchmarks have some problems.

An equivalent to Munnell's (*11*) public capital technique is to construct a pseudo highway capital stock starting with a zero benchmark for all states (or some mutually inclusive regional subdivision), then to scale all stocks to the Fraumeni (*1*) totals. Munnell and Holtz-Eakin (*12*) used BEA wealth stock as the relevant control total instead of a productive capital stock. The BEA wealth stock that they used differed from a productive capital stock as it was an earlier version of the BEA stock.

Holtz-Eakin (*12*) criticizes the Munnell approach for not being sensitive to differences in growth rates across states. Holtz-Eakin makes several points, including that states that grow faster than the national average will have final estimated capital stocks biased upward and vice versa for states that grow slower than the national average. In addition, he notes that the growth in capital stocks may differ between the period during which capital outlays are available and earlier periods, which would result in mis-estimation of the stocks.

An equivalent to Holtz-Eakin's public capital technique (*13*) is to construct a benchmark by divvying up the Fraumeni stock (*1*) according to expenditure shares. A pseudo stock would then be constructed and a geometric deterioration rate picked such that aggregate capital stock equaled the Fraumeni totals (*1*) in a given year, for example, 1985 following Holtz-Eakin. The resulting stock would not be systematically biased, but it still may not represent the actual level of capital stock.

Bell and McGuire (*14,15*) and Dalenberg and Eberts (*16*) explored a variety of benchmark techniques for both public and private capital. For public capital, the average of the ratio of state expenditure to U.S. expenditure was used to apportion national stocks to states to create the pseudo stocks beginning in 1977. Then, an imputed geometric deterioration rate was calculated from the implied initial year and final year benchmark. A benchmark was not used for their highway series beginning in 1931. The Bell and McGuire discussion (*15*, pp. 48–59) of benchmarking for private capital stock is of some interest because it comments on the appropriateness of a variety of techniques that might be used. For private capital stocks they constructed two variants of private capital stock, one using employment as allocators and the other using gross state product less indirect business taxes as allocators.

Garcia-Mila and McGuire (*17*) benchmarked their state estimates by allocating the total U.S. highway capital stock to states on the basis of a state's share of U.S. highway mileage. Although this appears to be an attractive assumption, it implies that all roads are equally productive, the share of different types of highways is the same across all states, and/or the efficiency pattern of all highway components is one-hoss-shay. Allocating the total U.S. highway capital stocks to states on the basis of a state's share of U.S. highway mileage by administrative level would be a significant improvement. The mileage data in *Highway Statistics* (*2*), Table HM-20, could be used to construct such a benchmark.

Whereas no method is optimal or even clearly the best, several summary comments are in order. First, a somewhat defensible benchmark is preferred to no, or a zero, benchmark. The benchmark procedures described above all seem defensible on at least one basis. Second, as the current BEA stocks can be used as productive or wealth stocks, they are an appropriate control total. Finally, adoption of the BEA geometric rate seems preferable to allowing the benchmark procedure to determine the geometric rate.

Numerical Example

Table 7 gives a numerical example of a $1,000 capital outlay in 1960. The information in the Tables 2–6 spreadsheets is the only input to the calculations. As the capital outlay is a one-time event, the constant dollar capital stock declines in size over time. This example is intended to serve as a blueprint for researchers attempting the more complicated approach.

In the numerical example, the column titles give the formula for the calculation of the numerical entry, a specific table location, the value of any data taken from the tables, and the location of any numerical entry in Table 7 used in the calculation. The split of the $1,000 current dollar capital outlay among administrative levels is calculated from the actual distribution of capital outlays in

1960. The numerical example has three sections: capital outlay, detailed capital stock in constant 1992 dollars, and total productive capital stock in constant 1992 dollars. The capital outlay section shows how to calculate capital outlay by administrative level (local, state, and interstate), by component type (ROW, pavement, grading, and structures), and by new construction and reconstruction, and other. In addition, it lists the deflators used to deflate current dollars to constant dollars and documents the methodology used in all subsequent current dollar to constant dollar transformations. Current dollar capital outlays also are deflated to constant 1992 dollar capital outlays. In the next section, the constant 1992 dollar capital outlays are used to calculate capital stocks by the same administrative levels and component types. Finally, in the last section, these capital stocks are summed to create total capital stock by administrative level and across all administrative levels.

CONCLUSION

Estimation of a productive highway capital stock is the first step toward assessing the contribution of highways to productivity and economic growth. However, research studies assume capital stock is an appropriate proxy for capital input or the actual benefits arising from highways. The problem of doing so is illustrated by the existence of highways leading to ghost towns as well as the potentially significant impact of highway networks. To understand a highway's contribution, the analyst needs to calculate capital input that reflects who uses the highway, where and how fast they are going, and what they are transporting. The measurement of highway capital input is the next step that needs to be taken in the attempts to accurately measure the contribution of highways.

The recent guidelines issued by the Government Accounting Standards Board (GASB) call for the construction of balance sheets for state and local government assets. As this could be a substantial undertaking, research in the area of public capital stock measurement probably will accelerate as a result of GASB's recent actions.

Hopefully this paper will demystify and simplify efforts to estimate highway capital stock, whether these stocks are needed for general economic research or to conform to GASB guidelines.

TABLE 1 Spreadsheet Data Available in Tables 2–6

Table 2: Percentage ROW is of capital outlay
- a. Local, 1921–1995
- b. State, 1921–1995
- c. Interstate, 1956–1995
- d. Capital outlay weighted average, 1921–1995

Table 3: Percentage split of capital outlay less ROW among pavement, grading, and structures
- a. Local
  - 1) Other than new construction or reconstruction
  - 2) New construction or reconstruction
- b. State
  - 1) Other than new construction or reconstruction
  - 2) New construction or reconstruction
- c. Interstate
  - 1) Other than new construction or reconstruction
  - 2) New construction or reconstruction
- d. Capital outlay weighted average
  - 1) Other than new construction or reconstruction
  - 2) New construction or reconstruction
- e. Simple average
  - 1) Other than new construction or reconstruction
  - 2) New construction or reconstruction

Table 4: Percentage of capital outlay including ROW that is new construction or reconstruction
- a. Local, 1921–1995
- b. State, 1921–1995
- c. Interstate, 1956–1995
- d. Capital outlay weighted average

Table 5: Pavement efficiency profiles
- a. Local
  - 1) Initial year = 1921
  - 2) Initial year = 1941
  - 3) Initial year = 1961
  - 4) Initial year = 1981
  - 5) Simple average
- b. State
  - 1) Initial year = 1921
  - 2) Initial year = 1941
  - 3) Initial year = 1961
  - 4) Initial year = 1981
  - 5) Simple average
- c. Interstate
  - 1) Initial year = 1958
  - 2) Initial year = 1978
  - 3) Simple average

Table 6: BEA capital outlay deflators
- a. Federal, 1956–1995
- b. State and local, 1921–1995

TABLE 2 ROW as Percentage of Capital Outlay Including ROW, 1921–95 (*1*)

				Capital Outlay: Current $			ROW as Percentage of Capital Outlay: Weighted Average
Year	Local	State	Interstate	Local	State	Interstate	
1921	0.049	0.133		530	301		0.079
1922	0.050	0.132		545	287		0.078
1923	0.049	0.132		470	280		0.080
1924	0.050	0.133		545	398		0.085
1925	0.050	0.131		626	404		0.082
1926	0.050	0.131		643	366		0.079
1927	0.050	0.131		746	419		0.079
1928	0.049	0.133		731	558		0.085
1929	0.049	0.132		692	575		0.087
1930	0.001	0.132		781	729		0.064
1931	0.000	0.133		605	798		0.076
1932	0.000	0.133		385	572		0.080
1933	0.001	0.132		304	532		0.084
1934	0.001	0.133		533	594		0.070
1935	0.007	0.131		419	449		0.071
1936	0.006	0.132		856	667		0.061
1937	0.015	0.133		725	601		0.069
1938	0.009	0.132		1062	582		0.053
1939	0.010	0.132		932	585		0.057
1940	0.019	0.132		796	636		0.069
1941	0.015	0.132		551	584		0.075
1942	0.018	0.133		333	429		0.083
1943	0.031	0.133		136	270		0.099
1944	0.038	0.133		131	211		0.097
1945	0.035	0.131		140	213		0.093
1946	0.035	0.132		270	508		0.098
1947	0.043	0.133		482	896		0.101
1948	0.050	0.132		592	1156		0.105
1949	0.053	0.132		708	1378		0.105
1950	0.066	0.132		686	1556		0.112
1951	0.052	0.132		710	1764		0.109
1952	0.044	0.132		857	1967		0.105
1953	0.049	0.132		955	2296		0.108
1954	0.065	0.132		1015	3020		0.115
1955	0.073	0.132		1092	3164		0.117
1956	0.072	0.138	0.130	1203	2443	1282	0.120
1957	0.070	0.126	0.164	1285	2485	1754	0.125
1958	0.073	0.101	0.198	1418	2773	2022	0.126
1959	0.063	0.121	0.197	1392	2736	2426	0.137
1960	0.061	0.135	0.191	1370	2555	2224	0.139
1961	0.060	0.133	0.198	1439	2761	2461	0.141
1962	0.059	0.128	0.198	1483	2987	2752	0.141
1963	0.063	0.117	0.166	1526	3111	3063	0.126
1964	0.059	0.128	0.172	1591	3040	3438	0.133
1965	0.065	0.129	0.182	1692	3038	3461	0.138
1966	0.063	0.147	0.176	1888	3384	3718	0.141
1967	0.071	0.141	0.161	2019	3555	3835	0.134
1968	0.073	0.148	0.144	2181	3924	4000	0.130
1969	0.062	0.145	0.143	2233	4182	3742	0.126

(continued)

TABLE 2 *Continued*

Year	*Local*	*State*	*Interstate*	*Capital Outlay: Current $* *Local*	*State*	*Interstate*	*ROW as Percentage of Capital Outlay: Weighted Average*
1970	0.055	0.125	0.139	2419	4864	4033	0.115
1971	0.049	0.121	0.110	2567	5264	4182	0.102
1972	0.049	0.135	0.104	2534	5132	4303	0.105
1973	0.050	0.128	0.105	2875	5103	3910	0.102
1974	0.047	0.110	0.085	3412	5689	3736	0.086
1975	0.030	0.086	0.069	3847	6451	3773	0.066
1976	0.027	0.081	0.063	3819	5999	3734	0.061
1977	0.027	0.098	0.079	3747	5707	3210	0.072
1978	0.025	0.080	0.068	4455	6624	3410	0.060
1979	0.024	0.074	0.034	5034	7761	4243	0.050
1980	0.027	0.085	0.067	5836	8723	5290	0.063
1981	0.026	0.094	0.062	6285	7783	4881	0.063
1982	0.022	0.106	0.074	6101	8547	3852	0.072
1983	0.016	0.120	0.087	6013	8736	4977	0.080
1984	0.019	0.087	0.089	6806	9723	6034	0.067
1985	0.021	0.092	0.060	7232	11371	7511	0.063
1986	0.022	0.095	0.060	8350	11909	8518	0.063
1987	0.029	0.149	0.079	9047	13658	7564	0.096
1988	0.031	0.157	0.068	9296	15813	7344	0.101
1989	0.037	0.154	0.082	9874	14887	8149	0.101
1990	0.043	0.158	0.083	10111	16106	8707	0.106
1991	0.042	0.145	0.075	10686	17385	8331	0.099
1992	0.047	0.145	0.085	10946	17780	9363	0.102
1993	0.046	0.126	0.066	10673	19586	8931	0.091
1994	0.043	0.085	0.025	11799	20143	10009	0.059
1995	0.044	0.099	0.025	13370	20308	10242	0.065

TABLE 3 Percentage Split of Capital Outlay Less ROW Among Pavement, Grading, and Structures (*1*)

	Pavement	*Grading*	*Structures*
Local			
Other than new construction or reconstruction	70.6%	13.2%	16.2%
New construction or reconstruction	53.1%	28.4%	18.5%
State			
Other than new construction or reconstruction	80.0%	12.6%	7.4%
New construction or reconstruction	63.6%	25.4%	11.0%
Interstate			
Other than new construction or reconstruction	73.6%	11.9%	14.5%
New construction or reconstruction	57.9%	23.1%	19.0%
Simple Average			
Other than new construction or reconstruction	74.7%	12.6%	12.7%
New construction or reconstruction	58.2%	25.6%	16.2%

TABLE 4 New Construction or Reconstruction as Percentage of Capital Outlay Including ROW, 1921–95 (*1*)

Year	Local	State	Interstate	Capital Outlay (Current $) Local	State	Interstate	New Construction or Reconstruction as Percentage of Capital Outlay: Weighted Average
1921	0.104	0.312		530	301		0.179
1922	0.104	0.312		545	287		0.176
1923	0.104	0.312		470	280		0.182
1924	0.104	0.312		545	398		0.192
1925	0.104	0.312		626	404		0.186
1926	0.104	0.312		643	366		0.180
1927	0.104	0.312		746	419		0.179
1928	0.104	0.312		731	558		0.194
1929	0.104	0.312		692	575		0.199
1930	0.104	0.312		781	729		0.205
1931	0.104	0.312		605	798		0.222
1932	0.104	0.312		385	572		0.228
1933	0.104	0.312		304	532		0.237
1934	0.104	0.312		533	594		0.214
1935	0.104	0.312		419	449		0.212
1936	0.104	0.312		856	667		0.195
1937	0.104	0.312		725	601		0.198
1938	0.104	0.312		1062	582		0.178
1939	0.104	0.312		932	585		0.184
1940	0.104	0.312		796	636		0.196
1941	0.104	0.312		551	584		0.211
1942	0.104	0.312		333	429		0.221
1943	0.104	0.312		136	270		0.242
1944	0.104	0.312		131	211		0.232
1945	0.104	0.312		140	213		0.230
1946	0.104	0.312		270	508		0.240
1947	0.104	0.312		482	896		0.239
1948	0.104	0.312		592	1156		0.242
1949	0.104	0.312		708	1378		0.242
1950	0.104	0.312		686	1556		0.249
1951	0.104	0.312		710	1764		0.252
1952	0.104	0.312		857	1967		0.249
1953	0.104	0.312		955	2296		0.251
1954	0.104	0.312		1015	3020		0.260
1955	0.104	0.312		1092	3164		0.259
1956	0.104	0.312	1.000	1203	2443	1282	0.440
1957	0.104	0.312	1.000	1285	2485	1754	0.482
1958	0.104	0.312	1.000	1418	2773	2022	0.489
1959	0.104	0.312	1.000	1392	2736	2426	0.523
1960	0.104	0.312	1.000	1370	2555	2224	0.515
1961	0.104	0.312	1.000	1439	2761	2461	0.521
1962	0.104	0.312	1.000	1483	2987	2752	0.532
1963	0.104	0.312	1.000	1526	3111	3063	0.545
1964	0.104	0.312	1.000	1591	3040	3438	0.564
1965	0.104	0.312	1.000	1692	3038	3461	0.560
1966	0.104	0.312	1.000	1888	3384	3718	0.553
1967	0.104	0.312	1.000	2019	3555	3835	0.548
1968	0.104	0.312	1.000	2181	3924	4000	0.540
1969	0.104	0.312	1.000	2233	4182	3742	0.520
1970	0.104	0.312	1.000	2419	4864	4033	0.513
1971	0.104	0.312	1.000	2567	5264	4182	0.507
1972	0.104	0.312	1.000	2534	5132	4303	0.515
1973	0.104	0.312	1.000	2875	5103	3910	0.488

(*continued*)

TABLE 4 *Continued*

Year	Local	State	Interstate	Capital Outlay (Current $) Local	State	Interstate	New Construction or Reconstruction as Percentage of Capital Outlay: Weighted Average
1974	0.104	0.312	1.000	3412	5689	3736	0.457
1975	0.104	0.312	1.000	3847	6451	3773	0.440
1976	0.104	0.312	0.000	3819	5999	3734	0.168
1977	0.104	0.312	0.000	3747	5707	3210	0.171
1978	0.104	0.312	0.000	4455	6624	3410	0.175
1979	0.104	0.312	0.000	5034	7761	4243	0.173
1980	0.104	0.312	0.000	5836	8723	5290	0.168
1981	0.104	0.312	0.000	6285	7783	4881	0.163
1982	0.104	0.312	0.000	6101	8547	3852	0.179
1983	0.118	0.355	0.000	6013	8736	4977	0.193
1984	0.103	0.311	0.000	6806	9723	6034	0.165
1985	0.094	0.282	0.000	7232	11371	7511	0.149
1986	0.094	0.282	0.000	8350	11909	8518	0.144
1987	0.110	0.329	0.000	9047	13658	7564	0.181
1988	0.114	0.343	0.000	9296	15813	7344	0.200
1989	0.117	0.352	0.000	9874	14887	8149	0.194
1990	0.108	0.324	0.000	10111	16106	8707	0.181
1991	0.112	0.337	0.000	10686	17385	8331	0.194
1992	0.110	0.329	0.000	10946	17780	9363	0.185
1993	0.104	0.311	0.000	10673	19586	8931	0.184
1994	0.092	0.277	0.000	11799	20143	10009	0.159
1995	0.085	0.255	0.000	13370	20308	10242	0.144

NOTES: The $ derived figure should be subtracted from capital outlay excluding ROW to determine capital outlays for other than new construction or reconstruction.

All capital outlays for interstates in 1956–75 for new construction or "reconstruction by assumption" are assumed to occur with a 2-year lag—for example, capital outlays in 1956 enter the stock in 1958 and capital outlays for 1975 enter the stock in 1977; in 1976 and 1977, however, capital outlays for new construction or reconstruction from lagged capital are entering the stock at the same time as current outlays for projects other than new construction or reconstruction.

TABLE 5 **Pavement Efficiency Profiles, All Levels, All Initial Years (*1*)**

Year	Local Net Efficiency % Year 0 = 1921	Year 0 = 1941	Year 0 = 1961	Year 0 = 1981	Simple Average
0	100.00000	100.00000	100.00000	100.00000	100.00000
1	99.23962	99.23793	99.03745	98.68114	99.04903
2	98.73360	98.82215	98.53666	98.10727	98.54992
3	98.34465	98.44181	98.11236	97.60409	98.12573
4	97.99811	98.07673	97.72190	97.12949	97.73156
5	97.67207	97.71624	97.34563	96.66546	97.34985
6	97.35470	97.35357	96.97395	96.20069	96.97073
7	97.03868	96.98190	96.60008	95.72667	96.58683
8	96.71889	96.59440	96.21606	95.23709	96.19161
9	96.38964	96.18475	95.81731	94.72506	95.77919
10	96.04523	95.74263	95.39522	94.18651	95.34240
11	95.67934	95.25821	94.94288	93.61621	94.87416
12	95.28277	94.71533	94.44930	93.01406	94.36537
13	94.84342	94.09486	93.90118	92.38172	93.80529
14	94.34283	93.37408	93.28051	90.48767	92.87127
15	93.75040	92.54277	92.56807	88.24660	91.77696
16	93.01463	90.17051	90.56681	85.78869	89.88516
17	91.54489	86.93957	87.46792	83.10973	87.26553
18	87.58888	83.36330	83.73243	80.15705	83.71042
19	82.55961	79.18203	79.22052	76.77346	79.43391
20	74.08884	72.79983	71.99158	72.40745	72.82192

TABLE 5 *Continued*

	State Net Efficiency %				
Year	*Year 0 = 1921*	*Year 0 = 1941*	*Year 0 = 1961*	*Year 0 = 1981*	*Simple Average*
0	100.00000	100.00000	100.00000	100.00000	100.00000
1	98.64133	98.64635	98.22445	98.08670	98.39971
2	98.18404	98.06213	97.62414	97.53775	97.85201
3	97.77927	97.58498	97.09923	97.12548	97.39724
4	97.39756	97.15034	96.61708	96.78991	96.98872
5	97.02513	96.73500	96.15451	96.46259	96.59430
6	96.65317	96.32641	95.74080	95.96044	96.17020
7	96.27603	95.91766	95.36290	95.76427	95.83022
8	95.88868	95.50121	94.96359	95.42931	95.44570
9	95.48546	95.07203	94.45956	95.09848	95.02888
10	95.06131	94.62633	94.17724	94.75472	94.65490
11	94.61246	94.15846	93.78025	94.39998	94.23779
12	94.13450	93.66527	93.40263	93.75314	93.73889
13	93.62553	93.14614	92.85283	92.74143	93.09148
14	93.08495	92.47994	91.98625	91.65908	92.30256
15	92.30255	91.26403	91.05883	90.53083	91.28906
16	91.00526	89.92497	90.04133	89.34147	90.07826
17	89.54337	88.49002	88.88221	88.10922	88.75620
18	87.88925	86.99107	87.55252	86.84295	87.31895
19	85.94730	85.45167	86.03854	85.55079	85.74707
20	83.32548	83.89162	84.48275	84.24841	83.98707

	Interstate Net Efficiency %		
Year	*Year 0 = 1958*	*Year 0 = 1978*	*Simple Average*
0	100.00000	100.00000	100.00000
1	98.43541	98.19913	98.31727
2	97.92168	97.65195	97.78682
3	97.51520	97.29105	97.40312
4	97.16393	96.99447	97.07920
5	96.84709	96.75682	96.80195
6	96.55372	96.56371	96.55872
7	96.27890	96.40590	96.34240
8	96.01769	96.23986	96.12877
9	95.76736	95.91133	95.83935
10	95.52572	95.86203	95.69388
11	95.29168	95.67860	95.48514
12	95.06358	95.50153	95.28256
13	94.84033	95.31666	95.07849
14	94.62138	95.12713	94.87426
15	94.40563	94.91260	94.65912
16	94.19309	94.70722	94.45016
17	93.98265	94.49084	94.23674
18	93.77375	94.28335	94.02855
19	93.52247	94.01042	93.76644
20	92.89928	93.50925	93.20427

TABLE 6 BEA Highway Capital Outlay Deflators, 1921–95 (*1*)

Year	*Federal BEA Deflator*	*State & Local BEA Deflator*	*Year*	*Federal BEA Deflator*	*State & Local BEA Deflator*
1921		0.1238	1959	0.2237	0.2213
1922		0.1178	1960	0.2154	0.2133
1923		0.1319	1961	0.2159	0.2142
1924		0.1391	1962	0.2228	0.2208
1925		0.1419	1963	0.2284	0.2263
1926		0.1343	1964	0.2310	0.2288
1927		0.1335	1965	0.2381	0.2365
1928		0.1241	1966	0.2518	0.2491
1929		0.1200	1967	0.2551	0.2580
1930		0.1116	1968	0.2697	0.2718
1931		0.0992	1969	0.2871	0.2877
1932		0.0758	1970	0.3182	0.3202
1933		0.0940	1971	0.3418	0.3447
1934		0.1089	1972	0.3536	0.3581
1935		0.1053	1973	0.3811	0.3900
1936		0.1155	1974	0.4909	0.5076
1937		0.1075	1975	0.5454	0.5527
1938		0.1038	1976	0.5290	0.5401
1939		0.1010	1977	0.5368	0.5349
1940		0.0983	1978	0.5406	0.5408
1941		0.1123	1979	0.5858	0.5851
1942		0.1456	1980	0.6778	0.6785
1943		0.1641	1981	0.8008	0.7939
1944		0.1508	1982	0.8716	0.8702
1945		0.1449	1983	0.8575	0.8558
1946		0.1554	1984	0.8265	0.8258
1947		0.1777	1985	0.8316	0.8322
1948		0.1988	1986	0.8731	0.8713
1949		0.1923	1987	0.9245	0.9238
1950		0.1741	1988	0.9407	0.9400
1951		0.2123	1989	0.9457	0.9475
1952		0.2184	1990	0.9834	0.9820
1953		0.2104	1991	0.9993	0.9991
1954		0.1991	1992	1.0000	1.0000
1955		0.1939	1993	1.0111	1.0111
1956	0.2173	0.2184	1994	1.0372	1.0385
1957	0.2305	0.2276	1995	1.0938	1.0950
1958	0.2247	0.2225			

NOTE: 1992 = 1.0000

TABLE 7 **Numerical Example**
(Summations of individual entries and totals may not be equal because of rounding.)

CAPITAL OUTLAY, 1960	*Current $*		*Constant $*
Capital Outlay	1000		
(Multiply by capital outlay split[a])			
Local: 1000 × 1370/(1370 + 2555 + 2224) =	223		
State: 1000 × 2555/(1370 + 2555 + 2224) =	416		
Interstate: 1000 × 2224/(1370 + 2555 + 2224) =	362		
ROW Capital Outlay			
(Multiply by ROW percentage[a])		(Divide by deflator[b])	
Local: 223 × 0.061 =	14	223/0.2133 =	64
State: 416 × 0.135 =	56	416/0.2133 =	263
Interstate: 362 × 0.191 =	69	362/0.2154 =	321
Outlay for New Construction or Reconstruction			
(Multiply by percentage of capital outlay including ROW[c])			
Local: 223 × 0.104 =	23		
State: 416 × 0.312 =	130		
Interstate: (Multiply by percentage of capital outlay less ROW[c]): 362 × 1.000 − 69 =	293		
Outlay for Other Than New Construction or Reconstruction			
(Capital outlay less ROW less outlay for new construction or reconstruction)			
Local: 223 − 14 − 23 =	186		
State: 416 − 56 − 130 =	230		
Interstate: 362 − 69 − 293 =	0		
Capital Outlay for Pavement, Grading, and Structures[d]			
Local			
Pavement: [(23 × 0.531) + 186] × 0.706 =	144		673
Grading: [(23 × 0.284) + 186] × 0.132 =	31		146
Structures: [(23 × 0.185) + 186] × 0.162 =	34		161
State			
Pavement: [(130 × 0.636) + 230] × 0.706 =	266		1248
Grading: [(130 × 0.254) + 230] × 0.126 =	62		290
Structures: [(130 × 0.110) + 230] × 0.074 =	31		147
Interstate			
Pavement: [(293 × 0.579) + 0] × 0.736 =	169		787
Grading: [(293 × 0.231) + 0] × 0.145 =	68		314
Structures: [(293 × 0.190) + 0] × 0.162 =	56		258

(*continued*)

[a] See Table 2.
[b] See Table 6.
[c] See Table 4.
[d] See Table 3

TABLE 7 *Continued*

DETAILED PRODUCTIVE CAPITAL STOCK IN CONSTANT 1992 DOLLARS

ROW Capital Stock

Year	*Local*	*State*	*Interstate*	*TOTAL*
1960–forever	64	260	321	645

Pavement Capital Stock

[(Capital outlay × Year 0 efficiency[e])/100 for 20 years]

Year	*Local*	*State*	*Interstate*	*TOTAL*
1960	673	1248	787	2708
1961	668	1231	774	2674
1962	666	1224	770	2660
1963	663	1218	767	2648
1964	660	1213	764	2638
1965	658	1208	762	2627
1966	656	1203	759	2618
1967	653	1197	757	2608
1968	651	1192	755	2598
1969	648	1187	753	2588
1970	645	1181	751	2577
1971	642	1175	749	2566
1972	638	1169	748	2555
1973	634	1163	746	2542
1974	629	1154	744	2528
1975	623	1139	743	2505
1976	607	1123	741	2471
1977	585	1105	739	2429
1978	561	1086	738	2385
1979	533	1067	736	2336
1980	0	0	0	0

Pavement Efficiencies[f]

Year	*Local*	*State*	*Interstate*
0	100.00000	100.00000	100.00000
1	99.23793	98.64635	98.43541
2	98.82215	98.06213	97.92168
3	98.44181	97.58498	97.51520
4	98.07673	97.15034	97.16393
5	97.71624	96.73500	96.84709
6	97.35357	96.32641	96.55372
7	96.98190	95.91766	96.27890
8	96.59440	95.50121	96.01769
9	96.18475	95.07203	95.76736
10	95.74263	94.62633	95.52572
11	95.25821	94.15846	95.29168
12	94.71533	93.66527	95.06358
13	94.09486	93.14614	94.84033
14	93.37408	92.47994	94.62138
15	92.54277	91.26403	94.40563
16	90.17051	89.92497	94.19309
17	86.93957	88.49002	93.98265
18	83.36330	86.99107	93.77375
19	79.18203	85.45167	93.52247
20	72.79983	83.89162	92.89928

Grading Capital Stock

(For 80 years)

Year	*Local*	*State*	*Interstate*	*TOTAL*
1960–2039	146	290	314	750
2040	0	0	0	0

Structures Capital Stock

[Previous year's capital stock × (1 – 0.01820), the geometric rate, forever]

Year	*Local*	*State*	*Interstate*	*TOTAL*
1960	161	147	258	566
1961	158	144	253	556
1962	156	141	249	546
1963	153	139	244	536
1964	150	136	240	526
1965	147	134	235	516
1966	145	131	231	507
1967	142	129	227	498
1968	139	127	223	489
1969	137	124	219	480
1970	134	122	215	471
1971	132	120	211	463
1972	129	118	207	454
1973	127	115	203	446
1974	125	113	200	438
1975	123	111	196	430
1976	120	109	192	422
1977	118	107	189	414
1978	116	105	185	407
1979	114	103	182	399
1980	112	102	179	392
1981	110	100	175	385
1982	108	98	172	378
1983	106	96	169	371
1984	104	94	166	364
1985	102	93	163	358
1986	100	91	160	351
1987	98	89	157	345
1988	96	88	154	338
1989	95	86	152	332
1990	93	84	149	326
1991	91	83	146	320
1992	90	81	143	314
1993	88	80	141	309
1994	86	78	138	303
1995	85	77	136	298
1996	83	76	133	292
1997	82	74	131	287
1998	80	73	128	282
1999	79	72	126	277
2000	77	70	124	272
2001	76	69	122	267
2002	75	68	119	262

(*continued*)

[e] See Table 5.

[f] See Table 5; in the calculations shown, the efficiency for year 20 is set equal to 0 as the asset is retired.

TABLE 7 *Continued*

Structures Capital Stock (*continued*)

Year	*Local*	*State*	*Interstate*	*TOTAL*
2003	73	67	117	257
2004	72	65	115	252
2005	71	64	113	248
2006	69	63	111	243
2007	68	62	109	239
2008	67	61	107	234
2009	66	60	105	230
2010	64	59	103	226
2011	63	57	101	222
2012	62	56	99	218
2013	61	55	98	214
2014	60	54	96	210
2015	59	53	94	206
2016	58	52	92	202
2017	57	51	91	199
2018	56	51	89	195
2019	55	50	87	192
2020	54	49	86	188
2021	53	48	84	185
2022	52	47	83	181
2023	51	46	81	178
2024	50	45	80	175
2025	49	44	78	172
2026	48	44	77	168
2027	47	43	75	165
2028	46	42	74	162
2029	45	41	73	159
2030	45	41	71	156
2031	44	40	70	154
2032	43	39	69	151
2033	42	38	68	148
2034	41	38	66	145
2035	41	37	65	143
2036	40	36	64	140
2037	39	36	63	138
2038	39	35	62	135
2039	38	34	60	133
2040	etc.	etc.	etc.	etc.

TOTAL PRODUCTIVE CAPITAL STOCK
IN CONSTANT 1992 DOLLARS
(Summation of ROW, pavement, grading, and structures)

Year	*Local*	*State*	*Interstate*	*TOTAL*
1960	1045	1945	1679	4669
1961	1036	1926	1662	4624
1962	1031	1916	1653	4600
1963	1025	1907	1646	4579
1964	1020	1900	1639	4558
1965	1015	1892	1632	4539
1966	1010	1884	1625	4519
1967	1005	1877	1619	4500
1968	1000	1869	1613	4481
1969	994	1862	1607	4462

TOTAL PRODUCTIVE CAPITAL STOCK
IN CONSTANT 1992 DOLLARS (*continued*)

Year	*Local*	*State*	*Interstate*	*TOTAL*
1970	989	1854	1601	4443
1971	983	1846	1595	4424
1972	977	1837	1589	4404
1973	970	1829	1584	4383
1974	963	1818	1578	4360
1975	955	1801	1573	4330
1976	937	1782	1568	4287
1977	913	1762	1563	4238
1978	887	1742	1557	4186
1979	857	1721	1552	4130
1980	321	652	813	1787
1981	319	650	810	1780
1982	317	648	807	1773
1983	315	647	804	1766
1984	314	645	801	1759
1985	312	643	798	1752
1986	310	641	795	1746
1987	308	640	792	1739
1988	306	638	789	1733
1989	304	637	786	1727
1990	303	635	783	1721
1991	301	633	781	1715
1992	299	632	778	1709
1993	298	630	775	1704
1994	296	629	773	1698
1995	295	628	770	1692
1996	293	626	768	1687
1997	291	625	765	1682
1998	290	623	763	1676
1999	289	622	761	1671
2000	287	621	758	1666
2001	286	620	756	1661
2002	284	618	754	1656
2003	283	617	752	1652
2004	282	616	750	1647
2005	280	615	747	1642
2006	279	613	745	1638
2007	278	612	743	1633
2008	277	611	741	1629
2009	275	610	739	1625
2010	274	609	738	1621
2011	273	608	736	1617
2012	272	607	734	1613
2013	271	606	732	1609
2014	270	605	730	1605
2015	268	604	728	1601
2016	267	603	727	1597
2017	266	602	725	1593
2018	265	601	723	1590
2019	264	600	722	1586
2020	263	599	720	1583
2021	262	598	719	1579

(*continued*)

TABLE 7 *Continued*

TOTAL PRODUCTIVE CAPITAL STOCK IN CONSTANT 1992 DOLLARS (*continued*)

Year	*Local*	*State*	*Interstate*	*TOTAL*
2022	261	597	717	1576
2023	260	597	716	1573
2024	260	596	714	1569
2025	259	595	713	1566
2026	258	594	711	1563
2027	257	593	710	1560
2028	256	593	709	1557
2029	255	592	707	1554
2030	254	591	706	1551
2031	254	590	705	1548
2032	253	590	703	1546
2033	252	589	702	1543
2034	251	588	701	1540
2035	250	587	700	1537
2036	250	587	698	1535
2037	249	586	697	1532
2038	248	586	696	1530
2039	248	585	695	1527
2040	etc.	etc.	etc.	etc.

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RESOURCE PAPER

Information for Transportation Economic Analysis

State of the Art and Relevance for Decision Making

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The U.S. economy has enjoyed a long period of overall economic growth since 1994, and policy makers and citizens alike have hopeful expectations of continued productivity improvement, with full employment, nearly full use of productive capacity, and rising real incomes combined with reduced income disparity. Whether such hopes can be sustained is the basic political question of the day. Whether sustained growth can continue without insupportable social and environmental costs is the overriding question in the long run. Transportation is an enabling and limiting factor in both the immediate case as well as over the longer run, in which production and productive techniques may change.

The views of economists appear to differ as to the key forces responsible for growth. Perhaps exogenous changes in technology, combined with increases in population and the labor force participation rate, have been the primary growth engines. Human capital advances may have played a part, with more educated and capable workers. Computers and automation have had a role. Perhaps, though, new and more targeted investment, spurred by institutional changes and aided by an increased money supply, has proven the most important stimulant to economic growth.

The debate among economists may go on, but transportation, as a derived demand, clearly has expanded its capabilities to meet the needs of a growth economy. Expanded capabilities have come about through the use of improved technology but also due to the competitive impacts unleashed by regulatory change. Despite evidence of congestion and service deficiencies, today's highway, rail, and air services are generally of greater capacity as well as of overall higher quality compared with those of a decade or two ago. The management of transport firms and government organizations likewise appears to have improved effectiveness and responded to demands with a broadened array of services.

In turn, an improved transportation system has reduced many costs of production, raising business profitability. Transportation is a mixed public-private service, and government investment spending in transportation has been needed to support economic expansion; that investment, many believe, also has raised the long-term rate of economic growth. [For reviews of some of the recent studies, see Jacoby (*1*) and Beshers (*2*).]

Transportation is an enabling factor in economic growth and in enhancing industrial competitiveness, which can be an overriding policy factor for the United States, as globalization of production and distribution accelerates with uneven impacts worldwide on national economies and labor forces. Transportation organizations increasingly recognize economic growth as a transportation goal. [For examples, see Magid (*3*), *Transportation and the Economy* (*4*), and *Transportation for a Competitive America* (*5*). There are also state examples, such as *Transportation: The Heartbeat of Wisconsin's Economy* (*6*).]

But transportation plays another, less global role as part of the public sector, because government transportation activity in the United States as elsewhere in the world is expected to provide leverage to achieve social goals at every geographic or political strata. Transportation expenditures and services are asked at national, state, or local levels to facilitate welfare reform, narrow regional wealth or opportunity disparities, manage growth, and help produce more livable cities or neighborhoods. Transportation provides employment, facilitates changed land uses, links businesses and employees, broadens distribution, enhances recreation, and in short is called upon to put in place the agenda of every political body.

It is no wonder that the information requirements are vast for those who must manage the process of making transportation investment and service decisions in the public interest. Transportation is necessary to support overall economic growth and activity in the national economy, but it also is expected to serve other goals of the community, support the desires of those who use its services, and do all this with the least expenditure of scarce resources. It may not be an easy task to ensure that a transit service be run on time and efficiently, that a highway project be constructed on a life-cycle basis appropriate to the demands of a forecast mix of traffic, or that an air traffic control system be safe and effective for all varieties of commercial as well as general aviation. Yet it takes far more knowledge to blend those transit services to the needs of a community in which some interest groups wish to change land-use patterns while at the same time others would like to enhance the mobility of targeted customers. It is more difficult to build and administer correctly when the highway is required to support the needs of just-in-time trucking, serve as an urban growth boundary, and stimulate the use of high-occupancy vehicles.

Do we have the information required to make satisfactory decisions about how best to apply transportation resources? If not, what information is desired, what might it cost, and how might it be obtained? Is research needed to decide either information needs or cost-effective ways of gathering that information? At the beginning of the past decade, the U.S. General Accounting Office (GAO) in a report describing five important transportation issues gave first position to "investing wisely to rebuild and enhance surface transportation infrastructure" (7, pp. 6–12). This issue was seen as encompassing (*a*) federal restructuring permitting modal trade-offs, as enabled by creation of the U.S. Department of Transportation's Bureau of Transportation Statistics and its Office of Intermodalism under 1991's Intermodal Surface Transportation Efficiency Act (ISTEA)[1]; (*b*) optimizing the investment of available funding; and (*c*) seizing emerging technological opportunities. We will address these questions, keeping in mind recent progress made under ISTEA and the Transportation Equity Act for the 21st Century, and conclude with our research recommendations to provide and communicate the information necessary for decision making.

It is clear that the work of the federal Department of Transportation (DOT) over the past decade has increased our store of transportation information through such efforts as resuming and expanding commodity flow surveys, developing an initial transportation satellite account, and initiating an American Travel Survey to provide intercity passenger information. Further important DOT efforts are underway. On the other hand, the decade also has brought a loss of information once provided by the federal economic regulatory agencies, and the 2000 U.S. Census may prove of less use for transportation planners than those of the past. Some state and local transportation agencies have stepped up their data efforts, perhaps stimulated by federally mandated transportation plans, although my observations suggest state data activities vary widely, and in some cases data once routinely obtained are no longer gathered. Data efforts may have been lost due to agency downsizing, or because of reduced budgets. However, lower-cost electronic methods of obtaining data may permit data restoration. As a general principle, more redundancy in data, with collection at different levels of government, should be encouraged to produce better answers.

Better transportation information about shipments and travelers, however, even if widely available, does not necessarily mean better knowledge of transportation interactions. Transportation information alone may not illuminate how transportation supports the achievement of nontransportation goals.

Better information at the national level also may not result in superior decisions if, for whatever reason, that information is not put to practical use. As I reviewed the literature on economic analysis for transportation for this conference, I was struck by two points: (*a*) how much attention currently is being paid to economic questions in transportation by policy makers and the press, and (*b*) how much literature recently has been generated on the subject by researchers. We are fortunate to have excellent reviews in our conference resource papers of some elements of these relationships, but I would like to focus more narrowly on the research of the past few years as managed by the Transportation Research Board (TRB).

Transportation Economic Research Products

It is impressive to note the large amount of applied research on transportation and economics managed in approximately the past 5 years by TRB. It would seem to me that any research recommendations that proceed from this conference ought to build upon this recent work. It may well be that I have missed or neglected some important components of the research, but following are what I believe to be the more important studies and reports that have come to my attention (the list also includes a few studies from slightly earlier in the past decade that are relevant and important[2]):

- *National Cooperative Highway Research Program (NCHRP) Report 342: Primer on Transportation, Productivity and Economic Development* (1991).

- *NCHRP Research Results Digest 200: Objectives and Decision Criteria for Infrastructure Investment* (1994).
- *Special Report 246: Paying Our Way: Estimating Marginal Social Costs of Freight Transportation* (1996).
- *NCHRP Report 389: Macroeconomic Analysis of the Linkages Between Transportation Investments and Economic Performance* (1997).
- *Transportation Research Circular 477: Assessing the Economic Impact of Transportation Projects: How To Choose the Appropriate Technique for Your Project* (1997).
- *Conference Proceedings 14: Information Needs To Support State and Local Transportation Decision Making into the 21st Century* (1997).
- *NCHRP Report 418: Research on the Relationship Between Economic Development and Transportation Investment* (1998).
- *NCHRP Report 40: Guidance for Estimating the Indirect Effects of Proposed Transportation Projects* (1998).
- *NCHRP Synthesis 267: Transportation Development Process* (1998).
- *NCHRP Report 421: Economic Trends and Multimodal Transportation Requirements* (1999).
- *NCHRP Synthesis 269: Road User and Mitigation Costs in Highway Pavement Projects* (1999).

We have additional TRB-managed work directly relevant to the issue of revenue for transportation (the topic of the resource paper by David Gillen):

- *NCHRP Report 377: Alternatives to Motor Fuel Taxes for Financing Surface Transportation Improvements* (1995).
- *Conference Proceedings 15: Transportation Finance for the 21st Century* (1997).
- *NCHRP Report 416: Alternative Approaches to the Taxation of Heavy Vehicles* (1998).
- *TCRP Report 34: Assessment of the Economic Impacts of Rural Public Transportation* (1998).
- *TCRP Report 31: Funding Strategies for Public Transportation* (1998).

The list of research products I have shared is idiosyncratic, and it does not include each recent TRB product or those underway for which results have not been published. Moreover, the list includes nothing from the many papers published annually in the *Transportation Research Record*. The list certainly does not extend to the vast amount of research published in academic journals, provided by consultants for clients, or produced by transportation agencies primarily for internal use.

The logical question would seem to be: when we have such a volume of recent activity, do we need more research? Have we investigated the wrong issues, or investigated too narrowly? Has the research been unsuccessful? Is the work, in various ways, incomplete?

Fortunately, as we analyze the research that has been done, to address new research needs, we will have available to us the majority of the researchers who have produced or reviewed this body of economic work or served on NCHRP and Transit Cooperative Research Program (TCRP) panels in this field. We can build together on the extensive and diverse body of work done by these talented experts to fill gaps and improve techniques.

Observations For Discussion

What strikes me is that rather than building upon and improving our economic research, we may need to take this work in a different direction. The answers to the questions of why we perceive additional research is needed to better understand transportation's impact on the economy and to understand the use of economics in making transportation decisions may be "all of the above." Based on my observations and experiences in government, however, I suspect we call for more research primarily because we neither communicate nor fully understand the research findings to date. Time pressures are simply too great; capable staff are too few. While further research is certain to be worthwhile, particularly because of the complexity of transportation interactions, the research has so far stopped short of technology transfer and therefore is not influencing the behavior of those entrusted with making transportation expenditures. The inability to communicate may be surprising because NCHRP and TCRP reports are designed especially to be practical, accessible, and readable. However, the fault is less with the research products or their presentation than with the reception of the research. We need to return to the GAO's foremost issue for the post-ISTEA era and focus more strongly on communicating investment trade-offs through better, and more understandable, technical assistance to those who are making expenditure decisions. This observation leads me to several hypotheses that I suggest be incorporated into the discussion:

Hypothesis 1. Communication of economic research results needs to be of first priority.

Hypothesis 2. Communication should be foremost to those at the technical level in state DOTs and metropolitan planning organizations, who understand their unique local circumstances and are best equipped to put the research findings to work. Those with technical expertise can then share their knowledge with decision makers and interest group representatives.

Hypothesis 3. Communication is greatly aided by examples and case studies.[3]

Hypothesis 4. For communication to be fully effective, organization change and institutional strengthening may be required. More technical personnel could be added and consultants used. The location and communication channels of technical people within the agency or their reporting responsibilities could be changed.

Hypothesis 5. Decision makers should be accessible and seek technical advice on economic questions. Important resource allocation decisions should call upon economic analysis. Just because "maintenance is absolutely necessary" or "safety is our first priority" is not reason to shield an expenditure decision from trade-off analysis. Economic advice needs to be balanced with other considerations, but it should not be missing from decision making for lack of communication.

Conclusion

Filling gaps and improving the techniques of economic analysis are important research goals. We should hope to carefully set our priorities for advancing the state of models and providing needed data. But just as necessary is communicating economic knowledge to those who are making and influencing transportation decisions. For successful communication we may need to refocus our attention from basic or even applied research to organizational change in federal, state, and local relationships.

Notes

1. These offices were seen as needing to define the federal role in transportation problem-solving, provide technical assistance to states and localities, and develop and disseminate data.

2. For greater completeness, *NCHRP Research Results Digest 233* (October 1998) lists and summarizes 24 recent National Cooperative Highway Research Program and Transit Cooperative Research Program economic research projects.

3. A field in which effective case studies have been provided is that of the impact of highway bypasses on communities. For examples, see *NCHRP Research Results Digest 210: Effects of Highway Bypasses on Rural Communities and Small Urban Areas* (1996) and Yeh (*8*).

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RESOURCE PAPER

How Levels of Investment in Transportation Affect Economic Health

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Competing uses for limited government funding at all levels of government have forced government agencies to scrutinize public spending more closely. Government agencies responsible for public infrastructure investment increasingly are asked to justify their expenditures by showing the linkage between investments and economic performance. At the federal level, the Government Performance and Results Act of 1993 requires federal agencies to develop strategic plans and annual performance plans and to prepare program performance reports. Agencies must adopt "objective" indicators of performance and measures of both outputs and outcomes. In this context, the output of a highway system, for example, would pertain to the direct performance of the facility, such as number of vehicle miles or pavement conditions. Outcomes would include the consequence of this facility output, such as the increase in economic activity in the area served by the highway.

This requirement to assess infrastructure performance was further expanded under Executive Order 12983, signed by President Clinton in 1994. The order established "principles for federal infrastructure investment," which directed benefits and costs to be assessed for all major programs with annual budgetary resources exceeding $50 million. Thus, benefit-cost analysis was expanded from a project basis to a program basis. It required that benefits and costs be quantified and monetarized considering both market and nonmarket factors. This order prompted many agencies to consider how to carry out this formidable task. Several initiatives to explore methodology and data needs have taken place since then, most notably the Transportation Research Board (TRB) Conference on Information Needs to Support State and Local Transportation Decision Making in 1997 and the American Association of State Highway and Transportation Officials report on transportation and the economy.

This TRB conference offers another opportunity to revisit and extend the evaluation of infrastructure projects, specifically highway investments, and continue to explore ways to make the analysis more relevant to practitioners and policy makers. Particular attention will be given to the needs of state, metropolitan, and local government entities. The primary focus of the conference is to explore what information is needed to address the following topics:

- How levels of investment in transportation affect economic health;
- Economic evaluation for decision making on transportation projects, programs, and policies; and
- Estimation of revenues from use charges, taxes, and other sources of income.

This paper addresses the first topic: data and methodological needs for assessing the relation between transportation and economic health.

Three issues will be addressed in this paper:

- What key questions should policy makers be asking?
- How well do existing data and tools answer these questions?
- How do we improve the data to answer key questions?

Assessing Performance

There is no doubt that transportation systems are the backbone of a developed market economy. However, assessing the performance of transportation systems requires an understanding of a complex relation between transportation and economic health. Many of these relations are not well quantified or understood. To establish these linkages, policy makers need to take two dis- tinct steps: (*a*) assess the effect of the characteristics of the system or facility on its output, and (*b*) estimate the effect of the output of the facility on economic outcomes. The first step is basically internal to the system or facility itself. It relates the size, type, and condition of the facility to outputs that the facility produces. The second step relates the output of the facility to conditions and activities outside the facility.

Figure 1 illustrates the relation among the system characteristics, output, and outcomes. In general, policy makers are more familiar with the inventory or characteristics of the transportation facility than they are with outcomes and even outputs. Key highway characteristics are measured in lane miles, grade, tightness of curves, pavement condition, number of bridges, bridge load capacity, or volume capacity. Direct outputs of highway facilities are access, mobility, movement of goods, reliability of service, and safety.

The first step as outlined above is to relate lane miles, grade, tightness of curves, and so forth to the facility's ability to produce access, mobility, and traffic flow. The second step is to estimate the effect of these outputs on broader outcomes, such as economic productivity, job creation, income generation, improved public health and safety, environmental quality, residential and business location, and subsequent job opportunities and income inequality. In this way, the characteristics of the highway facility are related to economic outcomes, but with an appreciation for the intermediate step that the efficiency in which highway infrastructure produces highway services matters.

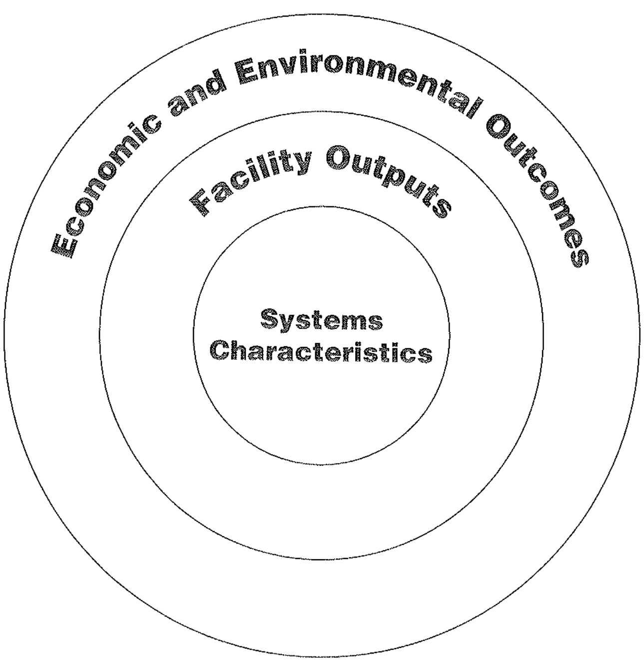

FIGURE 1 Relation among system characteristics, output, and outcomes.

In addition, these outcomes are geographically distributed, with the scope of possible effects radiating from the location of the facility. For example, job creation may occur at the interchange of two major highways, because of the increased access to transportation services, which increases reliability and reduces freight costs. Lower freight costs, in turn, make the area more attractive to businesses. An increase in business activity attracts other businesses that seek close proximity to suppliers or customers. The outcome of these activities spreads beyond the immediate vicinity of the highway interchange and the system. Increased vehicle usage of a highway system also may affect a broader geography, such as an increase in pollution affecting an area's air shed.

Obviously, facility outputs directly affect outcomes, whereas system characteristics have no direct effect on outcomes, except for perhaps construction costs. The distinction can be subtle for certain types of transportation infrastructure. However, the framework underscores two important points. First, decision makers must scrutinize the internal performance of the facility under their responsibility. Second, efficiency of the system (that is, that efficiency by which facilities yield output) is directly related to the capacity of the facility to generate outcomes valued by the decision makers. Succinctly, the ability of \$1 million of investment in highway infrastructure to generate economic outcomes depends upon the efficiency in which the resulting facility produces output. Size, condition, and type of existing infrastructure will have a bearing on output. A \$1 million investment to add a lane to a highly congested segment of highway will likely have a greater effect on improving traffic flow than a \$1 million investment in adding a lane to a segment that is grossly underutilized. Furthermore, the same dollar amount of investment in improving pavement conditions may not improve traffic flow to the same extent as adding another lane. The subsequent increase in traffic flow then affects economic outcomes, such as job creation or income growth.

As we will see in the next section, most studies do not distinguish between the type of investment nor do they include a measure of the output of the facility. The major problem is the lack of adequate measures of highway characteristics and outputs that readily can be used to analyze economic outcomes. Highway capital stock typically is measured by adding expenditures on highways over a sufficiently long time period and subtracting depreciation. Because of the lack of adequate data, no attempt has been made to construct measures of different types of highway capital stock. Consequently, a state that spends $1 million on adding a lane may generate greater levels of economic activity than another state that spends the same amount improving pavement conditions, assuming everything else is the same. As discussed in later sections, this distinction becomes important in trying to estimate the effect of transportation infrastructure on the economic health of regions such as states or metropolitan areas. Estimates of the effects of highways on economic outcomes depend upon the efficiency in which highways are built and meet the needs of local users. At best, analysts linking highway characteristics to economic outcomes can only assume that the optimal configuration of highway infrastructure has been put into place.

The Relation Between Benefit-Cost Analysis and Assessing Economic Health

Benefit-cost analysis has been the traditional means of estimating the relation between transportation and economic benefits. The Office of Management and Budget has endorsed it as the basic tool to use in evaluating government programs and projects. Benefit-cost analyses typically include, for example, the number of jobs created, the amount of income generated, and the increase in land as measures of economic activity. However, there is an underlying concern that benefit-cost analysis may not capture all the benefits associated with large infrastructure projects, such as the interstate highway system or an intermodal freight facility. Many of these projects generate significant indirect benefits, which are difficult to measure with sufficient precision. Without an accurate accounting of both direct and indirect benefits, benefit-cost analyses may reject projects that are economically viable. [Hulten (*1*) discusses the differences between the benefit-cost methodology and the production function methodology in capturing these additional benefits that may accrue from transportation infrastructure.]

The suspicion that benefit-cost analysis may undercount economic benefits was heightened about a decade ago when several macroeconomic studies of the overall effect of public infrastructure on the economy were conducted. These studies correlated aggregate output with various measures of privately provided inputs and public capital, including transportation infrastructure. Estimates have been derived at the national, state, and metropolitan levels. Some of these studies suggested that the total effect of public capital on output growth is far stronger than indicated by benefit-cost analysis. The research gained particular notoriety around 1990 when one study implied a payoff of nearly $2 in output for each additional $1 of core infrastructure investment (*2*).

The staggering returns to infrastructure investment gained immediate attention among policy makers who saw these returns as justification for additional infrastructure investment and as a way to grow the economy out of the mild recession during the early 1990s. On the other, the high returns raised immediate skepticism among many economists and launched a subspecialty of investigation within the economics profession to see whether these results would hold up under closer scrutiny. Proponents of these high returns defended the results by arguing that the macroeconomic approach to estimating returns to public investment accounted for additional benefits, such as externalities, increasing returns to scale, and network effects, that conventional benefit-cost analyses may miss.

Since then, researchers have devoted considerable time and effort exploring whether the macroeconomic approach using production/cost functions could detect the additional economic benefits that may accrue from investment in transportation. Several reports provide a summary and critique of this literature, most notably Bell and McGuire (*3*), Nadiri and Mamuneas (*4*), and McGuire (*5*). Table 1 displays the results of previous production function and cost function studies, compiled by Nadiri and Mamuneas. These studies typically include all infrastructure in the estimation, whereas only a few have estimated the results of highway infrastructure separately. I am not aware of studies that have related other forms of transportation, such as mass transit or air transit, to output. Output in most studies is measured as manufacturing output, because it is the most easily quantifiable and readily available. A few studies have used gross state product or gross domestic product.

The basic approach is to estimate a production function in which output is related to private inputs—capital and labor—and public capital. The relation is shown in the following equation:

$$\ln Q = a_o + a_H \ln H + a_K \ln K + a_G \ln G + \varepsilon$$

where

- Q = output (measured as value added),
- H = hours worked by production employees,
- K = private manufacturing capital, and
- G = highway capital stock.

In this example and in most studies, highway stock is measured by summing highway expenditures over a sufficiently long time period, typically 30 years or longer. Depreciation, usually assumed to be the same for all types of highways and their components, is subtracted

TABLE 1 Selected Production Function Studies

Author	*Equation*	*Data*	*Elasticity**	*Comments*
Aschauer (*2*)	Cobb-Douglas production function and TFP regressions	Time series, 1949–85; Private business; economy	0.39–0.36, 0.37–0.41: significant	Constant returns to scale (CRS) in all inputs, including public capital input
Munnell (*6*)	Cobb-Douglas production function reproduces Aschauer	Time series, 1948–1987; private nonfarm sector	0.34–0.41: significant	CRS in all inputs; also private and public capital coefficient equal
Munnell (*6*)	Cobb-Douglas production function	Cross-section time series; 48 states, 1970–1986	0.15	See Munnell (*7*) and other references
Munnell (*7*)	Cobb-Douglas production function	Cross-section average, 1970–1986; states values: 12 high endowment, 26 mid-endowment, 10 low endowment	0.14, 0.11, 0.22: significant	Returns to scale: 1.01, 1.03, 1.04
Garcia-Mila and McGuire (*8*)	Cobb-Douglas production function	Cross-section time series; 14 annual observations of 48 states' gross state production, labor, and capital expenditures on education and highways	Highways: 0.045–0.044; education: 0.16–0.072—significant	Returns to scale: 1.04; cannot reject increasing returns to scale
Eberts (*9*)	Translog production function	Cross-section, manufacturing, 1958– 1978 ; 38 metropolitan areas	0.04: significant	CRS; public and private capital; substitutes public and labor complements
Hulten and Schwab (*10*)	Cobb-Douglas production function with first differences	Time series, 1949– 1985 (same as Aschauer)	0.42: significant; 0.028 insignificant	Negative coefficient for labor
Tatom (*11*)	Cobb-Douglas production function, including energy price, with first differences	Time series, 1974–1987; business sector	0.146: insignificant	CRS
Mera (*12*)	Cobb-Douglas production function	Japan: pooled data of regions and time; three sectors; four classifications of social overhead capital	0.22. 0.20 (.50), 0.12–0.18: significant	
Ford and Poret (*13*)	TFP regressions	USA and 11 OECD countries: time series and country cross-sections	Half of countries significant effect after 1960; mixed support of Aschauer results	
Hulten and Schwab (*10*)	TFP regressions	Cross-section time series; regional study of Snow-Sun Belt; 1970–1986; gross output value added	Public capital insignificant in all regressions; private capital insignificant in gross output regressions; significance in value-added implying scale, .88	

* Coefficient of infrastructure capital in logarithmic equation.

from the expenditures. The result is a generic measure of highway capital stock. It is generic in that it does not take into consideration differences in the efficiency of highway facilities and differences in construction costs across states and regions due to material and labor costs, financing costs, and terrain. Thus, there is an implicit assumption that one dollar's worth of net highway capital stock in the generally flat state of Kansas is the same as in the mountainous state of West Virginia, or that one dollar's worth of net capital stock is the same in the higher-wage state of Massachusetts as it is in the lower-wage state of Mississippi.

To illustrate the relations that are typically found among these variables, consider estimates obtained from a pooled data set of state observations from 1988 through 1992. The variables are entered in log form, so that the coefficients (denoted by the *a*'s) are output elasticities, which are interpreted as the percentage effect on output of a 1 percent increase in each of the inputs. Plugging the results back into the equation shows the relative contribution of each input to output:

$$\ln Q = 0.56 \ln H + 0.38 \ln K + 0.15 \ln G$$

All coefficients are statistically significant. We see that a 1 percent increase in highway capital stock is associated with a 0.15 percent increase in output. However, while highway infrastructure has a positive effect on output, its effect is much smaller than the other two key inputs. Labor contributes the most to output, with an output elasticity of 0.56, and private capital is a relatively close second with an output elasticity of 0.38. In this case, each input contributes at least twice as much to output as highway capital.

Many (but not all) of the econometric studies have found a positive relation between net public capital stock investment and private-sector economic performance. However, results vary widely across studies, and the results of some studies, particularly those using a fixed-effect methodology, have been negative and statistically insignificant. For those production function estimates that are statistically significant, the magnitudes range from a low of 0.04 percent to a high of 0.41 percent.

The magnitudes vary by time period, technique, and level of aggregation. As shown in Table 2, estimates differ significantly by time period. Using national-level production function estimates, similar to the technique used by Aschauer (*2*), estimates are large, positive, and statistically significant for the period between 1949 and 1967. However, during the 1968 to 1985 period, the estimates turn negative and are statistically insignificant. The same decline in returns over time is found for highway investment. Nadiri and Mamuneas (*4*), using a cost function approach at the national level, find that the output elasticity of highway capital is 0.084 between 1950 and 1991 and half that amount (0.039) between 1981 and 1991. Fernald (*14*), using the same output and private input data as Nadiri and Mamuneas but estimating a production function, also finds that the productivity effects of highways decline over time. He concludes that "roads had an above-normal return before 1973, but probably do not have an above-normal return today" (*14*, p. 632).

TABLE 2 **Public Capital Elasticities**

I. Split Time Periods	
1949–1985	0.42
1949–1967	2.32
1968–1985	–0.08
II. Time Series	
Differenced	Statistically insignificant
Cointegration	Statistically insignificant
III. State-Level Equation	
Pooled	0.15
State dummies included	–0.02
State and time dummies	–0.03
Year dummies	0.16
Regional dummies	0.09

One problem with time-series estimation is the possibility of spurious correlation. Variables dominated by long trends produce strong correlations that offer a false sense of explanatory power. Studies, such as Tatom (*11*), that correct for the spurious correlation by first differencing or using other methods of correcting for nonstationarity in the data find much smaller and even negative and statistically insignificant effects of infrastructure on output.

Production functions using cross-section data and cross-section time-series (panel) data for states or metropolitan areas typically yield estimates that are much smaller than national-level estimates. For instance, Munnell (*6*) finds that the output elasticity of public capital is less than half as large as her time-series estimates using aggregated state data. Garcia-Mila and McGuire (*8*), using gross state product as the measure of output, find that highway capital per square mile has a positive and statistically significant effect with an elasticity of 0.04. Holtz-Eakin (*15*) argues that estimates based on cross-section time-series data are biased because they do not account for differences across states in factors that could affect output. Using methods to correct for these differences, Holtz-Eakin finds that infrastructure does not contribute to output. He interprets these results to suggest that some critical threshold level of infrastructure is essential to economic performance, but expansion in infrastructure beyond this level does not increase output.

Estimates also appear to vary somewhat systematically across different levels of aggregation. The general tendency is for national-level estimates to register the largest magnitudes, followed by state-level, and then by metropolitan-level. Munnell and others have argued that this ranking may reflect that narrower levels of aggregation do not capture the indirect effects of infrastructure as well as broader levels. For instance, according to this argument, metropolitan-level estimates would not include the network and other spillover effects that may be captured in national-level estimates. Of course, this relation between the size of estimates and level of aggregation may change depending upon specifications and the controls for nonstationarity that are included in the estimation, which may undermine this argument.

It is difficult to reconcile the different results obtained from different data, methodologies, time periods, and levels of aggregation. Garcia-Mila et al. (*16*) attempted to find a preferred production function specification based on various econometric tests. However, their preferred model, which controlled for nonstationarity and state-fixed effects, yielded results that suggest that public capital, both in aggregate and separated by type, has no significant effect on output.

The conclusion most supported by the literature is that there is no definitive estimate of the effect of infrastructure in general and transportation infrastructure more specifically on output. Different studies yield different estimates. Therefore, policy makers must understand the sensitivity of results to a host of factors, not least important of which is the effect of transportation within various economic circumstances, such as the robustness of the local economy and the availability of other economic factors that affect economic growth. The next section of this paper provides a framework for understanding the possible linkage between transportation and economic health.

WHAT KEY QUESTIONS SHOULD POLICY MAKERS BE ASKING?

The primary focus of this paper and conference is on state and metropolitan decision makers. Therefore, when considering the relation between transportation infrastructure and the economy, the emphasis is within specific state and metropolitan economies. For these decision makers, the health of the local economy takes on several dimensions including the need to create more jobs and generate income, to enhance the livability of the region, and to reduce urban sprawl. Policy makers and stakeholders may have different opinions about the appropriate outcomes to include in their analysis. Some areas will decide that the creation of new jobs takes precedence; others may focus on environment quality to enhance the livability of a region; whereas a third may emphasize mass transit as a means to aid low-wage individuals in gaining access to jobs. Although stakeholders and policy makers can place a higher priority on one outcome over another, most attributes are inextricably linked by a regional growth process. Therefore, some actions by decision makers may yield unintended results, whereas others may be difficult to obtain, particularly if they run counter to market forces inherent in the regional growth process.

Infrastructure Investment as a Stimulus of Growth

Many policy makers see infrastructure investment as a possible stimulus of growth.[1] For instance, state policy makers may be interested in the effect of additional highway spending on economic development within their borders. Local metropolitan planning organizations or other regional metropolitan governments may want to know how a proposed intermodal freight facility or the expansion of a regional airport might boost their local economy. The questions might be even more specific and concentrate on segments of highways and types of improvements. Policy makers may ask how adding another two lanes to an existing interstate segment between two major cities can stimulate the creation of jobs within that region. Policy makers also may want to know if a new interchange on an existing interstate may stimulate growth in and around that area.

As suggested by the questions, the queries regarding the economic benefits of highway and other types of transportation investment may focus on specific types of transportation within narrowly defined geographical areas. Understanding the economic development process provides a framework for judging the possibility of adequately answering these questions, given the current research methodologies and data available to address the questions.

Economic development is typically defined as the process by which additional income is generated within a region. As shown in Figure 2, there are several channels through which transportation investment might stimulate regional growth. Consequently, the appropriate questions raised by decision makers depend upon the source of growth and the role that infrastructure plays in affecting growth. Resource growth can occur in three ways. One source is an increase in the economic use of resources already residing in a region. This source is referred to as internal growth and includes increases in a region's employment rate or labor force participation rate. The second source is an inflow of resources from other regions. Referred to as external growth, this source results from the movement of households and businesses from one region to another. The third source is more efficient use of resources already in place and employed in

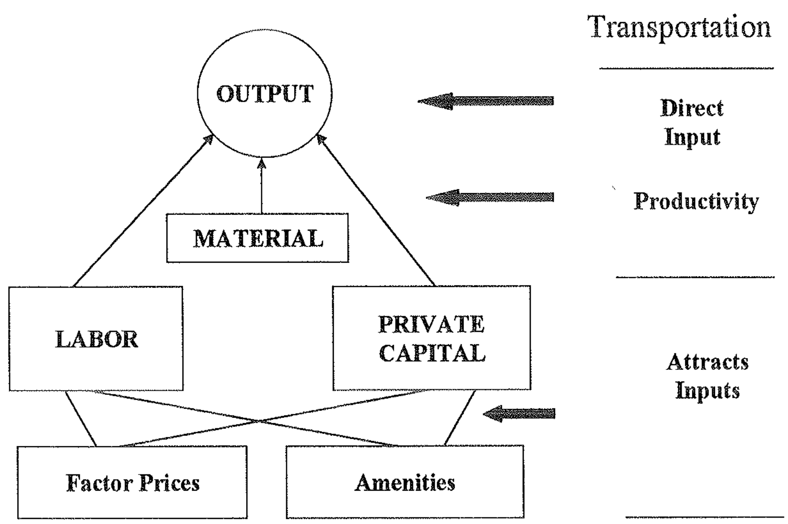

FIGURE 2 Regional growth process.

the area. More efficient use of resources leads to greater productivity gains.

The economic and social benefits of growth then depend upon the type of growth that takes place. For example, state policy makers may seek to promote growth within their own region by enticing businesses from outside the state to locate within their state. Obviously, any jobs created from the relocation of businesses in one state result in a loss of jobs (or foregone potential expansion of jobs) in another state. By pursuing this strategy, state policy makers may be able to meet their goal of stimulating growth in their own state in the short run. However, as other states pursue the same policy, a bidding war is likely to ensue, which typically results in economy-wide inefficiencies.[2]

Another important point to consider with respect to internal growth is that the creation of new jobs and income may not necessarily benefit the residents of the area. If the purpose of growth is to provide jobs for those unemployed in the region, Bartik (*18*) has shown that a large percentage of newly created jobs may not go to these people but to those who move into the region. Immigrants are typically more educated and otherwise better qualified for these jobs than unemployed residents.

State policy makers who pursue growth through the first channel of internal growth can do so without necessarily adversely affecting other states. In this case, unused or underutilized resources are used more fully and thus add to the resources of the state without detracting from the actual or potential resources of another state.

Several studies offer insights into which of the two sources of growth is more important to regional growth. With respect to labor, studies show that both sources of growth contribute equally to employment change. Population change, which can be considered a measure of external growth, accounted for half the labor supply response to employment change. Labor force participation and unemployment, a source of internal growth, together contributed to the other half (*19*).

Determinants of Increase in Resources

Both internal and external resource growth responds to price differentials and regional amenities. Higher wage rates and greater job opportunities offer better matches between job postings and an individual's work preferences. Nonworking residents in such areas will have more incentive to seek and obtain jobs. The same incentives increase local entrepreneurial activity, which leads to the formation of businesses. Factors such as relatively high entrepreneurial activity or business spin-offs from local research and development activities could account for the internal creation of capital. Also, lower wage rates in established jobs in the area may lead some individuals to pursue self-employment or to start up their own businesses.

External sources of input growth are related primarily to determinants of migration between regions. The traditional, neoclassical view of regional development is based on the notion of perfectly mobile inputs that flow to regions that offer the highest rate of return. Workers, for instance, migrate toward regions offering higher wages and away from regions offering lower wages, holding all other metropolitan characteristics the same. However, workers and their families are attracted to an area by more than higher wages. One important criterion in the household location decision is the level of amenities.

Amenities include a host of local attributes, including a comfortable climate, recreational opportunities, cultural attractions, good schools, public transportation, and an efficient highway system.

The flow of capital (that is, the location of plants and equipment) is determined in part by factor price differentials. Firms will locate in areas that provide the highest rate of return. Economic profits depend on the price and quality of the inputs that are used by businesses to produce their products. These inputs include labor, privately owned capital, materials, land, and transportation costs. Areas that offer these inputs at a lower cost to the firm typically are more attractive. However, the quality of inputs varies across regions, and the price of an input must be compared with its productivity. For instance, the quality of a region's labor force depends on the educational and training level of the workers, their work ethic, and whether or not there are institutional factors, such as trade unions, that may affect workplace arrangements. All of these attributes affect a worker's productivity. It may be the case that even though wages in one location are higher than another, the higher productivity of workers in the first area offsets their higher compensation. The business that locates in the high-wage *and* higher-productivity area would be more profitable, with all other factors the same.

The same holds for public inputs, such as government services and public infrastructure. Local government services typically are financed through some form of local taxes. Businesses typically seek low-tax areas. As with privately provided inputs, the price of government services should not be the only factor considered in business locations. Quality schools, responsive protective services, and adequate and dependable water distribution and treatment systems are important considerations. Transportation infrastructure also is important. In fact, recent surveys of chief executive officers place access to highways at the top of the list of factors important in location decisions. More will be said about transportation in the next section, but suffice it to say here that transportation infrastructure can enhance profitability either by increasing productivity or by reducing factor costs. One way the latter effect is achieved is by augmenting the efficiency of private inputs employed by firms. Another is by providing an attractive environment for households. Although government services, such as quality schools or plentiful open space, do not influence businesses directly, they do influence the type of worker who would be attracted to an area. Increasingly, businesses are concerned about attracting and retaining highly skilled workers. These workers are attracted to areas with governments services that improve their overall quality of life.

Several studies have examined the effect of infrastructure on the attraction of firms and households to an area. Fox and Murray (*20*) show that the presence of inter-state highways in a county is a significant determinant of where businesses locate. Eberts (*21*) finds that public infrastructure positively affects the number of firm openings in metropolitan areas, and Eberts and Stone (*22*) show that public capital stock positively affects employment growth through business start-ups and expansions. Fox et al. (*23*) examine the effect of local government public policies, of which infrastructure investment is presumably one such policy, on residential location. Although they do not include public infrastructure per se in their analysis, they do find that the level and quality of public services generally attract migrants, from which one can infer the positive link between infrastructure and household location. Obviously, given the large contribution of workers to output, as revealed in the production function estimates, more research needs to be conducted to look at the effect of transportation infrastructure on household location decisions.

Productivity Growth

Another source of regional growth is productivity growth. In this case, a region can expand output, even though the stock of inputs remains constant because of an increase in the ability of inputs to produce. This enhanced ability can be a result of new technological advances embodied in the capital stock and higher skill levels of workers. It also can come about because of increases in the size of plants and even in the size of the metropolitan area. In some industries, larger plants can produce goods at a lower unit cost, and if these so-called economies of scale increase in the region, then productivity also increases. The size of the metropolitan area also affects productivity by achieving a critical mass in which a variety of goods and services become readily available. [Eberts and McMillen (*24*) provide a review of the literature on the effect of metropolitan size on productivity.] Consequently, firms save transportation cost and time by being able to purchase locally instead of importing these inputs from outside the region.

Infrastructure Investment as a Tool to Manage Growth

In some high-growth regions of the country, the concern may not be how to stimulate growth but rather how to manage it more effectively. Policy makers in these areas may face issues of urban sprawl and the contribution of highway construction to the future outward growth of the metropolitan area. Or they may be figuring how an improvement in mass transit within the core city may encourage residents to move back to the center of the metro area, thus reducing sprawl. To analyze this issue, it would be important to examine factors that contribute to urban sprawl. For instance, it would be advantageous to understand the effect of transportation systems on commuter patterns, residential patterns, and business location behavior for specific areas. By understanding these components of regional growth, we can better understand the effect of transportation on regional growth. Yet, looking at regional growth in the aggregate would not give sufficient insight to policy makers as to which components of growth they might be able to influence through various policy instruments. How important is highway access for business location decisions relative to household decisions? These questions relate most directly to the internal sources of regional growth enumerated in a previous section. However, insights into these issues go beyond the typical treatment of internal growth and include topics such as the role of transportation infrastructure in influencing commuting patterns and the location of businesses.

Effect of Transportation Infrastructure on Regional Growth

With all these cases, the questions go beyond the direct economic benefits and costs of a specific project, as would typically be addressed by a benefit-cost analysis. Rather, the issue is the effect of transportation investment on various dimensions of a regional economy. The focus is not necessarily on a specific project but instead on a generic type of project, such as mass transit or rail freight transport, or simply the effect of an additional lane of interstate highway. Policy makers may or may not have a specific project in mind when asking these questions, but they want to know the effect of a type of project, such as mass transit. It is the broader scope of the questions with respect to the economy that separates this topic from the second of the three topics—economic evaluation for decision making on transportation projects, programs, and policies—addressed at this conference.

As shown in Figure 2, transportation investment can affect economic development in several ways. These effects can be divided into supply-side and demand-side influences. The supply-side effects refer to factors that can increase the amount of resources in an area or make existing resources more productive. In this role, transportation infrastructure can (*a*) contribute directly to output as an input in the production process; (*b*) augment other factors of production to allow them to operate more efficiently; and (*c*) attract mobile resources, such as business capital or households, from other areas.

The demand-side effects refer to factors that can increase the demand for a region's products primarily through expanding its market area. Access to efficient transportation can (*a*) lower the costs of a region's output, making it more competitive with the products of other regions; and as a result, (*b*) provide the stimulus for additional resources to enter the region. It is important to recognize that transportation infrastructure alone cannot stimulate growth or help to manage growth. An efficient transportation system, that is, one with minimal bottlenecks and congestion, is a necessary but not a sufficient condition for regional growth. Unless other factors are in place, a region will not grow, even though it may have an efficient transportation system. The previous description of the economic development process provides a basis for understanding the importance of the other determinants.

Other examples of public infrastructure as private but "unpaid" inputs include municipal water treatment facilities. If not provided publicly, firms would need to construct their own waste treatment plants, assuming firms would have an incentive to treat wastes, perhaps because of environmental protection standards set and enforced by government agencies.

Consequently, any firm entering a region that has constructed this infrastructure immediately benefits by initially earning profits or rents according to the value of the contribution of public capital to production. If local governments do not extract all the profits coming from public infrastructure through higher taxes, these profits will attract other firms into the area until the profits are dissipated as the infrastructure becomes used more fully.

Viewing public capital stock as another input into the production process raises an additional question about the effect of public investment on growth. So far, the discussion has concentrated on the effect of public capital stock (as an input) on the growth of output. But there is another dimension to considering public capital as an input, and that is how it relates to the other inputs. This relation is particularly important to regional growth, because growth is measured not only in output but also in terms of private investment and employment.

Two basic relations exist between inputs. First, inputs can be considered substitutes for each another. In this case, an increase in the amount of public capital may be considered by firms to provide the same services as private capital, so less of the private capital is demanded. An example would be water treatment facilities. If a local government provides the facilities, then private firms do not need to construct their own facilities. Consequently, less private investment would be observed in the area. The same relation could exist between public capital and labor.

The second possibility is that two inputs are complements. This means basically that one input cannot function without the other. The classic example is tires and automobiles. Automobiles cannot function properly without tires, and tires are not worth much unless they are attached to automobiles. In this case, an increase in one input would then induce an increase in the complementary input. One can extend this example to highways. Automobiles and highways are also complements in that automobiles are not as useful without an adequate highway system and a highway system would not be as valuable without automobiles.

How Well Do Existing Data and Tools Answer These Questions?

After the listing of possible questions that could be important to policy makers, the next issue is, how well do existing data and tools answer these questions? The short answer to this question is that analysis to date falls short of what generally can be used by state and local decision makers. There are several reasons for this shortcoming. One reason is that studies at the subnational level have not focused on specific regions when estimating the relation between transportation investment and the economy. Most studies have used specific state or metropolitan information as one of several observations to estimate the models. The result is an estimate of the effect of state- or metropolitan-level transportation investment in general on output, but these estimates per se do not provide insight into the effect of transportation investment within specific regions.

In order to derive estimates for a specific state or metropolitan area, we would have to approach the analysis in a different way. One way would be to collect observations on the specific state over a sufficiently long period of time. We would need enough observations or replications of a specific interaction between transportation investment and economic outcomes to derive precise estimates. A drawback of this approach is that the observations may extend back in time to a point in which the economy was sufficiently different or the transportation infrastructure was a different vintage. National-level analysis shows that the effect of highways on manufacturing productivity was considerably larger in the period from 1950 to 1970 than since 1970 (*4*).

Another approach would be to include in the production function or cost function estimation characteristics of transportation infrastructure and state economies. Characteristics such as the vintage and type of highway system within a state, the level of congestion, the pavement condition, and the type of vehicle usage may have an effect on the relation between highways and economic activity. Eberts (*25*), for example, included these measures and others to estimate production functions at the state level and found some significant effects.

Moreover, the characteristics of the state economy, such as its unemployment rate and other measures of resource utilization, its industrial composition, its degree of urbanization, and the stage of economic development (particularly for less developed regions), may influence how highways affect output. The effects of highways on the output of specific states then can be approximated by considering the characteristics of specific states and adjusting the estimates accordingly. Suppose that a state is characterized by high unemployment, low traffic congestion, poor pavement condition, and a low degree of urbanization. By including these characteristics, state decision makers can obtain estimates of the effect of transportation infrastructure on output that are more specific to their states.

Some researchers have argued that confining the estimation of production or cost functions to observations based on small geographical areas, such as counties or metropolitan areas, may reduce the ability of these estimation methods to capture the indirect benefits of transportation investment. Munnell (*6*), for one, has argued that the fact that state-level estimates of the effect of highways on productivity are smaller than national-level estimates is evidence that the state-level estimates are not capturing the externalities of networks and spillover effects of highways. Munnell's position is debatable. Furthermore, it may be possible to capture indirect effects by using measures of highways and other transportation systems that more directly measure the network effects.

Most production function and cost function estimates include measures of highways based upon the perpetual inventory method. This measure basically adds real expenditures on highways and subtracts off assumed depreciation rates. By accumulating expenditures over a sufficiently long period of time, one can measure the size of the capital stock. However, this approach has its shortcomings.[3] The measure does not include specific characteristics of that capital stock, such as functional type or condition. One possibility is to find alternative measures of highway capital stocks that measure network effects more directly. A measure explored by Eberts et al. (*27*) is to compare the number of miles between origin and destination that goods are actually transported with the shortest possible distance between the two points (i.e., as the crow flies). According to this metric, a highway network would be considered more efficient as the gap between the actual distance and the shortest possible distance narrows.

Factors such as highway speed and congestion also could be incorporated into the perpetual inventory method. Fernald (*14*) measures congestion as the ratio of miles driven by trucks, automobiles, and other motor vehicles to road stock (constructed using the perpetual inventory method). He shows that congestion measured in this way reduces productivity after 1973. Potentially better measures of congestion and service flow of highways are available from the Highway Performance Monitoring System (HPMS) data. Dalenberg and Eberts (*28*) have proposed a hybrid method of constructing highway capital stock that integrates highway characteristics into the perpetual inventory method.

Spatial Correspondence

Another level of criticism against current research practices is the lack of spatial correspondence between the location of transportation infrastructure and the establishments using the infrastructure. Transportation in-frastructure—roads, highways, rail—is location specific. Businesses benefit from their proximity to highways, which provide access to local suppliers and customers and to the wider national network of highways. National-level, and even state-level, estimates do not provide precise geographical linkages between infrastructure facilities and business activities. For national-level estimates, it is typically assumed that the entire highway system affects national productivity. This assumption may be defensible at this broad level of aggregation in which all economic activity in the country is related to all the stock of public capital. One also can argue that the national-level measure of highways captures the system or network effect of the highway system. However, even if estimates based on national-level studies were credible, they are not very informative from a policy perspective.[4] Highway investment takes place on a project-by-project basis. State decision makers want to know how their investment will affect the economic health of their state.

The lack of spatial correspondence between highways and businesses within national-level studies becomes more problematic when individual industries are considered. The problem is that some industries are concentrated in specific parts of the country, such as primary metal production or transportation equipment in the Great Lakes states. Therefore, national-level studies implicitly assume that highways in large states such as California and New York are as important to establishments located in Indiana or Rhode Island as they are to establishments located in those two states. Fernald (*14*) suggests that estimation bias due to differences in the location of manufacturing firms vis-à-vis highways could be substantial.

State-level estimates typically have the opposite problem. Most studies regress a state's productivity measure against its level of highway capital stock. Consequently, only the highway stock within the state is assumed to affect the state's output, which ignores the effect of the entire highway network, comprised of the highway stock in neighboring states and along major corridors, on business activity. Therefore, it is important to establish the spatial linkage between the business and the highway system it uses. Unfortunately, few studies have been able to make this correspondence. Eberts (*25*) finds that including capital stock from other states, which firms within a given state ship to, changes the estimates of the effect of highway capital stock on output.

Measures of Highway Utilization

Another issue that has not been satisfactorily treated in the literature is the utilization of highways. Since capital stock is fixed, at least in the short run, businesses do not have the capability of adjusting the quantity of capital in response to short-run changes in demand for highway services. Therefore, while the quantity of highway capital may remain unchanged, businesses may use their fixed stock with different levels of intensity. To account for the variation in private capital utilization over time and across plants, researchers typically include a variable in the production function that proxies the utilization rate. Yet, researchers have not typically included a variable that accounts for the difference in utilization of highways. Fernald (*14*) uses the share of vehicles owned by industry to account for utilization. However, this approach appears to be incomplete because most shipments by manufacturing firms are by trucks for hire.

Highway utilization takes two forms. The first is similar to the utilization of private capital. As product demand fluctuates in the short run, the firm's use of highway capital may fluctuate along with its use of private capital. In this case, the same variable used to adjust private capital stock for differences in use could be used to adjust highway capital stock. The second form of highway utilization is different, and it is not captured by the variable measuring fluctuations in product demand. Businesses in different industries and in different parts of the country use highways with different intensity. For example, in Illinois, businesses in the food and kindred products industry ship 64 percent of their output by trucks, whereas establishments in the chemical industry ship 83 percent of their products by truck. Similar differences in the use of trucks are found regionally. For example, 60 percent of the commodities originating within Illinois are shipped by trucks, while 77 percent of the commodities originating within Michigan are shipped by trucks. Therefore, since businesses within industries and states use highways with different levels of intensity, treating highway capital stock the same across industries and states would misrepresent its contribution to economic activity.

How Do We Improve the Data to Answer Key Questions?

The final issue is how to improve the data to answer key questions, keeping in mind the possible development of new and improved tools and methodologies.

Better Measures of Transportation Systems and Outputs

Most studies of the effects of transportation infrastructure on the economic health of a region use a blunt instrument when it comes to measuring transportation capital stock. As previously mentioned, the perpetual inventory approach has been the primary measure of transportation capital stock. This measure is inadequate for the more detailed questions that policy makers seek to answer. As suggested in the previous section, better measures would include more specific and detailed information about the transportation system. For highways, we would benefit from measures such as those that are included in the Highway Performance Monitoring System (HPMS). These measures include many of the system characteristics and facility outputs that were listed in the previous section on performance assessment. In order to use data such as appear in the HPMS, they must be recorded for several years and not simply updated as is the current practice. Thus, production and cost functions could be estimated using both cross-section variation in these data as they relate to regional output and time-series variation.

Another data need is to find better measures of the network effects of highway infrastructure. As mentioned several times, one of the basic differences between the production/cost function approach and the benefit/cost methodology for measuring benefits is the possibility that the former includes indirect benefits, which may be significant for transportation systems. Direct measures of network effects could include the ratio of actual to shortest distance traveled, as previously described. Another possibility is simply to consider the number of lane miles per square mile.

More emphasis should be placed on measuring the outputs of highway facilities. As presented in an earlier section, such measures include the service flow and reliability of highways. Considering this intermediate step between highway facilities and economic health helps to appreciate the characteristics and efficiency of the highway system and their effects on output. For instance, many businesses depend upon just-in-time delivery. For this type of operation to work, shipments must arrive consistently within a narrow window of time so that the material is at the plant when it is needed in the production process. There is no advantage in the product arriving early, but a great cost if it arrives late. Therefore, businesses are more concerned that shipments are not delayed due to bottlenecks on the highways than they are about the speed of delivery. Measures such as the variance of travel time should be included as a characteristic of the highway facility.[5]

A key factor missing in all production functions and most cost functions is a measure of the cost of providing transportation infrastructure. As previously mentioned, one benefit of infrastructure is as an unpaid factor of production. However, highway infrastructure is directly financed by a user tax (fuel tax) that is fairly closely related to the use of highways. In this way, it approximates the cost of using highways. Production functions typically contain no cost or price information, except in special cases in which factor demand equations are included as a second stage of estimation [see Eberts et al. (27), for example]. Cost functions include prices or inputs, but not the tax rates or other measures of financing infrastructure. If one is only considering the technical relationships between transportation infrastructure and output and other inputs, then a production function is appropriate and other prices are not important, except to address econometric issues of endogeneity. However, if one is considering the rate of return of highway infrastructure using a cost function, then omitting the cost of infrastructure may bias the estimates.

Another untapped source of information about highway facilities is geographic information systems (GIS). As these systems become more fully developed and maintained, they offer a wealth of information about the location, size, and condition of highway systems. Moreover, they also can provide information about the proximity of existing economic entities and other outcome measures to highways. This spatial correspondence would help address the issues regarding the current lack of this information and the omission of such variables in production function frameworks, except for some recent work.

More Comprehensive Measures of Outcomes

The relatively crude measures of highway capital stock, and other transportation systems, used in much of the recent literature is not the only problem with estimating the effect of transportation on economic health. It was not possible to deal with many of these issues until recently with the availability of the 1992 Commodity Flow Survey (CFS) (the first published survey since 1978) and access to individual manufacturing establishment data through the Census Bureau's Longitudinal Research Datafile (LRD). An ongoing project by Eberts et al. (27) uses both data sources. Furthermore, access to establishment-level data from both the LRD and the CFS offers the unique opportunity to combine the CFS with the individual establishment data. This matched data set provides the ability to track where and by what mode each establishment ships its products. This new data source opens the possibility of systematically addressing issues pertaining to spatial correspondence, the level of aggregation, the use of highways, causation, and the sufficient number of "natural experiments."

Another source of information on individual establishments is the state ES202 data. These data are compiled by state employment security offices to aid in administering the unemployment insurance program. They include information about employment for each establishment within the state that is included in the unemployment insurance system. These data are collected on a quarterly basis, which offers a large number of observations on individual establishments over a relatively short time period. The files also include total payroll expenditures for each establishment. Unfortunately, the files do not contain information on output or inputs other than labor. Nonetheless, by compiling the quarterly data into a longitudinal data set, we can track the employment dynamics by establishment.

Considerable emphasis has been placed on measures of economic outcomes of transportation systems, such as production output, employment change, and per-capita income. As mentioned previously, stakeholders also are concerned about other types of outcomes, such as land use patterns, environmental quality, and overall quality of life. However, little research has been devoted to the linkage between transportation and these outcomes, particularly exploring how they fit into a broader view of regional growth. Some work has been done on the environmental effects, such as noise pollution, of airports. More spatially specific data on environmental quality needs to be collected so that a closer relation can be drawn between the location of particular transportation systems and the quality of the local environment. Furthermore, regional models must be expanded to include the broader scope of outcomes.

Regional Growth Models

In addition to finding sources of better data, we also can improve our analytical capabilities by developing more complete models of regional growth. Production and cost functions typically do not include variables other than those that are related to technical and allocative relationships between inputs and outputs. The starting point for these studies is the firm, and states and metropolitan areas are considered simply as firms aggregated to those levels. Other characteristics of these areas seldom are included, except to adjust for capacity utilization or in the form of fixed effects estimation. Duffy-Deno and Eberts (*29*) extended the production function approach in a simple way by including in a two-stage regression determinants of public infrastructure investment, since it is unclear whether infrastructure determines output (and thus income) or income determines infrastructure investment. Including this additional equation reduced the estimate of the effect of infrastructure on output. Mehta et al. (*30*) construct a more comprehensive model of regional growth that includes explicit equations for growth rates of input and population. Within this framework, they find that investment in highways and streets is positively associated with per-capita income growth. Most other types of public infrastructure are found not to be statistically significantly related to output.

More work needs to be devoted to developing regional growth models and to incorporating more detailed measures of transportation infrastructure into the models. One suggestion has been to use large regional econometric models to estimate the effects. However, these models do not estimate relationship but only use estimated relations from other studies. Without reliable estimates of the relation, econometric models are not useful. It would be beneficial if research could be conducted to establish reliable estimates of key relations between different types of transportation systems and various outcomes that could be included in econometric models. This would be an ambitious project, and one of the keys to success would be whether these models would pertain to infrastructure investment within different economic environments.

Data Collection

Maintaining high-quality, quantifiable measures of transportation systems, their output, and outcomes requires the continuing commitment of appropriate agencies. Commitment to data collection and commitment to performance assessment are inextricable. One cannot exist without the other. Nevertheless, going beyond simply recording facility outputs and beginning to understand the broader outcomes of infrastructure investment require close cooperation among several agencies at different levels. Transportation infrastructure is a system with extensive networks of facilities, both within specific modes and across modes. The labyrinth of highways is useful only because the many segments are connected. Yet, for an efficient system, vehicular, rail, water, and air transportation systems must interconnect. Therefore, in order to undertake performance within this system and to collect relevant and useful information, agencies at the local, state, and federal levels need to coordinate their efforts in collecting data and in performing assessments. (It is apparent from this conference and other initiatives that the Bureau of Transportation Statistics is one entity that is assuming this role.)

The necessary collaboration goes beyond transportation agencies. Although many of the decision makers in the transportation arena are associated with transportation departments, the stakeholders in the outcomes of transportation investment extend beyond their offices. Stakeholders include economic development entities at the state and local levels, environmental protection agencies, land-use planning departments, to include a few. Some of these entities collect data that can be helpful in piecing together the linkages between transportation systems and outcomes. Greater effort needs to spent on finding ways to bring these groups together to share resources and to share the motivation to properly assess the performance of transportation systems. Broad initiatives are underway in other areas of government to collaborate in the sharing of information. The devolution of government services to state and local governments, particularly in the welfare and employment service areas, has prompted government agencies in some states to coordinate their data collection efforts. The same collaborative efforts could be pursued for transportation-related agencies.

Summary and Proposed Research Statements

Research on the linkage between transportation systems and economic health leads to the conclusion that transportation systems in general have a positive and statistically significant but small effect on several economic outcomes. The glaring deficiencies in the research are the lack of a deeper understanding of the avenues by which these linkages occur and a more comprehensive investigation of the effect of transportation on a broader scope of outcomes. As highways become more mature and the economy more developed, stakeholders who value and advocate outcomes, such as smart management of growth, job creation, quality of life, or environment quality, will demand that these outcomes be closely scrutinized and promoted when investing in new infrastructure projects. Knowledge of these linkages will be more than a way to justify new expansion. Proper and accurate assessment may be crucial for stakeholders to permit future investment to take place.

Expanded Measures of Transportation Systems

Description of Research Problem

Transportation systems have been constructed primarily using the perpetual inventory method and crude physical characteristics, such as lane miles of highways. These measures do not capture system utilization; output of transportation systems including traffic flow, reliability, safety, and volume; and characteristics of transportation systems including lane miles, grades, and functional types. Such measures are fundamental for estimating the relation between transportation systems and economic health that can be used by state and local decision makers. Omitting these characteristics from highway capital stock measures and from the analysis could lead to significant biases in the estimation of the effect of highways on economic activity. The lack of these measures also precludes state analysts from obtaining estimates specific to their states.

Work To Be Performed

This initiative proposes to improve the measures of transportation systems that typically are used in estimating the effect of transportation on economic outcomes. Highway stock estimates that incorporate these elements and that are consistent with the relationship among system characteristics, outputs, and outcomes will be pursued. This effort will be comprehensive in that it includes the several major types of transportation systems, including highways, rail, air, and water shipping. All efforts will be made to collect data so that they can identify facilities at specific locations (such as highway corridors) and so that they can be aggregated to various levels depending upon need. GIS will be explored as a means to organize this information. The primary product of this research is measures of highway capital stock at the state and local levels that incorporate the characteristics of that capital stock in those areas.

Cost Estimate: $750,000

Expanded Measures of Outcomes

Description of Research Problem

Most studies of the linkage between transportation and outcomes focus on a narrow range of economic outcomes, such as output or employment, and rarely include other types of outcomes, such as environmental quality and land-use configurations. A more complete list of outcomes is needed in order to offer greater insight into the various channels through which transportation systems affect economic health.

Work To Be Performed

This research initiative expands and improves the measures of outcomes from transportation systems. With respect to economic development, measures will include both the final outcomes such as per-capita income and the intermediate factors such as employment, private capital, and materials. Transportation costs also are included since one of the direct effects of transportation systems is the cost of shipping goods and of commuting by households. With respect to environmental quality and overall quality of life, measures such as air and noise pollution and land-use patterns are considered. Housing and land prices also are included since access to transportation systems affects land values. As with highway system characteristics data, these measures will be identified by location so that the two databases can be matched. Particular emphasis is placed on collecting establishment-level data that can be obtained from the Census Bureau's LRD and from state ES202 files. These data then are merged with the transportation systems data so that spatial correspondence between the users of transportation systems and the outcomes of businesses that use these systems can be established.

Cost Estimate: $600,000

Linking Commodity Flow Data to Establishment-Level Data To Measure Transportation System Utilization

Description of Research Problem

The primary purpose of transportation systems is to move goods and people. However, studies of the effect of transportation systems on economic activity have not taken into account the movement of goods. For example, with few exceptions, it is assumed that all highways are used with the same level of intensity, which is def-initely not the case. From a business perspective, the value of highways or rail depends upon the destination of shipments. The CFS shows that manufacturing establishments at the individual level and aggregated within broad industry classifications use highways with different levels of intensity. Thus, productivity estimates depend upon the extent to which businesses use highways.

Work To Be Performed

This project will build off of a study already begun at the Center for Economic Studies, Census Bureau, that has started to construct information that shows where and by what mode establishments ship goods. This is accomplished by merging the microfiles of the 1992 CFS with the establishment-level records of the Census Bureau's LRD files. In this way, information about commodity flows is linked to business outcomes (such as employment change, output growth, and productivity growth). The proposed research will extend this effort to more recent data as well as establish historical files so that estimates of the relation between systems and outcomes can be measured more precisely. To date, the focus of the project has been on highways. This effort also will be extended to other modes of transportation.

Cost Estimate: $700,000

Establishing Working Collaboration Among Agencies To Maintain and Improve Integrated Data Collection Efforts

Description of Research Problem

The ability to collect data on the characteristics and outputs of transportation systems and their related outcomes depends upon coordination among agencies to collect comprehensive and reliable data. It also depends upon the proper incentives and adequate resources to collect those data. Most transportation agencies collect information about the characteristics of the systems under their management. Most agencies also collect some information about the output of the systems, although in many cases more quantifiable measures would be desirable. However, more effort needs to be made to link the transportation agencies to organizations that represent the stakeholders of the outcomes of transportation systems. These organizations include economic development agencies, land-use planning departments, and environmental quality agencies.

Work To Be Performed

This initiative provides the motivation and some of the resources necessary to nurture the collaboration of agencies in collecting data that can link system characteristics with outcomes. Activities include forums to bring the various groups together to emphasize the benefits of such collaboration and training workshops to provide the hardware and software platforms that can combine the various data files. The activities will be patterned after similar efforts that have been started in other program areas such as welfare and employment services. This effort will provide for a more comprehensive assessment of the performance of transportation systems and thus help decision makers make investment decisions that take into account the broader outcomes of transportation systems.

Cost Estimate: $250,000

Acknowledgment

The suggestions and comments of David Forkenbrock are gratefully acknowledged.

Notes

1. Forkenbrock et al. (*17*) present a comprehensive and accessible description of the various channels through which highway investments may affect economic development. This book is particularly geared toward state and local transportation practitioners and policy makers.

2. Bartik (*18*) points out that under certain conditions, competition among states (or other jurisdictions) can lead to economy-wide benefits, primarily if the reallocation of resources goes from low-unemployment to high-unemployment areas.

3. The shortcomings of the perpetual inventory method go beyond the problems listed here. The basic assumptions regarding depreciation and discard schedules and price indexes also are questionable. Fraumeni (*26*) recently critically reviewed these assumptions and offered improved estimates based on actual highway depreciation data. She noted that public capital stock estimates from the Bureau of Economic Analysis are designed to measure the nation's wealth and should not be used in productivity studies. It is more appropriate to measure capital stock in efficiency adjusted units to reflect the decline in the productive services of an asset as it ages. Several studies, particularly at the national level, have made the mistake of using the wealth method. Fernald (*14*) uses the wealth method but states that using highway stock based on the efficiency method did not alter his results significantly. For researchers using an efficiency factor of 0.9 to construct highway capital stock, Fraumeni offers some comfort to researchers who used this depreciation assumption. She found that this assumption was a reasonably good approximation of the depreciation function that she estimated. However, her study focused only on national-level estimates and did not offer any additional insights into how these depreciation functions might vary across states or how differences in construction costs across regions may affect the capital stock estimates.

4. Furthermore, in order for national-level estimates to yield precise estimates, they rely on historical data. Therefore, since the relation between investment and output changes over time, most national-level studies do not provide estimates of current relations.

5. The importance of the reliability of highways and the measure of the variance of travel time was suggested to me by David Forkenbrock.

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RESOURCE PAPER

Selecting Public Transportation Projects: Informational Requirements

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In the early days of development of our country's transportation infrastructure, the public sector was not as involved in transportation system development as it is today. Landowners and developers not only performed most local street and road development, but they also played important roles in developing regional and interregional facilities. These facilities included most of the first toll roads, turnpikes, and canals of our nation and, later, urban streetcar and bus systems.

Government was not completely uninvolved, of course. Government provided financial assistance to private transportation initiatives through land grants and postal contracts, for example. Government's aim was to encourage settlement, thereby providing access to natural resources and military advantage and stimulating economic activity. Nevertheless, to an important extent, the project selection process was in the hands of the private sector and was guided significantly by commercial motives.

With the development of the postal road network early in the 20th century, however, the transition toward public development of the transportation infrastructure accelerated. In the highway arena, road finance evolved away from toll-oriented systems to a reliance on broad-based tax levies, first on property, then on the sale of motor fuel. In the transit area, private bus and rail transit systems were acquired by the public sector and financed, increasingly, out of broad-based taxes rather than fare box revenues. Similarly, airports and sea- and river-port facilities came into public hands or were developed as public enterprises. Increased public ownership meant that investor scrutiny and the discipline of the marketplace no longer operated to guide (however well or poorly) the path of transportation development.

This paper is about the transportation planning process—the public-sector analog to the investment decision-making process of the private sector. The paper, prepared for this conference, is one of three papers whose purpose is to identify the looming informational deficits in measuring the impact of transportation on regional economic health, in estimating the revenues available to finance transportation system development and operation, and in evaluating transportation alternatives.

This paper examines the informational requirements of the transportation decision process. The process is viewed as a hierarchy of policies, programs, and projects. The paper first describes how transportation economists believe the decision process should function, identifying the analytic steps and key informational requirements of the process. It then goes on to identify key deficits in the informational resources that are available to decision makers and provides draft research statements in key areas.

The information resources available to transportation economists have improved significantly since the passage of the Intermodal Surface Transportation Efficiency Act of 1991 and its authorization of the Bureau of Transportation Statistics (BTS). The American Travel Survey and the Nationwide Personal Transportation Survey have improved information on both interregional and urban personal transportation. Information on freight transportation has improved with the Commodity Flow Surveys conducted in 1993 and 1997 and the Truck Inventory and Use Survey.

Although the recently enacted Transportation Efficiency Act for the 21st Century promises to expand the data development and publication activities of the BTS, important gaps remain in the available information on travel behavior and conditions, and they are likely to remain without special effort. The conference offers an opportunity to discuss with policy makers the fundamental goals of transportation planning and implementation and to draw policy makers' attention to the types and sources of data that are needed to improve transportation decision making.

The Transportation Decision Hierarchy

The transportation decision-making process is typically portrayed as a top-down process, evolving from policy, to program, and, finally, to project evaluation and selection, as depicted in Figure 1. The policy articulates the general aim of planning, the program marshals the resources to implement planning these aims, and the project selection methodology moves the process toward concrete action and implementation. At every stage, information (data and analysis) plays a role, as do political and social considerations. Although there are more detailed ways to characterize the process [see, for example, Nijkamp (*1*)], Figure 1 captures the basic decision hierarchy of transportation planning.

The conceptual advantage of following a decision hierarchy rigorously is that there is an expeditious direction of effort, with rapid winnowing of alternatives. Programs and projects that are incompatible with the policy of objectives are, theoretically, shed early so that valuable time is not wasted evaluating projects that are policy dead ends. There should be greater economy and effectiveness in the final implementation process if it is guided by policy, nurtured by programs, and scrupulous in evaluating alternative projects.

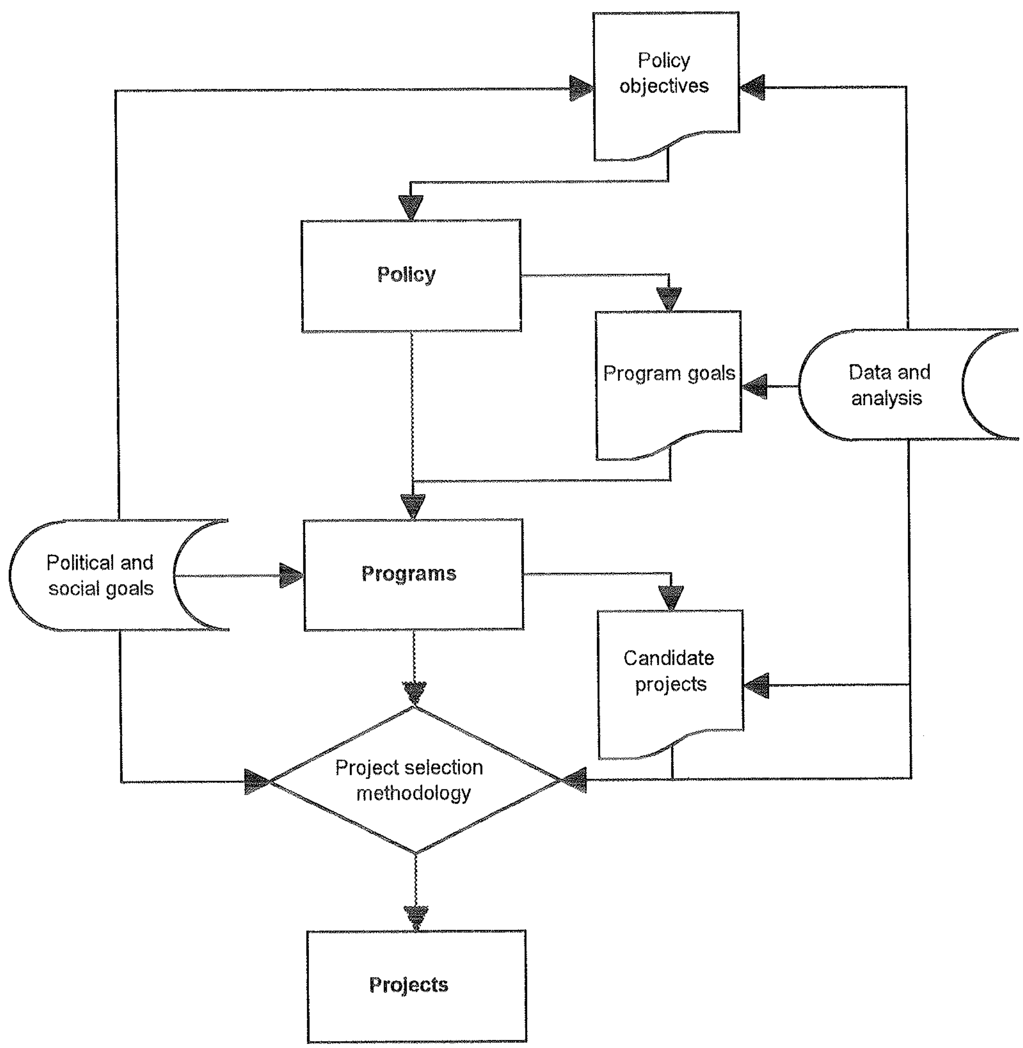

FIGURE 1 Schematic of the policy-program-project hierarchy.

Although most transportation planners probably subscribe to such a planning hierarchy in concept, the reality of transportation decision making is quite different. Optimizing transportation practice in all of these dimensions is difficult in the real world; at the project level alone, the location, scale, timing, and manner in which transportation improvements are implemented all can affect the effectiveness of the improvements, so that the potential menu of alternatives can be very large. Further complicating matters is the fact that policy makers live in a world in which purely technocratic decision making is rare. Considerations of equity, public acceptance, economic development concerns, and a variety of other practical constraints circumscribe the policy initiatives, program choices, and project menus of policy makers.

This phenomenon is observed even in Scandinavian countries, with a long tradition of technocratic planning. As Nyborg discovered in her recent survey (*2*), Scandinavian decision makers, too, tend to be guided by the transportation planning process in only a loose way, particularly at the level of project selection. Given the budgets involved and the risks associated with bad decisions, the weak role that formal project evaluation, in particular, plays in the decision-making process might be seen as anomalous. But the reality is that the planning process frequently is incompatible with the reward system and time horizons that decision makers face. In addition, and more relevant to the substance of this conference, there are areas of research that are not sufficiently well developed to support comprehensive transportation planning.

We turn first to the issues and informational challenges of the first two steps of the planning hierarchy: policy planning and program design.

Policy Planning and Program Design

Gaps in knowledge that exist at the policy level will necessarily propagate to program design and the identification and selection of programs. At the policy level, decisions are made about the objectives of the transportation system management. In order to articulate policy objectives and to design programs (and, ultimately, projects) to carry them out, there has to be general agreement about the evaluative principles that should guide policy making.

Transportation economists, for example, might argue that good policy in the transportation sector would have the same basic objectives as good economic policy in general:

- It would allocate scarce resources to transportation systems and services so as maximize the community's overall economic well-being. (Economists would call this an efficiency objective.)
- It would allocate cost responsibility so that those who benefit the most from transportation improvements, or impose the greatest costs on others, pay accordingly. (This is an objective that has both efficiency and equity implications.)

Given these policy objectives, program design then would be oriented toward identifying and screening high-productivity project alternatives and developing methodologies for measuring and assigning cost responsibility.

These notions are probably not too far from what most policy makers would articulate if asked how planning should be done. However, real-world decision processes frequently shortcut the project screening process, and institutional considerations and political goals often impose multiple (and sometimes conflicting) constraints on decision processes. Typical confounding forces that transportation decision makers face, for example, include the following:

- *Constitutional and legislative constraints.* Transportation funds often are earmarked or restricted in use. [California distributes highway funds, for example, using a complex, legislated revenue-allocation formula (*3*).]
- *Income redistribution goals.* Transportation policy often is used as a way to beneficially affect the cost of living of elderly, low-income, and student households. (Transit fare policy is one case in point.)
- *Financing considerations.* Broad-based taxes typically have greater political appeal than selective, user-based finance. (Since 1913, most U.S. roads have been financed with gasoline and general tax revenues, rather than tolls, for example.)
- *Status quo considerations.* It often is easier politically to build new facilities than to implement demand management of existing facilities.
- *Power barriers and power vacuums.* Decision-making authority often is not effectively placed.
- *Social planning objectives for transportation.* Transportation policy often is intertwined with policies toward land use, economic development and urban renewal, the disabled, organized labor, and so forth.

It is difficult to design effective programs, let alone select productive projects, if the objectives of the planning process are ill defined or conflicting. If the overarching policy basis of transportation cannot be clearly articulated, the process can become contentious, as individual actors in the process implicitly (or explicitly) assert their own policy interests. This, in turn, leads to conflict, delay, or deadlock downstream over particular program and project initiatives.

It is possible, of course, that the policy-program-project paradigm imposes an unnecessarily laborious framework on the transportation decision process. Might it be better, and ultimately more efficient, to invent and implement new projects one at a time, and not bog decision processes down with policy objectives, program planning, and other process overhead?

Examples of Policy and Program Dissonance and Its Effects

The state of the U.S. transportation system suggests otherwise, at least superficially. The project-first paradigm that has dominated U.S. transportation planning has not yielded a public transportation infrastructure that is either financially sound or efficiently configured. Most state departments of transportation (DOTs) report serious project backlogs, and the performance of urban interstates and arterials has continued to deteriorate in the past 5 years (*4*). The condition of public transit vehicles also worsened, as did transit's share of total trips. And while the private sector of the economy is booming, DOTs and transit agencies are almost uniformly financially weak. This at least implies that the projects and policies that have been yielded up by the existing transportation decision process fall short.

Closer inspection of transportation decisions and their outcomes in recent years supports this inference. The importance of building policy before projects, for example, is illustrated by the challenges that arose in the 1970s. In the 1970s, it was still common practice to include new highway routes in state and local transportation plans without first considering the rationale of the improvements. Indeed, for all practical purposes, transportation planning documents did not articulate transportation policy objectives; rather, they were blueprints for the road project developments of state and local jurisdictions. In essence, projects were leading road policy.

In the 1970s, citizens in many jurisdictions reacted to their sense that transportation system development was guiding economic and social development, rather than the other way around. In California, for example, this dissonance resulted in a rapid about-face concerning highway policy. In the mid-1970s, California state transportation policy was discernibly anti-road building, after decades of being proudly development oriented.

The lurch from pro- to anti-road sentiment that occurred in California and other states during this time undoubtedly had efficiency effects. Beneficial road projects suffered along with weak projects while road building was sidelined, and much-needed reform of highway finance was delayed. In my view, many jurisdictions still suffer from uncertainty about what compass to follow in defining, selecting, and implementing highway improvements.

Transit development is another area in which the consequences of the project-before-policy phenomenon have been apparent. In the 1970s and 1980s, many jurisdictions hastened to implement transit system improvements as alternatives to road development. I think it is fair to say that the enthusiasm for the capital-intense transit system development, in particular, was not the consequence of a considered transportation decision process. Transportation policy and program evaluation did not endogenously yield up most transit project proposals. Rather, the prevailing anti-road sentiment, the inducements of full or partial federal financing of certain types of transit improvements, and the public-works opportunities that such projects represented caused transit projects to appear in regional project agendas. Transit programs and policies were largely articulated after the fact; specific projects were the lodestars, and seldom even subject to comparisons with alternative projects. Because of funding compartmentalization, transit program spending and road program spending were typically not coordinated.

The ex-post review of the track record of transit investment suggests that something may have been lost in the departure from policy-directed decision making. Some analyses of the track record of the large transit investments in the past 20 years suggest that they were not particularly effective investments (*5,6*). These analyses are, understandably, disputed by transit developers and transit management. Resolving this debate is not our purpose here; rather, it certainly would not be surprising to learn that transit investments had low productivity if they were made by a process that did not have clearly articulated policy objectives.

Nor is the United States unique in having had a project-led transportation decision process yield up projects of debatable economic value. Similar decision processes, with similar consequences, have been observed in many other settings. A recent example is Spain's decision to embark on a high-speed rail program; though widely touted by transportation officials as a success, it apparently fails to generate benefits in excess of costs (*7*).

There has been considerable progress since the 1970s in establishing guiding policy principles as an element of the transportation planning process. In 1975, for example, California's State Transportation Board (an oversight body) urged the secretary of business and transportation to articulate its policy before the board would consider the project plan. The *California Transportation Plan* (and associated *Issue Papers*) that was published in 1977/78 presented the first fully developed articulation in a state plan of a state's role in transportation and the objectives and justifications for its policies (*8*).

Today, most state transportation plans have policy plan elements. However, like the original *California Transportation Plan* of 1977, there is a question of whether the existence of these documents has changed decision processes in a significant way. State transportation policy elements are much more coherent, and many modern plans (such as Oregon's) are built around reasonably good economic foundations. In addition, federal funding processes impose certain requirements for considering alternatives, measuring effectiveness, and so on. But the connection between policy plan goals and principles and implementation is still weak. It is still the case that transportation policy is largely project led.

Implications for the Role of Transportation Information Systems

In my view, there are two reasons for this state of affairs. First, political support for technical decision processes, in general, is weak. The performance of elected officials often is measured by their ability to garner projects and services for their constituents. Decision makers naturally prefer processes, therefore, that have some chance of being responsive to their individual efforts. The notion of identifying a project and advancing it in the planning process fits nicely into the real life of elected officials; the notion of overseeing a technically rigorous decision process does not. The importance and means of resolving this issue, however, is a matter for political science, and outside the realm of this paper.

Secondly, and more germane to the subject of the conference, there is not good information on the economic implications of broad policy alternatives, with the result that transportation policies and program orientations seldom are scrutinized critically:

- Is the conventional reliance on broad-based taxes for highway and transportation finance appropriate, or should there be increased reliance on user charges?
- What are the consequences of our failure (in many cases) to employ cost-benefit analysis as a guiding principle in transportation decision making?
- Is public ownership of transportation facilities necessary to achieve the appropriate ends of public policy?
- What are the economic consequences of selecting the wrong project or of emphasizing the wrong program?
- Is decision-making authority located at the appropriate levels of public authority?

Theorization and modeling help to understand the advantages and disadvantages of alternative policy stances and program structures to a certain degree. In the end, however, policy analysis must be made rigorous if established decision processes are to be disrupted in the name of improving the quality of planning outcomes. For that, information on actual transportation conditions and behavior is required.

Project Evaluation and Selection

As argued above, the purpose of the first two steps of the planning hierarchy (policy and program planning) is to identify candidate projects to be evaluated and considered for implementation. Though these benefit from better information in the same way that all policy research and program formulation benefit from good information, these steps are fundamentally process-oriented steps whose purpose is to ensure that all reasonable candidate projects with the potential to fulfill the policy objectives have been identified.

The last step of the planning hierarchy, project evaluation and selection, however, is a highly technical process with significant informational requirements. In this section, we will review the basic procedures for evaluating programs and projects and identify the basic types of methodological and data considerations needed to implement the procedures. The discussion will introduce the economic analysis framework to evaluating programs and projects. We will discuss, in particular, the fundamentals of benefit-cost analysis and how the process operates under (variously) unconstrained, fixed, or uncertain program budgets. Also discussed is how program and project prioritization is affected by the choice of policy objective. Later, we will discuss critical information and analysis needs and formulate research statements.

Economic Basis of Project Evaluation

The need to make decisions about which project or business venture to pursue is neither new nor confined to the public sector, let alone the transportation sector. The resources available to commit to new ventures have been, and always will be, limited. Project selection methodology is needed to make the best use of the limited resources.

Early business and government decision makers understood that the process involved weighing the pros and cons of alternatives. The economist Edward Gramlich once noted, for example, that even Benjamin Franklin employed what he called "prudential algebra" to organize his thinking about the pros and cons of alternative business opportunities. But early thinkers had only the most rudimentary understanding of how to implement "prudential algebra," and they were stymied by how to make decisions when some people were made better off, and some worse off, by a decision. Vilfredo Pareto, in the 1800s, offered the notion that a decision was clearly good for society if it made at least one person better off without impairing the well-being of others. This "Pareto principle" is not much help, though, in the real world where most projects create both winners and losers.

In the 1930s, two economists offered the more useful prescription that a project was worth doing if its benefits exceeded its costs and the winners could (at least conceptually) compensate the losers (*9,10*). This principle, called the Hicks-Kaldor principle after its authors, has evolved over time into the formal field of cost-benefit analysis. Cost-benefit analysis is very simple in principle: simply estimate the costs and estimate the benefits of each candidate project. Those projects for which benefits exceed costs, in the Hicks-Kaldor sense, are worth doing, and those that do not, are not.

Conceptual simplicity quickly gives way to technical complexity, however, when one attempts to practice cost-benefit analysis in the real world:

- How do you measure the benefits of something that does not yet exist, especially when it interacts in a complex way with other products or services?
- What do you do if some benefits or costs are not susceptible, at all, to measurement? What if the saving or loss of human life potentially is involved?
- What if the benefits and/or costs play out over a period of time? How should these delays be incorporated in the analysis?
- What if there is uncertainty about the measurements?
- What if many projects have positive net benefits, but budgets are limited? Which projects should be selected for implementation?
- What if a project has negative net benefits but is particularly effective at helping a targeted or protected class of user (such as the poor)?

Economists have developed at least partial answers to each of these questions. Much of the challenge in applying cost-benefit analysis in the transportation arena, however, arises from the fact that providing good answers in almost all cases requires specialized information and analysis techniques, most of which are only partially developed.

The discussion that follows summarizes the major elements of cost-benefit analysis. In the process, it tries to evoke the informational and analytical needs of the project selection process. Several of the most important of these needs will be discussed in detail in a later section of this paper, along with draft research statements designed to address these needs.

Measuring Transportation Benefits of Users

The benefits (and costs) of a transportation improvement redound to either users or nonusers. That is, they are enjoyed either by those who directly use the facility or service or by those who are affected in some indirect manner. A new road, for example, clearly benefits those who use the facility itself (users). However, if the new road reduces air pollution (say, because of reduced stop-and-go driving), it also may benefit nonusers (anyone who breathes the affected air). Of course, benefits can be positive or negative, and a negative benefit is the same as a cost in the cost-benefit framework.

Let us look at user benefits first. The measurement of user benefits might seem to be hopelessly complex; after all, by definition the project does not yet exist. What is there to measure? The answer is that all we need to do is characterize users' aggregate willingness to pay for transportation services at various quantities of those services. The willingness-to-pay relationship for, say, trips between A and B is a schedule of the aggregate quantity of those trips that the users would be willing to make at various levels of cost per trip. (Economists call the willingness-to-pay relationship the demand relationship.) The difference between what users (in the aggregate) would have been willing to pay and what they are asked to pay is called consumer surplus. When a transportation improvement reduces the users' cost of a trip between A and B, the willingness to pay remains the same, but since users' perceived cost of travel is less, consumer surplus will increase. Users who already were making the trip get to make the trip at a lower cost, and new users (those for whom the willingness to pay was less than the old cost of the trip) are induced to travel.

This leads to a simple way to calculate the benefits of the improvement: subtract the consumer surplus before the improvement from the consumer surplus after the improvement. To do so, we need to know only two things:

- The willingness-to-pay (demand) relationship that is involved, and
- The effect of the improvement on the users' perception of travel cost.

The process is sufficiently straightforward that user-benefit procedure manuals have long been available for use by transportation policy makers (*11*).

As it happens, we do not even have to know terribly much about the willingness-to-pay relationship to implement this procedure. A simple example is illustrated in Table 1, which depicts the schedule of willingness to pay at various trip levels and calculates the consumer surplus before the project improvement (when the cost per trip is 10 cents per trip) and after the project (which reduces the cost per trip to 5.9 cents per trip). Note that for the existing trips in the table, all we need to know to calculate the change in consumer surplus is the difference in the cost before and after the improvement (i.e., $10 - 5.9 = 4.1$). We do not need to know the demand curve.

To calculate changes in consumer surplus for new trips, however, we need to know how many additional users there will be after the improvement. Hence, we need to know how elastic the response of demand is to the travel cost reduction associated with the improvement. Economists measure the elasticity of travel demand relationships numerically as the percent change in the quantity of travel that results from a 1 percent change in the perceived unit cost of travel. The proper measurement of elasticity of demand with respect to travel cost is one of the key informational needs of transportation project selection

TABLE 1 **Stylized Calculation of User Benefits Resulting from a Reduction in Trip Cost**

Quantity of Trips	Willingness to Pay (cents per trip)	Consumer Surplus Before the Project (cost/trip = 10)	Consumer Surplus After the Project (cost/trip = 5.9)	User Benefit Change in Consumer Surplus
1.0	16.7	6.7	10.8	4.1
2.0	14.3	4.3	8.4	4.1
3.0	12.5	2.5	6.6	4.1
4.0	11.1	1.1	5.2	4.1
5.0	10.0	—	4.1	4.1
6.0	9.1	—	3.2	3.2
7.0	8.3	—	2.4	2.4
8.0	7.7	—	1.8	1.8
9.0	7.1	—	1.2	1.2
10.0	6.7	—	0.8	0.8
11.0	6.3	—	0.4	0.4
12.0	5.9	—	—	—
13.0	5.6	—	—	—
14.0	5.3	—	—	—
15.0	5.0	—	—	—
16.0	4.8	—	—	—
				Total 30.3

methodologies. Modern techniques for measuring demand elasticities are very accurate but are information intensive (*12*).

The calculation of user benefits gets a bit more complicated if the effects of the project are so large that they appreciably affect the income of the user; in that case, the income effect shifts the demand curve, and the price effect of the project improvement is intertwined with the fact that the users now feel better off. Separating the income effect impacts of the project itself requires knowing how much the demand relationship shifts in response to changes in income (that is, it requires knowledge of the elasticity of demand with respect to income). But separating these two effects is relatively straightforward, and it can be implemented with the information from good transportation demand models.

Measuring the effect of the improvement on users' perception of travel cost is the other piece of information needed to measure traveler benefits. An unusual aspect of transportation activity (relative to many other goods and services in the economy) is that users commit their personal time to transportation activities. Consequently, the perceived cost of travel includes not only expenses such as gasoline or transit fares but also the value of the time spent traveling. This makes the value of time a crucial factor in cost-benefit analysis in transportation, in addition to the various cash or out-of-pocket costs. Deriving the appropriate value of time for users of various types, income classes, and trip purposes requires the same detailed information on the demography of actual travelers and the pattern of their travel behavior that is used to estimate demand relationships (*13,14*).

Measuring Transportation Benefits of Nonusers

There are a variety of parties who, though nonusers of the affected facility, nonetheless might experience benefits or costs as a consequence of a proposed project:

- Suppliers of transportation services (transit companies, road authorities or departments, etc.);
- Users of facilities elsewhere in the transportation network on the same, or other, transportation modes; and
- Other businesses and households.

Suppliers (producers) of transportation services are affected by changes in use of their facilities. Analogous to the consumer surplus enjoyed by users, there is a producer surplus that suppliers enjoy if they are able to charge more for a service than they actually would be willing to charge to provide it. When the cost of a service declines from a user's perspective (thereby increasing consumer surplus), this may cause the supplier to experience a reduction in producer surplus. From a cost-benefit accounting standpoint, declines in producer surplus offset gains in consumer surplus. Calculating changes in producer surplus requires knowing the effect of the proposed project on

- The producer's willingness-to-supply relationship (usually referred to simply as the supply relationship); and

- The revenues enjoyed by the supplier (typically, the projected toll or fare revenue).

In my experience, producer surplus effects seldom are calculated, even when they may be important, as in the case when the supply relationship slopes down with additional load (i.e., when there are economies of scale or scope, as with bus transit).

Users of facilities elsewhere in the transportation network usually are affected by transportation projects that affect a select portion of the network. It is very common for a positive benefit that is generated in one portion of the network to be at least partially offset by a disbenefit elsewhere on the network as traffic levels adjust to improvements. The principle of measuring the benefits on these indirectly affected portions of the network is the same as for the primary users' benefits. The challenge here is primarily in quantifying these network effects.

Unfortunately, although the state of transportation demand and network modeling has advanced significantly, the linkages between these modeling technologies and cost-benefit analysis virtually are nonexistent. Establishing and automating these links is an important research agenda item, in my view.

Businesses and households can be affected apart from their use of some portion of the network. In economics parlance, these effects are externalities that the transportation system engenders. Externalities can result in positive or negative benefits, and include such phenomena as

- *Environmental impacts.* A transportation improvement may either improve or degrade environmental conditions. Transportation activity has significant impacts on air, noise, and water resources. Some also argue that transportation activity contributes significantly to the apparent global warming trends.
- *Impacts on the health of the regional economy.* As Randall Eberts discusses in this conference, transportation improvements can affect the health of a regional economy by increasing the overall production possibilities of the economy.
- *Impacts on the cost of public services.* The use of transportation facilities affects the activity of courts, police departments, emergency service departments, and so forth.
- *Tax effects.* If a transportation improvement is financed with general tax revenues (as opposed to user charges), there are impacts on the consumer surplus of taxpayers.

In the externalities arena, the accounting of benefits and costs could be improved significantly if there were better information on the linkage between transportation activity and emissions, public service costs, and so forth. In addition, however, there is debate over the value to assign to some externalities, and there have been only a few meta-analyses of transportation externalities (*15*).

Decision Making When Benefits Cannot Be Quantified

The issue of quantification of benefits is not confined to the value of environmental externalities, though these are notoriously contentious. The lack of consensus values plagues transportation cost-benefit analysis. Such crucial parameters as the value of time, demand elasticity, the value of human life, and impacts on regional economic growth and the environment are either contested or only partially developed. Can decision making proceed without resolving these important informational issues?

Decision making can and does proceed, of course. It proceeds by using either implicit or explicit procedures to adopt values from decision makers. Implicit valuation often occurs unbeknownst to decision makers. For example, when decision makers choose not to do something (say, not spending $10 million on a road improvement that would save one life every year), they are adopting de facto a value of life (or at least an upper bound on the value) as surely as if they had asserted it directly. If enough decisions were observed from this perspective, it would be possible to infer decision-maker values.

The most rigorous explicit procedures to engage decision-maker values generally involve what are known as multicriterion decision processes (*1*). In these processes, the decision makers (who may either be officials or the public) are asked to rank alternative transportation projects on a number of dimensions or criteria, such as net economic benefits and environmental soundness. In so doing, the decision makers implicitly reveal the weight they apply to various performance attributes of the projects, which, in turn, implies something about the value of the underlying cost-benefit parameters.

Multicriterion analysis methodologies have been developed that attempt to measure and enforce consistent valuation behavior. In the Analytic Hierarchy Process (AHP), for example, decision makers report pairwise rankings of alternatives that then are used to develop implicit weights and consistency indicators (*16*). This technique has been used to explore the preference structures of transportation officials in the Seattle region.

In my view, multicriterion analysis methodologies are not a good substitute for better information about key cost-benefit parameters. In essence, such methodologies presume that, as a group, decision makers somehow harbor knowledge about the "true" value of these parameters and that, once extracted from an AHP or similar processes, they can be usefully and repeatedly applied. It is unlikely that decision-maker intuition is able inherently to solve complex scientific questions. In the worst case, if the decision makers happen to be completely wrong, consistent reliance on the results of multicriterion exercises results in a large number of wrong decisions. It might be better, in fact, to introduce some randomness in the decision-making process to diversify the risk of making multiple bad decisions.

Discounting and Present Value: The Time Value of Money

Most transportation projects involving capital improvements provide benefits over an extended period of time. For as long as the project is operational, it is providing transportation services. Therefore, some benefits (and disbenefits) will be associated with it throughout its life. The savings (or increases) in user travel time and expense relative to what they would have been without the project extend far into the future. If a life is saved or lost because of the operational characteristics of the facility, the value of what that life would have produced over each year of its expected duration also must be calculated.

Similarly, the development and operating costs associated with the improvements play out over an extended period of time. Though the bulk of the capital or development cost usually occurs at the front end of the implementation process, operating costs and maintenance costs occur over the life of the project.

The process of telescoping the stream of benefits and costs over time into an equivalent single figure in today's dollars is the process of present valuation. Present valuation is not simply a matter of adding up each year's benefits net of costs in a simple, arithmetic fashion. An adjustment needs to be made for society's perception of what a dollar is worth when it is received or spent in the future, as opposed to today.

Financial markets provide one source of insight about how to treat future benefits and costs. Financial markets are willing to give us positive interest rates on money that we set aside today. A dollar invested even in a riskless manner (through an insured bank savings account or a government security, for example) returns more than one dollar later. Consequently, a dollar received today is worth more now than it would be if received later because you always have the option of investing it and turning it into more than one dollar later.

The implication of this is that future benefits and costs should be discounted relative to benefits and costs experienced today. The rate, per year, that future benefits and costs should be discounted to present value is the discount rate. The discount rate should be selected so that it represents the forgone economic opportunities of the funds involved in the project. This leads to a few simple guiding principles for selecting discount rates when doing project evaluations:

- When there is no risk or uncertainty about the stream of future benefits and costs, and the social rate of time preference is the same as the private rate (explained below), transportation projects should be discounted using the riskless interest rates that prevail in private financial markets. The reason is that public projects are taking resources away from private projects, and they should be permitted to do so only if they offer a commensurate return. A good choice for the discount rate thus is the riskless rate of return that financial markets currently are offering over the same horizon as a cost or benefit element. One thousand dollars in pollution benefits received 10 years from now, for example, would be discounted using the current yield on the 10-year U.S. Treasury bond. If that yield is, say, 7 percent per annum, then the discounting calculation is

$$\text{Present value} = \frac{\$1{,}000}{\left(1+0.07\right)^{10}} = \$508$$

Thus, $1,000 in benefits received 10 years from now has a present value of only half that amount. The benefits and costs discounted in this manner in each year of the project's life from today (year zero) result in the net present value of the project:

$$\text{Net present value} = \frac{\left(B_0 - C_0\right)}{\left(1+r\right)^0} + \frac{\left(B_1 - C_1\right)}{\left(1+r\right)^1} + \cdots + \frac{\left(B_T - C_T\right)}{\left(1+r\right)^T} = \sum_{t=1}^{T} \frac{\left(B_t - C_t\right)}{\left(1+r\right)^t}$$

where
B_t = the nominal value of benefits in year t,
C_t = the nominal value of costs in year t,
T = the life of the project in years, and
r = the discount rate.

- When there is some risk that benefits or costs will actually transpire as predicted, and the decision makers are risk-averse, then the net present value should be lower than that obtained when one is certain of the outcome. (Risk aversion means that decision makers value the possibility of gains less than they value the possibility of losses.) The best way to accommodate risk in cost-benefit analysis is to try to estimate benefits and costs on a certainty-equivalent basis by imagining inclusion of the costs of insurance policies and other protections against risk into the projections of the project costs. An alternative, rough-and-ready way to account for risk is to use a higher discount rate, $g > r$, obtained perhaps by looking at the rates of return required by investors in similarly risky enterprises. This method, however, is only useful when the pattern of risk affects all benefit and cost streams similarly.

- If private market considerations dominate financial markets, and private markets care only about the consumption prospects of the current generation of market participants, it may be the case that society is underinvesting. Specifically, the economist Kenneth Arrow and others argued that the social rate of time preference should be lower than the private-market rate of time preference (i.e., the private-market discount rate is higher than the one that should be used in public projects) (*17*). Many transportation projects involve high up-front costs, with benefits that play out only over long periods of time. If the social rate of time preference, s, is lower than the private rate, r, then projects discounted at s will have net present values that are higher than if they were discounted at r and thus be more likely to be undertaken.

Economists have debated whether very low discount rates should be used on public projects despite considerations such as the social underinvestment hypothesis (*18*). One reason for the debate is that through the operation of futures markets and by virtue of bequest behavior, the consumption prospects of future generations are adequately considered in present-day, private decision making. But these considerations, as well as the considerations of risk and uncertainty associated with individual projects, leave the matter of discount rate determination a field that still needs work.

Ranking Projects

Since we know that society has limited resources, it is obvious that we do not want to embark on transportation projects for which benefits are less than costs when properly converted to present value. Thus, the primary project selection rule is that the present discounted value of benefits, $\bar{B}$, should be greater than the present discounted value of costs, $\bar{C}$. Put differently, projects should be considered for implementation only if their net present value is positive:

$$\text{Net present value} = \left(\bar{B} - \bar{C}\right) > 0$$

Does this mean that society should pursue *all* projects with positive net present value? There are some obvious reasons why this simple prescription fails:

- *Projects are not necessarily mutually exclusive.* Candidate projects may overlap somewhat in the locus and type of some of the benefits they provide and may provide unique benefits in others. Similarly, there may be cost synergies (negative or positive) among subsets of candidate projects so that building a set of interrelated projects is more or less costly than building the projects individually.
- *Budgets are limited.* Decision makers may not have budget authority sufficient to build all of the projects that provide positive net benefits. In my view, this circumstance is rare; it is more likely that the list of transportation project "needs" includes many projects with negative net benefits. And, in any case, for projects with positive net benefits, the budget constraint could be resolved in many cases through user charges; indeed, if the projects are beneficial to users, properly structured user charges should be able to "capture" part of these benefits to provide the financing. Nonetheless, the perception of budget limitations is common, and there may in some cases be institutional rigidities that truly impose budget constraints arbitrarily.

As the nature of these issues suggests, the project selection process has the potential to get complex quickly. The nonmutual exclusivity of project benefits and costs means that the project selection process, rather than focusing on individual projects, should focus on alternative menus and configurations of projects in some cases. The issue of budget limitations means that a decision rule other than the simple $\bar{B} > \bar{C}$ rule must be evoked.

The solution to both of these issues can be found by remembering the purpose of cost-benefit analysis. Its purpose is to maximize social well-being from the available economic resources. What this implies, operationally, is that one needs to devise project configurations (the mutual-exclusivity issue) and affordable subsets of these configurations (the limited-budget issue) that maximize net present value. Hence, the project selection process can proceed using a dynamic screening process (*19*).

Although the process appears complex and time-consuming, it is guided by two relatively simple decision rules:

- *To deal with nonmutual exclusivity:* Projects should be included in project configurations if they maximize the sum of own-project and other-project net present value. By calculating beforehand the interactions of each project with all others (most of which will be zero), devising net present-value maximizing configurations is not arithmetically difficult (though seldom done).
- *To deal with limited budgets:* Projects and project configurations should be ranked in descending order of the ratios of $\bar{B}$ to $\bar{C}$. Candidate projects should be added to the implementation list until the budget is exhausted, starting with the project with the highest $\bar{B}/\bar{C}$ ratio.

The financial and arithmetic mechanics of project selection under constraints, therefore, are not a terribly important impediment to good transportation decision making. The procedures are well articulated in project planning manuals (*20*). The real impediments arise when the necessary data to evaluate net present value of individual projects fail to be developed. The most common reasons that this occurs are

- *Decision makers fail to consider all relevant alternatives.* It does no good to scrupulously develop accurate net present value calculations if the subset of project alternatives is arbitrarily truncated.
- *The underlying project impact analysis and modeling are poorly executed.* The calculation of benefits and costs *is* a complex exercise, particularly when the projects represent improvements to complex existing networks.
- *Net present value calculations are executed in a slipshod or intentionally distorted manner.* In the 1970s, the rapid expansion of state and federal requirements for environmental impact statements yielded many examples of inexpert application of cost-benefit analysis arithmetic, which, unfortunately, continues today.

The more readily good information for decision making is available, the more likely it is that project ranking exercises will be more robust and complete. It is hard to expect decision makers to scrutinize carefully a wide range of alternatives if it is impossible, or prohibitively costly, to assemble good information.

Dealing with Distributional Issues

The final aspect of project selection methodology that will be reviewed here is the issue of how to deal with the distributional or equity aspects of cost-benefit analysis, and the kind of measurement issues that thereby arise. As discussed earlier, distributional problems are not a conceptual fatal flaw in cost-benefit analysis from the Hicks-Kaldor perspective. If a project generates net economic benefits, it should be possible to use clever tax or pricing schemes to capture enough of the benefits from the winning group and redistribute them (in an effective way) to the losing group to nullify its loss. The only issue from the Hicks-Kaldor perspective, therefore, is whether it is possible to derive effective redistribution schemes. Even if it is not possible to implement a redistribution scheme within the context of the project itself, the adverse effects could be nullified through a tax scheme or other more general redistribution schemes. Hence, from a Hicks-Kaldor perspective, distributional issues are not a fatal flaw to implementation of efficient projects.

In the 1980s, economists raised the stakes on distributional issues in cost-benefit analysis by presenting ways that project selection processes could be modified to support the more general income redistributional aims of society, if so desired. They proposed that the selection of even inefficient projects (i.e., those with negative net present values) might be justified under some circumstances if those projects have the effect of improving the economic status of certain targeted or protected classes of individuals.

The logic of this argument is that when society decides to assist the less fortunate, it is implicitly saying that it is willing to trade off a certain amount of efficiency for improvement in societal equity. The only issue is selecting the method for effecting the income transfers; it should, of course, have the smallest possible adverse efficiency effects. By this reasoning, it may be worthwhile under some circumstances to "corrupt" the cost-benefit selection criteria if a project has sufficiently large, positive effects on the well-being of the targeted groups relative to the efficiency penalty.

Computationally, the conventional cost-benefit analysis procedures are accommodated to this goal by simply applying weights (greater than one) to the benefits that are received or costs that are paid, by the targeted class. As a result, a project is made to appear better or worse than it otherwise would in the normal course of net present valuation, thereby affecting its ranking and chances of selection for implementation.

The weights to use in this recalculation can, arguably, be derived by observing the relative treatment of various income groups in other aspects of policy (e.g., the tax or welfare systems) or by calculating the marginal value of additional income from other income and consumption data (*21,22*).

This extension of distribution considerations has the potential to cause great mischief in the evaluation of transportation project alternatives without additional research:

- To what extent does a project actually benefit or harm the targeted class? Existing transportation travel data and demand models are not particularly good at identifying the income class of beneficiaries of transportation projects. We know very little, from Census or other data, about precisely who travels where in our regions or interregionally. In addition to this (and partly because of it), travel demand parameters (such as demand elasticities) are not typically differentiated by income class. Hence, the measurement of the likely effects of a transportation project on any particular identified class of beneficiaries is highly speculative. Clearly, this is an area that would benefit from further research.
- Who is keeping track of the aggregate effect of such concessions to income distribution? If efficiency concessions are made, over time, to select projects that provide services to certain classes of travelers, how do we know when enough such projects have been adopted? Measured income statistics, of course, might well remain unchanged even if many transportation projects friendly to the targeted class have been built.

- Is the development of inefficient transportation services the best way to raise incomes? This is the central question that, to date, has been begged in decision makers' acceptance or rejection of transportation projects or policies because of equity considerations. Transit policy, policy toward older polluting vehicles, toward uninsured motorists, and congestion pricing have all been influenced, in my view, by the implicit grossing up of the benefits or costs of alternative actions on the poor.

Clearly, the subject of distributional impacts also is one that deserves considerable additional research.

Summary and Proposed Research Statements

The informational requirements of transportation decision processes are, in some sense, overarching; data on all aspects of travel behavior, travel cost, and network characteristics are needed, in one form or another, by the evaluation process. These are needed to set policy direction, to formulate and implement models of travel behavior and network conditions, and to measure the desirability of individual projects.

In addition, as the earlier discussion has hopefully made clear, transportation decisions also are influenced by conditions outside the transportation sector altogether: financial market conditions influence discount rates; information on income distributions and the cost of improving poor households' incomes affects the desirability of some transportation project alternatives; and the health consequences of air pollution influence the desirability of projects that change the quantity of emissions, to name but a few examples.

Finally, transportation decisions also are influenced by the quality of the available analytic tools and models. Some modeling tools are needed to measure the response of the transportation system to improvements. Others are needed to perform the proper cost-benefit accounting for individual projects or programs. Still others are needed to guide decision makers through the process of ranking and scheduling projects for implementation.

The following are some areas in which information initiatives would be particularly productive, in my view.

Expanded Information on Travel Behavior and Demographic Characteristics of Households

Description of Research Problem

The available Census of Transportation and Public Use MicroData Sample (PUMS) household census data provide only the most rudimentary basis for understanding how travel behavior varies with the demographic characteristics of households. The PUMS data, for example, do not provide trip length or place-of-work information. Neither source provides substantive nonwork tripmaking information or information about whether drivers have the option of free or fee parking. Consequently, it is difficult to build models that can be used to predict the differential response (and, thereby, the benefits enjoyed) by households of various incomes or other important demographic characteristics. Assembly of such information has been left to individual metropolitan planning organizations (MPOs) whose purposes and resources for assembling these kinds of data are limited. Even MPOs in large, complex regions such as the San Francisco Bay Area continue to rely on old and incomplete travel behavior surveys.

Work To Be Performed

This initiative would involve conducting a comprehensive survey of households, either through a large national sample or through a series of regionally focused samples. Data on trip information (trip origin, destination, mode, time, length, etc.) would be linked to detailed information on household characteristics (income, family structure, car ownership, out-of-pocket operating expenditures, workplace types, parking options, etc.). Modern transportation demand modeling argues that the surveys should utilize a tour orientation rather than a trip orientation. This way, the linking of trip purposes (such as the after-work shopping that is done on the commute trip home) can be better examined. A national sample would permit some comparisons of behavior across regions, but regional surveys can be used to develop demand models for the surveyed regions.

Cost Estimate: $4 million to $8 million for a national sample; $350,000 to $1 million for each regional sample

Improved Information on Transit Supply Conditions

Description of Research Problem

In the evaluation of highway and transit improvements, there is little attention paid to the nature of the transit system supply response. For example, when demand density rises in a particular corridor or between a particular origin-destination pair, transportation demand and network assignment models must make certain assumptions about how the road network performance will change and how transit service characteristics (headways, travel times, etc.) will change. Although reasonably thorough characterizations of how road networks will respond are available (namely, volume-delay relationships) and embedded in network assignment models, the characterization of how transit services will respond is usually highly stylized or ignored altogether. Transportation economists, on the other hand, believe that transit (bus transit, in particular) is characterized by significant economies of scope and scale as demand increases. Failure to accurately characterize the transit supply response can distort cost-benefit analysis since it mischaracterizes the size (and direction) of changes in producer surpluses.

Work To Be Performed

This initiative would involve two tasks: a meta-analysis of the theory of optimal transit service dispatch, and an empirical review of actual transit district dispatch behavior. The meta-analysis would survey and synthesize the literature on how to optimize route, vehicle, and headway choices. The empirical review would compare the actual behavior of a selected set of transit districts to see if those districts are behaving in a manner consistent with the prescription of the literature. To the extent the districts are behaving optimally, the theoretical characterization of transit supply can be used in long-term transportation modeling. To the extent that the districts appear to use rules other than optimal dispatch rules, the research would provide a critique of this behavior and provide recommendations of how to characterize transit supply responses in transportation models.

Cost Estimate: $550,000

Expanded Monetization of Transportation Externalities

Description of Research Problem

Environmental and other external effects of transportation are looming increasingly large in transportation planning decisions. However, such information is rarely included, in a monetized form, in cost-benefit analyses, even though much of this information is available. In addition, the available meta-analyses of transportation externalities have not tended to report relationships between transportation activity and externalities but rather have been oriented toward simple average or aggregate measures. In the evaluation of transportation projects in a cost-benefit framework, the failure to include monetizable information often causes the project selection process to be handed over to a multicriterion analysis. This introduces more subjectivity in project evaluation than is probably warranted.

Work To Be Performed

This initiative would involve a meta-analysis of the available literature on the economic value of public service costs, environmental externalities, and other transportation externalities. The literature review would be used to develop characterizations of the relationship (linear or nonlinear) between transportation activity and externalities. The research would yield ways to better incorporate analysis of externalities in transportation network modeling and planning.

Cost Estimate: $300,000

Improved Integration of Transportation System Modeling and Evaluation Models

Description of Research Problem

Very capable multistep transportation planning models have been developed in the past 5 years. Both trip- and tour-based travel demand models are tightly integrated with trip distribution and network assignment models such as EMME/2. The tools for using the information from such models for project or policy evaluation purposes, however, are rudimentary. The elements of such evaluation models exist in such decision support models as STE M and SP SM. But the integration between the typical four-step model operated by regional transportation planning and the evaluation models is weak, with the result that few transportation-planning processes produce economic impact measurements.

Work To Be Performed

This initiative would analyze the interface characteristics of the prominent transportation planning model suites and the available evaluation models. The interface characteristics include the form, dimension, content, and format of the output of transportation planning models and the analogous input requirements of the available evaluation models. The research would identify the compatible and incompatible aspects of various pairs of planning and evaluation models and discuss the best modeling suites for analyzing particular types of transportation improvements. It also would recommend enhancements to the existing models and develop intermediate models to better link the planning and evaluation models.

Cost Estimate: $500,000

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RESOURCE PAPER

Estimating Revenues from User Charges, Taxes, and Fees

Identifying Information Requirements

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In a statement on national transportation policy in the United States contained in *Moving America: New Directions—New Opportunities* (*1*), one of the clear messages was a significantly reduced role for the federal government. The fundamental assumption underlying this policy prescription was that the transportation network was mature. The major concern therefore should be with maintaining this system and encouraging more efficient use of facilities. The shift would be toward projects that complete the system and extend the useful life of facilities. The principal thrust was expected to be in management strategies involving pricing, vehicle control, and other instruments that focus on efficiency. States found they had additional responsibilities in policy, planning, and program development.[1]

Since the 1990 statement, however, infrastructure investment seems to have found its way to the top of the policy agenda in the United States as well as in other countries. The recently enacted Transportation Equity Act for the 21st Century (TEA-21) contained among its provisions a significant amount of monies for transportation (mostly highway) investment. Underlying this change of faith was the belief that investments in public capital would improve productivity, economic growth, and international competitiveness.

With the "crumbling" infrastructure needing replacement and the growing demand for new facilities, state departments of transportation (DOTs) are faced with establishing a set of programs that will satisfy the management and efficiency provisions contained in *Moving America* (*1*) and the financing and investment responsibilities contained in the evolution of TEA-21. If they are to invest in airport, highway, and transit capital, they need to understand how levels of investment in transportation affect our economic health (as Eberts discusses in another resource paper in these proceedings). Once this mechanism is understood, they need to put in place a planning process that will lead to a set of investments yielding the economic and social returns so desired (as Pozdena shows in his paper, also in these proceedings). Finally, all of this activity must be financed in some way, and forecasts of funds available for projects need to be made.

The problems just identified cross all modes of transportation. In some cases, additional problems such as international passenger travel and freight shipment demands make the planning and investment process even more complex. This paper will concentrate on highway transportation and will assess how well states are able to forecast revenues from taxes and fees levied on highway users and whether the models they employ in forecasting revenues are appropriate for the task. In addition, the paper investigates whether the information relied upon by these models is sufficiently accurate to support reliable forecasts, and how this information might be improved. (The focus will be on the highway sector although similar questions arise in aviation.) The paper then moves beyond questions of current practice and examines new methods of financing transportation infrastructure investments and their information needs for forecasting.

After a brief review of the evolution of highway finance and its components, the next section of this paper reviews variables that currently are used in forecasting state highway revenues, and it assesses the quality and accuracy of available measures of these variables. Factors that may affect the reliability of current information are explored, new options for measuring specific variables are examined, and their information requirements are outlined.

In the next section, the adequacy of current revenue forecasting models is investigated. This section poses two questions: First, how accurate are current models, and what assumptions do they impose? Second, are the models adequate for forecasting revenues in a world that places different demands on its transportation systems? This section also will identify the additional information demands that are likely to be imposed by new or improved forecasting models.

The next section examines the information needs that are likely to result from introducing new revenue instruments. This section requires a somewhat speculative examination of the specific financing measures states may be considering to augment their current revenue sources, including highway tolls and new forms of user taxes or fees. If states move toward closer linkage of user charges with actual road use, what additional information will need to be collected to ensure that accurate revenue forecasts can be made, and how can it be collected? Finally, the last section contains a summary and identification of critical research questions.

Evolution of Highway Finance

The growth and development of states' highway finance systems have reflected changes in several factors. These include developments in revenue collection technologies, an evolutionary process to legislation, a general disinterest in reviewing highway finance on a regular basis, and a move away from a user benefit principle to one of minimizing voter revolt. Starting with the movement away from tolls and property taxes to finance roads that began in the early 1920s, states increasingly relied on user taxes to finance highways.[2] The linkage of roads to property benefits was no longer as clear as that between use of a road and the benefits received by its users. In the language of economics, taxes on road users were adopted and implemented in a context of highways exhibiting the attributes of both private and public goods—attributes such as excludability, congestion, cross subsidy, and cost economies. This trend toward increased reliance on traditional user charge mechanisms generally has continued over the past several decades, more recently with some minor shift toward reliance on general taxation. At the same time, many European and Third World nations are seriously turning to toll finance—and in many cases, even outright privatization—to finance continued road building.

The principal sources of revenues used to finance highway construction in the United States have included state and federal fuel taxes, vehicle registration fees, motor-vehicle weight fees, sales taxes (revenue derived from sales taxes on vehicles and equipment), road and bridge tolls, and driver's license fees. Vehicle registration fees were the earliest forms of user tax to be widely adopted by states, partly because they could be implemented easily and were simple to administer since they were typically paid only once per year in a lump sum. This feature made them highly visible to motorists, with the result that they tended not to be changed frequently. However, registration fees are typically a "flat fee" (with some differentiation by vehicle classes) and thus have limited revenue-generating potential. Currently, about a third of the states base registration fees for light vehicles on weight, whereas half retain the flat fee system and the remainder base the fee on some combination of weight, horsepower, value, and age. The exact weightings on these characteristics tend to reflect political judgments and perceptions of equity among owners of different types of vehicles.

Fuel Taxation

Motor-fuel taxation, first introduced by Oregon in 1919, rapidly spread to other states: by 1929, all 48 states taxed gasoline, and 3 years later a one-cent-per-gallon federal fuel tax was enacted as part of the Revenue Act of 1932.[3] The weighted average state motor-fuel tax for gasoline has increased from 3.35¢ per gallon in 1930, the first full year in which taxes were collected in all states, to 18.5¢ in 1995. This figure compared closely to the federal tax on gasoline, which stood at 18.4¢ per gallon during 1995, although the federal levy on diesel fuel was considerably higher, at 24.4¢ per gallon.

Prior to 1980, fuel tax rates were changed infrequently and typically in small increments (generally by 1 percent or less). The stability in fuel tax rates was enabled by continuing growth in fuel consumption, which produced a continuing rise in total fuel-tax revenues. At the same time, because highway expenditure levels tended to be adjusted to correspond to growing revenues, there was little pressure to increase fuel tax rates in order to accelerate construction. After 1983, however, a number of states began to increase their fuel tax rates aggressively, often in increments as large as 3¢ per gallon, and there continues to be some adjustment by a minority of states in their per-gallon fuel tax rates. Whereas most states have retained the original convention of fixed tax rates per gallon of fuel sold at retail, others have indexed the per-gallon rate to some measure of general price inflation. Still others impose the tax as a sales or value-added tax—a fixed percentage of the dollar value of sales—levied either specifically on fuels or on all retail spending. The exact form taken of a state's fuel tax has a significant impact on the amount of revenues it generates, although this impact can vary with changes in overall economic conditions. As an illustration, the recent robust growth in travel, spurred by the booming U.S. economy, falling wholesale gasoline prices, and declining average fuel efficiency of the U.S. vehicle fleet, has produced rapid growth in gasoline consumption and in fuel-tax revenues collected by states that rely on the traditional per-gallon fuel tax structure.

Vehicle Registration Fees

Registration practices and taxation policies for commercial vehicles differ greatly among the states: some register a tractor-semitrailer combination as a single unit, whereas others register the tractor and the semitrailer separately. Some states register and tax buses similarly to trucks; others treat buses in the same way as automobiles, presumably because of their passenger-carrying function. For the most part, weight-based vehicle fees have been used in licensing trucks, but more recently some states (17 to date) have begun to levy fees on the basis of some combination of weight and annual distance traveled. A few states (notably, Virginia and Kentucky) levy a fuel tax surcharge on vehicles having three or more axles, whereas still others (Arizona, Pennsylvania, and New York) impose a gross tax on commercial trucks. Despite this wide variation in licensing fee practices, however, the magnitude of revenues generated from this source is relatively minor.

One factor complicating the assessment and collection of both vehicle registration fees and fuel taxes on commercial trucks is the interstate and international (Canada and Mexico) nature of their operations. The diversity of tax structures creates both tax competition among individual states and the potential for adoption of retaliatory taxation by adjacent or nearby states. However, several regional alliances of states (e.g., New England) have been formed in order to minimize the revenue diminution that typically accompanies such tax rivalry. In these agreements, states jointly establish how trucks will be treated in the home state and in adjacent or nearby jurisdictions. Registration fees generally are prorated on the bases of the amount of mileage recorded in each jurisdiction. Fuel-tax revenues tend to be generally "self-prorating" because of their collection by states in which fuel sales occur (as long as interstate tax differentials are not large enough to induce significant changes in sales patterns).[4]

Other Revenue Sources

The remaining sources of revenue, which are minor at the state level, include property taxes and assessments, driver's licensing fees, and personal property taxes levied on motor vehicles. In addition, many states now employ general-revenue bond financing for highway construction projects.[5]

More recently, some states have employed new tax instruments that include both road tolls and state sales taxes. Toll revenues generally are restricted to use on the facilities where they are collected, because facilities with tolls tend to be either bridges or tunnels, and they are often newly constructed facilities. Presently 29 states operate a total of 37 toll highways and 44 toll bridges; in 1989, tolls collected from vehicles using these facilities provided $3.01 billion in revenues for highway financing. At the same time, a few states have introduced dedicated (or "earmarked") sales taxes to finance selected investments in transportation infrastructure, often in response to voter-approved ballot initiatives.

The increased reliance on this form of financing stems from a number of factors, but the most important of these is undoubtedly reluctance on the part of state legislatures to adopt the tax rate or fee increases necessary to generate additional revenues from more traditional financing sources. Like tolls, the money collected from state sales taxes generally are earmarked for a particular set of investments, often specified in detail in the ballot initiatives approving their use.

Summary of Revenue Sources

Figure 1 illustrates highway revenue sources. What is most evident from the data is the dominant role that fuel taxes and fees play as a source of revenue for financing highway spending. The figure also illustrates the variability of revenue sources over time.

Tables 1 through 5 provide a detailed, state-by-state examination of the level and variability in taxation rates and in revenues from fuel taxation and vehicle registration fees and other taxes associated with vehicles. Table 1 shows the variability in tax rates among states as well as across types of fuels. The asterisk beside a state name indicates there are exceptions and conditions in the application of the tax. This complexity creates a significant challenge to developing a medium- to long-run forecasting model.

In Tables 2 through 5, the levels and changes in the revenues from two major sources of tax and fee revenue are examined. Table 2 shows the gross and adjusted total tax receipts from fuel taxes and other fuel-related fees. The adjustment results in a reduction in revenue due

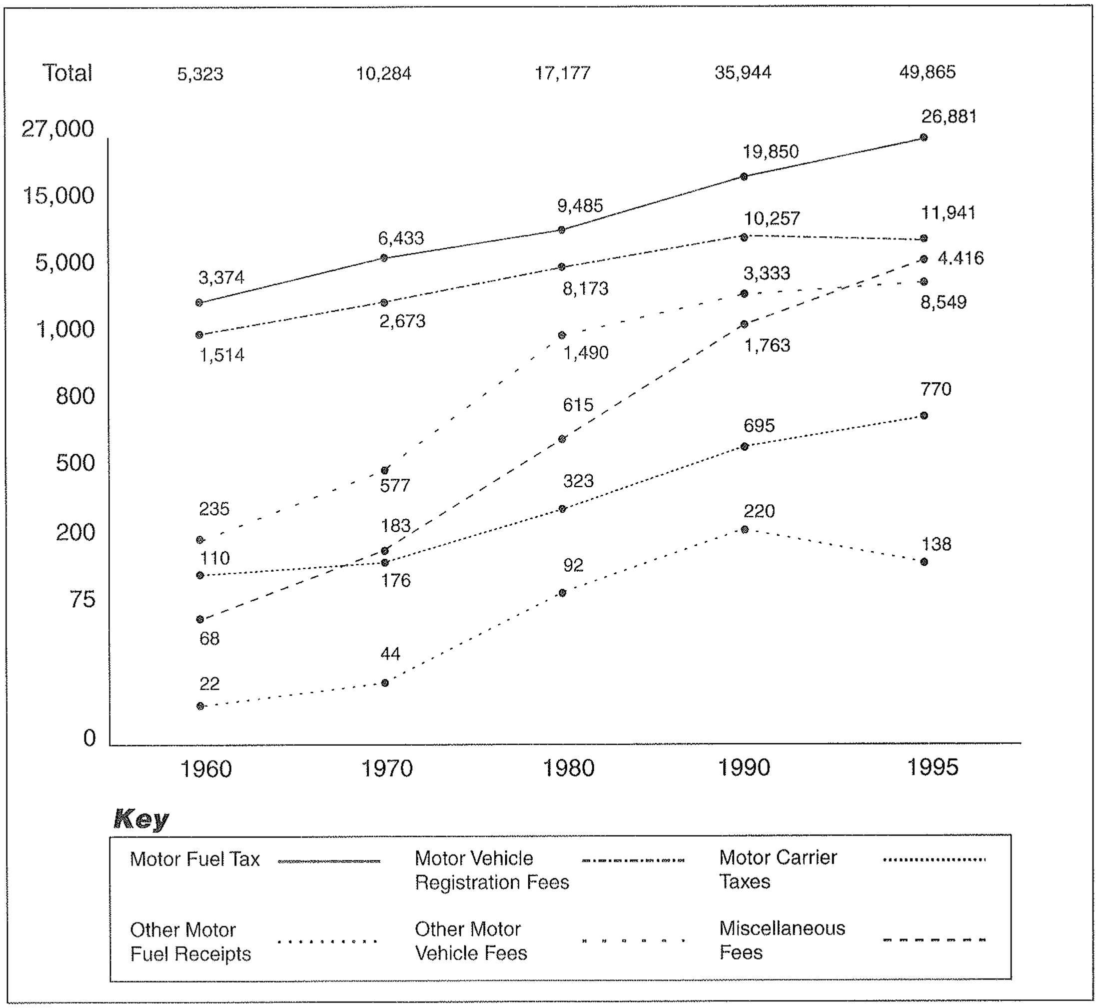

FIGURE 1 State highway user tax revenues (millions of dollars) (2).

to reimbursements and exceptions. Changes from one year to the next are illustrated in Table 3. In Column 1, for example, Alaska, Louisiana, North Carolina, Pennsylvania, and Utah have large reductions in tax revenues. A significant proportion of U.S. states exhibit large changes in revenue from one year to the next. Pennsylvania, for example, has a 3.8 percent increase in 1994–95, an 8.5 percent decrease in 1995–96, and a turnaround of a 14.32 percent increase in 1996–97. Even a simple time-series model for short-term forecasting would face challenges with such variability.

Table 4 illustrates the revenues available from license fees and other motor-vehicle-related taxes. (The table is a subset of a more detailed set of information and is condensed for presentation.) It is clear that a sizable proportion of "other" taxes is included in this source of revenues. Table 5 shows the year-to-year changes in revenue levels contained in Table 4. Unlike fuel-tax revenues, these series show remarkable stability with no subset of states having more fluctuation than others in this revenue source and very little intertemporal variation.

The Role of Revenue Forecasting

As the exhibits illustrate, states traditionally have relied on fuel taxes as the primary source of revenue to fund roadway construction, rehabilitation, and maintenance. In planning their year-to-year activities and accompanying spending levels in each of these categories, states thus require forecasts of revenues that will be available from the "pass-back" of federal fuel-tax revenues they receive, as well as from the fuel taxes, fees, and other charges they levy on highway users.[6] The Federal Highway Administration (FHWA), which is required to present to Congress the forecasts of revenues available in the Federal Highway Trust Fund, relies on information provided by the states in developing its forecasts.

Three approaches can be considered in producing forecasts. One is a simple model that uses previous values of revenues in each category, perhaps with a weighting structure on more recent values. This approach simply matches a function to the data and extrapolates the values to create a forecast. A second approach would use some econometric time-series techniques, such as the Box-Jenkins or ARIMA. Univariate Box-Jenkins models are sophisticated extrapolation methods using past values to generate forecasts. Despite not providing any explanation for the movement of variables, this approach is valuable because it is easy, inexpensive, and requires a minimum of information. This can be used in conjunction with other forecasts and can serve as a starting point for more sophisticated approaches. The "Achilles heel" of the time-series approach to forecasting is the misspecification of the dynamic structure. When lack of information or specification errors make econometric models impractical, the Box-Jenkins model is considered a superior form of time-series forecasting.

The third approach, causal forecasting, develops an econometric model that explains the underlying causes or sources of variation in the factors that effect revenues from fuel taxes and registration fees. This would use relevant demographic and economic variables in a set of behavioral equations to produce the forecast. This approach is information intensive and is subject to a number of errors. Nonetheless, it is the richest approach since once the model parameters are estimated they can be used to develop forecasts of the dependent variables.

Producing revenue forecasts requires projections of a state's fuel-tax structure and rates, the number of gallons of each type of fuel subjected to taxation that is expected to be sold, the number of vehicles expected to be registered during future years, and residual revenues from other sources, including excise taxes, licensing fees, and earmarked transfers from the federal government. Unfortunately, the only piece of information among these variables that tends to be predictable with any certainty is the state's tax structure and rate of taxation.[7] Total vehicle miles traveled (VMT) and the average fuel efficiency of the vehicle fleet will determine the number of gallons of each type of fuel sold. The present stock of vehicles varies with changes in the demographic makeup and economic status of households, and prevailing macroeconomic conditions will determine the number of licensed vehicles.

State policy makers and transportation officials require accurate revenue forecasts to plan investments as well as to set tax rates and fee levels that will achieve fiscal targets. There is some economic risk and sizable political risk in overforecasting revenues—that is, in producing forecasts that exceed actual revenue collections. If states are not able to accurately forecast revenues from taxes and fees levied on highway users, transportation planning agencies will be in jeopardy of having certain projects delayed, and prolonged delays of controversial projects may cause the consensus in support of them to be reconsidered or ultimately to unravel. In the case of projects that already have begun, overestimation of future revenues may subject political officials to the risk of having to adjust existing tax rates or fees or even to introduce new taxes or seek a new source of financing.

Recognizing the sources and consequences of these risks, there are three fundamental questions that policy makers should be asking that will assist in identifying the weaknesses in information and modeling. They are as follows:

- *Accuracy of information employed by current forecasting models:* With the focus on the current set of models used in revenue forecasting, are the variables used in these models measured accurately? If not, what are the sources of inaccurate measurements and what is needed to improve their reliability?
- *Adequacy of current forecasting models:* Are the models that currently are being used to forecast revenues satisfactory to meet future needs? What are their specific conceptual and empirical shortcomings, and how should they be redesigned to adequately reflect future changes in their likely use in transportation planning and policy making? How are proposed changes in the models used to forecast revenues likely to affect their information requirements?
- *Evolution of current forecasting models and information requirements:* How will new revenue instruments be integrated into the current set of forecasting models? The evolution of alternative bases for financing highways results in increasingly diverse and potentially complex informational requirements. Hence, there are different demands placed on both state and federal institutions responsible for generating information relied upon in forecasting revenues.

The Current Models: Information Demands

Because of the nearly universal policy of basing highway spending levels on revenues, both the federal and state governments depend critically on forecasts of revenue from taxes and fees levied on users for planning highway expenditures. The federal gasoline tax of 18.4¢ per gallon is approximately equal to the average state levy, so that total tax revenues average about 36¢ per gallon of fuel sold; Table 1 provides the complete breakdown, state by state. At the same time, however, it is equally important to examine developments in the world petroleum market and their effects on the wholesale or pretax price of gasoline, which had been declining but has risen sharply in recent months. In assessing the implications of

TABLE 1 Tax Rates on Motor Fuel, 1997 (Cents per Gallon)

	Gasoline		Diesel		LPG		Gasohol	
State	Rate	Date	Rate	Date	Rate	Date	Rate	Date
Alabama*	18	06/01/92	19	06/01/92	17	06/01/92	18	06/01/92
Alaska	8	07/01/61	8	07/01/61	—	—	—	—
Arizona*	18	07/01/90	18	07/01/90	18	07/01/90	18	07/01/90
Arkansas*	18.6	07/01/96	18.6	07/01/96	16.5	04/01/91	18.6	07/01/06
California*	18	01/01/94	18	01/01/94	6	01/01/76	18	01/01/94
Colorado*	22	01/01/91	20.5	01/01/92	20.5	01/01/92	22	01/01/91
Connecticut	39	01/01/97	18	09/01/91	—	07/01/96	38	01/01/97
	36	07/01/97					35	07/01/97
Delaware*	23	01/01/95	22	01/01/95	22	01/01/95	23	01/01/95
D.C.	20	10/01/94	20	10/01/94	20	10/01/94	20	10/01/94
Florida*	12.8	01/01/97	24.6	01/01/97	15.8	01/01/97	12.8	01/01/97
Georgia	7.5	07/01/71	7.5	07/01/71	7.5	07/01/71	7.5	07/01/71
Hawaii	16	07/01/91	16	07/01/91	11	07/01/91	16	07/01/91
Idaho*	25	04/01/96	25	04/01/96	18.1	04/01/96	22.5	07/01/94
Illinois*	19	01/01/90	21.5	01/01/90	19	01/01/90	19	01/01/90
Indiana*	15	04/01/88	16	04/01/88	—	—	15	04/01/88
Iowa	20	01/01/89	22.5	01/01/89	20	01/01/89	19	01/01/89
Kansas*	18	07/01/92	20	07/01/92	17	07/01/92	18	07/01/92
Kentucky*	16.4	07/15/94	13.4	07/15/94	15	07/01/86	16.4	07/15/94
Louisiana*	20	01/01/90	20	01/01/90	16	07/01/93	20	01/01/90
Maine	19	07/17/91	20	04/01/89	18	07/17/91	19	07/17/91
Maryland	23.5	05/01/92	24.25	07/01/93	23.5	07/01/93	23.5	05/01/92
Massachusetts*	21	01/01/91	21	01/01/91	9.5	01/01/97	21	01/01/91
Michigan*	15	01/01/84	15	01/01/84	15	01/01/84	15	01/01/84
	19	08/01/97					19	08/01/97
Minnesota*	20	05/01/88	20	05/01/88	15	07/01/95	20	05/01/88
Mississippi*	18.4	07/01/93	18.4	07/01/93	17	01/01/89	18.4	07/01/93
Missouri*	17	04/01/96	17	04/01/96	17	04/01/96	17	04/01/96
Montana*	27	07/01/94	27.75	07/01/94	—	—	27	07/01/94
Nebraska*	25.3	01/01/97	25.3	01/01/97	25.3	01/01/97	25.3	01/01/97
	24.9	04/01/97	24.9	04/01/97	24.9	04/01/97	24.9	04/01/97
	24.8	07/01/97	24.8	07/01/97	24.8	07/01/97	24.8	07/01/97
	24.5	10/01/97	24.5	10/01/97	24.5	10/01/97	24.5	10/01/97
Nevada	24.75	01/01/97	27.75	01/01/97	23	10/01/92	24.75	01/01/97
					22	07/01/97		
New Hampshire*	18.7	06/07/93	18.7	06/07/93	18	06/16/91	18.7	06/07/93
New Jersey*	10.5	07/01/88	13.5	07/01/88	5.25	07/01/88	10.5	01/01/92
New Mexico*	18.875	07/01/96	19.875	07/01/96	3	01/01/96	18.875	07/01/96
New York*	22.40	01/01/97	22.35	01/01/97	8	10/01/90	22.35	01/01/97
	22.80	04/01/97	22.65	04/01/97			22.65	04/01/97
North Carolina*	22.6	01/01/97	22.6	01/01/97	22.6	01/01/97	22.6	01/01/97
North Dakota*	20	01/01/96	20	01/01/96	20	01/01/96	20	01/01/96
Ohio*	22	07/01/93	22	07/01/93	22	07/01/93	22	07/01/93
Oklahoma*	17	07/01/89	14	07/01/89	17	07/01/89	17	07/01/89
Oregon*	24	01/01/93	24	01/01/93	24	01/01/93	24	09/01/93
Pennsylvania*	22.35	09/01/91	22.35	09/01/91	22.35	09/01/91	22.35	09/01/91
	25.9	05/01/97	26.0	05/01/97	25.9	05/01/97	25.9	05/01/97
			30.8	10/01/97				
Rhode Island*	29	07/08/94	29	07/08/94	29	07/08/94	29	07/08/94
South Carolina	16	01/01/89	16	01/01/89	16	01/01/89	16	01/01/91
South Dakota*	18	04/01/88	18	04/01/88	16	04/01/88	16	04/01/88
	21	05/01/97	21	05/01/97	19	05/01/97	19	05/01/97
Tennessee*	20	04/01/89	17	04/01/90	14	04/01/89	20	04/01/89
Texas*	20	10/01/91	20	10/01/91	15	01/01/87	20	10/01/91
Utah*	19	04/01/87	19	04/01/87	19	04/01/87	19	04/01/87
	19.5	06/01/97	19.5	06/01/97	19.5	06/01/97	19.5	06/01/97
	24.5	08/01/97	24.5	08/01/97	24.5	08/01/97	24.5	08/01/97
Vermont*	16	07/01/89	17	07/01/89	—	—	16	07/01/89
	20	08/01/97					20	08/01/97
Virginia*	17.5	07/01/92	16	07/01/92	10	01/01/94	17.5	07/01/92
Washington*	23	04/01/91	23	04/01/91	—	—	^23	05/01/94
West Virginia*	25.35	05/01/93	25.35	05/01/93	25.35	05/01/93	25.35	05/01/93
Wisconsin*	23.7	04/01/96	23.7	04/01/96	23.7	04/01/96	23.7	04/01/96
	23.8	04/01/97	23.8	04/01/97	23.8	04/01/97	23.8	04/01/97
Wyoming*	9	07/01/89	9	07/01/89	—	—	9	01/01/95
Weighted Avg.	**19.05**		**19.50**		**14.18**		**20.01**	
Federal Tax	**18.4**	10/01/97	**24.4**	10/01/97	**13.6**	10/01/97	**13.0**	10/01/97

TABLE 2 State Motor-Fuel Tax Revenues and Related Receipts (Thousands of Dollars)

	1997		1996		1995		1994	
State	Gross Collections	Adj. Total Tax Receipts	Gross Collections	Adj. Total Tax Receipts	Gross Collections	Adj. Total Tax Receipts	Gross Collections	Adj. Total Tax Receipts
Alabama	542,221	540,195	533,257	530,399	534,767	530,779	522,124	518,243
Alaska	18,906	17,187	20,960	18,756	21,791	20,016	23,450	21,883
Arizona	499,370	490,497	484,348	478,129	460,812	458,997	430,454	427,881
Arkansas	351,117	351,117	354,456	340,052	344,348	329,862	332,171	319,063
California	2,820,580	2,730,407	2,763,367	2,635,798	2,725,847	2,617,883	2,584,707	2,443,550
Colorado	447,795	442,262	445,266	439,774	433,013	427,220	420,369	414,540
Connecticut	546,553	544,663	499,517	498,120	462,824	461,619	432,081	430,858
Delaware	103,412	103,195	93,542	93,345	97,850	97,597	89,130	88,902
D.C.	32,529	32,570	31,987	32,028	34,821	34,862	35,880	35,924
Florida	1,400,107	1,400,795	1,310,236	1,300,895	1,275,008	1,276,616	1,202,944	1,200,062
Georgia	393,662	386,559	415,622	412,268	388,228	385,093	378,297	375,583
Hawaii	68,799	67,784	68,095	67,167	67,763	66,881	67,594	66,345
Idaho	202,419	194,170	188,858	179,514	157,808	149,905	151,733	143,280
Illinois	1,136,898	1,122,838	1,164,395	1,134,506	1,131,311	1,097,265	1,112,736	1,073,959
Indiana	703,766	695,106	671,811	664,718	670,551	665,555	618,090	613,186
Iowa	397,701	380,777	388,410	374,546	371,130	358,517	360,189	347,639
Kansas	313,902	311,834	299,231	296,996	290,941	289,078	286,146	283,821
Kentucky	413,776	406,004	400,874	400,698	377,504	377,433	364,047	363,820
Louisiana	589,912	500,272	699,060	529,232	505,690	492,839	497,002	474,108
Maine	155,570	150,741	150,504	145,803	138,964	134,306	143,143	138,639
Maryland	630,508	618,571	622,158	604,614	621,140	601,268	610,458	600,042
Massachusetts	598,547	590,775	599,660	591,807	578,218	570,639	563,308	555,541
Michigan	825,746	809,483	766,491	752,129	762,366	764,215	735,637	735,806
Minnesota	546,182	527,142	522,146	507,770	499,282	486,979	491,981	481,329
Mississippi	334,100	332,859	336,018	334,857	328,619	327,607	319,549	318,787
Missouri	632,969	631,720	591,994	591,526	535,374	535,258	500,857	500,355
Montana	177,809	167,107	179,535	167,857	158,202	154,844	160,011	150,261
Nebraska	293,014	279,931	261,782	249,759	248,840	235,311	249,914	235,691
Nevada	274,169	265,327	242,198	233,563	226,353	217,370	215,468	207,087
New Hampshire	123,687	121,409	116,183	116,902	110,647	111,010	107,006	107,021
New Jersey	488,049	488,216	464,170	463,664	431,181	431,165	441,427	440,876
New Mexico	232,707	230,908	224,128	223,780	246,959	246,449	224,674	225,230
New York	1,414,144	1,400,662	1,330,152	1,325,956	1,521,405	1,518,624	1,369,669	1,364,813
North Carolina	975,439	986,335	1,210,795	1,184,149	927,654	903,356	919,079	898,790
North Dakota	99,374	97,615	97,619	93,112	85,621	81,282	86,486	82,303
Ohio	1,426,954	1,365,308	1,394,619	1,341,859	1,329,351	1,301,962	1,278,089	1,256,379
Oklahoma	387,843	382,276	371,656	367,146	360,573	356,233	358,348	352,800
Oregon	387,521	378,293	374,573	364,425	369,967	360,706	355,557	347,208
Pennsylvania	1,538,470	1,533,638	1,317,925	1,314,011	1,424,605	1,425,219	1,369,864	1,370,177
Rhode Island	124,974	124,665	123,848	123,518	120,633	120,262	116,259	120,108
South Carolina	396,222	394,130	387,048	384,942	393,295	393,629	382,594	382,819
South Dakota	107,480	101,008	97,933	91,273	93,933	86,696	95,230	87,804
Tennessee	683,188	670,104	680,383	662,619	669,620	650,543	651,009	633,125
Texas	2,459,891	2,396,826	2,386,361	2,319,576	2,302,528	2,240,355	2,226,096	2,168,643
Utah	265,044	257,605	220,831	214,380	208,184	201,672	196,858	190,890
Vermont	71,111	69,811	67,667	67,405	67,463	70,192	64,882	68,206
Virginia	735,764	732,313	696,429	693,348	696,587	693,689	685,719	682,423
Washington	702,845	699,997	681,669	668,487	668,465	656,419	650,724	638,689
West Virginia	271,110	270,784	262,247	261,612	276,805	276,358	276,399	275,810
Wisconsin	707,102	685,336	696,820	675,345	666,993	646,468	648,914	630,268
Wyoming	54,056	53,225	54,683	53,461	49,788	50,607	51,451	50,637
Totals	**29,105,014**	**141,947**	**28,363,517**	**2,761,759**	**2,747,162**	**2,698,871**	**26,455,804**	**25,941,204**

SOURCE: Motor-fuel taxes and related receipts, Bureau of Transportation Statistics.

TABLE 3 Changes in Revenues from Fuel Tax Receipts

	1996–97		1995–96		1994–95	
	Change in Gross Collections	Change in Total Tax Receipts	Change in Gross Collections	Change in Total Tax Receipts	Change in Gross Collections	Change in Total Tax Receipts
Alabama	1.65%	.81%	–0.28%	0.07%	2.36%	.36%
Alaska	–10.86%	9.13%	–3.96%	6.72%	–7.61%	9.33%
Arizona	3.01%	.52%	4.86%	.00%	6.59%	.78%
Arkansas	–0.95%	.15%	2.85%	.00%	3.54%	.27%
California	2.03%	.47%	1.36%	.68%	5.18%	.66%
Colorado	0.56%	.56%	2.75%	.85%	2.92%	.97%
Connecticut	8.61%	.55%	7.35%	.33%	6.64%	.66%
Delaware	9.54%	.55%	–4.61%	4.56%	8.91%	.91%
Dist. of Columbia	1.67%	.66%	–8.86%	8.85%	–3.04%	3.05%
Florida	6.42%	.13%	2.69%	.87%	5.65%	.00%
Georgia	–5.58%	6.65%	6.59%	.59%	2.56%	.47%
Hawaii	1.02%	.91%	0.49%	.43%	0.25%	.80%
Idaho	6.70%	.55%	16.44%	6.49%	3.85%	.42%
Illinois	–2.42%	1.04%	2.84%	.28%	1.64%	.12%
Indiana	4.54%	.37%	0.19%	0.13%	7.82%	.87%
Iowa	2.34%	.64%	4.45%	.28%	2.95%	.03%
Kansas	4.67%	.76%	2.77%	.67%	1.65%	.82%
Kentucky	3.12%	.31%	5.83%	.81%	3.56%	.61%
Louisiana	–18.50%	5.79%	27.66%	.88%	1.72%	.80%
Maine	3.26%	.28%	7.67%	.89%	–3.01%	3.23%
Maryland	1.32%	.26%	0.16%	.55%	1.72%	.20%
Massachusetts	–0.19%	0.17%	3.58%	.58%	2.58%	.65%
Michigan	7.18%	.09%	0.54%	1.61%	3.51%	.72%
Minnesota	4.40%	.67%	4.38%	.09%	1.46%	.16%
Mississippi	–0.57%	0.60%	2.20%	.17%	2.76%	.69%
Missouri	6.47%	.36%	9.56%	.51%	6.45%	.52%
Montana	–0.97%	0.45%	11.88%	.75%	–1.14%	.96%
Nebraska	10.66%	0.78%	4.94%	.78%	–0.43%	0.16%
Nevada	11.66%	1.97%	6.54%	.93%	4.81%	.73%
New Hampshire	6.07%	.71%	4.76%	.04%	3.29%	.59%
New Jersey	4.89%	.03%	7.11%	.01%	–2.38%	2.25%
New Mexico	3.69%	.09%	–10.19%	10.13%	9.02%	.61%
New York	5.94%	.33%	–14.38%	14.53%	9.97%	0.13%
North Carolina	–24.13%	20.06%	23.38%	3.71%	0.92%	.51%
North Dakota	1.77%	.61%	12.29%	2.71%	–1.01%	1.26%
Ohio	2.27%	.72%	4.68%	.97%	3.86%	.50%
Oklahoma	4.17%	.96%	2.98%	.97%	0.62%	.96%
Oregon	3.34%	.67%	1.23%	.02%	3.89%	.74%
Pennsylvania	14.34%	4.32%	–8.09%	8.46%	3.84%	.86%
Rhode Island	0.90%	.92%	2.60%	.64%	3.63%	.13%
South Carolina	2.32%	.33%	–1.61%	2.26%	2.72%	.75%
South Dakota	8.88%	.64%	4.08%	.01%	–1.38%	1.28%
Tennessee	0.41%	.12%	1.58%	.82%	2.78%	.68%
Texas	2.99%	.22%	3.51%	.42%	3.32%	.20%
Utah	16.68%	6.78%	5.73%	.93%	5.44%	.35%
Vermont	4.84%	.45%	0.30%	4.13%	3.83%	.83%
Virginia	5.35%	.32%	–0.02%	0.05%	1.56%	.62%
Washington	3.01%	.50%	1.94%	.81%	2.65%	.70%
West Virginia	3.27%	.39%	–5.55%	5.64%	0.15%	.20%
Wisconsin	1.45%	.46%	4.28%	.28%	2.71%	.51%
Wyoming	–1.16%	0.44%	8.95%	.34%	–3.34%	0.06%

TABLE 4 State Motor-Vehicle and Motor-Carrier Tax Receipts (Thousands of Dollars)

	1997			1996		
STATE	Automobiles (including taxicabs)	Trucks and Truck Tractors	Total Receipts	Automobiles (including taxicabs)	Trucks and Truck Tractors	Total Receipts
Alabama	3,989	54,373	147,704	3,615	37,030	177,366
Alaska	11,957	9,466	31,758	11,872	9,532	30,932
Arizona	23,018	63,532	259,456	22,940	61,820	247,700
Arkansas	21,610	57,283	114,959	23,451	30,570	120,598
California	3,141,491	1,397,975	5,205,428	2,778,390	1,553,811	4,985,706
Colorado	66,179	56,670	211,939	64,881	52,963	203,793
Connecticut	20,525	4,332	245,200	108,846	22,974	238,920
Delaware	9,572	5,280	71,918	9,187	5,246	70,016
Dist. of Columbia	12,921	1,915	54,737	14,283	2,117	55,179
Florida	236,630	131,923	940,084	229,897	127,958	931,611
Georgia	133,457	31,447	249,064	102,995	65,913	245,742
Hawaii	55,907	11,643	82,881	54,673	12,417	83,035
Idaho	21,530	18,283	103,724	16,336	15,052	94,660
Illinois	320,265	201,460	746,505	349,832	187,259	764,186
Indiana	40,547	126,185	243,352	39,977	123,360	235,160
Iowa	183,600	86,200	320,922	163,500	87,600	304,541
Kansas	41,561	69,403	150,476	39,991	67,505	142,817
Kentucky	18,275	22,607	545,753	18,190	22,020	530,836
Louisiana	32,282	31,977	172,601	32,596	33,078	177,612
Maine	20,649	13,308	76,289	20,015	13,950	78,571
Maryland	98,971	35,165	761,117	95,339	35,308	742,747
Massachusetts	78,134	77,661	337,880	72,684	75,711	303,742
Michigan	380,465	159,817	688,287	357,676	151,788	674,148
Minnesota	339,004	151,433	571,167	317,082	137,806	504,184
Mississippi	30,572	27,165	124,787	29,877	27,298	125,380
Missouri	76,827	103,877	255,648	77,606	106,119	256,632
Montana	6,057	6,092	55,934	6,701	5,218	52,351
Nebraska	19,073	27,152	78,919	16,433	32,276	76,945
Nevada	45,154	19,495	129,823	42,871	18,509	109,597
New Hampshire	20,984	21,204	86,048	20,558	19,766	83,077
New Jersey	179,051	30,920	554,600	172,505	50,170	594,755
New Mexico	27,817	27,188	217,495	27,215	25,932	208,218
New York	230,425	66,512	772,189	226,596	66,272	719,823
North Carolina	84,448	115,271	318,930	90,180	105,612	387,029
North Dakota	18,682	15,986	48,059	18,973	16,086	47,904
Ohio	245,530	150,521	645,547	240,632	144,392	604,184
Oklahoma	245,775	45,583	422,353	240,851	43,191	389,462
Oregon	28,984	28,544	327,696	30,916	27,289	325,913
Pennsylvania	221,146	204,547	668,049	187,719	221,291	639,011
Rhode Island	18,801	8,674	64,172	16,958	9,031	62,776
South Carolina	30,625	26,265	105,710	24,094	35,143	106,719
South Dakota	11,147	25,263	46,637	10,874	23,854	44,714
Tennessee	41,680	62,522	206,307	49,780	56,389	202,364
Texas	441,079	307,610	2,864,885	419,957	307,402	2,742,591
Utah	15,570	19,735	81,421	10,833	13,201	66,165
Vermont	15,450	8,769	70,486	16,051	8,878	88,098
Virginia	31,825	14,961	724,532	31,250	13,768	697,963
Washington	618,229	323,983	1,070,543	377,556	307,079	1,000,759
West Virginia	27,701	32,308	209,570	25,529	33,789	205,981
Wisconsin	112,592	128,438	316,885	132,510	105,853	311,009
Wyoming	5,015	30,030	48,470	4,390	28,900	44,686
Total	8,162,778	4,697,953	644,520	7,697,683	4,787,496	22,137,908

SOURCE: Motor-fuel taxes and related receipts, Bureau of Transportation Statistics.

TABLE 4 *Continued*

1995			1994		
Automobiles (including taxicabs)	Trucks and Truck Tractors	Total Receipts	Automobiles (including taxicabs)	Trucks and Truck Tractors	Total Receipts
3,789	50,821	172,681	37,039	363	163,407
11,978	9,571	29,022	11,788	9,365	30,007
22,345	52,119	212,256	21,423	50,413	253,211
23,806	29,612	109,516	26,335	26,404	104,233
2,258,429	1,099,483	3,942,979	2,661,682	1,209,347	4,454,589
54,297	40,366	162,363	54,701	36,832	148,821
106,601	22,500	238,115	108,171	22,831	244,521
9,399	5,392	106,842	9,191	10,313	69,262
15,638	2,318	55,949	14,194	2,104	56,125
214,777	122,531	886,769	213,282	118,020	913,277
98,983	63,092	236,027	117,548	38,651	225,141
53,785	12,502	78,927	53,412	12,827	75,058
16,113	15,105	92,348	15,765	15,765	86,477
351,041	201,395	757,108	326,325	195,099	721,470
39,002	121,531	231,147	47,056	135,777	230,066
158,100	83,900	293,558	152,300	81,100	278,738
39,591	66,276	133,858	38,688	63,049	134,772
17,369	21,138	774,672	18,247	21,038	458,888
31,109	30,523	158,418	28,803	30,889	164,286
20,155	13,398	68,947	19,126	13,432	76,185
93,777	34,985	658,661	92,806	35,465	664,197
75,322	72,987	294,755	58,163	69,235	302,878
308,317	164,799	616,310	311,033	136,472	583,744
311,520	106,404	456,164	319,505	107,835	500,440
29,314	26,637	116,983	28,969	27,555	110,630
76,122	101,559	239,992	76,193	106,362	250,357
6,611	5,253	50,487	6,496	5,213	48,370
16,163	28,133	70,762	16,242	26,755	64,362
39,328	16,979	99,721	36,850	15,909	95,891
20,689	18,892	81,056	19,176	18,386	78,327
169,452	61,285	617,717	166,043	62,015	553,458
26,913	25,012	293,307	26,094	23,868	209,981
257,168	71,956	735,527	254,984	69,594	751,618
78,020	86,588	312,195	78,639	83,023	303,749
18,925	17,099	48,104	18,844	17,123	48,283
240,019	142,006	573,422	236,854	137,215	619,424
225,116	41,843	365,966	208,532	41,126	346,783
27,025	26,143	309,217	30,880	27,441	315,320
174,541	220,612	614,346	172,546	220,530	507,823
18,538	8,902	58,795	18,538	8,902	67,581
29,442	24,982	101,532	31,946	36,527	114,716
10,949	23,295	43,806	12,562	20,715	41,089
68,396	40,367	198,424	63,131	48,838	188,500
419,607	272,722	4,232,301	433,616	282,523	2,461,458
10,565	14,421	62,863	10,430	13,153	58,560
15,825	8,629	130,195	15,080	8,507	81,588
32,265	17,696	898,189	25,735	26,035	534,032
544,039	297,344	937,061	520,591	289,838	918,162
16,914	39,209	323,746	23,546	34,519	193,161
131,590	91,418	291,087	129,896	95,678	296,775
4,544	27,793	41,628	4,043	6,654	40,580
7,043,323	4,199,423	22,675,821	7,423,039	4,243,630	20,340,371

TABLE 5 Changes in Revenues from Vehicle Registrations

	1996–97			1995–96			1994–95		
	From Cars	From Trucks	Total Receipts	From Cars	From Trucks	Total Receipts	From Cars	From Trucks	Total Receipts
Alabama	0.09	0.32	–0.20	–0.05	–0.37	–0.03	–8.78	0.07	0.05
Alaska	0.01	–0.01	0.03	–0.01	0.00	0.06	0.02	0.02	–0.03
Arizona	0.00	0.03	0.05	0.03	0.16	0.14	0.04	0.03	–0.19
Arkansas	–0.09	0.47	–0.05	–0.02	0.03	0.09	–0.11	0.11	0.05
California	0.12	–0.11	0.04	0.19	0.29	0.21	–0.18	–0.10	–0.13
Colorado	0.02	0.07	0.04	0.16	0.24	0.20	–0.01	0.09	0.08
Connecticut	–4.30	–4.30	0.03	0.02	0.02	0.00	–0.01	–0.01	–0.03
Delaware	0.04	0.01	0.03	–0.02	–0.03	–0.53	0.02	–0.91	0.35
D.C.	–0.11	–0.11	–0.01	–0.09	–0.09	–0.01	0.09	0.09	0.00
Florida	0.03	0.03	0.01	0.07	0.04	0.05	0.01	0.04	–0.03
Georgia	0.23	–1.10	0.01	0.04	0.04	0.04	–0.19	0.39	0.05
Hawaii	0.02	–0.07	0.00	0.02	–0.01	0.05	0.01	–0.03	0.05
Idaho	0.24	0.18	0.09	0.01	0.00	0.02	0.02	–0.04	0.06
Illinois	–0.09	0.07	–0.02	0.00	–0.08	0.01	0.07	0.03	0.05
Indiana	0.01	0.02	0.03	0.02	0.01	0.02	–0.21	–0.12	0.00
Iowa	0.11	–0.02	0.05	0.03	0.04	0.04	0.04	0.03	0.05
Kansas	0.04	0.03	0.05	0.01	0.02	0.06	0.02	0.05	–0.01
Kentucky	0.00	0.03	0.03	0.05	0.04	–0.46	–0.05	0.00	0.41
Louisiana	–0.01	–0.03	–0.03	0.05	0.08	0.11	0.07	–0.01	–0.04
Maine	0.03	–0.05	–0.03	–0.01	0.04	0.12	0.05	0.00	–0.10
Maryland	0.04	0.00	0.02	0.02	0.01	0.06	0.01	–0.01	0.05
Mass.	0.07	0.03	0.10	–0.04	0.04	0.03	0.23	0.05	–0.03
Michigan	0.06	0.05	0.02	0.14	–0.09	0.09	–0.01	0.17	0.05
Minnesota	0.06	0.09	0.12	0.02	0.23	0.10	–0.03	–0.01	–0.10
Mississippi	0.02	0.00	0.00	0.02	0.02	0.07	0.01	–0.03	0.05
Missouri	–0.01	–0.02	0.00	0.02	0.04	0.06	0.00	–0.05	–0.04
Montana	–0.11	0.14	0.06	0.01	0.01	0.04	0.02	–0.01	0.04
Nebraska	0.14	–0.19	0.03	0.02	0.13	0.08	0.00	0.05	0.09
Nevada	0.05	0.05	0.16	0.08	0.08	0.09	0.06	0.06	0.04
New Hamp.	0.02	0.07	0.03	–0.01	0.04	0.02	0.07	0.03	0.03
New Jersey	0.04	–0.62	–0.07	0.02	–0.22	–0.04	0.02	–0.01	0.10
New Mexico	0.02	0.05	0.04	0.01	0.04	–0.41	0.03	0.05	0.28
New York	0.02	0.00	0.07	–0.13	–0.09	–0.02	0.01	0.03	–0.02
N. Carolina	–0.07	0.08	–0.21	0.13	0.18	0.19	–0.01	0.04	0.03
N. Dakota	–0.02	–0.01	0.00	0.00	–0.06	0.00	0.00	0.00	0.00
Ohio	0.02	0.04	0.06	0.00	0.02	0.05	0.01	0.03	–0.08
Oklahoma	0.02	0.05	0.08	0.07	0.03	0.06	0.07	0.02	0.05
Oregon	–0.07	0.04	0.01	0.13	0.04	0.05	–0.14	–0.05	–0.02
Pennsylvania	0.15	–0.08	0.04	0.07	0.00	0.04	0.01	0.00	0.01
Rhode Island	0.10	–0.04	0.02	–0.09	0.01	0.06	0.00	0.00	–0.15
S. Carolina	0.21	–0.34	–0.01	–0.22	0.29	0.05	–0.09	–0.46	–0.13
S. Dakota	0.02	0.06	0.04	–0.01	0.02	0.02	–0.15	0.11	0.06
Tennessee	–0.19	0.10	0.02	–0.37	0.28	0.02	0.08	–0.21	0.05
Texas	0.05	0.00	0.04	0.00	0.11	–0.54	–0.03	–0.04	0.42
Utah	0.30	0.23	0.19	0.03	0.05	0.05	0.01	0.09	0.07
Vermont	–0.04	–0.01	–0.25	0.01	0.03	–0.48	0.05	0.01	0.37
Virginia	0.02	0.08	0.04	–0.03	–0.29	–0.29	0.20	–0.47	0.41
Washington	0.07	0.05	0.07	0.06	0.03	0.04	0.04	0.03	0.04
West Virginia	0.08	–0.05	0.02	0.34	–0.16	–0.57	–0.39	0.12	0.40
Wisconsin	–0.18	0.18	0.02	0.01	0.14	0.06	0.01	–0.05	–0.02
Wyoming	0.12	0.04	0.08	–0.04	0.04	0.07	0.11	0.76	0.03

these developments for revenues generated by fuel taxes, it is important to identify the structure of the federal and each state's fuel tax, including whether the tax is levied on a value-added basis or as a fixed amount per gallon, as well as whether the state's general sales tax also applies to gasoline sales.

Calculating and Forecasting Fuel-Tax Revenues

Figure 2 displays the forecasting of automobile fuel efficiency. In calculating and forecasting total tax revenues likely to be generated by fuel purchases and usage, two variables are critically important: (*a*) total VMT by vehicles operating on each different type of fuel that is taxed, and (*b*) the average fuel efficiency of the fleet of vehicles operating on each different type of fuel. The fundamental accounting identity determining revenues from fuel taxation is

$$R \equiv \sum_i t_i \cdot G_i \qquad (1)$$

where

- R = total revenue from fuel taxes;
- t_i = the state tax rate on each particular type of fuel (gasoline, diesel, gasoline-alcohol blends, natural gas, etc.); and
- G_i = the (equivalent) number of gallons of each type of fuel subjected to taxation at sale.

Of the variables entering this identity, only the tax rates on different types of fuel (the values of t_i) are known with certainty; the number of gallons of each type of fuel subject to taxation (the values of G_i) must be forecast for each future period comprising the planning horizon.[8] In turn, the number of gallons of each type of fuel sold will be a function of total VMT by vehicles operating on that fuel type and their average fuel efficiency (expressed in miles per gallon, MPG, or gallon equivalent). The identity relating fuel sales to these variables is

$$G_i \equiv \text{VMT}_i \,/\, \text{MPG}_i \qquad (2)$$

In turn, however, both VMT_i and MPG_i will be influenced by other variables (some of which, such as the per-gallon price of fuel, may affect both VMT and MPG). Formally,

$$\text{VMT}_i = f(x') \qquad (3a)$$

$$\text{MPG}_i = g(x'') \qquad (3b)$$

Equations 3a and 3b simply show that VMT_i is a function of some vector of variables x', whereas average fuel efficiency of vehicles operating on that fuel (MPG_i) will

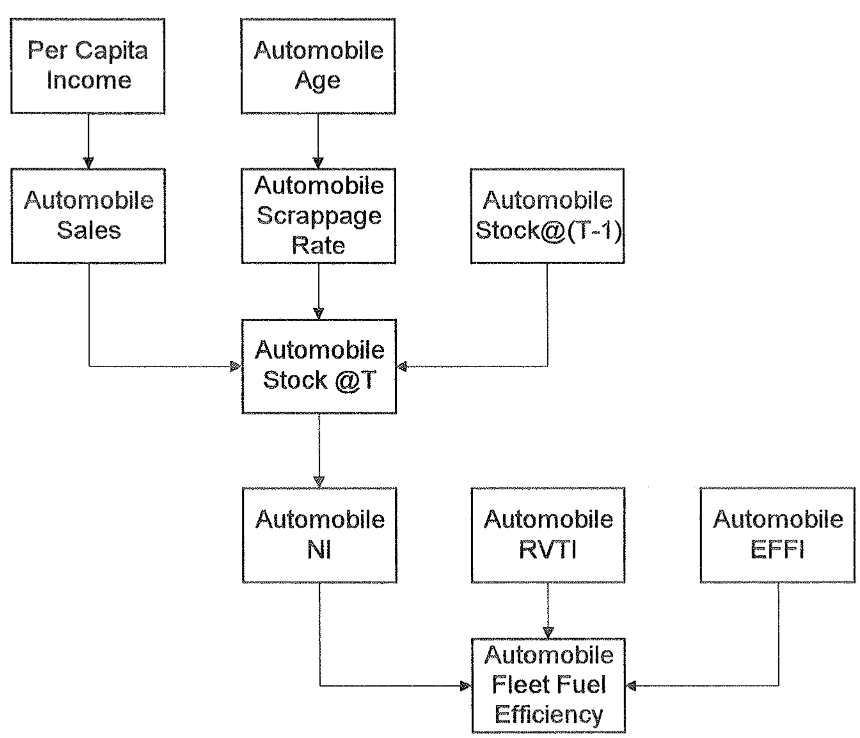

FIGURE 2 Forecasting automobile fuel efficiency. (Notes: NI is the proportion of automobile in *I*th age cohort; RVTI is the relative vehicle use by automobile in *I*th age cohort; and EFFI is the fuel efficiency of automobile in *I*th age cohort.)

be some function of another vector of variables x'', although these vectors may share some common variables. Therefore, total consumption of each type of fuel (G_i) also will depend on the variables that influence travel by vehicles using that fuel and their average efficiency:

$$G_i = h\left[\text{VMT}_i\left(x'\right), \text{MPG}_i\left(x''\right)\right] \tag{4}$$

(A more sophisticated model would consider whether different fuels are taxed at different rates, and it would incorporate the effect of differential taxation on the level of VMT recorded in vehicles operating on these different types of fuel.)

The value of this framework is that it makes clear that we need to understand the factors that influence the variables VMT_i and MPG_i, together with the form of their relationship to these two variables. Thus, the reliability with which revenues can be forecast depends, first, on the accuracy of available measures of the variables included in Equations 2 and 3 and, second, on our understanding of the relationships represented by Equation 3. Of equal importance will be the accuracy of models representing those relationships and on the reliability of available forecasts of the specific variables contained in x' and x''. Depending upon the state of information and knowledge in each of these areas, the most effective way to improve the reliability of revenue forecasts may entail improving measures of critical variables (or generating entirely new measures), developing more complete models of the relationships among them, or improving our ability to forecast the variables that influence travel behavior and vehicles' fuel efficiency—or a combination of these measures.

In the models for travel by vehicles operating on different fuels (VMT_i), shown above as Equation 3a, data on VMT usually are collected from state transportation departments. Economic and demographic variables that influence VMT (the elements of x' in Equation 3a) typically are obtained from departments dealing with economic activity and demographic information, such as state finance and commerce departments. Measures of each of these variables at the state level are required to develop a model suitable for estimating VMT. Analysts seeking to develop such models must distinguish between information that is available as continuing time series (typically monthly or annually) and information that is gathered by survey and is therefore only occasionally available, and they also must explore how these different types of data can be integrated and used. Another alternative is to explore the availability of cross-sectional data for substate geographic units (such as counties or municipalities), although the current state of cross-sectional VMT data within states appears to be crude.[9]

Measuring Fuel Use, VMT, and Fuel Efficiency

As Schipper (*3*) observes, the fact that fuel consumption, travel, and fuel efficiency are identically related according to Equation 1 means that measuring any two of those three variables enables us to estimate the third. However, reliable and continuous data are widely available only for consumption of different types of fuel—typically as a by-product of their taxation—so that either travel (VMT) by vehicles operating on each type of fuel or their average fuel efficiency (MPG) must be estimated in order to determine the third variable. (Two important caveats are that states typically do not estimate the distribution of sales of each type of fuel to different types of vehicles—for example, the distribution of gasoline sales among motorcycles, automobiles, and trucks—nor are they able to estimate reliably purchases of fuel within their borders for use in neighboring states.)

The procedure used by many states to estimate VMT is a "scaling" approach, in which year-to-year changes in loop-detector traffic counts are used to scale upward or downward an estimate of statewide VMT for the previous year; this procedure also is used often in short-term forecasting of VMT (typically within the current year). Many states operate statewide networks of loop detectors and permanent traffic counting stations, although these provide information on vehicle volumes—and thus indirectly on numbers of vehicle trips—and not on the distance or duration of the trips. Most states also have movable traffic counters that provide traffic counts in additional locations, but typically not on a continuous time-series basis. Many counties collect information on average daily traffic at permanent and some mobile sites. Although some employ these data in an attempt to measure total VMT, the resulting estimates are crude since vehicle counts alone convey no information on trip lengths and these sites tend to be located in older areas where development is mature and the level of growth of newer areas is rarely observed. As a result, there is widespread suspicion that these measures tend to underestimate growth in statewide VMT.

Using the sample of historical VMT data gathered on segments of different roadway types and locations, future VMT can be forecast using an econometric model that includes among its explanatory variables household or statewide income measures, fuel prices, and other important variables. Often such models are specified using a so-called "stock adjustment" framework, in which the previous year's value of the dependent variable, VMT, appears as an explanatory variable, since this often improves the performance of such models when used for forecasting. Where a state's historical time series of annual VMT data is too short to permit a reliable estimation of such a model's parameters, more frequent data (monthly or quarterly) can be used. This procedure requires that seasonal or other factors that vary by month or quarter also be included in the model, as well as monthly or quarterly estimates of the desired explanatory variables be available. Although it might be desirable to develop separate models for VMT recorded by vehicles operating on different fuels, historical data of this detail rarely are available. This generally results in forecasts of total VMT being "apportioned" among vehicles operating on different fuels using information on their relative representation in a state's registered fleet and any available estimates of how their average usage differs.

Another approach to estimating state-level VMT would be to use individual vehicles' odometer readings (Charles Lave of the University of California at Irvine has done some work in California), recorded in sequential years to develop estimates of average annual use per vehicle of different types. These data could be obtained from annual inspection programs, which many states conduct to verify the condition of vehicles' safety or emissions control equipment, or from odometer readings recorded at the time vehicles are registered in a state. The major complication with this procedure is that it also requires separate estimates of the number of vehicles of each type operating in the state throughout the year. This number can differ from the number registered or inspected because of resales, seasonal registration, selective exemptions from inspection programs, and other factors. Although this procedure appears to offer a promising alternative to VMT estimates based on annual fluctuations in traffic counts, it appears to have been attempted only experimentally to date.

The most common procedure for independently estimating the average fuel efficiency of the vehicle fleet (the variable MPG) is to develop a "vintaging" model of a state's vehicle fleet, similar to so-called cohort survival models used to forecast population growth. Developing such a model requires an age distribution of the vehicle fleet for some initial year, together with estimates of future new vehicle sales, the fraction of vehicles of each age or model year that will be retired from the fleet, the fuel efficiency of each model year represented in the fleet when it was new, and the rate at which fuel efficiency deteriorates with the passage of time. (An additional complication is that fuel efficiency ratings for new vehicles do not match their actual on-road performance, so the "gap" between these measures must be estimated.) This approach is illustrated below.

This discussion of data requirements for forecasting fuel-tax revenues and the procedures that commonly are used to estimate critical variables suggests two conclusions. First, the available estimates of state-level VMT probably are inadequate and require significant improvement in their reliability. California provides a good example of a state that measures VMT only in a limited number of locations and for a limited number of years, with estimates for the intervening years interpolated from values for the years in which VMT is measured. Similarly, local estimates of VMT are expanded to the entire state based on data collected on a relatively limited—and certainly older—part of the system. States need to invest more in collecting information on three attributes of VMT: the number of miles, the location of the miles, and the average trip length.

The second conclusion is that the models used to estimate travel and fleet fuel efficiency are relatively simple and essentially embody accounting rather than behavioral relationships. There are few linkages to variables other than aggregate income. Little or no attention is paid to the impact of different policies, for example, CAFE, on constituent variables such as fuel efficiency or VMT. Perhaps more significant is these models' general lack of responsiveness to changes in fuel tax rates or other components of transportation prices.

Are the Models Adequate?

The previous section focused on the accuracy of the data used to calculate the variables in developing revenue forecasting models. This section asks whether those models are structured in a way that adequately reflects the underlying economic and social influences on travel and fuel use and hence on fuel-tax revenues. The models used by most states to forecast travel and other variables affecting fuel-tax revenues appear to be accounting identities or simple statistical relationships predicting one of the components of revenues. They are simplistic and nonbehavioral. For example, in Indiana's revenue forecasting model, total VMT recorded by commercial vehicles (VMT_{COM}) is predicted from the number of combination truck tractors registered in the state (TT_{reg}) using the following equation:

$$VMT_{COM} = -1964.88 + 0.1077 \cdot TT_{reg} \quad (5)$$

In turn, a measure of the state's gross product (analogous to the gross domestic product, or GDP, at the national level) is used to forecast TT_{reg}. Aside from the apparent unreasonableness of the negative constant term in Equation 5, the model is not "causal," in the sense that it fails to include any variables likely to influence the usage of trucks within the state.

Similarly, the revenue forecasting model used by California's State Budget Office is a regression model with the previous year's consumption of fuel as its only "explanatory" variable. In other words, it is a simple trend model. The specific measure used by the model is gasoline consumption, and the model is used every two years to generate forecasts of fuel-tax revenues over a 7-year future horizon. (The state considered introducing a fuel efficiency variable in the model but decided against it because fuel efficiency was changing too much and it was not worth the extra effort, in their view!) One common but disturbing feature of such models is their implicit assumption that the demands for travel, vehicles, and fuel are not responsive to changes in social, demographic, and economic variables. This leads to the particularly troublesome implication that there is no response of fuel use to changes in fuel prices, either through the number and type of vehicles owned or the amount each one is driven; in economic terms, the demand for fuel is assumed to be perfectly inelastic. The penetration of sports utility vehicles (SUV) into the vehicle fleet over the past five years is a clear example of why such an approach is inadequate.

The argument can be made that there is some more or less general underlying behavioral model in which the long-run structure of transportation and fuel demand, hence fuel-tax revenues, is determined by a set of economic and demographic variables.

Vehicle use may exhibit a long-run trend, but households and businesses also adjust their use of available vehicles in the short term in response to their changing demands for travel. Over the longer run, however, they are likely to change the number of vehicles they own. Thus, one can think of households making decisions about the number and type of vehicles to purchase based on demographic considerations including family size, composition, and age structure as well as on economic factors such as their incomes and the prices of vehicles and fuel. At the same time, the household will make accompanying decisions about how much to use each vehicle in order to meet its members' collective demands for travel.

If fuel prices change—for example, if they increase—households are likely to alter the usage of each vehicle they own because the fuel efficiencies of those vehicles may not correspond to what the household would have purchased at higher fuel prices. (In economic terms, the household is in "disequilibrium.") On average, an increase in fuel prices would be expected to reduce the average number of miles driven by household members in the vehicles they own, thereby reducing the total number of vehicle miles they drive. With permanently higher fuel prices, however, the household may change the number or—more likely—the fuel efficiency of the vehicles it owns by selling one or more vehicles and possibly purchasing others. After it does so, the total number of vehicle miles it drives may return to a level closer to (although still below) what prevailed before the increase in fuel prices. As this example illustrates, the behavioral response to a change in any one of the variables ultimately determining fuel consumption and tax revenues may be quite complicated.

The "true" behavioral relationships of these intermediate variables to the underlying demographic and economic influences are complex, as illustrated by the ex- ample of changes in vehicle use in response to fuel price variation. Vehicle use is in turn only one of the determinants of total VMT (vehicle ownership, which also is quite complex, being the other). It would not be realistic for each state to try to model the entire behavioral system for forecasting purposes. What states probably need is some simplified model that captures the important behavioral responses but also "tracks" well for forecasting purposes. Therefore, one useful way to think about a model for forecasting is that demographic and economic variables affect fuel consumption through their influence on the intermediate variables that mathematically determine fuel consumption, namely VMT and vehicle fuel efficiency.

Reduced-Form Equation

A potentially useful approach is to estimate a "reduced form" equation for VMT that is derived from careful specification of the structural form.[10] Fuel efficiency can be modeled in the same way (econometric estimation of a reduced-form model), or we can do it "mechanically" using the cohort-survival approach. VMT would be the left-side variable and the right-side variables would be gross domestic product (GDP), price gas, and fuel efficiency. The price of gas/fuel efficiency would measure cost/mile. The right-side variables would come from state DOTs and other departments in the state government. Also included on the right side would be the degree of urbanization, per-capita road miles. Broad macro influences, household demographics, and location characteristics would be of interest as well. Building on these examples, states as well as the federal government could develop models that perform well in forecasting but also satisfactorily capture the critical responses to changes in fuel prices, tax rates, and fleet fuel efficiency (the SUV effect, for example). There are several examples of this approach in the literature (*4,5*).

As an illustration of the approach just described, Schimek (*5*) has estimated a time-series model of gasoline and travel demand. In the model, the per-capita demand for (highway) gasoline, G_H, would be a function of the price of fuel, P_F, and annual per-capita income, Y_t:

$$G_H = f\left(P_F, Y_t\right) \qquad (6)$$

However, gasoline demand can be decomposed into three key influences: the stock of vehicles, the fuel efficiency of the vehicle stock, and the usage of the vehicle stock. The systems of equations would be as follows:

- Vehicle ownership or stock equation: vehicles per capita = vehicle stock/population.
- Vehicle use equation: annual VMT/vehicle = total VMT/total gasoline consumption.
- Vehicle stock fuel efficiency: total VMT/total gasoline consumption.

From this system of three equations emerges the accounting identity, as we saw earlier, of

$$G = S/N \cdot D/S \div D/TG \tag{7}$$

where

S = vehicle stock,
N = population,
D = distance driven, and
TG = total gas consumption.

The value of the disaggregation is that by modeling the three factors separately, you are able to take account of the separate influences and the differences in adjustment periods for each of the factors. In effect, you can obtain more precise estimates of the parameters and hence more accurate forecasts.

Model components for gasoline demand are the following:

$$\text{Stock:} \quad S/N = f_S\left(P_F, Y_t, P_V\right) \tag{8}$$

$$\text{Efficiency:} \quad D/TG = f_E\left(P_F, Y_t, T\right) \tag{9}$$

$$\text{Usage:} \quad D/S_t = f_U\left(P_F, Y_t, S/N, D/TG, D74, D79\right) \tag{10}$$

where T is a time trend running from 1978 through 1994 used to control for the CAFE standards and $D74$ and $D79$ are dummy variables to control for gas-rationing years. These estimates are based on annual data for the entire United States from 1950 through 1994 inclusive. The model is estimated to control for the impact of the introduction of the CAFE, which turns out to be quite important. The long-run price elasticity of demand for gasoline was estimated to be −0.7, which is less than thought (−1.02), whereas the income elasticity is estimated to be 1.43. This latter estimate is similar to the previous literature.

Estimates also are available for the parameters of the three-equation model. In the stock equation, the fuel price elasticity is −0.14, in the VMT equation it is −0.26, and in the fuel efficiency equation it is 0.23. Therefore, a 1 percent decrease in real gas prices will increase vehicle holdings by 0.14 percent, increase VMT by 0.26 percent, and reduce the average fuel efficiency of the stock by 0.23 percent. Thus, this model indicates the long-run rebound effect may be as high as −0.3.

The impact of changes in income is measured in all three equations as well. The income elasticity of vehicle holdings is 1.14, of vehicle usage is 0.29, and of vehicle fuel efficiency is −0.06. Therefore, a 1 percent increase in real income will increase average vehicle holdings by 1.14 percent, increase vehicle use (measured in VMT) by .29 percent, and reduce average vehicle efficiency by 6 percent.

The importance of using models that are more sophisticated should be evident from these estimates. First, there are quite significant differences in the impact of prices on important variables that would be used to forecast revenues: usage, vehicle efficiency, and vehicle holdings.

Second, the models illustrate the relative importance of the economic variables and their influence on fuel consumption. Gasoline demand is more income than price elastic so if price/income trends continue, per-capita consumption of fuel will rise, as will tax revenues. The influence of income on fuel consumption occurs for the most part through vehicle ownership with a small effect on vehicle usage. Price affects fuel consumption through changes in fuel efficiency and reductions in VMT. Prices do not affect vehicle ownership to a significant degree, and the price effect on VMT is much greater than the price effect on fuel efficiency.

Third, it is possible to examine the impact of institutional, strategic, and policy changes on demand and hence on revenues. The introduction of CAFE standards has lead to a measurable long-run increase in driving associated with the reduced vehicle operating cost due to fuel efficiency standards. Do we need models that are more sophisticated? That is an open question, since on the one hand the disaggregation clearly shows some significant differences in the impacts on variables used in forecasting revenues, but on the other hand the parameters also exhibit significant long-term stability. So yes, we need better models, but we do not have to reestimate them every year or two. Perhaps the essential question is, what you are trying to forecast and why?

Suggested Modeling Approach

The argument has been made that the models now in use in many states are simplistic whereas in other states they are relatively sophisticated. The variance in modeling design and forecasting reliability is reasonably high. Perhaps it would be desirable to develop a generic forecasting model that could serve as the basis for all states to develop forecasts. States would have the opportunity to augment the basic model to meet their particular needs and circumstances. (FHWA takes information [forecasts] from these diverse set of models and aggregates it to yield nationwide measures.)

The gap between what is used now in the forecast of state revenues and what we have earlier argued is a desirable full structural model is large. To close this gap in a meaningful yet practical way, it may be prudent to proceed as follows: set out the full structural model to ensure the causal relationships are well understood, and then step down to a manageable reduced-form model. The manageability of the reduced-form model would be dictated to a significant degree by the availability of data. The gap between the structural and reduced-form model would provide information to states as to the types of data they should be collecting to augment their revenue forecasting models. (Estimating the reduced form might represent a reasonable compromise between what we do now, which is somewhat simplistic, and estimating the entire structural system, which is arguably too complicated for many states to manage.)

The structural model might take the form of estimating two relationships, the amount of travel (VMT) and the fuel efficiency of the fleet, and use an accounting identity for total fuel consumption. This would provide the requisite information to forecast fuel tax and registration fee and other fee revenues.

Total VMT is determined by a system with a structural form consisting of two equations and an accounting identity. The appropriate behavioral unit is probably the individual household, in which case the system determines annual VMT/household rather than total annual VMT, and we need another equation for the number of households. It also would require household-level data, which are difficult and expensive to come by. (One of the most difficult problems is the need for panel data to obtain enough cross-sectional variation in fuel and vehicle prices among households to identify coefficients on these variables.) Therefore, estimating the model using annual time-series data at the national or state level, rather than household-level data, could be done, albeit with some concerns for aggregation bias. The structural system could take the following form, where the subscript t indicates time periods:

$\left(\textit{Average vehicles/household}_t\right)$ = f_1 (average household size$_t$, fraction of total households of each type or composition$_t$, fraction at different stages in family "life cycle$_t$," average household income$_t$, fraction of households with different locations$_t$ [such as central city, suburban, or rural], vehicle prices$_t$, fuel price$_t$)

$\left(\textit{Average annual VMT/vehicle}_t\right)$ = f_2 (average household size$_t$, average household income$_t$, fuel price$_t$/average MPG$_t$, average vehicles/household$_t$)

$\left(\textit{Total annual VMT}\right)$ = average vehicles/household$_t$ · average annual VMT/vehicle$_t$ · number of households

The reduced form of this system would be

$\left(\textit{Total annual VMT}_t\right)$ = f_3 (average household size$_t$, fraction of total households of each type or composition$_t$, fraction at different stages in family "life cycle$_t$," average household income$_t$, fraction of households with different locations$_t$, vehicle prices$_t$, fuel price$_t$, average MPG$_t$)

States and the federal government could estimate this equation if the quality of the data measuring the dependent variable was improved. This assumes that the demographic, vehicle-price, and fuel-price data were adequate. The "forecasting behavior" of the model could be improved by using the lagged value of the dependent variable on the right side with the appropriate econometric corrections.

Fuel efficiency can be modeled analogously for the other determinant of fuel consumption. One possible structural form could be represented as

New MPG$_t$ = f_1 (income$_t$, fuel price$_t$, vehicle technology$_t$)

Fleet MPG$_t$ = f_2 (new MPG$_{t-1}$, new MPG$_{t-2}$, ..., new MPG$_{t-T}$)

where

new MPG$_t$ = the average fuel efficiency of new cars sold during year t,
income$_t$ = some measure of per-capita or household real income during year t,
fuel price$_t$ = the average retail price of fuel during year t,
vehicle technology$_t$ = some proxy for continuing progress in engine design (such as horsepower/cubic inch of engine displace), and
T = some arbitrary but reasonable upper limit on the lifetime of vehicles.[11]

Since all of the variables in new MPG$_{t-1}$, new MPG$_{t-2}$, and so on on the right-hand side are endogenous, the reduced form of this system would be

Fleet MPG$_t$ = f_3 (income$_t$, fuel price$_t$, vehicle technology$_t$)

Total fuel consumption is obtained by combining average MPG and adding the accounting identity:

Total annual fuel consumption$_t$ ≡ total annual VMT$_t$ · fleet average MPG$_t$

These three equations would produce a structural system for total fuel consumption. Since VMT and MPG have some explanatory variables in common, the reduced form of this system would not be more complicated that that for either of those two variables. Therefore, the reduced form could be represented as

$$\begin{pmatrix}\text{Total annual}\\ \text{fuel}\\ \text{consumption}\end{pmatrix} = f_1(\text{average household size}_t\text{, fraction of total households of each type orcomposition}_t\text{, fraction at different stages in family “life cycle}_t\text{,” average household income}_t\text{, fraction of households with different locations}_t\text{, vehicle price}_t\text{, fuel price}_t\text{, vehicle technology}_t)$$

In using this model, the states could forecast fuel tax revenues from the total annual fuel consumption. It would not even require improving the data on VMT and MPG, because it bypasses that stage, albeit at the cost of losing the ability to understand the behavioral response to changes in the explanatory variables.

Although the purpose of this paper is not to develop an alternative model for forecasting, proposing the alternative approach does suggest several research problems, which is what the paper ultimately is supposed to do. Three areas of potential research are

- Better measures of the relevant variables, including exploration of the use of household survey data (such as the Nationwide Personal Transportation Survey, or NPTS) or panel surveys to estimate household-level models;
- More insightful modeling of the "structural forms" that determine household automobile ownership and use, as well as the fuel efficiency of vehicles purchased by households; and
- Improved econometric techniques for estimating the reduced-form equations for total VMT (or VMT/household), fleet fuel efficiency, and total fuel consumption, using both annual time-series data at the national or state level and household cross-section or panel data.

Evolving Revenue Sources, Models, and Information Requirements

The traditional approach to highway finance and basing expenditures on the revenues raised within the system has led to the development of the present information base used in investment decisions and operations management. The use of conventional taxes and fees such as vehicle registration fees and fuel taxes provides the basis for designing forecasting models such as those described earlier. However, information needs may be changing as alternative financing instruments are developed and a more businesslike approach is taken in infrastructure management.

One important driver of the move to new fiscal instruments has been the unwillingness of states to increase fuel taxes. This reluctance is based partly on the growing revenues from the economy that has experienced high and sustained rates of growth. At the same time, there has been a shift to greater fiscal prudence and the unpopularity of any tax increases. There are other factors at work as well. The lack of investment in maintaining infrastructure over the past few decades has led to a call for reinvestment on a broad scale. (This is in addition to the argument that investments in public infrastructure will increase productivity.) This will require significant revenue. There is also a changing view of highway management, a shift from what used to be "needs" based to one in which benefits and costs are a critical part of the decision process. What is now required is information oriented to economic management rather than engineering operation and maintenance.

Financing new roads and facilities such as bridges and tollways has placed greater reliance on facility-based charges. "HOT lanes" and other examples of charging fees for the use of facilities have served to increase the awareness of this source of revenue. With increasing congestion in a number of the nation's cities and with the potential for using transportation demand management strategies for both congestion and pollution control, fuel taxes may be displaced or augmented by carbon-based taxes (6). In either case, the challenge of forecasting revenues is daunting because now the issue is setting the right price that will assure a desired outcome (level of traffic) rather than simply predicting revenues. In other words, price now becomes a signal for use and investment rather than a means of financing identified "needs." Furthermore, the problems of transportation finance change significantly as revenues either go to specific projects or are placed in the general revenue fund. In the latter case, transportation must compete with other demands (education, defense, health care) for this public capital.

In addition to tolls, states are pursuing a number of other innovative financing strategies. These have related to taking advantage of new provisions in federal highway funding programs. A number of states have undertaken to raise new funds in areas such as revolving trust funds, tax-supported toll roads, lease purchase agreements, fuel taxes indexed to the consumer price index, and public-private partnerships. If states maintain their current practice of setting expenditures equal to revenues and prioritizing projects until the money runs out, the new sources of revenues will place quite different demands on the forecasting models and therefore the information base. If states take a more economically efficient approach to transportation planning whereby they evaluate projects on their economic merit and set taxes and fees to fund what are economically desirable projects, new models and different information will be needed.

The current system appears to be well entrenched, yet a number of forces are pushing in the direction of different financing approaches, different management philosophies, and consequently, different information needs. If we believe these changes are more than a short-term aberration, we need to ask what models will be needed and what will be the type of information required in these models for forecasting revenues.

SUMMARY AND PROPOSED RESEARCH STATEMENTS

The paper takes an evolutionary approach to the examination of information requirements for forecasting revenues for state highway departments. Two primary attributes are data accuracy and data availability. Looking at the current set of models, we can ask, are the data used accurate and how might they be improved? How would this be accomplished? Next we ask the question, setting aside the issue of data accuracy, are the models that are presently in use correct and if not, how should they be modified? How will these changes alter the data requirements and who will assume responsibility for this? Finally, we ask, with the new and innovative financing methods available under TEA-21 and given the reluctance on the part of states to increase taxes and fees, what information is needed to forecast revenues when there is a portfolio of financing instruments? These questions can be formalized into the following research statements.

Improving Estimates of State-Level VMT

Description of Research Problem

Available estimates of state-level VMT are inadequate and require significant improvement in their reliability. A number of states measure VMT only in a limited number of locations and for a limited number of years, with estimates for the intervening years interpolated from values for the years in which VMT is measured. Similarly, local estimates of VMT are expanded to the entire state based on data collected on a relatively limited—and certainly older—part of the system. States need to invest more in collecting information on three attributes of VMT: the number of miles, the location of the miles, and the average trip length.

Work To Be Performed

VMT estimates can be obtained from three sources: surveillance, household surveys, and odometer readings. The research would involve activities in all three areas. There is an increasing number of modern surveillance techniques and surveillance locations; freeways are equipped with cameras, for example. This research would explore alternative technologies for collecting data. They would be evaluated in terms of cost and accuracy, and once a technology is selected, a time series of data of VMT including trip length and vehicle counts would be collected. The second source of improving VMT is household surveys. Total VMT can be obtained from the current Nationwide Personal Transportation Study (NPTS) by combining information from different files. It also is possible for urban areas (and perhaps states) to use the NPTS to obtain more detailed information at the subnational level by increasing the sample size in a given area. These survey data would yield information on household behavior. The third source for VMT information is odometer data. Odometer data can be collected in those states that inspect vehicles on an annual basis. From this source, it is possible to construct a data set that has VMT by number, age, and type of vehicle. The unit of observation would be the vehicle.

This research project would provide improved VMT data from three sources. It would identify the approach that is cost-effective yet maintains data quality. It would provide a basis of comparison across methods. Finally, it would have different behavioral units from the three sources and this would flow naturally into the improved modeling project discussed below.

Cost Estimate: $600,000

Developing a Generic Starting-Point Model for Forecasting State Revenues

Description of Research Problem

The argument has been made that the models now in use in many states are simplistic whereas in other states they are relatively sophisticated. The variance in modeling design and forecasting reliability is reasonably high. Perhaps it would be desirable to develop a generic forecasting model that could serve as the basis for all states to develop forecasts. States would have the opportunity to augment the basic model to meet their particular needs and circumstances.

Work To Be Performed

The gap between what is used now in the forecast of state revenues and what we have earlier argued is a desirable full structural model is large. To close this gap in a meaningful yet practical way, it may be prudent to proceed as follows: set out the full structural model to ensure the causal relationships are well understood, and then step down to a manageable reduced-form model. The manageability of the reduced-form model would be dictated to a significant degree by the availability of data. The gap between the structural and reduced-form model would provide information to states as to the types of data they should be collecting to augment their revenue forecasting models.

The structural model might take the form of estimating two relationships, the amount of travel (VMT) and the fuel efficiency of the fleet, and use an accounting identity for total fuel consumption. This would provide the requisite information to forecast fuel tax and registration fee and other fee revenues. The appropriate behavioral unit is probably the individual household, in which case the system determines annual VMT/household rather than total annual VMT. It also would require household-level data, which are difficult and expensive to come by. Therefore, estimating the model using annual time-series data at the national or state level, rather than household-level data, could be done, albeit with some concerns for aggregation bias. The model could be estimated on national data and then provided to each state, which could re-estimate the model if so desired, or the parameter estimates for the national-level model could be used to forecast revenues.

Cost Estimate: $400,000

Developing a Model of Commercial-Vehicle VMT

Description of Research Problem

The research into structural models of VMT for light vehicles has not carried over into commercial-vehicle VMT. We need a better understanding of how trucking, both private and for hire, is used by different industries. We find, for example, that VMT between Canada and the United States has increased since the North American Free Trade Agreement was signed. A major source of this VMT are industries specializing according to their competitive advantage and industries adopting strategies that place specific product production in specific locations (e.g., the automobile sector). As economic activity shifts between countries and among states, we can expect more truck VMT, but it also may involve significant redistribution of activity. Trucking registration fees present another set of challenges for forecasting since regulations governing registration can lead to gaming behavior by trucking firms. As rules change, forecasting becomes more difficult.

Work To Be Performed

This project would develop a model of truck use at the firm level to provide estimates of both the number of vehicles as well as the use of vehicles in the private trucking segment. A second model would examine two issues: the decision to use for-hire rather than private trucking and the amount of for-hire trucking to use. An integral part of this modeling effort is to develop an understanding of how different industries use more or less trucking and how the distribution of economic activity affects the level of VMT.

Cost Estimate: $700,000

Examining the Highway Finance Implications of Alternative Revenue Instruments

Description of Research Problem

The traditional approach to highway finance has led to the development of the present information base used in investment decisions and operations management. The use of conventional taxes and fees such as vehicle registration fees and fuel taxes provides the basis for designing current forecasting models. However, information needs may be changing as alternative financing instruments are developed and a more businesslike approach is taken in infrastructure management. States' legislators also are enabling local governments to earmark funds for specific purposes. Revenue streams also are being tied to specific investment projects. There is a need to explore the implications of changes in methods of financing transportation projects for the institutional relationships, forecasting approaches, and informational requirements. For example, if a broad-based carbon or energy tax were adopted, revenues would flow into a general revenue fund rather than be earmarked for transportation purposes. Highways, transit, and other modes of transportation would compete with other government demands for funding.

Work To Be Performed

The project would examine the jurisdictional, financial, and economic consequences and the information demands of three changes to revenue sources: (*a*) the movement to allow local governments to use traditional revenue sources to fund specific projects (e.g. bonds, sales taxes); (*b*) the movement away from fuel taxes and to economy-wide carbon or energy taxes; and (*c*) the move to rely more heavily on road tolls and road pricing. The purpose of this research is to explore the far-reaching implications of changes in the structure of highway finance.

Cost Estimate: $350,000

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Notes

1. The financial burden also was to be transferred away from general revenue financing toward user financing to "the maximum extent practicable." Thus, states and municipalities were to take a hard look at their existing fiscal arrangements and increase the amount that they captured from user charges or taxes on those facilities. Private-sector investment was to be partnered. The level of government and legal impediments, constraints, and distortions was to be removed, or reduced, to facilitate the implementation of the new policy.

2. The prevailing view of highway finance was practical as well as conceptual. The ownership and use of automobiles could be taxed easily and cheaply. Furthermore, the benefits of a well-developed road system were not simply local in nature, so neither should the responsibility for financing it remain strictly local.

3. By 1986, diesel fuel was taxed by all of the states. In some states, contrary to economic efficiency, diesel fuel is taxed at a higher rate than gasoline mainly because of the greater fuel efficiency achieved by diesel-powered vehicles.

4. Two organizations, the International Fuel Tax Association (IFTA) and International Registration Permits (IRP), are involved in redistributing tax revenue among states. Trucks pay fuel where it is burned, not where they bought it. They must report to IFTA the mileage in each state and pay those states on a pro-rata basis according to where they traveled. Fee payments for registration are handled in a similar fashion. Trucking firms report for each truck where it traveled and redistribute payments, through IRP, for using trucks in a different area than the state in which they are registered.

5. This practice has a number of drawbacks. These include exposure to financial market risk, a wide variance in individual states' credit ratings, and exposure to political risk due to the potential of legislators to support bond financing only for projects that clearly benefit their own constituents.

6. This can be viewed as the curse of the "needs" approach to transportation planning and highway expenditure. The current practice is to have revenues determine the capital program. Projects will be undertaken until revenues run out, and this is what makes the reliability of revenue forecasting so critical. The alternative is to develop a capital program based on some objective function and set taxes and fee levels to generate sufficient revenues to undertake the economically efficient projects.

7. Even this is not quite true, as illustrated in Table 1.

8. A similar identity would hold for revenue from registrations—with the G_i replaced by the number of vehicles of each class that are registered, and similar problems of information adequacy applying.

9. The question is, do states have decent data with some precision on VMT at the statewide level? FHWA has had a project over the past 10 years aimed at improving these data, since it uses these state data to predict the revenue accruing to the federal government.

10. Most existing models have assumed that the three components of demand (automobile ownership, VMT, and fuel efficiency) are determined simultaneously and have estimated the equations for each in their reduced form.

11. In the Fleet MPG equation, f_2 probably would be some sort of distributed-lag function. Thus, the parameter estimates on new MPG_{t-1}, new MPG_{t-2}, and so on would subsume several variables for which there *could* be explicit structural form equations, including the gap between test and on-road MPG, deterioration in vehicles' MPG with age and accumulated mileage, and so forth.

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APPENDIX A

Steering Committee Biographical Information and Committee Liaisons

William R. Black is a professor of geography and public and environmental affairs at Indiana University in Bloomington, where he teaches in the areas of transport planning and modeling and environmental impact analysis. He also served as a member of the Activation Task Force of the Consolidated Rail Corporation and as director of the Indiana Department of Transportation. He has directed 20 research projects covering all of the major transport modes, and he has presented or published more than 100 research papers and reports. He currently serves on one TRB task force and three TRB committees. He is chairman of the TRB Committee on Social and Economic Factors in Transportation.

Daniel Brand is vice president of Charles River Associates, Inc. (CRA). He is responsible for CRA's work in urban and intercity transportation. This work includes consulting on the planning, financing, and implementation of transportation facilities, including highway and transit travel demand/revenue forecasting and operations analyses, intelligent transportation systems high-speed rail, magnetic levitation and other new transportation technology studies, and transportation policy and pricing studies. Prior to joining CRA, Mr. Brand served as undersecretary of the Massachusetts Department of Transportation, associate professor of city planning at Harvard University, and a lecturer in the Massachusetts Institute of Technology Civil Engineering Department. Mr. Brand is the founding chairman and a current member of the TRB Intelligent Transportation Systems Committee.

Randall W. Eberts is executive director of the W. E. Upjohn Institute for Employment Research. Previously he served as an assistant vice president and economist at the Federal Reserve Bank of Cleveland. Dr. Eberts's current research centers on urban labor markets, determinants and dynamics of job creation and destruction, and the relationship between public infrastructure and economic development.

David J. Forkenbrock, cochairman of the Steering Committee, is director of the Public Policy Center of the University of Iowa. He is also professor of urban and regional planning at the university. He has conducted research, published, and spoken widely on many topics related to transportation economics and finance. Dr. Forkenbrock recently investigated the financing and revenue aspects of intelligent transportation systems.

Terry L. Gotts is the administrator of the Intermodal Policy Division of the Michigan Department of Transportation. As such, he guides the analysis and formulation of department federal and state policy and legislation in the areas of funding and economics, border crossings and international trade, passenger and freight transportation, motor carrier issues, the environment, and intelligent transportation systems.

Christopher R. Mann is the technical coordinator for programming and finance in the transportation program area for the Southeast Michigan Council of Governments in Detroit. He is directly responsible for all transportation project programming and finance. In this assignment, Mr. Mann is a liaison with the Federal Highway Administration, the Michigan Department of Transportation, and all regional, county, and local governments in acquiring and spending federal transportation funds for improvements to the transportation system.

Abigail McKenzie is director of economic analysis for the Minnesota Department of Transportation. She joined MnDOT in 1995 to lead economic analysis of transportation investments. Prior to joining MnDOT, Ms. McKenzie was director of information and analysis for the Minnesota Department of Trade and Economic Development for 11 years. Ms. McKenzie holds a master's degree in public policy from the University of Michigan. She is a member of St. Paul's Business Review Council, the TRB Economics Committee, the Economy Council of the University of Minnesota Center for Transportation Studies, and the State's Economic Resource Group.

Alan E. Pisarski, cochairman of the Steering Committee, is a consultant in private practice. His specialties include transportation policy, travel behavior analysis and statistics, and tourism. Previously he held several positions within the Office of the Secretary of Transportation. He has chaired four TRB committees and currently serves as chairman of the Committee on National Transportation Data Requirements and Programs and the Transportation History Task Force.

Anthony M. Rufolo is a professor of urban studies and planning at Portland State University, where he specializes in state and local finance, transportation, urban economics, and regional economic development. Prior to joining the faculty at Portland State in 1980, he was a senior economist with the Federal Reserve Bank of Philadelphia.

David W. Stropes is general director of costs and profitability for Burlington Northern Santa Fe Railway (BNSF). He is responsible for analysis of revenues, costs, and profitability of BNSF's business. He also is responsible for providing economic forecasts and market share data. This work includes developing activity-based systems and models used to determine the costs of providing transportation services, measuring the returns on investments in rail infrastructure, performing analyses used to prioritize BNSF's capital investments, and developing forecasts of demand for rail transportation services.

James P. Toohey is assistant secretary for planning and programming for the Washington State Department of Transportation. In this role, he is in charge of transportation planning and project programming for the department, and he also is responsible for research, economic analysis, and transportation data collection and analysis. Prior to joining the Washington State DOT, Mr. Toohey was employed by a national accounting firm. He currently serves on the State of Washington Land Use Study Commission. Mr. Toohey also participates on the AASHTO Standing Committee on Planning and has served on a number of TRB committees and advisory panels including the Statewide Transportation Planning Committee and the NCHRP Project Panel on Economic Implications of Congestion.

The Steering Committee for this conference enjoyed support from the following six liaisons to the committee:

Susan Binder, Federal Highway Administration, U.S. Department of Transportation.

Deborah Buchacz, American Association of State Highway and Transportation Officials.

Christopher Kubik, Indiana Department of Transportation.

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APPENDIX B

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