CAMBRIDGE SYSTEMATICS

Best Practice Methodology for Calculating Return on Investment for Transportation Programs and Projects

NCHRP Report 8-36, Task 62

final

report

prepared for

National Cooperative Highway Research Program: 8-36 Research for the AASHTO Standing Committee on Planning

prepared by

Cambridge Systematics, Inc.

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Economic Development Research Group

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Introduction

Despite developments in the analytical tools, data, and methodologies available to evaluate transportation projects and programs, transportation-based return on investment (ROI) analyses are undertaken using a wide range of variables, methodologies, models, and perspectives. The ultimate choice in these important ROI assessments is how to best to define the costs and benefits of potential projects and programs. As carefully explained in a recent Federal Highway Administration (FHWA) publication, benefit/cost analysis typically includes a fairly narrow range of benefit concepts related to project completion: user benefits (travel time, operating cost, crashes) and environmental effects (emissions, noise).[1] Further, the available literature does not provide consideration of public-private partnerships, and thus the differing perspectives of the private and public sector when prioritizing transportation investments.

The purpose of this report, therefore, is to develop best practice methodology for calculating ROI for transportation programs and projects. The emphasis here is to investigate a more comprehensive set of factors and impacts to include within ROI analysis. For example, agencies commonly refer to the potential for transportation improvements to improve travel time reliability and enhance economic development; however, these impacts are often not included within economic analyses. A second point of emphasis within this report is to discuss and clarify the public- and private-sector perspectives on how to evaluate transportation investment decisions. For example, for a 100-percent publicly funded investment, ROI analysis is essentially identical to benefit/cost analysis, incorporating benefit concepts that do not directly result in a revenue stream. The private-sector perspective, on the other hand, is almost exclusively focused on the revenue-generating potential of transportation investments and related user fees, tolls, and other revenue capture techniques.

Ultimately, this report identifies existing best practices and develops recommendations for the development of new standards to provide guidance for the standardization of the processes by which these analyses are conducted. This research focuses on addressing the challenges of incorporating the four major concepts of: 1) life-cycle costs, 2) travel-time reliability, 3) economic development and growth, and 4) public-private partnerships into ROI evaluations for transportation projects.

Traditionally, ROI is considered a standard analysis a business would undertake to internally evaluate capital investment decisions. Nevertheless, ROI and

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[1] "Economic Analysis Primer," U.S. Department of Transportation, Federal Highway Administration, Office of Asset Management, August 2003.

benefit/cost analyses have now come to mean a variety of related, but often different, concepts depending on measurement, perspective, and objective. As a result, standardization of methodology for calculating and including public ROI in transportation program and project analyses is needed.

CONCEPTS

The four specific concepts considered in the report are:

1. **Life-Cycle Cost Analysis (LCCA)** measures a project's total costs over time, including operations, maintenance, and reconstruction/re-surfacing. The dimensions of this concept can vary by mode, depending if the analysis is for highway or transit projects; and must account for initial and future agency costs, as well as measures of risk. Agencies have made significant progress in incorporating individual aspects of LCCA into larger evaluations and examples of best practices exist.
2. **Travel Time Reliability** is increasingly recognized as an important measure of the costs that congestion imposes on travelers, but has not yet been widely used in economic analyses of transportation programs and projects. The increase in just-in-time manufacturing processes and complex supply chain networks highlights the value of travel time reliability to businesses, in addition to commuters and personal travel. Agencies are increasingly interested in using and improving the accuracy of this measure as it becomes more widespread, because reliability is often a critical benefit and may even be valued greater than traditional travel time savings.
3. **Economic Development and Growth** refers to measures of a regional economy, most commonly jobs and income. Most current economic impact practices apply direct transportation cost savings effects to an economic model to capture economic development benefits to industries and individuals. Increasingly, agencies are interested in developing approaches to incorporating additional benefits and impacts. This requires further understanding of the actual impacts, benefits, and costs of economic development, and how these benefits can be incorporated within ROI analysis without double-counting other monetized travel benefits.
4. **Public-Private Partnerships (PPPs)** are financing structures that have garnered enthusiasm in the transportation community as a method to supplement more traditional funding sources. The range and complexity of these models introduce considerable challenges to effectively incorporate both private- and public-sector decision criteria into policy-making. Consistent methods for establishing comprehensive evaluations of the advantages and disadvantages of including the private sector in any transportation project are needed.

Considerable current or recent transportation-related research exists in each of these areas, representing important innovations in ROI analysis, yet many practices have not been widely implemented, consistently applied, or systematically documented. While each of the four topics above is presented in individual sections, all are discussed in the framework of the following three tasks.

1. **Review of Current Techniques and Methodology.** For each broad topic, a background is given on its exposure in existing analytical frameworks and common application as related to ROI analysis. Also detailed are examples of existing tools, data, and methodologies used to measure these concepts, as well as examples of best practices of their use in ROI assessments.
2. **Identify Gaps in Available Data and Methodology.** Despite the growth in research on the inclusion of these concepts within innovative approaches to ROI and benefit/cost analyses, there inevitably exist gaps in the data and methodologies. Instances in which data and methodologies are not commonly available are expensive to acquire, or simply require future research or additional data collection, are highlighted. As appropriate, this report attempts to note any performance measures or impacts that have received mixed treatment in terms of their inclusion in ROI analyses, and begin to suggest best practices for analysts and practitioners.
3. **Provide Recommendations on Criteria and Concepts for ROI Analysis.** This report includes detailed suggestions on how best to utilize and incorporate traditional benefit/cost and decision-making indicators within a more comprehensive ROI analysis framework. The report seeks to provide guidance on if, when, and how to include the four concepts discussed here within ROI analysis. Each concept represents innovative approaches to create a more comprehensive analysis of the benefits and costs of transportation.2

PUBLIC AND PRIVATE RETURN ON INVESTMENT

The term ROI, while originating as a private-sector financial measurement tool, is increasingly being used by the public sector. ROI has a precise definition for private firms, but when applied to public-sector transportation investments, has different meanings among practitioners, transportation users, investors, politicians, and other stakeholders.

In private-sector applications, ROI measures how effectively a firm uses its capital to generate profit and revenue, or the rate of return on profits. For any given use of money, ROI measures the tangible level of business income generated by

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[2] Traditional benefit/cost and ROI analysis for transportation includes user benefits (time, cost, safety) for travelers and select environmental effects (air quality, noise), along with capital and operations and maintenance (O&M) costs. Methods to estimate these effects are well-covered in the literature and perhaps best described in *A Manual of User Benefit Analysis for Highways*, Second Edition, 2003, American Association of State Highway and Transportation Officials.

the investment. An ROI calculation is sometimes used along with other approaches to develop a business case for a given investment proposal.

For public-sector applications, a project or program's ROI is best understood as a benefit/cost calculation. Informally, ROI is often presented as "for every $1.00 of investment in transportation project X, the state (or nation) receives $Y in benefits," which is simply the benefit/cost ratio. More formally, the ROI equals the discount rate at which the present value of its entire life-cycle costs is equal to the present value of its stream of benefits (also known as the internal rate of return). Since benefits typically accrue after an initial investment, the larger the benefits, the higher the discount rate (ROI) needed to balance costs and benefits.

The first challenge presented in defining public-sector ROI as such is how inclusive are the estimates of project benefits? Standard transportation benefit/cost analysis includes investment costs (along with operating and maintenance costs); user benefits (e.g., changes in vehicle operating costs, accident costs, average travel time delay costs); and, societal benefits (e.g., environmental, air quality, and noise impacts).

Increasingly analysts are including life-cycle costs assessments as a project's true total costs, as well as broader benefit measures such as travel time reliability impacts (e.g., reduction in nonrecurrent delay); network-level user benefits (e.g., increased capacity on one road segment may decrease demand on others); other societal benefits (e.g., economic development); and the tradeoffs of partnering with private-sector entities (e.g., public-private partnerships) in ROI analysis frameworks.

The second challenge and major difference between private- and public-sector ROI calculations is that a significant amount of the benefits measured by the public sector comprise nonmonetary value that cannot be considered revenue for the public agency. Even for a tolling project led by the public sector, for example, the consumer surplus (e.g., travel time savings) may contribute a significant proportion of the benefit, but would not be considered by a private firm or investors as part of the revenue stream they would use to calculate its ROI (instead they would simply focus on the projected future stream of toll revenue).3 This disparity has led to the public sector use of benefit/cost analysis and the private sector use of ROI for evaluation, although the terms are sometimes used interchangeably.

Recent developments in the use of private-public partnerships for transportation have begun to outpace the public sector's reliance on traditional benefit/cost analysis, forcing consideration of the value of tolling and congestion pricing to

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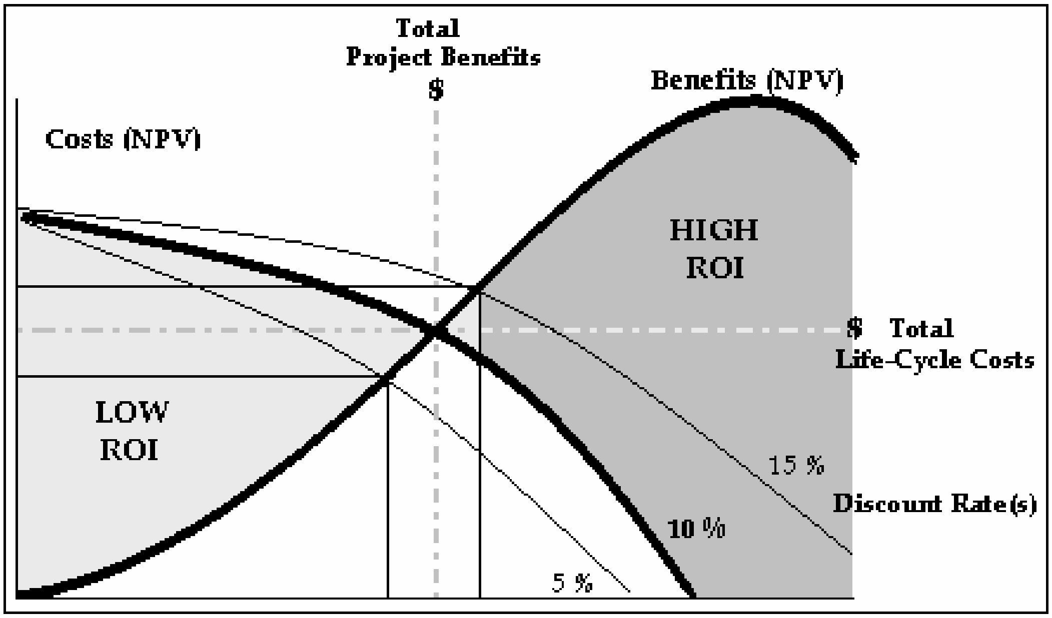
[3] Consumers' surplus is the difference between the price consumers are willing to pay (or reservation price) and the actual price. If someone is willing to pay more than the actual price, their benefit in a transaction is how much they saved when they did not pay that price. The difference between the two prices is the consumer surplus.

the public sector. For transportation projects that generate a revenue stream, ROI can demonstrate the degree to which project costs may be funded through project revenues and how large a public subsidy must be used to fund the remaining costs.

Figure I.1 Theoretical Illustration of ROI



TOWARD A MULTIFACETED FRAMEWORK

This report does not attempt to provide a single framework for today's ROI analyses, but rather seeks to move towards a multifaceted framework. It is particularly important to recognize the roles of life-cycle cost assessments, reliability, economic development, and public-private considerations in ROI analysis, for these elements all raise issues of *who* is benefiting from transportation investments. While reliability improvements are measured as traveler impacts occurring within a given area, its beneficiaries may be employers or suppliers located elsewhere. The economic development perspective also raises distinctions between positive impacts on local communities and net benefits to broader constituencies. From the viewpoint of PPP, there are also key distinctions between net public benefit and net private financial return.

In all of these cases, it is important to understand the nature of these distinctions in calculating appropriate ROI measures. There is no single societal ROI measure that is fully appropriate across all relevant constituencies. However, there can be a single framework that encompasses multiple forms of ROI measurement as appropriate for addressing the perspectives of public agencies, the private sector, and geographic-based jurisdictional stakeholders.

Table I.1 below presents a summary of recommendations and strategies for how to include each of the four central topics (LCCA, reliability, economic development, and PPP) within ROI analysis. In some cases, specific data sets or models are available to incorporate these effects within a more comprehensive ROI analysis.

Table I.1 Summary of Recommended Guidance for ROI Analysis

	Recommendations	Strategies/Concepts	Models/Data (As Appropriate)
Life-Cycle Cost Analysis	Improve initial capital cost estimates	• Develop cost templates for initial and future agency costs	Ministry of Transportation of Ontario: initial basic unit cost templates
		• Refine cost estimates through planning, design, and engineering stages	Ministry of Transportation of Ontario: more detailed templates
		• Develop consistent set of unit costs across geographies and facility types	
	Improve future O&M and reconstruction cost estimates	• Develop cost templates for rehabilitation and reconstruction	
		• Relate future costs to asset age	
		• Use existing models to estimate future costs	HERS-ST, PONTIS
	Incorporate cost uncertainty	• Use a threshold (e.g., $20 million) to determine when detailed analysis is warranted	Washington State Department of Transportation's (DOT) Cost Estimate Validation Process (CEVP)
		• Identify individual risk elements and uncertainty to develop range of cost estimates	90 technical, external, environmental, organizational, project management, right-of-way, construction, and regulatory risks
Travel-Time Reliability	Use Buffer Index concept to estimate reliability benefits	• Estimate reliability using relationship of travel congestion and variability found in national studies	Travel time under congested and free-flow conditions
		• Reliability defined as additional planning time to ensure on-time arrival 95% of the time	Ideally, use local/facility-specific data on variance of travel time

	Recommendations	Strategies/Concepts	Models/Data (As Appropriate)
Economic Development	Include measures of net economic development	• Gross Regional Product (value-added) or personal income economic impacts	Regional economic simulation models (e.g., REMI, TREDIS, Global Insight, REDYN)
		• Avoid double-counting other benefits and do NOT include impacts from construction or O&M costs	
		• Geographic and/or jurisdictional perspective matters – investment may create economic development benefits in local/regional or state markets	
Public-Private Partnerships	Public and private perspective on ROI differs	• Public-sector perspective is broader, incorporating nonfinancial returns; private-sector perspective is focused on expected revenue compared to cost	Benefit/cost analysis for public sector; internal rate of return for private sector
	Increase use of risk analysis	• Similar to the private sector, public agencies should more explicitly account for risk in terms of project delivery, revenue generation, etc.	
	Carefully distinguish between public, private, and societal benefits and costs	• Employ a multifaceted framework to assess the relative benefits from multiple perspectives	

1.0 Life-Cycle Cost Analysis

1.1 INTRODUCTION

This section evaluates the available methodologies for calculating agency life-cycle costs for transportation projects. Typically these methodologies have been defined through software tools and/or guides for performing life-cycle cost analysis (LCCA) or benefit/cost analysis (BCA). This review is broken down along the three major components of these analyses.

1. **Estimating initial agency costs.** Initial costs represent the cost of all activities up to the time that construction is complete. They include the costs of project development, land acquisition, and construction.
2. **Estimating future agency costs.** Future costs represent the cost of all activities on an asset after construction is complete. They include the costs of maintenance, rehabilitation, and reconstruction.
3. **Accounting for cost uncertainty.** Capital transportation projects are often inherently risky due to their size and level of complexity. Accounting for this uncertainty in LCC analysis helps ensure that the cost estimates are in line with actual costs, and that investment decisions are made based on valid estimates.

This section provides an introduction to the state of LCCA analysis today; summarizes the concepts and components; and reviews available tools and current approaches to estimating initial agency costs, future agency costs, and uncertainty in future costs. In addition, common gaps are identified in the estimation of agency costs and uncertainty. Recommended approaches for filling those gaps are discussed and the data required for each approach identified. Finally, recommendations for ROI evaluation in the three main areas of life-cycle cost analysis attempt to address a major gap in the state of the practice in LCC analysis; namely, the lack of a systematic process for efficiently and consistently estimating costs for a large number of projects.

1.2 OVERVIEW OF LIFE-CYCLE COST ANALYSIS

Agency costs are an important component of the ROI of transportation projects, and calculations usually include some estimate of the agency's cost in constructing a project. In addition, when project proponents or opponents refer to the cost of a transportation investment, they most typically refer to the initial capital cost calculation. However, such calculations should ideally include the full set of costs incurred by an agency over the life of a project, the "life-cycle cost." Since ROI analysis considers a multiyear stream of benefits after project construction, it should also include a multiyear consideration of costs. Given the prevalence of construction cost inflation nationally, increased attention is now being focused on estimates of the full range of project costs or life-cycle costs.

The primary dimensions of life-cycle cost analysis that should be included within ROI include the following:

- Initial capital/construction costs;
- Annual operating and maintenance costs;
- The expected life of the project;
- Resurfacing and reconstruction; and
- Construction escalation factors.

In addition, costing techniques can vary by mode as a highway investment is focused on that particular infrastructure asset, while bus transit costing typically needs to consider the purchases of buses and knowledge of depreciation, repairs, and new technologies. Costing also should ideally consider uncertainty and risk.

Several agencies have made significant progress in individual aspects of LCCA. Best practices in estimating initial agency costs include the Washington State DOT's Cost Estimate Validation Process, which provides a risk-based estimate of a project's costs; and the Ministry of Transportation of Ontario's (MTO) iterative approach, which takes advantage of the fact that a project's cost estimate improves as it moves through the project development process.

In addition to these tools, resources have been developed to assist in project-level economic analysis incorporating LCCA techniques. These tools incorporate a variety of analysis techniques and models. Examples include the FHWA's RealCost tool, Montana DOT's Highway Economic Analysis Tool (HEAT), California DOT's (Caltrans) benefit/cost tool, the FHWA's Intelligent Transportation Systems (ITS) Deployment Analysis System (IDAS), and the AASHTO's Redbook Wizard.

Existing LCCA resources[4] include FHWA's *Life-Cycle Cost Analysis Primer*; *Economic Analysis Primer*; case study of the Pennsylvania DOT's experience with pavement LCCA, and case study on the New York DOT's use of excess user costs, as well as NCHRP's *Bridge Life Cycle Cost Analysis*, and publication of a series of benefit/cost examples in *Analytic Tools to Support Transportation Asset Management*.

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[4] FHWA Office of Asset Management, Life-Cycle Cost Analysis Primer, August 2002; FHWA Office of Asset Management, Economic Analysis Primer, August 2003; FHWA Office of Asset Management, Life-Cycle Cost Analysis – The Pennsylvania Experience; FHWA Office of Asset Management, RealCost User Manual, May 2004; and Cambridge Systematics, Inc., with PB Consult and System Metrics Group, Inc., NCHRP Report 545, *Analytical Tools for Asset Management*, 2005.

1.3 MEASURING LIFE-CYCLE COSTS

Review of Available LCCA and BCA Tools

A number of tools have been developed for supporting LCCA or BCA with project-level cost analysis. The set of tools presented is based on a review of recent NCHRP research, and based on the experience of the researchers. All of the tools considered in this review are project-level tools that calculate initial agency costs and future agency costs of potential transportation investments. Two management systems generally used for program-level analysis, the Highway Economics Requirements System (HERS) and Pontis Bridge Management System (BMS) were included in the review as well, as these tools are representative of the state of the practice in transportation management systems, and incorporate approaches to predicting future agency cost that may be applicable. In some cases, the LCCA components of HERS and/or BMS have been used as stand-alone modules to estimate total costs. All of the tools have been implemented either through guides, spreadsheets, or information systems.

Project-Level Tools

Bridge Life-Cycle Cost Analysis (BLCCA). NCHRP Project 12-43 produced a BLCCA tool as part of a study to develop a comprehensive bridge life-cycle costing methodology.[5] The tool can be used to compute the present value of life-cycle costs for alternative sets of bridge construction alternatives, including consideration of agency costs for construction and maintenance; user costs (e.g., accidents, detour costs, and travel time); and vulnerability costs (e.g., risks of damage due to earthquakes, floods, collisions, overloads, and scour). For each project alternative, users must define a sequence of events (e.g., profile of repairs and rehabilitation projects throughout the analysis period), including an indication of costs and uncertainty in their timing.

BridgeLCC. The National Institute of Standards and Technology developed BridgeLCC to assist in the evaluation of alternative bridge designs.[6] For example, the system can be used to explore the long-term implications of alternative bridge materials (e.g., traditional versus high-performance concrete). It also can incorporate potential events (e.g., a terrorist attack or seismic event) into the results. BridgeLCC enables users to conduct a sensitivity analysis of key inputs and conduct a risk assessment using Monte Carlo simulations. The system enables users to enter agency costs on a unit cost basis or as a lump sum amount.

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[5] Engineering Technology Cooperation, NCHRP Report 483, *Bridge Life Cost Analysis Guidance Manual*, 2003.

[6] National Institute of Standards and Technology website, BridgeLLC, www.bfrl.nist.gov/bridgelcc/welcome.html, accessed December 2006.

RealCost. In 1998, the FWHA published a guide on analyzing the life-cycle costs of pavement designs. Subsequently, it developed RealCost as a software tool that supports its recommended approach. RealCost relies on user estimates of agency costs and predicts user costs due to work zones. It combines these costs into a life-cycle cost analysis and calculates net present value. RealCost provides a deterministic calculation and a probabilistic calculation of a project's net present value (NPV). It performs a Monte Carlo simulation to generate probability distributions for model inputs and outputs, so that users can assess levels of uncertainty.

HERS. HERS is a system developed by the FHWA for determining highway investment needs at the national or state level, including needs for widening, reconstructing, and repaving existing highways. HERS includes a comprehensive set of models for simulating pavement conditions over time for predicting highway investment needs, and calculating the economic impacts of highway improvements. The system uses data on Highway Performance Monitoring System (HPMS) sample sections as input. With this data for each highway segment, the system calculates the predicted pavement condition over time, the traffic on the section, traffic speed, and crash rate. The models are sensitive to changes in pavement condition, traffic levels, and numerous other variables. For calculating initial agency costs, HERS relies on a table of unit costs that vary based on the improvement class, functional classification of the highway, and terrain. For predicting future agency costs, the system first predicts future pavement condition, and then predicts the annual cost of maintenance using a mathematical formula derived from research on the relationship between pavement condition and maintenance costs.

IDAS. IDAS is a sketch planning tool designed to assist users with planning and deploying ITS improvements.[7] The system is used by transportation agencies to integrate the analysis of ITS projects into their long-range planning efforts, evaluate the costs and benefits of specific ITS alternatives, and evaluate current systems. For each project, users must enter ITS equipment capital, operations, and maintenance costs. IDAS predicts relative costs and benefits for 60 types of ITS investments in the following categories:

- Arterial traffic management systems,
- Freeway management systems,
- Advanced public transit systems,
- Incident management systems,
- Electronic payment systems,
- Railroad grade crossing monitors,

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[7] Cambridge Systematics, Inc., *IDAS User's Manual*, November 2001.

- Emergency management services,
- Regional multimodal information systems,
- Commercial vehicle operations,
- Advanced vehicle control and safety systems,
- Supporting deployments, and
- Generic deployments.

Pontis Bridge Management System (BMS). The Pontis BMS is used throughout the U.S. for tracking bridge data and predicting future bridge conditions and investment needs. Pontis models bridges at an element level (e.g., the bridge deck, girders, bearings, columns, etc.) and includes deterioration and cost models for each bridge element. The system estimates initial agency costs for bridge work using a set of unit costs specified at the bridge and element level for different operating environments. The system predicts future agency costs using a Markov modeling approach to determine the optimal least-cost policy for maintaining each bridge element over time. At least one state agency, Caltrans, has used the element-level estimates of future element life-cycle costs as an input to bridge life-cycle cost analysis in comparing alternative bridge designs.

Caltrans BCA Tool. Caltrans developed a spreadsheet tool for conducting BCA of its projects.[8] The tool enables the analysis of highway and transit projects. The tool considers agency costs and a number of user cost components. However, the focus of the analytics is on modeling user costs. Users are required to manually enter agency costs by year for each project.

PennDOT Benefit/Cost Analysis (BCA). The Pennsylvania DOT (PennDOT) has developed a spreadsheet tool to assist in the BCA of alternative pavement designs.[9] A focus of the tool is on comparing concrete and bituminous pavement alternatives. PennDOT has a policy requiring this type of analysis for interstate highway projects with initial costs greater than $1 million and all other projects with initial costs greater than $10 million. The tool enables users to estimate initial agency costs by estimating quantities and specifying unit costs. It assists users in estimating future agency costs by incorporating common maintenance strategies. For example, when estimating the future agency costs of a bituminous pavement, users are prompted to consider the cost of seal coating shoulders in year 5.

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[8] Booz Allen & Hamilton, Inc., Hagler Bailly, and Parsons Brinckerhoff, *California Life-Cycle Benefit/Cost Analysis Model – Technical Supplement to User Guide*, September 1999.

[9] Pennsylvania DOT, *Performing a Life Cycle Cost Analysis Using Microsoft Excel 97*, November 1998.

Priority Economic Analysis Tool (PEAT). MTO developed PEAT to analyze the costs and benefits of highway, bridge, and intersection projects.[10] The tool helps answer two questions: Is a project a good investment, and if so, when should it be implemented? PEAT is designed to support three levels of cost estimates, paralleling the different levels of information available at various stages of the project development process. In estimating future agency costs, the tool uses a simplified pavement deterioration model to trigger preservation work, and estimates annual minor maintenance costs based on pavement condition. For bridge projects, the tool uses estimates of future agency costs that have been developed by the MTO's bridge management system.

Washington DOT BCA Tool. The Washington State DOT has developed a BCA tool to analyze lane additions, climbing lanes, high-occupancy vehicle (HOV) lanes, intersection improvements, interchange improvements, and park-and-ride facilities. The tool considers agency costs and a number of user cost components. Users are provided with default unit costs for estimating initial costs. To estimate future agency costs, users specify a single annual maintenance and operations cost.

Washington Transit Life-Cycle Cost (LCC) Model. The Washington State DOT has developed an LCC tool to assist in analyzing alternative maintenance strategies for public transit vehicles and facilities. The tool helps structure estimates of initial agency costs and future agency costs for two maintenance strategies. Users enter unit costs for a number of common activities, such as tire replacement, engine repair, and brake service. They then specify the number of times these activities are required each year to estimate future agency costs.

Estimating Costs

The following discussion presents three types of costs: initial agency costs, future agency costs, and cost uncertainty.

Initial Agency Costs

Initial agency costs represent the cost of all activities up to the time that construction is complete and can include project development, land acquisition, and construction. There are generally three approaches to estimating initial agency costs ranging from the simple to the complex, as detailed below.

1. **Unit Cost.** Management systems used for program-level analysis, such as HERS, Pontis BMS, and many other LCCA and BCA tools, estimate initial agency costs by applying unit costs calculated based on historic data. These tools typically include tables of average unit costs by type of activity or project (e.g., cost per lane mile for constructing new lanes, or cost per square foot of deck for replacing a bridge).

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[10] Cambridge Systematics, Inc., with Harry Cohen, *PEAT User Manual*, November 2004.

2. **Detailed Unit-Cost.** Another approach to estimating initial agency costs is to build up a cost based on more detailed estimates of the labor and materials required to complete a project. Most agencies have historic data on construction costs based on bid tabulations that can be used to support such detailed costs estimates. Some agencies store these data by project conditions, geographic region, or functional class. For example, PennDOT's Contract Management System provides bid data that can be sorted by project size, location, and traffic conditions. In theory, the use of more detailed models for determining costs can provide a better estimate of initial construction costs than a single unit cost. However, few of the available tools support a cost estimate more detailed than the unit cost approach described above. In the case of the MTO's PEAT, the tool allows the user to use a unit cost approach, or supports a more detailed estimate if data on construction quantities and costs are available.
3. **Case-by-Case.** A third alternative to estimating initial agency costs is to develop the estimate on a project basis (often through careful engineering studies), and then enter the cost estimate directly into the LCCA or BCA tool. A number of the tools reviewed rely on this approach. Large transportation projects are typically planned well in advance and take more than one year to construct. Thus, construction cost escalation factors and discounting are important components of measuring costs for an ROI analysis.

In general, calculations of initial project costs performed in calculating return on investment should be determined using a unit cost approach, with unit costs calculated based on analysis of project history. Where sufficient data are available for a more detailed estimate of initial agency costs based on specific activities and materials quantities, this approach has the potential to provide a more accurate estimate and is preferred.

Future Agency Costs

Future agency costs represent the cost of all activities on an asset after construction is complete. They can include routine maintenance, operations, preservation, reconstruction, and demolition. Estimating future agency costs requires consideration of the expected life of a project and/or data on treatments and preservation strategies (e.g., the condition at which preservation work is recommended).

Pavement and bridge management provide approaches for modeling future costs of existing assets at a detailed level. In some cases, the models from these systems can be adapted to estimate future costs for new assets. For instance, the approach used by HERS for modeling future pavement maintenance costs as a function of pavement condition, though approximate, can be applied to estimate maintenance costs for any pavement section. Likewise, the modeling approach in BMS provides an estimate of the life-cycle preservation cost at an element level for an existing or new bridge.

Three of the project-level tools included in the following review (see Review of Available Tools below) estimate future agency costs in some manner. PEAT incorporates the modeling approach from HERS for modeling future agency costs of pavement, and uses results obtained directly from a BMS for estimating future costs for bridges. The Washington State Transit LCC model estimates future costs based on data provided on the frequency of different maintenance activities. The PennDOT tool does not include models of future agency costs, but does provide guidance on the agency's preservation strategies (e.g., consider seal coating the shoulder in year 5) to help facilitate generation of a cost estimate. Montana's HEAT model also measures future agency costs with annual O&M and resurfacing (after 10 years) costs as a function of initial construction costs.

With the exception of the systems described above, the other tools included in the review rely on the end user to explicitly define the future agency costs predicted for a given project alternative. In other words, the tools consider future costs, but only after forcing the end user to calculate them externally and specify them explicitly in the analysis. Preservation cost estimates can often be developed in a manner similar to the initial agency cost estimates described above (e.g., through estimating the frequency with which certain actions must be performed and using the unit cost for the action to calculate a cost).

Estimating routine maintenance and operations costs, however, can be more difficult, because agencies vary largely in the extent to which this information is collected and stored. Some maintain daily work logs of internal forces, while others keep track only of contracted maintenance. In these cases, significant work must be done to develop customized estimates of future agency costs. For example, the Florida DOT developed estimates for bridge maintenance, rehabilitation, and repair activities during its implementation of the Pontis BMS. This effort required a statistical analysis of raw data from a number of data sources. In addition, the results had to be extensively augmented with expert judgment, because the agency had enough cost data for a statistically valid analysis of only 50 percent of the activities reviewed.

Requiring users to conduct an analysis of future agency costs (what activities should be performed and when) and to provide this information as an input is a weakness of currently available LCCA tools and reflects the lack of solid data available for DOTs to reliably estimate future costs. Taking advantage of the analytics available in management systems could significantly improve LCCA results. Another opportunity for improvement is to provide default cost estimates for O&M activities, either based on general unit costs or on asset condition.

Cost Uncertainty

As a project moves through the project development cycle (from definition to design to procurement), more details regarding right-of-way acquisition, environmental and risk mitigation strategies, and construction requirements are determined. As this information becomes available, a project's scope and schedule can change dramatically. These changes may have a significant impact on the initial agency cost of a project and, therefore, a significant impact on the results of a LCCA. Uncertainty is inherent in all large transportation projects. It decreases as a project progresses through the project development process, although some risk of change continues during the construction period. Options for contending with uncertainty in future costs, using existing tools and approaches, include sensitivity analyses, probabilistic analysis, and iterative LCCA.

Sensitivity analyses can be used to explore the implications of major assumptions on the end result of an LCCA. Many of the tools described in the previous section are designed to support these analyses. For example, in some tools, once an analysis is defined, users can increase and decrease the initial cost estimate by 10 percent and assess the impact on the final NPV or benefit/cost ratio (BCR).

In probabilistic LCCA, several versions are run automatically for a specified range of inputs using Monte Carlo simulations. The end result is a mean, standard deviation, minimum, and maximum value of NPV, BCR, or other measures.

Washington State DOT's Cost Estimate Validation Process (CEVP) represents another type of probabilistic analysis. In the CEVP, a series of workshops is used to estimate a project's cost, identify risks, and estimate the potential impact of each risk in terms of cost and schedule. Monte Carlo simulations are then used to analyze a cost estimate. The results of the CEVP help the DOT determine a range of potential project costs and specific levels of confidence. For example, rather than estimating that a project will cost less than $1 million, the DOT may estimate that there is a 90-percent chance that the project will cost less than $1 million and a 95-percent chance that it will cost less than $1.2 million. CEVP has exposed the public and the Washington State Legislature to the use of a range of estimates for a project, rather than a single value.

The MTO's PEAT enables an iterative approach to LCCA. As more information about a project is known, the cost estimate will improve, and the latest estimate can be incorporated into the LCCA. A project that appears justified when it is in the preliminary design phase may not be warranted by the time the project details have been defined. To encourage this type of iterative analysis, PEAT provides a template for three levels of cost estimates, including a Level 1 estimate based on unit costs, a Level 2 estimate based on more detailed specification of project design and materials quantities, and a Level 3 estimate based on more detailed analysis performed outside PEAT. MTO intends to repeat analyses in PEAT over time as cost estimates become more detailed.

Analytical approaches that require estimates of future agency costs for transportation projects ideally should acknowledge the uncertainty that is inherent in these estimates. At a minimum, approaches to cost analysis should incorporate sensitivity analyses to establish a range of results that may be generated based on the potential values of key variables. The approach used by Washington State DOT, resulting in a confidence level on the cost estimates, represents the best practice in incorporating uncertainty in agency cost estimation.

1.4 METHODS AND GAPS IN MEASURING LIFE-CYCLE COSTS

Estimating Initial Agency Costs

Initial agency costs represent the cost of all activities up to the time that construction is complete. They can include land and equipment acquisition, and a wide range of construction and engineering activities. A common gap in life-cycle cost analysis is the lack of a systematic process for developing consistent cost estimates for a number of project alternatives in an efficient manner. This is especially true when comparing costs of multiple projects under consideration to develop a full program of investments.

To address this gap, it is recommended that agencies establish cost templates to assist in estimating initial agency costs. The best practice in this area is to develop a series of templates that can be used throughout the project development process, taking advantage of more detailed information as it becomes available. For example, Tables 1.1 and 1.2 illustrate cost templates developed by the MTO. Table 1.1 represents a basic unit cost template that can be used early in the project development process. Table 1.2 is a more comprehensive template that can be used as a project moves through the project development process and more design details become available. The MTO developed these templates so that LCC analysis could be performed multiple times throughout the project development process, using the latest cost estimate. To develop a cost estimate using one of these templates, users are required to enter information in the "Quantity" column for a project.

Table 1.1 MTO Level 1 Cost Estimate Example

Proposed Work	**Unit**	**Quantity**	**Default Unit Cost**	**Cost**
Resurface				
Asphalt	lane-km	-	$ 106	$ -
Concrete	lane-km	-	$ 365	$ -
Reconstruct				
Asphalt	lane-km	8.0	$ 349	$ 2,796
Concrete	lane-km	-	$ 547	$ -
Add Lanes				
Asphalt	lane-km	-	$ 456	$ -
Concrete	lane-km	-	$ 729	$ -
		Total Level 1 Cost Estimate		**$ 2,796**

Table 1.2 MTO Level 2 Cost Estimate Example

Proposed Work	Unit	Quantity	Default Unit Cost	Cost
Resurfacing				
50 mm	lane-km		$ 75	$ -
90 mm	lane-km		$ 100	$ -
220 mm	lane-km		$ 186	$ -
Concrete	lane-km		$ 300	$ -
Composite	lane-km		$ 300	$ -
Reconstruction				
90 mm	lane-km		$ 275	$ -
130 mm	lane-km	8	$ 300	$ 2,400
Deep Strength Asphalt	lane-km		$ 400	$ -
Concrete	lane-km		$ 450	$ -
Composite	lane-km		$ 500	$ -
Add Through Lanes				
90 mm	lane-km		$ 350	$ -
130 mm	lane-km		$ 400	$ -
170 mm	lane-km		$ 450	$ -
Deep Strength Asphalt	lane-km		$ 550	$ -
Concrete	lane-km		$ 600	$ -
Composite	lane-km		$ 650	$ -
Add Arterial/Crossing Lanes				
90 mm	lane-km		$ 350	$ -
130 mm	lane-km		$ 400	$ -
170 mm	lane-km		$ 450	$ -
Deep Strength Asphalt	lane-km		$ 550	$ -
Concrete	lane-km		$ 600	$ -
Composite	lane-km		$ 650	$ -
Add Detour Lanes				
90 mm	lane-km		$ 350	$ -
130 mm	lane-km		$ 400	$ -
170 mm	lane-km		$ 450	$ -
Deep Strength Asphalt	lane-km		$ 550	$ -
Concrete	lane-km		$ 600	$ -
Composite	lane-km		$ 650	$ -
Add Ramps/Speed Change Lanes				
90 mm	lane-km		$ 350	$ -
130 mm	lane-km		$ 400	$ -
170 mm	lane-km		$ 450	$ -
Deep Strength Asphalt	lane-km		$ 550	$ -
Concrete	lane-km		$ 600	$ -
Composite	lane-km		$ 650	$ -

Table 1.2 MTO Level 2 Cost Estimate Example (continued)

Proposed Work	Unit	Quantity	Default Unit Cost	Cost
Add Auxiliary Lanes				
90 mm	lane-km		$ 350	$ -
130 mm	lane-km		$ 400	$ -
170 mm	lane-km		$ 450	$ -
Deep Strength Asphalt	lane-km		$ 550	$ -
Concrete	lane-km		$ 600	$ -
Composite	lane-km		$ 650	$ -
Continuous Features				
Rock	lane-km		$ 300	$ -
Concrete Barrier, incl. Storm Drainage	km	4	$ 300	$ 1,200
Curb, incl. Storm Drainage	km		$ 200	$ -
Median Tall Wall Barrier, incl. Storm Drainage	km		$ 900	$ -
Temporary Concrete Barrier	km		$ 200	$ -
Electrical				
Illumination - Conventional	each		$ 5	$ -
Illumination - High Mast, incl. HMP Ftgs	each		$ 50	$ -
Traffic Signals - Single Phase	each		$ 60	$ -
Traffic Signals - Multi-Phase	each		$ 90	$ -
FTMS, incl CMS, str & ftg, cctv & electrical	lump sum			$ -
Minor Structures				
Retaining Wall - Concrete	m3		$ 0.80	$ -
Retaining Wall - Reinforced Earth	m2		$ 0.40	$ -
Major Concrete Culverts 3&4m spans	metre		$ 5	$ -
Major Concrete Culverts 5&6m spans	metre		$ 8	$ -
Major Concrete Culvert Rehabilitations	lump sum		$ 100	$ -
OH Sign Structures, incl. ftgs, sign & reloc.	each	5	$ 80	$ 400
Subtotal				**$ 4,000**
Indirect Costs (expressed as percent of contract total)				
Construction Administration			5%	$ 200
Supplies, Services & Sundry			5%	$ 200
Force Accounts & Contingencies			5%	$ 200
Indirect Costs Subtotal				**$ 600**
Utility Relocations	lump sum			$ -
Construction Total (contract total + indirect costs + utility relocations)				**$ 4,600**
Engineering Design (expressed as percent of construction)			5%	$ 230
Land Acquisition	hectares		$ 100	$ -
Total Level 2 Cost Estimate (construction total + eng. Design + land acquisition)				**$ 4,830**

Developing these tools requires an agency to identify common construction activities and develop unit costs for each activity. (Note that some of the default costs in Table 1.2 are specified as a percent of the construction total.) Ideally, the default unit costs would account for differences in costs across geographic areas, functional class, or other project factors. For example, an agency may provide a separate template for each of its regions. Most agencies have historic cost data in the form of bid tabulations.

Compiling these data in a standard set of cost templates would decrease the level of effort required to conduct LCC analysis, help document key cost assumptions, and result in more consistent cost estimates through an agency.

A related gap is consistent methodologies to estimate initial agency costs across modes. The tables above are focused on a variety of highway improvements, but investments in transit, for example, would require additional categories, such as rolling stock, rail line improvements, station area enhancements, etc.

Ideally, the engineers developing costs across modes would have a chance to meet and review bid data and cost assumptions to ensure reasonable comparisons for program development.

Estimating Future Agency Costs

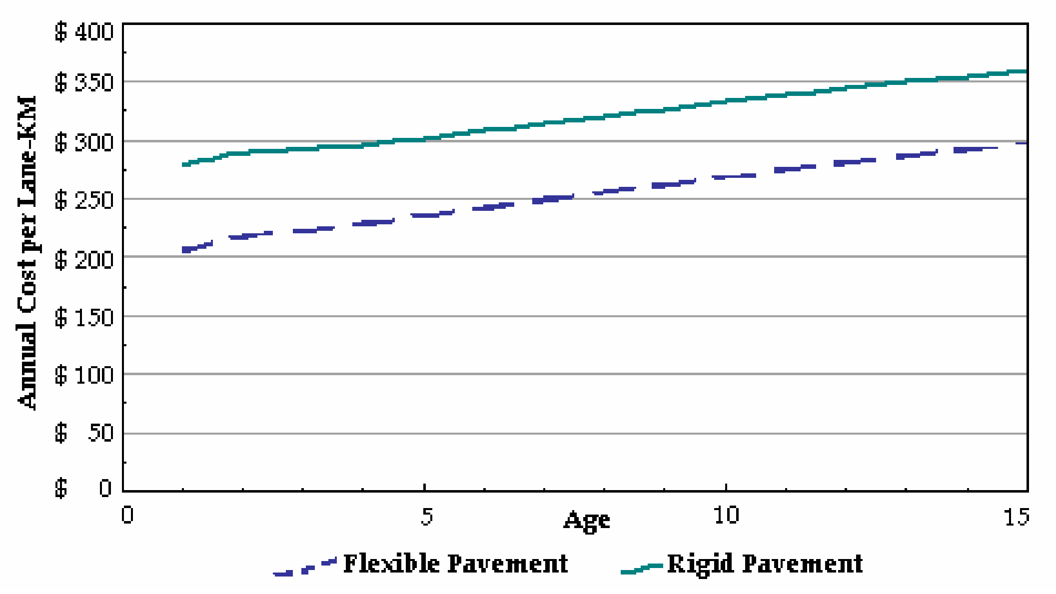
Future agency costs represent the cost of all activities on an asset after construction is complete. They include the costs of maintenance, preservation, and reconstruction. The main gap in this area is the same as that described for initial agency costs – a lack of a systematic process for efficiently estimating these costs for a large number of projects. For example, many tools that support LCC analysis require users to directly enter a cost for each year of the analysis. For example, while many ROI analyses will enter an O&M cost and will assume a useful life (of say, 25 years), it is more rare for resurfacing and thin overlays (representing costs above annual O&M) to be assumed.

One approach for addressing this is to provide a cost template similar to those described for initial cost estimates. Developing these templates would require agencies to compile the following data:

- A list of future activities,
- Recommended timing for each activity, and
- Default unit cost for each activity.

This type of template could help structure cost estimates for future capital work (e.g., preservation and reconstruction). It is much more difficult, however, to use this approach for maintenance activities, because most agencies do not have maintenance data in the form needed for LCC analysis. For example, maintenance activities are often scheduled reactively, so determining a recommended timing for them is difficult. In addition, maintenance costs are typically tracked at a very detailed level required for maintenance planning (e.g., cost per ton of asphalt or cost per gallon of sealant). Converting these data to unit costs that could be applied generally on a lane-mile basis for LCC analysis is difficult as well. One approach to estimating future maintenance cost is to develop a general relationship between cost and asset age. For example, Figure 1.1 illustrates a relationship between maintenance cost and age. This relationship was developed by combining a model of maintenance costs versus roughness used in the FHWA's Highway Economic Requirements System (HERS-ST) and a simplified model relating roughness to pavement age. This figure highlights that annual O&M estimates for transportation projects that use a constant value over time may underestimate total O&M costs, unless that estimate truly reflects costs as facilities age.

Figure 1.1 Maintenance Costs by Pavement Age



Another approach to improving the estimation of future agency costs is to leverage the modeling capabilities of pavement and bridge management systems. For example, Table 1.3 provides the long-term costs of a new bridge as calculated by the FHWA Pontis BMS. This system uses a series of deterioration, cost, and work activity models to determine an optimal preservation strategy for several types of bridge elements. The result of this analysis is a long-term unit cost for each element. (In Table 1.3, these costs are provided in the "Unit Cost" column.) In this example, calculating the LCC for a new bridge requires identifying the appropriate elements in a bridge, estimating the quantity of each, applying LLC unit costs from BMS, and summing the results.

The most significant gap in estimating future costs is the lack of a single list of data required to implement management systems in LCC analysis. The set of data used by these systems varies too significantly to do so. For example, HERS relies solely on data collected as part of the national HPMS, while Pontis relies on bridge data that goes well beyond that required for Federal reporting purposes.

Table 1.3 Life-Cycle Cost of a New Bridge

#	Element	Unit	Quantity	Unit Cost	LCC
13	Unprotected concrete deck	SF	65,014	$ 1.07	$ 69,565
302	Compression joint seal	LF	177	$ 53.08	$ 9,395
105	Reinforced concrete box girder	LF	1,493	$ 30.97	$ 46,238
331	Concrete bridge railing	LF	3,087	$ 4.66	$ 14,385
312	Enclosed bearing	EA	3	$ 855.76	$ 2,567
210	Reinforced concrete pier wall	LF	1,188	$ 40.01	$ 47,532
215	Reinforced concrete abutment	LF	79	$ 16.68	$ 1,318
				Total LCC	**$ 191,001**

Estimating Cost Uncertainty

The construction and enhancement of large transportation projects is inherently risky due to their size and level of complexity. Incorporating these risks in LCC analysis can help ensure that estimated project costs are in line with actual costs, and that decisions being made based on cost estimates are valid. Despite this knowledge, relatively few transportation agencies explicitly incorporate cost uncertainty into program and project decisions or ROI analysis.

The current best practice model in dealing with cost uncertainty is the Washington State DOT's Cost Estimate Validation Process (CEVP). The result of the CEVP is a range of potential project costs with associated levels of confidence. For example, an agency may estimate that there is a 90-percent chance that a project will cost no more than $1 million, and a 95-percent chance that it will cost $1.2 million or less.

In order to conduct a CEVP analysis, the following data items are required:

- List of project risks;
- The expected minimum, maximum, and most likely impact on project cost (expressed in dollars) of each risk;
- The expected minimum, maximum, and most likely impact on project schedule (expressed in dollars) of each risk; and
- The probability of each risk occurring.

The Washington State CEVP determines these data by soliciting expert opinions from a project team and other subject matter experts during a series of workshops. To guide the process, the DOT has developed a list of common risks. The list consists of 90 technical, external, environmental, organizational, project management, right-of-way, construction, and regulatory risks that should be considered as part of CEVP review.

Reducing the existing gap in estimating and incorporating risk and uncertainly into LLC analysis will improve confidence in analysis results.

1.5 RECOMMENDATIONS ON THE USE OF LIFE-CYCLE COSTS IN ROI ANALYSIS

Initial Agency Costs

- **Develop cost templates for estimating initial agency costs.** It is recommended that the templates provide default unit costs for common construction items and require users to enter only quantities.
- **Refine cost estimates as more detailed project data becomes available.** Ideally, cost templates are designed to work with varying degrees of information so that as a project moves through the project development process, the cost estimate will become more accurate. For example, an initial cost estimate may be based on an average cost per lane mile of reconstruction, while a more detailed one may require users to specify more detailed information on the cross section of the new pavement.
- **Develop a series of default unit costs.** It is recommended that agencies develop a series of unit costs to account for differences across geographic areas, functional class, and other project factors. For example, default unit costs for an urban area will likely vary significantly from those in a rural area.

Future Agency Costs

- **Develop cost templates for estimating future rehabilitation and reconstruction costs.** The following two types of templates for estimating the cost of future work:

  a. **Activity-based** templates provide a list of future activities, the recommended timing for each activity, and default unit cost(s) for each activity. (As described above, agencies should develop a series of default unit costs.) To use this type of template, users specify the timing of future activities.

  b. **Inventory-based** templates require the same types of information, but assume the optimal timing of future activities. For example, an agency's pavement design standards may be such that rehabilitation work is required in year 10. Inventory-based templates assume that this work will be done in this year. These types of templates enable users to estimate future costs by specifying physical quantities, such as lane miles of asphalt pavement or square feet of bridge deck area. It is recommended that future unit costs be consistent with initial unit costs in terms of units, so that double entry of quantities is not required.

  Activity-based and inventory-based templates are both valid options with their own set of advantages. Activity-based templates require less initial effort to develop and provide end users with the flexibility to explore the cost implications of different rehabilitation strategies. Inventory-based templates require less input from end users, and enable agencies to efficiently and consistently estimate the future costs of optimal rehabilitation strategies.

- **Develop models that relate future maintenance costs to asset age.** Incorporate this relationship into an inventory-based template that can be used to estimate the costs of maintenance activities: for example, the use of existing pavement and bridge management systems to support the development of future cost templates. State-of-the-art management systems are designed to estimate future agency costs. This functionality can be used to help determine the recommended timing and/or cost of future activities. For example, equations and models developed for the FHWA's Highway Economic Requirements System (HERS) can be used in estimating the relationship between maintenance costs and pavement age, and the AASHTO's Pontis bridge management system can be used to estimate the long-term unit costs of various bridge elements.

Cost Uncertainty

- **Develop a threshold (e.g., $20 million) above which a more robust assessment of uncertainty is warranted.** For projects below this threshold, use probabilistic life-cycle cost analysis. In probabilistic LCC analysis, several cost estimates are generated for a specified range of inputs (e.g., the unit cost of key activities, discount rate, future truck traffic, etc.) using Monte Carlo simulations. The end results are a mean, standard deviation, minimum, and maximum value of net present value, benefit/cost ratio, and other economic measures.
- **Identify individual risk elements and uncertainty to develop range of cost estimates.** For projects above the identified threshold, implement a more comprehensive approach to risk assessment that focuses on individual risks. As part of this assessment,
    a. Identify specific cost elements associated with risk;
    b. Estimate the expected minimum, maximum, and most likely impact on project cost (expressed in dollars) of each risk;
    c. Estimate the expected minimum, maximum, and most likely impact on project schedule (expressed in dollars) of each risk; and
    d. Determine the probability of each risk occurring.

Once all risks have been defined and quantified, use Monte Carlo simulation to determine their combined impact on cost. The result of this type of analysis is a range of potential project costs with associated levels of confidence. For example, an agency may estimate that there is a 90-percent chance that a project will cost less than $10 million, and a 95-percent chance that it will cost less than $12 million. This approach also will result in a list of potential projects risks that can be tracked and mitigated throughout the project development process.

1.6 EXAMPLES OF THE USE OF LIFE-CYCLE COSTS IN ROI ANALYSIS

The first of the following two examples or case studies of LCC applications involve initial and future agency costs. The second case study covers cost uncertainty.

Priority Economic Analysis in Ontario

The Ministry of Transportation of Ontario (MTO) currently is implementing a corridor investment planning process. A key component of this process is the ability to assess whether a transportation investment is justified in terms of its expected benefits. Across the highway network and various asset types, the Ministry would like determine which investments maximize the benefits to the organization and to the traveling public. In support of this effort the MTO developed the Priority Economic Analysis Tool (PEAT).

PEAT enables users to analyze rehabilitation and improvement projects for highways, intersections, and bridges using an economic approach that considers both agency and road user costs. PEAT helps answer two questions: 1) is a project a good investment; 2) and if so, when should it be implemented? PEAT answers these questions by calculating initial agency costs, future agency costs, travel time costs, vehicle operating costs, accident costs, and delay costs due to work zones. The remainder of this case study focuses on the agency cost components of the Ministry's analysis.

Initial Agency Costs

One of the issues the Ministry faced in conducting LCC analysis was the lack of constancy in how staff estimated initial agency costs, such as the costs of project development, right-of-way acquisition, and construction. To address this issue, the Ministry incorporated the following three cost estimation templates into PEAT.

1. **Level 1 cost estimates are based on average unit costs such as the cost of resurfacing a lane-kilometer of roadway.** This template is used at the sketch planning phase, when design details are not yet available.
2. **Level 2 cost estimates are based on more detailed unit costs.** For example, for highway projects, the cost of resurfacing depends on the depth of the asphalt overlay. For bridge projects, the Level 2 cost estimate is extracted from the Ministry's bridge management system.
3. **Level 3 cost estimates are based on detailed quantity take-offs and historic tender costs.** Because of the level of detail required to develop Level 3 estimates, there is no predefined template for estimating these costs. The tool provides a blank workspace for developing and/or documenting a project's final cost estimate.

MTO developed these templates so that LCC analysis can be performed multiple times throughout the project development process – as more detailed project information becomes available, it is incorporated into the analysis. The tool also improves the consistency of cost estimates by providing default unit costs for the Level 1 and Level 2 templates. However, users are able to override the default values if more information is available.

Future Agency Costs

To improve the calculation of future agency costs, such as the costs of maintenance, rehabilitation, and reconstruction, the Ministry incorporated models from its pavement and bridge management systems into PEAT.

For highway projects, the tool includes average deterioration rates from the Ministry's pavement management system. PEAT also provides default thresholds that determine when a segment of pavement should be rehabilitated or reconstructed. When pavement condition exceeds these thresholds, the tool assumes that the appropriate work is completed and estimates the cost using a default set of unit costs for these activities. In estimating future maintenance costs, PEAT applies a model of pavement condition versus annual maintenance costs developed by the FHWA for use in its HERS.

For bridge projects, the tool relies on future agency costs developed by the Ministry's BMS. For each of the Ministry's bridges, the BMS calculates two estimates of future agency costs – one for a bridge rehabilitation project and one for a bridge replacement project. These estimates are imported directly into PEAT.

The models described above are the basis for determining the default agency costs of a project in PEAT. They significantly reduce the effort required to estimate these costs. However, the tool also provides a template that users can use to specify a custom work strategy for a project and estimate its cost. The template requires users to specify the type of work to be performed each year (maintenance, rehabilitation, and replacement) and specify its cost. PEAT then incorporates this information into the LCC analysis.

Washington State DOT's Cost Estimate Validation Process

In an effort to provide decision-makers and the public with better information regarding the cost of major transportation projects, the Washington State DOT developed the Cost Estimate Validation Process (CEVP®). The DOT uses CEVP to validate a project's cost estimate and schedule, and identify specific risks that need to be mitigated throughout project development. The end result of the process is an estimated range of construction costs, rather than a single value that is traditionally used. For example, the DOT may estimate that there is a 90-percent chance that a project will cost less than $2 million, and a 95-percent chance that it will cost less than $2.2 million.

The process consists of the following steps:

1. Select a project and compile a team to review it. The review team consists of experts in construction techniques, cost estimation, risk assessment, and other areas related to the project.
2. Initiate a project workshop. The project team and the review team participate in the workshop.
3. Validate the project's cost estimate (e.g., review the estimate for completeness and accuracy and discuss the appropriateness of major assumptions).
4. Identify risks associated with the project. To improve consistency in how risks are identified, the DOT has developed a list of 90 common technical, external, environmental, organizational, project management, right-of-way, construction, and regulatory risks that should be considered as part of a CEVP review. Once a risk has been identified, workshop participants estimate the likelihood that it will occur and its potential impact on the project's budget and schedule.
5. Conduct an integrated analysis of the risks. The DOT uses a Monte Carlo simulation to determine a range of potential projects costs.
6. Develop a risk response plan. This plan identifies how the DOT will mitigate each risk identified during the workshop.
7. Implement the risk response plan as part of the project development process and monitor progress. For large projects, the DOT conducts a series of CEVP workshops in order to revisit project risks and update cost and schedule estimates.

CEVP enables the Washington State DOT to quantify the uncertainty associated with a project's cost, provides a tool for mitigating this uncertainty as a project is designed and constructed, and enhances communication with external stakeholders regarding a project's schedule and budget.

References

Cambridge Systematics, Inc., *Priority Economic Analysis Tool User Manual*, developed for the Ministry of Transportation of Ontario, November 15, 2004.

Washington State DOT's web site, www.wsdot.wa.gov/projects/projectmgmt/riskassessment, accessed November 16, 2007.

2.0 Travel Time Reliability

2.1 INTRODUCTION

Travel time reliability is being recognized as a major aspect of congestion that imposes significant costs on travelers, but has not yet been widely or consistently incorporated within economic analyses of transportation programs and projects.

This section of the study presents the evolving concept and varying definitions of reliability, current performance measures, and a review of the accepted data and methods used to estimate travel time reliability and incorporate those estimates in ROI analysis. Secondly, current methods and data are identified and the existing gaps in those measures are assessed. Finally, areas for improvement are identified.

Research on reliability is ongoing, and this study's authors have led recent research on how commuters, as well as freight shippers, place drastically different values on unpredictable or erratic events such as incidents, bad weather, work zones, and surges in traffic demand. This research, for example, indicates that commuters value the variable components of their travel times between one to six times as much as average travel times.

The increase in just-in-time (JIT) manufacturing processes and the use of efficient transportation networks as "the new warehouse" have been increasing the factor that must be applied to travel time reliability above the values currently in use. Nevertheless, agencies are increasingly interested in using and improving the accuracy of these relatively new measures, because travel time reliability can be a critical benefit and may even be larger than traditional travel time savings. For example:

- The FHWA now supports a national traffic monitoring program that tracks reliability measures in more than 30 cities.
- The Minnesota DOT and Cambridge Systematics studied the effects of a ramp meter shutdown on Minneapolis-St. Paul freeways. Turning off the ramp metering system worsened travel time reliability by 91 percent, while the average travel times worsened by only 22 percent. As a result, the Minnesota DOT continued operating its ramp metering program in 2001.
- The Washington State DOT tracks travel time reliability in its performance-monitoring efforts and provides reliability estimates to commuters. Commuters may select a trip on Washington State DOT's web site and generate a statistically robust travel time based on historical data.

Accurate measurement of reliability requires continuous measurement of travel times from which a distribution can be constructed. Unfortunately, modeling techniques for estimating reliability are scarce. The FHWA's IDAS model, however, was the first to compute incident delay as a function of recurring congestion level and incident duration and uses it as an indicator of reliability. The Southern California Association of Governments (SCAG) recently noted similar research on the relationship between reliability and base congestion level, and developed its own set of predictive equations.

2.2 OVERVIEW OF TRAVEL TIME RELIABILITY

Defining Reliability

In the Future Strategic Highway Research Program (F-SHRP) Reliability Research Program, travel time reliability was defined as:[11]

"…from a practical standpoint, *travel time reliability can be defined in terms of how travel times vary over time* (e.g., hour-to-hour, day-to-day)." This concept of variability can be extended to any other travel time-based metrics, such as average speeds and delay. For the purpose of this study, travel time variability and reliability are used interchangeably.

A slightly different view of reliability is based on the notion of a probability or the occurrence of failure often used to characterize industrial processes. With this view, it is necessary to define failure in terms of travel times and establish a threshold. Then, the number of times the threshold is not achieved or exceeded can be counted. These types of measures are synonymous with "on-time performance" since performance is measured relative to a pre-established threshold. The only difference is that failure is defined in terms of how many times the travel time threshold is exceeded, while on-time performance measures how many times the threshold is not exceeded.

In the forthcoming NCHRP Report 3-68, *Guidebook for Effective Freeway Performance Measurement*, it is noted that the variability and failure definitions have a common underlying theme – they both imply that a history or distribution of travel times exists. The history over which travel times are measured must be sufficiently long, so as to capture the variations that occur due to the random and planned events that occur on the roadway system. Once this distribution is established, it is possible to construct any number of measures to describe its size and shape.

Figure 2.1 below shows a travel time distribution for a freeway segment (I-75 in Atlanta, Georgia) derived from ITS detector data for the afternoon peak period on weekdays. The general shape of this distribution (roughly a log-normal distribution in statistical terms) is typical of weekday peak periods. A long tail is evident indicating some days with extremely long travel times. Both traditional

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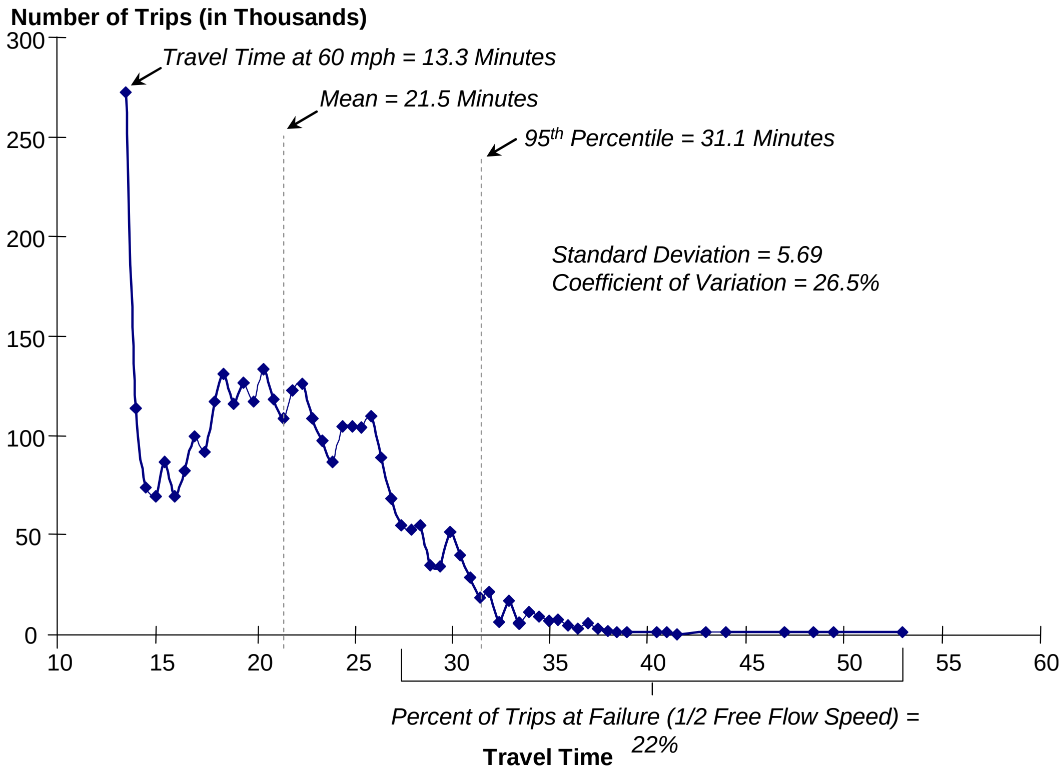
[11] *Providing a Highway System With Reliable Travel Times*, report for NCHRP Project 20-58(3), September 2003, http://trb.org/publications/f-shrp/f-shrp_webdoc_3.pdf.

measures of variation (95th percentile, standard deviation, coefficient of variation) and an "occurrence of failure" measure (e.g., percent of trips that occur at less than one-half the free-flow speed) can be defined with this distribution.[12] This leads to a more general definition of travel time reliability:

Travel time reliability is defined as the level of consistency in travel conditions over time and is measured by describing the distribution of travel times that occur over a substantial period of time.

Figure 2.1 **Reliability Is Determined by the Distribution of Travel Times** (*Example Measures Only)*



Source: Analysis of NaviGAtor data (Atlanta, Georgia): I-75 Northbound from I-285 to Wade Green Road (13.33 miles), 5:00 p.m. to 7:00 p.m., weekdays, 2004.

Note: Total number of trips for time period = 3.485 million (each point on the line represents the number of trips grouped by 30-second travel time intervals). Note that about 8 percent of trips (275,000 out of 3.485 million) occur at free flow during this period.

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[12] In this example, on-time performance would be the percent of trips that occur at one-half the free-flow speed or greater. The threshold can vary, but failure and on-time performance are basically the same thing; they just reference different sides of the threshold.

2.3 MEASURING TRAVEL TIME RELIABILITY

Given the foremost definition, the measures, or metrics, to monitor and predict travel time reliability must describe the size and shape of the underlying distribution in some manner. The distribution shown in Figure 2.1 is typical of congested urban freeways – the long tail to the right shows the effect of roadway events that cause travel times to be unreliable. Performance measures of reliability can include traditional statistical measures, such as standard deviation, but since the distribution has been found in empirical studies to be asymmetric, other indicators are more valuable in describing reliability. These include the textbook measures of skewness[13] and kurtosis.[14] But, as seen in Table 2.1, other measures specific for transportation applications have been recommended and are currently being used by some transportation agencies.

Table 2.1 Potential Reliability Performance Metrics

Reliability Performance Metric	Definition	Units
Buffer Index (BI)	The difference between the 95th percentile travel time and the average travel time; normalized by the average travel time	Percent
Planning Time	The 95th percentile travel time	Minutes
Failure/On-Time Measure No. 1	Percent of trips with travel times < (1.1 * Mean Travel Time)*	Percent
Failure/On-Time Measure No. 2	Percent of trips with travel times < (1.3 * Mean Travel Time)*	Percent
Planning Time Index	95th percentile Travel Time Index divided by the free-flow Travel Time Index	None
Travel Time Variance	Common statistical definition of variance	None
Percent Variation (coefficient of variation)	Standard deviation of travel time divided by the mean travel time	Percent
Misery Index (modified)	The difference between the average of the travel times for the (0.5-5) percent longest trips and the average travel time; normalized by the average travel time (useful primarily for rural conditions)	None

* Thresholds for failure/on-time metrics have not been examined in detail; these are only suggestions. Note that as shown these measures are for "on-time performance." For failure-based metrics, the sign would be changed to ">".

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[13] Skewness is the measure of the asymmetry of the data around the sample mean. If skewness is negative, the data are spread out more to the left of the mean than to the right. If skewness is positive, the data are spread out more to the right. The skewness of the normal distribution (or any perfectly symmetric distribution) is zero.

[14] Kurtosis is a measure of how affected a distribution is to outliers. The kurtosis of the normal distribution is 3. Distributions that are more outlier-prone than the normal distribution have kurtosis greater than 3, and distributions that are less outlier-prone have kurtosis less than 3.

Of the metrics listed in Table 2.1, the Buffer Index seems to be the one that resonates best with auto travelers and the transportation profession. It expresses the amount of extra "buffer" time needed to be on-time 95 percent of the time (or late one day per month). Indexing the measure provides a time and distance neutral measure, but the actual minute values could be used by an individual traveler for a particular trip length.

Other passenger modes that have schedule-based performance have used on-time performance as a way to describe reliability. This does not work as well for auto travelers, where every traveler's "schedule" is different. But it is possible to use on-time performance for highway reliability, just as it is possible to use the Buffer Index for transit trips. In all cases, it is necessary to develop the underlying distribution of travel times.

To understand travel time reliability, it is essential to understand the factors that cause travel times to be unreliable. As mentioned above, reliability is determined by the variability in conditions that travelers encounter from day to day. Therefore, reliability metrics reveal that variability exists in the system – but not the cause of it.

The so-called "Seven Sources of Congestion" identifies factors that cause travel times to be unreliable and contribute to total congestion and include incidents, inclement weather, work zones, special events, traffic control device timing, demand fluctuations, and inadequate base capacity.[15] These categories are helpful, but not detailed enough for the purposes here. Figure 2.2 below shows that by decomposing reliability into its components, a clearer picture of how improvement strategies affect reliability emerges. That is, reliability is determined by the contributions of each of its underlying factors; the delay caused by each source determines reliability. The amount of delay due to the sources is determined by the physical and operating characteristics. In Figure 2.2, incident delay is shown to be a function of incident duration (as well as other factors). In turn, incident duration is affected by activities aimed at managing incidents. This leads to a conceptual model that can be used in project analyses:

Improvement ➔ Δ *Event/Physical Characteristics* ➔ Δ *Source Delay* ➔Δ *Reliability*

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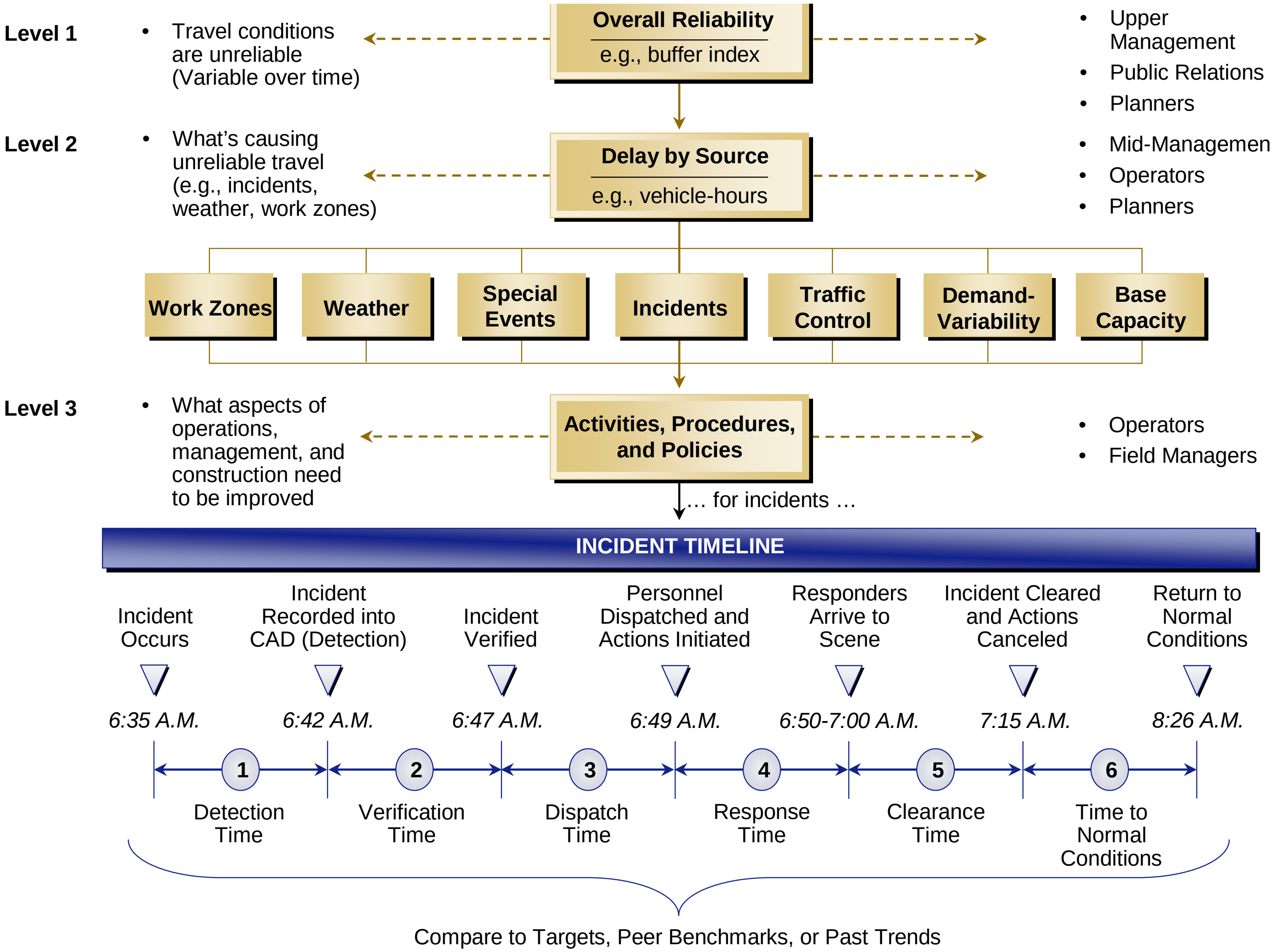
[15] Reference (1).

Figure 2.2 Measuring Reliability Requires Understanding Its Causes



Valuing Travel Time Reliability

Commuters and freight shippers are both concerned with travel time reliability. Variations in travel time can be more frustrating and more highly valued by both groups. Previous research[16] indicates that commuters value the variable component of their travel time between one to six times as much as average travel time. The increase in business logistics services has made a reliable travel time almost more important than an uncongested trip as significant variations in travel time decrease the benefits from the use of efficient transportation networks in today's economy. Therefore, in both the passenger and freight realms, some evidence suggests that travel time reliability is valued at a premium by users. In other words, the value of reliable travel is over and above what is expected or normal.

Unfortunately, there has been little application of these principles in practice. In the FHWA's IDAS, separate estimates of recurring (capacity-related) and incident delay are made and different unit costs for the value of time are applied. In the highway field, there has been only one effort to link costs directly to travel time reliability measures (e.g., the size of the Buffer Index). SCAG used continuously collected freeway data to derive a relationship between the Buffer Index and Travel Time Index (a measure of average congestion that can be computed using readily available models and methods).[17] The SCAG method is innovative and the only evidence to date of an agency using a direct measure of reliability in economic analysis. (IDAS uses congestion source delay.) However, the relationship they use is macroscale and specific to freeways in Los Angeles, and it is not known to what degree the various sources of congestion are present in the data. Direct estimation of reliability measures has been limited to analysis of continuous travel time data, so no model is currently available that can produce pure reliability measures.[18]

SCAG assumed that the value of time in the "buffer" was equal to the average value of time when it conducted an economic analysis of congestion's effect on goods movement. The assumption is that the buffer is built into trip planning by travelers, so they expect the trip to take that long. In other words, they carve out

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[16] Cohen, H., and F. Southworth, *On the Measurement and Valuation of Travel Time Variability Due to Incidents on Freeways*, Journal of Transportation Statistics, Volume 2, Number 2, December 1999, http://www.bts.gov/jts/V2N2/vol2_n2_toc.html (This paper summarizes previous research on the subject of the value of reliability.).

[17] The relationship showed Buffer Index increasing with Travel Time Index.

[18] NCHRP Project 7-15 is developing a simplified method for estimating reliability measures for planning applications; publication is expected in summer 2007. SHRP II Project L03 will also deal with this issue in detail; it is a two-year project expected to start in January 2007.

a bigger piece of their day than the average travel time would indicate. There are additional considerations when using this approach, however:

- On some days, travelers will arrive earlier than the buffer time – is there a penalty for this early arrival? These are probably not major, but there may be cases where penalties exist.
- On other days, travel time will exceed the buffer time (by the current definition, this will happen 5 percent of the time). What value should be placed on this late arrival? No research is available, but it is logical to assume that most travelers would value this at a higher rate.
- Savvy travelers making routine trips (e.g., commuters and some truckers) have the experiential knowledge to estimate what the buffer should be. What about travelers with no such information? Most of the delay experienced is unexpected, and because it is not accounted for in trip decision-making, is it valued at a higher rate?

Methods to Estimate Travel Time Reliability

The best way to develop travel time estimates is to measure times directly. Measuring the real time it takes for vehicles to traverse distances is the most desirable way of producing travel times. Probe vehicles – outfitted either with technology for toll purposes or with global positioning system (GPS) tracking – offer promise, as does the tracking of cell phones. However, all current methods have shortcomings and are expensive to undertake just for the purpose of developing performance data. (Leveraging data already collected for operations is cost-effective.) Also, for project evaluation, it is necessary to forecast both average congestion and reliability. Therefore, for the immediate future, it is assumed that modeling will be used to produce forecasts of delay by source, and the required data will support those models.

Nevertheless, a general approach based on a combination of the SCAG and IDAS methods can be applied to project-level analysis:

1. If continuously-collected travel time data are available locally, develop custom relationships between Buffer Index (BI) and Travel Time Index (TTI). (Note that these data will reflect the influence of events that took place over the collection period. Therefore, the extent of these events should be noted.)
2. Using the data and models indicated below, estimate the source of delay with and without the project over the time horizon being assumed.
3. Compute a TTI that includes all the sources of delay.
4. Compute a Buffer Index using the custom relationships developed between BI and TTI.
5. Value the buffer time based on roughly the same value being used for average travel time. Account for “premiums” for special trips and the 5 percent of the time the buffer time is exceeded.

Data and Models to Estimate Travel Time Reliability

Recurring (Capacity-Related) Delay

Models. Agencies use a wide variety of planning models and methods to estimate recurring delay. These include the Highway Capacity Manual (HCM), travel demand forecasting models, and traffic simulation models.

Data. Traffic demand (volumes, speed, vehicle mix); information on the physical characteristics of the roadway.

Incident Delay

Models. Traffic simulation models provide the most accurate depiction of incidents, but they only can only reproduce one incident at a time. IDAS predicts what the cumulative delay of incidents is by using national defaults for incident characteristics. The HERS uses a more complex method to estimate incident delay. A corridor-based procedure, that is the basis for the IDAS and HERS incident prediction models, is also available.[19]

Data. IDAS' relationship uses incident duration, incident rate, and peak volume-to-capacity (v/c) ratio as independent variables. HERS and the corridor procedure use incident duration, number of lanes, total incident rate, accident rate, shoulder width, and average annual daily traffic-to-capacity ratio as independent variables.

Work Zone Delay

Models. The FHWA's QuickZone model provides a planning-level estimation of work zone delay, but only for individual work zones.

Data. Traffic demand, physical characteristics of the roadway, work zone extent, and duration.

Weather Delay

No weather-specific models have been developed to estimate weather delay, but capacity reduction factors have been presented in the literature, as well as the HCM 2000.

Special Event Delay

Models. The same models as for recurring delay can be used.

Data. The same basic data as for recurring delay can be used, but traffic demand surges must be estimated.

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[19] Cambridge Systematics, Inc., *Sketch Methods for Estimating Incident-Related Impacts*, prepared for the FHWA, December 1998.

Incorporating Travel Time Reliability into ROI Analysis

Note that in the above discussion on models and data, the delay sources traditionally labeled as "nonrecurring," physical capacity has been shown to have an effect. Therefore, any project that expands physical capacity must have all the sources of delay estimated for it. Guidance for how various capital and incident management strategies affect incident characteristics may be found in existing literature. To estimate weather, work zone, and special event delay over the life of a project:

- Determine a set of representative events and how often they will take place. This may include the number of rain or snow events, routine maintenance or resurfacing, and special events.
- Estimate the effect of each event individually; sum over the project life.

For use within an ROI analysis, it is necessary to convert reliability performance measures into monetary effects. Unfortunately, there is no standard approach to do so within the literature, but the most simplistic and intuitive method may be to use estimates of the Buffer Index to estimate the additional planning time needed to ensure on-time arrival. In essence, results from the Buffer Index (or improvements to reliability) can be measured as reductions in various sources of travel delay and monetized similar to travel time savings and incorporated into an ROI analysis as an additional benefit of transportation projects.

Note that bus transit that uses general purpose lanes are subject to the same effects as autos. Bus transit that uses exclusive lanes must be analyzed separately, but the same models can be used. Nonhighway transit modes are not subject to the sources of congestion. Instead, historical reliability patterns may be extrapolated into the future, or improvements in equipment performance may be assumed to improve future travel time reliability.

2.4 METHOD AND GAPS IN MEASURING TRAVEL TIME RELIABILITY

Estimating Reliability and Delay

In order to understand the history of travel times, or distribution, that defines reliability, it is necessary to obtain continuously collected data so that a reasonably complete distribution of travel times exists. In many areas, however, this data is either not readily available or infrequently used, as the estimation of travel reliability is still a relatively new concept to many transportation agencies. Nevertheless, many urban freeways are instrumented, enabling travel time reliability to be measured directly. This instrumentation is almost exclusively roadway devices spaced close together (usually about one-half mile) that detect volumes and spot speeds of vehicles. Travel times may be synthesized from these measurements as long as the detectors are reasonably closely spaced.

Rural highways are not amenable to this type of instrumentation (the number of detectors required would be prohibitive), and travel times on signalized highways cannot be measured with this type of instrumentation (since most of the delay occurs at the signals where these detectors are useless). Nevertheless, recent developments in collecting travel times directly (rather than synthesizing them) are encouraging for all highway types, although there are still technical problems that plague the methods. Several options have been explored:

- **Toll tag readers to detect the passage of vehicles.** This is the most mature technology, but requires that roadside readers be used and that a sufficient number of vehicles use automated toll collection. Futuristic plans call for roadside readers to communicate with vehicles via onboard communication systems (the Vehicle-Infrastructure Integration, or VII concept), but this idea is still in the formative stages.
- **GPS-based measurements from vehicle trajectories.** Collecting vehicle positions in time and space allow the computation of travel times. It requires that vehicles have the ability to communicate data remotely through some long-distance wireless technology.
- **Cell phone-based measurements of time and position.** An alternative application of technology for locating vehicles in time and space.
- **Electronic license plate matching**. This method detects the passage of vehicles past fixed points similar to toll tag readers. It also requires deployment of roadside detectors.

The private sector has shown an increased interest in getting involved in both the collection and provision of travel time data, primarily for real-time traveler information purposes. As a result of this, and the desire to instrument highways more completely from the public-sector viewpoint, it is a near certainty that the availability of historical travel time data from which reliability estimates can be made will increase substantially in the near future. If so, analytical or short-cut methods for identifying current reliability levels will be needed much less frequently.

Assuming that continuously–collected data are available (at least on higher order highways), then computation of overall reliability metrics (see Table 2.1 above) will become relatively straightforward. However, estimating delay by source will still be problematic. This will require a careful synthesis of travel time and event data to decompose total delay and reliability into their component sources.

Valuing Reliability

In spite of a large number of studies, placing monetary values on travel time has been problematic throughout the history of transportation economic analysis. These studies have tried to determine the value of a static travel time, but the problem is exacerbated when variability (reliability) is introduced. Nevertheless, it is certain that the unpredictability introduced by uncertain travel times for a trip – even a familiar one – imposes costs on travelers. The cost is in addition to what the typical or average travel time is for a trip. The cost to travelers is realized by either adding a buffer to their typical travel time (i.e., leaving early), a penalty for arriving late at their destinations, or both. In some cases, the actual travel time will exceed the buffer. Therefore, the specific gaps in assigning value to travel time reliability are:

- The value of time in the buffer;
- How different users or trip types determine the size of their buffers;
- How different users, trip purposes, or goods receivers/shippers value reliability and on-time performance;
- The value of time in excess of the buffer (perhaps by trip type); and
- The value of delay for each source of congestion – is event-related delay valued at the same rate as recurring (bottleneck) delay, or should it be valued higher because it is unexpected?

There are models, such as the FHWA's IDAS, that attempt to value travel time reliability by trip purpose (e.g., higher value for trucks) based on empirical and statistical studies of value of time. The general finding was that the reduction of nonrecurrent delay is valued at three times recurrent delay. This value, derived though a Delphi method, is intended to convey a significantly higher value of time for improving reliability rather than assert a rigorous, empirical multiplier.

Forecasting Reliability

Reliability is a function of the relationships between the causes congestion. Each of causes of congestion, in turn, is a function of the influence of different factors. The four causes some of their most factors are:

1. **Physical capacity.** Number of lanes, width of lanes, shoulders, intersection characteristics, etc.;
2. **Traffic demand.** Both average and peak period variation, mix of trucks, characteristics of drivers, etc.;
3. **Event characteristics.** Duration, blockage, extent of accidents, construction, weather, etc.; and
4. **Operations strategies deployed**.

Once the relationship between factors is known, it will be possible to derive a forecasting method for reliability. It will also be necessary to develop data for each of these factors. Physical capacity and average traffic demand currently are commonly collected.

For the immediate future, two methods can be used as an interim way of forecasting reliability:

1. **Generate simple relationships between a reliability measure and general congestion level**. This is the approach taken by SCAG (based on work done for the FHWA)[20], as described above. The same approach can be used to develop a family of relationships for use within a given state.

   Recently, data from several cities were combined to develop a single (but simplified) relationship (see Figure 2.3 below). Several equation forms can be fit to this data; Figure 2.3 shows only one, which is based on an assumption that reliability is capped at an upper limit. (Whether this is true or not is unknown.) What the data generally show is that as the general congestion level (X-axis) increases, so does unreliable travel. So, any strategy that decreases the average congestion level also improves reliability. Developing different equations for facilities with different characteristics will probably yield less "noise" in the data. Adding more factors (such as proposed under the SHRP2 L03 project mentioned below) will also probably reduce the variation.

2. **Use available models to estimate as many of the individual sources of congestions as possible.** See discussion of methods of estimating reliability for estimation of delay sources and potential models and data.

   Even with plentiful travel time measurements, it will still be necessary to forecast reliability for project evaluations and short- and long-range planning applications. Almost no research has been done on this topic, although several methods are available for estimating delay, as cited earlier in this section. The SHRP2 Research Program has identified a potential research project to improve this process: Project L04 – *Incorporating Reliability Estimation into Planning and Operations Modeling Tools*. Also, a current SHRP2 research project, Project L03: *Analytic Procedures for Determining the Impacts of Reliability Improvement Strategies*, will expand our knowledge about how to estimate reliability.

2.5 RECOMMENDATIONS ON THE USE OF TRAVEL TIME RELIABILITY IN ROI ANALYSIS

The primary recommendation regarding travel time reliability is simply to include measures of reliability within ROI analyses. Most travel performance analyses of transportation investments are based on average travel conditions,

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[20] Cambridge Systematics, Inc., and Texas Transportation Institute, *Traffic Congestion and Reliability: Trends and Advanced Strategies for Congestion Mitigation*, September 2005, http://www.ops.fhwa.dot.gov/congestion_report/index.htm.

thus missing the effects of travel time variability, and the potential benefits of improving reliability and reducing the negative congestion effects of traffic incidents. Other major recommendations are the following:

- **Estimate reliability using relationships of travel congestions and variability as found in nations studies.** As discussed earlier, the most compelling performance measure is the Buffer Index (BI) concept, which accounts for the variability and uncertainty in travel time based on estimated relationships of highway conditions and travel variability from real travel data.
- **Define reliability as additional planning time to ensure on-time arrival 95 percent of the time.** This related recommendation, ideally, could be developed by continuing to collect local highway data that can be used to refine estimates of reliability and customize to regional traffic conditions.

The remainder of this section is a step-by-step description of how to estimate the Buffer Index and how to convert estimates of reliability into monetary terms for use as part of a ROI analysis. The methodology is based on current data and estimated relationships; however, this is an area of active research, and thus practitioners are advised to follow the most current research and guidance provided by the FHWA and the SHRP 2 research study.

Analytical Steps to Estimate Reliability Benefits for ROI Analysis

Inputs Required to Apply the Procedure

For the highway link, segment, corridor, or trip under study, all that is needed to estimate reliability benefits is data on "congested" travel time and free-flow travel time, as commonly produced by travel demand models:

- Estimated travel time (minutes) under prevailing conditions (aka, congested travel time); and
- Free-flow travel time (minutes; may be estimated from free-flow speed and length of trip).

Additional local data on travel time variability can also be used as described in Step 1.

Step 1. Develop Local Reliability Relationships

Research is currently underway under the SHRP 2 program to provide detailed relationships linking reliability with highway conditions, traffic characteristics, and the nature of roadway events (e.g., weather, work zones, traffic incidents).[21]

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[21] SHRP 2 Project L03: Analytic Procedures for Determining Impacts of Reliability Mitigation Strategies, http://onlinepubs.trb.org/onlinepubs/shrp2/ReliabilityResearchPlan0701.pdf.

That research will provide more detail on how to make the appropriate estimates of reliability using the same measures discussed in the previous sections.

In the interim, users should develop custom relationships using locally-available data wherever possible. An example is provided in Figure 2.3 below. The relationship of interest predicts the Buffer Index as a function of the Travel Time Index. This is a simplistic relationship since the BI is in fact a function of many other factors (e.g., incidents), but the procedure can be operationalized at this point in time. Also note that the data on which Figure 2.3 is based comes from freeway surveillance systems. Currently, no data exist on signalized arterials to allow companion relationships to be developed. (SHRP 2 Project L03 is considering this issue.)

The procedure for developing the data shown in Figure 2.3 is based on developing data from freeway surveillance systems (traffic management centers (TMCs)). Detailed guidance for developing performance measures can be found in a recent NCHRP report.[22]

In general, the procedure is as follows:

- Define "facility segments," sections of freeways (one direction) that are relatively homogenous in traffic and physical characteristics (typically 2 to 5 miles in length in urban areas).
- Develop travel times from the data if the data come from point-based detectors.
- Calculate performance metrics: the Travel Time Index and Buffer Index that will be used in this application plus any others that would be useful for other applications.
- Develop customized equations linking TTI and BI. Two such curves have been fit to the data in Figure 2.3: one that assumes that BI will never get above 60 percent, and one that increases monotonically but at a decreasing rate. The form that the curve should take is not known at this point, so discretion is advised on the part of the analyst until better guidance is developed.

In the absence of local data on which to develop a local TTI/BI relationship, one of the equations shown in Figure 2.4 can be used. The user should be aware that the data is from three large metropolitan areas (Atlanta, Seattle, and Los Angeles); and one medium-sized metropolitan area (Minneapolis).

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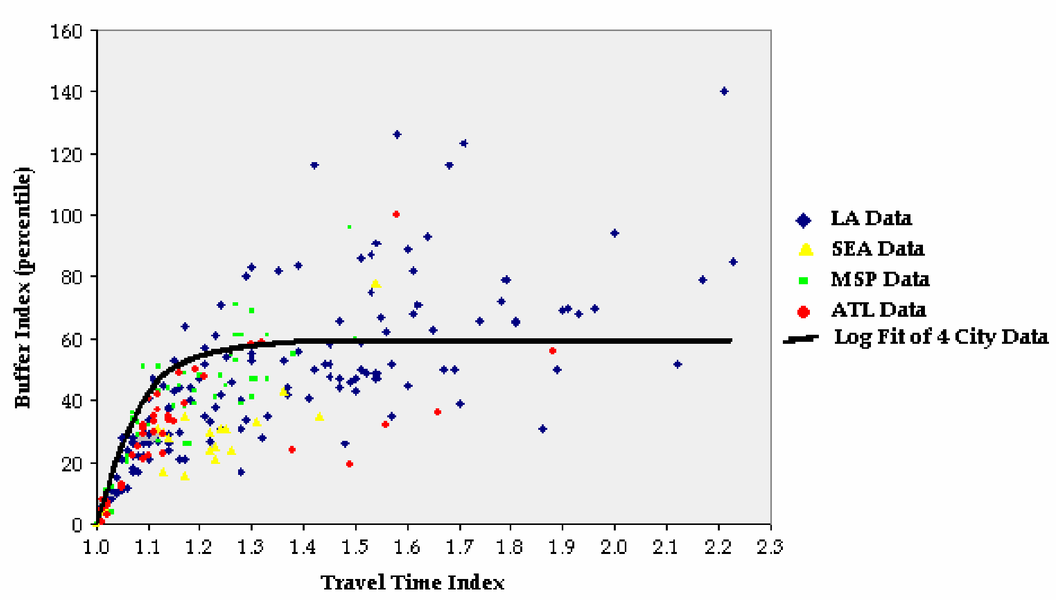
[22] Guide to Effective Freeway Performance Measurement, http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_w97.pdf.

Figure 2.3 Relationship between Buffer Index and Travel Time Index, With Two Representative Equations Fit to the Data (Freeways)



Log Fit Equation:

$$BI = 0.60 * (1 - \exp(-12.1 * (TTI - 1))) \quad (1)$$

Power Fit Equation:

$$BI = 0.8088 * ((TTI - 1)^{0.4459}) \quad (2)$$

Step 2. Convert Model-Based Congestion Calculations to the Travel Time Index

The Travel Time Index is one of many possible travel time-based measures of congestion; all of which can be computed from the same base data. It is the ratio of the actual travel time (for a link, segment, entire trip) to the ideal or free-flow travel time. Such data are available within common analytic procedures, such as travel demand forecasting models or the Highway Capacity Manual. These congestion calculations should be conducted for two highway modeling scenarios: 1) a "No-Build" scenario that does not include the transportation investment being evaluated; and, 2) a "Build" scenario that does include the relevant transportation investment.

Step 3. Compute 95th Percentile Travel Time Index

The "planning time," defined as the 95th percentile travel time, is the basis for economic analysis of travel time reliability. The procedure for computing the 95th Percentile Travel Time Index is as follows:

- Using the relationship and TTI (Steps 1 and 2 above), estimate the BI.
- The BI is defined as the ({95th Percentile TTI} – TTI) divided by the TTI. Rearranging this equation in terms of the PTI yields:

  95th Percentile TTI = (BI * TTI) + TTI (3)

Step 4. Convert TTI and 95th Percentile Travel Time Index to Pure Travel Times

The TTI (mean) and 95th percentile TTI are indices measured relative to the "ideal" travel time, interpreted to mean the travel time under free-flow conditions. Thus, a TTI of 1.2 means that the actual travel time is 20 percent greater than at free flow. To obtain the actual travel time and the 95th percentile travel times, multiply the free-flow travel time by the TTI and 95th percentile TTI, respectively.

Step 5. Estimate Value of Reliability and Travel Time Costs

It is assumed that the planning time needed to ensure on-time arrival is considered in freight shipping and personal travel decisions to account for reliability problems (i.e., disruptions from roadway events). The question then becomes what value of time should be assigned to this planning time? Travelers may not actually spend the full amount of time traveling within this buffer time on any given day (some days are better than others, in terms of travel conditions), but their schedule must allow for this time. That is, they have to leave earlier than desired to ensure that their arrival is on time. In this way, the planning time is assumed to be an opportunity cost. On "good" days, travelers do not actually spend that time traveling, but they have to budget for it in case travel was unreliable. Since it is assumed that travelers have "built in" the extra time to their travel budgets (i.e., they expect or anticipate the extra time), a conservative recommendation is that the planning time should be valued at the same rate as the average travel time from traditional transportation economic analyses.

In addition to the assumptions of the planning time being an opportunity cost and that it should be valued the same as the average travel time, this procedure also assumes the following:

- **No benefits for early arrivals.** Arriving early at a destination is assumed to be benign for travelers. Some individual travelers may view this as benefit, while some commercial travelers may view it as a disbenefit. (Truckers arriving early may be forced to wait in remote areas.) For simplicity, the procedure does not account for these factors.
- **No extra penalties for those days when the planning time is exceeded.** On five percent of the days, the travel time will be greater than the planning time. Since this time is "unexpected," it probably has a higher value. Nev-

ertheless, little research currently exists for valuing this unexpected time.[23] In this regard, the recommended procedure is conservative in its estimates of economic value.

2.6 EXAMPLE OF ESTIMATING TRAVEL TIME RELIABILITY BENEFITS FOR ROI ANALYSIS

An extended urban freeway section is being proposed for improvements. The existing cross-section is six lanes, and the proposed improvements widen this to eight lanes. The section is eight miles long, with interchanges every mile. The assumed free-flow speed is 60 mph. Table 2.2 presents estimates of speeds and volumes for each link sections between interchanges using travel demand model output.

Table 2.2 Example of Speeds and Volumes for Links Between Interchanges

	Peak Hour, Peak Direction			
	Existing 4-Lane Section		Proposed 6-Lane Section	
Section No.	Speed	Demand Volume	Speed	Demand Volume
1	60	3,000	60	3,000
2	55	3,500	60	3,500
3	55	3,500	60	3,500
4	45	4,100	60	4,100
5	35	4,600	60	4,600
6	35	4,600	60	4,600
7	20	5,200	55	5,200
8	20	5,200	55	5,200
Average		4,213		4,213

Step 1. Develop Local Reliability Relationships

No local ITS-generated data are available, so the default relationships are chosen.

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[23] The FHWA software ITS deployment Analysis system (IDAS) predicts non-recurrent delay and values that portion of travel delay at three times the value of time for recurrent delay.

Step 2. Convert Model-Based Congestion Calculations to the Travel Time Index

Since each segment is one-mile long, the peak-hour travel times are simply the inverse of the speed: (1/speed) times the length (in miles). The unimproved travel time is thus 13.9 minutes, and the improved travel time is 8.2 minutes. Assuming the free-flow speed is 8.0 minutes, the Travel Time Indices (TTI) are 1.73 and 1.03, respectively.

Step *3. Compute 95th Percentile Travel Time Index*

Using the "Power Fit" default relationship, the Buffer Index (BI) is computed as:

Unimproved: $BI = 0.8088 * (1.73 - 1)^{0.4459}$

$= 0.703$

Improved: $BI = 0.8088 * (1.03 - 1)^{0.4459}$

$= 0.169$

The 95th Percentile TTIs (Planning Time Index, PTI)) are computed as:

Unimproved: $PTI = (0.703 * 1.73) + 1.73$

$= 2.946$

Improved: $PTI = (0.169 * 1.03) + 1.03$

$= 1.204$

Step 4. Convert TTI and PTI to Pure Travel Times

The travel times have already been computed from the model outputs and are 13.9 and 8.2 minutes for the unimproved and improved cases, respectively. The 95th percentile travel times are obtained by multiplying PTIs by the free-flow travel time (8.0 minutes) and are:

Unimproved 95th percentile Travel Time = 23.57 minutes

Improved 95th percentile Travel Time = 9.63 minutes

Step 5. Estimate Travel Time Costs (Peak Hour)

For this analysis it is assumed that "time in the buffer" is estimated to cost at the same rate as the average travel time. The annual reliability travel time costs are computed as:

*(95th percentile travel time) * (value of travel time) * (average traffic volume) * 365*

Assuming the unit value of travel time is $13 per hour ($0.22 per minute):

Unimproved Travel Time Cost = 23.57 * 0.22 * 4,213 * 365
= $7,973,820
Improved Travel Time Cost = 9.63 * 0.22 * 4,213 * 365
= $3,257,870

3.0 Economic Development and Growth

3.1 INTRODUCTION

When considering the public return on investment from transportation projects, economic development benefits are often raised as an element of public benefits not fully captured by current methods of valuing travel time, cost, and safety benefits.

This section highlights the current state of economic development and growth considerations in literature of transportation analysis. In addition, this section reviews the measurement of economic development benefits, their relationship to measures of transportation efficiency benefits, and ways that they are incorporated into various benefit/cost and decision support tools.

This section also provides a review of the methods and data for estimating four classes of economic development impacts, along with 15 specific types of performance measures associated with them. Similar to previous sections, gaps in these methods and data that constrain their calculation or application are reviewed. The section concludes with key recommendations regarding the treatment of economic growth and development within transportation ROI analysis, including the preferred performance measures and techniques.

3.2 OVERVIEW OF ECONOMIC DEVELOPMENT AND GROWTH BENEFITS

Relationship of Transportation to Economic Development

Economic development refers to the process of growing jobs and income in a local, regional, or national economy through the attraction or expansion of business activity in that area.[24] In most case studies and guides on the topic, it is noted that transportation projects can support broader economic growth as a consequence of achieving cost savings and other efficiency benefits for travelers.[25] Transportation projects also can lead to negative externalities through

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[24] Economic Development Planning, International Economic Development Council, 2002.

[25] TRB Circular 477: Assessing Economic Impacts of Transportation Projects (Weisbrod, 1997); APTA: Public Transportation and the Nation's Economy (Vary, 1999); UK: A Framework for Assessing Studies of the Impact of Transport Infrastructure Projects on

Footnote continued

environmental (air, visual, or noise) impacts, or through displacement or shifting of the locations of some activities.

There are three processes by which travel performance benefits lead to broader economic growth:

1. **Savings.** Reducing the cost of doing business in a place, thus making it more attractive for business investment – either attraction of new activities or expansion of existing activities.
2. **Reliability.** Improving the travel time, reliability, or schedule frequency of movement or delivery, thus enabling or expanding the scope of business processes – such as "just-in-time" manufacturing, "same day delivery," or other on-demand services.
3. **Access.** Expanding market access in terms of the breadth of area from which workers can commute, customers can shop, or deliveries can be made within a given travel time – thus enabling a variety of business efficiencies and expansions.

It is useful to note that cost savings is a primary basis for calculating transportation system user benefits (also known as system efficiency benefits). Nevertheless, the total benefit of cost savings on the economy can be greater than the travel cost savings alone, insofar as it can also trigger additional business efficiency benefits. It also is important that reliability is sometimes, but often not, counted as a factor affecting traveler benefits, and market access is almost never counted in traveler benefit analysis. The use of these three measures in economic impact and benefit/cost studies is growing.[26]

It also is critical to note that all three of these processes for creating economic development benefits occur as a direct result of transportation system changes, as discussed at length in NCHRP 456, *Guidebook for Assessing Social and Economic*

Economic Activity (National Economic Research Associates, 1999); FHWA: Toolbox for Regional Policy (ICF et al, 2001); NCHRP 456: Guidebook for Assessing Social and Economic Effects of Transportation Projects (Forkenbrock and Weisbrod, 2001); FHWA Guide: Benefit/cost Analysis Model for Freight Transportation Improvements (FHWA, 2002); and U.S. DOT: Guide to Quantifying the Economic Impacts of Federal Investments in Large-Scale Freight Transportation Projects (Cambridge Systematics et al., 2006).

[26] Weisbrod, G., 2006, *Evolution of Methods for Assessing Economic Development Impacts of Transportation*, presented at the Third International Conference on Transportation and Economic Development (TED2006).

Effects.[27] There are dangers of "double counting" that would occur if an analyst adds economic development benefits on top of direct travel time and cost impacts.[28]

Economic development benefits can show up not only as changes in jobs and income, but also as changes in land development patterns and land costs. The FHWA commissioned a study and guide on alternative metrics for assessing actual economic impacts of highways, and noted that the same processes that create investment in jobs also affect property values and development activity levels by increasing demand for land and buildings to locate those jobs.[29] In general, land impacts are but an aspect of the more fundamental business investment process aimed at creating jobs and income, and are not a separate type of benefit to be counted separately and added on top of job and income benefits.[30]

While some aspects of travel performance benefits lead to additional economic impacts that are above and beyond what is counted as transportation user benefits, there also are some types of transportation user benefits that can be given a dollar value as a social benefit, but do not necessarily lead to any direct impact on the flow of currency in the economy. That includes the value of personal travel time and the value of various environmental and quality of life factors.

Current Practices

The broad category of economic development impact or growth benefit can refer to a disparate range of effects. Most current economic impact practices apply direct transportation cost savings effects to an economic model to capture economic development benefits to industries.

The core issue in considering economic development in ROI analysis is the need to carefully classify and appropriately treat different types of economic development effects. Some practices measure direct effects on construction and operations of transportation facilities, which affect the flow of expenditures on labor and materials. These actually reflect effects of spending on project costs; in which case they should not be counted again as benefits in a benefit/cost or ROI analysis. However, they may be still considered by local residents and agencies as an economic stimulus.

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[27] Forkenbrock, D., and G. Weisbrod, *Guidebook for Assessing Social and Economic Effects of Transportation Projects*, NCHRP Report 456, National Academy Press, 2001.

[28] UK: Analysis of Transport Schemes, 1999; Transport Canada: Guide to Benefit/Cost Analysis, 2000; FHWA: Asset Management Economic Analysis Primer, 2003; and Caltrans: Internet Guide to Benefit-Cost Analysis, 2004.

[29] FHWA: Using Empirical Information to Measure Economic Impact of Highway Investments, Economic Development Research Group, and Cambridge Systematics, Inc., prepared by the Federal Highway Administration, Washington, D.C. 2001

[30] FHWA: Toolbox for Regional Policy 2001, Federal Highway Administration, U.S. DOT. ICF.

More frequently, studies focus on longer-term economic growth effects of transportation investment measured by gross state/regional product or personal income. These impacts are sometimes considered by agencies as a reflection of the productivity benefits of transportation investments. When incorporated into ROI analyses at the state or local level, economic growth can reflect business location shifts from other areas (i.e., not a pure efficiency gain).

Another common practice assesses transportation program or project effects on economic development due to increases in local labor and business delivery markets. These effects can generate economies of scale in business operations and savings in supply chain logistics resulting from network connectivity and intermodal linkage improvements (i.e., second-order logistics effects).

For the past five years, this study's researchers have adopted the best practice (still uncommon) of including additional benefits from potential business attraction, taking care not to double-count these with the user benefit effects. In doing so, it is important to scale benefits according to jurisdiction, where gains in one county (or one state) may come at the expense of adjacent counties (or states). Authors' current work with the Federal Transit Administration (FTA) and U.S. DOT in developing a consistent approach to incorporating economic benefits as part of the funding decision process has pushed the state of the practice in all of these methodologies.

All together, these various techniques point to a diversity of practices that vary in application and appropriate use in ROI evaluations. There are a number of methods available for evaluating the economic development impacts of transportation investments. These range from simple input-output multiplier models, such as RIMS-II and IMPLAN; to regional economic simulation models, such as REMI and REDYN; and to integrated systems, such as HEAT and the Major Corridor Investment Benefit Analysis System (MCIBAS). HEAT and MCIBAS are used in various states, such as Montana and Indiana, to link transportation models with user benefit and accessibility models, and ultimately with economic impact models. The key, however, is to account properly for economic development benefits in an ROI analysis by distinguishing them from other transportation effects already measured.

3.3 MEASURING ECONOMIC DEVELOPMENT BENEFITS

Existing Tools and Systems for Analysis

A variety of economic development tools are coming into use specifically to assess the economic development impacts or benefits of transportation projects. They are summarized in the bullets that follow:

- **Local Economic Assessment Package (LEAP)** is a web-based analysis tool distributed by the Appalachian Regional Commission (ARC) to local and state agencies in 13 states. It relies on ESRI's geographic information system

(GIS), a national highway network, and U.S. DOT datasets to calculate access time from any community in the nation to rail, air, and marine terminal/port facilities with regularly scheduled services. This information can be used to calculate impacts of highway changes on business attraction.[31]

- **Highway Economic Analysis Tool (HEAT)** is a large-scale, GIS-based analysis framework that was originally developed for the Montana DOT's system to integrate detailed state transportation models, commodity flow data, and economic models within customized GIS software. That system provides further detail on changes in access to international trade gateways, as well as intermodal facilities and delivery markets for specific industries and commodities. It incorporates regional economic impact models to evaluate the full implications of those changes.[32]
- **Transportation Decision Analysis Software (TRANSDEC)** was developed as part of NCHRP 20-29 to allow for evaluation of transportation investment decisions spanning multiple modes of ground transportation. This package is notable because it is explicitly concerned with freight, as well as passenger transportation and considers multiple objectives, such as improved accessibility, connectivity, cost-effectiveness, resource impact, and economic growth. The system is designed for comparing multiple alternatives with minimum performance thresholds.[33]
- **Transportation Economic Development Impact System (TREDIS)** is a web-based evaluation system that is most notable for its distinctions between both freight and passenger benefits, and its simultaneous coverage of roadway, railroad, aviation, and maritime transportation. This economic analysis system evaluates how changes in transportation costs and accessibility relate to the operating requirements of various industries and resulting productivity and growth. It can work with the REMI, REDYN, or IMPLAN models with cost response factors, and then process results to show benefits and costs from alternative perspectives.[34]

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[31] See Appalachian Regional Commission: Handbook: Assessing Local Economic Development Opportunities with ARC-LEAP, Economic Development Research Group, 2004; and Appalachian Regional Commission: Handbook for Assessing Economic Opportunities from Appalachian Development Highways, Economic Development Research Group with Cambridge Systematics, Inc., 2001.

[32] See Montana DOT: Economic Effects of Reconfiguring Montana Two-Lane Highways, 2005.

[33] See NCHRP 20-20(2).

[34] See Weisbrod, G., *Evolution of Methods for Assessing Economic Development Impacts of Transportation*, presented at the Third International Conference on Transportation and Economic Development, 2006.

Transportation-Related Economic Development Effects

At the state and local levels, the interest in estimating the economic development benefits of proposed transportation project investments typically comes when either urban congestion or rural isolation are perceived to be factors that are holding back economic development by increasing travel times and costs. Most current studies of economic development separately examine the classes or "market segments" (both categories of travel and economic activity) that are most affected. These include the following types of transportation-related economic impacts, as identified in current literature:

- **Commuter Transportation.** In urban areas, growing congestion can raise costs of travel and costs of parking to congested center city and suburban sites. Research has shown that, in competitive urban labor markets, a significant portion of this added cost becomes reflected in the wage rate that employers end up offering to attract workers to those areas.[35] The NCHRP 463 Report, *Economic Implications of Road Congestion*,[36] analyzed Chicago and Philadelphia to show how congestion can lead to time delays that can add to business costs by also affecting the breadth of labor markets for various occupations. That same study also demonstrated the importance of travel time reliability to commuters and freight shippers and receivers.

  Several urban areas have since built on these principles to analyze the benefits of investing in major urban transit and roadway projects by showing how the costs of unchecked congestion growth can stifle future economic growth. This includes studies of Vancouver, British Columbia; Chicago, Illinois; and Portland, Oregon.[37] Studies in rural areas have also shown how highway network limitations reduce the effective spatial breadth of labor markets, thus discouraging some types of business activity that requires a minimal

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[35] Zax, J. S., *Compensation for Commutes in Labor and Housing Markets*, Journal of Urban Economics, Volume 30, 1991, pages 192-207; and Madden, J. F., *Urban Wage Gradients: Empirical Evidence*, Journal of Urban Economics, Volume 18, 1985, pages 291-301.

[36] Weisbrod, G., D. Vary, and G. Treyz, *Economic Implications of Road Congestion*, NCHRP Report 463, National Academy Press, 2001.

[37] Vancouver: Economic Impact Analysis of Investment in a Major Commercial Transportation System for the Greater Vancouver Region, Delcan Corporation and Economic Development Research Group for the Greater Vancouver Gateway Council, 2003, (Chicago Metropolis Freight Plan – (Ch.7) Assessing the Economic Impacts of Congestion Reduction Alternatives, Economic Development Research Group for "Chicago Metropolis 2020," 2004. (Note: This report referred to the TREDIS model by its original name, MEDIA – Multimodal Economic Development Impact Assessment), and (Cost of Congestion to the Portland Region, Economic Development Research Group, for the Portland Business Alliance, Port of Portland, Metro and Oregon DOT, December 2005.

size labor market threshold. This topic is discussed in the Appalachian Regional Commission's (ARC) *Sources of Economic Growth*.[38]

- **Customer/Delivery Markets.** Improving highway system connectivity between cities can sometimes lead to significant improvements in product and material deliveries. Through either industry surveys or use of commodity flow data, existing research has documented freight origin-destination flows and the specific industries that can benefit from some new highway connections.

  At a smaller spatial level, several empirical research studies have shown how delivery areas also can affect urban and rural districts, including a study that found the "effective density" of delivery opportunities affects economic efficiency and economic growth for some sectors.[39] This concept was used in the ARC's, *Sources of Growth* study to demonstrate how highway connectivity improvements can increase this effective density, and thus support further economic growth. That same study also used a GIS to show how highway improvements can expand the effective population or economic base located within a 40-minute drive time of a central location, and it used extensive statistical analysis to estimate the relationship between delivery opportunities and higher levels of trade and service industries in a given area. Notable studies include cross-state highways, such as the Wisconsin 29 Study, the Indiana's Major Corridor Investment Benefit Analysis System, and the Montana's Highway Reconfiguration Study.[40]

- **Production Processes.** There is a substantial and growing interest in the economic efficiency benefits of emerging "just-in-time" (JIT) production/assembly processes, which depend directly on truck delivery speeds and schedule reliability. Values of economic cost savings assigned to JIT benefits, as well

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[38] Appalachian Regional Commission: Sources of Regional Growth in Non-Metro Appalachia, four volumes, prepared for the Appalachian Regional Commission by Economic Development Research Group, MIT Dept. of Urban Studies and Planning and Regional Technology Strategies, Inc., 2006.

[39] Harris, Timothy and Yannis Ioannides, "Productivity and Metropolitan Density," Tufts University Department of Economics, 2000.

[40] Weisbrod, G., and J. Beckwith, *Measuring Economic Development Benefits for Highway Decision-Making: The Wisconsin Case*, Transportation Quarterly, Volume 46, Number 1, pp. 57-79, January 1992; Kaliski, J., S. Smith, and G. Weisbrod, *Indiana's Major Corridor Investment-Benefit Analysis System*, proceedings of the Seventh TRB Conference on Application of Transportation Planning Methods, 1999; and Montana DOT: *Economic Effects of Reconfiguring Montana Two-Lane Highways*, Cambridge Systematics, Economic Development Research Group, ICF Consulting, and SEH for Montana Department of Transportation, 2005.

as values of freight delivery delay savings, are shown in NCHRP 463 report on the economics of congestion.[41]

Another facet of economic benefit's to production processes is associated with the ability of high-speed highway corridors to support supply chains, such as the I-65 and I-70 "auto alley" – a manufacturing corridor that allows auto assembly plants to utilize parts suppliers that are dispersed wherever they can reliably provide same-day delivery. The concept of "dispersion economies" associated with highway corridors is discussed in some recent literature.[42] A further review of supply chain logistics and the impacts of truck and rail speed and availability are provided in the U.S. DOT's *Guide to Quantifying the Economic Impacts of Federal Investments in Large-Scale Freight Transportation Projects*.[43]

- **Intermodal Connections.** Another line of research and practice has focused on impacts on intermodal connections. In particular, it has been noted that even local highway projects often have some impact on travel times and connectivity to airports, marine ports, intermodal rail facilities, or interstate highway interchanges. As a result, even single-mode projects can be considered from an intermodal connectivity perspective. That is the concept behind the TREDIS system that was used to evaluate how highway improvements would affect airport and marine port connectivity in both Portland, Oregon, and Vancouver, British Columbia. A predecessor tool was used by Tennessee DOT for evaluation of how the proposed Appalachian Corridor "J" highway would lead to greater economic development by improving airport access.[44] The Montana Highway Reconfiguration Study used the HEAT to similarly examine how highway network improvements can enhance connections to other modal terminals.[45]

  A series of recent research has further improved the ability to estimate the economic development benefit associated with enhancing ground access to transportation terminals. For instance, the ARC *Sources of Growth* study included a statistical analysis of how travel time to airports differentially

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[41] Chicago Metropolis Freight Plan, *Assessing the Economic Impacts of Congestion Reduction Alternatives*, 2004.

[42] Polenske, K. R., 2001, *Competitive Advantage of Regional Internal and External Supply Chains*, Regional Science Perspectives in Economic Analysis (Edited by M. L. Lahr and R. E. Miller), New York: Elsevier.

[43] U.S. DOT., *Guide to Quantifying the Economic Impacts of Federal Investments in Large-Scale Freight Transportation Projects*, 2006.

[44] Tennessee DOT: Appalachian Corridor J Traffic Forecast, Travel Efficiency Benefits, and Economic Impact Analysis, Wilbur Smith Associates for Tennessee DOT, 2005.

[45] Montana DOT: Economic Effects of Reconfiguring Montana Two-Lane Highways, 2005.

affects various industries. The forthcoming NCHRP 4-32 report also discusses the economic value of truck-rail intermodal options for various industries.[46]

- **International Trade.** Highway and rail connections to border crossings and international gateways are often examined separately in economic analyses, because of the direct connection between the access and capacity characteristics of international gateways and the economic expansion of export industries that rely on them. Concern about the future sufficiency of international gateways and the potential stakes for economic development were a core element of recent studies, including the Latin American Trade and Transportation Study and the Ontario Goods Movement Study.[47] A study of international trade clusters for ARC also showed how export gateway access for those shipments would be affected by the completion of new segments of the Appalachian Development Highway System.[48]

Additional Considerations for Measuring Benefits

Motivation for Measuring Benefits and Impacts

Interest in assessing the economic development impacts of transportation comes from a variety of different motivations. They include the following:

- For an environmental impact report on effects of completing proposed transportation projects;
- For a local development strategy that involves identifying needed transportation investments to support that strategy; and
- For transportation investment decision-making where economic development benefits are a component of the public return on investment.

While this report focuses on transportation decision-making, it is important to recognize that there also is public interest in the topic due to the other two classes. In terms of environmental decision-making, the need to cover economic development factors is explicit in most guidelines for environmental impact reports. In terms of category local decision-making, ARC developed a guidebook specifically to help local agencies develop strategies to take advantage of

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[46] NCHRP 4-32, *Guidebook for Assessing Rail Freight Solutions to Roadway Congestion*, Global Insight and Economic Development Research Group, 2006.

[47] Goods Movement in Central Ontario: Trends and Issues, iTRANS Consulting, et al., for the Ontario Ministry of Transportation, 2005.

[48] Appalachian Regional Commission: Analysis of Global Competitiveness, Trade and Markets, Jack Faucett Associates and Economic Development Research Group, 2004.

new transportation projects.[49] Alternative reasons for examining economic development impacts and benefits are discussed in various guides, including the Caltrans' Internet Benefit/Cost Site; the TRB Circular 477, *Guide to Assessing Economic Impacts*; and the NCHRP 456 *Guidebook*. The rest of this report focuses on the use of economic development benefits for transportation analysis, specifically benefit/cost and return on investment appraisal of projects.

Economic Benefits vs. Economic Impacts

In transportation research, it is clear that economic development impacts of transportation projects are not the same as the economic value of project benefits. For example, for business-related travel, we can define total societal benefit and economic development impact measures. Both reflect not only the value of business travel time and travel cost effects, but also nontravel benefits for business users.

Yet total societal benefit and economic development impact differ in important ways. Measures of total societal benefit can include the value of a various personal time, quality of life, and environmental benefits, which may not necessarily be fully reflected in economic growth impacts. On the other hand, measures of economic development impact on a specific locality or region also can reflect income generation from business relocation effects, as well as indirect and induced regional multiplier effects – which would not be counted among the total societal benefits. For this reason, we use the term "impact" rather than "benefit" as a label for the basic economic development measure. So, using precise definitions, we can develop unique measures of the net present value of societal benefit/cost, as well as the net present value of economic development impact-cost. The similarities and differences between these two concepts are summarized below.[50]

The benefits and impacts of projects are similar when they may be counted or measured in more than one manner. For example, business-related travel time savings and travel-related money savings (including personal household costs and business productivity impacts) can be counted as elements of traveler benefit, but also measured as affecting the economy through business operating cost changes.

Economic development measures are considered broad when the measured impacts of a project on the economy include some factors that may not be counted in the net value of a project, or economic benefit. For instance, economic

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[49] Appalachian Regional Commission: Handbook for Assessing Economic Opportunities from Appalachian Development Highways, Economic Development Research Group, with Cambridge Systematics, Inc., 2001.

[50] Reprinted from *Evolution of Methods for Assessing Economic Development Impacts of Transportation* (Weisbrod, 2006).

growth impacts on a region or country can include short-term effects of construction spending, as well as longer-term effects of attracting business investment from another region or country. However, in benefit/cost accounting, construction spending by itself does not necessarily bring any net income benefit over the alternative of spending the same money on other investments. (That is the opportunity cost of the project's direct expenditures.) In addition, while business relocation decisions are typically motivated by the opportunity to increase profitability and return on investment, the net productivity benefit for the broader nation or world is usually less than the impact on a local area's economic growth.

Economic development measures are considered narrow when the project's measured impact on the economy excludes some factors that may be counted in the net economic value, or benefit. For instance, the dollar value of personal travel time improvements (an element of traveler impact) and the dollar valuation of air quality improvements (an element of social impact) are both real project benefits that can be assigned an economic value. However, that value does not automatically turn into an equivalent change in the flow of money and income in the economy. In addition, improvements in transportation safety are a clear social benefit, but they do not necessarily create any more net jobs and income in a local economy; it could be possible that they could lead to a loss of jobs and income in medical and car repair occupations.

Spatial Perspective for Measuring Economic Development Impacts

The nature of economic development impacts can appear very different depending on the spatial level of analysis – whether the focus is on localized impacts or broader regional or state impacts or national-level effects. For instance, local economic growth can occur by diverting some investment from other places, and some jobs may shift from one location to another. In some areas, the impacts may even appear to cancel out.[51] However, it is generally recognized that this tradeoff is not a zero sum matter, for businesses would not incur the added costs of moving to other locations unless there were net efficiency gains associated with doing so. Nevertheless, it is true that the economic change for some local areas may appear to be much larger or smaller than the net gain for the larger region. Thus, it is important to recognize how economic development impacts can be measured differently when viewed from different spatial perspectives.[52]

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[51] Boarnet, M., *New Highways and Economic Growth: Rethinking the Link*, access: Research at the University of California Transportation Center, Number 7, pp. 11-15, 1997.

[52] Weisbrod, G., and B. Weisbrod, *Assessing the Economic Impact of Transportation Projects: How to Match the Appropriate Technique to Your Project*, Transportation Research Circular 477, Transportation Research Board, 1997; Weisbrod, G. and M. Grovak,

Footnote continued

The concept of separately evaluating local, state, and national impacts has been incorporated in various analysis systems and studies. Most notably, the Airport Benefit/Cost System used by Wisconsin DOT explicitly distinguishes the local economic impact and the statewide economic impact for every airport studied.[53] That same distinction also has been a fixture of many major highway corridor studies conducted for various state transportation departments.[54]

Measurement of Nonmonetary Impacts

While there has been a growing literature on the value of including economic development impacts as an element of return on investment assessments, there is also growing realization that care must be taken to:

- Avoid double-counting transportation and economic benefits, and
- Distinguish real money flows that affect personal and industry costs and income from valuation of other factors that do not affect monetary flows.

That has led to the type of framework shown below in Table 3.1, which is based on U.S. DOT guidelines.[55]

Table 3.1 Example of an Accounting Framework that Distinguishes Economic Value of Benefits from Impacts on the Economy

Benefits Measured in Dollars	Travel Efficiency	Full User Benefit	Societal Benefit	Economic Development Benefit
Passenger time savings for personal travel	Yes	Yes	Yes	–
Passenger time savings for business travel	Yes	Yes	Yes	Yes
Travel vehicle operating expense savings	Yes	Yes	Yes	Yes
Shipper/recipient productivity gain	–	Yes	Yes	Yes
Indirect (downstream) productivity gain	–	–	Yes	Yes
Value of environmental benefits	–	–	Yes	–
Local income growth from business attraction	–	–	–	Yes

Comparing Approaches for Valuing Economic Development Benefits of Transportation Projects, Transportation Research Record, #1649, TRB, 1998.

[53] Wisconsin DOT, 2001.

[54] Wisconsin Highway 29 Study (Weisbrod and Beckwith, 1992); the Kentucky State Highway 69 Study (Weisbrod and Grovak, 1998); Southwest Indiana Highway Study (Kaliski et al., 1999); Zachary Taylor Parkway Study (EDR Group, 2001); and North Country Transportation Study (Hodge et al., 2003) in New York.

[55] Guide to Quantifying the Economic Impacts of Federal Investments in Large-Scale Freight Transportation Projects, 2006.

3.4 METHODS AND GAPS IN MEASURING ECONOMIC DEVELOPMENT BENEFITS

Performance Measures for ROI Analysis

The process of measuring or estimating economic development performance involves a sequence of four elements:

1. **Inputs** that are the driver of economic development impacts,
2. **Intermediate processes** that are the mechanism of economic development change,
3. **Core metrics** of economic development impacts, and
4. **Ancillary metrics** that reflect additional aspects of economic impact.

While it is possible to focus exclusively on the third category of the core measures of economic impact, most transportation agencies need a transparent and traceable analysis process and explanatory story to convince both constituents and decision-makers that the results are believable. Accordingly, performance measures are identified for all four of these elements, and the most appropriate measure(s) for ROI analyses are highlighted.

Input Measures

This category represents the four forms of transportation impact that lead to economic impact. All four of these measures can be important as a basis for understanding subsequent elements of economic impact. They are:

1. **Travel time**. Vehicle hours of travel (VHT) savings and its monetary value;
2. **Travel cost**. Monetary cost savings, including vehicle operating cost savings and safety improvement value, based on changes in VMT and VHT;
3. **Access**. Reduction in average travel times to workplaces, shopping, and other activity centers, controlling for the size of affected worker, shopper, or delivery travel markets; and
4. **Reliability**. Improvement or reduction in variability, calculated in terms of reduced hours/minutes of travel time (as described above).

These measures can either be derived directly from travel demand models (VHT and VMT impacts, speed calculations), or can be estimated using travel demand model output and other analytical processes. They are listed here because they also are needed as part of the process of calculating economic development impacts.

Intermediate Measures

This category represents the three mechanisms spurring economic growth impacts. They are not mutually exclusive, but rather a sequence of mechanisms, each of which incorporates the prior steps, as well as other considerations.

1. **Travel Efficiency.** Reduction in travel cost, expressed per vehicle trip or per travel quantity (number of travelers or quantity of freight affected) across trip purposes (business, commute, personal); vehicle/mode type (auto, truck, rail, air); and sometimes commodity.
2. **User Productivity.** This measure can be computed separately for transportation service operators and for businesses that are affected by commuting, worker travel, and/or business delivery trips. It is expressed as the reduction in total business operating cost per dollar of output (sales volume), or per dollar of labor. It also can be expressed as the inverse of these values – increase in output per dollar of labor or per total factor cost – which represents the classic measure of business productivity. (Note that this measure of business operating cost savings incorporates the preceding travel cost savings, as well as logistics/production scheduling savings and/or economies of scale in labor and product/service market access.)
3. **Competitiveness.** This measures of improvement in the ratio of business operating cost and business productivity (by industry), relative to corresponding averages for adjacent areas, competing areas, or national averages. (Note that this measure of change in the relative cost of doing business incorporates the preceding productivity measure, as well as comparisons with other areas.)

All of these measures involve the application of unit economic factors applied to the preceding travel time, expense, access, and reliability factors.

Core Metrics

This category represents the four basic measures of economic growth outcomes. Their values cannot be added together, as they represent alternative perspectives for viewing the same growth in economic activity. In all cases, they reflect net economic growth resulting when transportation improvements lead to increases in the productivity and attractiveness of an area for business investment.

1. **Employment.** The net increase in total number of jobs in a region resulting from economic growth. Job expansion is universally seen by economic developers as a benefit, because it represents an increase in opportunities for workers to obtain better paying and more satisfying jobs. Even the eventual attraction of more people to fill a net growth in jobs is widely seen as a benefit since that can ultimately bring greater shopping, recreation, and educational opportunities, increasing quality of life in many areas.
2. **Personal Income.** The increase in wages and other forms of income associated with economic growth. It results directly from increases in jobs, and

sometimes also from increases in average wage levels. This can be measured in terms of total wages for salaried workers, or alternatively in terms of total personal income, including wage income, self-employed proprietors income, and farm income. (Note that personal income growth is a direct outcome of the increase in employment plus any increase in pay per job).

3. **Gross Domestic Product (GDP).** This also is sometimes referred to as gross regional product (GRP) or gross state product (GSP). It represents the increase in total worker income plus net corporate income (profits). This effectively represents income generated by growth of local business activity and growth of business productivity. However, the increase in net corporate profits may flow to owners in the form of dividends, or reinvested in the business (which can be used to upgrade facilities, increase competitiveness, and/or expand operations). So while this is the best measure of income generated locally, we cannot be sure if all of that income flows to the local area since that depends on the extent of local ownership or the extent of capital reinvestment in local facilities. (Note that the increase in GDP incorporates the preceding increase in worker income plus corporate profit.)
4. **Output**. The increase in volume of business sales or revenue associated with economic growth. (Note that increases in business output incorporate the growth in GDP, as well as the cost of business inputs.) Output impacts are the largest of these measures of economic growth impact, but they can be misleading since they do not differentiate growth of business sales that has a high local value added from business sales that add relatively little income to the local area. For example, business output includes the value of purchases of intermediate goods, which can be substantial and from areas outside of the region of interest.

All of these measures involve the application of economic models to estimate or forecast economic growth impacts. In terms of ROI analysis, personal income and gross domestic product are the most commonly used metrics – as described, personal income is a slightly more conservative value to use (excludes corporate profit), and probably more appropriate for smaller geographic areas where profits are more likely to leak out of the region. GDP is a more comprehensive economic growth measure, although it can represent income benefits to nonresidents.

Ancillary Metrics

This category represents the five basic dimensions of economic benefit for residents. They each represent a different type of benefit that reflects that composition or nature of economic change, as opposed to the aggregate economic growth measures covered in the preceding section. In each case, they give credit to forms of economic growth that create more desirable jobs, attract more desirable industries, or take place in areas of particularly high need for economic development.

- **Better-Paying Jobs (income per capita).** The increase in average wages or household income associated with the attraction of higher-paying jobs. This measure provides credit to economic development impacts that attract higher-paying industries and higher-paying jobs.
- **Higher Growth Industries (industry mix).** The increase in prevalence (or percentage) of new jobs that are in high-growth industries. This measure provides credit to economic development impacts that attract jobs in those industries that are most likely to provide sustained or increased job and income growth in the future.
- **Reduced Unemployment (transfer payments).** The reduction in public unemployment and welfare payments due to growth of local jobs. This measure provides additional credit for job creation in areas where there is higher than average unemployment.
- **Retention of Young Workers (age mix).** The reduction in out-migration of workers under age 30 due to lack of job opportunities. This effect can be measured in terms of 1) the reduction in out-migration of the 18 to 30 age group, or 2) the increase in percentage of the workforce in this age group. This measure provides additional credit for job creation in areas where there is higher than average loss of younger age workers.

All of these measures combine the core metrics of economic growth together with some measure of the composition of that growth or the degree of local of economic hardship.

Gaps in Data and Methods

The performance measures identified for all four of the economic development elements cited in the previous section cannot all be readily available, adaptable, or appropriate for inclusion in ROI analyses or assessments of development impacts. The following sections highlight the data or methodological needs for developing measures to be used in assessments for each of the four impact categories (input, intermediate, core, and ancillary).

Needs for Input Measures

As mentioned above, all four of these measures – travel time, travel expense, access, and reliability – can be calculated from travel demand model results; however, only the first two elements (represented by VMT and VHT changes) are basic outcomes of travel demand models.

The third element, access times, can be produced via a straightforward highway network time “skim tree” process that derives average travel times from origin zones to various types of destinations. However, a GIS also is needed to assess changes in the magnitude of population, job, or workforce markets that are accessible to or from a given business location or intermodal transportation facility. Some models and systems, including HEAT and TREDIS, incorporate or make use of GIS systems to directly pinpoint locations of interest for access calculations, and also to measure market changes, using network access times together with population and employment data at a census tract or traffic zone level of detail.[56]

The fourth element, reliability, is critical to the economic development impact evaluation process in terms of accurate direct benefit estimation, as well as capturing benefits to businesses of meeting delivery windows and reducing the costs of unexpected delay (e.g., overtime pay, late shipments). Issues concerning the measurement of reliability are discussed earlier in this report.

In general, more work is needed to standardize the measurement and methods for using GIS to assess transportation project impacts on labor markets, truck delivery markets, and urban service markets at both peak and off-peak times.

Needs for Intermediate Measures

All three intermediate impact measures – travel efficiency, user productivity, and competitiveness – depend on the application of unit economic factors applied to the preceding travel time, expense, access, and reliability factors. In most cases, the values of these unit cost factors are still being refined by research.

For measures of travel efficiency value, the most critical factor is the measurement used to represent the value of time. Around the country, there is an increasing use of different values of time for different travel market segments – combinations of vehicle types and passenger trip purposes or freight commodities. The higher values assigned for truck freight movements, which is also the fastest growing segment of travel, is having a particularly important impact on valuation of highway and intermodal projects. This is an area for improvement, as new time values are being recognized, but standards should be agreed upon and promulgated in years to come.

For measures of user productivity, a critical factor is the measurement used to represent logistics cost. There is general agreement that logistics costs, including warehouse delivery schedules, can be a cost of travel delay that is beyond the mere cost of driver time and vehicle operations. There also is general agreement that just-in-time production processes can also incur costs from travel delays. A growing number of logistics studies are helping to define the range of these effects for various commodity and industry classes, and these values are now being used in a variety of transportation economic impact studies. However,

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[56] Other economic modeling tools (e.g., REMI, TranSight) calculate accessibility as the endogenous (unobservable) result of a series of equations operating at a county level of geography. This latter approach is problematic insofar as its broader geographic level can severely limit measurement of differences in alternative highway or rail line routing patterns, as well as the measurement of their very different impacts on market size and access to intermodal terminal facilities.

some economists still worry that the process of adding logistics costs and just-in-time production costs is susceptible to double counting of delay impacts. This is another area where new measurement methods are currently emerging, which will facilitate the development of better standards in the future.

The other critical factor for user productivity measurement is the economies of scale associated with access to broader labor and delivery markets. Two lines of study are serving to establish a basis for this measurement. One is the NCHRP study of the economic costs of congestion, which established a method for measuring the value of access to more diverse labor and supplier inputs. The other is the Appalachian Regional Commission study of the sources of economic growth. Both provide indirect methods for inferring the productivity benefits via observations of differences in business attraction and location. Both are now being used in some transportation evaluation studies. Clearly, more work is needed to better standardize these methods.

The final intermediate measure is competitiveness. This is actually a straightforward process, once the direct impact on business operating cost is calculated. However, there is substantial variation among economic models in the basis of reference (comparison) used for calculating competitiveness. For instance, the TranSight model compares costs for each local area to the national cost average to forecast the change in their predicted shares of national growth. On the other hand, the HEAT and TREDIS approaches compare costs for each local area to surrounding areas and highway linkage areas to assess opportunities for supply chain advantages and economic gains. In general, the basis of comparison is a topic of disagreement among economists, and transportation planners must select among the comparison basis that they deem most relevant for their particular case. It is less likely that there can never be standards developed for this issue.

Needs for Core Metrics

All four of these measures – employment, worker income, gross domestic product, and output – are typically calculated by regional economic impact models. The key problems are not with the internal mechanisms of various economic impact models, but rather, with the current state of practice in how these models are used. The two key issues are discussed below.

First, there is no standardization in the selection of alternative outcome measures to be used. Studies that focus on economic impact commonly emphasize the employment impact, since economic developers and public audiences find that measure to be most useful for judging success and this measure also is not susceptible to inflation over time. On the other hand, studies that involve some benefit/cost measurement or impact-expenditure comparison commonly emphasize either the income or GDP impact. There are arguments for both measures. GDP is the more complete measure of economic activity changes; it does not distinguish between profit that may be exported from the region to a company headquartered in another region and profit earned and reinvested in the local economy. In an increasingly global economy, not all of the profit generated will be reinvested always in the local area. Personal income, however, understates all of the economic activity generated from an investment (see the discussion in Section 3.5, Net Income as the Core Benefit Measure of Economic Development in ROI Analysis). As mentioned above, from an ROI analysis perspective, personal income or GDP is the preferred option to use as a measure of economic growth benefits (in addition to nonbusiness travel benefits and other social or environmental impacts).

Second, care must be taken in directly using income or GDP impacts in a benefit/cost or project prioritization context, since some elements of societal benefit may not be fully captured in income or GDP impacts, while other impacts that are irrelevant to benefit/cost analysis (such as construction spending effects) may also be included in the income or GDP measures. The benefit/cost web site, developed by American Society of Civil Engineers (ASCE) and Caltrans, provides guidance on this matter, although it is not always followed. There are several model accounting systems that do, however, clearly demark differences between economic development impacts and net economic efficiency benefits. So this is an area where appropriate procedures are generally clear to experts, although there is need for further promulgation of them to practitioners.

Needs for Ancillary Metrics

All four of these measures – job pay levels, industry mix, transfer payments, and age mix – are most commonly overlooked in transportation impact and prioritization studies. Nevertheless, there are exceptions, most notably in environmental impact studies (such as Indiana I-69, where all of these measures were actually used).

It is recommended that these types of performance measures be emphasized for greater use in the future for two reasons. First of all, they address needs of specific target groups that are of direct policy interest to governors and legislators. Second, inclusion of factors such as unemployment transfer payments can be used to more completely represent the full benefits of some projects. These factors, while challenging to incorporate within an ROI analysis, can be used in a broader, multifactor decision-making process.

3.5 RECOMMENDATIONS ON THE USE OF ECONOMIC DEVELOPMENT MEASURES IN ROI ANALYSIS

This section discusses criteria and recommended concepts for the inclusion of economic development performance measures in transportation ROI analysis. The key recommendations regarding the treatment of economic growth and development within transportation ROI analysis are:

- Economic development benefits can and should be included within a comprehensive ROI analysis, but
    - Need to be carefully distinguished from user benefits to avoid double-counting; and
    - Cannot include the economic impacts of capital investments or ongoing operations and maintenance spending to construct and run a transportation facility.
- Economic development benefits should be captured within an ROI analysis as either personal income and value-added (both concepts represent net income gains).
- The geographic (and often jurisdictional) perspective matters as economic gains may be larger in local/metropolitan areas compared to state or national levels.

Net Income As the Core Benefit Measure of Economic Development in ROI Analysis

The discussion of economic development performance measures earlier in this section made an important distinction between core metrics of economic growth and ancillary metrics that are also of policy interest. Among the core metrics, economic developers are often most interested in creating jobs, and economic impact studies often reference job impacts. However, for calculating return on investment and for combining economic development benefits with other transportation benefits, it is appropriate to calculate the income creation associated with that economic growth.

Possible income measures may include gross business income (output or revenue), net business income (value added or GDP), and personal income (wages and proprietors income). Among these measures, economists most often use GDP, which reflects changes in the value-added that is generated by the economy. It is calculated as business revenue net of the cost of nonlabor inputs. This effectively represents the value of worker income generated plus net corporate profits – which may be paid out to owners or retained for corporate reinvestment.

A narrower measure, however, may be appropriate when the analysis focuses on benefits to residents of a particular area (e.g., state), in which case it could be appropriate to use the narrower personal income measure. That measure does not count corporate earnings that may in fact flow to owners and investments located outside of the state or nation. When using the narrower measure of personal income, a benefit/cost or ROI measure can effectively reflect the amount of generated income flowing into the pockets of local residents, relative to the cost of taxes and fees flowing out of their pockets. Thus, the preferred measure for use of economic development impacts in a transportation investment ROI is net income growth (either value added or personal income).

Distinguish Economic Impacts from Benefits

Economic development impact measures can capture effects that are beyond the traditional traveler time, cost, and safety benefits. In particular, economic development benefits capture efficiency benefits for a broader group of beneficiaries of travel improvements (i.e., nonuser benefits), but are not necessarily the vehicle driver or passenger (i.e., the direct-user benefits).

Economic development impact measures provide a way to more fully account for these factors. Thus, they should be taken into account in any comprehensive consideration of transportation investment return on investment. Economic development benefit measures may also include some benefits that are not relevant to ROI analysis, and they may also cover factors that are already counted as traditional user benefits. The challenge for use of economic development benefits in transportation ROI analysis, then, is to avoid double counting or overlap with traditional transportation benefit measures. For instance, the value of travel cost savings is usually already covered by traditional transportation benefit measures. To the extent that these types of adjustment are done, then it is only necessary to consider additional economic development benefits insofar as they cover nonuser benefits that are not yet counted.

Transportation projects can have notable impacts on the creation of local income and jobs in ways that go beyond productivity and efficiency factors. For instance, they can lead to short-term growth of jobs for local construction activity, and longer-term growth of jobs for ongoing maintenance and operations of facilities and services. To a local area, that economic stimulus can translate into more business income and more personal income for residents, which can be particularly valuable if the area has significant unemployment or underemployment. It can also lead to some additional public and private revenues. From a benefit/cost or ROI perspective, however, the construction and operations are cost factors, and the income that flows to local workers cannot be counted as a net benefit.

The correct resolution to this situation is to include all construction and operating impacts as costs and explicitly omit them from the benefit calculations in all benefit/cost and ROI calculations. Nevertheless, the existence of those effects should not be totally ignored, as they do need to be recognized as an effect in environmental impact studies or economic impact studies.

- The inclusion of nonuser economic benefits should be adopted as standard practice in transportation investment ROI analysis. Economic development benefits represent one way of measuring such impacts, and can thus be used in an ROI analysis; however, care must be taken to distinguish user benefits to avoid double-counting.
- There should be an explicit distinction made between economic *impacts* and economic efficiency *benefits* ROI calculations of project efficiency benefit should explicitly omit construction and ongoing spending impacts on the economy, as well as localized shifts in activity patterns.

- ROI analysis of economic development impact should be explicitly recognized as limited to the measure of the efficiency of spending.

Accounting for Study Area Distinctions

Traditional travel efficiency measures include benefits regardless of whether the ultimate beneficiaries are located inside or outside of a given study area. For instance, a new highway that relieves network traffic bottlenecks may benefit travelers who never use the improved facility. Nevertheless, study area definitions do matter when assessing private return on investment in a toll road, or economic development benefits associated with business growth.

When measuring economic growth effects, it is important to recognize the potential effect of transportation investments on business location shifts. In general, business relocations occur when there is an opportunity to take advantage of new operating efficiencies enabled within, out of, and into areas served by the transportation improvements. The end result can be a large local income impact, but a much smaller regional or national income efficiency impact. Thus, from a benefit/cost or ROI perspective, the geographic perspective does matter. For instance, in the case of substantial local economic development benefits, the resulting benefit/cost ratio could be higher for the local jurisdiction (e.g., county) than it is for a regional jurisdiction (MPO or state). Therefore, the practitioner must distinguish between differences in the public benefits when viewed from alternative levels of spatial or jurisdictional detail (e.g., regional, state, Federal benefits).

Additional Support for Public Decision-Making

The ancillary metrics noted in the previous sections refer to secondary policy interests – increased job quality, reduced unemployment and welfare transfer payments, retention of young workers, reduced economic volatility, and better future growth prospects for economic growth. It is important to recognize that there is a clear public interest and benefit in achieving all of these types of goals. Nevertheless, they all relate to some aspect of the distribution of economic growth impacts, which is distinct from ROI measures that capture the efficiency of spending. Good policy-making should, of course, consider both efficiency of spending and its equity or distributional effects.

It is possible that some improvements in the distribution of benefits can also enhance economic productivity, and hence the efficiency of spending. For instance, investments that improve job quality and/or reduce unemployment can lead to enhanced worker productivity and reduced public costs of transfer payments (particularly when they occur in areas of economic distress). If these types of benefits can be included in the measurement of net income benefits, then they can be reflected in ROI measures (with less need for ancillary benefit measures).

The problem at this time is that available economic impact models cannot really account for these benefits in estimating overall impacts on net income growth. Available economic impact models generally have little or no sensitivity to issues of job quality, workforce skills, industry volatility, and unemployment costs. For that reason, there is a remaining need to recognize a range of ancillary benefit measures in any complete public accounting of benefits and overall return on public investment. Thus, ROI analysis should be explicitly recognized as a measure of the efficiency of spending. It should be accompanied with other measures of distributional economic impacts for public policy decision-making.

3.6 EXAMPLE OF ESTIMATING ECONOMIC DEVELOPMENT FOR ROI ANALYSIS

The Portland Business Council, Portland Metro (Council of Governments), and Port of Portland together sponsored a study of the *Cost of Congestion to the Economy of the Portland Region*.[57] The project was designed to assess the regional economic ROI associated with alternative levels of long-term capital investment in regional highways and public transportation facilities.

The study focused particularly on the economic cost of rising traffic congestion and delay over time, and the economic benefit of increasing investment in programs and policies that could hold down the rate of increase in congestion delays over time. Conversely, those results also were interpreted as showing the regional economic loss associated with failure to adequately invest in transportation facilities to address rising traffic congestion.

A notable element of this study was that it distinguished between economic efficiency benefits and larger economic development impacts of the policy alternatives. The study also included a benefit-cost analysis that showed results in terms of three measures:

1. A traditional *travel efficiency benefit* measure, representing the value of improvements for travelers (measured as the valuation of travel time savings, travel cost savings, and travel safety improvements).
2. An *economic development benefit* measure, representing the growth in income flows generated in the region (which excludes nonmoney savings such as the value of personal travel time, but adds nontraveler economic benefits such as the income from business growth associated with logistics efficiencies from improved reliability and income growth from larger product and service delivery markets).
3. A broader *societal benefit measure*, which includes the above-referenced economic development benefit (regional income generation measure), but also

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[57] Weisbrod, G., Portland, Oregon Regional Study: Cost of Congestion, EDR Group, 2005.

adds the value of nonmoney benefits (specifically, the value of personal travel time for nonwork-related travel). The value of air quality and other environmental benefits would also be reflected in this latter measure, though they were not estimated in the study.

The inclusion of economic development benefits was predicated on the development of a case that the regional economy has a particularly strong vulnerability to congestion delays, and that such delays are in fact already having nonuser (business) impacts beyond the value of travel efficiency factors. The first step was thus an evaluation of the region's economy and its transportation sensitivity. The study showed that the region is particularly sensitive to congestion impacts because of Portland's role as an international sea and air gateway, with navigable rivers, two intercontinental rail lines, and major intercontinental highway routes. It showed that this has created a particularly large reliance on warehousing and distribution activities serving broad markets, which are sensitive to delivery times and travel time reliability.

A second step was documentation of how rising congestion differs among locations, time periods, and origin-destination classes that particularly affect those key congestion-sensitive industries. Through business interviews, congestion effects were shown to be particularly important to industries that incurred costs for additional drivers and trucks due to longer travel times, loss of productivity due to missed deliveries, revenue loss due to reduced market areas, and costs for additional inventories and decentralized facilities needed to serve the same market area under increasingly congested conditions.

In the third strep, Metro's transportation model of the region (EMME/2) was used, along with corridor-specific volume/capacity and time delay studies for peak periods, to show the nature of future transportation impacts associated with alternative investment scenarios. These included not only changes in travel times and costs, but also peak period volume/capacity ratios affecting travel time reliability and the access area for 40-minute labor markets and same day truck delivery trips. The regional economic impacts of those factors, including impacts on nontravelers, were then estimated using the TREDIS economic analysis system. The system represented those impacts in terms of regional income changes.

The final step was the calculation of the total economic impact of rising congestion under the alternative scenarios. The importance of the economic analysis system was that it very explicitly distinguished between "economic development impacts" and "economic efficiency benefits." The former was defined to include economic growth associated with construction and ongoing spending impacts on the economy, as well as localized shifts in activity patterns. Those effects, however, were *not* included in the separate benefit/cost (b/c) calculations. As previously noted, those b/c calculations were defined in three ways, using: 1) a traditional travel efficiency benefit measure, 2) an economic development benefit measure, and 3) broader societal benefit measure.

The study compared a Planned Investments Scenario, anticipated to be funded over the next 20 years, to an Improved System Scenario, which would more than double transportation investment over the next 20 years. The analysis showed that the total value of benefit from such an investment was estimated to be $844 million per year, as of 2025. This total combines the value-added income generated in the region and the value of time savings to individuals. The ROI analysis examined the net present value of the benefit and cost streams, and showed a benefit/cost ratio of $2.00 to $3.00 to every $1.00 invested (depending on whether a 7 percent or 5 percent real discount rate is used).

4.0 Public-Private Partnerships

4.1 INTRODUCTION

Public agencies and project sponsors are increasingly considering private-sector involvement as a way to spur implementation of large projects. While searching for alternative sources of revenue, transportation agencies around the country are experimenting with public-private partnerships (PPPs) to help deliver, operate, maintain, and in some cases, even finance highway and transit infrastructure.

The expansion of private-sector involvement in tolls roads, intermodal projects, and other transportation investments, has brought more sophisticated and refined application of financial measures to benefit/cost analyses of PPPs. The state-of-the-practice has evolved as the risks to private investors have become better understood and as the role of specific projects in driving ROI may be forecasted with more certainty. However, much remains to be developed and consistently applied, particularly in determining the most accurate performance measures that should be used, given private-sector involvement.

This section introduces PPPs, including their use, typology, and ramifications on benefit/cost or ROI analyses. The available data and methodologies that are in use for measuring PPPs are summarized, as are existing best practices and guidance on the many unique challenges of evaluating these partnerships through typical transportation analysis. Those key challenges are addressed, particularly as related to the treatment of benefit/cost variables and methods of calculating uncertainty. Finally, this section concludes with recommendations for evaluating PPPs in ROI analyses.

4.2 OVERVIEW OF PUBLIC-PRIVATE PARTNERSHIPS

Benefits of Public-Private Partnerships

Public private partnerships encompass a range of contractual arrangements by which public (Federal, state, local government, and special authorities) and private entities (Financial institutions, private equity firms, transportation companies) collaborate in the development, operation, ownership, and financing of a transportation infrastructure project or program, including long-term lease arrangements.

This hybrid mechanism seems to be best suited for large, complex projects with acknowledged need and strong governmental support. The structure of PPPs is diverse and range from design-build-operate-maintain (DBOM), private investments (e.g., commercial paper, private activity bonds, capital appreciation bonds, tax–credit bonds, etc.), value capture techniques, to concessions. They often involve tolling scenarios where private investors are repaid their capital (plus interest) through the toll stream. This approach to public-private financing involves a complex layering of private investment, public funding, and risk management techniques.

Partnerships may increase a project's ROI by accelerating completion, enabling more efficient operation through contracting flexibility, expanding access to and familiarity with technology, transferring construction and performance risk away from government, and utilizing incentive-based compensation. PPPs may reduce a project's finance cost through a mix of financing that combines the advantages of private investment with public tax-exempt status, thereby enhancing ROI. In some cases, these partnerships can even attract net new investment capital that otherwise might not be available.

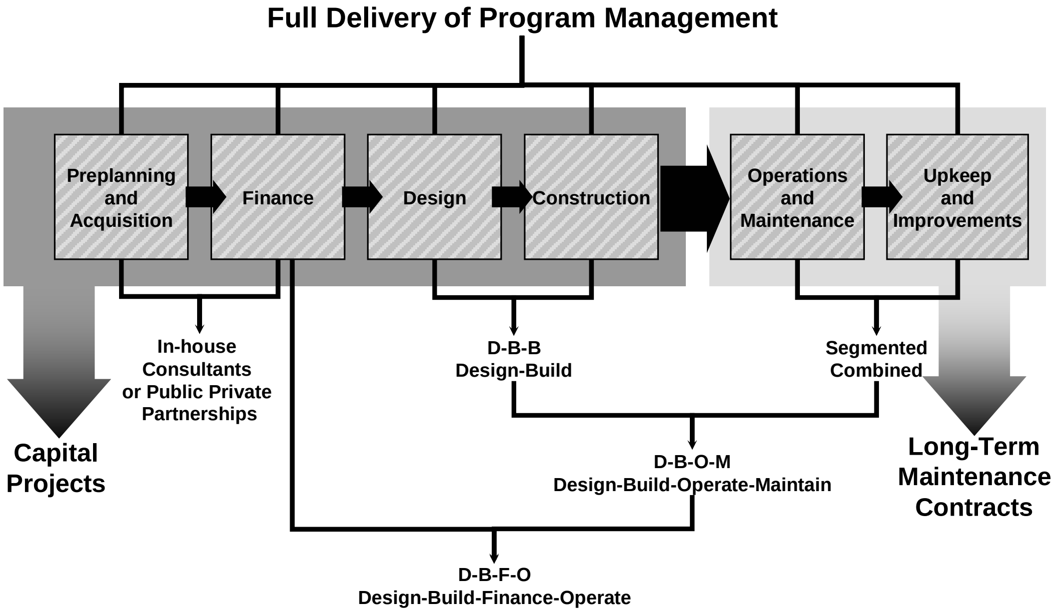
The benefits produced by collaboration may enable a project to generate additional profits to be shared by both private investors and public agencies. Some of the unique characteristics of private partners include the following:

- Greater discretion to set revenue maximizing tolls (e.g., dynamic pricing and other yield management techniques);
- Ability to utilize and finance aggressive and sophisticated marketing (e.g., branding); and
- Opportunity to employ innovative financing arrangements (e.g., using subordinated public debt to lower the risk and attract private investment).

Structures of Public-Private Partnerships

Joint ventures have been used for some time in various forms and Figure 4.1 presents a typology of PPPs based on different forms of contractual arrangements and the level of public/private responsibility and risk. For instance, the public sector retains responsibility for financing, operating, and maintaining infrastructure procured using the traditional design-bid-build approach. Separate contracts are awarded to private entities to complete design and to construct the facility. In the case of a toll facility, all risk remains with the public sector. At the other end of the spectrum, on a build-own-operate model, the private sector is granted the rights to develop a facility and assumes all the risks related to design, construction, operations, and traffic on the facility. The figure below shows variations of PPPs based on six categories of a typical transportation project that include four stages of capital construction and two of ongoing operations, maintenance, and improvements.

Figure 4.1 Typology of Public-Private Partnerships: Alternative Variations



Source: FHWA (http://www.fhwa.dot.gov/ppp/options.htm).

The benefit/cost analysis or ROI evaluation may vary depending on the partnership model or structure selected to deliver a project. A brief overview and description of how some of these PPP models might impact the benefit/cost evaluation is summarized as follows:

1. **In-House Consultants.** This approach, sometimes known as private contract fee services, deviates from the norm by contracting private firms to provide additional services that public entities have traditionally conducted in-house. For example, rather than limiting outside contracts to the realms of planning, design, and construction, public entities might also contract out to a private firm to provide pre-planning, or financial-management services.
2. **Design-bid-build (DBB).** This is the traditional approach, in which the public-sector contracts with a private firm(s) to design a construction project, then accepts bids for the project as designed, and then awards a contract to a private firm(s) to construct the project as designed. The public entity retains ownership and responsibility for operations, maintenance, and financing. If applicable, toll revenues are considered transfers and are excluded from the benefit/cost formulation.
3. **Design-build.** In this approach, the public-sector contracts with a single private entity to both design and construct a project, and to assume responsibility for the risks associated with fulfilling the contract for a flat fee. But as with design-bid-build, the public entity retains ownership and responsibility for financing, operations, and maintenance. This approach may result in cost savings by accelerating project implementation, and increased benefits from earlier implementation that could be measured in BCA formulations.

4. **Design-build-operate-maintain (DBOM) or build-operate-transfer (BOT).** This approach provides a contract to a private entity to design and build a project and then to assume responsible for ongoing operation and maintenance (O&M) of the project. The public entity continues to retain ownership and responsibility for financing. Under the DBOM model, the benefit/cost formulation is similar to that for a DBB model, but a project may also benefit from a prescribed level of maintenance that discourages deferred maintenance and may improve life-cycle costs.
5. **Design-build-finance-operate (DBFO).** This approach, including long-term lease agreements, transfers responsibility for design, construction, O&M, and some or all of the financial responsibility to the private sector. In reality, a combination of different types of revenues may be cobbled together from public and private sources, including project-generated funds (such as tolls), tax or user-fee revenues, Federal funding, leveraged funds, and private equity. The public entity retains ownership of the asset and, in the case of leases of existing facilities, can provide short-term revenue generating benefits. Long-term leases and DBFO contracts provide large up-front payments or revenue sharing over the life of the lease, these revenues are directly related to tolls paid by users, and as such should be considered transfers for the purpose of a benefit/cost analysis. In some cases, immediate revenues used to support other transportation needs and the cost and benefits of these projects may be included in benefit/cost analyses.
6. **Build-own-operate (BOO).** This approach transfers facility ownership to a private entity, such that the private entity assumes all risk, responsibilities, and rights to any surplus revenues generated by the project. In practice, "ownership" is usually granted only through a long-term lease, lasting 30 to 100 years, such that although the public agency technically retains ownership, the private entity enjoys most of the risks and rewards of ownership, as delineated in the contract.

4.3 MEASURING PUBLIC-PRIVATE PARTNERSHIPS

Overall, the impact of public-private partnerships on ROI may be measured with a number of simple metrics, including the share of a project's cost that the private sector is willing to finance, or the total public subsidy in comparison to the life-cycle cost of the project if funded entirely by public means. However, ROIs for the public sector and private sector are often calculated and understood in different manners.

For the private sector, the key factor is the financial return on investment. The benefits are driven by what passenger and freight travelers are willing to pay to use the facility or what the public sector is willing to pay the private operator (which may be related to net social benefits). For example, the public sector may be willing to subsidize a project to maximize net social benefits. With public involvement, tolls could be set at less than the private-sector revenue-generating level in order to maximize net social benefits (e.g., in uncongested conditions when the marginal cost of road use is low or zero).

The private return that can be captured will depend upon the finance mechanism of the project, as defined in the project agreement, as well as the project's benefits. A threshold rate of return of approximately 10 percent, with a range of 8 to 12 percent, is typically required by the private sector. Public-sector agencies entering into partnerships may negotiate maximum Internal Rates of Return (IRR) to limit private entity returns from tolls or other revenue sources. For example, recently negotiated IRR values have included 17 to 18 percent for the Dulles Greenway and SR 91 Toll Road.

Thus, as the application of PPPs in transportation projects grows, new techniques and analytical tools will have to be developed that incorporate both perspectives, or at least seek to understand and balance the approaches. The next section describes some additional tools for measuring PPPs.

Existing Tools for Measuring and Assessing PPP Projects

The following analytical approaches represent modeling or financial tools used in the U.S., the United Kingdom, and by the World Bank to assess ROI and uncertainty for PPP projects. Future government approaches to assessing PPPs should incorporate private-sector considerations and financial analytical methods.

Value for Money (VFM) analysis is a technique used to estimate the added value of procuring a project through a public-private concession compared to conventional procurement. It requires the development of a "public-sector comparator" (PSC), or the calculation of the NPV of the project if procured solely by the public sector, and an adjustment for risk, or measure of uncertainty.

In the United Kingdom, Her Majesty's Treasury[58] has developed a standardized methodology to calculate VFM, including the definition of public-sector comparator and private finance initiatives options. It includes both a quantitative and qualitative analysis. The outputs of the quantitative analysis includes the IRR under the private financing option, net present values for both the public and private options, and the crude private finance initiative's value for money. The latter indicates how the net present value of the private financing option compares to the public-sector comparator option –providing careful evaluation of pure public and pure private financing options using traditional metrics such as internal rate of return and net present value.

Toolkit for PPPs in Highways developed by the World Bank and the Public-Private Infrastructure Advisory Facility provides some guidance in the design and implementation of PPPs to decision-makers from transition economies. The

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[58] Her Majesty's Treasury, *Value for Money Assessment Guidance*, November 2006; and Her Majesty's Treasury, *Value for Money Quantitative Assessment User Guide*, August 2004.

toolkit includes two Excel spreadsheet models (numerical and graphical simulations) that calculate the following:

- Return on equity;
- Internal Rate of Return (after tax);
- Net Present Value;
- Minimum toll rate to attract private investors (graphical simulation);
- Loan life coverage ratio; and
- Debt service coverage ratio.

Both models have been developed for educational purposes, and the toolkit suggests the development of project-specific financial models for project evaluation.

Internal Rate of Return (IRR) is often calculated by the private sector to determine whether a PPP is worth pursuing. A critical shortcoming of the IRR method is that it is commonly misunderstood to convey the actual annual profitability of an investment. Most private actors would not reinvest intermediate cash flows at the same level of the project's IRR; and, therefore, the actual rate of return is lower. A measure called (MIRR) may be used instead, which has an assumed reinvestment rate, usually equal to the project's cost of capital. Despite a strong academic preference for NPV, industry surveys indicate that private-sector investors prefer IRR/MIRR measures over discounted values because they find it intuitively more appealing to evaluate investments in terms of percentage rates of return. NPV, however, remains a more accurate reflection of value to the business.

Texas Transportation Institute's (TTI) states that the value to the private sector is measured in ROI; value to public sector is measured in Net Benefits which may include social benefits.[59] TTI developed a tool for analyzing PPP investment in rail improvements and its methodology is one of the few examples of an existing assessment tool that values the public benefits of partnerships. TTI's methodology was applied to intermodal service and measures the tradeoff between the net present value for the Texas DOT (TxDOT) and the internal rate of return for the railroad, as a function of the level of TxDOT funding. Increasing levels of TxDOT funding results in a lower public agency NPV, but a higher IRR for the railroad. This tradeoff (shown in Figure 4.2) identifies a range of opportunity that produces both net savings for TxDOT (positive NPV) and an acceptable IRR for railroad (at least 10 percent). Depending upon the project, it may or may not be possible to achieve both of these conditions.

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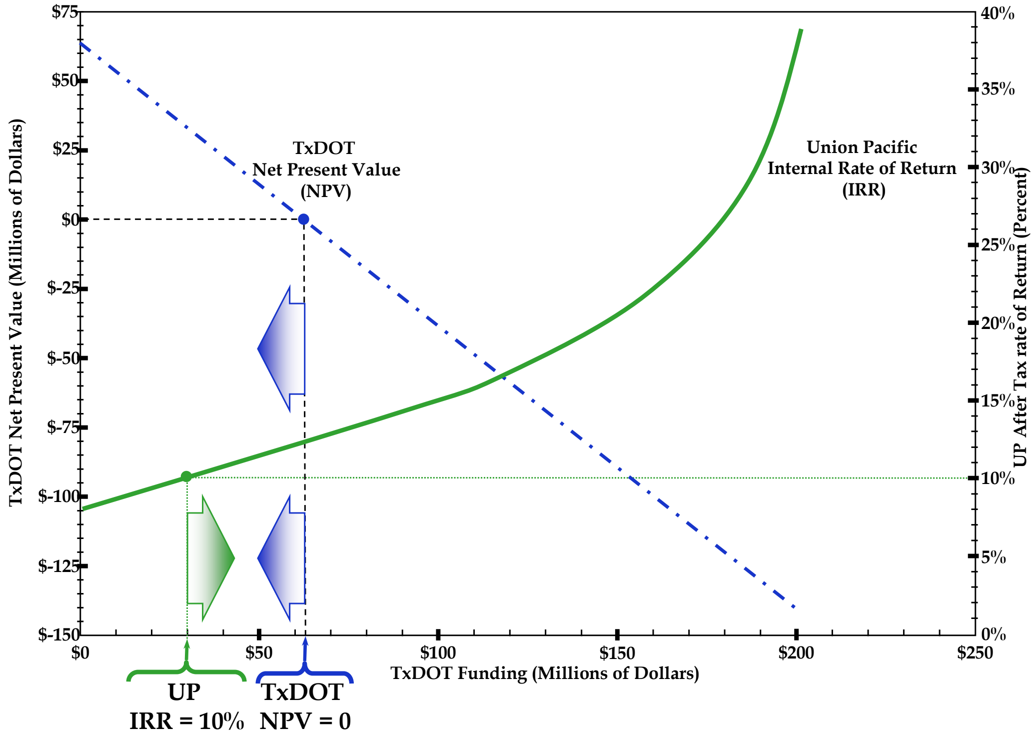
[59] Report 0-4565-1, *Enhancing Intermodal Service through Public-Private Partnerships in Texas*, 0-4565-P1, Benefit Calculation Methodology, 0-4565-P2, Summary of Case Studies, available at http://tti.tamu.edu/documents/0-4565-S.pdf.

Figure 4.2 Public and Private Economic Benefits for the Laredo-Dallas Corridor



Source: Texas Department of Transportation.

Additional Measures for public perspective analysis of PPP contractual arrangements are most likely to be concentrated on minimizing construction delays and the costs of construction, maintenance, or operations. The general types of measures that can be used to compare PPPs with traditional public-sector projects include the following:

- **Construction costs**, net of user fee revenues.
- **Life-cycle costs**, as noted in the first section of this report.
- **Discounted construction costs, benefits, and life-cycle costs**. Future metrics that could evaluate the difference between private vs. public projects costs should include the discounted value of any future stream of benefits
- **Duration of construction.** The more rapid the completion of construction, the earlier the project begins operating and accruing benefits of revenues from toll streams, travel time savings, accident reductions, etc. The earlier these benefits appear, the less they are discounted and the higher their present value. A metric that captures this relationship might show that, for example, if a private design-build approach had higher costs but shorter the construction time, whether this produced a greater present vale than the slower, but less expensive approach provided by the public sector.

- **Uncertainty**. Private investors tend to bundle deficiencies in accurate assessment data and methods in the public sector into overall estimates of the financial risk or uncertainty of a project. This measure of risk transfer is then used to adjust a net present value or internal rate of return over the life of the project. The PPP toll road experience, for example, has led investors to associate much higher risk levels with revenue forecasts that depend heavily on future development in a corridor than forecasts based on current developed activity. In addition, there are many other market conditions and uncertainties that will increase risk to both public agencies and private investors (i.e., cost overruns, operational difficulties, maintenance expenses, etc.).

PPPs may also present challenges of transparency when private firms' approaches to risk management, detailed cost assumptions, and other competitive information are usually closely guarded. Under current practices, most government procurement processes require private partners to disclose critical information. If given access to complete cost data, pricing assumptions and revenues forecasts, public entities may conduct reasonably comprehensive benefit/cost analysis of proposed public-private projects.

Additional information and literature reviews for current tools, guidance and best practices for measuring and evaluating PPPs is included in Appendix A.

4.4 METHODS AND GAPS IN MEASURING PUBLIC-PRIVATE PARTNERSHIPS

Measuring and Evaluating PPPs

The following gap analysis for ROI evaluation of PPP covers best practices on the key methodological issues mentioned above that often arise during ROI and benefit/cost analysis of PPP transportation projects, as well as providing guidance on inclusion of risk – the most important variable from the private-sector perspective.

For the purposes of this report, there is the assumption that almost any public-private partnership will involve some toll stream or other form of user fee revenues that would be used to repay investors. Furthermore, the focus here is on projects where the toll revenues are insufficient to sustain a purely private venture and thus require some additional public funding (or other forms of public subsidy in order to attract private investors. Such a partnership will involve evaluations of return on investments for each of the public and the private entities and in comparison to each other. These differing ROI analyses require different data and methodologies depending on perspective. This section is focused on the gaps in data and methodology that may be confronted when evaluating the private components of any PPP.

In contrast to private investment criteria, the application of benefit/cost analysis to a publicly funded project is intended to help policy makers evaluate long-term tradeoffs between alternative investments. These investments choices are almost always intended to address multiple social objectives that must be evaluated in addition to a project's financial feasibility. PPP investment decisions, on the other hand, have relatively simply objectives of generating sufficient profit for investors. Given these alternative decision-making criteria, the supporting data and methodologies differ substantially. Traditionally, the private-sector perspective has been focused on quantifying risk and the certainty of forecasted demand and revenue. The public sector's decision and information requirements tend to be broader.

The transportation benefit/cost literature on PPP tolling alternatives is relatively underdeveloped and thus analysts at all levels are using different techniques and making different assumptions about what should and should not be considered a benefit or cost. From this limited experience, we gather that the key data and methodological deficiencies to consider include the following:

1. What are the core set of benefits and costs that should be estimated when evaluating a PPP tolling project?
2. Should the revenue collected through tolling and congestion pricing alternative be considered a benefit, a cost, or neither?
3. Should the travel benefits stemming from tolling revenues used to add capacity or improve service on the transit system be counted as benefits?
4. What are differences between actual return on investment (both IRR and NPV) compared to projected estimates. (This comparison applies to before and after benefit/cost analyses.)
5. What other considerations may exist? For example, how are benefits measured in travel demand models? How are private equity contributions considered?

1) Core Benefit and Cost Concepts to Include in ROI Analysis of PPP

There are a set of core benefits and costs that should be considered, and to the extent possible quantified, in most tolling or congestion pricing benefit/cost evaluations. A key point is that any benefit/cost analysis should use a reasonable time period to evaluate the range of benefits and costs as some impacts (e.g., implementation) will be near-term while some of the benefits (e.g., travel time savings) will occur over a number of years once a facility is constructed or reconfigured with pricing.

Benefits

- **Travel time savings.** In many cases, the largest direct benefit of tolling or congestion pricing projects is reflected in terms of reduced travel time. Tolling typically reduces travel times, either by introducing new facilities to reduce travel time and distance, or pricing existing facilities to reduce peak period demand. The value of time by different trip purposes and vehicles needs to be considered for this benefit.

- **Reliability.** The reduction in travel time variability is a key benefit of tolling, especially in urban congestion pricing examples. As noted in the second section of this report, examples of methods capturing the standard deviation of travel using Buffer Index concepts are the most accurate measures.
- **Improved safety.** To the extent that tolling policies reduce traffic volumes on specific highway segments or, more importantly, reduce overall highway trips (e.g., urban cordon pricing strategies), safety benefits in the form of reduced accidents should be counted as a social benefit.
- **Air and noise emissions.** Reduced highway trips will typically reduce air and noise emissions and standard parameters are available to quantify these benefits.

Costs

- **Implementation and/or investment costs.** There are upfront capital costs to project implementation, whether the project involves construction of new tolling facilities or implementing tolling on existing facilities.
- **Tolling scheme operating costs.** There are annual costs associated with operating any tolling scheme, even one that does not require toll both collectors. These costs are reflected in the form of maintenance and purchases of new equipment, compliance, and monitoring costs, etc.
- **Traffic management.** Tolling, especially in urban areas, may also require increased bus service, alternative transit choices, or other traffic management to accommodate the changes in trip behavior caused by tolling. These costs should be considered.
- **Deterred drivers.** From a strict economics perspective, a toll increases the cost of highway travel and results in a consumer surplus loss. Deterred drivers are those that choose not to drive due to changes in tolling or congestion pricing policies, and in effect using a second-best option.[60]
- **Due Diligence.** PPP projects require the intervention of financial advisors, lawyers, and other entities not typically involved in the conventional procurement of transportation projects. These costs should be captured in the ROI analysis, by inclusion in the development of a public-sector comparator when conducting a value for money analysis.

Additional Considerations. Previous studies have incorporated the issue of distortionary taxes and the marginal cost of taxation into assessments. This is a level of analysis likely beyond most evaluations but worth considering. For example, a reduction in motor fuel taxes collected due to tolling (stemming from

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[60] Leape, J., *The London Congestion Charge*, Journal of Economic Perspectives, Volume 20, Number 4, Fall 2006, pp. 171; and Eliasson, J., *Cost-Benefit Analysis of the Stockholm Congestion Charging System*, Transek AB, 2006.

reduced VMT) would appear to simply be a transfer from transportation agencies to individuals. However, if those forgone revenues need to be replaced through direct or nonuser taxation mechanism (e.g., personal income), the effect of the tolling policy could have secondary negative effects as taxation tends to be distortionary.[61]

2) Treating Toll Revenue in Benefit/Cost Analyses

From the perspective of a transportation agency, toll revenue is a benefit. It provides a revenue stream that the agency can use to offset capital or operating costs on tolled or even nontolled facilities. From the perspective of a traveler who pays the toll, it is a cost. Travel choices are dependent on a variety of travel time, cost, and reliability factors and adding a toll to an existing roadway or using a toll on a new facility is a cost to the traveler.

From a pure benefit/cost analysis perspective which is focused on economic efficiency toll revenue is neither a benefit nor a cost. It is considered a transfer as the toll revenue is transferred from private travelers to transportation agencies. Two recent cordon pricing benefit/cost evaluations in London and Stockholm illustrate this point succinctly:

> "The charge payments made by drivers are not included [in the benefit/cost analysis], as they represent a transfer rather than a resource cost."[62]
>
> "In principle, and contrary to what some commentators believe, the money raised as toll payment…should be ignored. This amount is neither a gain nor a cost. It is a transfer."[63]

3) Benefits from Future Use of Toll Revenues

For traditionally financed highway tolled facilities, the revenue stream earned through ridership is typically used to help pay back bonds or other financing mechanisms directly related to that transportation facility. Thus, the financing and impacts are more concentrated on that individual facility.

For urban congestion pricing schemes, however, the revenue earned may be used to increase funding on other parts of the transportation system. For example, in the London congestion charge scenario, the program was marketed and sold to the public not just in terms of reduced congestion but also based on a promise to use toll revenues to improve transit (primarily bus) service. For example:

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[61] Prud'homme, R., and P. Kopp, *The Stockholm Toll: An Economic Evaluation*, 2006.

[62] Leape, 2006, pp. 171.

[63] Prud'homme and Kopp, 2006.

> "…given the UK government requirement that all charge revenues be spent on transport improvements, the charge payments are likely to be generating significant additional benefits in reduced travel times and accidents and other savings…"[64]

Consequently, in cases when toll revenue is large and the additional transit service required to handle the drivers who switch to transit is modest, there can be additional benefits as the charge payments produce a virtuous cycle of funding to improve other parts of the system and mitigate any negative network effects.

It should be noted, however, that evaluators of the Stockholm pricing scheme find that in that case, the tolling revenue was modest compared to the increase in public transport required to handle the demand from new transit riders. Thus, the key factors when analyzing potential systemwide benefits from new tolling revenue seem to be:

- The amount of toll revenue;
- New transit service required, and
- Capacity and service levels of existing transport system.

4) Before and After Evaluations Compared to Prospective Analyses

Many of the current congestion pricing assessments available are empirical evaluations that compare traffic data both before and after the implementation of a congestion pricing scheme. Meanwhile, project decisions on whether or not to attempt tolling strategies are unavoidably based on projected impacts. In either case, the list of benefit and cost concepts to include should be the same. However, the main differences are that the data and tools used to capture effects are often different.

Before and after evaluations use detailed traffic effects to simulate consistent travel conditions and derive pre/post estimations of travel behavior changes. Other factors can contribute to changes but most analyses isolate changes to a tolled facility or pricing scheme based on historical trends. Prospective analyses typically require careful travel demand simulation models to estimate travel behavior changes due to tolling. Travel demand models are far from perfect, but they do provide a consistent set of data and relationships to compare scenarios.

Pre-/post-evaluations are often based on small samples of observed data and should be treated with caution. For example, the Stockholm analyses are based on a 6-month trial program and since the users of the system knew the program was temporary, it's possible that their behavior was different had they known (or thought) that the congestion pricing scheme was permanent.

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[64] Leape, 2006, pp. 157-176.

5) Additional Considerations

Travel Demand Models, Tolling, and Travel Benefits

For prospective analyses that employ travel demand models to forecast traffic patterns and volumes with and without tolling schemes, it is critical that the models account for both travel time and cost (including the toll). Many of the urban area travel demand models assign traffic to the highway system solely based on travel time. Thus, using generalized cost equations and some sort of distribution of values of time is appropriate when assigning traffic and estimating ridership on tolled facilities.[65] Developing reasonable and realistic travel distribution patterns based on observed data from current tolled facilities is an important consideration for future travel modeling of tolling.

Finally, while it is completely appropriate to use a generalized cost approach to estimate toll-related volumes, it is not appropriate to use the same generalized cost approach to estimate benefits. The primary benefit of tolling and pricing schemes is in the form of travel time savings and the tolls paid represent a transfer. Modeling traffic behavior needs to take into account the cost of tolling, benefit calculations should simply be made from the resulting vehicle hours of travel (VHT) reductions by applying appropriate values of time by trip purpose.

Capturing Private-Sector Contributions and User Fees in the ROI Analysis

Equity assumptions impact the debt service requirements, including finance costs, interest, and principal payment estimates. In the case of concessions on existing facilities (e.g., the Chicago Skyway and Indiana Tollway), any ROI evaluation must account for the up-front payments by the concessionaire to the public sector.

Value for money analysis does not account for private equity contributions as a benefit to the public sector, since the calculation assumes that the project will be delivered through conventional procurement. Both value for money analysis and the World Bank's methodology (discussed earlier) require a forecast of third party payments to estimate the amount of government subsidy, private-sector debt service, and/or performance payments that may be included in the concession agreement.

Estimating the revenue stream over the life of the concession agreement is required to estimate the return on equity and the IRR. Equity contributions are treated differently in the two methodologies discussed above. The value for money method assumes that all equity for the project will be provided through private debt, whereas the World Bank methodology assumes that the private sector will provide equity in the amount of 10 to 30 percent of the project construction costs.

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[65] *Mobility Alternatives Finance Study: Final Report*, prepared for Capital Area Metropolitan Planning Organization, Austin, Texas by Charles River Associates, December 2006.

4.5 EXAMPLE OF THE MEASUREMENT OF ROI IN PUBLIC-PRIVATE PARTNERSHIP

There are no examples of ROI analysis applied to PPPs that follow the recommendations set forth in this report that the authors are aware of. In order to illustrate the recommended approach developed in this report, this case study has been reworked from the original case study analysis to show how a more comprehensive economic impact analysis conducted in accordance with the approach recommended in this report would yield a different result.

The Mid-Atlantic Rail Operations Study (MAROps) report released by the I-95 Corridor Coalition in 2002 noted that significant choke points existed within the region, and that these were hurting current rail performance and limiting future rail growth.[66] The report specifically stated that the "*CSX Howard Street Tunnel [in Baltimore, Maryland]…[is an] antiquated, single track tunnel with limited vertical clearances that preclude double-stack trains.*" When the tunnel was hit by a fire in July 2001, the dependence of the United States' east coast corridor rail traffic on key stretches of track was effectively demonstrated. The 60-car CSX fire took the emergency services almost a week to bring under control, and severely impacted east coast rail operations for some time afterwards. Other tunnels in Baltimore include the Union Tunnels (built in the 1920s) and the B&P Tunnel (built in the 1870s), both of which are in need of rehabilitation due to deterioration and lack of vertical clearance.

A study commissioned by the Maryland Department of Transportation (MDOT) was entitled, *The Economic Benefits Estimates for the Baltimore Rail Framework Plan*. The focus of the Baltimore Rail Framework Plan study was the congested railroads located in and around Baltimore. The rail track is shared by freight and passenger rail, with ownership resting in the hands of several companies. Following a series of train delays and reports indicating the need for track improvements, the decision was made to study the economic benefits of the Rail Framework Plan that had been designed to reduce the pressure on the congested tracks. The plan suggested improvements that included new tunnels beneath the city of Baltimore and alternate alignments that would bypass the city.

The improved alignments represent link level capacity enhancements by upgrading track and tunnel conditions. The project might also be considered a link level operational improvement. To the extent that these improvements to rail service characteristics attract more rail users, the project might also have modal diversion impacts.

MDOT conducted a benefit/cost analysis to estimate the value of the Baltimore rail improvements. Consistent with standard practice, the benefits and costs

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[66] *Mid-Atlantic Rail Operations Study Summary Report*, I-95 Corridor Coalition, April 2002.

were examined over the first 25 years of operation of the new rail bypass route (in addition to the upfront capital expenditures needed to complete the project). This section provides a summary of the assumptions and methodology used in the analysis.

It was assumed that the capital costs would be incurred during a three year construction period (2007 to 2009) and that the project would be in operation starting in 2010. While the actual alignment of the project is still being evaluated, the preliminary cost estimates were for $2.5 billion in construction/capital costs, assumed to be spent equally throughout the construction period.[67] Furthermore, it was assumed that the operating and maintenance costs would be 3 percent of the capital costs annually ($75 million).

This analysis captured the projected benefits for the 25-year period between 2010 and 2035. The public and private benefits are composed of those to existing freight rail operators, shippers, highway users, Amtrak travelers, and the supply chain benefits to industries and the economy. This figure amounts to approximately $279 million in the year 2010, increasing to $693 million by 2035.

The costs and the benefits were discounted to the year 2006 using a 6 percent discount rate. As shown in Table 4.1 below, the analysis indicates that the national benefits of the proposed system outweigh the costs by a factor of 1.6 to 1. With a total discounted cost of approximately $3 billion for the system, and total discounted benefits of $4.7 billion, the net present value is $1.68 billion. These values (shown in the last column of the table) reflect all of the benefit concepts recommended in this report.

Table 4.1 Benefit/Cost Ratios (Millions of Dollars)

	Maryland Benefits Only[1]	National Benefits	National Benefits[1]	Total National Benefits
Freight Rail Operators	$270	$270	$270	$270
Shipper Costs	$1,052	$1,656	$1,656	$1,656
Amtrak	$176	$626	$626	$626
Highway Benefits	$565	–	$874	$874
Supply Chain Benefits	–	–	–	$1,303
Total Benefits	$2,063	$2,552	$3,425	$4,729
Total Costs	$3,046	$3,046	$3,046	$3,046
B/C Ratio	0.7	0.8	1.1	1.6

Source: Baltimore Rail Studies by PB Consult for Maryland DOT and Cambridge Systematics, Inc.

1. Excluding Supply Chain Benefits

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[67] It is important to view these costs as preliminary as actual costs could vary significantly once the actual alignment is chosen and more detailed engineering work is completed.

2. Excluding Full Highway User Benefits And Supply Chain Benefits

Note: The three definitions of national benefit differ in the breadth of coverage as shown in the table.

Table 4.1 also presents how the results vary depending on the perspective in viewing the project's benefits from a private versus regional versus national standpoint, as well as accounting for added benefits such as highway travel time and supply chain benefits to industries. While combining all of the benefits at the national level results in a favorable 1.6 B/C ratio, analyzing only the statewide benefit results (and without supply chain benefits) produces $2.1 billion of benefits, a figure outweighed by costs (B/C ratio of 0.7).

Evaluating the three rail-related criteria (existing rail, shipper costs, and Amtrak benefits) at the national level provides a slight increase in total benefits, increasing from $2.1 billion to $2.6 billion. As a result, the B/C ratio increases to 0.8. Furthermore, adding the highway benefits at the national level ($874 million) results in benefits outweighing costs by a factor of 1.1. Finally, the last column reveals the importance of including the expected private benefits to industries of reduced transportation costs. Evaluating the supply chain benefits results in a significant increase in total benefits (38 percent), and a larger B/C ratio with $1.7 billion in net benefits.

The progression of including a more complete accounting of benefits to both transportation users and the private industries that benefit from more efficient goods movement reveals the importance of this analytical framework. In addition, taking a national perspective on freight investment projects is especially important considering the dispersed origin-destination pattern of goods movement. In this example, a rail bottleneck in Baltimore has larger implications for industries and shippers outside of Maryland than within the State.

It is also important to understand the effect that methodological assumptions have on the outcome of the analysis. In particular, the mileage assumptions for average length of rail trip (and the corresponding implication to truck VMT) have a very large effect on the magnitude of benefits. Average distances for through-trips and trips with Maryland origins or destinations have an especially significant effect on the final results since it directly affects the benefits for both rail shippers and remaining highway travelers, and it indirectly alters the supply chain benefits.

The original analysis assumed that freight rail moving through the state would travel on average 750 miles, while freight rail originating or terminating in the state would travel 500 miles. These numbers are higher than the average trip lengths estimated from 2002 Commodity Flow Survey data for Maryland freight trips (500 miles for trips through the state and 300 miles for trips with origins or destinations within the State). For trips originated/terminating in Maryland, the CFS' shipment characteristics for the State reveal an average trip distance of approximately 300 miles. The original analysis assumption of 500 miles represents a significantly longer trip with corresponding impacts on the cost per ton mile of shipping and truck VMT impact.

Table 4.2 shows how the benefit/cost results vary when using the 500/750 and 300/500 average trip length assumptions. Using the scenario with 500 and 750 miles increases the expected benefits for the shippers and the highway users by approximately 63 percent (a net increase of nearly $1.6 billion), and by consequence, boosts the supply chain benefits by 55 percent ($710 million). The combined result is an increase in total benefits of 49 percent, representing nearly $2.3 billion, and a more favorable benefit/cost ratio of 2.3, compared to 1.6 for the 300/500 scenario. This comparison demonstrates the importance of testing and reporting the robustness of key assumptions and parameters. In this case, the basic story holds – benefits do not exceed costs from a Maryland state-level perspective, but when viewed from a national perspective with a full accounting of likely private and public benefits, benefits are estimated to exceed cost by two to three times.

Table 4.2 Sensitivity Analysis

Benefit	Scenario 1: 750/500	Scenario 2: 500/300	% Difference
Freight Rail Operators	$270,229,331	$270,229,331	0.00%
Shipper Costs	$2,694,157,018	$1,655,796,822	62.70%
Highway Travelers	$625,621,147	$625,621,147	0.00%
Amtrak Users	$1,422,398,587	$873,653,722	62.80%
Supply Chain	$2,013,629,007	$1,303,373,082	54.50%
Total Benefits	$7,026,035,090	$4,728,674,104	48.60%
Total Costs	$3,046,338,138	$3,046,338,138	–
Benefit/Cost	2.31	1.55	48.60%

Source: Baltimore Rail Studies by PB Consult for Maryland DOT and Cambridge Systematics, Inc.

The quantification of both private and public benefits provides a critical basis for allocation funding responsibility between public and private stakeholders. This *nexus* between benefits and funding responsibility may be applied to the assessment of user fees on private beneficiaries such as railroads, businesses, and truckers.

4.6 RECOMMENDATIONS FOR THE MEASUREMENT OF ROI FOR PUBLIC-PRIVATE PARTNERSHIPS

Key Recommendations

Public-private partnerships for transportation investments and various tolling/ congestion pricing projects are increasingly being considered by transportation agencies nationwide. Evaluating PPP projects presents a unique set of challenges given the mix of public and private-sector perspectives, funding options, and the spectrum of possible project structures. Key recommendations related to these challenges as related to ROI analyses include:

- Explicitly recognize the different perspectives of the public and private sector;
- Increase the use of risk analysis in ROI for the public sector, especially as it relates to risks of project delivery, operations, and revenue generation potential; and
- Carefully dissect the expected benefits and costs, and distinguish between social economic efficiency-based benefit/cost analysis and return on investment to the private or public sector.

Recognizing Public and Private Perspectives

ROI for the public sector and private sector would typically be calculated in different ways, based on different perspectives related to benefits realized through implementation of a project and the application of ROI methodologies.

- **Recognizing and incorporating different perspectives into assessments is as important as the criteria used for evaluation.**

  Objectives

  - The public sector is primarily interested in net social benefits, which often include benefits beyond those that people are directly willing to pay for, such as externalities (congestion relief, reduced air pollution, etc.) and social equity. A project with significant social benefits does not necessarily yield an ROI that is attractive to the private sector.
  - The private sector desires a financial return on its investment (i.e., ROI, which or revenue compared to cost). The benefits are, therefore, narrowly driven by what travelers (passenger and freight) are willing to pay to use the facility.

  ROI Analysis

  - For the public sector, this is equivalent to the application of benefit/cost analysis to a publicly funded project, and intended to help policy makers evaluate long-term tradeoffs between competing investments.
  - For the private-sector ROI analysis is intended to determine whether a project can generate sufficient revenue, such that investors receive an expected return on investment.

Estimating of Risks in ROI Analysis

In the case of project delivery through PPP, the risks related to project delivery, operations and management are shared by both the private and public sectors. The share of risks is determined by contractual agreements between parties and other considerations. In the case of value for money analysis, the public-sector comparator requires the assessment of the financial impact of transferred and retained risks to be included in the calculation of the net present value. While the private sector typically accounts for risk when evaluating the internal rate of return of a project, the public sector may not include these risks when considering conventional procurement.

- The risk calculation to be included in the value for money analysis will be unique for each project. Nevertheless, the value for money quantitative assessment includes optimism bias factors to capture uncertainty in the estimation of project costs for both the public-sector comparator and the PPP project delivery alternative.
- Classify risk between transferable and retained risks. The proposed evaluation of risks takes into consideration the probability distribution of each potential risk, and the monetary value of risk is added to the base estimate of capital, operating and maintenance costs for the proposed project.

Dissecting Costs and Benefits

The increasing appearance of complex and expansive PPP and tolling projects is likely to produce an even more diverse set of project parameters that need to be carefully evaluated in terms of potential inclusion in ROI analyses as benefits or costs. A simple rule is that the financing components of toll projects tend to be transfers to/from individuals and transportation or other public agencies and thus should not be included. Other benefits to travelers, impacts on the economy, and costs to transportation agencies may be considered valid benefits or costs.

- **Additional guidance should be provided about capturing indirect benefits in the evaluation of PPP projects** (e.g., travel time savings and air quality improvements). The World Bank methodology to calculate net present value of PPP projects does not account for indirect benefits of the project, most likely because indirect benefits of transportation investments are accrued to the public sector, rather than a private benefit. The value for money methodology used in the United Kingdom allows for the inclusion of indirect benefits in the creation of the public-sector comparator.

Appendix A. Guidance and Best Practices for Evaluating PPPs

The state-of-the-practice has evolved as the risks to private investors have become better understood and the underlying characteristics of projects and their role in driving return on investments may be forecasted with more certainty. The following excerpts are examples of current, but not necessarily best practices for evaluation.

> Credit Suisse in its Illinois Toll System Valuation Study Report set the target range for the internal rate of return between 8.5 and 12 percent.
>
> A paper prepared for the ADB/PPIAF Conference Infrastructure Development, found that the private sector is concerned with financial benefits, while the public sector is concerned with overall economic benefits. It states:
>
> "A balance between economic and financial benefits is always part of the investment decision. While the private sector is only really concerned with the financial return, it is usually very important to the government to achieve the economic gains expected from the investment…. The balance between these considerations is a matter of Government policy, with the primary tradeoff being between maximizing social benefit, which will in general lead to low or zero tolls, and maximizing revenue which can then be used to finance highway construction and /or maintenance and management."[68]
>
> A World Bank paper states "There are three main reasons for pricing infrastructure services below costs. First, the provision of some services might create positive externalities, thereby justifying higher levels of consumption than those that would exist if users had to pay the full cost of services. Second, authorities might want to keep prices equal to marginal costs in an industry characterized by increasing returns to scale (which requires that the

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[68] Private Solutions for the Poor, the Asian Perspective, W.G. Wood (Public Private Partnerships In Toll Roads In PRC, CPCS Transcom Ltd., 2002, available at http://www.ppiaf.org/conference/docs/Papers/China%20roads.pdf.

firm obtain additional sources of revenues to cover its fixed costs). Third, it might be considered desirable to provide public subsidies to some users." [69]

On the web site, "World Bank – Toll Roads and Concessions," the Banks states "Maximizing net toll revenue and maximizing economic return from the road are contradictory objectives. Hence the Government needs to understand where the appropriate balance lies. This balance will be set where economic return and revenue raised meet Government objectives, and the revenue raised is sufficient to finance the project as structured. This will usually mean that the Government needs external financial advice – Investment Bankers may well take a different view on "revenues sufficient to finance the project" from bureaucrats."[70]

On the Federal Highway Administration (FHWA) Public-Private Partnerships web site, FHWA states: "Private businesses are established to provide an attractive return on company resources by providing needed services to clients and by making strategic investment decisions. PPPs can offer them opportunities to improve profitability and expand markets." Furthermore, it says: "Project owner-sponsors themselves typically carry a portion of the risk as most limited recourse financings require some type of contribution from the public agency sponsoring the project. In the end, it is the role of the sponsor to make projects bankable in order to maintain the confidence of the investor."[71]

A U.S. Department of Transportation report suggests that the benefits of PPPs may include cost savings due to various efficiencies in design, construction, operations, and maintenance (reduced delay, project integration, incentives for value engineering, more efficient staff/resource utilization, innovative project management, allocation of risk management, etc.). These efficiencies may include reductions in life-cycle costs, e.g., through the use of warranties, performance-based contracts, or other incentives to encourage LCC-minimizing construction and maintenance techniques. (But, PPPs do not always result in cost savings). Furthermore, U.S. DOT states "Projects serving each individual link may or may not be able to generate revenues that cover facility costs and yield a return on investment, as required by the private sector, even though unmet highway needs are evident." The report goes on to emphasize that the major challenge of PPPs remains predicting revenue. "These revenue forecasts for toll roads, although critical to the evaluation of whether to invest in a proposed project, have not been reliable

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[69] World Bank Technical Paper No. 399 (Concessions for infrastructure: A Guide to Their Design and Award, p.148), available at http://rru.worldbank.org/Documents/Toolkits/concessions_fulltoolkit.pdf.

[70] http://www.worldbank.org/transport/roads/toll_rds.htm.

[71] PPPs Defined, available at http://www.fhwa.dot.gov/ppp/defined.htm.

and add to the uncertainty about the financial viability of public-private partnerships." Other revenue uncertainties include new modes, parallel roads (diversion of traffic); limits on revenue & pricing due to government policy, fuel prices, risks in land acquisition, environmental process, construction, tort liability, etc. Its summary conclusion states that "Private proposals cannot in most cases be self-financed using toll revenue alone, and need to get an infusion of tax support from the public sector." [72]

Finally, the Congressional Budget Office has evaluated the recent experience and has made the following findings:[73]

"Under certain circumstances, debt financing can play a socially beneficial role. If a road project yields benefits that exceed its costs, then society gains by proceeding with the investment. (Of course, such calculations must discount costs and factor in the opportunity cost of borrowed funds and any implicit or explicit subsidies.)" [Public sector concerns associated with borrowing include reduced fiscal discipline and loss of creditworthiness.] "Given those concerns, governments have implicitly opted for a tradeoff: they will risk under spending, thus forgoing earlier returns on investments, to avoid wasting money on projects for which benefits had been incorrectly estimated to exceed costs."

"Innovative financing cannot solve all of the problems associated with transportation projects. What it can do is to help some projects get under way sooner than would be possible with traditional financing."

"The state could also try to tap resources of the private sector to build the road. Public/private ventures can take several forms, with varying degrees and types of private capital at risk. At one extreme, the state could simply rely on a private firm, which would use the debt and equity it raised by itself, to finance the entire road. At the other extreme … the state could issue bonds that were backed solely by revenues from the project and not by taxes."

"Making money available sooner can enhance a state's resources in two ways. First, it can increase a state's buying power when construction costs are escalating but Federal aid remains fixed in nominal terms. Second, it can generate more income and wealth for the community through investment in highway projects. The latter result assumes that states use the added flexibility to build the projects with the greatest returns on investment first."

"Governments may be better able to assume many of the risks associated with building new roads. By bearing some of those risks, governments can

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[72] United States Department of Transportation, "Report to Congress on Public-Private Partnerships". December 2004.

[73] Congressional Budget Office, *Innovative Financing of Highways: An Analysis of Proposals*, January 1998, available at http://www.cbo.gov/showdoc.cfm?index=320&sequence=0.

make investing in road projects more attractive to private entities… achieving a proper balance of risks between the public and private sectors can contribute to economic efficiency and equity."

"Private investment in roads will remain limited as long as most highways are provided by government and financed with taxes rather than tolls. To be attractive to private investors, a project must carry the expectation of profitability. The number of projects that have the potential to offer enough value to motorists that they will be willing to pay tolls when toll-free alternatives are available appears relatively small."