TCRP REPORT 78

TRANSIT COOPERATIVE RESEARCH PROGRAM

Sponsored by the Federal Transit Administration

Estimating the Benefits and Costs of Public Transit Projects: A Guidebook for Practitioners

TRANSPORTATION RESEARCH BOARD

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Estimating the Benefits and Costs of Public Transit Projects: A Guidebook for Practitioners

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Portland, OR

Subject Areas
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TRANSIT COOPERATIVE RESEARCH PROGRAM

The nation's growth and the need to meet mobility, environmental, and energy objectives place demands on public transit systems. Current systems, some of which are old and in need of upgrading, must expand service area, increase service frequency, and improve efficiency to serve these demands. Research is necessary to solve operating problems, to adapt appropriate new technologies from other industries, and to introduce innovations into the transit industry. The Transit Cooperative Research Program (TCRP) serves as one of the principal means by which the transit industry can develop innovative near-term solutions to meet demands placed on it.

The need for TCRP was originally identified in *TRB Special Report 213—Research for Public Transit: New Directions*, published in 1987 and based on a study sponsored by the Urban Mass Transportation Administration—now the Federal Transit Administration (FTA). A report by the American Public Transportation Association (APTA), *Transportation 2000*, also recognized the need for local, problem-solving research. TCRP, modeled after the longstanding and successful National Cooperative Highway Research Program, undertakes research and other technical activities in response to the needs of transit service providers. The scope of TCRP includes a variety of transit research fields including planning, service configuration, equipment, facilities, operations, human resources, maintenance, policy, and administrative practices.

TCRP was established under FTA sponsorship in July 1992. Proposed by the U.S. Department of Transportation, TCRP was authorized as part of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA). On May 13, 1992, a memorandum agreement outlining TCRP operating procedures was executed by the three cooperating organizations: FTA, the National Academies, acting through the Transportation Research Board (TRB); and the Transit Development Corporation, Inc. (TDC), a nonprofit educational and research organization established by APTA. TDC is responsible for forming the independent governing board, designated as the TCRP Oversight and Project Selection (TOPS) Committee.

Research problem statements for TCRP are solicited periodically but may be submitted to TRB by anyone at any time. It is the responsibility of the TOPS Committee to formulate the research program by identifying the highest priority projects. As part of the evaluation, the TOPS Committee defines funding levels and expected products.

Once selected, each project is assigned to an expert panel, appointed by the Transportation Research Board. The panels prepare project statements (requests for proposals), select contractors, and provide technical guidance and counsel throughout the life of the project. The process for developing research problem statements and selecting research agencies has been used by TRB in managing cooperative research programs since 1962. As in other TRB activities, TCRP project panels serve voluntarily without compensation.

Because research cannot have the desired impact if products fail to reach the intended audience, special emphasis is placed on disseminating TCRP results to the intended end users of the research: transit agencies, service providers, and suppliers. TRB provides a series of research reports, syntheses of transit practice, and other supporting material developed by TCRP research. APTA will arrange for workshops, training aids, field visits, and other activities to ensure that results are implemented by urban and rural transit industry practitioners.

The TCRP provides a forum where transit agencies can cooperatively address common operational problems. The TCRP results support and complement other ongoing transit research and training programs.

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The members of the technical advisory panel selected to monitor this project and to review this report were chosen for recognized scholarly competence and with due consideration for the balance of disciplines appropriate to the project. The opinions and conclusions expressed or implied are those of the research agency that performed the research, and while they have been accepted as appropriate by the technical panel, they are not necessarily those of the Transportation Research Board, the National Research Council, the Transit Development Corporation, or the Federal Transit Administration of the U.S. Department of Transportation.

Each report is reviewed and accepted for publication by the technical panel according to procedures established and monitored by the Transportation Research Board Executive Committee and the Governing Board of the National Research Council.

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FOREWORD

By Staff
Transportation Research Board

This report provides a valuable resource for people who have the difficult and often cumbersome responsibility of analyzing the benefits and costs of public transportation services and presenting the results of these analyses to decisionmakers, the media, and the public. TCRP Project H-19, "Estimating the Benefits and Costs of Public Transit Projects: A Guidebook for Practitioners," was conducted by the research team of Parsons Brinckerhoff Quade & Douglas, Inc., in association with ECONorthwest. The researchers prepared a guidebook and CD-ROM (*CRP-CD-18*), which constitute *TCRP Report 78*. The research results will be of particular interest to individuals who plan and evaluate the benefits and costs of new investments in public transportation. Other audiences for this report include policymakers, transportation activists, other transportation professionals, and students in related fields.

The guidebook was developed largely to support transit planners in state, regional, and local government who evaluate transit investments. The theory and methods for estimating the benefits and costs of public transportation projects are presented to provide practical tools for practitioners. The guidebook is divided into five sections. Section I explains how to use the guidebook and provides an overview of benefit-cost evaluation concepts and their application to transit projects. Section II addresses the basic benefits and costs of transit projects, including impacts on travel, secondary impacts on the environment and safety, and the direct costs and revenues of transit projects. Section III discusses other benefits and costs of transit projects, including impacts on land use and land development, economic impacts, and the distribution of impacts. Section IV provides an example with sample analyses. Section V consists of four appendices that provide a bibliography, integrated models for conducting comprehensive benefit-cost analysis, sample calculations, and conversion factors for calculating constant dollars.

An electronic version of the guidebook is included on the CD-ROM, which accompanies the printed guidebook. The electronic version allows for quick referencing of the guidebook's contents through an interactive table of contents. The CD-ROM also contains practical materials and resources for public transportation practitioners. These include the following:

- **Downloadable analytical tools.** A series of Microsoft Excel spreadsheets are included to help analysts organize data and make calculations to carry out benefit-cost analyses. Each worksheet can be tailored to specific situations and cross-referenced with the text of the guidebook.
- **Presentation templates.** Downloadable, Microsoft PowerPoint slideshows that can be easily customized are provided to help practitioners prepare presentations for decisionmakers, the public, and the media about the results of cost-benefit analyses of transit projects. The slideshows complement the guidebook.

- **A resource library.** The CD-ROM contains resources to support practitioners as they evaluate the costs and benefits of transit projects. These include a glossary of terms to clarify topics in the guidebook, a list of transportation organizations and website links where additional data may be found for cost-benefit analyses, and a list of websites that contain useful electronic maps and geographic information systems data.

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AUTHOR ACKNOWLEDGMENTS

ECONorthwest (ECO) managed the research and writing of the guidebook. Terry Moore of ECO was the project manager and editor. He is primary author of Chapters 1, 2, 4, 5, 8, and 9. Randy Pozdena of ECO is primary author of Chapter 3 and contributed to Chapters 4, 5, and 9. David Lindahl of ECO is primary author of Chapter 7 and contributed to Chapter 9. David Helton, Christina Halvorson, Brett Sheckler, Michelle Egerdahl, Steve Grover, and Daniel Malarkey of ECO also did some research and writing.

Sam Seskin, of Parsons Brinckerhoff Quade & Douglas, Inc., is the project manager for the larger project of which this guidebook is a part. He is primary author of Chapter 6. Parsons Brinckerhoff Quade & Douglas also contributed substantially to revisions to parts of Chapters 4, 5, and 8. Robin Christians of Parsons Brinckerhoff designed and managed the production of the CD, which includes the guidebook in its contents. Donald Camph of Aldaron, Inc., and Bob Sloane of Howard/Stein-Hudson Associates contributed valuable advice on the form and content of the CD.

Mark Delucchi, of UC Davis, and Alan Horowitz and Edward Biemborn, of the University of Wisconsin-Milwaukee, reviewed a draft of the guidebook. Many of their comments improved the guidebook, but they bear no responsibility for any problems that remain. In addition to supplying extensive written comments on all aspects of the draft guidebook, Mark Delucchi contributed substantially to Chapter 4 both indirectly (by supplying his forthcoming work on relevant topics) and directly (by giving specific suggestions about how that material might be incorporated into Chapter 4).

PREFACE

This document is a guidebook intended to help regional and local transit agencies evaluate the benefits and costs of new investments in transit. The theoretical framework for such evaluation is well developed in the professional literature, but moving from theory to measurement is time-consuming and difficult. Ideas that make sense in the abstract and in general become problematic when one tries to apply them to specific situations and in detail. The realities of the type, extent, and reliability of the data for making these measurements compound the problem. The result is that rigorous evaluations of transit projects are not done, not done well, not done efficiently, or not understood by the ultimate audience of policymakers and the public.

This guidebook takes a step toward addressing these problems. It summarizes the theory of how benefits and costs should be measured, but then focuses on what it takes for a regional or local transit agency to actually do the measurement and make the calculations for a real project.

The guidebook is also included on a companion compact disk (CD), where all sections, subtopics, and tables and figures can be quickly referenced via an interactive table of contents. The CD also includes

- Analytical tools (downloadable Microsoft Excel spreadsheets) to help analysts organize and calculate data to complete a benefit-cost analysis. These worksheets emulate the methods illustrated in the guidebook and can be easily customized for a wide range of applications. Each worksheet includes references to sections of the guidebook where more information can be found.
- Presentation templates (downloadable, easily customized Microsoft PowerPoint slideshows) to help transit agencies effectively communicate their findings and conclusions to a wide range of audiences (e.g., elected officials, the media, and the general public). The slideshows are organized by the major topics in the guidebook and prompt the user for relevant findings for their particular project based on the analysis conducted (e.g., "Our project reduces auto vehicle miles traveled by X").
  - A resources library to further clarify concepts in the guidebook, obtain data for an analysis, or develop maps for presentations. More specifically, the library includes
  - A glossary of terms to clarify and elaborate on topics in the guidebook,
  - A list of transportation organizations and website links where additional data may be found, and
  - A list of websites where electronic maps and Geographic Information Systems (GIS) data can be obtained to create maps for analysis or presentations.

The preparation of this guidebook was sponsored by the Transit Cooperative Research Program (TCRP) of the Transportation Research Board (TRB). The prime contractor for the entire project is Parsons Brinckerhoff Quade & Douglas. ECONorthwest prepared this guidebook as a subcontractor to Parsons Brinckerhoff. The following organizations and people contributed to the guidebook.

SECTION I:

OVERVIEW

This section provides an introduction to the purposes, organization, and concepts used in this guidebook. Chapter 1 describes the purposes of the guidebook, and gives advice on how to use it. Chapter 2 is an introduction to the practice of benefit-cost analysis and project evaluation as it applies to transportation in general and transit projects in particular. An elementary understanding of the ideas in Chapter 2 is essential to understand the measurements and analytical techniques described in Sections II and III.

CHAPTER **1**

INTRODUCTION

SUMMARY

This report synthesizes theory and empirical work to provide practical methods for estimating the benefits and costs of many typical transit improvements. It is written primarily for transit planners in state, regional, and local government responsible for evaluating transit investments. For that audience, the best way to read the report is chapter by chapter. How the report gets used depends on the detail of the analysis that is desired and achievable given schedule and resources. Tables in this chapter provide guidance on the right level of analysis.

WHY THIS REPORT?

A great deal of theoretical and practical work has been conducted on the benefits and costs of public transit and its competing mode, the private automobile. Hundreds of books, reports, and studies have addressed benefit-cost analysis, the full costs of automobile ownership, the effects of transit and autos on urban form, transportation modeling, air pollution, global warming, social equity, and other issues related to the benefits and costs of transportation.

Only a small part of the work done by academics, consultants, and agencies in enumerating, classifying, and measuring the benefits and costs of transit has made its way into planning practice. Planners in transit agencies could benefit from understandable synthesis of practical methods they can use to estimate the benefits and costs of transit.

Prior to this guidebook, TCRP completed one project that provided a list of definitions and relationships among transit's positive and negative effects and a second that presented a broad array of predictive and evaluative methods that focus on the economic impacts of public transportation investments.[1] This guidebook builds on this earlier work but tries to package it in a way that will make it more accessible to local transportation planners. It attempts to provide practical guidance and techniques for quantifying the effects of existing transit services and proposed improvements. It attempts to help transit system planners and managers respond to questions from local decisionmakers and the public about transit's impacts on things like congestion, travel time, pollution, and community development. These questions reflect concern about the true social cost of transportation investments and a desire for assurance that data and analysis support the proposed level of public investment.

This guidebook adopts the framework of benefit-cost analysis for thinking about transit's effects. The professional literature on public decisionmaking in general, and on transportation in particular, is replete with articles debating the advantages and limitations of benefit-cost analysis. We have nothing new to add to the debate, which we summarize briefly in Chapter 2. Our conclusions, which we admit are not universally shared, are that

- If policy decisions are at least modestly tractable to technical analysis, then better analysis (i.e., better theory, data, and methods) should lead to better decisions.
- Technical analysis of alternatives is always about their relative advantages and disadvantages—about their benefits and costs. It should be possible to agree, at least, on the categories of benefits and costs that transit has and how they might be measured and evaluated.
- The theory and techniques of benefit-cost analysis, while not without limitations, provide the most solid foundation for a clear exposition of benefits and costs and a solid structure to which any number of subanalyses of impacts can be added.

Thus, this guidebook works within the framework of benefit-cost analysis, but acknowledges that an analysis of benefits and costs cannot, and should not, be all that drives decisions about transit programs and projects. Benefit-cost analysis provides a consistent framework for consolidating estimates of impacts from many different sources, but many impacts are difficult to quantify, much less denominate in dollars. Although economists have been responsible for developing most of the theory of benefit-cost analysis and many of the measurements of benefits and costs relevant to transportation projects, benefit-cost analysis is not their exclusive domain. Many types of impacts are better analyzed and measured by engineers, social scientists, planners, and, in some cases, the public (e.g., the value of different distributions of benefits and costs). We have tried to develop a guidebook

[1] TCRP Project H-2, "Measuring and Valuing Transit Benefits and Disbenefits" (*TCRP Report 20*), and TCRP Project H-9, "Economic Impact Analysis of Transit Investments: Guidebook for Practitioners" (*TCRP Report 35*).

that is neutral on the issue of the net benefits of any particular transit project. We try to provide a logical and comprehensive list of potential benefits and costs and point out where transit's proponents and opponents tend to disagree. We hope this guidebook can expand the areas of agreement on transit's effects and how they can be measured, but expect many issues will remain for debate.

HOW TO USE THE REPORT

The previous section gives an idea of whom this report is written for:

- **Primary audience**. People with responsibility for the technical evaluation of transportation and transit improvements and programs in transit agencies, state departments of transportation, and metropolitan planning organizations (MPOs).
- **Secondary audience**. Policymakers and transportation activists.
- **Tertiary audience**. Interested transportation planners and engineers and students of those fields.

For all three audiences, the fundamental *reason to read the report* is similar: it provides a solid framework for evaluating transportation options and some estimates of many of the benefits and costs of investments in transit. *How to read the report*, however, is different for the different audiences. Figure 1-1 illustrates the recommendation for the primary audience.

Figure 1-1 suggests that how one uses this report depends on (1) whether one intends to evaluate transit programs or policies soon and (2) the level of detail to which one is willing and able to carry that evaluation. Figure 1-1 illustrates the obvious point that the more sophisticated methods build on the simple ones and on the theory of transportation economics that underlies both of them. Thus, *the focus of this report is on the simple, practical methods.* It is written to explain underlying theory and basic empirical work. For those who already have this background and who want to go further, it points to other documents for more detail.

In developing this guidebook, we did research to determine whether it would be possible to develop empirical estimates, rules of thumb, and look-up tables that would allow a transit agency of any size to make rough estimates of the benefits and costs of any type or size of proposed transit investment without having to do any research beyond that summarized in this guidebook. We concluded that this approach would not be feasible. The performance of transit and how it affects highway congestion depends critically on local conditions: on city size and density, development patterns, topography, the current highway network and transit system, existing levels of congestion, the type and size of the proposed transit improvement, the socioeconomic status of affected travelers and nontravelers, and so on. Each of those variables can be viewed as a dimension of a hyper-cube, or as a new level of nested tables. In short, if those variables have significant impacts on performance, then this guidebook would have to specify values for key benefits and costs for hundreds or thousands of combinations of those variables.

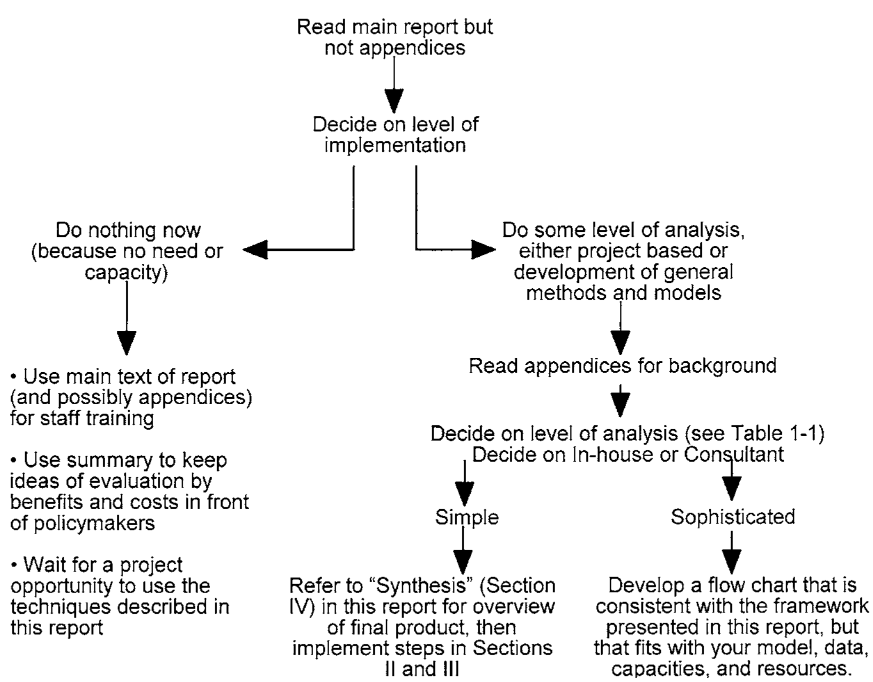


Figure 1-1. How to read this report.

Instead, it seems more reasonable to us, and ultimately more useful to transit agencies, to focus on a clear exposition of concepts, a logical set of analytical steps, a summary to provide a sense of the likely limits for key data items, illustrative calculations, practical advice on dealing with data limitations, and references to reports that can provide more detailed information.

Some technical experts who reviewed drafts of this guidebook found it too detailed and complex for the primary audience and wanted a shorter document; others asked for more detail on data and methods. We tried to find a middle ground. The guidebook is long and technical; it is not a recipe into which one can drop local quantities for each ingredient and produce a savory benefit-cost analysis that decisionmakers will readily consume and digest. We have tried to make it more accessible in two ways:

- Each chapter has a summary.
- In Chapters 3 through 8, which discuss methods and data, the guidebook occasionally calls out a *Key Point* to help readers keep track of the main ideas as they wade through the details.

Table 1-1 provides a list of considerations (about the size and urgency of the transportation issues facing an agency and its capacity and resources) to help readers decide which path in Figure 1-1 is optimal. Given the number of considerations, and the qualitative nature of many of them, Table 1-1 does not lead to unambiguous conclusions about the proper level of analysis. It should, however, help readers decide on the level of analysis most likely to be appropriate for their agency.

Table 1-1 does not include as a variable the type of transit project being considered (e.g., new fixed guideway versus expansion of existing service). The appropriate level of analysis depends more on the size of the investment decision than on the type of investment.

The rest of this report is organized as follows:

Section I: Overview

This section provides a framework for benefit-cost evaluation. It defines terms and principles, describes the basic analytical steps with a full list of the potential benefits and costs of transit improvements, makes recommendations about the subset of those benefits and costs that later chapters will address in more detail, and describes the example that is carried throughout the guidebook to illustrate how to do the calculations.

Section II: Transit's Impacts—The Basic Benefits and Costs

This section deals with the types of benefits and costs that are standard for transportation and transit evaluation: benefits to travelers, spillover environmental costs to society, and costs (for construction and operation) to taxpayers. We refer to it as the basic analysis because it focuses on benefits and costs that (1) are directly related to changes in travel times and characteristics, (2) do not overlap substantially (i.e., they are generally mutually exclusive and, thus, additive), and (3) use generally accepted methods for measurement. It focuses on

TABLE 1-1 What level of analysis is right for your agency?

Criterion	Simple Methods	Grey Area	Sophisticated Methods
MPO size (000s people)	25 50	100 500	1,000+
Staff modeling expertise	None	Some	Staff modeler
Staff economics expertise	None	Some	Staff economist
Highway and transit forecasting models	None	Basic demand model	Advanced model with good calibration
Desires and commitment of policymakers	Little	Some	A lot
Schedule for decisions	Less than 6 months	Within 6 to 12 months	More than 12 months
Expected impacts of investment on travel behavior	Insignificant / Unmeasurable	Small but measurable	Significant
Value of big investment decisions next five years	Less than $5M	$5 – $50M	$50M +
Budget for the analysis	1-2 staff people; or less than $50K	3-5 staff people; or less than $150K	More than 5 staff people; $250K +
Environmental Impact Analysis (EIS); Major Investment Study (MIS)	Not available	No EIS or MIS, but similar information available from different sources	Completed or in process, with data on system performance and environmental effects

Source: ECONorthwest.

efficiency and takes a national and aggregated social perspective, rather than a local and disaggregated individual or group perspective. It is an incomplete analysis, but provides a solid foundation upon which other measures of benefits and costs can be added later (Section III).

Section III: Transit's Impacts—Other Benefits and Costs

This section goes beyond the basic analysis of Section II to discuss other types of benefits and costs that may be harder to measure, more speculative, or potentially double counting of benefits and costs measured in Section II. This section looks at impacts on land use, economic development, and other factors.

Section IV: Synthesis

This section draws together the results of Chapters 3 through 8 to come to some conclusions about the overall effects of transit projects and describes how transit planners might incorporate the technical analysis in this guidebook into a local decisionmaking process.

Section V: Appendices

The report is written to provide an overview of key issues and simple evaluation techniques. Several appendices add technical details.

CHAPTER **2**

OVERVIEW OF BENEFIT-COST CONCEPTS AND THEIR APPLICATION TO TRANSIT

SUMMARY

There is general agreement among policymakers and analysts that, in theory, good policy evaluation requires the identification and measurement of significant benefits and costs: ideally, the measurement of all types of impacts, on all people, over time and across geography. But there is disagreement about how well those benefits and costs can be identified, measured, and summed in practice. This chapter discusses the key principles for measuring benefits and costs, the inherent and remediable limitations of benefit-cost analysis, and implications for how this guidebook categorizes and attempts to measure benefits and costs.

There are several principles of benefit-cost analysis that apply generally to all policy evaluation: (1) all significant impacts should be addressed, (2) relative differences between alternative policies are often more important than absolute impacts, (3) the distribution of impacts can be more important that their totals, and (4) a benefit or cost in the future has less value than the same one now. Although the series of steps for applying these principles are well known and accepted by practitioners of benefit-cost analysis, both the principles and steps have limitations that have been extensively debated in the professional literature. The debate extends to how benefits and costs (impacts) should be categorized so that all significant ones are counted, and counted only once.

There are many ways that benefits and costs can be categorized. This chapter provides some examples. It concludes by explaining the reasons for the structure adopted in this guidebook and reflected in subsequent chapter headings: travel benefits and costs to travelers (both transit and auto), and non-traveler benefits and costs (some of which are in addition to traveler impacts and some of which may already be counted in travel benefits and costs). The guidebook attempts to provide a solid framework, summary data, and understandable examples to help local transportation planners and decisionmakers evaluate the benefits and costs of transit improvements.

INTRODUCTION

Transit development and operations in the United States are strongly influenced by policies adopted by different levels of government. Those policies include not only regulations and operating schedules, but investments. In general, society should have a preference for policies that are more efficient or fairer than alternative policies (including the alternative policy of making no change in policy).

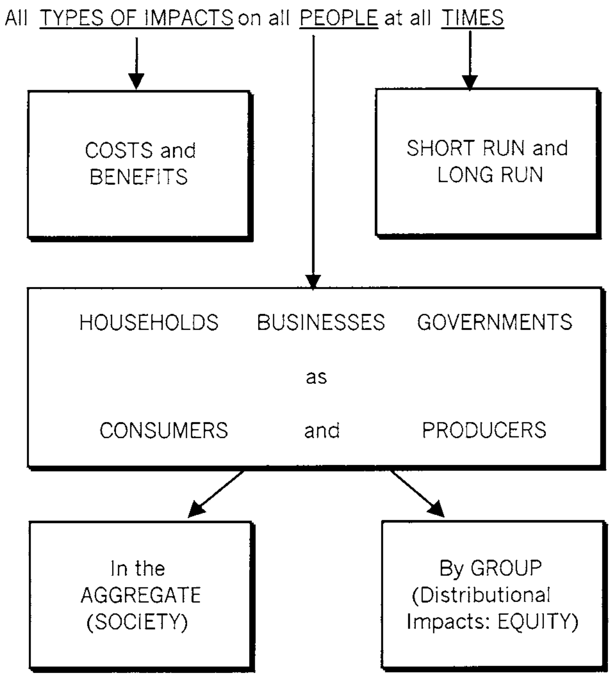
At the heart of benefit-cost analysis (and of all rigorous policy evaluation) is the hope, if not the presumption, that most of the significant efficiency and equity impacts of alternative policies can be identified, described (and, in many cases, quantified), and compared in order to make rational choices among alternative policies.

In theory, benefit-cost analysis is inclusive: its objective is to quantify (and value in dollars, if possible) all significant benefits and costs that stem from a particular action. In practice, benefit-cost analysis is partial. Its critics argue that the practitioners of benefit-cost analysis spend all their time quantifying impacts that are amenable to valuation in dollars, and no time on other types of impacts that are no less real for being difficult to measure. At the extreme, they argue that what benefit-cost analysis can measure is only a small part of the full impacts of transit and that such analysis is therefore largely irrelevant to decisions about transit investments.

In summary, there is generally (1) agreement among policymakers and analysts that, in theory, good policy evaluation requires the identification and measurement of significant benefits and costs; and (2) disagreement about how well those benefits and costs can be identified, measured, and summed in practice.

We start with the theory, where there is more agreement. Figure 2-1 shows the goal of benefit-cost analysis: to be able to describe all types of impacts, on all types of people, over all time periods, for all the relevant areas of impact. The literature of policy evaluation and benefit-cost analysis sometimes refers to this goal as *full-cost evaluation*. That term can be confusing because it seems to imply a concern only with costs. In fact, benefits and costs are mirror images of each other. For example, a benefit of travel time savings is the same as the removal of a travel time cost. Thus, in practice, a full-cost framework is usually synonymous with a framework that attempts to identify and quantify all impacts, which is also the goal of benefit-cost analysis.

In theory, good answers to questions about the net impacts of investments in transit require a full-cost framework. In practice, calculating and summarizing full impacts are extremely difficult. The simple picture in Figure 2-1 hides a



Source: ECONorthwest.

Figure 2-1. A full-cost framework for evaluating the impacts of public policies and investments.

lot of complexity in each of its boxes. Consider the following:

- **Impacts**: not just on transit, or even just on transportation, but on environmental quality, quality of life, economic development, and everything else that citizens and their representatives care about;
- **People**: not just as travelers (by transit, auto, or other modes), and not just as citizens, but as parts of organizations (e.g., business, government, and interest groups). A consideration of subgroups rather than society as a whole addresses questions about the *distribution* of impacts and the *equity* (fairness) of that distribution; and
- **Time**: both *impacts* (type and magnitude) and *people* (and, therefore, the incidence of those impacts) change over time.

Another cornerstone of the structure for rational policymaking is the need to compare alternative futures that one posits will result from alternative policies. This procedure is so common in policy evaluation[1] that its importance (and the possibilities for error) is often overlooked. For planning projects,[2] analysts are asked to describe at least two future worlds, both hypothetical: one of which results from a continuation of today's policies, the other (or others) that result from a change in those policies, and both of which embody many assumptions about economic, demographic, and policy variables. A full-cost evaluation of policy options would then attempt to measure *differences* in outcomes (i.e., impacts: their amount and distribution) from different decisions (i.e., policies/investments).

The notion of *differences* in impacts is important; many project evaluations are ambiguous about key assumptions in this regard. Consider, for example, a project evaluation that is attempting to decide how to spend $100 million local dollars on building two new lanes on an arterial in a corridor. The lanes could be for autos, or they could be exclusive bus lanes. Proponents of the bus lanes want to estimate its economic impacts. They count $100 million in construction costs as if they were benefits, add multiplier effects, and estimate the number of construction jobs to make the case for big economic impacts.[3] But, to a close approximation, $100 million spent on the construction of auto lanes has the same effect on these economic variables: the difference is zero. If $100 million of local money is going to be spent on transportation construction projects no matter what, then the job, income, and multiplier effects, whether for transit or highways,[4] should be irrelevant to decisionmaking.

Typical policymaking, including that related to transit, fails to deal with all this complexity. Alternatives are not well defined; forecasting is nothing more than the recent past pushed forward; only a small subset of impacts is considered and the distribution of those impacts may be ignored; and so on. Those problems have led many policymakers and analysts to support a pragmatic approach to policy: "it will always be political and facts are only marginally important, so let's not waste time by having technicians building, burnishing, and worshipping models of suspicious character and dubious worth." A more extreme extension of this argument is that not only does the complexity of transit investment decisions make them intractable to a disaggregated analysis of benefits and costs, but the outcomes of a political decisionmaking process are inherently more likely to be optimal because all the immeasurable impacts get evaluated implicitly in the process of reaching agreement on public policy.

Maybe. But this report is based on the assumptions (and the hope) that logic and facts can, when presented intelligently by credible sources, influence policy and that better evaluation leads to better decisions. These assumptions make benefit-cost analysis a logical framework for beginning an evaluation of transit's benefits and costs.

A BASIC BENEFIT-COST FRAMEWORK

This report is **not** meant as a primer on benefit-cost analysis, full-cost evaluation, or least-cost planning. Several recent

[1] It is used, for example, in Environmental Impact Statements (the "No Action" alternative compared with the "Build" alternatives).

[2] As opposed to *ex post* evaluation projects, where the analyst is typically working with historical data about what *did* happen, not forecasts about what *might* happen.

[3] With this example we are making a separate point: that many analyses may incorrectly identify costs as benefits, and then may count them more than once.

[4] We ignore, in this example, the possibility that the multiplier effects of highway and transit projects may be different.

reports are available that go into these topics in more detail, both in general and in particular, for transportation.[5]

But one cannot understand the estimates of transit benefits and costs presented in this report without a basic understanding of the principles of benefit-cost analysis as context. If you already have that understanding, skip ahead to the final section of this chapter, which summarizes our conclusions about how to organize our discussion of benefits and costs in the rest of this report.

ISSUES FOR ESTIMATING BENEFITS AND COSTS[6]

General Steps of Benefit-Cost Analysis

The general steps for evaluating the full benefits and costs of transit follow the logic of all policy analysis and are roughly as follows:

1. Identify policy/investment options.
2. Describe the scope of the analysis. In particular, (a) what types of impacts are likely to be significant and will be evaluated and (b) what level of measurement and evaluation is desired, possible, and appropriate?
3. Classify categories of impacts by their ability to be measured or monetized and in a way that avoids double counting. For example, the travel-time benefits of transit improvements are amendable to quantification (How much time does the average transit user and auto user save as a result of the improvement?) and monetization (What is the value of that time savings?). Other impacts (e.g., effects on air quality) are more difficult to measure and monetize. Still others may be intractable to measurement and monetization (e.g., feelings of civic pride associated with a state-of-the-art transit system), or there may be different ways of measuring, and therefore double-counting in a technical sense, other impacts (e.g., changes in property values may be largely a capitalization of travel-time savings already measured).
4. Make measurements of those significant impacts that can be measured. To the extent possible, these measurements should be disaggregated over geography, time, and interest groups (i.e., the distribution of impacts—or, to use a normative term, the fairness or equity—is also important to decisionmaking).
5. Convert, where possible and reasonable, any of the measures of impacts into dollars ("monetize" the benefits and costs).
6. Discount the future stream of monetizable benefits and costs to present value. Sum the present value of benefits and the present value of costs to estimate a net benefit for each alternative.
7. Measure or discuss non-monetizable impacts.
8. Conduct sensitivity analysis to show how changes in key assumptions affect the outcomes of the analysis.
9. Combine the analysis of all impacts (which, in essence, are equivalent to evaluation criteria) into a display of impact information (monetizable, quantifiable, and non-quantifiable) for each alternative (at least a transit-action alternative compared with a do-nothing alternative).
10. If the information in Step 9 does not suggest an obvious preference, develop a formal or informal method for scoring and weighting different criteria to facilitate the selection of a preferred alternative by decisionmakers. This method should incorporate other factors of interest for consideration in the final decisionmaking process.

Step 1, identifying the policy or investment option, is not addressed in this guidebook: transit analysts will complete this step for themselves for each project. A subsequent section of this chapter, "Categorizing the Impacts (Benefits and Costs) of Transit," provides some guidance for Steps 2 and 3. Sections II and III of this guidebook (Chapters 3 through 8) address Steps 4, 5, 6, and 7. Section IV (Chapter 9) addresses Steps 8, 9, and 10.

Before getting to the details of these steps, however, one must understand some of the assumptions, techniques, and problems that any full-cost evaluation must address. The rest of this section provides some background and advice on issues for estimating benefits and costs.

Evaluate All Significant Benefits and Costs

The main reason for making some investment in a transportation system should be to improve the performance of the system over what it would be in the absence of that investment. Thus, it is typical to begin a description of benefits and costs with the ones related to direct costs of the investment and to the changes in travel performance one buys by paying those costs.

The direct costs of transit improvements are relatively easy to enumerate and measure. They include the costs of planning, design, construction, operation, and maintenance (which includes costs to both users and institutions). Typical measures of transportation performance are travel time (a measure of the amount of congestion), operating cost, and safety. Analysts need to know how the transportation system will perform with the investment compared with how it will perform without the investment.

Many of the costs of transportation projects can be measured by adding up the market costs of the resources those projects use. New rail transit lines require labor (for planning,

[5] See the bibliography for more detail. The literature on benefit-cost analysis as applied to transportation goes back a long way. It was summarized best in the AASHTO "Red Book" of 1977, but that report was technical and is currently being updated (NCHRP Project 02-23). A more friendly (for the non-economist) recent summary of benefit-cost analysis and its relationship to least-cost planning can be found in *Least-Cost Planning: Principles, Applications and Issues* prepared by Parsons Brinckerhoff Quade & Douglas and ECONorthwest.

[6] Much of this section is drawn from previous work of ECONorthwest.

design, and construction), concrete, steel, machinery, and so on. Most economists believe that the markets for these resources operate relatively well,[7] and that the prices paid for these resources are a relatively good approximation of what society gives up by committing these resources to one use instead of another. The costs can be added and expressed in dollars.

But other benefits and costs of public projects are ones not typically registered through market transactions. Some of these benefits and costs are not internalized in the prices paid for the goods and services needed to build and operate the project—for example, the costs of air pollution on people and property near highways where automobiles generate that pollution. Economists call such costs spillovers or externalities and argue that society should consider them in its evaluation of a project because they result in real gains or losses.

An example makes the point clear. Suppose a city is evaluating two options for adding travel capacity across a river: one that adds new highway lanes to the existing bridge, and one that adds lanes for non-auto modes only (i.e., bus, bike, and pedestrian). Assume the costs and benefits are identical in both cases except that (1) the average travel time improvements are only slightly greater for the auto-oriented improvement, and (2) air quality is substantially worse with the auto-oriented improvement. If the decision is based only on user benefits and costs, one chooses the auto-oriented alternative. When the air-quality benefits of the second alternative are considered, however, the decision could be for the non-auto alternative.

Extensive literature exists in policy analysis in general, and in transportation in particular, on issues relating to identifying and valuing benefits and costs. The following is a summary of some key issues:

- **Costs are real economic resources used by a policy or project**. Money facilitates the exchange of useful resources, but it is not a resource itself. Steel, concrete, labor, driver time, and gasoline are real resources that are expended in the process of trip-making. Concrete laid in a freeway is concrete not available for a sidewalk, and vice versa. Economists express this point by referring to opportunity cost: the value of a resource in its next best use (if it had not been used for what it was, in fact, used for). Most goods in a market economy sell at their opportunity cost—thus market costs can be used to measure the value of many benefits and costs. The cost of goods purchased from subsidized markets (e.g., goods purchased from the public sector) may need to be corrected to account for the true economic cost. Costs should be counted only when resources are used.

  This point has some important implications. It is not uncommon, for example, for evaluations of transportation projects to count costs as benefits, and sometimes more than once. To build a transportation project, one must use labor. It is a cost. But evaluations often count it as a benefit (income to the economy), then double or triple it (the multiplier effect), and then count it as a benefit yet again under the heading of jobs. A related point is that what are often listed and added as either benefits and costs are actually transfers. Taxes and grants are usually transfers: money may move from one place to another, but no resources are used. This point illustrates the importance of *the perspective* of the analysis, and explains why federal agencies and local governments may have different ideas about the value of some transit projects.
- **Benefits are negative costs; costs are negative benefits**. Many of the benefits of transportation improvements are best expressed as reductions in costs that would have been incurred in the absence of the improvement (for example, decreased travel time, accidents, and operating cost). The convention in the transportation literature is to discuss these reductions as user benefits (i.e., they are desirable impacts). The convention derives from the reasonable assumption that for any transportation improvement to merit consideration, it should reduce these costs; the reductions in costs are benefits for the users.
- **Benefits and costs should be defined, to the extent possible, in a way that is both comprehensive and mutually exclusive**. Accounting for all benefits and costs requires identifying a comprehensive list of all (or at least the significant) benefits and costs. But the categories should not overlap, or else some will be counted twice.

  Extensive lists of potential benefits of public investment are particularly susceptible to double-counting: the more categories, the more likely that they overlap. Many of the overlaps result not from an overly zealous attempt to illustrate benefits, but from the inherent complexity and uncertainty of causal relationships and the theory for disentangling it.

  For example, transportation evaluation typically counts reductions in travel time as a benefit. But some evaluations go on to count as benefits the increases in property values and tax revenues that might be primarily the effects of such reductions in travel time, thereby double-counting the benefit. In other words, to the extent that the benefits of travel-time are capitalized into the increases in property values (as theory suggests they are, to a large extent), double-counting occurs.

[7] Most economists also acknowledge that in any of these markets there are imperfections that distort market prices: things like tax policy, monopoly power, imperfect information. A key category of such imperfections for transportation analysis is external costs (and perhaps benefits) that are not reflected in market prices. Most economists assume that these external costs are either (1) small relative to market prices, or (2) too far removed from the analysis of a transit investment to be amenable to analysis or useful for decisionmaking. Other analysts believe that these external costs are at the heart of critique of benefit-cost analysis. This guidebook deals with some of the external costs of the construction or operation of the transit improvement itself, but not with possible externalities in the markets for resources that go into building those improvements (e.g., external costs in the production of steel for rails or buses).

Although changes in property values are important, they should be estimated separately and noted as not necessarily additive. Moreover, increases in property values may be viewed as good or bad depending on the reasons for the increase and the perspective of the analysis. Increases that result from increased efficiency of auto and transit are arguably benefits. Those that result from constraints on land supply may not be (depending on the intention of constraining land usage). From the perspective of a property owner, increased value is probably a benefit (setting aside short-run issues of taxation). From the perspective of a purchaser or renter, such increases may be indicators of other benefits (e.g., better accessibility) that are causing property values to rise, but the price increases in themselves are costs and undesirable.

- **Measuring all benefits and costs means considering some that do not have obvious market prices**. The most obvious example is reduction in environmental quality from pollution. Less obvious is the loss of time because of congestion. Though air quality and travel time are not traded in any established market, they are real costs that must be considered in any full evaluation of the costs of transportation investments. The professional literature of transportation and environmental economics provides a range of estimates for the value (in dollars) of these types of costs.

Focus on Differences Between Alternatives

Project evaluation can be simplified by comparing each project with a "reference" or "base case" alternative. To choose among alternative actions, it is sufficient to know how their effects differ. In all cases, the concern should be with reasonable estimates of the additional (marginal) costs and benefits resulting from a proposed action, compared with some baseline.

Transit agencies may want to estimate the benefits of their existing systems rather than some marginal increase in service. The same logic would apply, but its application can lead to problems. In all cases, the analyst must forecast the differences in costs and travel behavior between the base case or "no-action" scenario and the proposed transit alternatives. In this instance, the base case would be the current level of transit service and the alternative would be the removal of that system from the regional network. But for an area with a well-developed transit system, trying to estimate how the transportation system would function without any of that transit in place would be difficult at best, and potentially misleading or irrelevant. Neither the methods proposed in this guidebook nor any quantitative measurements will deal well with this type of evaluation.

An important corollary of this point relates to the idea of *avoided cost*. Some analysts count among the benefits of transit the costs of highways and auto travel that are avoided in cases where transit improvements may reduce the amount of auto travel. Implicitly, an estimate of such avoided costs requires a comparison with an alternative—in the simple case, with a "no-change" alternative.

Our experience is that avoided costs get handled more cleanly, not as a separate category called "avoided cost," but by always having a base case alternative for comparison with a proposed transit improvement. For example, with two alternatives—transit improvement versus no change—one can then estimate the amount of auto travel in both, and the impact of that travel on, say, automobile operating costs or air pollution (or fuel consumption, land use patterns, or whatever else might otherwise have been measured as an avoided cost). One can then compare the performance of the two alternatives on any impact deemed significant to estimate differences. This method avoids much of the confusion that often accompanies attempts to directly estimate avoided costs.

This guidebook, however, is about the benefits and costs of transit projects. If an analyst wishes to compare a transit build alternative with a highway build alternative, he/she will have to consult other sources (many are identified in this guidebook) for much of the highway part of the analysis. This guidebook does, however, address some highway and auto issues, to the extent that a transit project changes the demand for and performance of highway travel. In this guidebook we assume, unless stated otherwise, that the analyst is comparing transit alternatives with a "no-build" or "do-nothing" alternative.

Discount to Present Value

Assume that all costs and benefits have been identified, categorized properly to reduce double-counting and transfers, quantified, and expressed in dollars. It is not enough to simply add them up. Benefits and costs that occur at some time in the future are worth less to most people than are the same benefits and costs occurring today. Benefit-cost analysis incorporates this preference for present consumption.

Given the choice of $100 today or a note redeemable for $100 one year from now, most people would choose the $100 today. But if that note were worth $1,000 in one year, most people would choose the note over the immediate $100. That is, they would accept the postponement of gratification, the erosion of inflation, and the risk that, for whatever reasons, the payment in a year will end up being less than $1,000. At some future payment amount more than $100 and less than $1,000, people are indifferent between $100 today and some larger future payment. In other words, individuals discount future dollars: a dollar next year is worth less than a dollar today, even if there were no inflation. Likewise, society as a whole is indifferent to receiving a dollar's worth of benefits in the future or some lesser amount today. This lesser, discounted amount is called the present value of the future benefit.

The discount rate should reflect the opportunity cost of alternative uses of the money. Most often the opportunity cost of capital is viewed as the real rate of return on investments in the private sector. While the basic notion of opportunity cost is straightforward, the theory for selecting the appropriate discount rate gets complicated. Most economists who do research on discount rates recommend real—that is, ignoring inflation—discount rates between 2 and 10 percent. Rates at the lower end used to be recommended for public projects. More recent work is moving consensus toward higher rates (5 percent to 8 percent) based on the assumption that public funding must necessarily draw funds from private investment, so the real rate of return (opportunity cost of capital) in the private sector is a better measure of the time value of money.

Three points make the choice of a discount rate a little less intimidating. First, for federal projects the discount rate may be set by the federal government.[8] Second, in any spreadsheet model one can insert the discount rate as a variable assumption and later quickly test the effects of different discount rates. Third, for similar types of projects, changes in the discount rate are unlikely to change the rank order of benefit and cost estimate.

Describe, and Estimate Where Possible, the Distribution of Impacts

Analysts know that the distribution of impacts is important, but the difficulty of measurement and the normative nature of evaluations of equity often mean that this type of analysis gets little attention.

In concept, measuring the *distribution* of impacts is technical and objective: if one can measure the impacts in the aggregate, then dealing with the distribution of impacts just requires finer subdivisions of measurement.

In practice, at least three problems exist. First, the finer measurement is difficult because of (1) data limitations (e.g., disaggregated estimates of, say, travel time savings by income class may not be available), and (2) the added cost of the analysis (e.g., at the simplest level the amount of reporting of impacts doubles if for every impact one must report the unique impacts on, say, the central city versus the suburbs). Second, decisionmakers usually want and are accustomed to a summary discussion under the heading of *equity*, not an independent discussion of distributional issues for each type of impact. Third, the technical exercise of measuring distribution inevitably gets mixed with the normative exercise of deciding whether the measured distribution is *fair* or *equitable*.

Several considerations influence the decisions made here about how this report will deal with distributional impacts:

- **Every type of direct or indirect impact has distributional impacts**. This point is obvious, but its implications are often overlooked. If a transportation investment has 10 to 20 major categories of direct impacts (e.g., direct dollar costs, job creation, economic multiplier effects, pollution, environmental degradation, travel time savings, out-of-pocket travel costs, land use change, and so on), then the magnitudes, and even the directions of each of those categories of impacts are potentially (and probably) different for different groups. Yet most EISs, at best, have a single short section on "Equity Impacts" that discusses only some of these impacts.
- **There are some groups commonly considered when distributional impacts are evaluated**. Many of the concerns about distributional impacts are about groups that policy has identified as special classes: for example, low-income, minority, or physically disabled.[9] Distribution also has a spatial location; for example, is one state, city, or even smaller area (e.g., central city versus suburbs) getting more than its fair share of benefits or costs? For transportation projects, the distributional question can be organized by type of traveler: transit versus auto; non-auto versus auto; commuter versus off-peak traveler; local traveler versus through traveler.

  The ideal data base for a complete distributional analysis would be one that would have a record for each person in the determined area of impact and that would list in fields all significant impacts on that person (e.g., travel, environmental, and economic), and all relevant personal characteristics (e.g., income, race, disabilities, age, location of work, location of residence, and mode of travel). An analyst could then query the data base to summarize, say, the impacts of a project on low-income transit riders in Area 1 versus Area 2. The difficulty of ever assembling such a data base points out the difficulty of conducting thorough distributional analysis.
- **Many distributional impacts are *transfers*, not net benefits or real economic costs**. This point reiterates the importance of the *perspective* of the analysis. For example, assume a metropolitan region is trying to make the decision described previously: between spending $100 million on building a bus lane or spending it on building two new auto lanes on an arterial in a corridor. But assume this difference: that instead of 100 percent local funding, the bus lane is 80 percent federally funded and the auto lanes are eligible for 20 percent federal funding. The projects are no different: they still require the same amount of labor and materials that they did before, and a

[8] The Office of Management and Budget (1992) Discount Rate Policy states that a **real** discount rate of 7.0 percent should be used for public investment and regulatory analyses. This rate should be applied to a base case scenario to reflect "the marginal rate of pretax rate of return on an average investment in the private sector." The policy also suggests that analyses should show the sensitivity of the discounted net present value and other outcomes to variations in the discount rate. If the shadow price of capital is used to capture the effects of government projects on resource allocation, then OMB concurrence with the chosen rate is required. This policy can be updated with an executive order, at the recommendation of OMB officials.

[9] Distributional issues are at least partially addressed in transportation projects as part of Environmental Justice. Chapter 8 discusses these issues, and relevant federal guidelines, in more detail.

total of $100 million to pay for them. From a *national* perspective, they cost the same. From a local perspective, however, the auto alternative costs four times more than the bus alternative.

A related point is that more disaggregated analysis may provide some useful information for the inevitable debate about the proper level of subsidies (payments not directly from transit users) to transit. For example, transit on high-density corridors may be able to support itself from fares. But because, for other policy reasons, service is extended to low-density areas, discounts are given to seniors, and special facilities are created for people with disabilities, the overall ratio of farebox revenue to cost is low. Is that a problem with transit, or is that a cost that society has decided is worth bearing and, therefore, attributable to general fund expenditures on social programs?

- **Simple analyses of distributional impacts can easily be wrong**. Consider this example. Transit improvements are made that increase mobility in a low-income, rental-housing area. So low-income families receive all the benefits, right? But wait. The apartments belong to high-income owners. Do they raise the rents to capture and thus offset some of the travel-time-savings benefits? The answers depend on market conditions. If there are numerous alternative sites with equivalent housing and access, then price increases may be insignificant: if they were significant, too many vacancies would result. To the extent the market is tight, however, landlords could capture a large part of the transit benefit in increased rents. Even in an intermediate case in which prices rise and as new housing is built, landlords get some of the benefits.

Our conclusion is mixed: (1) the most logical way to talk about distributional impacts is as a subset of the type of direct impact under investigation, but (2) that format potentially means not only a lot of extra analysis, but also a report organization that may not be suitable for the type of high-level evaluation that policymakers are willing to do. The organization of this report reflects that conclusion. Where we think distributional impacts are significant, we discuss them as a subset of other impacts. In any case, the final chapter of this guidebook (Chapter 9, Synthesis) brings any independent analysis together into a summary conclusion about the overall distribution of impacts.

Score (Weight) Different Impacts Measured in Different Units If They Are to Be Combined into a Single Measure of Net Benefits

A typical critique of benefit-cost analysis is that it measures everything in dollars, or only what can be measured in dollars. In fact, though practitioners of benefit-cost analysis try to measure more things in dollars (e.g., putting a dollar value on, say, a measured increase in air pollution), they acknowledge that it would stretch credulity if some impacts were measured in dollars (e.g., the benefit of civic pride or the value of political acceptability). Their recommendation, and one endorsed here, is that some impacts be measured in dollars, some be measured in natural units (e.g., parts per million, number of people affected), and some be only described (i.e., not quantified).

Because transportation projects always have multiple impacts and multiple criteria for evaluation, they always lead to a situation where decisionmakers are asked to look at multiple performance measures for several alternatives and somehow come to a conclusion about the preferred alternative. In the worst case, the relative importance of the different impacts measured is ignored entirely. More often, the measures are weighted implicitly or explicitly as being equal (e.g., "This alternative performed best on more criteria than any other, so it wins."). Sometimes, formal scoring or weighting occurs, but such methods are inherently flawed and, in addition, often poorly implemented.

Most of this report focuses on how to identify and measure categories of benefits and costs. Chapter 10 provides some guidance on how to add or compare those measurements and on methods that would facilitate discussion and decisions about preferred alternatives.

LIMITATIONS OF BENEFIT-COST ANALYSIS

Despite its many advantages, the benefit-cost framework we have described has limitations. Some of transit's effects are difficult to measure and those that can be measured are difficult to express in dollars. Moreover, the distribution of benefits may matter as much as their total amount: providing mobility to people with low incomes and disabilities may matter as much as, or more than, aggregate transit-time savings.

A recent critique of benefit-cost analysis as it applies to transit is provided by Lewis and Williams (1999). The critique is extensive, but the fundamental arguments are that (1) benefit-cost analysis does not, and cannot, measure everything of importance to decisionmakers and the public that elects them, and (2) many benefit-cost analyses find many transit investments to have costs in excess of benefits, while at the same time the public sector continues to allocate funds to subsidize transit, meaning that "it is the Cost-Benefit Analysis that must be faulty, not the budget decisions themselves" (Lewis and Williams 1999, 3).

Their critique does not dismiss all technical efforts to measure benefits and costs as irrelevant. On the contrary, the bulk of the book contains attempts to categorize and measure transit's benefits and costs.[10] Thus, the critique is more that benefit-cost analysis, as it has been applied to transit, has

[10] Lewis and Williams make measurements of transit benefits in an attempt to explain, primarily at a *national* level, *why* decisionmakers make the decisions they do about investment in transit, while this guidebook suggests, primarily at a *local* level, *how* to evaluate marginal additions to local transit systems.

focused too narrowly on travel-time benefits and construction costs and has missed or mismeasured several significant categories of benefits.

In our opinion, that critique is not fatal to benefit-cost analysis as we have defined it. If analysts and policymakers generally accept the idea that better identification and measurement (where possible) of transit's full benefits and costs can be useful in public debates about transit policy and investment, then the methodological debate is not about the benefit-cost framework, but about the details of the measures and measurement. We address those issues in the next section and throughout the rest of this report.[11]

A different, but related, critique of benefit-cost analysis is that its quantification of benefits and costs leads to a false sense of confidence in the validity and reliability of the estimates. All of the calculations described later in this guidebook rest on some or many assumptions, alternative assumptions are always possible and often justified, and final results may vary (perhaps substantially) when different assumptions are made.[12]

CATEGORIZING THE IMPACTS (BENEFITS AND COSTS) OF TRANSIT

The *impacts* referred to in Figure 2-1 may be good ones (benefits) or bad ones (costs). There are many different ways to categorize benefits and costs in general, and for transportation and transit projects in particular. This section shows several.

Before making that list of impacts, we note a critical issue in the application of benefit-cost analysis to transportation. Remember that the ultimate objective of benefit-cost analysis is to get to a measure of net impacts for decisionmaking. One way to do that—typical and logical—is to list all the separate types of impacts that a transportation project might have and then measure and add those impacts (positive and negative) to arrive at a measure of net impacts. The work scope for this project, and much of the work we reviewed on this topic, assumes that to be the method for estimating net impacts. This assumption, intuitively reasonable, is potentially flawed in general, and particularly for transportation evaluation. The fundamental reason is that the assumption fails to account for the interaction among effects.

An example illustrates the problem. Consider the hypothetical benefits to the users of some new transit service: ability to make new trips to new destinations or at different times; more comfort, convenience, security, and safety; and so on. Benefits might also include cost reductions, or there may be cost increases: changes in fares, travel times, automobile operating costs, and so on. In fact, because benefits are reductions in costs, and vice versa, it is sometimes tricky to disentangle them. The main point is that transit users consider all these things (some explicitly) when they make their travel decisions (regarding destination, time, mode, route, and so forth). Arguably, if transit users decide to make a new trip, or drivers switch to transit, they have, by whatever internal calculus they use, made a decision that they are better off. In other words, they see net benefits.

Transportation economists have agreed for a long time on the basic principles of how to measure that net benefit, when summed across all users of a particular mode and geographic market. They compare an estimate of the maximum amount that a person would be willing to pay to make a trip (a measure of its total value to that person) with what that person actually believes he/she is paying (his/her perception of his/her travel costs). The difference is the net benefit of the trip for that individual. The sum for all individuals gives an estimate of total net benefits to users. In practice, it is impossible to look at every trip made by every traveler, calculate net benefits, and sum them for all travelers. Instead, economists estimate the difference between trip value and trip cost directly from aggregated demand and supply relationships (if positive, it is called consumer surplus, denoting that consumers get more in benefits than they perceive they are paying in costs).

The key difference with this method is that all of the many different benefits and costs that travelers directly incur as travelers are not evaluated separately and added, but are evaluated collectively as a change in consumer surplus. The advantage of that measure of the net travel benefits to travelers of transit improvements (other benefits and costs accrue to society at large in addition to these) is that it is simple and theoretically sound, it reduces double-counting, and economists already know how to calculate it.

Net user benefit (consumer surplus) is probably the most important and significant of the total impacts to society of a transportation improvement. Net user benefit is not, however, likely to be complete in itself. There are other impacts that are not considered fully by tripmakers when they make trip choices, so these are not included in the calculation. Many analysts believe these "external impacts" (usually costs) to be significant (a point we address later in this guidebook).

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[11] A more extreme form of the critique of benefit-cost analysis is that the benefits and costs of transit are so many and interconnected that any attempt to disaggregate them and measure them separately will always fail to give even an approximation of the real net values to society. In that case, all technical arguments are partial (in both senses: incomplete and biased) and one presumably relies on a political process (democratic, pluralistic, and incremental) to make decisions. That type of decisionmaking process might use voting or polling as the ultimate measure of net benefits: if a majority support some policy or investment, then it must be providing a net gain to society.

We do not accept that argument. We believe that there is ample evidence that decisionmakers and the public will vote based on little and biased information; that a majority of votes rarely represents a majority of society; that opinions change substantially based on how contingent questions are worded; and that there is no reason to believe that the preferences of a majority of voters or survey respondents coincide with optimal social policy.

Given those beliefs, we do not examine in this report techniques for gathering public opinion as a way of measuring the benefits and costs of transit. That is not to say that polling has no place in evaluating transit policy. Clearly, one wants to know how citizens and voters feel about alternative policies. We expect larger transit agencies, such as corporations that emphasize the importance of customer service to profitability, will be polling customers (riders). This report acknowledges that some of the data about benefits and costs may come from surveys (e.g., travel-activity journals), but does not attempt to describe survey methods.

[12] We are assuming here that the basic theoretical constructs described in this guidebook are generally accepted; we are referring here only to changes in the specification of the parameters that are consistent with the underlying theory.

That said, the rest of this section takes a disaggregated approach to transit benefits and costs and tries to identify all the individual impacts. That approach is more typical of the transportation literature and more intuitive and understandable to a non-technical audience. Chapter 3 returns to this discussion of consumer surplus as it tries to find practical ways for transit analysts to measure the user benefits of transit improvements.

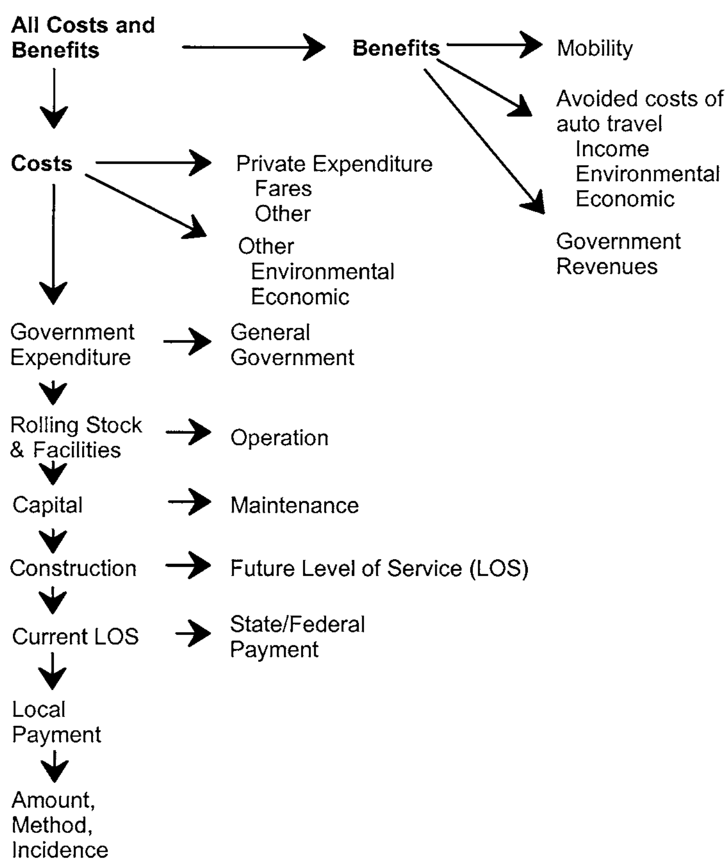
The introduction or expansion of transit service induces a wide range of potential changes in transportation patterns, the natural environment, social welfare, public expenditures, social interaction, and the local economy. Many previous studies make that point, including several recent ones published by TCRP. A smaller number of reports go into the details of what benefits and costs those general categories comprise. Few studies get to the level of specifying measurements for each type of benefit and cost and how those measurements may overlap.

Figure 2-2 illustrates how studies often, and sometimes unintentionally and without acknowledgement of the fact, evaluate only a subset of the full benefits and costs of a transit improvement.

Figure 2-2 starts at the top left with all benefits and costs bundled together and then unwraps them. The point of Figure 2-2 is that the farther down the left side one goes, the more things have been removed from the kind of comprehensive analysis to which benefit-cost analysis aspires.

Figure 2-2 focuses on the cost side–the left side of the figure (subsequent figures will provide more detail about benefits) and illustrates that costs may be borne directly by transit users (e.g., fares) or by a larger society (through government expenditures and the taxes paid to support those expenditures) and that costs may be borne indirectly by society through environmental or economic costs (again, borne by consumers either as reduced welfare or as increased taxes to government to ameliorate the indirect impacts). Not all government expenditures on transit go into facilities, and those that do get split between capital and operation. The construction costs vary depending on level of service.

As one moves from the top to the bottom of Figure 2-2, one moves from a theoretically comprehensive to an empirically narrow definition of cost: in the bottom left corner only direct, local, public costs of transit are left. No one would argue that this is a measure of the full costs of transit, and it



Source: ECONorthwest.
Note: Not all the items in Figure 2-2 are benefits and costs in the strict sense used in benefit-cost analysis. Fares, for example, are costs from a rider's view, revenues from an operator's view, and transfers from an economist's view.

Figure 2-2. A hierarchy of costs and benefits for transit improvements.

does not even consider benefits. Thus, Figure 2-2 illustrates how it is possible to leave out certain aspects of cost when evaluating full cost.

Figure 2-2 is for a generic transit improvement. Such improvements can be of different types (e.g., construction of facilities, addition of rolling stock, change in service characteristics, and new programs) and scales, all of which could change the type and magnitude of the benefits and costs.

Table 2-1 starts to get more specific about transit and its benefits. Table 2-1 shows the relationship between transit's principal desired *impacts* (i.e., benefits, which are also the reasons for supporting transit investments), and the *people* who enjoy those benefits (from Williams 1998, and Lewis and Williams 1999). The cells of the table are intentionally left blank: the table illustrates only the dimensions of the classification scheme (the rows and columns); it is not presenting data that relate impacts to people. Two strengths of the table's organization are that (1) it is simple and understandable (the importance of this attribute will become clearer as we present more complicated organizations below), and (2) it addresses not only the impacts of transit, but also their distribution. Table 2-1 makes it clear that some benefits of transit improvements accrue to transit users (e.g., better service that results in more access, travel time savings, or more comfort), and other benefits accrue to larger groups (e.g., the benefits of congestion reduction to all regional motorists, or the benefits of reductions in air pollution to all regional households [society at large]).

Table 2-2, summarized from Litman (1999), goes to the next level of detail. Where Table 2-1 showed only one line for "Mobility," Table 2-2 shows four separate types of mobility measures. On this point alone, the contrast between Table 2-1 and Table 22 illustrates a key problem with any benefit-cost evaluation; namely, that the sum of the parts can often be greater than the whole.[13] The more ways one can describe and measure a certain type of benefit, the more likely are higher benefit estimates if the different measures are considered mutually exclusive and additive.[14] We do not comment at this point on whether there should be one, four, or more categories of mobility effects—we simply note the implications and importance of the decision about the number and that this kind of listing leads to a different type of analysis than one that starts with the intention of measuring consumer surplus.

Like Table 2-1, Table 2-2 also pays attention to the distribution of impacts (last column). Table 2-2 also recognizes that the impacts of improved transit service can be to allow new trips (categorized under *Mobility* effects) and to decrease travel time for existing transit riders (under *User cost savings*) and for auto riders (under *Congestion reduction*). Most of what Table 2-2 categorizes as *Efficiency Benefits* are derived from expectations about the avoided cost of highway construction (assuming that transit allows for the reduction of forecasted trips that would otherwise congest highways, reduce travel times, and lead to more highway construction).

Table 2-3 is based on Beimborn et al. (1993). It is probably the most comprehensive hierarchy of benefit categories.

In concept, the right-most variable on every line of the table is a unique type of impact that should be measured, and the measurements of all these unique variables should be additive to a single measure of the benefits of a particular transit improvement. Its comprehensiveness comes with some disadvantages. First, the table does not explicitly distinguish among types of travel changes caused by the transit improvement (e.g., whether the improvement causes new trips, or displaces trips from transit, auto, or other modes). Second, it does not deal explicitly with the distribution of impacts.

The current state of the practice tends to focus on just three of the branches: transit supply purchases, and the user effects for transit and auto users. This emphasis is appropriate because the costs of transit are primarily concentrated in the supply of transit service and most of the benefits of transit accrue to the transit users and, to a lesser extent, auto users. However, the benefit tree makes clear that transit has other potential effects that alter the amount and distribution of social benefits. Williams and Lewis (1999) provide evidence that these other benefits are actually quite large when added at a national scale.

Although called a *benefits* tree by its authors, Table 2-3 also helps clarify *costs*, which can frequently be treated as negative benefits (i.e., as disbenefits). For example, time spent traveling is a cost of travel, so travel-time savings from a transit investment are a benefit of that investment (the benefit is the reduction of a cost).

That tight relationship between benefits and costs—because the benefits of one investment option are often the reduction in costs of an alternative investment option—can create some problems for evaluation. Many studies of alternatives end up with a lot of double counting. Consider Tables 2-2 and 2-3, which attempt to provide a comprehensive list of the benefits of transit. They list not only the direct benefits of transit (i.e., better travel characteristics, primarily reduced travel time, on transit), but also count as benefits the avoided costs of automobile trips. In concept, both benefit-cost analysis and social science research support the idea that impacts of a change (e.g., an investment, a policy, or a treatment) get measured by (1) introducing the change into a system and (2) measuring everything that changes as a result of that initial change.

But one must be careful to keep the measurements straight. For example, new bus service may change auto travel: some

[13] This is usually more of a problem for counting benefits than costs. For costs, especially direct costs, an accounting perspective usually avoids double counts: add up the cost of labor, materials, financing, and so on, and one has a pretty good estimate of the costs of building or operating a new transit project.

[14] For example, if the categories in Table 2-2 are assumed mutually exclusive and additive, we believe several benefits and costs would be double-counted, and transfers of benefit would be counted as real increases in net welfare.

TABLE 2-1 Chief benefits and beneficiaries of transit (per Lewis and Williams)

Transit's Desired Benefits	Groups of Beneficiaries		
	Transit Users	Other Travelers/ Community Members	Society-at-Large
• Low Cost Mobility • Congestion Management • Location Efficient Neighborhoods and Commercial Centers			

Source: based on Williams 1998, and Lewis and Williams, 1999.
Note: The cells of the table are intentionally left blank: the table is to illustrate only the dimensions of the classification scheme (the rows and columns); it is not presenting data that relates impacts to people.

TABLE 2-2 More detailed list of benefits and beneficiaries of transit (per Litman)

	Description	Distribution
Mobility Benefits	**Benefits from travel by transit that would not otherwise occur**	
1. Economic	Economic benefits of increased employment	Benefits all of society
2. Personal	Benefits to users from increased employment, education, recreation, and social activities	User benefit
3. Equity	Benefits of providing mobility to people who are also economically, socially, or physically disadvantaged	Both users and society benefit
4. Option Value	Maintaining transportation options in case of changes in individual or social needs	Benefits all of society
Efficiency Benefits	**Benefits resulting from reduced motor vehicle traffic**	
5. User Cost Savings	Users' vehicle and time savings	Users
6. Economic Development	Increased regional economic activity due to the larger portion of local inputs in transit expenditures compared with automobile expenditures	Regional community
7. Congestion Reduction	Reduced traffic congestion resulting from reduced vehicle traffic	All road users, road agencies, tax payers
8. Parking Cost Savings	Reduced parking problems and parking facility cost savings from reduced automobile use	Auto users, businesses, and government
9. Safety Benefits	Relative safety of bus travel compared with automobile travel	Bus riders, all road users, and society
10. Reduced Roadway Facility and Service Costs	Reduced costs for roadway construction, maintenance, traffic police, and related services	Government agency budgets, society
11. Reduced Roadway Land Requirements	Reduced need to use land for roads, increased tax revenue	Government agencies, the environment, society
12. Land Use Impacts	Reduced urban sprawl, loss of greenspace and negative aesthetic impacts of roads	Government agencies, utilities, the environment, society
13. Air Pollution Reductions	Reduced vehicle air pollution	Society
14. Noise Impacts	Changes in vehicle noise emissions	Society
15. Water Pollution	Reduced vehicle water pollution due to reduced automobile use	Society
16. Resource Conservation	Reduced use of energy and other natural resources	Society
17. Reduced Barrier Effect	Improved mobility for pedestrians and bicyclists due to reduced vehicle traffic	Current and potential pedestrians, cyclists, society
Costs	**Costs of transit service (not incorporated in benefit analysis)**	
Fares	Fares charged to transit users	Transit users
Travel Time	Additional travel time costs for transit users	Transit users
Subsidies	Financial subsidies to provide transit service	Local, state, and federal government

Source: Litman (1999), *Evaluating Public Transit Benefits and Costs.*

TABLE 2-3 More detailed hierarchy of the benefits of transit (per Beimborn et al.)

Transit Trips	Change in Well Being		
	Change in Lifestyle	Privacy	
		Contact with Others	
		Freedom	Trip Tours
			Time Table
			Connectivity
		Confidence of Place	
		Equality	
	Security		
	User Effects	Time	
		Use of Time	
		Operating and Parking Costs	
		Vehicle Ownership	
		Destination Choice	
Fewer Auto Trips	User Effects	Time	
		Operating and Parking Costs	
		Destination Choice	
	Environmental Effects	Energy Use	
		Air Pollution	
		Noise Pollution	
	Facility Needs	Highways	
		Parking	
		Control Systems	
Provides Alternatives	Long Term Option		
	Unusual Occurrences	Severe Weather	
		Family Circumstances	
		Vehicle Breakdown	
		Emergencies: Evacuation, etc.	
	Recreational Riding		
	Independent Living	Discretionary Activities	
		Access to Health Care	Reduced Public Cost
		Employment	Welfare
Land Use / Economic Activity	Efficiency of Public Services	Facility Needs	
		Operations	
	Interaction among People	Interpersonal Contacts	
		Networking/Productivity	
	Land Preservation	Open Space, Agriculture	
		Privacy, Interaction	
		Isolation	
Transit Supply	Operations	Employment	
		Environmental Effects	Energy Use
			Air Pollution
			Noise Pollution
		Purchases	Employment
			Materials
	Community Support	Prestige	
	Facilities	Facility Construction	Pollution
			Disruption
			Labor
			Materials
		Land Consumption	

Source: Beimborn, et al. (1993).

travelers may switch from auto to bus and avoid auto costs. But many of the costs avoided are internalized by the individual travelers and are what motivates them to switch to transit. This guidebook returns to this issue of double-counting, avoided cost, and consumer surplus (a measure of net benefits) in Chapters 3 and 5. It will illustrate why measuring all those components of benefits and costs (as shown, for example, in Tables 2-1, 2-2, and 2-3), comprehensively and without double-counting, is extremely difficult.

In sum, Tables 2-2 and 2-3 illustrate how large an evaluation of transit benefits can get and different ways that impacts can be organized. By providing the detail they do, they also make it easier to see what might be double-counted or left out. The next section describes how we incorporate these ideas into an organization of impacts that we believe is economically correct and logically consistent, and, hence, useful for explaining and performing transit evaluation.

IMPLICATIONS FOR THIS REPORT

Despite their length, the previous sections provide only an overview of the complexity of developing and implementing methods for a rigorous full-cost evaluation of transit improvements and investments. There is clearly a conflict between a desire to prepare a simple, readable guidebook, and the desire to prepare one that is rigorous and complete. We have had to make some choices. Our conclusions, as they relate to the organization of this report, are as follows:

- The idea that each of transit's benefits can be isolated, measured, and added to a total benefit is intuitively appealing, but technically flawed. The problem derives from the fact that consumers do not disassociate and add separately the components of travel cost when they make travel decisions. Transportation economists have long agreed on the theory of measuring net travel benefits to

travelers: it is measured as the sum of the change in consumer surplus that travelers enjoy from a new travel option. That surplus is measured as a demand-supply relationship between perceived trip cost and the quantity of trips. Full trip cost includes many of the components that the previous tables break out individually. In sum, most transportation economists would argue that the only correct way to get at the net benefits of transit improvements is by measuring consumer surplus,[15] and that adding separate measures of transit benefits almost certainly over-counts benefits.
- The challenge for this guidebook is to provide an analytical framework that is consistent with economic theory, capable of being implemented without requiring the use of sophisticated modeling methods, and an advancement of the state of the practice with respect to the measurement of certain transit impacts. Many transportation and transit planners, analysts, and decisionmakers understand basic transportation issues, but may have little understanding and no formal training in benefit-cost analysis.
- Simplification will make this report more useful. Simple, practical methods are more useful than complex, complete ones. Figure 1-1 shows how planners can start with this report and move on to the other reports it references for more detail. Table 2-3 shows how complicated the identification of impacts can be. In doing so, it does not translate easily into chapter headings and subheadings.

These considerations lead to the following organization for our report. Impacts are first divided into two categories, which correspond to the next two sections of the guidebook. Each section is then divided into chapters that address common types of benefits and costs. Each category is further divided into subcategories of impacts. For example, transit's travel impacts are divided into those that affect transit users directly and those that affect users of other modes. The organization is as follows.

Section II: Transit's Impacts—The Basic Benefits and Costs

This section addresses impacts about which there is a general consensus that they are (1) directly attributable to transportation improvements, (2) quantifiable and probably monetizable, and (3) mutually exclusive (not double-counting).

- **Chapter 3, Transit's Travel Impacts**. This chapter focuses on measurements of the primary impacts of any transportation project or program: improvements in travel characteristics (e.g., more trips, speed, safety, convenience, or comfort). The chapter covers impacts on both transit users and users of other modes (especially auto) and the distribution of impacts on subclasses of users.
- **Chapter 4, Transit's Secondary Impacts**. The term *secondary impact* does not imply impacts of less importance, but rather impacts that derive from the primary impact of building, operating, and maintaining more transit facilities and service. The main categories of secondary impacts are Environmental, Land Use, Economic Development (including impacts on jobs, income, and profits), and Other. This chapter focuses on the environmental impacts because they are clear spillover costs that are not otherwise counted. Other secondary impacts addressed are accidents. Parking, other transportation-related service costs, and other social service costs are addressed in Chapter 5.
- **Chapter 5, Transit's Direct Costs and Revenues**. This chapter focuses on money transactions, the most obvious of which for transit and transportation are the direct costs of planning, building, operating, and maintaining facilities and vehicles. We start with costs because (1) cost impacts are the easiest to understand and measure in dollars; (2) a discussion of costs facilitates a discussion of several general methodological issues (e.g., discounting to present value) that apply to other types of impacts; and (3) the direct, dollar costs of planning and construction are really the initiating impacts, in the sense that those expenditures create the transit projects from which other impacts flow.

Section III: Transit's Impacts—Other Benefits and Costs

This section deals with impacts that are harder to measure or potentially redundant (i.e., double counts) of the basic benefits and costs measured in the previous section or both.

- **Chapter 6, Transit's Impacts on Land Use and Development**. This chapter addresses impacts on land use that derive from the primary impact of building, operating, and maintaining more transit facilities and service.
- **Chapter 7, Transit's Impacts on Economic Development**. This chapter addresses impacts on economic development derived from the primary impact of building, operating, and maintaining more transit facilities and service.
- **Chapter 8, Distribution of Transit's Impacts**. This chapter is about what is often referred to as "equity." Where other chapters have focused on estimating total costs and benefits, this chapter talks about how to disaggregate the analysis to try to identify how different groups benefit or pay.

Section IV: Synthesis

- **Chapter 9, An Example**. This chapter draws together the results of Chapters 3 through 8 to come to some conclusions about the overall effects of transit projects and describes how transit planners might incorporate the technical analysis in this guidebook into a local decisionmaking process. It summarizes and abstracts from Chapters 3 through 8 to describe how different

[15] Chapter 4 and an appendix discuss these points in more detail.

groups are affected by transit investments—who gains and who pays?

Section V: Appendices

The report is written to provide an overview of key issues and simple evaluation techniques. Several appendices add technical details:

- Appendix A, Bibliography
- Appendix B, Integrated Models for Conducting Comprehensive Benefit-Cost Analysis
- Appendix C, Sample Calculations
- Appendix D, Converting Monetary Costs and Benefits to a Common Base Year (Constant Dollars)

SECTION II:

TRANSIT'S IMPACTS—THE BASIC BENEFITS AND COSTS

This section focuses on the benefits and costs that have traditionally been identified with transportation improvements. The common acceptance of these benefits and costs derives from the fact that they are (1) logically connected as direct consequences of a transportation improvement, (2) generally mutually exclusive—in other words, they do not overlap substantially in the impacts they measure, and (3) measurable and, in most cases, monetizable. This section addresses these benefits and costs in three parts:

- Those associated directly with activity of travel itself and its effect on *users*. This section introduces the notion of *consumer surplus* and presents the basic arithmetic of calculating user benefits (Chapter 3).
- Those that are *secondary impacts*, which include such things as the option value of transit (Chapter 4).
- Those that are *direct costs* of building, operating, and maintaining a transit improvement (with revenues as potential offsetting benefits) (Chapter 5).

The impacts discussed in this section are not *all* the benefits and costs of a transit improvement, but they are among the most significant ones and a good place to start an evaluation. Thus, the chapters in this section focus on impacts that are quantifiable using accepted benefit-cost analysis techniques. Section III then discusses other impacts that Section II does not cover.

CHAPTER **3**

TRANSIT'S TRAVEL IMPACTS

SUMMARY

Transit's impact on travel behavior (for all modes) is the primary source of societal benefits from transit. Benefits are realized when transportation users perceive that their cost of travel has been reduced. If a transit improvement does not change the cost of travel perceived by users (of all modes in the aggregate), it cannot affect user travel behavior. This chapter describes the different components of perceived user costs (other chapters discuss real costs that are not perceived by users).

The largest perceived cost of using transit is travel time, which is comprised of time spent walking to transit, waiting, riding, and transferring between routes. Generally, time spent walking to and waiting for transit is perceived to cost two to three times the cost of time spent traveling, which is usually valued at 50% of the gross hourly wage rate. These values are applied to estimates of the amount of time that is saved by the improvements, which will be a function of transit headways, vehicle operating speeds, and how service is integrated (i.e., how many transfers are required to make trips). This chapter gives some rules of thumb to estimate how different operating characteristics affect total travel time, although careful project specification and engineering analysis is recommended for detailed studies.

The other major category of perceived transit cost costs is fares. Analysts should use existing or proposed fare structures to estimate costs per unit of travel. Regarding transit passes, permits, and ticket books, average fare costs can be calculated by dividing the purchase price by the number of primary (e.g., commute) transit trips expected to be taken.

It is likely that transit users already incorporate perceived accident and crime costs into their subjective values of travel time, and thus they can be ignored. Alternatively, when transit improvements are judged to significantly increase safety or risk, or when the analyst suspects that crime or accidents are generally trending up or down, special analysis may be needed. This chapter provides average cost data for crime and accidents, which can be adjusted and added into the calculation of perceived user costs.

Auto and truck trips can be directly affected by transit improvements, as autos are frequently used to connect to transit service, and transit improvements can change roadway operating conditions (e.g., reduced congestion levels). As for transit, the largest perceived cost for auto and truck users is travel time, although different components must be calculated (in-vehicle time, walking time, and parking search time). These calculations can be more complex, however, as auto users sharing vehicles may value their time differently, and estimating reduced (or increased) inventory costs for trucks due to travel conditions can be difficult. This chapter provides estimates for auto and truck values of in-vehicle time (based on wage rates) for a range of trip purposes, which can be applied to travel time savings calculated with standard travel demand models or generalized volume-delay relationships.

Auto and truck operating costs related to fuel consumption, parts replacement, insurance, and other categories are another important cost that can change with travel behavior and traffic conditions. This guidebook lists average costs for these items per vehicle mile, although analysts are advised to estimate their own local cost data as this data changes frequently. In addition, the amount that auto users pay out-of-pocket to park their vehicles should also be included in the cost calculations, although data limitations may require that these costs be estimated using probability methods. All of these costs should be converted to costs per passenger mile if transit cost data is measured this way.

As with transit, the cost of accidents and crime for autos and trucks is likely to be incorporated into value of time estimates, which should be augmented with insurance costs. These numbers should only be adjusted when transit improvements significantly affect perceptions of risk or safety.

To measure aggregate net user benefits, the analyst needs to know 1) the amount of travel before the improvement (by mode and time of day using a travel demand model); 2) the perceived costs for these travel patterns (per unit of travel); 3) the amount of travel after the improvement; and 4) the perceived costs for the changed travel patterns. Once these elements are known, user benefits are calculated by multiplying the change in perceived user costs (by mode) by the average travel volume for that mode (comparing the base case with the improved conditions alternative).

OVERVIEW

Transit improvements alter the characteristics of a region's transportation network. In response, travelers may change their choices of the time, mode, path, and frequency of travel.

Change occurs not only in the use of transit services, but also in the use of competing and complementary modes of travel. Changes may take place not only in the character of trips that were already being made, but also in trip-making overall. That is, travel may be *induced* or *retarded* by the improvement.

The impact of a transit improvement on travel behavior is the primary source of societal benefits from transit. Other impacts (such as environmental, land use, and regional economic impacts) are also important: they are discussed later in this guidebook. Typically, however, the impacts on *users of the transportation system* constitute the major share of transit benefits.

Benefits to travelers from transit improvements come about primarily as the result of reductions in the users' perceived cost of travel. Such reductions leave the user with surplus *willingness to pay*: they are willing to pay more for the trip than what they perceive the trip is costing them. User benefit calculations, therefore, emphasize measurement of the willingness to pay. Measurements of willingness to pay for transportation services allow transportation analysts to convert changes in travel activity to changes in economic benefits to travelers. In the overall picture of benefit-cost analysis, this focus on willingness to pay makes sense, too. If users of a service are collectively unwilling to pay what it takes to provide or improve that service (conceptually, at least), then it is harder to argue that these users receive net benefits from the service enhancement.[1]

Economists describe the willingness-to-pay relationships with *demand curves* and use the term *consumer surplus* to talk about the difference between the travelers' willingness to pay and their perceived cost of travel. Figure 3-1 shows the basic relationship. The demand curve in Figure 3-1 portrays the relationship between the volume of trips and the user cost per trip that travelers must bear. The less the transit service is perceived to cost, the more trips users will make, everything else being equal. In the case depicted in Figure 3-1, a certain number of users (V_o) are willing to incur costs of U_o, but additional users would be willing to use transit if the costs are reduced to U_i. The notion of consumer surplus recognizes that, at virtually any point on the demand curve (such as that level of demand associated with cost U_o), most of the people who are using transit services would be willing to pay more than they are actually paying.

Consumer surplus is defined as the cumulative difference between the costs users perceive they incur and what they would be willing to incur. In other words, consumer surplus is a measure of net benefits: the excess of value over cost. From this perspective, the demand curve can be seen as a *marginal benefit* curve. For any given volume of trips, it indicates the benefit that is derived from the last trip at that volume. The reason that the trip cost U_o is associated with no more trips than V_o is that the marginal benefit of an additional trip would be less than the user's cost to make that trip. The area under the demand curve at a given level of trip making, therefore, represents the aggregate of the gross benefits that travelers enjoy from trip making. Calculations of *changes* in this area (changes in *consumer surplus*) can be used to measure the user benefits of a transit improvement.

> *Key point: Changes in consumer surplus are the primary measure of user net benefits.*

Suppose, for instance, a transit investment were to reduce the costs of using transit from U_o to U_i, as described in Figure 3-1. This improvement not only benefits existing users, but also can induce additional travel because user costs fall below the willingness to pay of some previous non-users.[2] In the case depicted in Figure 1, the shaded area represents the change in consumer surplus associated with the reduction in cost. Travelers who were already using transit (making V_o trips) enjoy a cost reduction per trip of $U_o - U_1$ and a benefit equal to that reduction times the number of trips (V_o) as represented by the shaded rectangle. New trips in excess of V_o create progressively less consumer surplus (the shaded triangle). The last new trip, at V_1, generates no net benefit because the marginal benefit is exactly offset by the user cost, U_1.[3]

BASIC MODULES OF ANALYSIS

In concept, consumer surplus is what one needs to measure to get a preliminary estimate of the net benefits to travelers of a transit improvement. It is apparent from Figure 3-1 that user benefit accounting requires:

- Estimates of the quantity of trip-making before and after the improvement.
- Estimates of changes in perceived user costs that result from the improvement.

For travel that occurred before an improvement and continues after an improvement, the gross gain in consumer surplus is the change in perceived user costs multiplied by the pre-improvement quantity of travel (the rectangle on the left in Figure 3-1). Travel that is induced by the improvement generates benefits that are equal to the change in perceived user costs times approximately one-half the induced volume of travel (in Figure 3-1, the shaded triangle between V_o and V_1). Total user benefits, *B*, can be calculated, therefore, as:

[1] Possible benefits to others in non-traveler capacities (e.g., as residents, workers, and business owners) are discussed later.

[2] If the improvement causes someone on the network to experience higher user costs than before, of course, it can also cause previous users (whose willingness to pay was barely above their perceived costs) to reduce trip-making.

[3] The purpose, intended audience, and space limits of this guidebook all suggested that it not get into all the details of consumer surplus: issues like shifts in the demand curve, the graphics and math illustrating the impacts of external costs on individual travel decisions and aggregate travel volumes, and producer surplus.

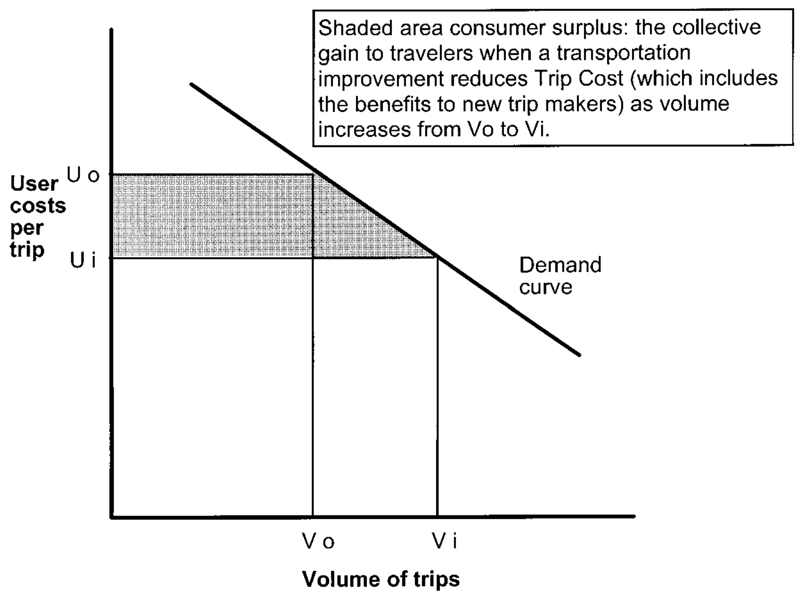


Figure 3-1. User benefits from transportation improvements.

$$B = \left(\frac{V_0 + V_1}{2}\right)(U_0 - U_1).^{4}$$

This calculation (which we call the Basic Benefit Calculation) highlights the factors that influence the benefit calculation and the basic modules of analysis that must be put together to do a transit evaluation:

- **Measuring User Costs.** The consumer surplus calculation relies on changes in *perceived* user costs. Therefore, a logical module of the analysis is the calculation of changes in perceived costs. This calculation can be done by one analyst, while others work on other matters.

  Key point: The consumer surplus calculation relies on changes in ***perceived*** *user costs.*

- **Measuring User Benefits.** The basic methodology for calculating user benefits outlined here requires procedures that bring together information on changes in perceived costs and travel volume data. The example calculations used below are fairly simple. In a real-world application, decisions must be made about the level of detail desired and precisely how (and at what detail) to measure travel volumes.

The rest of this chapter is organized into two remaining sections around these two categories: the first gives guidance on estimating *unit costs* (e.g., of travel time and accidents) in terms of costs per passenger- or vehicle-mile; the second shows how to combine changes in these costs with estimates of *demand* (*how much* people travel by mode before and after the transit improvement) to estimate *user benefits*.

SELECTING THE UNIT OF TRAVEL MEASUREMENT AND THE LEVEL OF DETAIL FOR THE ANALYSIS

Before beginning to assemble information, an analyst must decide what units of measurement to use and the level of detail or "grain" of the analysis. These decisions will depend on the kinds of questions the analyst hopes to answer and the data available. Benefit-cost analysis can be performed using various data types, but the precision and detail of the analysis will be determined by the structure of the data employed.

The volume of travel and the user cost of travel must be measured in the same units, as the consumer surplus calculation suggests. The *unit of travel* can be passenger- or vehicle-*trips* or passenger- or vehicle-*miles*.[5] In the former case, trips are defined in the context of pairs of origins or destinations (or an aggregate of these pairs); in the latter case, vehicle miles are measured over individual links in the network or the link mileage of the network as a whole.

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[4] This formula is derived from the standard formula for the area of a trapezoid. It presumes that the demand curve is essentially linear over the range of the calculation. This is generally a reasonable assumption since changes in user costs tend to be small. More sophisticated specifications are possible, but add needless complication to the exposition in this guidebook.

[5] Some new demand models are based on *tours*, the notion of trips that originate and end at the same place, e.g., the residence. Tours help the demand modeler explain travel behavior because travelers' decisions about what mode to use depend on what combination of tasks they plan to perform over the course of the day (e.g., work, shopping, and pickups at day care). Because tours are just a complex form of *trip*, they are not discussed separately here.

Key point: The volume of travel and the user cost of travel must be measured in the same units. They can be measured on a passenger or vehicle basis using either trips or miles as the volume measure.

If travel is measured using *passengers,* then user costs must be calculated on this basis. Costs that vary by vehicle must then be re-expressed on a per-passenger basis using information on vehicle-occupancy rates. Conversely, if travel is measured on a *vehicle* basis, then costs that vary by passenger (such as the value of time) must be expressed on a per-vehicle basis using vehicle-occupancy rates. Conversions in either direction involve the following, simple arithmetic:

Passenger-miles = Vehicle-miles × Passengers/Vehicle

Vehicle-miles = Passenger-miles ÷ Passengers/Vehicle

Key point: In the examples given in this guidebook, passenger-miles are used as the unit of travel and user-cost measurement. The principles of the calculations are easily extended to other measurements.

The *grain* of the analysis refers to whether different *classes of vehicles or passengers* are measured separately (or consolidated into a single class) and how much *geographic* detail is preserved in the data. The purpose of a fine-grain analysis is twofold. First, it can facilitate analysis of the impacts of the improvement on different groups of travelers (e.g., different income classes or travelers who live in different parts of the region). Second, it can improve the precision of the analysis. If the analysis is overly aggregated, it is likely that some of the effects of the transit improvement may be overlooked. As a practical matter, the grain of the analysis is largely driven by the data that are available to the analyst and the resources available to manipulate and process the data.

This section has emphasized user benefits and costs as the basic measure of the net benefits of a transit improvement. But user benefits do not capture all of the benefits of a transit improvement. User benefit calculations are based on *perceived cost* notions only. There are unperceived and secondary impacts, as well as direct costs of implementing the transit improvement, that must be considered in a full evaluation. All these need to be analyzed and are presented in later chapters of this guidebook.

MEASURING USER COSTS

The first logical task in appraising the impact of a transit improvement is to measure its impact on user costs. If a transit improvement does not change the cost of travel perceived by users, it cannot (by definition) affect user travel behavior.[6] In turn, if an improvement has no effect on travel behavior, it is hard to argue that it will generate direct user benefits. It is also hard to argue that it will have significant effects indirectly (through changes in emissions, impacts on land use, and so on) since travel behavior is unaffected. The demonstration of reductions in perceived user costs, therefore, is central and essential to the demonstration of benefits from transit improvements.[7]

Key point: A transit improvement must reduce perceived user costs if it is to generate user benefits.

The costs perceived by users have two main components: (1) monetary or "out-of-pocket" costs and (2) the value of time spent traveling.

Since the value of time typically varies from user to user because of differences in users' incomes and the mode being used, the benefit of a transit improvement will also vary from user to user. To measure and address equity issues, therefore, one must measure user benefits separately for different income classes of users. Lewis and Williams (1999) estimate consumer surplus, for example, for transit users in the U.S., by income group. Though the aggregate estimates are not useful for local projects, the distribution might be. For example, they estimate that about 80 percent of all consumer surplus accrues to households making less than the median income.

A transit improvement may affect not only the monetary and travel time costs of transit itself, but also the user costs of alternative modes, such as the automobile, carpools, or other transit modes. These effects on other modes occur because of the interconnected nature of the typical urban transportation network. A transit improvement in one part of the network may cause road conditions or passenger demand for other transit services to change there or in other parts of the network. These changes, in turn, may affect roadway speeds or the speed or headways of other transit modes. A light rail improvement, for example, may require dedication of existing surface road capacity to its right-of-way. In those parts of the network so affected, roadway speeds may be reduced as a result of the loss of road capacity. This change in roadway speeds, in turn, affects auto users' perception of the cost of using the automobile.

Key point: The more interconnected is the transportation network, the more important it is to measure changes in user costs of all modes across the whole affected network.

The interconnectedness of transportation networks and their modes means that the impact on both transit user costs and the user costs of other modes often must be measured. Con-

[6] Chapter 2 explains why user benefits and user costs are really two different ways of viewing the same impact. For example, a decrease in the cost of a trip is a travel benefit.

[7] In the remainder of this discussion, the terms "perceived user costs" and "user costs" will be used interchangeably, but it should be noted that the emphasis in this entire chapter is on perceived costs.

sequently, the discussion in this section proceeds first with a discussion of transit user costs, followed by discussions of truck, auto, and bike/pedestrian user costs.

TRANSIT USER COSTS

Transit user cost estimates require fairly detailed calculations. Even a simple transit trip involves a complex pattern of travel time and cash outlays. A transit user typically must get to the transit vehicle, wait for it to arrive, travel in the vehicle, and then get from a transit stop to a final destination. If the trip involves transfers from one transit vehicle to another, there may be additional waiting, walking, and in-vehicle travel. Other modes may also be involved in the trip if, for example, a traveler first drives (or is dropped off by another driver) to reach the transit line.

Travel Time (Walk, Wait, Transfer, In-Vehicle Time)

Framework

The major component of the perceived cost of transit use is travel time. The value of travel time depends on the disutility (cost or negative value) that travelers attribute to travel time. This disutility varies with the type of activity involved, such as walking to a transit stop, waiting for transit, riding transit, or transferring between routes. Qualitative factors, such as the comfort of the ride and the pleasure (or displeasure) associated with traveling with others, is usually implicit in the time value calculation and not calculated separately.

The literature of transportation economics is replete with works on the theory and measurement of the value of travel time. Most of the travel-time measurements are based on travel in automobiles. Small (1992) provides a summary of that literature. Among Small's conclusions are the following:

- In concept, how people value time spent in travel depends on the mode of travel, the purpose of the travel, the trip component (e.g., waiting versus riding), the total travel time, socioeconomic characteristics (which are often measured generally by income), and other preferences.
- The value of travel-time savings typically accounts "for a very large portion of the total benefits from a transportation improvement."
- Although the value of time savings per minute may vary somewhat with the total amount of time savings involved, Small concludes that "the safest assumption based on current knowledge is that any such differences are negligible."
- Estimates of the value of time are typically linked to wage rates on the assumption that time spent traveling would be spent at work instead. This notion is relevant to non-work as well as work trips, because economists believe that the implicit value of all non-work ("leisure") time is affected by the opportunity to work instead. Depending on other amenities and disamenities associated with travel of various kinds, however, the implicit value of travel time may be greater or less than the wage.
- "The value of in-vehicle time for non-business travel is usually found to be less than the gross wage rate," but it rises as wage rises. For business/work trips, empirical estimates value time as a percentage of gross wage to be as low as 20 percent and as high as 100 percent (in a few cases, even higher). Small concludes "a reasonable average value of time for journey to work is 50% of the gross wage rate." Higher-income travelers value their time more, but the increment in value is proportionately less than the increment in income. Small cites evidence that a person with three times the income of someone else may value travel time only 30 percent to 40 percent more. Taxes, the ability to conduct work or leisure activities while traveling, the relative comfort of the trip, etc., may be responsible for this loose relationship between wages and time values.
- The value of walking and waiting time can be two to three times greater than riding (in-vehicle) time, but there is a lot of variability. The activities of walking and waiting (as part of a motorized trip) are apparently generally perceived as less enjoyable than actual travel in a vehicle.[8] This may be a result of the exposure to weather, crime or other disamenities, and a greater sense of uncertainty about the trip progressing in a timely manner.
- Business travel has a higher value than commuting (though, generally, still lower than the wage rate), perhaps because it is a more stressful activity. Leisure travel may have a higher or lower value than commuting: some empirical work supports the intuitively reasonable conclusions that social and recreation trips tend toward higher time values than shopping or commuting trips, and that weekend trips have higher time values than weekday trips.
- Limited evidence suggests that time values are higher in peak than off-peak travel periods, and higher for longer than average trips (one study suggests that the value is 20 percent higher for trips longer than 30 minutes compared with trips less than 20 minutes).

More recent work by Winston and Shirley (1998) is consistent with Small's conclusions. Generally, they found the value of peak period travel to be approximately 40 to 50 percent of the average pre-tax hourly wage (except for trips of less than 1 mile).[9] Off-peak values had the same pattern, but

[8] But, people who choose to walk often argue that they value their time the same or less than they would for other modes.

[9] Winston and Shirley (1998) found that time values range from 8 percent of the pre-tax wage rate for trips less than 1 mile, to 49 percent for trips between 11 and 25 miles. Values increased with trip distance to distances of up to 25 miles (49 percent), then dropped (to 41 percent).

were consistently lower than peak values (generally, about two-thirds of peak values). Winston and Shirley explain the high time value for medium-distance commutes as self-selection: "people facing the longest commutes have made residential location decisions (to be near suburban schools, for example) that attach less importance to longer travel times than many who prefer to live closer to work."

In summary, most research suggests that non-commercial travelers generally value their travel time at a substantial fraction of their wage[10], but that the actual value can vary with the type and length of trip and other factors.

Key point: Travel time is typically valued as a percentage of the wage rate. A reasonable estimate of the value of in-vehicle time is 50 percent of the gross wage rate of the traveler, with waiting, walking, and transfer time being valued at two to three times that level. There is only limited evidence to suggest that the value of time varies also with trip length and other trip characteristics.

Data and Analysis

The lesson from the record of empirical studies of time value is that the wage rate is an important determinant of absolute and relative time values. The variation that is observed in time studies gives the analyst the latitude to use time values estimated from local studies if they fall within normal ranges. It is imperative, however, that the analyst use time values in a consistent manner and make sure that the decision to proceed with the transit improvement is not crucially dependent upon the use of an unusual time value. It is also important to treat various time components (e.g., waiting, walking, in-vehicle time) appropriately, because transit and auto modes differ importantly in the relative amounts of time spent waiting, walking, and in the vehicle.

Generally, if the same time values are used to compare alternative projects, the *relative* benefit-cost ranking of these projects will be accurate, even if the *absolute* benefit-cost performance is uncertain because of uncertainty about time values. The first measurement task in a transit evaluation exercise, therefore, is to assemble a table of appropriate time values. These values allow the conversion of *quantities* of time to *dollar-valued* time.

Tables 3-1 and 3-2 present generally accepted estimates of the value of transit travel time for various transit time elements. Table 3-1 displays the value of in-vehicle time as a percent of the gross wage rate for various types of transit trips and time elements. These percentages are high relative to the literature just cited. An analyst could justifiably scale these numbers back, provided the reduced estimates were applied consistently across alternatives. To illustrate the application of these percentages, Table 3-2 converts these percentages to dollar values for a range of gross wage or total compensation rates.

Note that research has not identified an important distinction between time values on bus or light or heavy rail systems. Although rail transit is often considered a "higher amenity" service than bus transit, time value studies do not support this notion.

The unit value of time spent traveling is only half of the calculation; the other half, which is more difficult to estimate, is the *amount* of time saved. Transit improvements' operating and route characteristics affect the various time components of the transit trip:

- **Headways affect waiting time.** Increasing the frequency of transit vehicles (buses or trains) on a given route decreases the average time between arrivals of the transit vehicles (headways). This decrease in headways reduces the average, expected waiting time. Simple, probabilistic models of travelers' arrival patterns suggest that the average waiting time is equal to approximately one-half the headway. However, for large headways (say, greater than one-half hour) it is likely that travelers will schedule their arrivals to minimize the waiting time cost. Therefore, the simple "one-half the headway" rule will overstate waiting time costs when headways are large. In practice, unless specific information is available on schedule delay, most analysts assume that headway time equals the lesser of 15 minutes or one-half the actual headway.

  Headways of on-demand type services (dial-a-ride services, for example) impose a different type of headway-related waiting time cost. Within limits, the user can choose the arrival time of the transit vehicle. The waiting time element occurs when the actual arrival time departs from the desired or scheduled arrival time of the vehicle.
- **Operating speeds affect in-vehicle time.** The faster a transit vehicle travels, the lower are the in-vehicle time costs of the trip.
- **Integrating feeder and line-haul service reduces transfer waiting time.** Line-haul type transit improvements provide high-speed service along a fixed route. (Rail transit service and busway or "freeway flyer" type services are typical line-haul services.) Feeder services get users from or to their ultimate origin or destination and the line-haul service. Certain types of services (such as bus transit or vanpool services) permit the feeder and line-haul services to be provided by the same vehicle, thereby eliminating one time-cost element—the transfer wait. Other types of line-haul transit (such as rail transit and ferry service) require travelers to access the service by another mode (e.g., bus, kiss-and-ride auto, park-and-ride auto, taxi). These services impose a transfer wait on the user.

[10] Recent work by Calfee and Winston (1998) used data from stated preference surveys to conclude that time "value is low [for automobile commuters] and surprisingly insensitive to travel conditions…." They believe that other adjustments commuters make to reduce travel time (choices about mode, residential and workplace locations, and departure times) reduce the marginal value of travel time to on the order of 15 percent to 25 percent of the gross wage, the low end of Small's estimates.

TABLE 3-1 Value of transit travel time for various time elements

Time Component	Value of Time as % of Wage or Total Compensation
In-Vehicle Personal (Local)	50%
In-Vehicle Personal (Intercity)	70%
In-Vehicle Business	100%
Excess (waiting, walking, or transfer time) Personal	100%
Excess (waiting, walking, or transfer time) Business	100%

Source: Authors, from U.S. Department of Transportation, 1997 , as reported in the Federal Register, 1997.

TABLE 3-2 Value of transit travel time for various average wage levels

Hourly Wage ($/hour)	In-Vehicle Personal, (Local)	In-Vehicle Personal, (Intercity)	In-Vehicle, Business	Excess (waiting, walking, or transfer time), Personal	Excess (waiting, walking, or transfer time), Business
$5.00	$2.50	$3.50	$5.00	$5.00	$5.00
$10.00	$5.00	$7.00	$10.00	$10.00	$10.00
$20.00	$10.00	$14.00	$20.00	$20.00	$20.00
$30.00	$15.00	$21.00	$30.00	$30.00	$30.00

Source: Application of data in Table 3-1.
Note: Evidence from recent studies suggests that values of time expressed as a fraction of hourly earnings may decline as hourly earnings rise. Figures included in this table, however, represent the recommended fractions for each time element applied uniformly to a range of average hourly earnings. These values, therefore, should be used with caution.

- **The number of transit lines affects walking time and transfer waiting time.** Multi-line service can decrease both walking and waiting time. It permits the starting and ending points to the line to correspond better to the start and end of individuals' actual trips. Consequently, less time is spent accessing the transit service and, by reducing the number of transfers, waiting time can be reduced.

For unusual transit improvements, or ones that are highly dependent on local conditions, detailed engineering simulations are required to accurately determine the effect of the improvement on travel time. (Dial-a-ride service, for example, is one such service.) It is possible, however, to provide some general guidance for more typical types of improvements if one is willing to assume that the dispatch behavior of the transit service is reasonably close to optimal.[11] In particular, simple models of transit service optimization allow one to roughly estimate perceived user costs from a few key parameters of the service. These models also give some guidance as to how much the user time costs will change with changes in the assumed parameters.

Appendix C presents calculations that illustrate the results of some simple models of transit service optimization. The tables in Appendix C provide a starting point for estimating transit user costs and some rules for adjusting these estimates to local circumstances. The implications of this analysis for transit travel times can be summarized as follows for different types of service:

- **Fixed route service.** This type of service involves vehicles operating on a fixed route. It is an appropriate model for simple rail or transit improvements or for bus transit services that feed other rail, bus, or ferry transit services. The only dimension on which a single-line service can be optimized is in terms of the frequency of service (*headways*), which directly affects waiting costs. Optimal dispatch behavior in a simple setting like this suggests a simple useful rule for relating waiting time to the volume of transit users. Specifically, optimal vehicle or train frequency increases with the *square root* of the level of transit demand. Hence, if corridor transit demand doubles, vehicle frequency should increase by the square

[11] Optimal dispatch behavior is behavior that minimizes the total of transit user time and transit agency operating costs. Consequently, optimal dispatch behavior depends partly on the transit agency's operating costs. The basic notion is that if a transit agency is operating effectively, it will operate so as to economize on travelers' time as long as creating savings in travelers' time does not cost the agency more than the patrons' time is worth.

root of two (i.e., 1.41 times). Consequently, the relative average waiting time at the higher demand will be the inverse of this amount (i.e., 1/1.41 = 0.70). Access time (i.e., the time travelers spend getting to the transit line) is unchanged.[12]

- **Integrated transit service.** With integrated transit service, both waiting time and access time are reduced with additional service. Integrated transit service involves buses that both collect passengers (i.e., provide *feeder* services) and go on to carry them *in the same vehicle* at higher speed in a *line-haul* fashion. The service is optimized both in terms of frequency of the service (*headways*) and the number of routes (which affects walking or other access costs). Under some simplifying assumptions, the optimal number of routes should increase with the *cube root* of demand, with service frequency (across all routes) increasing with the *⅔ power* of demand. Hence, a doubling of demand should be served by 1.25 times the number of routes (the cube root of 2 is 1.25) and 1.59 times the number of vehicles (the ⅔ power of 2 is 1.59). For an individual passenger, the increased frequency and proximity of service (because of the increased number of routes) yields a reduction in both waiting *and* access time per trip that will decline with the inverse of the *cube root* of transit demand. Hence, if corridor transit demand doubles, the combined waiting and access (walking) time will be 0.79 of the previous level of these components.[13]

These are rules of thumb that can help the technically oriented analyst determine quickly the effects of different assumptions about transit demand on service characteristics and, hence, user time costs. These rules depend on a number of simplifying assumptions and are no substitute for careful project specification and engineering analysis. For the analyst who is charged with measuring the benefits of a transit improvement, however, these rules of thumb can be useful. It is common, for example, for the level of transit ridership to be somewhat uncertain. Consequently, the level of transit service that is consistent with the projected demand is also uncertain. By applying these rules of thumb to alternative transit demand scenarios, the analyst can determine how sensitive the results are to the assumed level of transit demand.

> *Key point: There are simple rules of thumb to determine the approximate effect of different transit demand assumptions on transit access and/or waiting time. For fixed route services, the rule is a <u>square root</u> rule. For flexible route, integrated services, the rule is a <u>cube root</u> rule. These rules are not a substitute for careful project engineering, but can be useful for sketch planning analysis.*

[12] This "square root dispatch rule" has been recognized in the literature for some time. See, for example, Newell, 1971.

[13] The cube root dispatch and routing rules were developed in Pozdena, 1975.

Fares and Other Monetary Costs

Framework

The other major components of transit user costs are fares and other monetary costs. To preserve our focus on the travelers' perception of benefits, measurement of monetary costs should focus on those monetary costs *that affect the users' perception of the cost of travel*. It is important to recognize that users may not perceive all of the monetary costs associated with their travel. For example, in most places transit service is partially funded by general property tax or other levies; that is, not all of the monetary costs of transit service are represented by fares. Although these subsidized cost elements are certainly costs directly attributable to transit services, they are not perceived to vary with usage. Consequently, they do not affect transit travel behavior and should not be included in consumer surplus calculations. Chapter 5 of this guidebook discusses in more detail fares versus agency costs and other revenues.

> *Key point: The user cost of transit only includes those monetary components that are perceived by the user, such as fares and ancillary charges such as parking. Other transit costs borne by transit users and non-users are accounted for elsewhere.*

Data and Analysis

The out-of-pocket, or monetary, elements of transit user costs are relatively straightforward to calculate. As with travel time costs, they must be converted to unit costs on the basis of the selected unit of travel measurement—passenger-miles in the case of the sample calculations presented in this report.

Transit fares are not necessarily related to the cost of providing transit service. In most jurisdictions, transit service is subsidized, and fares are a discretionary policy variable. This discretion can extend to the elimination of transit fares altogether. Consequently, to properly calculate user benefits, the analyst must know something about transit fare policy. Public policy toward transit fares generally shows some common patterns that the analyst may find helpful if he or she must make assumptions about this policy before the fact.

Table 3-3 illustrates recent trends in transit fares. Although average fares have generally grown with inflation, most transit systems employ simple fare structures. As Table 3-3 illustrates, it is relatively uncommon to have peak period, transfer, or zone surcharges. Most transit fare structures are flat fares (a fixed fare per trip, regardless of length or transfers) or a simple zone fare (where fares vary with distance, but only with a few fare zones). The simplicity of fare structures

TABLE 3-3 Passenger fares summary (current $, not inflation adjusted)

Year	Passenger Fares Received per Unlinked Trip ($)	Adult Base Cash Fare (a) Highest ($)	Adult Base Cash Fare (a) Average (b) ($)	Percent of Systems with (c) Peak Period Surcharges	Percent of Systems with (c) Transfer Surcharges	Percent of Systems with (c) Zone or Distance Surcharges
1984	0.503	1.50	0.569	9.5	36.6	34.0
1985	0.530	1.50	0.584	8.6	37.0	33.1
1986	0.583	2.10	0.617	8.8	30.7	27.9
1987	0.585	2.75	0.634	8.4	29.5	33.1
1988	0.603	2.75	0.662	7.8	30.2	33.2
1989	0.607	2.75	0.670	6.4	27.7	31.5
1990	0.669	2.75	0.730	6.5	28.8	38.9
1991	0.704	6.00	0.823	5.5	24.2	39.4
1992	0.724	6.00	0.860	5.6	26.6	39.0
1993	0.773	6.00	0.860	5.6	26.6	39.0
1994	0.850	6.00	0.955	6.4	25.2	37.7
1995	0.876	7.00	0.992	6.5	23.8	36.9
1996	0.933	7.00	1.047	7.0	22.9	32.6
1997	0.888	7.00	1.058	7.0	22.9	32.6
1998	NA	7.00	1.065	6.1	21.9	32.9

Source: American Public Transportation Association.

Notes:
(a) Lowest base fare is $0.00 (free).
(b) Unweighted average of adult base cash fares; excludes surcharges; each transit agency counted equally.
(c) Percents represent an approximately 300-transit-agency sample, not estimated for all transit agencies.

is usually a concession to the administrative difficulty of implementing more refined structures. The rail transit systems in San Francisco and Washington, D.C., are able to employ more complex systems of specific fares for every origin and destination station pair because they have computerized ticket and access systems.

Some transit fare policies require a separate payment for each ride; others involve passes, permits, and ticket books. The latter make the derivation of the actual, effective fare per passenger-mile somewhat more uncertain. As Table 3-3 indicates, the actual fare received is less than the average, posted fare by 15 to 20 percent because of the use of passes and ticket books.

Although unlimited-ride passes and permits make the marginal cost (to the user) of an additional trip essentially zero, the analyst should not assume that this means that the perceived cost is always zero. Typically, in fact, such passes are purchased for a *primary trip* use (such as the commute trip), so the user perceives that the fare cost of each such *primary* trip is the cost of the pass averaged over the number of primary trips. Since transit passes permit use of transit for *non-primary* trips such as weekend and shopping trips at no additional cost, however, the analyst may wish to make a different assumption for these trips. The perceived fare cost of each *non-primary* trip is probably close to zero.

The analyst should, of course, use existing or proposed fare structures in the evaluation of a transit improvement. If the fare structure for a new transit improvement is unknown, the analyst may wish to use, as a placeholder for the real number, a fare per passenger-mile drawn from Table 3-4. This table presents average, actual transit fares per passenger-mile in 1997 dollars. Using inflation factors, these numbers can be adjusted to the value appropriate to the analyst's project at the time. As the table indicates, in 1997, the fare per passenger-mile ranged from $0.04 for vanpool to $0.30 for trolley bus.[14]

There may be other monetary costs associated with transit trips if the trips involve accessing or leaving the transit trip by other modes. The monetary costs of such feeder and distribution activities include auto operating costs, parking costs, and taxi fares. Whether or not these costs are included in transit trip cost accounting will depend on the unit of travel measurement chosen by the analyst. If the analyst has chosen to measure travel activity as *passenger-trips* between origin-destination zones, for example, it is necessary to include such

[14] The average fare per passenger-mile presented in Table 3-4 represents the empirical average of total transit fare revenues divided by total passenger-miles. Thus, both primary and non-primary trip making are included in this average. As indicated by the discussion in the text, the analyst may wish to use a slightly higher figure for primary trips and figure closer to zero for non-primary trips.

TABLE 3-4 Passenger fare by mode, 1997 dollars

Mode	Fare per Passenger Mile (a)	Highest Adult Based Cash Fare (c)	Average Fare per Unlinked Passenger Trip
Bus	0.18	2.30	0.70
Commuter Rail	0.15	7.00	3.30
Demand Response	0.19	NA	1.83
Ferryboat	0.14	4.00	0.89
Heavy Rail	0.19	2.00	0.97
Light Rail	0.13	2.00	0.53
Trolleybus	0.30	1.60	0.47
Vanpool	0.04	NA	1.34
Other (b)	0.65	7.00	0.66

Source: American Public Transportation Association.

Notes: All data are preliminary
(a) Calculated from trip length reported at http://www.apta.com/stats/.
(b) Includes aerial tramway, automated guideway transit, cable car, inclined plane, and monorail.
(c) Lowest adult-based cash fare is $0.00 since there are numerous free services around the country.

costs in the transit cost accounting. Such non-transit operating costs are discussed later in this chapter.

Costs of Accidents and Crime

Framework

Accidents and crime are significant features of transit travel, as they are of other modes. Travel behavior is affected by perceptions of these costs, which affect the user benefit calculation. Because the value of travel time is usually obtained from *revealed preference* or *stated preference* studies,[15] it can be argued that the *perceived* costs of accidents and crime per passenger-mile are implicitly incorporated in the time-cost elements of user cost. Specifically, the more dangerous a mode is perceived to be, the more costly will be the value of time that users appear to assign to time spent on that mode.

Though this point sounds simple, it is not discussed in the literature of transportation economics. Its superficial implication is that no special attention needs to be paid to the *perceived* cost aspects of accidents and crime because changes in the perceived burden of these events is already accounted for when changes in travel time are accounted for in the benefit calculation. This is probably an oversimplification; value of time studies have not identified differences in the value of time among various modes of travel. This result is inconsistent with data that suggests that the incidence of accidents and crime is quite different among modes. Nevertheless, if it is not clear that the transit improvement under study is going to affect perceived accident and crime rates per passenger-mile in an unambiguous way, the analyst may have to ignore this element of perceived user costs.

> *Key point: It is likely that the perceived cost of accidents and crime is already represented by the subjective value of time spent traveling. In simple settings, therefore, perceived user costs per passenger-mile do not have to incorporate special calculations for accident and crime costs.*

There are circumstances, however, when changes in the perceived cost of accidents and crime are important features of the transit improvement under study. In addition, even if there are no changes in the perceived cost of transit travel, there can be important changes in the costs of accidents and crime that are *not* perceived by users. These cost elements are treated in Chapter 4 of this guidebook.

Data and Analysis

Given the likelihood that the perceived costs of accidents and crimes are already incorporated into the travel time values, there are only a few circumstances in which the analyst need perform special analyses of accident/crime perceptions when constructing perceived transit user costs:

- **When the transit improvement presents an unusually safe (or risky) profile**. In this instance, the analyst must establish what level of accident and crime risk is implicit in the value-of-time studies that are being used in the analysis. The analyst must then estimate the relative *difference* in safety that the proposed improvement repre-

[15] Revealed preference studies use as basic data people's behavior: for example, what are they observed to do in response to a change in transit service or fare. Stated preference studies use as basic data what people say they would do.

sents (either positive or negative). When converted to a per-passenger-mile basis, this difference can be added to the perceived cost estimate for the improvement.

- **It is important to account for general regional trends in accident and crime rates**. Since transit improvement evaluation is a forward-looking exercise, it may be important to adjust for trends in accident and crime rates. Again, the task of the analyst is to estimate the relative difference in safety that the trend imposes and adjust perceived cost estimates accordingly.

In both cases, the adjustment is achieved with what might be called a *safety increment* adjustment to perceived user costs. As an aid to performing this analysis, Table 3-5 presents the level and average rate (per passenger-mile and per vehicle-mile) of incidents, fatalities, and injuries associated

TABLE 3-5 The incident rate and value of accidents and crime (combined) on transit, 1998

	Incidents per 100 Million Passenger-Miles[b]			Value in cents per Passenger-Mile[c]			
Mode	Incidents	Fatalities	Injuries	Property Damage	Fatalities	Injuries	Total
- Large Motor Bus[a]	293.0	0.5	292.9	0.3	1.5	2.9	4.7
- Medium Motor Bus[a]	184.1	0.5	183.2	0.2	1.5	1.8	3.5
- Small Motor Bus[a]	194.8	1.8	166.8	0.2	5.4	1.7	7.3
Motor Buses[a] - total	243.2	0.6	239.8	0.2	1.8	2.4	4.4
Demand Response	632.6	2.1	551.3	1.1	6.3	5.5	12.9
Commuter Rail	29.6	1.2	20.6	0.1	3.6	0.2	3.9
Heavy Rail (Rapid Rail)	110.0	0.4	90.0	0.1	1.2	0.9	2.2
Light Rail (Streetcar)	100.5	2.1	96.5	0.2	6.3	1	7.5
Automated Guideway	228.2	28.5	171.2	-	85.5	1.7	87.2
Vanpool	64.6	-	22.3	0.1	-	0.2	0.3
Total	153.5	0.7	143.0	0.2	2.1	1.4	3.7
	Incidents per 100 Million Vehicle-Miles[b]			**Value, in cents per Vehicle-Mile[c]**			
Mode	**Incidents**	**Fatalities**	**Injuries**	**Property Damage**	**Fatalities**	**Injuries**	**Total**
- Large Motor Bus[a]	3,166.6	5.2	3,165.9	3	15.6	31.7	50.3
- Medium Motor Bus[a]	1,730.5	4.7	1,722.4	1.8	14.1	17.2	33.1
- Small Motor Bus[a]	1,282.5	12.0	1,098.2	1.5	36	11	48.5
Motor Buses[a] - total	2,339.3	6.1	2,306.6	2.3	18.3	23.1	43.7
Demand Response	777.1	2.5	677.1	1.4	7.5	6.8	15.7
Commuter Rail	994.1	38.8	691.7	2	116.4	6.9	125.3
Heavy Rail (Rapid Rail)	2,389.3	9.5	1,955.0	1.8	28.5	19.6	49.9
Light Rail (Streetcar)	2,589.9	53.1	2,486.0	6.2	159.3	24.9	190.4
Automated Guideway	1,103.6	138.0	827.7	-	414	8.3	422.3
Vanpool	441.8	-	152.6	0.7		1.5	2.2
Total	2,121.3	10.1	1,976.4	2.2	30.3	19.8	52.3

Source: U.S. Department of Transportation, Federal Transit Administration. 1998 Safety Management Information Statistics (SAMIS) Annual Report. Includes injuries to non-passengers. Value estimates from ECONorthwest: see notes below.

[a] Size reflects the size of the transit agency operating the bus, not the vehicle size itself. The "Motor Buses" categories combines data from all sizes of transit agencies, but FTA records these data separately.

[b] Personal casualties includes those occurring inside vehicle, entering/exiting vehicle, in stations/bus stops, parking facilities, and right-of-way.

[c]Value for property damage is calculated from reported values. Value for fatalities assumes $3 million per fatality. Value for injuries assumes $10,000 per injury.

with transit-related accidents and crimes against passengers. These data suggest the following:

- **Accident and crime costs are not trivial.** Across all transit modes, the value of accidents and crime on transit averages 3.7 cents per passenger-mile or 52.3 cents per vehicle-mile through loss of property and life or through injury.
- **There is variation across modes, but only at the extremes.** Automated guideways (a nascent technology) and demand-responsive systems appear to impose the greatest costs, and vanpools and rail systems the least.

Calculation of the safety increment from these data is straightforward. For example, if an existing, demand-responsive system is being replaced with a fixed-route motor bus system, the improvement might reasonably be credited with an 8.5-cent lower perceived user cost, per passenger-mile, in the transit mode calculation of user costs. This is because, according to Table 3-5, the demand-responsive system imposes a safety cost of 12.9 cents per passenger-mile, while the motor bus average is only 4.4 cents (8.5 = 12.9 – 4.4).

The accident and crime rates in Table 3-5 represent recent national averages, but will undoubtedly change over time. They should be used directly, only if better localized information is not available. The monetization of these crime rates in Table 3-5 uses approximate values that must be updated or localized to best represent the conditions of the analysis.

Understandably, there is vigorous debate over the appropriate value to assign to the loss of life and to injury. The measure that is appropriate for the perceived cost analysis is the value that travelers implicitly place on their own lives and injuries, because this is presumably what is reflected in their valuations of perceived risks. In the language of the literature on fatality and injury risk, therefore, the appropriate value is the *hedonic* value of fatalities or injury–i.e., the value that the travelers themselves appear to use when making decisions to reduce or insure against risk of death or injury.

The table makes the simplifying assumption that the value of fatalities is $3 million per fatality and that injuries have a value of $10,000 per injury. There is great debate over the appropriate value of fatalities and injuries, but these values are close to the values represented by recent hedonic value-of-life and injury analyses.[16, 17] If a proposed transit improvement is believed to have especially important effects on traveler safety, the analyst should review available life and injury valuation studies or engage an economist trained in risk analysis.[18]

AUTO AND TRUCK USER COSTS

Auto and truck user costs are affected indirectly by transit improvements. The cost of using these modes is affected by the transit improvement in several ways:

- **Automobiles are used in a complementary fashion with transit trips.** The automobile often provides feeder or distribution services in transit trips.
- **Transit improvements cause general changes in network performance.** A transit improvement will cause some existing automobile users to switch from using the automobile to using transit. It will also cause a change in overall trip making. As a consequence, there will be changes in the performance of the network. Some links in the network may enjoy improved speeds and others may suffer reduced speeds. These performance changes affect the remaining auto and truck users.

The potential for a transit improvement to affect conditions elsewhere in the local transportation network should not be underestimated. Roadway facilities are prone to congestion, especially as vehicle volumes approach the capacity of the roadway. Under congested conditions, even small changes in vehicle volumes can have significant effects on the performance of the roadway. Hence, travel time and vehicle operating costs can change measurably, even if the impact on traffic volumes is small.

Travel Time (In-Vehicle Time, Parking Search Time, Walking Time)

Framework

As with transit, the major component of the perceived cost of auto and truck use is travel time. The basic principles of travel time valuation discussed above for transit user costs apply to automobile and truck user costs as well. The important components of travel time, however, differ somewhat, as does the unit value of these time components.

The key components of travel time that apply to auto and truck user costs are *in-vehicle time*, *parking search time*, and *walking time*. Changes in the pattern of auto and truck travel primarily affect in-vehicle time, as roadway links congest or

[16] See, for example: Berla et al., 1989; Miller, 1989a; Miller, 1989b; Miller et al., 1995; Viscusi, 1992; and Ward, 1992.

[17] The injury risk literature suggests that the hedonic value of injuries resulting in lost work days may be two to three times the $10,000 figure used in Table 3-5. (See, for example, Moore and Viscusi, 1992.) Unfortunately, the transit accident data does not distinguish between injuries that resulted in lost work days and injuries that did not. The use of the $10,000 figure reflects the belief that some transit injuries are minor.

[18] The *Journal of Forensic Economics*, published by the National Association of Forensic Economists (NAFE), is a source of current studies. The NAFE itself is a source of referrals to consulting economists knowledgeable in this area. http://www.nafe.net

decongest as a consequence of the transit improvement. Policies (such as a change in parking policy or facilities) may affect parking search time and walking time as well. In addition, after the transit improvement, the automobile may be involved in compound, auto-transit trips (such as park-and-ride trips) for which these time components are an important element.

Multi-occupant vehicles (i.e., vehicles with a driver and one or more passengers) raise additional issues about the proper way to value time. Time-value studies suggest that the driver and the passenger may value their time differently. The driver has the high-attention responsibility of driving, whereas the passenger may be able to relax or work. Consequently, the average value of in-vehicle time per passenger-mile or per vehicle-mile for multi-occupant vehicles needs to accommodate the occupancy characteristics of the vehicle and the different values of time of the occupants.

Trucks and other commercial vehicles (including business-use automobiles) pose an additional complication. The value of in-vehicle time that should be applied to commercial travel time needs to incorporate not only the appropriate value of the time of the occupants of the vehicle, but also value of other time-related costs:

- **The value of drivers' time.** The value of the drivers' time is the primary perceived cost for the managers of the enterprise or trucking company that operates the vehicle. Logically, the relevant perceived measure of this cost is the commercial wage rate, inclusive of the benefits enjoyed by the drivers. This cost concept is referred to as "total compensation."
- **Time-related inventory costs.** For vehicles carrying high-value cargo, delay also imposes costs in the form of *inventory costs*. Inventory costs are the opportunity costs associated with storing commodities before they are used. Cargo that is moving about the transportation network is essentially in inventory, since it cannot be used until it is delivered. This is clearly a perceived cost element in the case in which the entity that owns the inventory also operates the truck. Even for contract shippers, however, inventory cost can be a "perceived" cost because the owners of the inventory are willing to pay the shipper more for timely delivery.

Data and Analysis

The first time element is in-vehicle time. Truck and auto in-vehicle times are affected by the level of service of the roadways on which the vehicles operate. The relationship between level of service and roadway characteristics and loads has been extensively studied and is represented mathematically by *volume-delay* relationships.

Volume-delay relationships relate the vehicle volume (usually expressed in terms of *passenger-car equivalents* or PCEs) to delay, measured as the number of minutes it takes to travel a mile. These relationships are embedded in the traffic assignment element of all modern transportation planning models.

If an analyst is performing benefit-cost analysis in the context of such a modeling environment, the changes in travel time associated with changes in vehicle volumes will be generated by the model (on a link-pair or origin-destination-pair basis). For the analyst who does not have access to these modeling resources, impacts on travel time must be calculated by hand, using volume-delay relationships relevant to the links or corridors being affected. These relationships are presented in the *Highway Capacity Manual*.[19]

Monetizing the changes in auto and truck in-vehicle time caused by a transit improvement requires information on the value of time. Research on automobile and truck travel time valuation has yielded a rich, but sometimes bewildering, body of evidence about the value of automobile and truck travel time. (See the subsection on travel time, under Transit User Costs, for a summary of the literature.)

Tables 3-6 and 3-7 synthesize recent studies on the value of in-vehicle time as it applies to automobile and truck travel. The studies rely on estimates of the value of various time components as a fraction of the wage (or total compensation level, in the case of commercial travel). Table 3-6 displays the value of in-vehicle time as a percent of the wage rate or total compensation for various types of auto and truck travel. To illustrate the application of these percentages, Table 3-7 converts these percentages to dollar values for a range of nominal compensation levels.

Generally, transit improvements mostly affect automobile work trips, which typically have a duration of about 20 minutes. For these types of trips, the time values presented in Tables 3-6 and 3-7 are generally appropriate. If, however, a transit improvement is likely to affect very short or very long automobile trips on congested facilities, the analyst may wish to allow time values to vary with trip length. There is some evidence that a minute's time savings is more important if it is a minute out of a short trip than a minute out of a long trip. Although this refinement is not addressed in this guidebook, the analyst may wish to investigate this further in special circumstances.[20]

As indicated above, for commercial travel (business use of automobiles or trucks), it is probably more appropriate to use total compensation, rather than the simple wage rate, in estimating the value of time. The opportunity cost of an hour of a commercial truck driver's time, for example, is the benefit-loaded cost of hiring the driver, not just the driver's base wage. As Table 3-8 suggests, on average, total compensation

[19] Transportation Research Board, 1998.
[20] See Small, 1997.

TABLE 3-6 Value of automobile and truck in-vehicle time

Transportation Mode	Recommended Value of Time
AUTO	
In-Vehicle Personal (Local)	50% of the wage rate
In-Vehicle Personal (Intercity)	70% of the wage rate
In-Vehicle Business	100% of total compensation
Carpool Driver	60% of the wage rate
Carpool Passenger	40% of the wage rate
Excess (waiting, walking, or transfer time) Personal	100% of the wage rate
Excess (waiting, walking, or transfer time) Business	100% of total compensation
TRUCK	
In-Vehicle Personal (Local)	50% of the wage rate
In-Vehicle Personal (Intercity)	70% of the wage rate
In-Vehicle Business	100% of total compensation
Excess (waiting, walking, or transfer time) Personal	100% of the wage rate
Excess (waiting, walking, or transfer time) Business	100% of total compensation

Source: Authors, from U.S. Department of Transportation, 1997, as reported in the Federal Register, 1997.
The recommendation to use automobile percentages for in-vehicle truck travel and the values for excess (waiting, walking and transfer time) was not in the original study, but is a recommendation of the authors of this manual.

TABLE 3-7 Value of automobile and truck travel time savings for various wage rates[21]

Hourly Wage ($/hr.)	AUTO In-Vehicle Personal (Local)	AUTO In-Vehicle Personal (Intercity)	AUTO In-Vehicle Business (Local)	CARPOOL Driver	CARPOOL Passenger	TRUCK In-Vehicle Business	AUTO, TRUCK or CARPOOL Excess Time
$5.00	$2.50	$3.50	$5.00	$3.00	$2.00	$5.00	$5.00
$10.00	$5.00	$7.00	$10.00	$6.00	$4.00	$10.00	$10.00
$20.00	$10.00	$14.00	$20.00	$12.00	$8.00	$20.00	$20.00
$30.00	$15.00	$21.00	$30.00	$18.00	$12.00	$30.00	$30.00

Source: Compiled by ECONorthwest from sources in text.

is 20 percent greater than the hourly wage, and 21 percent higher for the trucking and warehousing sector, in particular.[22]

An often-overlooked time-cost of commercial travel is the inventory cost of the cargo that is carried in the vehicle. Because the "warehousing" of the cargo on the vehicle must be financed, directly or indirectly, by the owner of the cargo, there is a financial opportunity cost associated with the time the vehicle (and the cargo) spend on the road. Consequently, the travel time of commercial vehicles imposes an *interest* or financing cost.

Table 3-9 presents the inventory cost, per vehicle-hour, for cargoes of various values at various interest rates. As the table indicates, the inventory costs of cargo can be very high; a $1,000,000 cargo (such as a truckload of electronic equipment) has an interest cost of $11.40 per vehicle-hour at an interest rate of 10 percent. Much like the cost of the driver's time, this cost should be included in perceived traveler costs. It is especially important, of course, to do so in settings where truck traffic volumes are high and/or cargoes tend to be unusually valuable.

Vehicle Operating and Ownership Costs

Framework

If a transit improvement alters the modal balance between auto and transit, it affects not only travel times, but also automobile and truck operating costs. It also may change households' decisions about owning automobiles. This section dis-

[21] Evidence from recent studies suggests that values of time expressed as a fraction of hourly earnings may decline as hourly earnings rise. Figures included in this table, however, represent the recommended fractions for each time element applied uniformly to a range of average hourly earnings. These values, therefore, should be used with caution.

[22] The hourly wage reported in Table 3-8 is the hourly average of all cash compensation (including wages, salary, and overtime compensation).

TABLE 3-8 Average wages and total compensation, by industry, 1990

Industry Type	Average Wage ($/hr.)	Average Total Compensation ($/hr.)	Total Compensation as a % of the Average Wage
All employees	13.93	16.71	120%
Private industry	13.62	16.08	118%
Transportation & public utilities	16.64	20.50	123%
Trucking and warehousing	13.12	15.94	121%
Finance, real estate, insurance	17.63	20.62	117%
Services	13.29	15.23	115%
Private household services	4.27	4.36	102%
Government	15.37	19.69	128%
Federal non-military	20.59	27.85	135%
Federal military	12.18	17.08	140%
State and local	14.91	18.52	124%

Source: Adapted from Delucchi (forthcoming, 2000), Table 5-12. Data is from the National Income and Product Accounts (NIPA) of the United States, for 1990, as reported in U.S. Department of Commerce, 1992.

cusses how to measure the perceived unit costs of operating and owning automobiles and trucks.

The operation of an automobile or truck involves costs that are, to a large extent, directly variable with the use of the vehicle (fuel, oil, tire wear, tolls, maintenance and repair, parking charges, etc.), as well as costs that are relatively fixed once the decision to own a vehicle has been made (insurance and the capital costs of the vehicle). There is a debate as to whether all ownership costs are *perceived* (and, hence, influence the consumer surplus calculation) or whether only a subset of such costs influence travel cost perceptions and, hence, behavior.

Proponents of the latter view argue that many travelers already own a motor vehicle and, hence, their decisions about using transit or changing routes are made on the basis of *marginal* cost differences only. In the context of automobile operating costs, such costs would include only those costs directly variable with the use of the vehicle (primarily, fuel, tolls, and parking charges; secondarily, oil, tire wear, tolls, maintenance and repair). Proponents of this view argue, therefore, that the operating cost component of perceived user cost should only include these marginal cost elements.

TABLE 3-9 Cargo inventory costs (dollars per vehicle-hour)

Cargo Value per Vehicle ($)	Annual Interest Rate			
	5%	10%	20%	40%
10,000	0.1	0.1	0.2	0.2
50,000	0.3	0.6	0.9	1.1
100,000	0.6	1.1	1.7	2.3
500,000	2.9	5.7	8.6	11.4
1,000,000	5.7	11.4	17.1	22.8
10,000,000	57.1	114.2	171.2	228.3

Source: ECONorthwest.

In contrast to this position, the view taken in this guidebook is that transit improvements affect relatively long-run decisions, including decisions to own motor vehicles. Hence, the relevant demand relationships that should be used in the analysis and the relevant user-cost perceptions that properly belong in the analysis are *long run* in perspective.[23] To measure the benefits of a transit improvement, all costs (variable and fixed) should be reduced to unit costs (per vehicle-mile traveled or per trip) and incorporated in the long-run perception of cost.

Data and Analysis

Automobile and truck operating costs associated with operating a motor vehicle can change if the speed of travel changes or if the type of vehicle used to make the trip changes. Changes of this nature are a likely effect of a transit improvement. Changes in the speed of travel affect fuel consumption, and different types of vehicles consume motor fuel, oil, tires, and parts at different rates.

The American Automobile Association performs research each year to calculate the cost of operating automobiles of various types. Its research provides useful, average per-vehicle-

[23] Most of the available studies of travel demand are inherently measuring long-run behavior. Most of the information about the responsiveness of demand to user costs comes from observations on the behavior of a *cross-section* of households at a *particular* point in time. The differences in behavior observed across households are long-run in nature because they reflect variations in auto ownership, residential location, and workplace location decisions. Not only is this long-run orientation the most appropriate to transportation investment decisionmaking, but it is also consistent with the view that, over the long run, users consider the effect of vehicle ownership costs when making travel decisions.

mile costs of gas and oil, maintenance and tires, insurance, license, registration fees, and property or use taxes, depreciation, and finance charges. Table 3-10 contains its recent estimates for operating and ownership costs by type of vehicle. Table 3-11 reports earlier research for FHWA that attempts to break down costs into variable and fixed costs.

These reports and others like them age quickly and are reported in dollars from different years. Moreover, not all the costs reported are real economic costs: some are transfers. We advise an analyst to check relevant local prices at the time of the analysis. At the time this report is being written, regular gasoline has been priced at the pump between $1.60 and $2.00 a gallon. For a mid-sized car getting 20 miles per gallon, the cost per mile of gas is between 8¢ and 10¢, substantially higher than any of the estimates in Tables 3-10 or 3-11. Other costs to consider adjusting are insurance and license, registration, and tax, which can vary substantially by locality. Vehicle cost per mile, in constant dollars, can be estimated as the average vehicle price (say, $20,000) divided by average life (10 to 20 years, with, say, 15 years as an average), divided by average mileage per year (say, 15,000). Those particular assumptions yield a cost of about 9¢ per mile. Finance costs, using this method of calculation, can be ignored: they are transfers. Other variable costs not shown in Table 3-10 include parking and tolls.

Among the problems in constructing and using an estimate of average vehicle operating costs is the tremendous variability of the vehicles on the road. Some are new, some 20 years old. Some are expensive ($50,000); some are inexpensive ($500). Some require a lot of maintenance; some get little. Mileage varies and so on. The analyst can either apply average numbers to all vehicles or create tables more like Tables 3-10 and 3-11 for different classes of vehicles. The additional problems of the last method are that one would need at least a few more columns to deal with used cars and one would have to estimate the percentage of vehicles in each class.

Key point: Given the assumption that in the long run users perceive all of their direct costs of vehicle ownership (the costs that they pay in money as

TABLE 3-10 Automobile driving costs, 1999

CATEGORY	Small Car	Midsize Car	Large Car	SUV	Van
OPERATING COSTS (cents per mile)					
Gasoline & Oil	4.8	5.7	6.3	6.5	5.8
Maintenance	3.1	3.4	3.5	3.7	3.5
Tires	1.3	1.6	2.2	1.4	1.3
SUBTOTAL	9.2	10.7	12.0	11.6	10.6
OWNERSHIP COSTS (cost per year)					
Insurance	1,012	885	1,012	1,316	972
License, registration, taxes	175	223	279	410	392
Depreciation	2,871	3,355	4,084	3,648	3,468
Finance charge	603	812	1,070	958	890
SUBTOTAL	4,661	5,275	6,445	6,332	5,722
DEPRECIATION FOR EXCESS MILEAGE (per 1,000 miles over 15,000 miles annually)	151	161	168	129	157
TOTAL ANNUAL COST					
10,000 miles per year	4,826	5,526	7,036	6,416	5,783
15,000 miles per year	6,041	6,880	8,245	8,072	7,313
20,000 miles per year	7,256	8,219	9,685	9,297	8,628
TOTAL COST PER MILE (cents per mile)					
10,000 miles per year	48.3	55.3	70.4	64.2	57.8
15,000 miles per year	40.3	45.9	55.0	53.8	48.8
20,000 miles per year	36.3	41.1	48.4	46.5	43.1

Source: American Automobile Association and Runzheimer International. Data for a popular model of each type listed with ownership costs based on 60,000 miles before replacement.

TABLE 3-11 Cost of owning and operating selected motor vehicles (1991 cents/mile)

Component	Cost Basis	Vehicle Size			
		Sub-Compact	Intermediate	Full-size Van	Full-size Pickup
Fuel & Oil	Variable	3.5	4.6	8.1	6.2
Maintenance	Variable	4.0	4.2	4.2	4.3
Tires	Variable	0.7	1.0	1.4	1.2
Insurance	Fixed	7.1	7.0	8.5	7.2
License & Regis.	Fixed	0.8	0.9	1.2	0.9
Fuel Taxes	Variable	1.3	1.7	3.0	2.3
Depreciation	Mixed	8.6	10.7	14.2	9.5
Finance Charges	Fixed	1.6	2.0	2.9	2.2
Parking & Tolls	Variable	1.3	1.3	1.3	1.3
Total		28.9	33.4	44.8	35.1

Source: Jack Faucett Associates, 1992, as cited in Litman, 1999.

vehicle owners), and given assumptions in the text about average vehicle cost, miles per gallon, and mileage, then the costs per vehicle-mile of an "average" vehicle are probably in the range of 40¢ to 50¢ per mile.

The costs per vehicle-mile can be converted to costs per passenger-mile by dividing them by the average number of passengers per vehicle (probably 1.1 to 1.5, depending on local conditions). Again, the caution to beware of, or at least be aware of, is the averages. Average vehicle occupancy will vary by trip purpose, time of day, gasoline price, and local conditions.

Some experts critique the static nature of the fuel estimates and recommend using an estimate that varies by speed. They point out that a policy that increases the speed traveled on highways not only produces travel-time savings, but it also results in better gas mileage for vehicles. Some argue that the STEAM model (FHWA) does the best job of incorporating variable fuel consumption rates. STEAM relies on the fuel consumption rates published in the Institute of Transportation Engineer's *Transportation Planning Handbook* (1992), as summarized in Table 3-12.

With these numbers, it is possible to calculate more accurately the costs and benefits of proposed changes to the operating costs of a vehicle, given average vehicle-miles traveled and gasoline costs. If the transit investment is expected to cause only minor changes in vehicle speeds, analysts may safely use the average costs per the calculation described above. However, if the investment is expected to cause significant changes in average vehicle speeds, then the analyst can calculate fuel costs separately using current prices and the appropriate STEAM fuel consumption rates.

Parking costs are an element of vehicle operating cost that deserves special attention in a transit evaluation context. Parking costs only enter the consumer surplus calculation to the extent that the parking costs are *perceived* as part of the user cost of operating the vehicle. In contrast to most other elements of vehicle operating costs, however, parking is often not charged for explicitly, but rather is charged for *implicitly* or *bundled* with other activities.

Parking at work, for example, is frequently an unpriced amenity. Many employers have determined that it is less costly to offer free employee parking than it is to pay employees slightly more and charge them for parking. Similarly, shopping centers, malls, and other retail establishments have determined that it is more profitable to attract shoppers with free

TABLE 3-12 Fuel consumption rates used in STEAM, auto and truck

	Gallons per Mile	
	Autos	Trucks
5 mph	0.066	0.481
10 mph	0.042	0.314
15 mph	0.039	0.255
20 mph	0.029	0.223
25 mph	0.027	0.203
30 mph	0.025	0.189
35 mph	0.024	0.179
40 mph	0.023	0.171
45 mph	0.023	0.165
50 mph	0.022	0.160
55 mph	0.021	0.157
60 mph	0.020	0.153
65 mph	0.019	0.150

Source: Cohn et al., 1992.

parking and to underwrite the cost with slightly higher prices on the products they sell. Shoup and Pickrell estimated in 1980 that 93 percent of automobile commuters park free at their place of work.[24] Pucher estimated in 1993 that 90 percent of customer and employee parking is free,[25] and the 1990 Nationwide Personal Transportation Survey (NPTS) data suggested the average probability of paying for parking was 5.6 percent in the 20 consolidated metropolitan areas surveyed. A number of factors predispose this behavior, including tax policy and the relatively high administrative cost of charging for parking in many locations.[26]

Most urban transportation demand models typically recognize that most employees and shoppers do not pay for parking, even though some do. The models use the nominal, posted parking price *multiplied by* the probability that the traveler actually pays for parking as the measure of perceived parking charges.[27] Since many analysts will be using transit demand estimates from just such a model, it is important to use parking cost estimates in the benefit-cost calculation that are formulated in the same way. Consequently, this guidebook recommends using the probability-weighted parking charge as the representation of the parking component of user charges.

That recommendation results in an accurate characterization of consumer surplus (and one that is consistent with typical travel demand models). But in order to fully account for the effect of a transit improvement on parking costs, transit's effect on parking utilization and the *unperceived* costs of parking must be addressed as a separate calculation.[28] The details of this calculation are presented in Chapter 5.

Costs of Accidents and Crime

Framework

The traveler's perception of the cost of accidents and crime is an element of automobile and truck user costs. This includes perceived costs associated with two types of risks:

- Risks borne directly by the traveler as the potentially injured party from accidents or crime and
- The risk of being held financially responsible for the injury caused to others or damage to their property from an accident.

Analogous to the earlier discussion of this issue in the context of transit user costs, any net risks that impinge upon the driver of the truck or automobile are likely incorporated in the value of time that travelers appear to be applying. That is, these costs contribute to the disamenity value of time spent in truck and automobile travel.

Travelers can, and do, insure against these risks to some extent. The greater the tendency for travelers to insure against these risks (of self-injury or liability), the less likely it is that the observed value of time incorporates these disamenity elements. Hence, it is appropriate to include average insurance premiums in the user cost as a partial characterization of perceived costs of accident and crime risks.[29]

From this perspective, therefore, once the value of time and insurance costs are incorporated in the measure of user costs, there is no need for separate accounting of perceived auto and truck accident and crime costs. The exception is if the analyst believes that the transit improvement will result in *changes* in the travelers' perceptions of the average riskiness of travel. With respect to accidents, this could occur if, for example,

- The transit improvement caused a shift in travel from the automobile to transit, and
- This shift changed average driving speeds for those remaining in their autos (and trucks), and
- Accident rates changed as a result of the increase in speed (which will probably increase fatalities),[30] and
- This change in accident rates was incorporated in travelers' perceptions about risk.

Similarly, the transit improvement could change the traveler's perceptions of the riskiness of encountering crime. For example, the improvement could cause a change in the traveler's chosen route. The change could either move the traveler into areas of higher crime rates or force a longer, more costly route to avoid crime. The analyst could then incorporate these estimates of changed risk perceptions, as either a change in the value of time or a change in the average cost of insurance per vehicle- or passenger-mile.

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[24] Shoup and Pickrell, 1980.

[25] Pucher, 1993.

[26] Transportation Research Board, 1998.

[27] For example, the Puget Sound (Washington) travel demand model uses survey information on nominal off-street parking rates and the proportion of parkers who pay those rates.

[28] An alternative perspective is that *in the long run* travelers see through the veil of the bundled or implicit pricing of parking. That is, they behave as if they pay the full cost of parking because they recognize that they are earning less or paying more for goods at locations that bundle parking pricing. From this perspective, travel demand is, in fact, influenced by the *full cost* of parking, not just the explicitly priced component. Although this approach has the advantage of incorporating consideration of parking costs entirely in the consumer surplus framework, it is inconsistent with the demand models that many analysts will be using, in practice.

[29] It is conceivable that an improvement could be made that decreases accidents but does not change insurance premiums. In this case, if the user perceives a reduction in safety, this reduction will be reflected in a change in the value of travel time, as discussed earlier in this chapter. Even if the traveler does not perceive the reduction in accidents, there may be unperceived benefits to the safety improvements. These are discussed in more detail in Chapter 4.

[30] Though Lave (1997) has found that increases in state speed limits in 1995 not only did not increase fatalities: they actually dropped slightly. Lave suggests as reasons: better use of highway patrol resources, a shift back to limited-access highways from more dangerous two-lane roads, and a reduction in speed variance.

Key point: Once the value of time and insurance costs are incorporated in the measure of user costs, there is typically no need for separate accounting of perceived auto and truck accident and crime costs. The exception is the special case where there is a clear reason to believe the transit improvement changes the average risk perception of auto and truck travelers.

As a practical matter, there is very little known about the relationship between traffic characteristics and accident rates or crime rates. For example, there is contradictory evidence on the relationship between traffic volumes or speeds and accident rates. One theory and some evidence support the notion that, the greater the traffic volume, the greater the probability of an accident because of the greater likelihood of encountering other drivers. Since higher traffic volumes are associated with lower speeds, everything else being equal, this notion suggests that accident rates decline as traffic thins and speeds increase.

A potentially contradictory viewpoint is that accidents increase as volumes decline and speeds increase because of reduced reaction times at higher speeds. Some analysts report confirming this notion empirically too.[31] Thus, the conclusion in this guidebook is that the evidence is probably too weak to warrant adjusting the unit cost of automobile travel simply because there have been transit-induced changes in network volumes or speeds. As long as the perceived costs include properly valued average travel times and insurance costs, a good argument can be made that any benefits in the form of reduced travel risks will be properly accounted for in the Basic Benefit calculation.

Data and Analysis

Although there is not a strong case for linking transit improvements to changes in the average risk of travel, the analyst might encounter a circumstance in which it makes sense to assume a reduction in these risks as the result of a transit improvement. To this end, Table 3-13 provides generalized information on the costs of fatalities and injuries associated with the use of motor vehicles.[32]

Death and injury to themselves are not the only risks, however, that drivers of autos and trucks may perceive as an element of user costs. Pedestrians, cyclists, and occupants of other types of vehicles are also exposed to significant risks of death and injury, partly due to interactions with automobiles and trucks. As Table 3-11 indicates, auto owners pay 7.0 to 8.5 cents per vehicle-mile, on average, to insure against losses to themselves and the liability of such encounters. If a transit improvement were to eliminate perceived risks of driving altogether, therefore, the analyst could use the level of insurance costs as a first approximation of the potential for risk reduction. The value of uninsured risks (which, in our analysis, remains embedded in the value of time) could be added to the insurance costs, but it is difficult to know how large travelers perceive that to be.

Key point: If the analyst wishes to speculate that a transit improvement reduces the average risks associated with driving, actual accident rates or insurance premiums can be used to bound the estimated reduction in truck and auto user costs that would result.

BICYCLE AND PEDESTRIAN USER COSTS

Framework

Transit improvements may affect biking and walking. Both modes can serve as feeder and distribution mechanisms for transit trips. In addition, if transit is used as a primary commute mode, the resulting reduced need for automobile ownership may result in increased walking and biking generally for other purposes. Therefore, it is sometimes necessary to consider bicycle and pedestrian user costs.

Data and Analysis

The primary perceived cost of both modes is travel time. In addition, however, there are cash cost elements associated with both modes as well. In the case of bicycling, there is a capital outlay associated with bicycle ownership and a wear-and-tear element associated with bicycle use (tires, time or cost associated with maintenance and repair, etc.). In the case of walking, however, there are probably no significant, specific capital or out-of-pocket costs that can be associated incrementally with this activity.

Table 3-14 presents typical estimates of the user costs associated with the bicycle and walk modes. Bicycling and walking time both should be valued at walking time values. As the table suggests, because of the slow effective speeds of these modes and the high value that users typically place on walking time, the effective perceived user cost per mile is high. Consequently, transit improvements that compel significant use of these modes in lieu of other modes may raise perceived user costs significantly in some cases. The economic justification for the use of these modes, therefore, must come from secondary impacts and lower capital costs (factors that are considered in the next chapter).

[31] Miller (1989b), and Gomez-Ibanez (1997) offer data in support of this notion.

[32] There are anomalies in the data in Table 3-5, Table 3-13, and Table 4-10 in Chapter 4. Since the method recommended in this section is based on insurance cost as a measure of *perceived* accident costs, those differences do not affect the estimates here. See the section on unperceived accident costs at the end of Chapter 4.

TABLE 3-13 Motor vehicle occupants and non-occupants killed and injured in 1998

	Injuries/Deaths in 1998	Rate per 100 million VMT (a)	Cost, in cents per VMT(b)
Killed			
Total Occupants	35,359	1.35	4.05
Total Non-occupants	6,112	0.23	0.7
Total Killed	41,471	1.58	4.74
Injured			
Total Occupants	3,061,000	116.9	1.17
Total Non-occupants	131,000	5.0	0.05
Total Injured	3,192,000	121.9	1.22

Source (of data on number of injuries, deaths, and vehicle miles traveled): U.S. Department of Transportation, National Highway Traffic Safety Administration, Traffic Safety Facts 1998, Table 4.

(a) Vehicle miles traveled in 1998 totaled 2,618,701,000,000 [per same source as above (TSF1998), 1998 National Statistics table].
(b) Assumes $3,000,000 per death, and $10,000 per injury (per ECONorthwest).

SUMMARY

This section emphasizes the cost perceptions of the user of a transportation network. When a transit improvement is made, there are changes in those perceptions. Changes in perceived costs are a major element of user benefits and, hence, of the benefits of transit improvements.

As Table 3-15 summarizes, this analysis involves first determining time values and the basic units in which activity will be measured and then gathering data to characterize how the components of user costs change in reaction to the transit improvement. Table 3-15 provides pointers to the tabular and graphical information in this guidebook for each step of the data assembly process.

TABLE 3-14 Typical user costs of biking and walking

	Bicycling	Walking
	Typical Assumptions	
Assumed average speed (mph)	8	2.5
Capital cost	$500	-
	Cost per Pass-Mi. (cents)	
Time (time value = $10 per hour)	125+	330+
Vehicle capital	7	-
Operating and maintenance	2	-
Total	134+	330+

Source: ECONorthwest.
[a] Most people who commute have relatively good bikes; lights; racks; packs; helmet; lock; and rain gear. $500 seems like a reasonable average estimate of total capital cost.

Later in this chapter, sample worksheets are presented that show how these user cost data are merged with travel data to measure user benefits.

MEASURING TRANSIT'S BENEFITS TO USERS

The previous sections of the report provide information on how to measure the *unit costs* associated with the use of each type of vehicle in the transportation network. These sections also discuss how to measure the effect of the transit improvement on these cost measures.

We now need to talk about the transit improvement's effects on *how much* use is made of each vehicle type and how unit cost and travel activity levels integrate into the basic measures of transit benefits. The basic methods require knowing

- The amount of travel before the improvement, by mode;
- The perceived user cost associated with that previous travel pattern;
- The amount of travel after the improvement, by mode; and
- The perceived user cost associated with the revised travel patterns.

The list reinforces an obvious point: little analysis is possible without some measure of the impact of the transit improvement on travel activity by mode. If a transit improvement is an attractive alternative to automobile use, there will be an increase in the level of transit use and a decrease in automobile use. The use that trucks make of the transportation net-

TABLE 3-15 Summary of user cost analysis

Data Assembly Steps	Parameters to Measure	Guidebook Resources
Step 1: Determine time values	Value of walk, wait, in-vehicle and transfer time	Tables 3-1, 3-2
Step 2: Determine units of travel measurement	Corridor vs. link Pass.-mile vs. veh.-mile	"Selecting the Unit of Travel Measurement"
Step 3: Measure transit user costs, before and after the improvement	Travel time Accident costs (if changed from status quo) Fares and other out-of-pocket costs	Tables 3-3 through 3-8, Figure 3-1
Step 4: Measure auto/truck user costs, before and after improvement	Travel time Accident costs (if changed from status quo) Vehicle ownership costs Vehicle operating costs and tolls	Tables 3-9 through 3-13, Figure 3-2
Step 5: Measure bicycle and walk user costs, before and after improvement	Travel time Vehicle ownership costs Vehicle operating costs	Table 3-14

Source: ECONorthwest.

work may also change as an indirect effect of any decrease in automobile use that occurs.[33]

This section discusses how to measure changes in travel activity and how to integrate the travel activity changes with user cost changes to measure travel benefits.

Assembling the Required Data on Travel Activity

Framework

A transit improvement changes the users' perception of the cost of using the transportation network. Predicting the response elicited from the user is called *travel demand analysis* or *travel demand forecasting*. This analysis is the most difficult part of measuring transit benefits, but it is also the most important part. Without a thorough understanding of how both transit and auto users react to the transit improvement, it is impossible to know whether the improvement yields net traveler benefits.

The analysis proceeds within the context of a *base case* and the *improvement alternative*, studied over the relevant *analysis horizon*. In specifying the base and improvement alternatives, the following points should be borne in mind:

- The base case should represent the conditions that the transit improvement is building upon. In most metropolitan areas there will already be some level of transit service in the base case.
- The improvement alternative should not mix transit improvements with unrelated other investments, such as an unrelated highway improvement. To do so runs the risk of obscuring the independent effects of the transit improvement.
- The representation of the transportation system, both in geographic extent and detail, must be sufficient to capture the full range of effects of the transit improvement. Hence, the nature of the transit improvement determines, to a large degree, how complex the modeling must be.
- The analysis or planning horizon should correspond to the expected life of the transit improvement or policy. In cases involving significant, fixed capital improvements (such as a light rail system), the analysis horizon should correspond with the anticipated life of that investment. For other policies, the analysis horizon should correspond with the anticipated duration of the modeled policy.
- The analyst should perform the evaluation exercise for at least two points in time, spanning the analysis horizon. The results from these two points in time can then be interpolated to periods in between for the purposes of making present value calculations of costs and benefits over the analysis horizon.
- Within each point in time, the analyst may need to perform the analysis for several times of day or days within

[33] In general, much less is known about the response of truck travel to changes in network conditions than is known about automobile and transit responses. If appropriate, the truck mode can be ignored in user benefit calculations.

a week in order to capture traffic peaking behavior properly. In an urban commute-oriented setting, for example, analyses are performed for the AM peak hour, PM peak hour and midday periods. Results for other periods of the day are derived by extrapolation or ignored.

- The time horizon for evaluating both the base case and the improvement alternative will be identical, with the time horizon set for the expected life of the improvement. Similarly, the geographic scope of the analysis should include all that will be impacted by the improvement and will be identical for both the base case and the proposed alternative.
- In general, assumptions regarding normal infrastructure improvements and related amenities will be identical between the base case and the proposed alternative over the life of the project. The exception to this will be those situations where the improvement shifts the level of other amenities supplied so that there is a secondary effect other than the direct effect of the project. For example, it may be that a proposed mass transit project shifts demand away from parking as more people opt for transit. If area parking garages then lower parking costs to attract more business, the change in parking costs needs to be taken into account in the project out-years.

Data and Analysis

Analysts in some jurisdictions have very sophisticated travel demand modeling tools at their disposal. Others do not have such models and must either hire consultants to perform the analysis or make do with rough estimates of the travel demand responses to the transit improvement. The latter type of analysis is acceptable for coarse screening analysis, but is not acceptable when significant public investments are involved.

The conclusion that travel demand models are probably a necessary component of modern transit planning may seem to be in contradiction with this guidebook's stated intent of providing simple tools for small transit agencies. But even many small jurisdictions (50,000 people) are now running travel demand models, and it is unlikely that cities much smaller than that will be making a major transit investment (certainly not fixed guideway projects). The reality of current transit planning is that travel demand models will probably be used to estimate changes in trips by mode. Jurisdictions without such models are probably of a size that their projects and resources will lead them to choose not to implement the types of methods suggested in this guidebook in any case, so the lack of a travel demand model will probably not be the main impediment.

This manual cannot provide travel demand modeling assistance suitable to the vast range of circumstances and transit improvement projects. Hence, the discussion that follows is primarily intended to describe the kind of travel demand data that are needed and how they are typically derived.

First, assume the perspective of the analyst in a large urban area. Transportation analysts there usually have full-fledged computer models at their disposal to perform demand modeling. These models are very useful for analyzing transit improvement benefits because they account for the effect of the improvement on all modes, everywhere in the regional transportation network. A highway travel demand model is essential for assessing transit improvement benefits because many of those benefits occur on the road network where reduced use of vehicles improves road network performance for the vehicles that remain on the road.

The large-scale, urban transportation planning models typically have the following elements:

- **A traffic assignment model.** This model contains a description of the transportation network, often at the level of individual links. The roadway and/or transit guideway systems are represented mathematically in the model, permitting automatic consideration of the effects of traffic on network loads and performance. Traffic assignment models are used to determine volume and speeds, by link, mode, and vehicle class.
- **Trip tables.** The traffic assignment model uses as input *trip tables* that give the number of trips, between all possible pairs of origin and destination *zones*, that are assigned to the network. The trips are typically differentiated by mode. For example, there is typically a separate trip table for single-occupant vehicles (SOVs), carpools, trucks, and buses. Advanced models also differentiate the trip table by vehicle or traveler *class*. For example, auto and transit trips can be differentiated by the income class of the user. This is helpful in performing benefit-cost analysis because the value of time varies with income class.
- **Travel demand models.** The trip tables are generated by travel demand models. These models predict the volume of trips, by vehicle class or mode, between zone pairs. These predictions are based on the characteristics of the various origin and destination zones (their attractiveness) and the *user cost of travel* between the various zone pairs. The travel demand models typically include both a *mode choice* step and a *destination choice* step. Together these steps permit both of these types of behavioral responses to be automatically simulated. Advanced models also have a *residential location choice* step, allowing even the number of residents in each zone to be determined within the model.

As this description suggests, transportation modeling offers a natural way to analyze the benefits and costs to travelers of a transit improvement. With a working, calibrated model, the analyst's task reduces to making changes in user costs and changes in the transportation network configuration that correspond to the transit improvement being modeled. Analysts with a computer-based, multi-step demand modeling suite can then take the following steps to generate the travel activity data they need:

- **Run the modeling suite for the *base case* conditions.** The base case conditions are the conditions (user costs and network configurations) that the transit improvement is building upon. The volumes and user costs (by link or by corridor, depending upon the type of model used)[34] are captured from the base run output at the level of detail that the model permits. For example, volumes may be differentiated by mode and class, as well as link, corridor, or origin-destination zone pair. It is this *modeled* base case against which model improvements are compared. Calibration is important for reliable model output, but analysts should not compare modeled improvements to actual traffic conditions.
- **Edit the model network to incorporate the transit improvement.** Depending upon the type of improvement, this involves (1) editing the network characterization to include new transit guideway or highway links and (2) changing the volume-delay or impedance relationships that characterize the links in the network, as necessary.
- **Run the modeling suite for the transit improvement conditions.** After editing the model network, the model is rerun. New volumes and user costs are captured from this run.

The volume and user cost data generated in the base case and in the improvement case serve as the basis for transit benefit-cost calculations. They should be tabulated by link, corridor, or origin/destination zone pair to perform the calculations described in the next section. Table 3-16 is an illustration of how the data for a corridor or zone pair might be tabulated in the base case and with the project in place.

Table 3-16 shows a 9-mile-long corridor that carries both automobiles and bus transit vehicles. The transit improvement illustrated in this case is an increase in the frequency of bus service in the corridor from 10 to 25 vehicles per hour. The transit improvement attracts auto passengers to transit by reducing walking and waiting time and reduces the number of automobiles in the corridor; thereby increasing speeds for the remaining autos and for the transit buses themselves.

Note that there is a net inducement of trips as a result of the improvement. The combined passenger-miles of auto and bus travel rises from 45,450 to 46,800. These may be new trips, or trips that are diverted from other corridors or times of the day because of the improved service. If they are diverted trips, of course, then it is important to calculate changes in travel activity on other corridors and/or other times of day, which would be part of the impact of the transit improvement.

The structure of Table 3-16 is a fair representation of the table structure that is used in actual transit evaluation studies. In an actual application, of course, a table such as Table 3-16 would have to be expanded to the extent required by the desired grain of the analysis:

- Table 3-16 incorporates only two modes. Additional modes, such as carpools, light rail transit, and trucks might be important to include.
- All travelers in the table have the same average value of time. If, in fact, it is important to tabulate the effects on different traveler classes, the travel data can be disaggregated accordingly.
- Only one corridor (and only one direction of that corridor) is represented in the table. Multiple corridors, or multiple links, are typically necessary to capture all of the effects of a significant transit improvement, since traffic diversion effects across corridors is very common.[35]
- The table represents only one point in time and one time of the day. Namely, the table represents the travel activity in the AM peak hour of the year 2000. Calculations at different times of the day and different forecast years are typically necessary to calculate the present value of travel benefits over the life of the proposed improvement.
- For simplification, Table 3-16 does not include the value of accidents or crimes show in Table 3-5: they should be additive.

Transportation analysts in smaller and rural jurisdictions typically do not have large transportation planning models at their disposal. Unless consultants are engaged to develop the necessary data, the analyst must make the estimates from the information available. This can be both time-consuming and risky, especially if the funds or reputation of the organization are at stake to a significant degree. The countervailing advantage, however, is that smaller, isolated jurisdictions also typically have fairly simple networks. Even if estimates of change in demand are done "by hand," some rough estimates are possible. The goal is still the same: to generate user cost and volume data before and after the transit improvement at the necessary grain. All significantly affected links or corridors should be included in the tabulation.

[34] Most large urban transportation planning models operate on a link basis and provide origin/destination travel demand estimates in trip tables. The STEP model written by the late Greg Harvey, however, works on a corridor (zone O-D pair) basis. If the model operates on a link level and the benefit-cost analysis is to be performed at this level, it is necessary for the base case to include any new links that will be associated with the improvement. However, these links will not receive any traffic assignment in the base case.

[35] Multiple corridor analyses may also call for a more complex analysis, with estimates for each pair of origin and destination (O-D). FHWA's SPASM model performs the single-corridor analysis shown above. STEAM incorporates the more complex analysis of multiple O-D combinations.

TABLE 3-16 Hypothetical travel activity data (one corridor, AM peak hour, year 2000)

Data Type and Abbreviation		Data Units	Calculation	Corridor 1 Autos		Corridor 1 Bus Transit	
				Base Case	With Project	Base Case	With Project
			Raw Activity Data				
Corridor length	L	miles	-	9	9	9	9
Vehicles	M	number	-	4,000	3,500	10	25
Passengers per vehicle	D	number	-	1.2	1.2	25	40
Passengers	Q	number	M*D	4,800	4,200	250	1,000
Speed	S	miles per hr.	-	45	54	35	45
Travel time, walking	W	min./pass.	-	5	5	5	3
Travel time, waiting	G	min./pass.	-	-	-	15	7
Travel time, in-vehicle	T	min./pass.	(L/S)*60	12.0	10.0	15.4	12.0
Transfer time	E	min./pass.		-	-	-	-
Fares	F	cents/pass.-mi.	-	-	-	5	5
Tolls	R	cents/veh.-mi.	-	5	5	-	-
Operating costs paid by pass.	C	cents/veh.-mi.	-	20	18	-	-
Value of travel time, walking	X	dollars/hour	-	20	20	20	20
Value of travel time, waiting	Z	dollars/hour	-	20	20	20	20
Value of travel time, transfers	J	dollars/hour		20	20	20	20
Value of travel time, in vehicle	Y	dollars/hour	-	10	10	10	10
			Intermediate Calculations of Perceived Costs				
Cost of walk, wait, transfer	H	cents/pass.-mi.	(100/L)*(W*X+G*Z+E*J)/60	18.5	18.5	74.1	37.0
Cost of in-vehicle time	N	cents/pass.-mi	(100/L)*(Y*T)/60	22.2	18.5	28.6	22.2
Out-of-pocket cost	P	cents/pass.-mi.	F+(R+C)/D	20.8	19.2	5.0	5.0
			Final Calculations of Perceived Costs				
Total perceived user cost	U	cents/pass-mi.	N+H+P	61.6	56.2	107.6	64.3
Travel volume	V	pass.-miles	L*Q	43,200	37,800	2,250	9,000

Source: ECONorthwest.

Calculating User Benefits

Framework

Once the data are assembled and tabulated in the manner discussed above, the next step is the actual calculation of user benefits. The arithmetic of the calculation is not complex (as the equations in travel demand models often are). In calculating user benefits, however, it is important to maintain consistency between the grain of the analysis that has been chosen and the method of calculating benefits.

Data and Analysis

Recall that the basic idea for measuring user benefits is to measure the shaded area of Figure 3-1 using volume and user cost information. That area represents the net user benefit from changes in user costs and changes in trip volumes that results from the transit improvement. Specifically, the net user benefit, *B*, is calculated from the volume before the improvement (V_0) and after the improvement (V_1), and the user cost before the improvement (U_0) and after the improvement (U_1), using the Basic Benefit Calculation formula:

$$B = \left(\frac{V_0 + V_1}{2}\right)(U_0 - U_1).$$

As the formula indicates, benefits depend fundamentally on the *change in travel values (V_0 to V_1) and change in user costs,* ($U_0 - U_1$). The first component of the formula calculates an average volume by adding before and after volumes and dividing by two. That calculation is consistent with trying to estimate the triangle of consumer surplus in Figure 3-1. Everything else being equal, when ($U_0 - U_1$) is large, benefits are large. That is, when user costs after the improvement are smaller than before the improvement, benefits are accordingly larger. Note also that if there is no induced or retarded travel (i.e., $V_0 = V_1$), then the formula simplifies to $V(U_0 - U_1)$; that is, travel benefits equal volume times the change in user costs.

This formula can be applied at whatever grain is appropriate to the analysis:

- **Link level analysis.** In this case, the *V*'s and *U*'s are the volumes and user costs associated with individual links. The total benefits of a transit improvement are calculated by adding the benefits from every affected link. Again, if there are multiple modes or classes of trips, the calculation is repeated for each such mode or class.
- **Corridor level analysis.** In this case, the *V*'s and *U*'s are the volumes and user costs associated with traversing the corridor or origin-destination pair. The total benefits are calculated by adding the benefits from every affected corridor. In addition, if there are multiple modes or classes of trips, the calculation is repeated for each such mode or class.
- **Aggregate sketch-level analysis.** In this case, the *V*'s and *U*'s are the average volumes and user costs across the region as a whole. At a slightly lower level of aggregation, the region-wide calculation can be performed by mode or by traveler class.

Sample Calculation

The Basic Benefit Calculation formula presented above is at the heart of any user benefit calculations. Even for extremely complex networks, with many different modes and classes of users, many links or corridors, and long project time horizons, the Basic Benefit Calculation formula is used. The formula itself does not get more complex. The only difference is that many more individual calculations must be tracked and properly merged.

The user cost and volume data in Table 3-16 can be used to demonstrate the application of the Basic Benefit Calculation formula in a simple setting. In that table, there is only one corridor, with two modes, and one time period for one day. To calculate total benefits, the analyst calculates the user benefits for autos on the corridor and adds to them the benefits to bus transit users.

Table 3-17 walks through the simple calculation. It shows that the user benefits associated with the transit improvement

TABLE 3-17 User benefit calculation in a simple, one-corridor case (AM peak hour, year 2000)

Data and Abbreviation[a]		Data Units	Calculation[a]	Corridor 1 Autos		Corridor 1 Bus Transit	
User Cost and Travel Volume Data (from Table 3-16)							
				U_0	U_1	U_0	U_1
Total perceived user cost	U	cents/pass.-mi.	N+H+P	61.6	56.2	107.6	64.3
				V_0	V_1	V_0	V_1
Travel volume	V	pass.-miles	L*Q	43,200	37,800	2,250	9,000
User Benefit Calculation							
Change in user cost	ΔU	pass.-miles	(U_0 - U_1)	= (61.6 – 56.2) = 5.4		= (107.6 – 64.3) = 43.3	
Average volumes	$\underline{V}$	cents/pass.-mi.	(V_0 + V_1)/2	= (43,200 + 37,800)/2 = 40,500		= (2,250 + 9,000)/2 = 5,625	
User benefits by mode	B	dollars	ΔU*$\underline{V}$	= (5.4 x 40,500)/100 = 2,187.0		= (43.3 x 5,625)/100 = 2,435.63	
Total user benefits		dollars		= 2,187.0 + 2,435.63 = 4,622.63			

Source: ECONorthwest.

[a] See Table 3-16 for definition of abbreviations and for some of the data.

are $4,622 for every AM peak hour in the year 2000. The benefits are approximately equally derived from benefits enjoyed by automobile users and benefits enjoyed by bus transit users. Though this simple example illustrates the basic calculations involved, in practice, such a calculation needs to be repeated for other times of day, for future years, and so on.

The user benefit calculation in a real-world setting has many more dimensions than the simple calculation above. Although the individual calculations proceed as in Table 3-17, by using the Basic Benefit Calculation formula, the user benefits need to be calculated for a variety of corridors (or links), modes, user classes (values of time), times of the day, and project years over the life of the improvement.

Table 3-18 shows how the calculations might be arranged, with four modes, two user classes per mode, six daily time periods, and 20 project years. (Note that the table only portrays one corridor.) Each of the user benefit entries requires the assembly of data identical in concept to that presented in Tables 3-16 and 3-17. This underscores the computational effort required to assess a transit improvement in detail and illustrates why so many analysts have turned to computer models of their region's transportation network as a way of rapidly and consistently assembling the necessary data.

Though the task of assembling user benefit data appears daunting, in practice a number of simplifying procedures are employed:

- Instead of modeling each of, say, 20 years of a transit project's life, analysts frequently model two years (usually

TABLE 3-18 Annual user benefits, by corridor, mode, user class, time of day and year, in dollars

	Corridor 1							
	Single Occupant Auto		Carpool Auto		Bus Transit		Trucks	
User Class	Low Income	High Income	Low Income	High Income	Low Income	High Income	Heavy	Light
				User Benefits Year 1				
AM Peak	2,271	4,769	3,091	3,824	1,221	1,409	3,366	1,991
AM Shoulder	799	634	1,391	970	1,169	605	576	1,747
Midday	743	763	411	472	913	485	435	897
PM Shoulder	1,933	1,524	1,515	1,480	651	1,834	1,205	1,987
PM Peak	1,727	4,570	3,309	4,564	2,162	4,270	2,947	2,943
Night	178	195	331	534	407	490	289	157
				User Benefits Year 2				
AM Peak	2,407	5,055	3,276	4,053	1,294	1,494	3,568	2,110
AM Shoulder	847	672	1,474	1,028	1,239	641	611	1,852
Midday	788	809	436	500	968	514	461	951
PM Shoulder	2,049	1,615	1,606	1,569	690	1,944	1,277	2,106
PM Peak	1,831	4,844	3,508	4,838	2,292	4,526	3,124	3,120
Night	189	207	351	566	431	519	306	166
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
				User Benefits Year 20				
AM Peak	4,996	10,492	6,800	8,413	2,686	3,100	7,405	4,380
AM Shoulder	1,758	1,395	3,060	2,134	2,572	1,331	1,267	3,843
Midday	1,635	1,679	904	1,038	2,009	1,067	957	1,973
PM Shoulder	4,253	3,353	3,333	3,256	1,432	4,035	2,651	4,371
PM Peak	3,799	10,054	7,280	10,041	4,756	9,394	6,483	6,475
Night	392	429	728	1,175	895	1,078	636	345
				User Benefits Years 1 through 20				
Present Value @ 8 percent	84,165	137,010	110,525	130,285	71,750	100,025	96,995	106,935

Source: ECONorthwest.

the first and the last), and interpolate the data for the in-between years. This is an acceptable practice, of course, only if one anticipates a fairly smooth and linear trend in travel behavior over the 20 years. If this is not the case, the analyst should model additional intervening years.

- Instead of modeling every daily time period, analysts frequently model only the AM or PM peak periods, and extrapolate the behavior to other time periods using factors or weights. This is acceptable practice only where trends in travel activity are fairly gradual over time and where the network has a reasonable amount of peak capacity. If the network is already heavily loaded in, say, the AM peak, future growth will tend to move into shoulder and midday periods, requiring alteration of the factors or weights.
- The number of user classes (time values) can also be kept small if there is no interest in portraying the pattern of benefits by user class. Frequently, analysts use a single value of time, for example, for all auto or transit users. However, one has to be careful not to have so few user classes that the analysis misses important differences in behavior among user classes. In practice two, or preferably three, income class distinctions should be used. As noted later in the guidebook, any simplifications in classes of user costs will mean complications in estimating equity impacts.
- Developing the data at a link level is very burdensome computationally and usually adds little to the benefit-cost analysis. By analyzing user costs and travel volumes on an O-D pair or corridor basis, a much simpler and more transparent appraisal results.

CHAPTER **4**

TRANSIT'S SECONDARY IMPACTS

SUMMARY

This chapter describes benefits that derive from transit's primary impacts on travel behavior. One such benefit is the concept of option value. Although some travelers use transit very infrequently, transit still provides direct value for them by virtue of its availability. In this case, transit acts as a hedge against contingencies that limit the use of other modes, such as poor weather, repairs, or rapid fuel price increases. This chapter provides a methodology to estimate the option value of transit using well-known financial formulas.

Transit improvements can also provide significant environmental benefits, such as reduced air, water, and noise pollution when auto use decreases (these benefits are not perceived by users, so they must be calculated separately). When measuring these impacts, special care must be taken to account for the vehicle fleet mix (types of buses, rail, and autos), local and regional traffic conditions, roadway types, existing environmental conditions, and built environment factors (adjacent land uses and population densities), all of which can greatly affect the benefits that are realized. Area-specific data can usually be obtained from state DOTs, environmental agencies, or MPOs.

Analyses of air pollution typically consider levels of five standard pollutants identified by the Environmental Protection Agency (EPA) and include both local analyses (based on project-specific land use and traffic data) and area-wide analyses, for which this chapter provides a general methodology and sample calculations using emission algorithms developed by EPA. For air pollution in particular, the analysis timeframe is important in that it will incorporate assumptions regarding general growth in vehicle miles traveled and also removal of older, more polluting vehicles.

Noise pollution is more localized than air pollution, and costs can vary substantially as a function of adjacent land use density, mitigation measures (e.g., sound walls), existing ambient conditions, and the nature of the noise (frequency, time of day). This chapter provides estimated noise costs for different types of vehicles traveling on different types of roadways (per vehicle-mile traveled). Compared with other types of impacts, noise impacts (costs) are likely to be relatively minor unless a large project is constructed that causes new noise in heavily populated areas with relatively low existing noise levels.

Water pollution arises from vehicle exhaust, tire wear, oil leaks, and numerous other sources. While some researchers have estimated these costs at a national level in the aggregate, there are no reliable figures that disaggregate costs by mode or local area. Based upon the national estimates, however, these costs are likely to be very small per vehicle-mile of travel and can probably be dropped from the analysis unless special conditions exist.

Finally, this chapter gives guidance to estimate the cost of accidents that are not perceived by users (Chapter 3 describes how most accident costs are perceived as additional travel time costs and/or through insurance payments). An example of this type of cost might be publicly borne accident response costs. Based on national data, this chapter suggests that a reasonable range for these costs (for all modes) is probably 1 to 10 cents per vehicle-mile traveled.

OVERVIEW

The user benefits calculated through consumer surplus measurements typically capture the biggest share of travel benefits. However, some benefits and costs that result from transit improvements are not captured by consumer surplus calculations. This guidebook classifies these benefits (or costs) as *secondary impacts*. They are secondary not because they are unimportant or necessarily smaller, but because they generally derive from a transit project's primary impact on travel behavior.

Secondary impacts of transit improvements arise in a number of ways. One way is through changes in travel-related costs that are not perceived by travelers. For example, the cost of highway patrol and road maintenance services are often paid for through general taxes, such as property taxes. Consequently, when a traveler switches modes from the automobile to transit, there is no perception that the cost of these services has changed. But with fewer drivers on the road, the level of highway patrol and road maintenance services can be reduced. Similarly, if not all parking costs are perceived by travelers as a cost of driving (because, for example, employers and merchants give "free" parking), the user costs in Chapter 3 will not fully reflect the total cost of travel. These travel cost savings are properly attributed to the transit improvement, but will not be accounted for in the consumer surplus calculation. Most of these types of costs are evaluated in Chapter 5, Direct Costs. A subset of these costs not appropriately handled as direct capital or operating costs is addressed at the end of this chapter.[1]

The *option value of transit* is another secondary benefit of transit improvements. People may be willing to pay for a transportation improvement, even if they do not plan to use it regularly (and, thus, get little user benefit), in order to preserve their option to use it. Transit, of course, is not unique in offering expanded options; arguably, a new road also expands travel options slightly, and non-users may be willing to pay something to achieve this. However, transit service provides opportunities to travel without driving, without owning an automobile, in inclement weather, and so on that probably add more "option" for most travelers than additional road capacity. Conventional, consumer surplus-type calculations do not capture this effect, and special procedures and data are required to place a value on this benefit.

Unperceived travel costs, producer surplus, and the option value of transit are secondary impacts that affect travelers or providers of travel services. There is a large, additional class of secondary impacts, however, that affects those wholly outside the travel market because of environmental and economic *externalities* generated by travel activity. Air pollution and noise caused by transportation represent the most commonly discussed externalities, but transportation can also affect the economy of a region or a neighborhood. These latter effects can occur because transportation can affect the general productivity of an economy and can affect the location of economic activity.

THE OPTION VALUE OF TRANSIT

Framework

Most passenger travel in urban areas involves modes other than public transit. The fact that most travelers do not use transit, however, does not mean that transit has no direct value to them. Even travelers who have never used transit may value the *availability* of transit service. Specifically, they may value transit as a hedge against events that affect their ability to use the automobile, such as

- Bad weather,
- The automobile being unavailable or broken down,
- Increases in fuel prices or other factors that raise the cost of operating an automobile, and
- Loss of the ability to operate a vehicle.

In economics parlance, the value that is associated with avoiding such contingent events is called *option value*. Many other types of services in the economy involve similar, contingent events and option value, including insurance policies, mortgage contracts, club memberships, etc. In financial markets, explicit agreements that give parties the option to buy or sell a security are, themselves, bought and sold. Because of the ubiquity of option value concepts in the economy, economists have developed mathematical procedures for quantifying option value.

The option of having transit available will only be valuable to those in the population that might conceivably use the transit system at some point during the year. For example, people that drive themselves to work will likely place some value on having transit as an option on those days when the weather is especially bad or when their car is being repaired. Conversely, it could be the case that the transit system does not serve the needs of a certain population, such as residents living in outlying areas outside the transit service area. In this case, it is reasonable to assume an option value of zero for users who are unlikely to use transit under any conditions.

Some of the mathematical formulae that are used to evaluate financial options can be used to establish transit's option value. The application to transit options involves linking the parameters of the conventional financial options formula to the analogous dimensions of transit service availability.

In the case of financial options on stock, the option that is being valued is the opportunity to buy[2] at price X a stock that is currently being sold today at price S. The price X is called the *exercise* or *strike* price; it is the price at which the holder of the option gets to exercise an opportunity to buy the underlying stock. Whether the option is worth holding (and, hence, the option's value) depends not only on the exercise price agreed upon, but also the likelihood that actual stock prices, over time, will move in such a way that exercise price looks attractive.[3] The *volatility* of stock prices (measured as the *standard deviation*, s, of stock price movements) is the factor that affects this likelihood. Because the chance of volatile stock prices moving favorably improves the longer one waits, option value is also affected by the amount of time over which the option may be exercised (called *time until expiration*, T, in years, in the finance parlance) and the risk-free rate of return per annum (r) that might have been enjoyed in other investments while waiting to exercise the option.

[1] A second type of secondary impact is the *producer surplus* that may accrue to the suppliers of transportation services as the result of transit use. The notion of producer surplus is analogous to the notion of consumer surplus. The cost that suppliers (such as transit districts and highway agencies) are willing to bear to provide transportation services is affected when travel shifts among modes. If these suppliers enjoy economies of scale (or suffer diseconomies of scale) in the provision of their services, there can be changes in *producer surplus*, i.e., changes in the relationship between the costs suppliers are willing to bear and what they receive in compensation.

For example, a policy to increase parking charges could cause a shift of auto travelers to transit, which could reduce costs per passenger-mile to transit agencies. In cases where the economy is competitive, however, there is little or no difference between the costs suppliers are willing to bear and the compensation they receive. If there are approximately constant returns to scale within the range of change to the transit operating system, then there is no producer surplus. Since this is the most common situation, it is assumed throughout this guidebook that there is no producer surplus associated with the projects being discussed.

[2] This type of option is called a *call option*.

[3] That is, the market price moves so that it exceeds the exercise price. In such a circumstance, the option is said to be "in the money."

The mathematical formula that derives the option value (C, the *call premium*) is called the Black-Scholes formula, after two of its authors.[4]

Data and Analysis

One can use the Black-Scholes call option pricing formula to evaluate transit's option value, because transit's value to an automobile user depends on factors analogous to the factors described above for financial options. Specifically, analogous to stock prices, the "price" of automobile services (S) is volatile because of the risk of weather, breakdowns, and other factors described above. Transit provides a way (at "exercise price" X) to buy replacement services. If the auto user perceives that there is a strong possibility that the price of auto services will move such that the transit price becomes attractive, the option will have value. This will be the case if the price of automobile services has a high standard deviation, σ, over time.

The remaining factor for which we must find an analogy is the *time to expiration*, T, of the transit option. A good number to use would be the time period over which the auto user expects to take advantage of the option the first time. Hence, if the auto user expects to use transit 10 times a year, T would equal 0.1 (T is defined for the analysis as 1/[number of expected uses of transit]). In the course of a year, one would expect the auto user to be willing to "buy" 10 such options and, over a 20-year horizon, 200 such options. In this way, one can estimate what the option value of transit is over extended periods.

Table 4-1 illustrates how the option value varies with the various key parameters. The table employs the following assumptions or ranges of assumptions:

- S, the usual or expected "price" of an automobile trip. Since transit is most viable for commute trips, this price should be the full marginal cost (auto operating costs plus the dollar value of time spent traveling) of a typical commute trip. For the purposes of this illustration, the figure $5 per trip is used.
- σ, the standard deviation of S. This parameter captures the volatility or uncertainty of travel by auto. The standard deviations presented in this table range from $0.25 to $2.50, or 5 to 50 percent of the $5 price of a trip. This represents a very broad range and is used here only to provide additional possible values for the option value calculation. The actual standard deviation will likely be less volatile in practice as the uncertainty of travel by auto is likely to be smaller than indicated by the range shown here.
- X, the "exercise price" of a transit trip. This figure should be the marginal full cost of taking the trip by transit. As described in Chapter 3, the marginal full cost of a transit trip perceived by a user is a combination of out-of-pocket costs, travel time, (which may differ depending on whether the time is spent walking, waiting, or riding), and other travel characteristics (safety, comfort). Since transit is (by assumption) not the typically used mode, its expected price must generally be higher than S. For purposes of this illustration, we will use the range of $5 to $8 per trip.
- T, the time to expiration of the transit option. The parameter, as discussed above, essentially should capture the frequency with which transit might be optionally used. For purposes of this illustration, we use one-tenth (0.1, the equivalent of 10 trips) and one-half (0.5, the equivalent of two trips) year for T.
- r, the risk-free return. In the illustration, the rate 4 percent is used.

Table 4-1 displays the transit option value (per option) for various exercise prices (i.e., marginal cost of transit), time to expiration (length of time before expected exercise), and volatility of auto costs. The table shows that

- The higher the exercise cost of the transit option, the lower the option value of transit. For transit to have a high option value, therefore, it must provide a reasonable-cost alternative to the automobile.
- The higher the volatility of automobile costs, the higher the option value of transit. This is because this increases the chances that auto use will become excessively costly.
- The longer the interval before expected exercise (T), the higher the option value of transit.

The values in Table 4-1 can be converted to annual transit option values. If one expects to use transit ten times a year (i.e., Time = 0.1), with a marginal transit cost of $6.00, and volatility of $1.50, the option value is $0.61. If one expects to use transit only twice a year (Time = 0.5), that value rises to $1.78 under the same circumstances. Note, however, that the annual cost of the option is lower in the second case, because you expect to only exercise two options, versus ten. Hence, the annual option value of transit is $6.10 for the ten-times-a-year case, and $3.56 for the twice-a-year case. These values can be extrapolated into the future if a long-run planning horizon is relevant by calculating the annual transit option values for each year and discounting that stream of annual option values at an appropriate interest rate. (See Chapter 9 for an example of discounting.)

[4] In addition to the factors S, X, σ, and T, the formula uses the normal distribution *N()*. The formula is usually written as:

$$C = SN(d_1) - Xe^{-rT}N(d_2)$$

where

$$d_1 = \frac{\ln(S/X) + (r + \sigma^2/2)T}{\sigma\sqrt{T}}$$

$$d_2 = d_1 - \sigma\sqrt{T}$$

TABLE 4-1 Transit option value, by exercise price, time, and volatility (per option)

	Marginal Full Cost of Transit Trip (X)						
σ	$ 5.00	$ 5.50	$ 6.00	$ 6.50	$ 7.00	$ 7.50	$ 8.00
				Time = 0.1			
$ 0.25	$ 0.17	$ 0.03	$ 0.00	$ 0.00	$ 0.00	$ 0.00	$ 0.00
$ 0.50	$ 0.32	$ 0.14	$ 0.06	$ 0.02	$ 0.01	$ 0.00	$ 0.00
$ 0.75	$ 0.48	$ 0.29	$ 0.17	$ 0.09	$ 0.05	$ 0.03	$ 0.01
$ 1.00	$ 0.64	$ 0.45	$ 0.31	$ 0.21	$ 0.14	$ 0.09	$ 0.06
$ 1.25	$ 0.79	$ 0.60	$ 0.46	$ 0.34	$ 0.26	$ 0.19	$ 0.14
$ 1.50	$ 0.95	$ 0.76	$ 0.61	$ 0.49	$ 0.39	$ 0.32	$ 0.25
$ 1.75	$ 1.10	$ 0.92	$ 0.77	$ 0.64	$ 0.54	$ 0.45	$ 0.38
$ 2.00	$ 1.25	$ 1.07	$ 0.93	$ 0.80	$ 0.69	$ 0.60	$ 0.52
$ 2.25	$ 1.40	$ 1.23	$ 1.08	$ 0.96	$ 0.85	$ 0.75	$ 0.67
$ 2.50	$ 1.54	$ 1.38	$ 1.24	$ 1.11	$ 1.00	$ 0.91	$ 0.82
				Time = 0.5			
$ 0.25	$ 0.40	$ 0.20	$ 0.09	$ 0.04	$ 0.02	$ 0.01	$ 0.00
$ 0.50	$ 0.75	$ 0.55	$ 0.40	$ 0.29	$ 0.21	$ 0.15	$ 0.11
$ 0.75	$ 1.09	$ 0.90	$ 0.75	$ 0.62	$ 0.52	$ 0.43	$ 0.36
$ 1.00	$ 1.42	$ 1.25	$ 1.10	$ 0.97	$ 0.86	$ 0.76	$ 0.68
$ 1.25	$ 1.74	$ 1.58	$ 1.45	$ 1.32	$ 1.21	$ 1.12	$ 1.03
$ 1.50	$ 2.05	$ 1.91	$ 1.78	$ 1.67	$ 1.56	$ 1.47	$ 1.38
$ 1.75	$ 2.35	$ 2.22	$ 2.10	$ 2.00	$ 1.90	$ 1.81	$ 1.73
$ 2.00	$ 2.63	$ 2.51	$ 2.41	$ 2.31	$ 2.22	$ 2.14	$ 2.06
$ 2.25	$ 2.89	$ 2.79	$ 2.69	$ 2.61	$ 2.53	$ 2.45	$ 2.38
$ 2.50	$ 3.14	$ 3.04	$ 2.96	$ 2.88	$ 2.81	$ 2.74	$ 2.68

Notes:
1. S = $ 5.00
2. r = 4%

Clearly, the option value of transit depends crucially on the availability of transit service at a cost that is reasonably close to (albeit above) the cost of auto for the affected portion of the population. Hence, the key factors needed to estimate the transit option value for an entire region are

- The transit exercise price (*X*) and automobile trip costs (*S*) for each transit service subgroup;
- The volatility of automobile trip costs (which will depend on weather, congestion levels, and other local variables); and
- The expected number of times per year that an optional user might use transit.

ENVIRONMENTAL EXTERNALITIES: OVERVIEW

This guidebook rejects the idea of estimating "avoided cost" in favor of always comparing a transit improvement with some alternative. The analysis in the guidebook assumes that the transit alternative gets compared with a 'do nothing' alternative. The analysis could be extended to consider non-transit transportation options (e.g., increased highway capacity), but to do so would require an analyst to have information for highways parallel to all the transit information provided in this guidebook.[5] Though this guidebook does not provide measurements of all types of highway costs, it does so where such costs should enter into the calculations. Therefore, this section (and others) discusses not only transit impacts, but also impacts of other modes (in this section, primarily on air quality).

An effective transit improvement can provide environmental benefits, primarily from a decrease in automobile use and the accompanying reductions in air pollution, water pollution, and noise associated with that travel mode. Often these environmental costs or benefits are not considered by travelers in everyday decisions about whether to drive or ride transit. In addition to those costs that travelers willingly pay for or bear, transportation system users and non-users bear other costs without compensation, or enjoy other benefits without charge. Externalities occur when private benefits or costs do not equal total benefits or costs to society. For example, a typical driver does not pay the cost that the air pollution from his or her car imposes on human health and environmental quality in the region. A large literature

[5] There are many sources for that information, many of which are listed in the bibliography of this report. The point is that such information is the subject of guidebooks similar to this one in content, length, and complexity. This guidebook does not aspire to being a comprehensive guidebook for all transportation projects. It is limited to a discussion of methods for evaluating transit, and primarily intra-metropolitan transit.

on *environmental externalities* describes and seeks to estimate many of these unaccounted-for costs and benefits, including air pollution, global warming, water pollution, and noise.

For transportation projects, it helps to divide these environmental costs into two categories: those that occur during construction, and those that occur during operation. Construction externalities have a lot of similarities to the externalities of any large construction project in an urban area. They consist primarily of short-term effects on air and water quality (e.g., dust and erosion). These impacts are heavily dependent on site conditions, construction techniques, and mitigation. Moreover, there is no compelling reason, and no comparative empirical evidence, to suggest that the *construction* of a transit project is more or less damaging, during construction, than the construction of an equally sized highway project. For example, adding a bus lane to an arterial probably has the same effects during construction as adding an auto lane to the same facility. For this reason, we do not evaluate these impacts in this guidebook. We note, however, that if the travel demand analysis suggests that travel needs could, for example, be met by more buses or a new highway lane, then the environmental impacts of the highway construction option, during construction, will clearly be greater than those of the transit options and should be estimated.

Environmental impacts during operation could be very different for transit and auto transportation improvements because such improvements result in the use of a different number and type of vehicles and in a difference in vehicle trips and vehicle-miles. During operation, the main impacts are on air quality (emissions, road dust), water quality (oil from roadway water runoff), and noise.

The modeling and measurement of environmental externalities is an important part of evaluating transit improvements because in certain settings these externalities can be significant. The procedure for measuring these impacts is to link the level of emissions or other impacts to measures of vehicle activity and then to assign monetary value to the effects.

This guidebook is written from the perspective that evaluating the benefits and costs associated with a transit improvement involves comparing the results of that improvement with an alternative world in which the improvement is not made. The alternative for comparison is the “No-Build” alternative typical of an environmental impact statement, not a “Highway Improvement” alternative. Though the general methods described in this guidebook would apply to a highway improvement, we have not presented enough highway-specific benefit and cost information in this manual to allow an analyst to conduct that type of evaluation based only on the information in this manual. In contrast, for the “No-Build” alternative, the analyst should be able (by using a travel demand model or by back-of-the-envelope calculations) to make some estimate of how highway trips and congestion will differ from their values in the transit-improvement alternative, and the benefits and costs of those differences can be calculated using the methods and data described in this guidebook.

Applying this approach to comparing alternatives necessitates that transit planners consider automobile impacts in addition to effects associated with transit. For each alternative, planners should conduct a full-cost analysis that examines the impacts associated with the levels of use for both autos and transit expected in the scenario. Accordingly, this section reviews environmental impacts associated with various travel modes, including cars, trucks, and transit.

Measurements of the physical impacts of environmental impacts of transportation are clearly important, but for evaluation, more is required: those physical measurements need to be valued. There are two general approaches to evaluation: estimating costs based on damages (What effect does the environmental damage have if it occurs?) or based on control (What does it cost to keep the damage from occurring?).

The most extensive work on estimating the environmental costs of motor vehicles has been done by Delucchi.[6] That work includes reviews and evaluations of most of the literature on the topic. This section draws heavily from Delucchi’s article, which provides a summary of the state of the practice.

AIR QUALITY

Framework

Transit projects generally benefit air quality since they reduce reliance on motor vehicles and thereby decrease the amount of air pollutants generated in a region. However, adverse air quality impacts could result from increased traffic volumes near transit stations, loss of roadway capacity due to construction of transit facilities, increased use of diesel-fueled vehicles, and increased emissions from remote power-generating facilities.

The air quality impacts of a proposed project depend on many factors—source emissions (i.e., tail pipe emissions from gasoline- or diesel-fueled motor vehicles or emissions released from power-generating facilities that supply the electricity to rail systems); patterns of vehicle use (i.e., stop-and-go versus steady-speed driving, vehicular operating conditions, etc.); the physical environment in which vehicles operate (i.e., background air quality levels, local meteorological conditions, etc.); and the human environment in which the vehicles operate (i.e., density of development, health of people exposed, etc.).

Estimating changes in air quality resulting from a proposed project, therefore, requires information on fleet and trip characteristics, level of traffic congestion, the location of project facilities relative to sensitive land uses, and local meteorological conditions and pollutant levels. The large number of variables that affect air quality levels makes it difficult to estimate accurately the air quality impacts of a proposed project. It is equally difficult to estimate precisely the costs of these impacts to human health and welfare.

[6] Delucchi, 2000. This article synthesizes extensive work he has conducted on this topic over the previous decade.

Recognizing the uncertainties inherent in making these estimates, the following provides a summary of current methodologies used to evaluate the air quality impacts of a proposed transit project. Included is a discussion of the air pollutants of concern, the variables that affect potential impacts, the costs associated with the emissions of transportation-related air pollutants, and a simple approach (with sample calculations) that can be used to approximate the air quality-related costs of a proposed transit project.

Pollutants of Concern

The use of automobiles, light trucks, commercial trucks, buses, light rail vehicles, heavy rail vehicles, commuter rail vehicles, and other vehicles all result in the emission of air pollutants due to the combustion of hydrocarbons, either directly from their tailpipes or indirectly from electrical power-generating facilities. These emissions contribute to a number of local, regional, and global air quality problems that affect human health, agriculture, buildings, and the natural environment, including animals, vegetation, water quality, and scenic vistas.

Pollutants of principal concern for transportation projects include carbon monoxide (CO) and particulate matter smaller than 10 microns in diameter (PM_{10})—pollutants that are emitted from vehicular tailpipes. Nitrogen oxides (NO_x) and volatile organic compounds (VOCs) are also released from transportation sources and are of concern as precursors in the formation of ozone (O_3) in the atmosphere. Diesel-fueled vehicles (buses and rail) also emit sulfur oxides (SO_x). These pollutants are also emitted from the power-generating facilities that produce electricity used to power light-rail and heavy-rail vehicles.

Elevated ozone levels can cause respiratory problems, reduce visibility in the atmosphere, and cause damage to plants, trees, and crops. CO can impair the flow of oxygen in humans—high levels can result in death; lower levels can cause breathing difficulties and dizziness. PM_{10} can cause respiratory problems and premature death and is the primary source of haze that reduces visibility. NO_x and SO_x can cause lung damage and respiratory illness and contribute to acidic deposition, with resultant harm to water bodies, vegetation, and buildings.

Air Quality Standards and Regulations

As required by the federal Clean Air Act (CAA), National Ambient Air Quality Standards (NAAQS) have been established by the U.S. Environmental Protection Agency (EPA) for O_3, CO, NO_2, PM_{10}, and SO_2. "Primary" standards have been established to protect the public health while "secondary" standards have been established to protect the nation's welfare and account for air pollutant effects on soil, water, visibility, materials, vegetation, and other aspects of the general welfare. Many states have promulgated additional, and sometimes more stringent, ambient air quality standards.

The CAA requires that plans (State Implementation Plans or "SIPs") be developed to attain and maintain the NAAQS within all regions of the country. Under these requirements, the air quality impact of transportation projects must be studied to determine if they conform to SIP requirements.

Analysis Types

In general, two types of air quality analyses are conducted to estimate the impacts of a proposed transportation project: (1) a localized (or microscale) analysis to estimate pollutant concentrations (generally expressed in parts per million or micrograms per cubic meter) at sensitive land uses located near heavily congested roadways or intersections that would be affected by a proposed project and (2) an areawide (mesoscale) analysis to estimate the total amount of pollutant emissions ("regional emission burdens," generally expressed in tons per year) that would be generated by the transportation network as a consequence of a proposed project. These analyses are used to demonstrate that a project would not cause or exacerbate a violation of the NAAQS or increase regional emissions to levels greater than those allowed in the applicable SIP.

Detailed information about the project and the surrounding roadways and land uses is required to determine, based on a microscale analysis, whether a proposed project would cause or exacerbate a violation of the NAAQS. Analysis sites have to be selected, based on the project's effect on local traffic conditions and roadway configurations, and then evaluated in detail. Localized air quality effects are project-specific, and the costs associated with these effects cannot be estimated using a generalized procedure. The following discussion, therefore, focuses on estimating the costs associated with the areawide (or mesoscale) effects of proposed transit projects. To conduct a mesoscale analysis, estimates must be made of the total volume and average speed of vehicles using the affected roadway network. This information usually comes from a regional traffic assignment model.

Emission Estimates

The EPA has developed a motor vehicle emission factor algorithm ("MOBILE") that can be used to estimate vehicular emissions of CO, VOCs, and NO_x. The EPA and all states (except for California, which uses its own model, EMFAC), and planning agencies use the latest versions of the MOBILE model (currently MOBILE5B) to estimate vehicle emissions. Variables that must be considered in the emission factor estimates include vehicle mix of the fleet (e.g., cars, light-duty trucks, and heavy-duty trucks), vehicular speeds and operating conditions, ambient temperatures, local vehicular inspection and maintenance and anti-tampering programs, low emission vehicle credits, fuel additives requirements, vehicular age distribution, and mileage accrual rates.

The EPA PART5 program is used to estimate vehicular emission factors for PM_{10} and SO_x. In addition to many of the MOBILE variables, PART5 requires the identification of roadway type (e.g., expressways and local streets), vehicular weight, and roadway surface silt content.

A critical parameter affecting vehicular factor rates is the analysis year. Two competing conditions affect the analysis year determination. On the one hand, vehicular emissions generally decrease in future years due to increasingly stringent emission control requirements and the removal of older, more polluting vehicles from the roadway network. On the other hand, vehicular emissions may increase in future years because vehicle-miles of travel tend to increase due to regional growth.

NO_x, VOCs, PM_{10}, and SO_x emission factors for the power facilities that generate the electricity for rail projects can be obtained from EPA's *Compilation of Air Pollution Emission Factors* (AP-42). While the type of fuel used by a power generating plant directly affects emissions, this information is not usually readily available since the power supplied to a particular facility usually comes from a power grid that is powered by multiple facilities using various fuel types. Regulatory agencies often do not account for emissions from generating facilities when estimating transportation-related emissions.

Cost of Air Pollution

Air pollution may result in increased costs due to its impacts on human health and welfare. Order-of-magnitude estimates of these costs may be developed using data provided in Delucchi (1998) (see Table 4-2). Provided in this table are low and high estimated air pollution costs (in 1991 dollars) associated with health, visibility, and crop damage for emissions per kilograms of pollutant emitted. PM_{10}, VOCs, CO, NO_x, and SO_x are considered.

In order to utilize this information in this guidebook, the values estimated by Delucchi were summarized and simplified. The revised values, which are presented in Table 4-3, roughly approximate the low and high total cost (health + visibility + crop) of emissions per kilogram of pollutant. For simplicity (and also because the values are small), the health costs of VOC and NO_x emissions as O_3 precursors were split equally and added to the VOC and NO_x costs in Table 4-3. The values shown in Table 4-3 can be used to estimate the low and high total costs associated with a proposed transportation project.

Procedures to Estimate Air Quality Costs of a Proposed Project

The following procedures can be used to estimate order-of-magnitude air quality costs of a proposed transit project. Table 4-3 provides estimated pollution cost per pollutant per kilogram of pollutant emitted. To use these values, project-specific information must be obtained, including changes in regional vehicular volumes and speeds for the vehicles using each type of affected transportation system (i.e., roadway networks, transit projects utilizing diesel buses, and light and heavy rail projects) and the emission factors for the affected vehicles.

Changes in regional volumes and speeds associated with a proposed transportation project are usually available from the project's sponsor or the area's metropolitan planning organization (MPO). Depending on the level of analysis that was

TABLE 4-2 Summary of the health, visibility, and agriculture cost of emissions from motor vehicles

Emitted pollutant -->	PM_{10}	VOCs	CO	NO_x	SO_x	VOCs+ NO_x
Ambient pollutants -->	*PM_{10}*	*Organic PM_{10}*	*CO*	*NO_2, nitrate PM_{10}*	*Sulfate PM_{10}*	*O_3*
G/mi -- low	0.20	3.10	38.20	3.60	0.20	6.70
G/mi -- high	0.30	3.70	45.30	4.00	0.20	7.70
$-Damages/kg-emitted[a]						
Health -- low	9.75	0.10	0.01	1.17	6.90	0.01
Health -- high	133.78	1.15	0.09	17.29	65.22	0.11
Visibility -- low	0.4	0.0	0.0	0.2	0.9	0.0
Visibility -- high	3.9	0.1	0.0	1.1	4.0	0.0
Crops -- low	0.00	0.00	0.00	0.00	0.00	0.19
Crops -- high	0.00	0.00	0.00	0.00	0.00	0.30

Source: Delucchi, 1998.

[a]Dollar value (in 1991 dollars) of health, visibility, and crop damages due to a change in ambient pollution resulting from a 10% reduction in direct emissions from all motor-vehicles (heavy-duty diesel trucks as well as gasoline passenger cars), in all areas of the U. S. (rural as well as urban), in 1990. Emissions from upstream sources such as refineries, and emissions of road dust, are not included here.

TABLE 4-3 Simplified cost factors* (dollar damages per kilogram of pollutant emitted)

Emitted pollutant --> Total Costs	PM_{10}	VOCs	CO	NO_x	SO_x
Low Factor	10	0.2	0.01	1.5	8
High Factor	138	1.5	0.1	19	69

*Based on the data presented in Table 4-2. A kilogram equals 2.2 pounds.

conducted for the project, this information could be available by roadway type (e.g., expressways or local streets), subarea (e.g., by county or neighborhood), or time period (e.g., AM or PM peaks or a 24-hour weekday average period). These estimates should be converted to an annual basis.

Motor vehicle emission factors for proposed roadway projects are usually developed using the MOBILE and PART5 programs. Area-specific inputs to these models can usually be obtained from a state's department of transportation or environmental protection or the local MPO. This analysis is usually conducted for a project's first year of operation and/or its design year.

Emission factors for rail projects can be obtained directly from the sources cited at the end of this section, under *Sample Calculations*. When conducting this analysis, it is important to estimate how a rail project would affect roadway traffic. It is likely that the emissions generated directly by a proposed rail project would be more than offset by an indirect reduction in motor vehicle emissions.

The estimation of the air-quality-related costs of a project per pollutant would be conducted by multiplying the values in Table 4-3 (in dollars per kilogram of pollutant emitted) by the emission factor for that pollutant (in kilograms of pollutant emitted per vehicle-mile of travel) by the annual vehicle-miles of travel. This calculation should be made by pollutant with and without the proposed project.

The following sample calculations are provided to show how these calculations could be completed. Two sets of calculations are provided—one for estimating the air-quality-related costs associated with changes in mobile source (i.e., motor vehicle) emissions and the other with changes in rail emissions. Hypothetical estimates of vehicle-miles of travel were developed in both cases, and these values were multiplied (on a pollutant by pollutant basis) by both the appropriate emission factors (in kilograms per vehicle-mile) and health-related cost factors (in dollar damages per kilogram of pollutant) presented in Table 4-3. The total cost for all the pollutants combined were then summed.

Sample Calculations

Sample Calculation: Mobile Source

Provided below is a sample calculation that was completed in estimating the air pollution costs of CO, PM_{10}, VOC, NO_x and SO_x emissions from the mobile sources associated with a hypothetical transportation project. The following assumptions were made in completing this sample calculation:

- 2007 analysis year;
- National default cold and hot start percentages (20.6 percent cold and 27.3 percent hot start);
- Vehicle Mix (MOBILE5B default values):
  - LDGV (light-duty gasoline vehicles) 56.5 percent
  - LDGT1 (light-duty gasoline trucks 1) 19.8 percent
  - LDGT2 (light-duty gasoline trucks 2) 9.1 percent
  - HDGV (heavy-duty gasoline vehicles) 3.6 percent
  - LDDV (light-duty diesel vehicles) 0.1 percent
  - LDDT (light-duty diesel trucks) 0.2 percent
  - HDDV (heavy-duty diesel vehicles) 10.3 percent
  - MC (motorcycles) 0.4 percent
- Average Daily Vehicle-Miles Traveled (VMT):
  - 2007 Future Baseline 410,000
  - 2007 Future Build 400,000
- Average Daily Vehicle-Hours Traveled (VHT):
  - 2007 Future Baseline 21,025
  - 2007 Future Build 20,000
- Number of commuter travel days per year: 250

VMT was divided by VHT to estimate average speeds, with the following results:

- 2007 future baseline speed: 19.5 mph
- 2007 future build speed: 20.0 mph

Based on the above information, emissions factors for each pollutant were estimated using the MOBILE5B and PART5 models. These are provided in Table 4-4.

To obtain total annual emission rates, the following formula was used:

$$ER = VMT \times EF \times 1 \text{ kilogram}/1000 \text{ grams} \times 250 \text{ days per year}$$

Where

ER = emission rate (kilogram/year)
VMT = average daily vehicle-miles traveled (vehicle-mile day)
EF = emission factor (gm/ vehicle-mile)

The estimated emission rates for the sample scenario are provided in Table 4-5.

TABLE 4-4 Pollutant emission factors (grams per vehicle-mile)

Pollutant	2007 Baseline EF	2007 Build EF
CO	14.05	13.68
VOC	0.91	0.89
NO_x	1.52	1.52
PM_{10}*	0.076	0.076
SO_x	0.064	0.064

*Tailpipe emissions only; re-entrained roadway dust not included.

TABLE 4-5 Pollutant emission burdens (kilograms per year)

Pollutant	2007 Baseline Emissions	2007 Build Emissions	Project-Related Changes
CO	1,440,125	1,368,000	-72,125
VOC	93,275	89,000	-4,275
NO_x	155,800	152,000	-3,800
PM_{10}	7,790	7,600	-190
SO_x	6,560	6,400	-160

The estimated costs associated with these emissions, based on the cost factors presented in Table 4-3, are provided in Table 4-6.

Sample Calculations: Emission Estimates for Rail Engines

Rail locomotives in the U.S. are of two types: electric and diesel-electric. Electric locomotives are powered by electricity generated at power plants and distributed by a third rail or other system while diesel-electric locomotives use diesel engines and an alternator or generator to produce the electricity required to power traction motors.

Two methods are available to estimate emissions from diesel-powered locomotives—one uses emission factors in grams per brake horsepower-hour (Method I); the other uses fuel consumption rates in grams per gallon (g/gal) of fuel consumed (Method II).

To estimate annual average emission rates using Method I, the following formula can be used:

$$M_i = N \times HRS \times HP \times LF \times EF_i,$$

Where

- M_i = emission rate of the i pollutant during inventory period (kilogram per year)
- N = number of units
- HRS = annual hours of use (hrs)
- HP = average cycle-weighted rated horsepower (hp)
- LF = typical load factor
- EF_i = emission factor or average emissions of the i pollutant per unit of use (e.g., grams per horsepower-hour).

TABLE 4-6 Annual daily costs of pollutant emissions (1991 dollars)*

Pollutant	Low	High
CO	-721	-7,212
VOC	-855	-6,413
NO_x	-5,700	-72,200
PM_{10}	-1,900	-26,220
SO_x	-1,280	-11,040
Total	**-10,456**	**-123,085**

*Negative values indicate an estimated reduction in air pollution costs.

To estimate annual average emission rates for the locomotives using Method II, the emission factors per pollutant in g/gal are multiplied by the fuel consumption rate of the locomotives in gallons of fuel per day and by number of days per year of use.

The EPA has recently established emission standards for oxides of nitrogen (NO_x), hydrocarbons (HC), carbon monoxide (CO), and particulate matter (PM) for newly manufactured and remanufactured diesel-powered locomotives and locomotive engines. Three separate sets of emission standards have been adopted, with the applicability of the standards dependent on the date a locomotive is first manufactured. The first set of standards (Tier 0) applies to locomotives and locomotive engines originally manufactured from 1973 through 2001. The second set of standards (Tier 1) applies to locomotives and locomotive engines originally manufactured from 2002 through 2004. The final set of standards (Tier 2) applies to locomotives and locomotive engines originally manufactured in 2005 and later.

Emission factors can be obtained from U.S. Environmental Protection Agency, Office of Mobile Sources (1997). Information regarding locomotive type, horsepower rating, type of fuel and fuel consumption rate, loading factor, and annual hours of use can be obtained from manufacturers' specifications.

Annual emissions of NO_x using Method I for fleet average locomotive for year 2007 could be estimated as follows:

$$\begin{aligned} M_{NOx} &= 1 \times 8 \text{ hours/day} \times 250 \text{ days/year} \times 3000 \text{ bhp} \times 0.5 \\ &\quad \times 8.51 \text{ g/bhp-hr} \times 1 \times 10^{-3} \text{ kilogram/grams} \\ &= 25{,}530 \text{ kilograms/year} \end{aligned}$$

The costs associated with these emissions (in 1991 dollars) are between \$38,295 (low) and \$485,070 (high).

Annual emissions of NO_x using Method II for fleet average locomotive for year 2007 could be estimated as follows:

$$\begin{aligned} M_{NOx} &= 177 \text{ g/gal} \times 228 \text{ gal/day} \times 250 \text{ days/year} \times 1 \\ &\quad \times 10^{-3} \text{ kilogram/gram} \\ &= 10{,}089 \text{ kilograms/year} \end{aligned}$$

The costs associated with these emissions (in 1991 dollars) are between \$15,134 (low) and \$191,691 (high).

In order to approximate emissions from electrically powered rail cars, it is necessary to consider an equivalent emission source at a power plant, which could be powered, for example, by natural gas or diesel-powered gas turbines. Emission factors for gas turbines can be obtained from EPA AP-42 Document *Compilation of Air Pollutant Emission Factors*, Vol.1, Table 3.1-1 and/or 3.1.2, EPA, Office of Air Quality Planning and Standards, Research Triangle Park NC 27711, 1995.

Emission factors are presented for turbines burning gas and/or distillate fuel oil and expressed in g/kW-hr or lb/hp-hr (power output) or ng/J or lb/MMBtu (fuel input). To convert a standard from g/kW-hr to g/bhp-hr, multiply it by 0.7457.

Annual emissions of NO_x using emission factors in lb/hp-hr for fuel oil could be estimated as follows:

$$M_{NOx} = 400 \text{ hp} \times 5.60 \times 10^{-3} \text{ lb/hp-hr} \times 8760 \text{ hours/year} \times 0.454 \text{ kilogram/lb} = 8{,}909 \text{ kilogram/year}$$

The costs associated with these emissions (in 1991 dollars) are between $13,363 (low) and $169,262 (high). Note that these values are ranges of estimates, taking into account a wide range of factors, assumptions, and conditions.

(NO_x emission factors for natural gas-fired electric generating facilities are 3.53×10^{-3} lb/hp-hr or 0.44 lb/MMBtu.)

NOISE

Framework

Noise pollution is a more localized phenomenon than air pollution, and the scale of the impact depends on the density of the affected residential and commercial development as well as whether sound walls or other barriers help contain the noise. The nature of the noise (i.e., level, intermittency, frequency, time of day or night, etc.) affects its significance, as do the ambient levels of noise. The location is also relevant, as some land uses, such as libraries, churches, hospitals, parks, and residences, are more sensitive to noise than industrial or commercial areas.

Rough measures of impacts can be obtained from information on vehicle speed and average density of adjacent development. Higher vehicle speeds, acceleration rates, and operating weights typically result in increased noise emissions. Traffic levels also influence noise impacts: an additional vehicle-mile traveled on a low-volume roadway generally has a larger impact than an additional vehicle-mile on a high-volume road.[7]

Data and Analysis

Delucchi and Hsu (1997) updated and expanded on the work of Fuller et al. (1983) to estimate the total external damage cost of motor-vehicle noise in the United States. This estimate is a function of the percentage loss of housing value per decibel of noise above a threshold, the average annualized value of a housing unit, the number of housing units exposed to motor-vehicle noise, the amount of noise exposure above the threshold, and a scaling factor, and it accounts for costs in non-residential areas. The amount of noise above the threshold is a function of the speed, volume, and mix of vehicle traffic; the noise-absorption characteristics of ground surfaces; the extent that objects, such as hills and buildings, shield the receptor from the source; and other factors.[8]

The key parameters in this analysis are the damage cost per decibel, the damage threshold, and the extent of shielding. Studies of the shadow price of noise in the housing market indicate that each decibel of noise above a threshold reduces the value of a home by 0.2 percent to 1.3 percent. Ideally, one would estimate damage per decibel as a function of noise level, rather than assume that below some threshold (typically 55 dBA) the damage is zero and above which the damage per decibel is constant, but there is insufficient data to do this. Based on this model, Delucchi and Hsu (1987) estimate that motor-vehicle noise costs are $0.5 to $15 billion per year. This estimate of total damage is quite sensitive to the assumed damage threshold: if the threshold is 50 dBA rather than 55, the total damage roughly triples.

Assessments of noise impacts associated with expanded transit or automobile use should focus on the noise increment accompanying the change because housing transactions are expected to internalize existing noise impacts. Table 4-7 shows the marginal cost of noise as a function of VMT (based on a 10 percent increase in VMT) for various vehicle types and roadways. This table shows the noise costs of buses as two to six times greater than those for an average car, depending on road conditions. Since it is unclear how vehicle occupancy would affect noise levels, we prefer the vehicle-mile data shown in Table 4-7. We report Table 4-7 in its original form—dollars per 1,000 VMT—but in the rest of the text convert it to "cents per VMT," the measure used elsewhere in this Guidebook. For example, $2.96 per 1,000 VMT is identical to 0.3¢ per VMT (rounded): i.e., less than 1/3 of one cent.

The costs shown in Table 4-7 are "base case" estimates. As with other estimates of the environmental costs of vehicle use, the low and high estimates span several orders of magnitude; for example, the cost for light-duty autos on an interstate highway is $0.11 in the low-cost case and $40.11 in the high-cost case. The low- and high-cost cases, however, maintain the relative difference between vehicle types. Note also that noise damage is clearly case specific. Additions to VMT that result from adding a new road or transit guideway (where there was none before) are likely to be more damaging than more trips on an existing highway; ambient conditions and the density of surrounding development clearly make a difference.

To apply the costs in Table 4-7, the analyst should estimate the change in VMT (by mode, if possible) and roadway type and apply the costs shown. For example, assume an overly simple situation where a transit project will cause bus VMT on a principal arterial to increase by 200 VMT per weekday and will cause auto trips to decrease by 4,000 VMT per weekday. An analyst converts that to a 50,000 VMT per year addition for buses and a 1,000,000 VMT per year decrease for autos: the benefit of the resulting reduction in noise is $821 per year ((1,000,000/1,000 × $1.18) – (50,000/1,000 × $7.18)). This example, admittedly simplified and incomplete, suggests that noise impacts are likely to be insignificant: they will be too small to have any noticeable effect on net benefits unless the project is a big one that will create new noise in populated areas with low ambient noise.

[7] U.S. Department of Transportation, Federal Highway Administration, 1997.
[8] Delucchi, 2000.

TABLE 4-7 Estimated marginal cost of noise in urbanized areas (1991 dollars per 1,000 vehicle-miles traveled, base case estimates)

Vehicle Type	Interstate Highways	Other Freeways	Principal Arterials	Minor Arterials	Collector Roads	Local Roads
Light-duty autos	$2.96	$4.25	$1.18	$0.57	$0.07	$0.00
Medium-duty trucks	$8.50	$13.20	$7.02	$5.37	$1.05	$0.00
Heavy-duty trucks	$16.69	$30.80	$20.07	$29.93	$4.93	$0.00
Buses	$6.36	$9.77	$7.18	$6.42	$1.22	$0.00
Motorcycles	$17.15	$27.03	$8.71	$4.67	$0.56	$0.00

Source: Delucchi, 1997, p. 55. Marginal estimates are based on the assumption that VMT increases by about 10%.

Table 4-8 provides estimated noise costs for various modes, including buses, per passenger mile in the Boston area. Table 4-8 is consistent with the relative impacts shown in Table 4-7; the noise costs of a transit vehicle are four to five times those of a single-occupant vehicle on an expressway at peak hours. Tables 4-7 and 4-8 suggest that a transit project would need to remove at least two to six automobiles from the road per transit vehicle added to have a net reduction in noise costs, depending on roadway type and time of day.

Most of the data in this section covers passenger vehicles and buses, but not rail. We expect that a transit agency studying a proposed rail project would need to conduct a much more thorough analysis, such as an Environmental Impact Statement, which would necessitate more detailed noise measures and calculations than those covered in this report. For a less extensive study, such as an evaluation of a new bus route, the simpler method of estimating noise impacts by estimating changes in VMT by mode should provide a reasonable estimate of the value of noise impacts associated with a proposed transit improvement that affects the type and number of vehicle-miles traveled in a region.

WATER QUALITY

Framework

Water pollutants from transportation sources include heavy metals, particulates, organic chemicals, and other substances from vehicle exhaust, tires, oil, vehicle fluids, rust, and other sources. Tire wear, litter, and leaks of oil, transmission fluid, brake fluid, and antifreeze deposit pollutants on the roadway. These pollutants enter surface waters and groundwater through polluted rainfall, deposition of particulates, percolation, and stormwater runoff. Chemicals applied on or near roads, such as road de-icing salts, herbicides, pesticides, and fertilizers, can also enter waterways. In addition, vehicle fuels can taint water supplies through oil spills or leaking storage tanks. The increased impervious surface area associated with the road itself also speeds the conveyance of water—and pollutants—into streams, lakes, and other surface waters. Air pollutants can lead to water quality problems as well. For example, both nitrogen and sulfur oxides create acid precipitation that can harm aquatic life in lakes; also, deposits of nitrogen from NO_x emissions can contribute to excessive nutrient levels (eutrophication) in surface waters.

Data and Analysis

Delucchi notes that a number of factors make it difficult to determine the national cost of water pollution impacts from transportation. He reviewed the relevant literature and developed estimates for the total water pollution damage in the United States from motor-vehicle use ranging from $0.4 to $1.5 billion (see Table 4-9).[9] Litman (1999) estimates costs of 0.2 to 2 cents per mile for oil spills, road salt, hydrologic impacts, and other water pollution costs, and he suggests that total water pollution costs from roads and motor vehicles may total more than $28 billion annually.[10] In a 1976 study conducted for the United States, EPA estimated the total cost of road salt at $8 billion annually, including $600 million per year in damage to water supplies, vegetation, and health.[11] Based on original research and a literature review, Lee (1997) estimates water pollution costs associated with highways at $10 billion annually and transit impacts at $0.1 billion (1991 dollars).[12]

A completely different method for estimating the cost of water pollution is to estimate what it would take to reduce the pollution to very low levels (control costs). As a purely hypothetical example, assume that for $200 per year per vehicle all significant oil leakage could be eliminated. If the vehicle goes 10,000 miles per year, then the cost is 2¢ per VMT.

The analyst looking for a local estimate of costs faces several problems, the two most difficult of which are (1) that there are no data to distinguish among transit (bus, LRT, train) impacts and auto impacts and (2) that the rolled-up national averages are not directly applicable to local jurisdictions. (Converting average total values in Table 4-9 to costs per VMT yields costs on the order of 0.04¢ per VMT. On the

[9] Delucchi, 2000.
[10] Litman, 1999.
[11] U.S. Department of Transportation, Federal Highway Administration, 1997.
[12] Lee, 1997.

TABLE 4-8 Estimates of noise costs by mode in medium-density Boston area (1990 cents per passenger mile traveled)

	Single-Occupant Auto on Expressway	Bus Transit	Rail Transit
Peak	0.1	0.5	0.4
Off-Peak	0.1	0.2	0.3

Source: Apogee Research, Inc., 1993.
Note: Costs in this study for bus and rail appear to be estimated by a relative comparison to truck noise; assumed occupancy for calculating ¢/pmt not described.

other hand, Lee's $10 billion estimate would be about 0.5¢ per VMT). Thus, there are no good estimates of the marginal costs of water pollution from vehicle operation. That said, something in the range of 0.1¢ to 2¢ per VMT is what the data above suggests.

As with air pollution and noise, there are reasons to expect a bus to make a larger contribution to costs than an automobile (because it is a heavy truck with lower fuel efficiency). But a counterargument is that transit agencies do routine maintenance that keeps the average bus in better repair and leaking less oil than the average auto. Since the costs are relatively small and the differences between vehicle types undeterminable, we recommend dropping this impact from any local evaluation, unless special conditions suggest including it.

Sample Calculation

Many of the impacts described in this section are (1) either relatively small compared with user benefits (Chapter 3) or with direct costs of construction and operation (Chapter 5) or (2) not much different between base case and bus alternatives for many projects, because the reduction in environmental impacts that results from reduced VMT when auto trips shift to bus (for air quality and noise) is at least partially offset by the greater environmental impacts of a bus vehicle-mile compared with an auto vehicle-mile. Regarding this second point, for both air quality and noise the evidence we reviewed is that a bus has an impact that is 1 to 10 times the impact of a car. This variability is not all uncertainty: some of it results from real variability in conditions (e.g., noise impacts clearly vary depending on ambient levels and surrounding development).

Our assessment is that it is reasonable to assume that, as a crude point estimate, the air quality and noise impacts of a bus vehicle-mile are on the order of five times greater than those of an auto vehicle-mile. Thus, if the travel demand model (or other means of estimate) suggests that a transit project will reduce auto VMT by about five times more than it will increase bus VMT, the environmental impacts (as measured by the studies cited in this chapter) would be about the same. In that case, an analyst can skip the details of valuation: if the physical impacts are approximately equal, so are the costs of the impacts.

This back-of-the-envelope analysis suggests an obvious conclusion: bus transit projects will have to be effective (get good ridership, much of which is being shifted from the auto) if they are to have measurable environmental benefits. To be effective, they will have to offer service in high-demand corridors. Transit projects that send diesel buses to outlying areas in the interest of providing low-cost mobility are not likely to have net environmental benefits: losses are even possible, since the mobility may simply increase, not shift, trips. Those new trips have benefits, but those benefits are measured in Chapter 3 as benefits to users.

In higher-density, congested corridors, bus trips might result in a 10-to-1 or even (with hyper-congestion) 20-to-1 substitution of auto trips for bus trips. Assume an analyst could document that a transit project reduced auto VMT 20 times more than it increased bus VMT (bus VMT increase 50,000; auto VMT decrease 1,000,000). For this to happen, it would probably have to be the case that the existing bus service was inefficient, and the new project, in part, used existing buses more efficiently. Assume further the simple rule of

TABLE 4-9 Estimates of annual water pollution costs of motor-vehicle use, 1990–1991 (billions of 1991 dollars)

Water Pollution Impact	Low Est.	High Est.
Health and environmental effects of leaking motor-fuel storage tanks	$0.1	$0.5
Environmental and economic impacts of large oil spills	$0.2	$0.5
Urban runoff polluted by oil from motor vehicles	$0.1	$0.5
Health and environmental effects of leaking solid-waste storage sites	not estimated	not estimated
Total (not including unestimated impacts)	**$0.4**	**$1.5**

Source: Delucchi, 2000, Table 6.

thumb we just posited. In this case, the transit alternative would have net environmental savings equal to 75 percent of the auto VMT, equal to 750,000 VMT per year. Previous estimates in this chapter are based on air quality costs in the range of 2¢ to 10¢ per auto VMT, and noise costs in the range of 0.01¢ to 0.4¢ per VMT. Assume a combined point estimate of 5¢ per VMT: then the annual value of the environmental savings is on the order of $40,000: real money, but probably an insignificant consideration in what will likely be a multimillion dollar investment decision.

OTHER IMPACTS

There are several other categories of secondary impacts that various researchers have identified as real impacts that are not double-counting of impacts enumerated elsewhere (Section III of this guidebook deals with those impacts that we believe are primarily derived from and different ways of expressing the savings in travelers' user costs). The main categories are

- Parking,
- Transportation services,
- Other social services, and
- Accidents.

The first three of these categories are measurable as direct construction, operation, or maintenance costs: they are addressed in Chapter 5. The last category, Accidents, fits the theme of this chapter: accidents create real costs, some of which may not be completely perceived by users (i.e., some of the costs are external). If so, the unperceived part of those costs must be estimated and added to the benefit-cost calculations. We address that possibility in the next section.

ACCIDENTS

Framework

Travelers, and the vehicles they travel in, sometimes have accidents. Other things being equal, the more travel that occurs (measured by trips, vehicle-miles, or passenger-miles), the more accidents there will be. The relationship, in theory, is likely to be somewhat non-linear, with accidents increasing at a greater rate than vehicle-miles because congestion increases the risk of accident.

Accidents vary substantially in their consequences: from minor damage to a vehicle to multiple fatalities. Thus, the value of preventing an accident varies. A lot of research has been done on the value of accident losses and accident prevention. That research typically values the various components of accident costs: the value of a human life (fatalities); the cost of injury and other health effects (morbidity); the cost of property damage (primarily to vehicles); and miscellaneous costs (e.g., police, firefighters, EMS, and wreckers to clean up the accident; courts, and so on). Sometimes insurance costs are counted, though that raises issues of double-counting.

Therefore, again in theory, a transit analyst would like information about two related but distinct issues: (1) whether a particular transit improvement changed the number or severity of accidents and (2) what value to place on those changes.

Few transit projects (none that we know of) are undertaken with a principal goal being the reduction of a known traffic hazard. Thus, few project evaluations (if any) make explicit estimates of changes in the type, number, or severity of accidents. Travel demand models do not provide such estimates. Rather, the typical project evaluation, if it considers the value of accidents at all, does so by (1) estimating changes in VMT (perhaps by vehicle type) and (2) applying a general relationship between VMT and accidents to calculate changes.

Though that method is typical, it is not inevitable. There are clearly cases of highway projects done primarily for safety reasons (straightening curves, changing the geometrics of dangerous intersections or interchanges). Experience with such changes must provide engineers with some data about accident rates before and after the changes or (on a cross-sectional basis) with different accident rates for different configurations. Thus, it is conceivable that an analyst could make explicit estimates for changes in accidents that will result from a specific transit project.

Even if such a detailed analysis were done, however, there are still problems of sorting out what should count where. We argued in Chapter 3 that a lot of the costs of accidents are already included in the perceived cost of travel through a combination of insurance and travel time differentials. A driver knows that there is some risk of an accident with any trip, and that trips at certain times and locations are riskier than others. If highway conditions are particularly bad (at night, bad weather) they may skip a trip entirely. They buy insurance to reduce their risk of financial loss (primarily property losses, medical costs, and liability risk): that insurance is part of their long-run perceived costs.[13]

The point is that some part of accident costs are perceived by travelers and included in their calculation of travel cost. At a minimum, taking estimates of the full costs of accidents (e.g., from studies that show that the cost of death, injury, property damage, clean up, courts, and mental suffering are billions of dollars per year for the United States) as 100 percent additive to other impacts we have previously discussed in Chapter 3 and 4 definitely overstates the impacts.

Some of the costs of accidents, however, are almost certainly externalized by travelers. For example, the costs paid by municipal and state governments to respond to accidents are probably not part of the costs that travelers perceive when making travel decisions, even though they may ultimately pay a share of those costs as local, state, and federal taxpayers.

[13] In theory, employees should consider insurance coverage as part of their overall compensation when they take a job: in that sense, the costs are perceived. In practice, many employees may pay little attention to this cost. We assume that travelers count employer-paid insurance as a long-run cost.

As hard as it may be to estimate the costs of accidents, it is harder still to determine what portion of that estimated cost is already accounted for in the user benefit calculations described in Chapter 3.

Data and Analysis

Murphy and Delucchi (1998) "review the purpose, scope, and conclusions of most of the recent major U.S. studies [on the social cost of motor vehicle use], and summarize the cost estimates by individual category." Most of these studies have explicit estimates for accident costs. Rather than go into the details of how all the components of accident costs are calculated, we refer analysts to that paper and the reports it cites. The estimates from the strongest studies, when converted to cost per vehicle-mile, range from about 1¢ to 20¢. Within this range is the National Highway Traffic Safety Administration estimate that the economic cost in 1994 of motor vehicle crashes was more than $150 billion,[14] approximately 6¢ per vehicle-mile.[15]

Of the studies we reviewed, Ketcham and Komanoff (1992) distinguish between accident costs borne by users and those borne by non-users: by their calculations, non-users bear roughly 25 percent of the costs. If we assume (a big assumption) that users (travelers) roughly perceive the accident costs that they are risking, then this study suggests that about 75 percent of the accident costs are perceived. If so, that narrows the range of external accident costs to about 1¢ to 5¢ per vehicle-mile.

These estimates are not broken out by vehicle type. Table 4-10 shows one set of estimates for costs per vehicle-mile. The costs for the average auto (12¢ per VMT) are in the range we discussed above. This table suggests that a bus has over 2.5 times the accident cost of a car per VMT. Table 3-13 in Chapter 3, however, provides a very different conclusion: the number of fatalities and injuries on buses is so small that it is almost immeasurable on the basis of cents-per-VMT, while auto costs are on the order of 1.6¢ per VMT. Table 3-13, however, looks at just fatalities and injuries, not comprehensive costs, and looks at what mode people were in when they were hurt, not what mode was responsible for the damage.

As a final way to look at accident cost data, consider Table 4-11, which shows a breakdown of the component costs of accidents. It illustrates that the severity of an accident makes a difference to its costs. That point is obvious, but its implications are important. First, it means that any of the average estimates of accident cost per VMT are not only approximations, but they are approximations for situations where an analyst can expect the distribution of accident types to be roughly comparable with national averages. The smaller the metropolitan area and the transit improvement project, the worse that assumption. Second, it means that any attempt to estimate accident costs based on local data about actual accidents must be clear about the type of accidents being increased or decreased by the improvement.

TABLE 4-10 Comprehensive estimate of motor vehicle accident costs

Mode	Cost Per Vehicle-Mile
Bus	$0.32
Light truck	$0.19
Medium/heavy truck	$0.13
Combination truck	$0.23
Car (average)	$0.12
Car, Drunk driver	$5.50
Car, Sober driver	$0.06
Motorcycle	$1.50

Source: Presentation of Federal Highway Administration Colloquium on Social Costs of Transportation, December 12, 1994, Washington, D.C.; Miller *et al.*, "Railroad Injury: Causes, Costs, and Comparisons with Other Transport Modes," *Journal of Safety Research*, Vol. 25, No. 4, 1994, pp. 183-195, as cited in Litman, 1999.

In 1994, the annual cost of motor vehicle crashes in the United States totaled more than $150 billion. This total represents the economic costs associated with 40,676 fatalities, 5.2 million non-fatal injuries, 3.7 million uninjured vehicle occupants, and 27 million damaged vehicles. Property damage costs totaled $52.1 billion, and lifetime losses in marketplace production were estimated at $42.4 billion. Each *fatality* represented average discounted lifetime economic costs to society of more than $830,000, mainly due to the value of lost productivity in the workplace and household. However, this figure does not represent less tangible consequences, such as pain and suffering, to individuals and families. Nor does it incorporate the concept of "willingness to pay" to avoid death or injury.

The National Highway Traffic Safety Administration reports a value of reducing fatal risks in the range of $2 to $5 million per life saved.[16] The cost of *non-fatal injuries* ranged from about $1,100 to more than $700,000 per individual for the most severe damages. Transit riders submit a high number of accident claims with non-fatal injuries. The cost of crashes in which only *property damage* occurred totaled $38.9 billion, or more than $1,600 per damaged vehicle. The property damage portion of this total is about $1,300; the additional costs include emergency response, insurance administration, and travel delay. Additionally, crashes with injuries or fatalities also include property damage, raising the total for all property damage to $52.1 billion. Costs per damaged vehicle range from about $1,300 for property-damage-only to $9,600

[14] Blincoe, 1996.

[15] U.S. Department of Transportation, National Highway Traffic Safety Administration, 1999, Table 2 estimates the total vehicle-miles traveled in 1994 at 2,358,000,000,000, yielding a cost of approximately 6.38 cents per vehicle-mile. Blincoe, 1996, estimates the total economic cost of crashes in 1994 at $150.5 billion.

[16] Also, based on a range of other studies, the *1997 Federal Highway Cost Allocation Study: Final Report* uses low, middle, and high estimates of the cost of a statistical death of $1 million, $2.7 million, and $7 million, respectively (Federal Highway Administration, http://www.ota.fhwa.dot.gov/hcas/final).

TABLE 4-11 Summary of unit costs of accidents (1994 Dollars)

	Property Damage Only	MAIS 0	MAIS 1	MAIS 2	MAIS 3	MAIS 4	MAIS 5	Fatal
Injury Components:								
Medical	$0	$1	$956	$8,144	$28,064	$100,820	$354,819	$12,089
Prem. Funeral	$0	$0	$0	$0	$0	$0	$0	$3,389
Emergency Medical Svc.	$28	$19	$152	$337	$506	$1,150	$1,171	$1,055
Voc. Rehab.	$0	$0	$15	$99	$217	$410	$620	$0
Market Productivity	$0		$1,315	$11,645	$35,776	$58,073	$184,260	$576,266
Household Productivity	$42	$28	$413	$3,598	$10,903	$18,746	$54,119	$132,630
Insurance Admin.	$103	$69	$573	$3,481	$11,219	$21,165	$49,576	$28,646
Workplace Cost	$44	$29	$217	$1,681	$3,671	$4,043	$7,049	$7,489
Legal Costs	$0	$0	$136	$2,179	$7,655	$17,087	$45,919	$60,766
Subtotal	**$218**	**$146**	**$3,777**	**$31,164**	**$98,011**	**$221,494**	**$697,533**	**$822,328**
Non-Injury Components:								
Travel Delay	$125	$106	$203	$203	$203	$202	$203	$453
Property Damage	$1,320	$877	$3,263	$3,356	$5,771	$8,346	$8,018	$9,138
Subtotal	**$1,446**	**$983**	**$3,466**	**$3,559**	**$5,974**	**$8,548**	**$8,221**	**$9,591**
TOTAL	**$1,663**	**$1,129**	**$7,243**	**$34,723**	**$103,985**	**$230,042**	**$705,754**	**$831,919**

Source: Blincoe, 1996, Table 2.

Note: MAIS, the Maximum Abbreviated Injury Scale, represents an estimation of the severity of accident, which is typically estimated soon after the crash occurs (see Blincoe 1996 for a more detailed explanation). Unit costs are on a per-person basis for all injury levels; "property damage only" costs are on a per-damaged vehicle basis.

for fatal crashes.[17] Another study estimates costs per accident as follows: fatality, $1.2 to $2.9 million; injury (no fatality), $24,000 to $83,000 (higher incapacitating injuries); property damage only, $2,000 (1996 dollars).[18]

We recommend analysts use one of the following methods to estimate accident costs:

- Make an adjustment for the component of those costs that is already counted in the perceived travel costs that are part of the consumer surplus calculation in Chapter 3. A reasonable estimate is probably 25 percent to 75 percent.[19]
- *Where accident data is available* and proposed improvements can be shown likely to reduce those accidents by some estimated amount (or increase them in other places because of greater volumes without any improvements), estimate directly accident cost changes. Accident reports usually give an indication of fatalities, injuries, and property damage. Table 4-11 gives some idea of the costs of that damage, depending on severity.
- Where accident data is unavailable or the scope or type of transit improvement makes estimating changes in specific types and locations of accidents impractical, estimate accident costs based on changes in VMT, by vehicle type if data exist, and in the aggregate, if not. A reasonable range of estimates for the unperceived component of total accident costs across all modes is probably 1¢ to 10¢ per VMT. Our review of the literature suggests to us that the true value is closer to the low end than the high end: 3¢ to 4¢ per VMT is our best estimate of an average point value.[20]

[17] Blincoe, 1996.

[18] Weisbrod and Weisbrod, 1997. These estimates are similar to those of the often-cited Urban Institute study, *The Costs of Highway Crashes, Final Report (1991).*

[19] The choice of the percentage of total accident costs that are perceived can significantly affect benefit estimates and comparisons between transit and highway. (DeCorla-Souza, TRB paper no. 990227).

[20] Most reviewers of drafts of this guidebook found it too long and detailed. Its length was reduced. As a result, some variations on the many techniques described in Chapters 3 through 8 are not mentioned. In the case of accidents, for example, the preponderance of evidence is that big vehicles (trucks) reduce safety for smaller ones (autos). By analogy, one might expect buses to have the same effect. Thus, there could be an interaction: as auto VMT becomes bus VMT, the remaining auto VMT has a slightly higher accident risk, which reduces (however slightly) the savings in accident costs from reduction in total VMT.

CHAPTER 5

TRANSIT'S DIRECT COSTS AND REVENUES

SUMMARY

This chapter describes how to include the capital and operating costs of transit in the cost-benefit framework. These are costs that are paid by non-transportation users, including transit agencies, private sources (if they help to administer transit programs), and other public agencies. Capital costs are primarily for right-of-way, facilities, and vehicles (rolling stock). Operating costs are recurring costs that include salaries, wages and benefits, materials and supplies, utilities, and other expenses related to ongoing operation and maintenance. National (average) data are available to help analysts estimate these costs, however local data should be used whenever possible. Agency staff, consultants, and vendors can usually provide data on capital costs and can also help to estimate transit patronage from which operating costs can be derived.

Analysts should also include other direct costs related to, but not specifically associated with, the construction or operation of the transit improvement. Transit improvements, for instance, that require other roadway improvements to support operations should account for these additional costs, while benefits (cost savings) should be counted when reduced highway traffic can reduce costs correlated with traffic levels (e.g. policing). The other major type of direct cost that should be included is avoided costs not already perceived by transportation users. Auto users, for instance, often only pay a portion of the full cost of parking. The amount that they actually pay for parking and save by switching to transit is calculated when direct user benefits are estimated. The cost that others (typically employers) pay should also be estimated and tabulated separately.

Revenue accounting is primarily done to determine financial feasibility (i.e., Will revenues cover costs?). Revenues are not additional societal benefits. In the benefit-cost framework, it is really only necessary to compare benefits and costs, although it is worthwhile to analyze revenue devices (e.g., fare levels) that will significantly affect user cost perceptions (described in Chapter 3).

OVERVIEW

This chapter discusses how to integrate the direct costs of the transit improvement into the benefit-cost analysis and discusses the role that revenue considerations play in this analysis. The purpose of this discussion is to make sure that the resources that are used to implement and operate the transit improvement are properly counted for comparison with the benefits that the transit improvement generates.

We call the resources that are used to implement and operate the transit improvement *direct costs*. Project evaluation requires an estimate of any change in direct costs that is specifically associated with implementation of the transit improvements. Thus, the analyst should be interested in the dollar value of costs that are

- Incurred for the planning, construction, operation, or maintenance of transit or other transportation facilities or equipment;
- Typically paid by the non-user sector (as opposed to many user costs that are paid directly by travelers, such as gas, insurance, and travel times); and
- Measured *relative* to the base (non-improvement) case. (For this third condition, the analyst needs to be interested only in *changes* in costs associated with the improvement, as against the circumstances that will prevail without the improvement.)

For this guidebook, direct costs are defined to include only direct public sector expenditures incurred in the course of implementing a transportation project. This does not mean, however, that only transit agency costs should be included. Any direct cost incurred by a transportation agency or non-user that is required to implement the transit improvement is considered a cost (including private sector costs of administering transit programs). If police department costs, for example, need to be increased to police the transit facility, this cost should be included in the direct costs enumerated in this chapter. No user costs are included in direct costs because these are already accounted for in the users' perceived cost calculations. Like benefits, periodic costs (such as annual operating and maintenance expenses) and any other costs that are not borne immediately are reduced to a present value through discounting.

The analysis must also treat properly the revenues associated with the transit improvement. Specifically, it must account for any changes in revenue that occur as a result of the transit improvement. The revenues of interest are

- Any sources of funds that are collected by transportation agencies or companies from users of the transportation system (either directly, e.g., fares, tolls, and gas taxes; or indirectly, e.g., employer taxes and property taxes); and
- Depending on the circumstances, these revenues may include transfers from other levels of government (e.g., capital or operating grants from the federal government to local transit agencies).

In general, transit's direct costs are borne by the transit agency and the public, or a private provider of transit services. The transit agency or private firm typically generates the revenue needed to defray these costs through user fees (fares) or general taxes. The precise mechanism for collecting revenues is irrelevant to benefit-cost analysis in the accounting sense. What is needed to perform the benefit-cost calculation properly is an estimate of all of the direct costs attributable to the transit improvement; these are then compared with the user- and non-user benefits calculated in Chapters 3 and 4. Benefit-cost analysis is a way to determine *economic feasibility*, i.e., whether society gets more out of a transit improvement than it puts in. For the benefit-cost test to be performed, the sources of revenue do not even have to be identified. It is enough to compare benefits with costs: revenues can generally be ignored. There are only a few caveats to this general rule:

- The benefit-cost calculation is affected by revenue devices that affect user cost perceptions. Consequently, it is always best to understand the likely sources of revenue before embarking on a benefit-cost analysis. For example, if the transit service levies fares, these fares need to be known and incorporated in the perceived cost calculations that produce the user benefit estimates.
- Taxes affect regional economic efficiency. Hence, when unrelated economic activity is taxed to subsidize transit services, it imposes efficiency costs. The reason is that most taxes change economic behavior. For example, financing transit through a tax on income may cause people to work less and, thereby, produce less income. Similarly, a tax on property may change people's willingness to acquire or maintain their property, reducing the output of property-related services. The so-called *excess burden* of a tax is the value of these ancillary losses in economic output. The calculation of excess burdens is complex and beyond the scope of a transit benefit-cost manual.
- An underlying assumption of benefit-cost analysis is that any excess revenue generated by an activity is returned to society in a beneficial way. That is an important basic assumption of this guidebook. In general, if a transit improvement is being evaluated and chosen consistent with the principles described in the guidebook, this assumption is reasonable.
- Revenue from outside the political jurisdiction of the transit improvement is sometimes considered "free" from the viewpoint of local decisionmakers. It is not free, of course, from a societal standpoint, and true, economic efficiency is unaffected by this local perspective. Nevertheless, for a locality with a limited budget, the appropriate selection among alternative transit projects can be affected by the extent to which the project relies on "free" sources of revenue. For reasons discussed in Chapter 2, economists typically disapprove of that type of analysis because it sets economic efficiency aside as the key criterion for investment decision. But if it must be implemented, it can be done by "zeroing out" those direct transit system costs that are financed by these "free" funds.

With these caveats, the revenue characteristics of the transit improvement scenario are largely irrelevant to the calculation of basic benefits and costs that is the focus of Section II of this guidebook. The focus of this discussion is on *economic* feasibility as measured through a benefit-cost calculation.

Revenues are, of course, of interest for an evaluation of a related, but quite different, feasibility test: whether the improvement generates enough money to pay for its development and operation. This test is called the test of *financial feasibility* (*revenue*-cost analysis, not *benefit*-cost analysis). This test is important in determining whether the improvement has the potential to be implemented, but does not affect the underlying economic efficiency potential of the improvement.

> *Key Point: While revenue sources are almost always of interest to policymakers, in the context of benefit-cost analysis they are <u>transfers</u>, not benefits, and should not be added to other benefits.*

These considerations lead to the following organization for this chapter. It first discusses costs, and then revenues. An implication of the preceding discussion is that the *direct costs of transit* are of key importance in a benefit-cost analysis: they are a big part of the costs that must be compared against the user and non-user benefits of a transit investment. These costs consist of both direct costs associated with the transit program and other transportation costs affected by the improvement. Thus, this chapter discusses those costs in two sections: (1) the direct costs of implementing a transit improvement, program, or policy that falls on transportation agencies (agencies whose primary responsibility is the construction, operation, and maintenance of transit and highway facilities); and (2) the direct costs to other agencies that occur as a result of the improvement (in the section, Other Direct Costs).

DIRECT COSTS OF TRANSIT IMPROVEMENTS TO TRANSPORTATION AGENCIES

Framework

There are two dimensions to direct transit program costs—(1) capital and (2) operating and maintenance (O/M) costs:

- **Capital costs** are primarily for right-of-way, facilities, and rolling stock. The costs of new fixed guideways for transit (rail or highway) would be included in facility costs, but an allocation for the costs of existing highways that normal buses use usually is not (it is a “sunk” cost).
- **Operating and maintenance costs** include salaries, wages, and benefits; services; materials and supplies (e.g., fuel and tires); utilities; casualty and liability costs; taxes; purchased transportation (contracted transportation and services); expense transfers, and miscellaneous expenses. Operating costs can also be separated by specific function. These functions are vehicle operations and general administration. Operations include vehicle operation (including ticketing and fare collection), vehicle maintenance, system security, transit-related roadway maintenance, and non-vehicle maintenance.

Data and Analysis

Tables 5-1 and 5-2 show the kinds of information that a transit agency should try to assemble about its own direct costs. Capital and operating costs can vary depending on the mode and type of facilities offered; location (routing and alignment); system size (capacity); level and quality of the service provided; and areas served by the transit system. Various departments or consultants of a transit agency will have information needed to compile rough cost estimates for a given project. If a project is big enough and far enough along in the decision-making process to merit a rigorous evaluation of its benefits and costs, then it is very likely that an agency will have some rough estimates of its costs.

Agency staff, staff at other public agencies (e.g., a state or regional agency), consultants, or vendors will have information about capital costs for rolling stock. Table 5-1 shows the kind of information desired. If the project is a large one, each of the columns may be further subdivided both by cost category and time (if the project is developed over several years). Detailed spreadsheets or cost reports would frequently be used in developing a table like that shown as Table 5-1.

> *Key Point: For very preliminary planning analysis, order-of-magnitude estimates of capital costs from standard sources or comparable projects should be adequate. As planning gets more detailed, so will the cost estimating, and attention to local conditions and costs will increase.*

There are some national data sources that can be used for these estimates and other estimates in this chapter. Data from the *Characteristics of Urban Transportation Systems*[1] are largely based on 1989 Section 15 data. More recent data, though slightly different in coverage and definition, comes from APTA and other sources. This guidebook uses 1997 APTA data in the example tables.

The same experts can estimate level of service and its characteristics (e.g., speed and frequency) for the transit project. These data can be used to estimate patronage of the service, which, in turn, can define operating costs (Table 5-2). Most transit agencies will have the data to be able to make estimates for the operating costs of expansions to existing services (e.g., adding a new bus line). Local data will be superior to national averages.

Whenever transit alternatives have been specified and some planning-level engineering cost estimates are available for construction and operation, those estimates will probably be superior to national averages. Similarly, if an analyst is at an agency that is already operating the type of facility or service that is under consideration for addition to the system, then agency-specific estimates of per-unit operating costs should be used. In some cases, however, agencies may be considering new services for which they have no operating experience, or may wish to see how their operating estimates compare with some benchmarks. Tables 5-3 through 5-6 show average capital and operating costs for U.S. transit agencies.

The data are compiled from the1997 National Transit Database and administered and compiled by the Federal Transit Administration. Tables 5-3 through 5-5 show capital and operating costs, for different transit modes, for three different city sizes. Only the dollars resulting in capital expenditures for the given year are reported. The largest component of each cost category (rolling stock under capital costs; labor under operating costs) is displayed in a per-unit-cost basis. Data are simple averages of public transit agency modes where data from more than two transit agencies are available, in 1997 dollars. One consequence of this simple-average methodology is that per-unit costs reported by larger agencies are given no more weight than costs of smaller agencies.

While the cost per passenger-mile estimates shown are based upon historical ridership levels (from many diverse cities), we recommend using this unit of measure because (1) it better reflects what transportation is trying to do—move a traveler (person) some distance (mile); moving a vehicle is a derived objective; (2) it makes comparisons across modes more intuitive and highlights conclusions about efficiency

[1] Prepared for Federal Transit Administration under a grant to The Urban Institute, September 1992, by Cambridge Systematics, Inc.

TABLE 5-1 Transit capital costs for a proposed transit improvement (template for type of data desired)

Transit Mode	Rolling Stock	Facilities	Other	Total
Mode 1				
Mode 2				
Mode 3				
Total				

Source: ECONorthwest.

(e.g. comparing $/passenger-mile for buses versus $/passenger mile for cars); with cost per vehicle-mile, transit always loses—even if a transit vehicle is carrying 50 times more people than an automobile; and (3) cost per revenue-vehicle-mile does not account for deadhead costs—real costs that are incurred and need to be tabulated.

In any event, we expect that most users will be doing their own ridership estimates, which will change their costs from the examples provided.

The data in the previous tables are easier to use for project sketch-planning if they are converted to costs per passenger-mile. This permits the analyst to link direct cost calculations to the service and benefit calculations, permitting quick comparisons of project alternatives. Table 5-6 shows estimates of passenger-miles per capita in a transit agency service area. It displays the minimum, maximum, and average annual passenger-miles per capita for the three service area sizes used in the previous tables. An analyst can use these estimates (or, better, those of his or her own transit agency) to convert capital and operating costs to costs per passenger-mile.

Key Point: An analyst can use estimates from national data (or, better, those of his or her own transit agency) to convert capital and operating costs to costs per passenger-mile, which may be easier to use for sketch-level planning analysis.

OTHER DIRECT COSTS

Framework

Other direct costs not specifically associated with transit operation could change as the result of a transit improvement. There are two general types of costs to consider in this context:

TABLE 5-2 Transit operating costs for a proposed transit improvement (template for type of data desired)

Expense Class	Function				
	Vehicle Operations	Vehicle Maintenance	Non-Vehicle Maintenance	General Admin.	Total Expenses
Labor					
Operators' salaries and wages					
Other salaries and wages					
Fringe Benefits					
Services					
Material and Supplies					
Fuel and lubricants					
Tires and tubes					
Other					
Utilities					
Casualty and Liability Costs					
Taxes					
Purchased Transportation					
Miscellaneous Expenses					
Total Expenses					

Source: ECONorthwest.

TABLE 5-3 Capital and operating costs by travel mode for small cities (population <200,000) (1997$)

	Commuter Rail	Heavy Rail	Light Rail	Bus	Vanpool	Demand Responsive
	Small City (Service Area Population <200,000)					
Transit Agencies Reporting	-	-	-	225	1*	241
Capital Costs						
Rolling Stock						
per passenger trip	-	-	-	$ 0.83	-	$ 3.65
per passenger mile	-	-	-	$ 0.24	-	$ 0.65
Total Capital Costs						
per passenger trip	-	-	-	$ 1.15	-	$ 3.78
per passenger mile	-	-	-	$ 0.31	-	$ 0.69
Operating Costs						
Labor(incl. fringe benefits)						
per passenger trip	-	-	-	$ 1.45	-	$ 6.24
per passenger mile	-	-	-	$ 0.43	-	$ 1.20
per bus/train mile	-	-	-	$ 1.77	-	$ 0.99
per bus/train hour	-	-	-	$ 23.87	-	$ 12.74
Total Operating Costs						
per passenger trip	-	-	-	$ 2.93	-	$ 13.43
per passenger mile	-	-	-	$ 0.78	-	$ 2.76
per bus/train mile	-	-	-	$ 3.12	-	$ 2.32
per bus/train hour	-	-	-	$ 43.30	-	$ 30.38

*Note: Data compiled from less than 3 agencies are not reported.

Source: ECONorthwest, National Transit Database, 1997.

- Required improvements or other improvement costs that are imposed on other parts of the transportation system and
- Changes in the cost of services financed by non-users.

The first of these types of costs is relatively easy to characterize. The transit improvement may require roadway or other improvements to support transit operations, or it may acquire property without market transactions. These are often not included in the direct cost accounting of the project itself, but rather are passed along to other jurisdictions, agencies, and private parties. All such direct costs, whether paid for as part of the improvement or not, should be valued at their fair market value and included as direct costs. If service actually reduces highway congestion, then other operating costs that are correlated with that congestion (e.g., highway patrol and municipal traffic courts) may be reduced.

The second type of cost involves more subtle issues. If a service is paid for directly by users, through user charges, the consumer surplus calculation properly measures the benefits of saving these costs. Because the savings in user charges is part of the user benefit calculation, the savings in the *costs* underwritten by those charges is thus automatically accounted for. There are some services, however, that are paid for indirectly, through general taxes or through other non-user charges. Some individuals, for example, enjoy "free" parking at their place of work, paid for by their employer (though, ultimately, by the worker in the form of lower wages). To the extent that the transit improvement permits some travelers to travel without the need for parking, there is a reduction in the cost of providing parking spaces, relative to the base case. Since the cost of this service is not reflected in user charges, however, we cannot count on the user-benefit calculation to automatically account for such cost changes. They must be calculated separately. Savings in this type of cost are sometimes called *avoided costs*, referencing the notion that these are costs that would otherwise have occurred, but were avoided by making the transit improvement.

Since a lot of the transportation literature refers to avoided costs (usually, as the cost of auto travel that is avoided when travelers shift to alternative modes, change origins and destinations to reduce trip length, or drop the trip completely), we want to clarify here what should and should not be counted. Avoided costs are the benefits of avoiding the costs that (1) would have been incurred if an alternative choice had been made *and* (2) were not considered in making the choice. For example, suppose a traveler is deciding between traveling by bus or by auto. The traveler's choice of transportation modes is determined in part by the costs he or she incurs in using those modes. In this case, the price of gasoline, auto travel time, and parking costs paid out-of-pocket by the traveler will all be considered when deciding his or her demand for taking the bus.

While these costs are foregone when the traveler opts for the bus over the auto, they are not considered as avoided costs in this context because they are explicitly taken into

TABLE 5-4 Capital and operating costs by travel mode for medium cities (population >200,000 and <1,000,000) (1997$)

	Commuter Rail	Heavy Rail	Light Rail	Bus	Vanpool	Demand Responsive
	Medium City (Service Area Population 200,000-1,000,000)					
Transit Agencies Reporting	4	3	5	156	8	155
Capital Costs						
Rolling Stock						
per passenger trip	$ 4.63	$ 0.22	$ 1.27	$ 1.35	$ 1.57	$ 3.89
per passenger mile	$ 0.16	$ 0.02	$ 0.91	$ 0.22	$ 0.04	$ 0.48
Total Capital Costs						
per passenger trip	$ 10.09	$ 1.61	$ 7.49	$ 1.61	$ 1.48	$ 4.95
per passenger mile	$ 0.34	$ 0.16	$ 3.56	$ 0.27	$ 0.04	$ 0.64
Operating Costs						
Labor(incl. fringe benefits)						
per passenger trip	$ 0.91	$ 2.83	$ 1.18	$ 1.37	$ 0.47	$ 4.66
per passenger mile	$ 0.03	$ 0.33	$ 0.59	$ 0.32	$ 0.01	$ 0.72
per bus/train mile	$ 3.95	$ 27.05	$ 10.69	$ 2.01	$ 0.12	$ 0.71
per bus/train hour	$ 147.67	$ 697.60	$ 134.73	$ 28.09	$ 4.71	$ 10.29
Total Operating Costs						
per passenger trip	$ 12.73	$ 3.33	$ 1.57	$ 4.26	$ 1.82	$ 16.97
per passenger mile	$ 0.50	$ 0.38	$ 0.79	$ 0.87	$ 0.05	$ 2.36
per bus/train mile	$ 39.41	$ 31.82	$ 14.02	$ 4.46	$ 0.42	$ 2.43
per bus/train hour	$ 1,404.83	$ 828.66	$ 178.81	$ 64.79	$ 16.30	$ 36.40

Source: ECONorthwest, National Transit Database, 1997.

account when deciding the bus/auto choice. Consequently, the benefit of foregoing these costs is automatically captured in the consumer surplus calculation for this traveler.

Other costs that are not explicitly factored into the traveler's decision are considered avoided costs. These avoided costs consist primarily of external costs and costs borne by others that a user does not actively consider when making his transportation choice. Examples of these avoided costs include the costs of congestion, emissions, noise, increases in accident rates, and the employer's share of parking costs. These costs are avoided when the traveler chooses to travel by bus over auto, but, unlike direct user costs, these costs are not explicitly factored into the decision of whether or not to travel by bus or by auto.

Key Point: Many of the costs of auto travel that a shift to transit allows a traveler to avoid (hence, "avoided costs") are already counted as benefits in the calculation of consumer surplus (Chapter 3). Costs that a traveler does not actively consider when making a transportation choice may, however, appropriately be considered as additional benefits of a new transit project if it allows these costs to be avoided.

Given these definitions, there are three types of services that may generate avoided costs as the result of a transit improvement:

- **Transportation support services**. Police, fire, and roadway emergency services are frequently provided through general tax levies, but provide services to highway and transit travelers. To the extent that driving is reduced, some of these costs may be reduced (avoided) from what they would have been in the absence of the transit improvement, and the improvement should be credited with that benefit. Less direct are hospital and other emergency medical services that are paid for partly by user-borne costs (i.e., insurance charges), but that may also be underwritten by general levies.
- **Parking**. Employer parking is often underwritten by employers and provided free to employees. If the transit improvement reduces the need for parking, this too can be a source of avoided costs.
- **Other public services**. Some analysts argue[2] that transit can provide low-cost mobility that can reduce expenditures by other branches of government on social services. For example, a new bus line may allow a person to get to a clinic appointment without having to have the agency pay for a taxi or run a special van, or it may mean that a more expensive home call can be avoided.

Changes in most of these costs are probably best accounted for by deriving estimates of these costs on a per-passenger-mile basis and linking these estimates to the changes in travel

[2] See, for example, Lewis and Williams (1999).

TABLE 5-5 Annual capital and operating costs by travel mode for large cities (population >1,000,000) (1997 $)

	Commuter Rail	Heavy Rail	Light Rail	Bus	Vanpool	Demand Responsive
	Large City (Service Area Population >1,000,000)					
Transit Agencies Reporting	13	11	14	72	3	55
Capital Costs						
Rolling Stock						
per passenger trip	$ 10.93	$ 0.09	$ 0.60	$ 0.28	$ 2.09	$ 4.48
per passenger mile	$ 1.11	$ 0.02	$ 0.17	$ 0.06	$ 0.07	$ 0.61
Total Capital Costs						
per passenger trip	$ 14.86	$ 1.08	$ 2.78	$ 0.47	$ 2.50	$ 5.83
per passenger mile	$ 1.17	$ 0.20	$ 0.62	$ 0.10	$ 0.08	$ 0.80
Operating Costs						
Labor(incl. fringe benefits)						
per passenger trip	$ 2.17	$ 1.46	$ 1.58	$ 1.40	$ 0.68	$ 6.33
per passenger mile	$ 0.10	$ 0.33	$ 0.48	$ 0.27	$ 0.02	$ 0.83
per bus/train mile	$ 16.83	$ 29.31	$ 12.50	$ 2.60	$ 0.15	$ 0.80
per bus/train hour	$ 544.54	$ 582.15	$ 173.10	$ 35.12	$ 5.26	$ 10.05
Total Operating Costs						
per passenger trip	$ 9.76	$ 2.05	$ 2.26	$ 6.04	$ 2.70	$ 29.33
per passenger mile	$ 0.49	$ 0.46	$ 0.65	$ 1.18	$ 0.09	$ 4.02
per bus/train mile	$ 50.81	$ 38.82	$ 18.01	$ 5.52	$ 0.60	$ 4.19
per bus/train hour	$ 1,597.43	$ 774.73	$ 256.60	$ 85.71	$ 21.73	$ 54.04

Source: ECONorthwest, National Transit Database, 1997.

that generally generate these costs.[3] Of course, if the change in costs is *negative* (i.e., there are cost savings or avoided costs), then this component of indirect costs will be a *reduction* in costs, rather than an increase.

In measuring avoided cost, it is important to count *only* the portion of these costs that are *not* represented by user charges in the user benefit calculation. Failure to follow this rule will result in double-counting of some of the improvement's effects. Take, for example, the case where the transit improvement reduces automobile travel. The user benefit calculation will capture, among other things, the benefit of reduced payments for gasoline made by travelers. The reduction in auto travel might also be expected to reduce the need for additional freeway capacity. The avoided cost analysis should consider the following factors, before reducing direct costs by the avoided cost of the freeway, in addition to counting the benefits of the reduced gasoline payments:

- On the one hand, it may be the case that the gasoline taxes collected in the corridor (as a percentage of total payments for gasoline) are the mechanism through which much of the new freeway capacity would be financed. In this case, it is a double-count to reduce costs by the avoided cost of the freeway *and* claim a user benefit from the reduced gas taxes paid.
- On the other hand, the freeway expansion that is avoided may be only partially paid for by the gasoline taxes levied in the affected corridor. In this case, there is some justification for including a direct cost-reduction in the direct cost accounting.

In summary, changes in non-transit direct costs can be an important consideration in benefit-cost calculations. If a transit improvement causes direct costs to increase or decrease significantly, these cost changes should be included in the direct cost accounting for the project.

Data and Analysis

Transportation-Related Services

There is a plausible argument that as traffic volumes increase, more transportation-related services (e.g., police, incident response, and courts) will be needed. If one accepts that argument, as we do based on casual observation of increased traffic volumes and the amount and cost of transportation-related services over the last 50 years, then one must allow the possibility of a symmetrical relationship: as traffic volumes decline, service and service costs decrease.[4] If one accepts

[3] For parking costs, a cost per vehicle trip is better than cost per passenger-mile, because it will not be dependent on trip length and car occupancy assumptions.

[4] In the short-run, for small areas and small projects, it is certainly possible that public budgets for policing, incident response, and courts do not drop in response to better transit. Maybe the effect is too small to notice, maybe service standards increase slightly instead, maybe other endogenous factors overwhelm any cost reductions. For a long-run project evaluation, however, it seems reasonable to assume that these costs are a function of traffic volumes and to attribute cost savings or increases based on changes in volumes.

TABLE 5-6 Passenger-miles per capita by service area size

	Service Area Population											
	<200,000				200,000-1,000,000				>1,000,000			
	Min	Mean	Max	n	Min	Mean	Max	n	Min	Mean	Max	n
	Passenger Miles per Capita (Overall)											
Commuter Rail	-	-	-	313	-	1.6	96.0	154	-	18.2	379.2	75
Heavy Rail	-	-	-	313	-	9.0	1,166.8	154	-	33.4	969.9	75
Light Rail	-	0.0	3.8	313	-	1.7	128.3	154	-	4.8	81.1	75
Bus	-	26.9	244.3	313	-	56.5	395.9	154	-	62.1	272.9	75
Vanpool	-	0.8	148.1	313	-	2.0	73.8	154	-	0.9	32.8	75
Demand Responsive	-	6.1	937.3	313	-	2.7	15.7	154	-	1.2	8.7	75
	Passenger Miles per Capita (Modes where Pass.-Miles > 0)											
Commuter Rail	N/A	N/A	N/A	-	17.3	60.2	96.0	4	0.8	113.6	379.2	12
Heavy Rail	N/A	N/A	N/A	-	83.6	460.4	1,166.8	3	2.5	228.0	969.9	11
Light Rail	3.8	3.8	3.8	1	0.8	51.0	128.3	5	0.3	25.6	81.1	14
Bus	1.0	40.0	244.3	210	0.2	66.9	395.9	130	0.0	84.7	272.9	55
Vanpool	11.5	60.3	148.1	4	1.0	18.2	73.8	17	5.2	10.7	32.8	6
Demand Responsive	0.0	8.9	937.3	215	0.1	3.3	15.7	126	0.2	2.1	8.7	45

Source: ECONorthwest, National Transit Database, 1997.

that argument, then it is logical to attempt to estimate some relationship between some measure of traffic reduction (e.g., trips and vehicle-miles) and these costs.

As with other cost categories described in this guidebook, estimates have been made based on aggregated national data of the average cost per vehicle-mile of transportation-related services. Recent work by Delucchi (1997) estimates the total cost of police, fire, judicial, and correctional services related to motor-vehicle use at $17.6 to $27.4 billion annually (in 1991 dollars), or 0.8¢ to 1.3¢ per vehicle-mile. Other studies have estimated these costs to be in the range of 1¢ to 4¢ per vehicle-mile.[5] Most of these costs are unperceived in the sense that they are not paid by drivers as drivers (though the drivers certainly fund the services as state, federal, and local taxpayers).

Perhaps better estimates could be made using local data, but there would be many technical problems relating to definitions and data that suggest to us that the estimates would not necessarily be any better. Our opinion is that credit to transit for some cost savings is justified if traffic volumes are forecasted to be less than they would otherwise be without the transit project.

Parking

Chapter 3 presents evidence on parking that suggests that many drivers probably do not perceive the full costs of parking when making trip decisions. In contrast to most other elements of vehicle operating costs, parking is often not charged for explicitly, but is *bundled* with other activities.

Parking at work, shopping centers, malls, and other retail establishments is frequently an unpriced amenity. Businesses have decided that it is better for business to bundle those costs in a benefits package for employees or the price of goods for shoppers. Chapter 3 showed several studies that suggest that about 90 percent of work and shopping trips have no explicit parking charge. It also noted that many transportation models use a probability-weighted parking charge to specify the perceived cost of parking, which implies that only some fraction, and probably a small one, of the cost is providing parking.[6]

The lack of a charge obviously does not mean that parking costs nothing to provide. Depending on underlying land values and landscaping, surface parking may cost between $1,500 and $3,000 per space; stalls in structures cost from $10,000 to as much as $25,000 each, depending on land value, structure type (height, whether it goes below ground), and architectural quality. Somebody is paying those costs: in many cases it is the drivers using them, but they may be paying only partially or not at all as drivers, but rather as employees, shoppers, and taxpayers.

So, what does this imply about the magnitude of parking costs that are unperceived and should be included as a separate line item in a benefit-cost evaluation of a transit project? Here is a suggestion for the steps of a basic analysis:[7]

- Get data specific to the area being influenced by the transit project on (1) the cost of providing parking of different types, (2) the rates being charged for parking,

[5] Terry Moore and Paul Thorsnes. 1994. *The Transportation/Land Use Connection*. Planning Advisory Services Report 448/449. American Planning Association. Chicago.

[6] Assuming that the prevailing parking price for pay-parking is roughly equivalent to the cost of providing it. For high-demand surface lots, revenues probably exceed annualized capital and operating costs. For most for-fee parking structures, they probably do not.

[7] For more details, and slightly different methods and data, see Cambridge Systematics. 1998. *TCRP Report 35: Economic Impact Analysis of Transit Investments: Guidebook for Practitioners*. National Academy Press, Washington, D.C.

and (3) the percentage of drivers using different types of parking (if available).

- Calculate the extent to which prevailing rates support the cost of the parking. For example, a daily rate of $8, for 250 workdays, generates $2,000 per year. If the construction and land cost per stall of a parking structure is about $15,000 and is financed over a 20-year period at 7.5 percent interest, then the annual cost of capital for the stall is about $1,500. If operation cost per stall is about $1 to 3 per month (say, $24 to $50 per year), then, as a first approximation, the users of the parking are roughly paying the annual cost of the parking. In that sense, the perceived cost of parking is close to the total cost, and there may be no unperceived portion to add. An analyst could make other adjustments that seem reasonable, for example, by surveying developers and parking operators about capitalization rates and operation costs.
- Estimate the percent of drivers who pay for parking. If in a downtown only 50 percent pay, while the other half use parking paid for by employers or supplied by retailers, then in the previous calculation half of the costs of parking in the downtown are not perceived by drivers and, therefore, are not included in the consumer surplus calculation. Similarly, if there is additional information on parking costs (such as residential parking fees or differences between long-term and short-term parking costs) then these should also be incorporated in the consumer surplus calculation.
- Estimate, based on the travel demand estimate of changes in auto trips, how the proposed transit improvement will reduce demand for auto spaces.
- Multiply the estimate of the unperceived cost of an average parking space by the reduction in parking spaces to get an estimate of the additional savings in parking costs attributable to the transit project. In this example, if a transit project reduces the need for 500 daily auto trips to the downtown, then the annual value of that savings is roughly $400,000 ($1,525 × 50 percent × 500).

Other Social Services

The argument that low-cost mobility reduces costs to a variety of non-transportation public agencies that provide social services seems to double-count transportation benefits. Chapter 3 shows how to calculate benefits to travelers. If the methods there generally do what they purport to do (we believe they do), then one must ask what other, *non-travel* benefits are to be measured here?

There are several ways to answer this question. One might assert that the benefit of improved transit is strictly that travel is cheaper so that lower-income people can now save money on trips or, more importantly for social services, make trips that they would otherwise not make: then those travel benefits are already captured in the user cost analysis described in Chapter 3. Some have argued that economies of scale in transit allow social service agencies to shed costs they now pay for taxis, vans, and employee trips to the field.[8] Even if that is true, the analysis of user benefits using a travel demand model should roughly capture the net user benefits.

The issues here are hard to unravel. Consistent with Chapter 3, a transportation improvement that decreases travel time should provide a user benefit, but, in this case, the users may not be the ones paying the cost anyway (i.e., it may be paid by the social service agency). If such an agency takes advantage of the improvement by switching the transportation options it offers, or if riders now have reductions in travel time, the social benefits may still be approximately captured in the user benefit calculation.

The issue may be more one of the distribution of impacts (discussed in Chapter 8). The argument could be that one should add up all the downstream savings (e.g., because people can now afford to travel to see a doctor or employment counselor, society saves the costs of more expensive interventions later). If so, measurement becomes intractable and arbitrary. The implication of that argument seems to be that low-income households have no transportation options (i.e., that it is available below some threshold price or it is not). Our conclusion is that these purported benefits derive from and are measured by lower transit-travel cost and increased transit ridership and should generally be captured in the measurements of consumer surplus described in Chapter 3.

REVENUES

Revenue accounting is primarily done for the purpose of determining financial feasibility. The analyst should, at a minimum, prepare a table like Table 5-7. For reasons described previously, the analyst must be clear that this tracking of revenues is, in the context of benefit-cost analysis, a description of *transfers*, and that *revenues are not additive to social benefits*. It can be crucial information, however, for policymakers who must find ways of subsidizing a transit improvement that cannot be financed fully out of the fare box. In addition, if the analyst wishes to “zero-out” some costs because they are financed with non-local funds, accounting for sources and uses is important.

The row headings in Table 5-7 can become as detailed as necessary to show specific sources of funds. The main point is to distinguish between local (i.e., the relevant service areas for the transit improvement) and non-local funds, and, for local funds, between user fees and other general sources of revenues. A table like this one can be used (1) to answer general questions about expenditures and revenues for policymakers and the public, (2) to assist an analyst in making decisions about whether adjustments need to be made to net benefits in the benefit-cost calculations, and (3) to describe equity impacts (by evaluating how different households contribute to the sources of funds). Chapter 8, Distribution of Transit’s Impacts, provides additional information about these issues.

[8] Lewis and Williams (1999, page 160 and following).

TABLE 5-7 How to describe revenues for a transit investment (template for type of data desired)

Sources of Funds	Uses of Funds (dollars)		
	Planning	**Construction**	**O&M**
Local Sources			
Fares			
Other user-based fees			
Other local sources			
Non-Local Sources			
State grants			
Federal grants			

Source: ECONorthwest.

SECTION III:

TRANSIT'S IMPACTS—OTHER BENEFITS AND COSTS

To a rough approximation, most of the impacts described in Section II are distinct and additive. But the literature on the impacts of highway and transit improvements lists additional impacts. In the framework of a benefit-cost evaluation, many of these impacts are double counts of the impacts in Section II. That does not mean that they are not real impacts or that they should be ignored. Rather, it means that a careful analyst must measure and present them in such a way that decisionmakers are aware of the potential for double counting.

There are clearly overlaps among the impacts described in the three chapters of this section: *Land Use*, *Economic Development*, and *Distribution of Impacts*. For example, if transit projects facilitate more intense development, that implies effects on land development patterns, property values, infrastructure costs, the amount and pace of development, and regional economic indicators. The distribution of impacts (equity) overlaps all categories of impacts—they report the same impacts, but allocated in pieces to different groups of interest. As elsewhere, we offer advice on how to go about collecting the information that decisionmakers may want.

Nonetheless, the public and its elected officials are clearly concerned about these types of impacts, and assertions about their magnitude can affect policy decisions.

CHAPTER **6**

TRANSIT'S IMPACTS ON LAND USE AND DEVELOPMENT

SUMMARY

Transportation investments can improve the accessibility and attractiveness of locations by reducing the cost, measured in time or dollars, of traveling to them. Increased accessibility makes properties more desirable, which is reflected in higher sales or rental values. These increased values, in turn, affect the type and density of development that occurs.

While identifying and measuring these impacts are of interest to policymakers from an economic development, planning, and equity perspective, increases in property value that result from reduced travel times are already counted as direct user benefits in the benefit-cost framework and should not be added twice in the final tabulation of net benefits. At the same time, when transportation improvements are leveraged to develop land at higher intensities, indirect benefits may be realized via reduced infrastructure costs. The degree of cost savings realized would depend upon local construction, infrastructure, and other costs, which can vary greatly between jurisdictions, and the amount of excess infrastructure capacity.

Predicting and measuring land use changes is a complex process that must take into consideration numerous local factors, such as the degree of improved accessibility, specific site characteristics (e.g., size, price, and constraints), and the local and regional real estate markets. Generally speaking, land use effects will be more pronounced in growing markets, although they will take longer to materialize than changes in travel behavior. In addition, land development will also be affected by local public policies such as zoning, development incentives, and infrastructure provision. To estimate land use impacts, analysts must jointly consider the quality of transit service, private sector market conditions (e.g., household and business preferences), and the effectiveness of available public policy tools.

Large investments that offer significant accessibility benefits (i.e., they serve many travelers and/or generate large time savings) are more likely to have large land use impacts. Transit's impacts would be more localized than impacts caused by highway improvements and, for both highways and transit, most types of improvements are more likely to redistribute, rather than generate, economic growth.

Several tools can be used to estimate land use impacts, ranging from very complex and data-intensive computer models to more qualitative (and typically less expensive) methods such as expert panels. Several of these tools and their different advantages (e.g., ease of use) and disadvantages (e.g., high cost) are described in the chapter.

OVERVIEW

Transportation allows interaction between activities or land uses. This interaction is measured as accessibility, which reflects both the attractiveness of potential destinations and the ease of reaching them (Handy 1993). The potential for interaction between any two places increases as the cost of movement between them—in terms of either money or time—decreases. The structure and capacity of the transportation network, obviously, affect the level of accessibility.

For transit (or any other mode), accessibility can be measured as the number and extent of destinations in the region that can be reached from a particular transit-served location. The larger and more extensive the transit system (and the greater its ridership), the more a given transit improvement is likely to influence land use in the vicinity of a new corridor, transit center, or station.

Accessibility, and transportation's strong contribution to it, affect the desirability (and, hence, the price) of different locations. These different prices in turn influence the type and intensity of land use. That, in short, is the connection between transportation improvements and land use. Behind this short description, however, are many complex and confounding relationships that make predicting the impacts of a transportation investment on land use and development anything but mechanical.

From the perspective of benefit-cost analysis, there are several points about the impacts of a transit project on land use that must be clarified:

- **Travel benefits get capitalized into property values.** Changes in land values may be of interest to decisionmakers and the public and may have implications for assessments of equity, but may reflect a double-count of travel benefits.
- **Property values are correlated with the intensity and, to a lesser extent, the type of development.** How development might change around a transportation investment is certainly of interest to decisionmakers.

For benefit-cost analysis, the same point applies: if transportation improvements create travel benefits by reducing travel times and increasing accessibility, and those improvements are reflected in increases in property values, which in turn cause increases in development, the real benefits should be measured at one end or the other, and certainly not added up for every point in between.

- **Not all land use impacts are double-counting of user benefits.** The literature of urban economics and economic development is generally in agreement that there are *agglomerative economies* of various types (also called economies of clustering or proximity). Such clustering may allow exploitation of scale economies, reduced labor cost, better communication, and innovation. *TCRP Report 35*[1] notes that such benefits, and those of infrastructure cost savings from compact development patterns, may be real, additional benefits of a transit improvement. A subset of these agglomerative economies is *development costs*: a large literature has been developed over the last 30 years that attempts to measure how *infrastructure costs* (public facilities) might change with different development patterns. The simple idea is that greater density means less extension of roads, pipes, and lines, so that costs would be lower (we discuss this later in this chapter).

Any of the above may be of importance to decisionmakers. The first two categories of effects are likely to double-count travel benefits to some extent and each other to a great extent. The third category is more likely to be measuring unique and additive benefits.

This chapter addresses each of these points under four headings:

- **Changes in land development**. This is the longest section of the chapter. It focuses on the fundamental issues: if transportation affects land use, through what mechanisms does it work, how would such effects be measured in concept, and what data sources and techniques are available for that measurement?
- **Changes in property value**. If transportation improvements change land use, theory and practice suggest that such changes be measured as changes in property: the value of the travel-time saving should get capitalized in land value, which theoretically reflects the future stream of travel benefits provided by the improvement. This section is also, however, logically part of economic development impacts, which is where this guidebook presents it. Thus, this section simply points to Chapter 7.
- **Changes in the cost of development**. When transit influences land development, the result is construction or redevelopment on one or more parcels of land. This section describes how the costs of land development around transit can differ, distinguishing between capital and operating, and public and private costs. Measuring and comparing these indirect costs requires care, and this section provides general guidance regarding how to conduct a case-by-case assessment and where relevant cost data may be found.
- **Agglomerative economies**. As with property values, this discussion logically could be included in this chapter or the next one. This section simply points to Chapter 7 on economic development issues for a discussion of agglomerative economies.

Key point: Transportation improvements can increase the accessibility of properties when it becomes relatively less expensive in terms of money or time to travel to them. These reductions in travel cost become capitalized into (increased) property values. While increased property values are simply another measure of accessibility (they are not additional benefits), additional benefits can arise when the clustering of business activity creates scale economies or if infrastructure cost savings result from compact development (an indirect benefit of transportation).

CHANGES IN LAND DEVELOPMENT

Framework

Consider the construction of a new transit station. Locations in the vicinity of the station are made more accessible, and some shift in travel patterns occurs. As travelers make more trips to this location, development pressures intensify, leading to increased land values as competition for sites increases (provided land use policies allow for changes in land use and density). The new development that occurs, in turn, causes additional shifts in travel patterns.

The magnitude of changes in land use depend upon a number of factors, including how much accessibility is improved, the relative attractiveness of the specific parcels near the station, and the real estate market in the station area. The regional real estate market will mediate the changes further. In a robust fast-growing economy, demand for new housing and commercial activities will be high. Under these conditions, the effects of accessibility changes will be stronger than they are in a weak market.

The likelihood of development near a transportation investment is influenced by both the public and private sectors. Public policy, including zoning and development incentives, may attract or deter development. The size, price and characteristics of specific sites also influence development potential.

For transit in particular (rather than for transportation in general), case studies have shown several factors to influence

[1] Cambridge Systematics. 1998. *TCRP Report 35: The Economic Analysis of Transit Investments: A Guidebook for Practitioners*.

the type, intensity, and timing of development near stations.[2] Some of these fall within the realm of public policy, such as the quality of the transit service and the variety and quality of the policies and tools available to influence development. Others clearly are exogenous, such as regional growth. Others may be affected by citizens' purposeful activity, but may be fixed in the short run (see Figure 6-1). These include the presence or absence of a regional land use vision and a transit-supportive political culture.

Understanding the relationships between transportation and land use also requires an understanding of the context in which transportation investment decisions are made. It is difficult to measure, predict, and coordinate transportation and land use because of differences in the parties making decisions, the types of organizations involved, and the time that it takes for effects to be seen. The public sector is a major provider of transportation infrastructure, but most land use decisions are made by the private sector. Land policies are largely a responsibility of local governments, while federal, state, and local governments determine transportation policies. Travel responses to land use and transportation system changes are seen much more quickly than land use responses.

To estimate or quantify the land use impacts of a transportation investment, one must understand who is making decisions affecting land use and what factors influence their decisions. These "actors" include households, business firms, developers, and government agencies.

Households seek housing that satisfies their needs and preferences and fits within their budgets. Accessibility is only one of many factors that households consider in making these choices. Since the majority of trips are made for non-work reasons, households consider access to stores, services, friends, and other destinations besides work when choosing housing. Many households are more concerned about affordability than with access to jobs, provided they are not too distant from the current jobs or primary destinations of household members.

[2] For more information on the nature and influence of these factors, see Parsons Brinckerhoff Quade & Douglas, *TCRP Report 16: Transit and Urban Form*, Vol. 1, Part 1, and Vol. 2, Part 2.

For households who have a large set of affordable choices, other factors such as school quality, neighborhood amenities, and the type of people living in the community can also play a decisive role in their final choices.

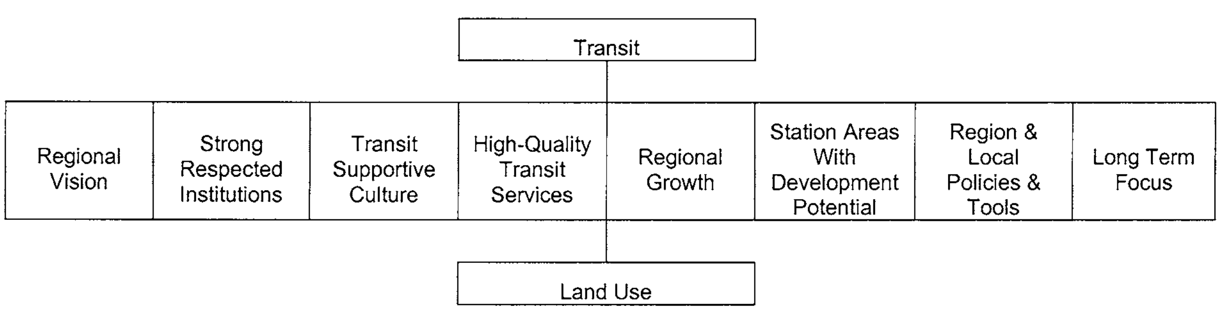
Firms seek locations where they can make a profit. Different types of firms place different emphases on access to workers, customers, suppliers, and others. Like households, firms must consider multiple factors, including accessibility and affordability in making location decisions. The final site selection may hinge on factors such as differences in local tax rates, the cost and availability of services, and the prestige of the location.

Developers balance the needs and preferences of potential customers with the costs of developing in different locations when deciding where and what to build. They consider both the factors that influence household and location choices, such as preferred locations and site characteristics, and the costs and land supply limitations, if any, due to governmental policies.

Government policies influence the supply of land available for development and affect the cost of development. The supply of land available for different types of development is constrained by zoning, environmental regulations, and the provision of water, sewer, and other infrastructure. The cost of development can be lowered with economic development incentives. The cost of development can increase with multiple and ambiguous requirements for obtaining permits, infrastructure standards, or parking or design standards.

These players interact in a market where the price for land acts to sort the type and location of development. Households, businesses, and developers are willing to pay for land up to the amount they anticipate they will receive in future benefits. Some stand to benefit from certain locations more than others and will outbid all others for these desirable sites.

Key point: Accessibility alone does not determine changes in land use development, particularly for transit. The timing and intensity of development are also influenced by rates of regional growth, local support for transit, local and regional growth



Source: Parsons Brinckerhoff, Transit and Urban Form, Vol. 1, Part 1, 1996.

Figure 6-1. Mediating influences on the transit-urban form relationship.

management policies and tools, household and business preferences, and land availability and zoning near station areas.

Data and Analysis

For analysts seeking to conduct land use impact assessments, the steps are

1. Understand existing conditions and trends,
2. Establish policy assumptions,
3. Measure the transportation outcomes with and without the projects or service changes,
4. Estimate the total study area population and employment growth with and without project or service,
5. Inventory the land with development potential, and
6. Estimate how the project will change the location and type of development within the study area from what would occur anyway.

MPOs and DOTs can use a variety of tools for land use forecasts and land use impact assessment, depending upon their size, the questions they have been asked to answer, and their interests in advancing the practice. There are eight basic types of analytical procedures or tools currently available and in use.[3]

- **Comprehensive plans and other land use regulations**. It is important to understand that land use regulations influence where and what type of development can occur. However, much current analytic practice relies too heavily on public policy as the primary shaper of urban form. For political reasons, many regions produce "plancasts" that assume that development will occur where land use policies and regulations direct that growth. When using comprehensive plans in impact assessment, it is important to evaluate realistically the effectiveness of these tools at shaping growth and to consider how the land market might produce different outcomes from those described in policy.
- **Qualitative methods that tap expert knowledge.** MPOs and DOTs use a variety of qualitative methods to understand the complexity of urban development. These tools can be used as the primary method of analysis or in conjunction with other tools. Panels of experts, Delphi methods, interviews, surveys, and case studies are qualitative techniques that rely on the knowledge and skills of one or more experts to determine where growth is likely to occur. These methods can combine understanding of the theory of urban development, empirical knowledge of transportation–land use interactions, and understanding of local situations.

  Qualitative methods are not substitutes for data collection. They should be based on a sound understanding of existing conditions and trends, but this information is analyzed by experts without statistical techniques or quantitative models to estimate what the future will hold. The results of qualitative approaches depend upon the breadth and depth of knowledge of the experts involved in the process.
- **Allocation rules for assigning population and jobs to zones**. Allocation rules use simple trend extrapolations (e.g., fast-growing areas will continue to grow rapidly) or simple measures of accessibility and other attractiveness factors to allocate expected growth to different zones. They are easy to use and do not require extensive data. They work best in typical situations and for widespread activities like retailing and residential development. They must be supplemented with other methods, such as qualitative analysis, to decide how to handle issues such as the location of large employers, changes in household and business location preferences, and other factors that might cause future development to differ from past patterns. All assumptions must be explicit.
- **Decision rules**. Many land use forecasting or impact assessments require some simple decision rules that quantify certain relationships between transportation and land use. These rules are based on empirical evidence from the region or from other locations with similar projects. Decision rules are often needed because the process of urban development is too complex to analyze in its full detail. They are typically used in conjunction with other processes such as GIS analysis of developable land. Especially when using decision rules from another location, the context in which they were developed must be carefully compared with the study area to determine whether there are any critical differences in these places that might invalidate the use of the rule.
- **Statistical methods**. Multiple linear regression and discrete choice models are two statistical methods for evaluating the relative roles of multiple factors in shaping land use patterns. Because they consider the effects of multiple variables, they can represent more of the complexity of urban systems than simple allocation or decision rules, provided the appropriate variables are included in the analysis. These methods require considerable technical skills and large data sets to provide accurate results. Like other methods that rely on recent local data, they assume that past trends will continue into the future. These models provide information about what happens "on average."
- **Geographic information systems.** Increasingly MPOs and DOTs are using GIS to manage, analyze, and map geographic relationships. GIS can be used in conjunction with any of the other tools to help understand trends and development opportunities and to sort out the complex behavior and interactions in the land market. While the cost and difficulties of using GIS have been declining as new PC-based systems have been developed, considerable staff time is still required to set up and maintain the databases for an effective GIS.

[3] Parsons Brinckerhoff Quade & Douglas, Inc. *Land Use Impacts of Transportation: A Guidebook*. NCHRP Project 8-32(3). 1998.

- **Regional economic models.** Regional economic models simulate an area's economy and are useful for estimating regional population and employment growth totals that are needed as input to other forecasting processes. Such models can also be used in inter-metropolitan impact assessments to assign growth to individual counties for large geographic scale projects. Some models predict only job growth; others include both job and population growth. A number of models are commercially available, and others have been developed for particular regions by MPOs, DOTs, and other state agencies. It is important to understand the assumptions of the regional economic model when interpreting the output.
- **Formal land use models.** The principal formal model systems in use or available today include DRAM/EMPAL, MEPLAN, TRANUS, METROSIM, HLFM II+, LUTRIM, URBANSIM, and CUF. While this class of analytic techniques is suited to large-scale analyses for which few other tools exist, users of formal land use models are concerned about how difficult they are to use; their high costs in time, data, and consulting needs; the accuracy of the results; the lack of integration with transportation models; and insufficient documentation.

  DRAM/EMPAL and HLFM II+ are based on Lowry gravity models that assume that accessibility is the key concept in location choice. They do not adequately represent other factors that influence the location choices of households and firms.

  Some of the models, such as CUF, TRANUS, MEPLAN, and URBANSIM, have been designed for ease of policy analysis. The experience with these models is, however, limited, with the first full-scale applications of these models in the United States currently underway.

Table 6-1 shows how these tools can be applied in assessments of land use impacts.

Table 6-2 summarizes the state of knowledge about the impacts of transportation investments and policy on land use. It necessarily oversimplifies things, since all transportation initiatives that change accessibility, to whatever degree, have an effect on the location, intensity of uses, land prices, and possibly the mix of uses over the long term.

Table 6-2 shows the *relative elasticity* or magnitude of land use impacts from various types of highway and transit investments and policies. In other words, it provides a relative measure of the degree to which land use impacts will occur. When an action is labeled as having "high" land use elasticity, this means that the changes are significant in relation to other types of investments or policies, not that the changes are necessarily large in the absolute sense. In addition, these elasticities are generalized to illustrate the "average" impacts of the "average" transportation investment of

TABLE 6-1 Summary of analytical tools and their relationship to the behavioral framework

Analytical Tool	Relationship To The Behavioral Framework	Use In Impact Assessment
Qualitative methods	Means of gathering and analyzing information on local actors, their choices, and their motivations. Way to estimate future location choices based on understanding of development processes in the region.	Understand existing conditions. Establish policy assumptions. Estimate total population and employment growth. Inventory of developable land. Assign households and jobs to zones.
Allocation rules	When based on local data, they reveal typical outcomes of the land market for widespread activities like residential development and retailing.	Assign households and jobs to zones.
Decision rules	When based on local data or empirical evidence from similar regions, they reveal relationships that are outcomes of the land market.	Inventory of developable land. Assign households and jobs to zones.
Statistical models	By estimating the relative effects of multiple factors on location choices, they clarify the role of these factors in location decision-making.	Understand existing conditions. Estimate total population and employment growth. Assign households and jobs to zones.
Geographic Information System	Analyze and map the relationships between land supply, constraints and opportunities for development, and choices of households and firms.	Understand existing conditions. Inventory of developable land. Assign households and jobs to zones.
Regional Economic Models	Simulate the economy to estimate county or regional population and employment growth.	Estimate total population and employment growth.
Formal land use models	Only models that incorporate the supply and demand for land and the choices of the key actors in the market fit within the behavioral framework.	Assign households and jobs to zones.

Source: Parsons Brinckerhoff. 1998. *Land Use Impacts of Transportation: A Guidebook.* NCHRP Project 8-32(3).

TABLE 6-2 Land use impacts of transportation investments and policies

Action	Land Use Elasticity	Land Use Impact	Mitigating Factors
New highway facilities	high	Redistribution of metropolitan growth to highway corridors Decentralization of population and employment Increased land values and concentration of development around interchanges	Local and regional economic conditions Degree of impact on regional accessibility Congestion levels Local land use policies "NIMBY" phenomenon
Added highway capacity (lanes, intersections)	high	Same as above, but to a lesser degree	Same as above
Automated highway systems (AHS)	high	Decentralization of population and employment Increased land values and concentration of development at nodes and terminals Possibly new towns	Magnitude of change in travel speeds Extensiveness of system Cost of use Local land use policies NIMBYism
System management	low	None likely	Levels of congestion and latent demand
Congestion pricing	high	Possible shift of population and jobs toward more accessible locations. Possible shift of population and employment to exurban areas	Local and regional economic conditions Magnitude and spatial extent of pricing policy Degree of congestion Availability of alternative modes, routes
Parking pricing, management	high	Possible increased development of major employment centers Likely increased development density	Local and regional economic conditions Magnitude and spatial extent of pricing policy Long-run incidence of parking fees Availability of alternative modes
New rail transit facilities	moderate	Increased land values and development density Redistribution of development to downtown, station areas Decentralization of population	Local land use policies Degree of impact on accessibility Local economic conditions Station access and local circulation patterns Corridor congestion levels
Rail transit extensions, stations	moderate	Same as above, to a lesser degree	Same as above
New high capacity arterial bus lines, stations	moderate	Possible redistribution of development to major bus transit corridors	Local economic conditions
Changes in local service	low	Possibly some redistribution of development to transit corridors	N/A
Fare policy changes	low	none expected	N/A

Source: Parsons Brinckerhoff. 1998. *Land Use Impacts of Transportation: A Guidebook.* NCHRP Project 8-32(3).

that type. Some areas or projects may have impacts that are greater or less than these elasticities would suggest depending, for instance, on the life cycle stage of the improvements or any of the other mitigating factors that are listed.

Table 6-2 shows that potential land use impacts include increases in both land value and development density. Major transit infrastructure investments are less likely to have significant land use impacts than highway investments if they serve a smaller travel market. In these situations, they may not have the same range of impacts as added highway capacity. However, in locations well-served by transit, localized land use changes can be significant, particularly when clear accessibility advantages are conferred to nearby properties. As with highways, anything less than major infrastructure investments is not likely to have significant, measurable land use impacts.

Most studies of transit and property values have focused on rail investments and show that nearby transit service increases residential property values. The closer to transit, the greater the increase in value. However, reductions in value are frequently found for properties immediately adjacent to stations due to noise and other impacts.

Table 6-2 addresses impacts in general and in the aggregate, but highway and transit improvements may have different spatial impacts. Highway impacts tend to be more diffused and, thus, may be harder to measure than transit impacts. Highways are multimodal; they serve individual travelers, public transit, and goods movement. Changes in highway accessibility, therefore, directly affect all aspects of economic activity.

Because transit only serves passengers and usually a small percentage of those, its land use effects are likely to be more localized and, thus, more definable than those of highway projects. Moreover, transit's impacts are likely to be redistributive; land uses that locate near transit are unlikely to represent a net change in the overall rate or magnitude of regional growth. Rather they represent changes in the location of activities within a region.

At the same time, transit can be used to help redefine where economic activity will occur within a region and provide a means to implement other regional planning goals (e.g., compact growth, increased affordable housing, preserving existing neighborhoods). When used as a redevelopment tool, transit station areas can attract investment from redevelopment boards, transit agencies, housing groups, local and regional governments, and business associations. An articulated and funded strategy for transit investments provides part of a framework for efficient development; investment coming from different sources can be combined to create higher levels of benefits than would otherwise occur.

The same is true for most land use impacts of highways; they are more likely to be redistributive than additive. But, there are conditions under which a highway investment is more likely to influence net regional growth than is a transit investment. These include situations in which highway investments (including ITS investments) enhance the travel times for the movement of goods. This would have the effect of enhancing the productivity of area firms, making possible a real growth in regional production, income, and employment.

In communities with large transit systems, the same conditions may apply. The ability to move passengers who are traveling for business reasons to and from a region's airport or to and from neighboring metropolitan areas by high-speed rail would be ones in which travel time savings by transit could result in net regional economic growth. These situations are increasingly important as the service sector's domination of regional economies continues to increase.

But, for all but the largest investments in the largest transit systems, it is reasonable to assume that land use impacts represent little or no net change in the overall rate of regional economic or population growth. Rather, land use impacts would be intra-metropolitan in nature.[4]

[4] *NCHRP Report 323A* furnishes the analyst with extensive information on each of the tools described here and specific examples and references for their application.

The elasticities in Table 6-2 reflect the general experience of many diverse transit investments; specific investments, however, may show greater or reduced impacts. It is beyond the scope of this report, however, to discuss the specific impacts of multiple transit systems. Rather, users can refer to the list of mitigating factors that is provided and the discussion of other important factors (e.g., zoning and policy) to see how their own improvements may yield similar or different results.

It is fair to say that formal land use models, with their extensive data inputs and lengthy calibration process, are only suited to the largest and most complicated transit investment decisions, such as the creation or substantial expansion of a regional rail system. Such models should be developed at a regional scale, in agencies with strong commitments to GIS data, and where there are likely to be numerous, ongoing studies of land use/transportation interactions.

Even in these circumstances, the analyst should consider the use of other techniques besides formal models. Extensive interviews, the use of expert panels, the Delphi Process, and/or the use of case studies may be both cost-effective and informative.

By contrast, examinations of the land use impacts of local transit investments (including the construction of a transit center or station, for example) require almost exclusively the use of techniques that incorporate substantial local knowledge of individual property owners, parcels, zoning designations, and real estate conditions. The analyst will likely find one or more of the qualitative methods well suited to this task.

Experience in the application of the above tools and techniques for land use impact analysis suggests the following lessons for analysts:

- **Think through the process of development and improve understanding of the particular players in your region.** Households base their location choices on similar factors in most parts of the country, and developers of national franchises consider a standard set of criteria in the selection of their sites. But regions do differ in the types of developers who work there, in the mix of households and firms, and in the role of public policies. It is equally important to understand these differences from general patterns.
- **Recognize that other factors may be just as important as, or even more important than, accessibility.** Most households and firms consider a wide variety of factors before making location choices. Accessibility is just one such factor. It is unwise to base a land use impact assessment solely on changes in accessibility.
- **Remember that public policies interact with market forces to shape the pattern of development.** Zoning land for particular types of development does not guarantee that those types of development will occur; neither do economic development incentives. However, when these polices work in concert with market forces, they can shape development.

Key point: Several tools exist to help analysts estimate land use impacts. These tools offer different strengths and weaknesses and vary substantially with respect to their flexibility, complexity, quantitative rigor, data requirements, cost, and ease of use. No one tool is necessarily best—frequently multiple tools are used if resources permit.

Key point: For all types of transportation improvements, major investments that confer large accessibility advantages are more likely to have significant, measurable land use impacts. Transit's impacts will be more localized than those generated by highway improvements. For both highways and transit, improvements in access are more likely to redistribute, rather than generate, economic growth.

CHANGES IN PROPERTY VALUE

These impacts are addressed in Chapter 7, Transit's Impacts on Economic Development.

CHANGES IN THE COST OF DEVELOPMENT

Framework

When transit influences land development patterns, the result is the construction or reconstruction of improvements on one or more parcels of land. The costs and benefits associated with land development near transit are indirect; they are not directly associated with the transit improvement. This issue takes on special importance in light of the ongoing debate about the "costs of sprawl," because in a full-cost framework it is appropriate to ask not only about the types of development that may occur but also about public and private costs.

We divide the discussion, as is traditional, into separate ones for capital and operating costs for both the public and private sectors.

Private Capital Costs

Private capital costs for the construction or renovation of real estate vary by region. A standard reference for such costs is the Dodge Company, whose publications are used by cost estimators across the United States. This source provides unit costs for real estate construction.

Capital costs in the private sector vary for reasons other than regional location. First, requirements of local building codes affect costs from location to location. Second, "soft" costs of construction vary from jurisdiction to jurisdiction and may, in some cases, be significant. These costs include the amount of time necessary to negotiate approvals for building and site design, for which a dollar value can be estimated. Third, many developments result in the need to improve existing infrastructure. These improvements could pay for replacement or upgrading of water and sewer mains and connections, storm drainage or service, or transportation (streets and roads) in the vicinity of the project.

Note that to this point we have assumed implicitly that an approximately identical development (same type, intensity, and design) could occur either with or without some transit development. That assumption limits the analysis to the question: Does the transit investment change the cost of that development for a private developer? The broader questions—the ones that people concerned about the cost of sprawl are interested in—have to do with the overall efficiency of public infrastructure: they are addressed in the next section.

In summary, development "induced" to sites near transit may have different (either higher or lower) capital costs in a transit-served location than it might in another location. These differences may be due to differences in construction, infrastructure, or soft costs.

Public Capital Costs

The debate about the public capital costs of development, including development near transit, has two important dimensions. The first is the distribution of the costs. Communities continue to debate whether the public sector ought to pay for extending infrastructure necessary to support growth, or whether these costs ought to be borne directly by developers (and indirectly by homebuyers and tenants). This has led to a separation of public and private sector capital costs altogether, a distinction which in the context of this report has bearing, because we advocate a full-cost framework in which both public and private sector costs ought to be combined and compared with benefits.

A second dimension of the debate is technical rather than political. It bears on whether development in areas already served by public utilities is more economical, because infrastructure already exists to serve it. Thus, if sites near transit are already served by water, sewer, and streets, does redevelopment there represent a lower-cost alternative than development at the urban edge, where the services are absent?

Not all sites near transit may be served (partially or fully) by utilities. Even if they are, however, various circumstances influence whether the development of these sites represents an economically more efficient solution. Most of the arguments for the increased efficiency of density turn on assumptions about better use of underutilized capacity of infrastructure or buildings. Many developed residential neighborhoods and many older commercial areas are occupied less densely than they were at the time of their construction. Average household sizes have decreased, leading many neighborhoods to have fewer people today than they did a generation or two ago. Many commercial buildings are underutilized, with substantial vacant space.

There is little debate in the professional literature that, in the short run, the marginal capital cost for infrastructure will be lower if excess capacity already exists—that point is true almost by definition. There is debate, however, about whether average costs might be a better measure than marginal ones for a long-run analysis of the infrastructure savings of development patterns (in which case, excess capacity is just a one-time opportunity that can be taken advantage of now or later). These concerns can be addressed through determining the timeframe in which the benefit-cost analysis will be conducted.

Another aspect of the debate about the efficiency of urban development and redevelopment results from the densities at which urban sites are used relative to their suburban counterparts. A recent TCRP report on costs of sprawl[5] synthesizes the debate on this and related subjects. Reviewing available literature, the report concludes that "compact development," which is both contiguous and at higher density than that found at the urban edge, is associated with infrastructure costs that are 75 to 95 percent of those found in "sprawling" development patterns. The largest cost savings result from the need for fewer roadways. The authors estimate road costs in compact areas to be 75 percent of those in sprawling areas. They also estimate the cost of water and sewer to be 80 percent and schools to be 95 percent of those in sprawl.

Although there is extensive literature on this topic, no consensus about the effects of density on development costs has been reached. Transit analysts must be careful not to assume a direct causal relationship that goes from transit, to density, to savings in infrastructure costs:

- Capital costs can vary dramatically. The costs of a specific development on a specific site may vary widely from the average cost in an area.
- Small infill developments have the smallest impact on infrastructure and the smallest marginal public capital costs because they are most likely to take full advantage of existing available infrastructure and add only modestly to the demand for these systems. Thus, scattered infill and redevelopment near high-capacity transit services may be able to take advantage of local sewer, water, and road networks by using capacity that would otherwise be idle. For central plants (e.g., water and wastewater treatment) the analysis is more complicated, because their excess capacity that gets used may be independent of development patterns.
- Claims for the high costs of redevelopment and infill projects may be traced, not necessarily to a lack of capacity in public infrastructure, but rather to the common practice of negotiating exactions to rehabilitate, maintain, or upgrade existing infrastructures. Since most city government budgets for capital investments are underfunded, municipal departments seek to recover as much as possible by various means. From the point of view of benefit-cost analysis, the costs of replacing or rehabilitating public infrastructure, which has long been subject to under-maintenance, should properly not be attributed to a redevelopment or infill project budget. Desperate times may result in desperate actions, but the benefit-costs ledger of a transit-served development project should not be burdened with costs attributable to conditions unrelated to its development.
- There is a reasonable case for concluding that transit-served sites in existing developed areas may require less public capital for infrastructure than sites at the urban edge. *There is also a body of evidence suggesting that compact, contiguous development patterns are similarly less costly.* However, transit's strongest role in creating these patterns is limited to those metropolitan areas where transit access confers a clear accessibility advantage. Generally, these are the largest urban areas, with the largest transit systems and highest levels of congestion.

[5] Burchell et al. 1998. *TCRP Report 39: Costs of Sprawl Revisited: The Evidence of Sprawl's Negative and Positive Impacts*. Washington D.C.: Transportation Research Board.

Public and Private Operating Costs

The major focus of research interest in this topic has been on the extent to which public sector operating costs, in the form of public services such as police, fire, emergency vehicles and the like, vary as a function of urban density. To the extent that development near transit would be at densities systematically higher than those possible in the absence of the transit improvement, it is relevant to ask the extent to which marginal costs for public services might be lower.

In general, the literature on public service operating costs shows that, unlike capital costs, service costs are slightly higher at urban densities than suburban ones. The cost curve is U-shaped, meaning that government service costs are high at the lowest and highest density ranges and lower in the middle range of densities.

Researchers do not agree, however, on whether these higher costs are a function of density or whether they are attributable to other factors. To the extent that urban areas have relatively higher proportions of households with lower incomes, they provide higher levels of services to meet the needs of these citizens. In addition, as communities mature, it is common for their citizens to demand and pay for various services and amenities not commonly provided in less well-organized jurisdictions. These could include parks, community, civic, and performing arts centers. Thus, tastes and preferences, combined with social and economic factors, may explain a good deal of the variation observed in public service costs.

Summary

Costs of development near transit are examples of indirect costs, rather than direct ones. Measuring and comparing these indirect costs requires care. The alternatives must be clearly defined. Is the comparison between development of a given site at a higher density with transit versus a lower density without it? Or, is the comparison between development of an urban site and some unnamed suburban one in an automobile-served location? Both of these, it could be argued, are indirect consequences of transit investments.

If the alternatives have been clearly specified, the next set of challenges pertains to determining whether and how public and private capital and operating costs vary for the developments in question. The literature suggests that the following factors are relevant.

- Private construction costs, as influenced by local codes;
- The length of time required to obtain development approvals;
- The extent to which local governments have impact fees and how those fees are calculated;
- The extent to which local negotiations result in exactions and the reasons for them;
- The extent to which the density of the development proposal might result in more economical provision of water, sewers, roads, and other municipal services on site; and
- The location and amount of excess capacity available in the infrastructure at the locations being compared.

Key point: The costs and benefits associated with land development near transit are indirect and are not directly caused by the transit improvement. Jurisdictions may wish to analyze these costs, however, to see if capital and operating costs are/can be reduced. Construction, infrastructure, and soft costs are likely to vary greatly between jurisdictions, and local conditions should be carefully assessed. For any particular site well served by transit, however, costs for linear infrastructure (roads, water, sewer) may be reduced via compact development, but will depend on existing excess capacity and local cost allocation methods.

In the section that follows we describe alternative means of obtaining these kinds of information.

Data and Analysis

The analyst will not need to assess the indirect costs associated with land development on every occasion. Most transit improvements can be evaluated without taking on these complex questions. *Most transit investments are not large enough to influence land use and would not require this indirect cost analysis*. In communities and metropolitan areas where a large transit improvement is being proposed, land use issues become sufficiently important that the analyst may need to address both the impacts and the costs described above.

Even if the transit project is large enough to warrant an investigation of land use impacts, there may still not be a need to do the indirect cost analysis described above. Such an analysis would only be warranted under one or more of the following conditions:

- A particularly large development proposal near transit is pending, and the presence of transit is a crucial factor in its viability.
- The land use impacts associated with the build versus no-build alternatives involve a substantial amount of development locating in one community versus another.
- The communities or jurisdictions in which the development is located have substantially different building code standards, impact fees, or exaction requirements.
- The density, mix, and design of development near transit would be substantially different than what would occur in its absence.

Under any of these circumstances, the analyst may need to develop data to address questions raised by policymakers or citizens regarding development costs. It will be important to remember that benefit-cost analysis requires focusing first on the magnitude of the benefits and costs, rather than their distribution. While the question of "who pays" has significant political consequences, its economic issues are less consequential.

For rules of thumb on the different infrastructure costs associated with "compact" versus "sprawl" development, we refer the analyst to *TCRP Report 39*. Information in that report will be relevant if the analyst is comparing the costs of development in two quite different locations, one of which would likely be a "greenfield" site and the other well within the fabric of the existing metropolitan area.

If the analyst seeks to compare development costs for two different developments on the same site, the task becomes easier. Under these circumstances, the analyst should consult engineering staff in the agencies or departments responsible for water, sewer, roads, drainage, and other key utilities. The analyst can discuss with staff the marginal costs of accommodating one or another development plan, assuming that transit would be "responsible" for inducing some different mix or intensity development on the site than would otherwise occur in the no-build scenario. Information on capacity constraints would influence the estimate of the marginal capital costs for the needed infrastructure. The analyst should be careful not to attribute to the development such costs as rehabilitation of existing facilities, routine maintenance and repair, or the correction of deficiencies, which would be required under any circumstance.

If the scale of the proposed transit project is large enough, and the analyst determines that the system is capable of influencing development patterns enough to warrant the evaluation of regional development costs, it likely will be necessary to engage in a relatively laborious evaluation of utility costs at the system level. In some metropolitan areas, local topographic, environmental, or geologic conditions can influence the cost of building the infrastructure on which development depends. Only a thorough, careful planning exercise for the affected utilities is capable of producing cost estimates under these circumstances.

Key point: Most transit investments are not large enough to affect land use significantly and, therefore, would not require an assessment of indirect cost impacts. Land use impacts are more important to estimate for large development projects near significant transit improvements or where the density, mix, and design of development is likely to be affected substantially by the presence of transit.

AGGLOMERATIVE ECONOMIES

These impacts are addressed in Chapter 7, Transit's Impacts on Economic Development.

CHAPTER **7**

TRANSIT'S IMPACTS ON ECONOMIC DEVELOPMENT

SUMMARY

There is general agreement that transportation investments contribute to overall economic output at the national and state level. Substantial disagreement remains, however, regarding the magnitude of these contributions and the level of geography to which benefits accrue. Some research has found increases in personal income of up to 0.2 percent for each additional 10 percent of transit expenditure, while other studies have found much smaller or non-existent impacts. Most researchers agree that economies of urbanization (e.g., shared labor pools) and agglomeration (e.g., choice among many suppliers) do exist. Measuring these impacts in isolation from other factors may be difficult, however, as these benefits would be capitalized into property values along with many other local advantages, such as accessibility. In addition, these impacts may produce net benefits that may only be measurable at the state or national levels.

Transit can provide an important mobility option for unemployed residents in areas with few local jobs. While some contend that, in the long run, workers and firms adjust locations to match their employment needs, it is likely that other conditions (e.g., zoning policies) perpetuate jobs imbalances. Generally speaking, benefits will be greater when transit or potentially lower cost services (e.g., vanpools) connect areas of high unemployment with areas with labor shortages for similar skill sets.

Transit improvements will often increase property values in corridors or near transit stations in the long term. Most research to date has focused on rail investments and shows that impacts will largely be concentrated within a 1/4 mile of stations, with heavy rail having greater impacts than light rail. These increases, however, are primarily an alternative measure of travel time (user) benefits, as opposed to being an additional measure of benefits. In the short term, properties may experience declines in value due to loss of parking, access barriers, increased truck traffic, and other construction-related impacts. For some types of businesses, such declines in value can be substantial.

Formal cost-benefit analysis does not include the direct and indirect economic impacts (employment, payroll, and output) generated by the construction and operations of transportation projects. As policymakers are likely to be interested in these impacts, however, this chapter describes methods that can be used to estimate them. When estimating these impacts, only funds from outside the region or study area should be considered, and only those funds which will be spent locally.

OVERVIEW

When considering a transit investment, policymakers frequently cite benefits related to the broader economic development objectives of a region. Some of these benefits may result in an overall increase in economic welfare for the region. Others are *redistributive*, in that most or all of the economic impacts are really a gain for one area at the expense of another. This chapter provides guidelines for evaluating these economic impacts, which include

- Increases in regional productivity and benefits of urbanization and agglomeration;
- Enhanced employment accessibility;
- Impacts on property values; and
- Employment, output, and income effects due to construction and operations of transit projects.

We provide guidance for estimating the first three impacts: specific methodologies are either not well developed or are well documented elsewhere (and we point to where additional information can be found). For the last category of impacts—employment, output, and income effects due to transit construction and operations—we provide a more detailed series of steps to estimate these impacts. These latter impacts are commonly analyzed as a part of Environmental Impact Statements (EISs), and the methodology is well defined.

INCREASES IN REGIONAL PRODUCTIVITY AND BENEFITS OF URBANIZATION AND AGGLOMERATION

General agreement exists that transportation investments, which include those in transit, contribute to overall economic output. Experts disagree, however, regarding the magnitude of this contribution and the geographic scale where this relationship holds. At the national level, numerous studies have measured the relationship between economic performance and transportation infrastructure investment: the consensus is that the relationship is positive and significant.[1] The causes of these effects are not well defined but revolve around transportation both being a direct input into the production process as well as facilitating the efficient use of other inputs (labor and capital).

While many of the empirical studies have focused on the role of highways in economic production, some comparable studies evaluate mass transit's impact on overall production. One study, in particular, finds a relationship between mass transit expenditures and personal income (at the *state* level), though the cause and effect are not clear. The researchers found for every 10 percent increase in mass transit expenditures, there was a corresponding increase in personal income ranging from 0.1 percent to 0.23 percent.[2] The same research indicates that these returns are one-third to one-half that associated with highway expenditures.

Thus, at a macro level, there appears to be some relationship between transit investment and overall economic output, but this relationship is not substantial and cannot be quantitatively identified at a regional or metropolitan area level of analysis.

Disagreement remains regarding the *drivers* of this relationship (i.e., Does a higher level of transportation investment lead to increases in personal income, or do regions with higher incomes spend more on transportation?). Further, other studies reach alternative conclusions, finding that "major efforts at increasing public infrastructure in local areas may not generate anything beyond normal rates of return or have anything but a modest effect on growth in per capita income."[3] While users of this guidebook may wish for a recipe or formula to calculate these larger economic benefits to the overall economy, there simply are no reliable relationships or methods for calculating them that can be applied directly to a local transit project.

Key Point: There is a positive relationship between investment in transit and economic growth at the national and state level, but this relationship is much more ambiguous at the metropolitan and regional levels.

Related sets of effects at the metropolitan area or subregion level involve what are collectively known as *urbanization* and *agglomeration economies.*[4] In general, these are the efficiencies derived from denser settlement patterns in cities and metropolitan areas. These two sets of effects are generally defined as follows:

- **Urbanization economies** are economic benefits attributable to cities and urban areas as a result of firms and households sharing common resources and infrastructure. The unit costs for sewer and water systems are decreased as larger systems yield scale economies. Shared pools of labor and other inputs lead to overall efficiencies compared with areas where such pools are smaller and require higher costs of search and labor training.
- **Agglomeration economies** are also a result of a more compact form of settlement and stem from benefits of *accessibility*. In a more dense setting, firms and households may more efficiently handle needs for face-to-face interaction, supplier relationships, proximity to labor, and so on.

Urban economists and other researchers generally agree that these effects exist, though there is widespread disagreement regarding exactly *where*, *when*, and at *what magnitude* they are found. For example, cost savings to firms and households attributable to urbanization economies in a dense city setting may be more than offset by lower occupancy and labor costs in a less dense suburban location.

Determining the relationship of transit investments to these urbanization and agglomeration economies becomes even more problematic, particularly any attempts at quantifying such a relationship. There are at least three reasons for these difficulties:

- Some of these urbanization and agglomeration economies may simply capture the travel time benefits captured in a formal cost-benefit analysis: counting them as additive benefits is counting them twice.
- It is empirically almost impossible to measure accurately the extent of these economies; a later section of this chapter discusses how transit affects property values, and such changes will embody these urbanization and agglomeration economies as well as other effects.
- The urbanization and agglomeration economies that are uniquely attributable to a transit investment may, in fact, simply reflect largely a redistribution of benefits (or costs). If, for instance, settlement patterns are shifted to areas near transit stations at the expense of other areas not served by transit, then these other areas may lose any agglomeration and urbanization economies that they may have experienced.

Key Point: Transit projects may facilitate denser forms of land use, thereby creating economic benefits, but many of these benefits are redistribution from elsewhere in the urban area.

[1] See Michael E. Bell, Therese J. McGuire, et al., *NCHRP Report 389: Macroeconomic Analysis of the Linkages between Transportation Investments and Economic Performance*, 1997; and Randall W. Eberts, *How Levels of Investment in Transportation Affect Economic Health*, Paper presented at the Conference on Information Requirements for Transportation Economic Analysis, August 1999.

[2] Michael E. Bell, Therese J. McGuire, et al., *NCHRP Report 389: Macroeconomic Analysis of the Linkages between Transportation Investments and Economic Performance*, 1997, Ch. 5.

[3] Michael E. Bell, Therese J. McGuire, et al., *NCHRP Report 389: Macroeconomic Analysis of the Linkages between Transportation Investments and Economic Performance*, 1997, Ch. 6.

[4] See *TCRP Report 35: Economic Impact Analysis of Transit Investments* for a more detailed description of these effects.

Given this evaluation, this guidebook makes no specific recommendations about data sources or empirical measures of this category of economic impact. The most we can say is that (1) there is a theoretical argument for this type of economic benefit; (2) the empirical evidence is very thin; and (3) the few studies that do exist show the effects of transit improvements to be small, less than those of equivalent investments in highways, and only measurable at an aggregate level of geographic detail (state level or higher).

ENHANCED EMPLOYMENT ACCESSIBILITY

Framework

A transit system—from simple dial-a-ride bus service in a predominantly rural area to a major multi-modal mass transit project in a metropolitan area—offers the prospect of allowing people who would not otherwise have any means of mobility to gain access to employment, particularly where job opportunities are scarce to non-existent in the immediate area of their residences. This situation is most often found in rural areas, particularly in lower income areas where automobile ownership is low. It is also found in urban areas, where a "mismatch" exists between the demand for labor possessing certain skills and the locations where labor with those skills resides (particularly when residents in these areas do not have access to auto transport or the auto travel costs—real and perceived—to the locations possessing the jobs are excessively high).

From a regional economic perspective, the actual impacts of such a mismatch are difficult to quantify and vary based on a short- or long-run timeframe. In the *short run*, regions that have a high demand for labor to the point where a *labor shortage* occurs and, at the same time, have areas with a pool of unemployed or underemployed persons may find that bus or other transit service has the potential to "unlock" this pool of labor to serve the areas with high demand. An example would be a growing suburban retail center with a regional mall lacking service workers, coupled with an inner city area with high unemployment.[5]

Studies of larger urban areas indicate some significant associations between proximity to transit stops (especially bus) and employment levels. For instance, in an analysis of Atlanta's transit system, average work employment levels decreased by approximately three weeks for every 0.5 km from the nearest bus stop.[6] However, the same study showed a weak and mixed relationship in Portland for bus, and a weak relationship in both cities for rail (a few days less work per year for employees not within walking distance of a station, adjusting for other demographic and access characteristics). Overall, access to an automobile has the most significant impact on accessibility to employment opportunities.

In the *long run*, many economists would argue that imbalances between the demand and supply for labor will be alleviated as firms and workers adjust (with firms either offering higher wages or locating in areas with a lower-cost labor pool, or workers moving to areas of greater job availability). There is evidence that such a process indeed occurs, but there are other long-lasting characteristics of both urban and rural economies indicating that this adjustment never fully alleviates these imbalances. Transit represents one means by which these imbalances may be alleviated. Where the effects of transit are real in this respect, it may have other fiscal benefits such as savings in welfare, unemployment compensation, and other social programs.[7] Though, as discussed in Chapter 5, the mere introduction of a transit option does not automatically lead to any measurable benefits that have not already been captured in a formal analysis of user accessibility benefits and costs.

The literature of many professions (planning, economics, political science, and sociology) has many articles arguing that the efficiency of urban economies is diminished by structural problems, like discrimination and zoning, and that a functioning market is no assurance against undesirable impacts on many groups (e.g., lower income households may lose options for tenure, housing type, and location as higher income households bid up the price of the housing stock). The presumed connection between transit or, more generally, lower cost transportation, would have to be that (1) these forces have created economic segregation of households, (2) business productivity in other areas is constrained by a lack of labor at wages commensurate with those of wage earners in these lower income households, and (3) lack of good public transportation makes the perceived price of getting to the businesses too high for workers in the lower income neighborhoods. The argument would have to be that the economies of public transit provide transportation more cheaply than the businesses themselves could otherwise provide it (e.g., with subsidized or free van pooling), so transit provides a net reduction in regional transportation costs.

Even if one assumes all those points, one must also note that the *net* transportation savings is what matters to regional efficiency (the difference between the cost per trip via transit and the cost via the next best alternative). Most of the effects, however, are distributional (e.g., people in the neighborhoods served by transit are now better off, as are businesses), a point addressed in the next chapter.

Data and Analysis

One can calculate the potential number of employment opportunities that derive as a result of transit alleviating the

[5] There is substantial literature regarding "spatial mismatch," particularly in urban areas. See Sanchez, T. W., "The Connection Between Public Transit and Employment," *Journal of the American Planning Association*, Summer 1999, 284–296, and Lewis, D. and F.L. Williams, *Policy and Planning as Public Choice*, Brookfield, VT: Ashgate, 1999, Ch. 4.

[6] See Sanchez, 1999, p. 291.

[7] See Lewis, D. and Williams, F.L., 1999, p. 160–178.

spatial mismatch predicament, with the major caveat being that these impacts are not necessarily additive, nor do they necessarily reflect new jobs created in the regional economy. Instead, these calculations can be used to demonstrate the capacity of a transit system to facilitate mobility between where workers reside and the location of specific employment opportunities.

The factors used to forecast these affects are often estimated using surveys of actual riders. The method is as follows:[8]

1. Conduct a statistically significant survey of transit riders on a particular route to determine the following information about each respondent:
   - Use of transit system for commuting
   - Ownership of a car or access to alternative transportation in the absence of transit (e.g., carpool)
   - Annual earnings
2. Extrapolate the results of the survey to estimates of total ridership to calculate the number of persons using the system to travel to work who *otherwise would not be able to do so without the system*.
   - Multiply the number of jobs attributable to the route by the average earnings of respondents who answered they would not be able to travel to their employment without the transit services.

After making these calculations, keep the following guidelines in mind when discussing the results:

- Bus projects will generally have a greater impact on accessibility to employment than commuter or light rail.
- Where a transit project connects areas of high unemployment (e.g., 10 percent or greater) to those with very low unemployment (e.g., 5 percent or lower), the net effects on the regional economy will be greatest. Further, where there is the greatest *match* of labor skills demanded by the area of full employment (e.g., a need for retail clerical employees) and those skills supplied by the area of relative high unemployment, there will be the most substantial effect.
- Larger metropolitan areas will experience the greatest impact (in part because of the potential for the largest disparity of unemployment variances within the region).

IMPACTS ON PROPERTY VALUES

Framework

Property values are correlated with the intensity and the type of development. Decisionmakers are usually interested in these changes, as property owners and citizens are highly sensitive to fluctuations in real estate values, both positive and negative. During a project's construction, for instance, right-of-way takings require an assessment of the direct impacts of the project on property owners in its path and impacts on value. As a project is placed into full operation, property owners and communities may see real increases in the value of their properties around transit stations as residents and businesses make locational decisions based on increased access. *Transit systems, over the long term, will often have an overall positive and noticeable impact on property values around stations and along transit corridors.*

While property value changes are often real, they mainly reflect an *alternative* as opposed to an *additional* measurement of the system's benefits. *The value of a property affected by a transit system largely reflects the capitalization of the net travel benefits* (i.e., increases in accessibility). In other words, a purchaser of a home near a transit station will include an assessment of travel time benefits of that system in his or her willingness to pay for that home. A business tenant of commercial space will pay additional rents to the landlord (who then holds a higher valued property) with the knowledge of increased traffic around a transit station or shorter commutes for employees.

Changes in property values around a transit corridor may also reflect conditions independent of the system. For instance, many preferred transit alignments coincide with existing arterials or the routes that would have been selected for highway improvements in lieu of transit. Increases in property values around a transit station located at a major highway interchange may, in fact, have little to do with the station itself. In other words, as with other benefit-cost calculations, one must apply a *with-or-without* framework as opposed to a *before-and-after* analysis.

Property value changes along a transit corridor may be completely offset by changes observed where the system is absent. Households and firms may shift their location decisions with the introduction of a transit system, desiring residences and spaces near stations. These decisions may come at the expense of those locations now considered less desirable.

Finally, there is evidence that *a transit system may have negative, as well as positive, impacts on property value during both its construction and long-term operations.* During construction of a project, such as a rail transit system, transportation agencies are bound by law to compensate owners for the market value of their properties taken due to the project's physical right-of-way or where the project severely harms the economic capacity of a property.[9] Other negative impacts on property owners may include detrimental impacts of construction, barriers to access (including restriction of

[8] See Burkhardt, J.E. et al., *TCRP Report 34: Assessment of the Economic Impacts of Rural Public Transportation*, 1998 for more detail of method and applications to specific projects in rural areas.

[9] What defines "takings" may vary according to State law and current legal interpretations. For a current discussion of these issues, see Economics Research Associates, Rivkin Associates, Daniel Mandelker, and Brian Blaesser, Robinson & Cole, prepared for U.S. Department of Transportation, Federal Highway Administration, *An Assessment of the Effects of Public Project Acquisitions on Adjacent Business* (October 1996).

left-hand turns or traffic delays), loss of parking, noise, and loss of visibility or views.

Despite these caveats, often very real and measurable property value impacts (mainly *corridor* impacts) are associated with transit projects,[10] and there are methods to estimate the magnitude of these impacts.

> *Key Point: Transit projects generally increase property values around stations and sometimes along corridors; most of the economic impacts of these value increases, however, are already captured in a formal analysis of user benefits.*

Data and Analysis

Calculating property value impacts of a transit project should be done at the level of particular segments or specific transit stations. There are two main categories of transit impacts on property values:

1. Direct valuation impacts of the project's construction and physical characteristics, which are both short and long term and mainly negative.
2. Accessibility and agglomeration valuation impacts around transit stations and corridors, which are mainly long term and mainly positive.

Direct Impacts

Construction of a new transit system, particularly rail, will have an immediate and direct impact on the value of parcels along its physical right-of-way as well as properties immediately adjacent to the right-of-way. Some of these impacts will be short term (such as the impacts of construction), while others will be long term and even permanent (such as the permanent takings of property or the elimination of access to parcels due to the physical presence of the project).

Right-of-Way Impacts

Under the takings clause of the Fifth Amendment to the U.S. Constitution and promulgated in what is known as the federal "Uniform Act,"[11] transportation and related government agencies are bound to compensate private property owners for land acquired for public use. These takings include entire parcels where the physical right-of-way of the project requires complete acquisition ("full takings"), as well as portions of parcels where the physical right-of-way infringes upon a property or severely damages its existing economic use ("partial takings"). What ultimately determines full or partial takings includes not only the legal requirements of federal laws and policies, but state laws as well. To estimate the value of these takings, analysts are strongly advised to procure the services of qualified appraisers. Alternatively, analysts can look at the data sources that an appraiser would—sales data, assessment data—and try to do their own valuation.

Construction Impacts

During the construction of fixed-guideway transit projects (as well as many street and highway projects), nearby properties that are not subject legally to full or partial takings may suffer adverse effects. These negative impacts can include access restrictions (including temporary lane and road closures, increased truck traffic, and detours), loss of parking, loss of visibility, disrupted utility service, noise, and dust. For commercial properties, such disruptions lead to losses in business revenues and thus lower achievable rents, which is the driver of value for any commercial real estate asset. For residential properties, the achievable market sales price of properties is impaired at least temporarily.

For commercial properties, rents may decline as much as 40 percent or more and average 10 percent for the typical business, based on case studies of rail and road construction impacts.[12] Studies suggest that typical businesses may face about a 10 percent loss in annual revenues due to construction impacts. Businesses that are highly dependent on customer access, such as gasoline service stations, may experience revenue losses of 40 percent or higher. Retail establishments typically experience the greatest revenue losses, but construction impacts can affect other businesses as well.[13] Table 7-1 provides sample ranges, drawn from case studies, of the impacts of construction on gross sales volumes. Note that the particular effects of construction delays and other impacts will vary considerably according to the duration and magnitude of the project, as well as other project-specific characteristics. For example, studies have shown that delays associated with the construction of road projects may outweigh the benefits of the eventual time savings due to the finished project, depending upon the nature of the project construction.[14]

To estimate such losses, there are two possible methods. The first method is to quantify the business receipts for the

[10] These impacts, as well as the methods to estimate them, apply to most types of transit projects.

[11] U.S. Public Law 91-646, "Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970" and subsequent amendments.

[12] See Economics Research Associates, Rivkin Associates, Daniel Mandelker, and Brain Blaesser, Robinson & Cole, prepared for U.S. Department of Transportation, Federal Highway Administration, *An Assessment of the Effects of Public Project Acquisitions on Adjacent Business* (October 1996), p. 50, in a case study of Indiana Department of Transportation projects; see also p. 59, case study of Wisconsin Department of Transportation projects.

[13] Economics Research Associates, Rivkin Associates, Daniel Mandelker, AICP, and Brian Blaesser, Robinson & Cole, prepared for Federal Highway Administration, *An Assessment of the Effects of Public Project Acquisitions on Adjacent Business*, October 1996.

[14] See Surface Transportation Policy Project, *Road Work Ahead: Is Construction Worth the Wait*, 1999, www.transact.org.

TABLE 7-1 Sample ranges of construction impacts on businesses

Type of Business	Reported Declines in Sales Volume during Highway Construction
Gasoline service stations, car washes, and other non-repair automotive service establishments	13 to 42%
Groceries, convenience stores, bakeries, and other food stores	13 to 31%
Restaurants and taverns	16%
Home furniture and furnishings, consumer electronics, music, computer stores, and other retail businesses	17 to 28%
Wholesale businesses	3%
Professional services	2%

Source: From case studies in Indiana and Wisconsin, as described in Economics Research Associates, Rivkin Associates, Daniel Mandelker, AICP, and Brian Blaesser, Robinson & Cole, prepared for Federal Highway Administration, *An Assessment of the Effects of Public Project Acquisitions on Adjacent Business*, October 1996. Note that these figures are based on information reported by companies following construction; the data were not independently verified, and businesses that failed during the construction period are not included.

affected corridor from state employment data (which often requires special permission for its use). From these numbers, one can derive estimates of total business sales and use the general guidelines found in Table 7-1. Note that these estimates are from highway studies. And again, the longer the delay associated with a project, the greater the magnitude of these construction period impacts.

The second method typically requires the expertise of an appraiser and involves identifying comparable sales, leases, or both for properties with and without construction impairment.

Longer-Term Direct Impacts

The physical construction of a transit project may have other property value impacts in the longer term, aside from properties that are fully or partially taken. Access restrictions that the project creates, particularly along commercial corridors, may have either positive or negative impacts on businesses and resulting property values. For instance, restrictions of left-hand turns have been found to affect business revenues up to 25 percent or more for certain types of "drive-by" customer-dependent businesses.[15] Loss of both onsite and offsite parking may also have negative impacts; the magnitude of these losses depends upon the nature of those businesses and periods when parking is at full capacity (e.g., holiday season shopping for consumer goods, peak-hour travel times for convenience stores).

In general, loss of onsite parking will have a greater impact on businesses—and, thus, property values—than loss of offsite parking. Offsite or street parking would typically have a greater impact on areas of high densities, where many businesses lack onsite parking options. Loss of parking, on the other hand, does not necessarily mean that there is an overall cost. Many municipal zoning and land use requirements in fact may lead to too many parking spaces, if one considers all of the development and opportunity costs associated with such requirements.

A small reduction in either onsite or offsite parking as a result of a transit project may have little adverse impact, except for corridors and areas where parking is already in short supply (particularly during peak capacity periods). However, a substantive long-term loss in parking due to right-of-way and other displacements would be considered a negative economic impact, particularly on commercial uses.

Accessibility and Agglomeration Impacts

On the positive side, the greater access afforded by certain transit projects will increase property values.

Many of the overall economic benefits attributable to a transit project—those measured in the previous chapters of this guidebook—may be reflected in increased property values across the transit system. These long-term property value impacts exist, though the evidence is mixed as to their extent and magnitude.[16] In general, an inverse relationship exists between the distance, or travel time, from a rail transit station and property values. This effect is most pronounced within an approximately quarter-mile radius around certain stations; beyond that distance, the effect diminishes substantially. Further, heavy rail appears to have a stronger positive effect on property values than does light rail.

TCRP Report 35: Economic Impact Analysis of Transit Investments: Guidebook for Practitioners, Section 9.2, provides a comprehensive methodology for estimating these property value impacts. The general steps in the methodology outlined in *TCRP Report 35* are as follows:

[15] See National Cooperative Highway Research Program, *Research Results Digest 231*, "Economic Effects of Restricting Left Turns" (August 1998).

[16] See Ryan, S. 1999. "Property Values and Transportation Facilities: Finding the Transportation-Land Use Connection," *Journal of Planning Literature*, col. 13, no. 4, p.412–427.

1. Estimate the amount of development to occur along a transit corridor, using a transportation and land use forecasting model such as DRAM/EMPAL.
2. Estimate the land value premiums for each land use at varying distances from a transit station, based on other comparable projects or a detailed study of the existing transit project.
3. Forecast total land value changes for each station or corridor.

Evidence suggests that rail transit systems can increase nearby property values by providing greater access throughout the metropolitan region. The literature shows that positive impacts are most pronounced in areas within a quarter-mile radius of light rail stations. As a rough guideline, Table 7-2 summarizes the range of property value impacts from some of the many studies that have been conducted on rail transit projects.

These figures cited in the literature estimate the "premium value" of locations near rail stations for different property types and distances from transit. Use these ranges as a guideline, understanding that most of these studies were conducted in larger urban areas. In general, greater impact will occur where densities are higher, travel-time savings are large, transit stations coexist with other transportation junctions such as highways, and regions are experiencing a high degree of population and employment growth. In addition, one would expect greater impacts on properties near larger systems, since access to such systems offers a greater accessibility advantage than does access to a system with only limited service or coverage. Commuter rail has a greater positive impact on property values than does light rail. Also, studies suggest that some positive effects on property values may not appear for more than a decade after completion of the transit system.[17]

Summary

Different aspects of transit projects have different component effects on property values. Construction impacts are generally negative, but short term. It may be that investors cannot see past the problems of construction to the benefits of operation and that property values do not increase or even drop.

Property values could also drop because of a realistic assessment that the long-run change in accessibility will be small or negative. That could certainly occur for some properties affected by a transit project. For fixed guideway projects, it is clear that accessibility benefits occur primarily at transit stops. Property along the corridor but not at the stop could easily see a decrement in value from direct reduction in access (e.g., reduction of automobile turning movements), construction hassles, and operating noise.

The challenge for analysts is to determine the net effect for all affected properties: the present value of changes in property value for the study area.

If appraisers were to try to estimate these changes in property values, their key questions would probably be: What are the expected changes in access and related public facilities that this project will create, how do businesses and investors value that accessibility, and how confident are they that the accessibility will be improved? In other words, the changes in property values depend primarily on changes in access, and, therefore, are primarily a different way of expressing the benefits of access. Thus, any property value changes that an analyst estimates cannot properly be added to the benefits and costs estimated in Chapters 3, 4, and 5.

EMPLOYMENT, OUTPUT, AND INCOME EFFECTS DUE TO CONSTRUCTION AND OPERATIONS OF TRANSIT PROJECT

Framework

In general, a formal benefit-cost analysis should not account for any direct or indirect economic activity generated by the construction and ongoing operations of any transportation project. Such activity includes the output, employment, and labor income generated by both the initial investment in the project and subsequent expenditures to operate and maintain it once constructed. Although policymakers and others are often interested in the number of jobs created from a large public investment for a particular state, regional, or local economy, for various reasons these impacts should be excluded

[17] Bernard L. Weinstein and Terry L. Clower, *The Initial Economic Impacts of the DART LRT System*, prepared for Dallas Area Rapid Transit (University of North Texas, Center for Economic Development and Research, July 1999), and Cambridge Systematics, Inc., Robert Cervero and David Aschauer, *TCRP Report 35: Economic Impact Analysis of Transit Investments: Guidebook for Practitioners*, Transit Cooperative Research Program (Washington, D.C.: National Academy Press, 1998).

TABLE 7-2 Range of property rent and value impacts due to rail transit projects

Distance to Rail Station	Office Rents	Retail Property Sales Price	Multi-Family Housing Rents	Single-Family Home Sales Price
Less than 500 feet	0 to 20%	1 to 8%	0 to 5%	-11 to +17%
500-1000 feet	0 to 4%	0 to 8%	0 to 5%	0 to 6%
1000-2500 feet	--	--	0 to 5%	0 to 11%

Source: Cambridge Systematics, Inc., Robert Cervero, and David Aschauer, *Economic Impact Analysis of Transit Investments: Guidebook for Practitioners*, Report 35, Transit Cooperative Research Program (Washington, D.C.: National Academy Press, 1998), Table 9.6.

from the benefit-cost analysis. These impacts can, however, be measured and identified separately.

At least three reasons exist for excluding these impacts from the formal benefit-cost analysis. First, construction costs are first and foremost just that: costs. That is how Chapter 5 accounts for them. To account for them again as a benefit is not consistent with the basic principles of benefit-cost analysis described throughout this guidebook.

Second, investment in a large public project such as transit is actually a transfer of fiscal resources from one or more other possible investments. Depending upon the geographic and jurisdictional scale of this transfer, the overall impact of these expenditures could range from being negligible (e.g., at the scale of the nation as a whole) to substantial (e.g., at the scale of a municipality where a major portion of a project may be located). Moreover, the investment might be fungible—if the funds are not spent on a particular transit project, they might be spent on a different transit project, transportation project, or other infrastructure projects (e.g., sewer, parks). In that case, assuming the investment amount is similar, the regional economic impacts would be similar, although the distribution of those impacts would vary.

Third, focusing on the employment impacts of a project may be more or less important to a region, depending upon the degree of economic health in the geographic area studied. For instance, in an area with nearly full employment, any new jobs created would not be considered a true benefit if the labor supply is already constrained. In fact, it could be considered a detriment to the region if the demand for labor results in increased costs to businesses and labor shortages. Employment gains may be considered a benefit in regions where there is not full employment or where the types of jobs created by the construction, maintenance, and ongoing operations of a transit project are preferred over existing employment opportunities.

In cases where policymakers, planners, or the public are interested in these employment and output impacts, various methods can estimate them, including simple employment multipliers, input-output analysis, and econometric models.

New investment in a region that generates new economic activity that otherwise would not have occurred is considered to have a net positive impact on the region's overall economy. This activity is typically measured in terms of output (sales), labor income (payroll), and employment (new jobs). At the regional and local level, the underlying concept behind calculating these impacts stems from what is commonly known as *economic base theory*. This theory posits that the economic growth of any given region is attributable to the level of goods and services sold outside the region (*basic* commodities or regional exports) or that otherwise bring money into the regional economy. A portion of this money will be spent on goods and services from local suppliers (inputs, or *backward linkages*); a portion will be spent on paying employee wages and salaries; and a portion will be spent outside the region (known as *demand leakage*) for both inputs and labor income to employees residing outside the region.

A portion of the money is spent locally by firms, generating first-round activities on goods and services. The businesses supplying those services spend portions of it yet again on other goods and services, as well as wage payments to employees in the region, creating a *multiplier effect* as dollars are spent and re-spent in the region. Each successive round of expenditures diminishes in magnitude due to demand leakage, or the purchase of regional imports. Industries and activities selling a major portion of their goods and services outside the region are deemed basic sectors, while other activities focused on largely serving local markets are non-basic.

Examples of basic sectors would include an automobile manufacturing facility (where the final products are sold outside the region), a specialized law firm whose clients are located distant from the firm's offices, a military base where the source of funding comes from outside the region (e.g., the federal government), or tourism (where tourists bring in non-local dollars). Examples of non-basic activities include grocery stores, most consumer services such as family doctors and movie theatres, and housing contractors.

With respect to a transit project, outside money may enter a region in the form of federal and state funds, which could act much like a "basic" industry that sells goods and services to customers outside the region. In these cases, one can estimate the number of new jobs and the amount of output and labor income directly attributable to these funds, which would have not been available to the region absent the project, as well as the additional activity generated from the labor, material, and other inputs necessary for these direct jobs.

The most commonly applied method of determining the employment, output, and income impacts of a transit investment is through application of multipliers in an *input-output* analysis, where one can determine the *direct* and *indirect* effects. Input-output analysis quantifies the multiple economic effects resulting from a change in the final demand for a specific product or service. These effects will accrue from both the initial investment or construction (capital costs) and the ongoing operations of the system (operating costs). Capital costs will have upfront, more short-term impacts, while operating costs will occur later and be sustained as long as the transit system is running. As a system is improved, there will be additional periods of short-term effects from capital expenditures. It is important that these two separate categories of expenditures and their effects be identified separately throughout the analysis.

Key Point: Construction and ongoing operation of a major transit investment can enhance the regional economy in total output, employment, and labor income, but only to the extent that the project is financed by funds from outside the region.

Data and Analysis

Defining the Area of Interest

Before conducting the impact analysis, one must determine at what scale the impacts are being calculated. In theory, the determination should be driven by the extent to which the transit investment would generate some form of impact. At the least, this scale would be the geographic boundaries of the area the transit system serves (e.g., a metropolitan area), with consideration for the effects outside this immediate area (e.g., the project may be funded from a larger regional entity encompassing multiple counties, while the service area may comprise a smaller portion of this larger region). In reality, one will typically be forced to conduct the analysis at a scale consistent with the availability of data for the inputs and the geographic unit at which the input-output tables are based. The most commonly applied input-output multipliers are found at the state, county, and metropolitan area level (using the IMPLAN model, applied below). While some methods focus on other geographic units of analysis,[18] these models require more sophisticated approaches and customized analyses.

Identifying the Sources and Amount of Funding from Outside the Region

An important, though often ignored, component of an economic impact analysis is to identify only those funds and activities from *non-local* sources or funds from outside the study area. Funds that stem from local sources, such as dedicated local sales tax levies, should be excluded from the analysis. Table 7-3 identifies some of the most common sources of transit funding and their inclusion or exclusion in an economic impact analysis at a county or metropolitan area level.

If possible, these funds should be allocated to the capital and operating expenses of the project. For instance, if federal highway funds are used solely toward the construction of the project, then these resources should be designated only for the capital costs (and included in the impact analysis). If, on the other hand, the operating costs are funded through general county and municipal budgets to a regional transit authority, then they would be excluded from a region-level analysis.

Calculating the Impacts of Capital and Construction Costs

Transit projects usually receive outside funding in the form of state and federal assistance. This money is invested in the local economy and will directly result in more jobs and, thus, the indirect and induced benefits associated with more jobs. To quantify the effects of the infusion of new money in the study area, analysts must measure only non-local funds that will be spent in the study area.

Chapter 5 identified the direct capital and construction costs of a transit project, and these line items serve as the inputs to the impact analysis. These line items should be evaluated for (1) the amount funded from outside dollars (based on the analysis above) and (2) the proportion of these items purchased from businesses in the study area, as identified below in Table 7-4. For the latter figure, the most accurate means is through a survey of the likely contractors for the project, asking each what proportion of their expenditures are purchased within the region. Such a survey could be both costly and time-consuming; an alternative approach would involve more targeted interviews with informed individuals, as well as commonsense judgment by a seasoned analyst.

Multiplying the total direct expenditures by the percentage of funding from outside the region and the amount of purchases made within the region, results in the net direct expenditures of the project, as indicated in Table 7-4.

The next step is to calculate the total output generated by the construction of the project on the regional economy. Table 7-5 demonstrates these calculations.

The multiplier applied in Table 7-5 is what is known as a "Type II multiplier."[19] This multiplier captures (1) the direct expenditures of the project; (2) the indirect expenditures, based on purchases from regionally based businesses and payments to labor; and (3) the "induced" expenditures made by workers in the regional economy. The size of the multipliers will depend on the linkages of industries within the region studied. Generally, as a larger region is analyzed (e.g., a state versus a county), the multiplier will be higher, as more expenditures are kept within its boundaries. Rural regions generally have lower multipliers than metropolitan areas. Table 7-6 provides a range of multipliers for selected industries associated with transit projects across varying levels of geographic scale. These ranges are not inclusive of every possible region and should not be applied in any rigorous or formal analysis of impacts without incorporating more information specific to the locale.

Another type of multiplier is applied to calculate the labor income associated with the direct expenditures of a transit project. Table 7-7 shows these calculations.

The labor income effects multiplier shown in Table 7-7, as with all the multipliers in this example, is obtained through an input-output analysis such as IMPLAN or RIMS II. In Table 7-7, we see that the total net direct expenditures of $419 million result in $251 million in the regional economy. Table 7-8 illustrates ranges of labor income multipliers for varying geographic scales.

[18] For instance, one can apply location quotients, or measures of sectoral concentration, to adjust aggregate level models (see Isard, Walter et al. 1960. *Methods of Regional Analysis: An Introduction to Regional Science*. Cambridge, MA: MIT Press.)

[19] See MIG Inc., *IMPLAN Professional: User's Guide, Analysis Guide, Data Guide*, www.IMPLAN.com, 1999, for a more detailed explanation of multipliers. A Type I multiplier captures only the indirect (not induced) expenditures.

TABLE 7-3 Examples of funds and their inclusion or exclusion in economic impact analysis

Definitely Included	Possibly Included	Definitely Excluded
Federal grants and funds	State funds from outside region that otherwise would have been used for alternative purposes in the region State motor fuel taxes Non-local licenses, permits, and fees Motor vehicle excise taxes State sales taxes State grants Private donations of funds and property	Local funds derived within the study area Local sales or fuel taxes Local-option transportation taxes (street utility fees, commercial parking taxes, etc.) Property taxes

Source: ECONorthwest.

TABLE 7-4 Example calculation of regional economic impacts of transit construction: calculating net direct expenditures

Expenditure Category	Total Direct Expenditures ($Million)	% Funding From Outside Region	Total New Money ($Million)	% Spent in Region	Net Direct Expenditures ($Million)
Transit Construction	2,100	33	693	60	416
Vehicles	200	33	66	5	3
Right of Way	100	0	0	100	0
TOTAL	2,400		1,370		419

Source: compiled by ECONorthwest. Example loosely based on *Final Environmental Impact Statement: Economics Technical Report*, Sound Transit, Central Puget Sound Regional Transit Authority, U.S. Department of Transportation, Federal Transit Administration, November 1999.

TABLE 7-5 Example calculation of impacts of transit construction on regional output

Expenditure Category	Total Direct Expenditures ($Million)	Multiplier (Indirect and Induced Output)	Total Direct, Indirect, and Induced Impacts ($Million)
Transit Construction	416	1.7	707
Vehicles	3	1.5	5
Right of Way	0	N/A	0
TOTAL	419	1.7	712

Source: ECONorthwest.

TABLE 7-6 Example ranges of output multipliers for project construction (direct, indirect, and induced expenditures)

	Rural—County	Metropolitan Area	State
Highways and Streets	1.2—1.6	1.5—2.2	1.6—2.4
New Government Facilities	1.3—1.5	1.6—2.0	1.7—2.3
New Industrial and Commercial Buildings	1.3—1.5	1.6—2.0	1.7—2.3
Vehicle Assembly	0.0*—2.0	1.6—2.2	1.7—2.3
Business Services	1.3—1.6	1.5—2.1	1.6—2.3

Source: ECONorthwest analysis; IMPLAN; RIMS II.

* Note that where an industry does not exist in a region, there will be a multiplier of zero. Industries such as vehicle assembly may have substantial variations in their impacts on small regions.

TABLE 7-7 Example calculation of impacts of transit construction on regional output

Expenditure Category	Total Direct Expenditures ($Million)	Labor Income Effects (Direct, Indirect, and Induced) Multiplier	Total Labor Income Expenditures ($Million)
Transit Construction	416	0.6	250
Vehicles	3	0.3	1
Right of Way	0.0	N/A	0
TOTAL	419		251

Source: ECONorthwest.

TABLE 7-8 Example ranges of labor income multipliers for project construction (direct, indirect, and induced)

	Rural—County	Metropolitan Area	State
Highways and Streets	0.3—0.5	0.5—0.8	0.5—0.8
New Government Facilities	0.4—0.6	0.6—0.9	0.6—0.9
New Industrial and Commercial Buildings	0.4—0.6	0.5—0.8	0.6—0.9
Vehicle Assembly	0.0—0.5*	0.3—0.6	0.3—0.8
Business Services	0.5—0.8	0.7—1.1	0.7—1.1

Source: ECONorthwest analysis; IMPLAN; RIMS II.

* Note that where an industry does not exist in a region, there will be a multiplier of zero. Industries such as vehicle assembly may have substantial variations in their impacts on small regions.

Finally, one can calculate the employment impacts of a transit project's construction using similar ratios and multipliers. For employment, two means exist for estimating the number of direct jobs associated with the project: (1) actual employment information and (2) application of output-per-employee ratios for various categories. In general, one should use actual estimates of project employment by category, if known. Table 7-9 illustrates the first method.

In Method 1, known direct employment associated with project construction is multiplied by the percent of outside funding and the percent spent in the region. This number is then multiplied by an employment multiplier to yield the total direct, indirect, and induced employment impacts.

The alternative, Method 2, is applied when construction project employment is not known. Table 7-10 illustrates this calculation.

Table 7-11 identifies ranges of output to employment multipliers for project construction.

To summarize, the construction impacts from the example calculations yield the following results in Table 7-12.

These construction impacts are short-lived and will be spread over the construction period. The next section sum-

TABLE 7-9 Example calculation of impacts of transit construction on regional employment—Method 1

Category	Actual Direct Employment	% Outside Funding	% Spent in Region	Net Direct Jobs	Employment Multiplier (Direct, Indirect, Induced)	Total Regional Employment Impacts of Project Construction
Transit Construction	15,000	33	60	2,970	2.1	6,237
Vehicles	400	33	5	7	4.7	33
Right of Way	200	0	NA	0	N/A	0
TOTAL	15,600			2,977		6,270

Source: ECONorthwest.

TABLE 7-10 Example calculation of impacts of transit construction on regional employment—Method 2

Category	Net Direct Expenditures	Total Direct, Indirect, and Induced Employment per $1 million	Total Regional Employment Impacts of Project Construction
Transit Construction	416	12.5	5,198
Vehicles	3	10.2	34
Right of Way	0.0	N/A	0
TOTAL	419		5,232

Source: ECONorthwest analysis.

TABLE 7-11 Example ranges of output to employment (direct, indirect, and induced) multipliers for project construction (per $1 million of net direct output)

	Rural—County	Metropolitan Area	State
Highways and Streets	15.0—19.0	17.0—21.0	16.0—20.0
New Government Facilities	16.0—21.0	17.0—22.0	17.0—22.0
New Industrial and Commercial Buildings	15.0—20.0	18.0—21.0	19.0—22.0
Vehicle Assembly	8.5—9.5	8.5—9.5	8.5—9.5
Business Services	25.0—50.0	25.0—60.0	20.0—60.0

Source: ECONorthwest analysis; IMPLAN; RIMS II.

TABLE 7-12 Example calculation of impacts of transit construction—summary

	Output ($Million)	Labor Income ($Million)	Employment (Jobs)*
Transit Construction	707	250	5,198
Vehicles	5	1	34
Right of Way	0	0	0
	712	251	5,232

Source: ECONorthwest. * Using Method 2, from Table 7-10.

marizes the method for calculating the long-term impacts of a transit project's ongoing operations.

Calculating the Impacts of Operation and Maintenance Costs

The method for calculating the impacts associated with the operation and maintenance of the project is essentially the same as for the construction impacts, except the impacts span the life of the project. First, an inventory of all budgeted operation and maintenance expenditures must be taken, ideally in a stable year of operation. As in the example above, the portion of the budget items funded from non-local sources should be identified and the amount of the expenditures that will be spent in the study area should be estimated. The resulting number is the net direct expenditures, or eligible funds. Table 7-13 summarizes these calculations.

As with estimating construction impacts, these multipliers are from input-output analysis tables such as IMPLAN and RIMS II. Where possible, the analyst should categorize expenditures according to specific industries and apply the associated multipliers. Table 7-14 provides a range of example multipliers for five different expenditure categories typically associated with transit operations across various geographic scales. Depending upon the nature of the transit project and its particular expenditures, one can apply the appropriate category, or mix of categories, to the project. For instance, where the direct expenditures of the operation of the transit system are known, one can apply the "Local and Suburban Transit" multiplier ranges. For governmental administrative expenditures, one should apply the "State and Local Government" or "Federal Government" figures. "Business Services" include private companies providing such services as architecture and engineering, legal, accounting, and consulting services. Note that these multipliers are guidelines and should not be applied in any rigorous analysis of economic impacts without incorporating more region-specific information.

A More Comprehensive Approach

Obviously, the multipliers given in the previous section are an approximation based on specific conditions in specific economies. They were provided to give transportation decisionmakers quick tools to estimate the potential economic impacts from the construction and ongoing expenses of a transit project. For a more comprehensive approach than the one outlined above, use input-output models like IMPLAN or RIMS II. These models contain data for each county or

TABLE 7-13 Example calculation of impacts of transit operations

		Output		Labor Income		Employment	
Category	Eligible Annual Expenditures ($Millions)*	Multiplier	Net Impact ($Million)	Multiplier	Net Impact ($Million)	Multiplier (Jobs per $Million)	Net Impact (Jobs)
Vehicle Operations	20.0	1.8	36.0	0.9	18.0	35.0	700
Admin.	5.0	3.0	15.0	2.1	10.5	20.0	100
Maintenance and Repair	5.0	1.7	8.5	0.8	4.0	24.0	120
Other	2.0	1.9	3.8	0.6	1.2	30.0	60
TOTAL			**63.3**		**33.7**		**980**

Source: Calculations by ECONorthwest.
* Calculated in same manner as in Table 7-2. Only include expenditures spent locally and funded by outside sources.

TABLE 7-14 Example multipliers for transit operations and maintenance

	Rural—County	Metropolitan Area	State
Output Multipliers			
Local and Suburban Transit	1.2 - 1.6	1.6 - 2.0	1.6—2.0
Maintenance and Repair	1.4 - 1.7	1.6 - 2.0	1.6—2.0
State and Local Government	1.5 - 1.9	1.8 - 2.2	1.6—2.1
Federal Government	1.1 - 1.5	1.2—1.6	1.2—1.6
Business Services	1.3 - 1.6	1.5—2.1	1.6—2.3
Labor Income Multipliers			
Local and Suburban Transit	0.3 - 0.6	0.7—1.0	0.5—0.9
Maintenance and Repair	0.5 - 0.8	0.6—0.9	0.6—0.9
State and Local Government	0.3 - 0.6	0.5—0.8	0.5—0.9
Federal Government	0.2 - 0.4	0.2—0.6	0.2—0.6
Business Services	0.6 - 0.8	0.7—1.1	0.7—1.1
Employment Multipliers **(Jobs per $million)**			
Local and Suburban Transit	40 - 60	50—80	40—70
Maintenance and Repair	20 - 30	20—30	20—30
State and Local Government	10 - 20	15—25	15—25
Federal Government	5 - 10	5—15	5—15
Business Services	25 - 50	25—60	20—60

Source: ECONorthwest analysis of sample RIMS II and IMPLAN multipliers.

metropolitan area in the country and provide specific information by industry for employment, output, and income.

REMI and Other Econometric Approaches

Input-output models have their own limitations, most notably that they are static models that deal with a one-time infusion in an economy. Other analytic techniques may prove more rigorous, but they require a great deal more time and expertise to run. Econometric models incorporate many more equations and variables than simple multiplier relationships. REMI, or the Regional Economic Models, Inc., econometric model, is one of the most widely used of these more comprehensive (and expensive) models. The advantage of these models is that they can provide a more detailed assessment, particularly in regions with diverse urban economies.

CONCLUSION

Frequently, benefit-cost analyses erroneously include transfers of benefits within a region, which have been mistaken for economic development benefits. Carefully prepared benefit-cost analyses exclude these transfers and include only those benefits that result in an overall increase in economic welfare for the region. Transit projects do have the capability of advancing other legitimate economic development objectives, particularly for specific sub-areas and corridors within a region. In some cases, these effects can be estimated, such as localized impacts on land values or new jobs created as a result of the construction and operation of a major project. However, practically all of these other effects should be considered outside the formal framework of analyzing the benefits and costs of a transit project.

CHAPTER **8**

DISTRIBUTION OF TRANSIT'S IMPACTS

SUMMARY

The benefits and costs that are described in previous chapters are frequently not distributed evenly across population subgroups, and decisionmakers are often called on to make judgments regarding the equity or fairness of transportation impacts. While the determination of "fairness" essentially remains a value judgment, methods to calculate and describe the distribution of impacts have been developed and are discussed in this chapter.

Distributional analyses typically distinguish project benefits and costs by travel mode (e.g., transit riders and auto users), income level and ethnicity, and location (by neighborhood, county or state). Other subgroups that may denote special standing, such as age, gender, or physical ability, may also be used, particularly if it can be shown that some group's basic transportation needs are not being met. When federal funds are to be used to build transportation projects or an Environmental Impact Statement is to be completed, specific federal guidelines must be followed in identifying affected subpopulations. These guidelines generally require that transportation agencies avoid, minimize, or mitigate disproportionately high or adverse impacts to minority and low-income populations. This chapter concludes with descriptions of various data sources that associate travel mode with income, ethnicity, and location, to which analysts can turn in order to describe the local distribution of transit's impacts.

OVERVIEW

Chapter 2 noted that the unattainable ideal for public policy choices is to have information about all types of impacts, on all types of people, at all times. Chapters 3 through 7 then discussed those types of impacts, focusing on aggregate effects in the long run (i.e., on summary measures of impacts for the relevant study area). But those aggregate impacts are, in theory, the summation of all the impacts on individuals in the relevant study area. It is not only possible, but likely, that aggregate benefits are a result of benefits to some that more than offset losses to others. Losses to certain subpopulations in the study area, and how much they lose, is a relevant consideration for policymaking: the *distribution* of impacts matters.

How impacts are distributed is often referred to as *equity*. The term "equity," however, has a normative component that the term "distribution" does not. Equity implies a judgment about whether the distribution of impacts is desirable. This chapter limits itself to describing how the aggregated impacts described in Chapters 3 through 7 might be measured for different subgroups; it does not address the value of those distributions in any detail. Chapter 9 gives some ideas about how those distributional measurements can get incorporated into public decisionmaking.

FRAMEWORK

For transportation analysis, the main subcategories of the aggregate analysis of concern for policymaking are

- Mode—for example, transit riders compared with other trip-makers, with consideration of groups with special transportation needs.
- Income and ethnicity—for example, low-income groups compared with other income groups.
- Location—for example, inner city areas compared with suburban areas; one city compared with another.

Groups could also be defined by age, type of job, type of trip (work versus discretionary), physical ability, type of household (single parents have less flexibility as to mode or time of day), and gender. Or, one could evaluate the distribution of impacts on different levels of governments (e.g., federal versus state, or special district versus city). This chapter simplifies the discussion by focusing only on the groups listed in the bullets above. Its ideas can be expanded and applied to other groups as well.

The underlying concern about the distribution of impacts is that some group judged to have special standing may have impacts (benefits or costs) that are not in the same proportion as the average, aggregate impacts. This idea has been institutionalized in transportation evaluation (in fact, in all Environmental Impact Statements) under the heading of "Environmental Justice." Evaluation of significant public works must examine whether special groups (usually defined by income or ethnicity) have "disproportionate impacts." Executive Order 12898, "Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations," reinforced the importance of following existing federal law—primarily the National Environmental Policy Act (NEPA);

Title VI of the Civil Rights Act of 1964 (Title VI); the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970, as amended (URA); and the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA)—when evaluating projects that will be built using federal funds.[1] For detailed guidance regarding Environmental Justice issues, analysts should refer to these documents.

With respect to large capital projects, to meet the requirements of Executive Order 12898, transportation agencies must avoid, minimize, or mitigate disproportionately high and adverse human health or environmental effects, including social and economic effects, on minority populations and low-income populations.[2] Compliance can be demonstrated by a careful analysis of the distribution of costs and benefits, typically carried out in support of an Environmental Impact Statement.

Since distributional analysis must describe the costs and benefits by subsets of the population, it is important to define the subsets of the population. For example, dividing the population into two groups based on income (high income and low income) may yield different results than an analysis of impacts by income quintiles. Defining the basis and parameters of a distributional analysis by income, ethnicity, and location can have a significant effect on the results. For example, parameters and their impacts include the following:

- Defining the affected area. Choosing the appropriate scale of analysis is important, since a large analytic area will almost certainly be similar to the reference population, whereas the smaller the area, the more likely disproportionality will be determined. Given that overlapping environmental impacts are likely, it may be necessary to develop multiple buffers (1/2-mile, 1-mile, 2-miles) around the project area to capture the true impacts of noise, air pollution, and potential groundwater contamination. The demographic composition of these buffers must be calculated and then used to determine the environmental impacts on minority and low-income populations. The Environmental Protection Agency (EPA) recommends that an Environmental Impact Statement also report the demographic composition of non-chosen alternatives,[3] noting that pockets of minority or low-income communities may be located within a much larger analytic area (investigators are to be mindful of such pockets). In practice, this means that all Census block groups within the analytic area should be scanned for minority and low-income populations.
- Stratifying the population by ethnicity and income (e.g., the lower the income threshold, the more likely are findings of disproportional impacts). With respect to environmental justice requirements, low-income populations are those below the Bureau of the Census' poverty threshold. Minority should be taken to mean an individual who is a member of the following population groups: American Indian or Alaskan Native; Asian or Pacific Islander, African-American; or Hispanic. Analysts must identify areas where 50 percent or more of an affected area is populated by minorities or low-income individuals or where the minority population percentage is meaningfully greater than the reference area.
- Defining the "general population" or reference area that will be used for comparison purposes (the more the reference population is unlike the impacted population, the more likely disproportionality will result). The EPA recommends that the next higher geographic unit of analysis be used (compared with the affected area), such as the entire municipality or township.
- Choosing a concept of "disproportionate" that is consistent with applicable thresholds (either "preponderance of impact" or "fair share of impact"). The determination of whether or not a minority or low-income community faces disproportionately high and adverse environmental impact should be based on three factors:
    1. Whether there will be a significant adverse impact (as defined by NEPA) on a minority or low-income population,
    2. Whether the significant adverse impact exceeds the impacts on the general population or the population within the reference group, and
    3. Whether a significant adverse impact will occur in a minority or low-income area affected by multiple adverse impacts.
- Distinguishing between populations (number of people) and communities or neighborhoods (number of households, or defining an area as a "minority community" when its population consists of minority and nonminority individuals).[4]

Key point: Most distributional analyses estimate project benefits and costs by travel mode, income and ethnicity, and location, although other groupings (e.g., age) may be warranted. For projects that receive federal funds, distributional analysis is required. Federal regulations provide detailed guidance regarding what information must be developed and methodologies that are generally accepted.

Distributional analysis is also affected by the units used for evaluation of the distribution of benefits. Using vehicle mileage to measure travel, and traffic congestion to measure need, tends to favor automobile travel. Using passenger mileage gives greater weight to transit expenditures and benefits.

[1] Department of Transportation (DOT), Order To Address Environmental Justice in Minority Populations and Low-Income Populations, *Federal Register*: April 15, 1997 (Volume 62, Number 72) pp. 18377-18381.

[2] Ibid.

[3] Environmental Protection Agency (EPA), Final Guidance for Incorporating Environmental Justice Concerns in EPA's NEPA Compliance Analyses, April 1998.

[4] Crisp, Wynnlee (1999). "Objective Determination of Disproportionate Impacts In Environmental Justice Analysis." Presented at the National Association of Environmental Professionals Annual Meeting, June 22.

Using person-trips to measure transportation gives greater weight to transit, bicycling, and walking. Using access to measure transportation gives greater weight to non-travel options, such as telecommuting and location-efficient land use patterns.

Distributional analysis usually considers the distribution of benefits and costs among groups at a single point in time, but a lifecycle analysis may often be more appropriate. For example, although motorists may not currently use public transit, they may when they are too young or old to drive, or when living in a large city. Since demographics shift over time (especially, as a large cohort of baby-boomers moves from middle-age to elderly), a dynamic view of need and impact is desirable. This example illustrates another point as well: that different groups will value and benefit from transit differently and that the young and old may have special status that would cause society to value transportation benefits to them more highly than to all age groups in between, which generally are more able to find transportation options. This example illustrates the complications of a distributional analysis: it is not the case that all young and elderly have special transportation needs. The young may have few and short trips and be much more able to bike or walk. The elderly may have more income and schedule flexibility and be able to drive wherever they want without concern about cost.

For each group, the focus will be on the distribution of benefits (transportation performance) and associated direct and indirect costs. For instance, does one group get better transportation performance that either (1) another group pays for but does not receive (e.g., a downtown transit station costs central city residents but primarily benefits suburban commuters) or (2) comes at the expense of the travel performance of another group (e.g., transit riders get reduced travel time while auto drivers get increased travel time)?

> *Key point: While absolute levels of benefits and costs (by group) are important to distinguish, the relationship of benefits to costs is important to estimate also (do some people pay disproportionately more for greater transportation performance?). In addition, the measurement units (e.g., vehicle miles) used for the analysis can favor particular modal solutions, and longer term impacts may be important to consider where travel behavior or demographics are expected to change significantly from current conditions.*

Note that a description of the distribution of effects is something that a technical analysis can achieve, while a description of the equity or fairness of an implementation is not. Fairness is a value judgment: ten people could look at the same distribution of effects and have ten different opinions about fairness. The best an analyst can hope for is a clear description and estimation of distributional impacts and of standard principles for a normative discussion of equity. Those principles include *horizontal equity* (Are people in roughly the same situation treated the same?) and *vertical equity* (Are people in different situations that society cares about treated differently? For example, do those with special needs get extra resources?).

There is general agreement that everybody deserves "equal opportunity." As a practical matter, this idea is implemented in policy by laws that give equal access to education and employment opportunities to all people, regardless of ethnicity, sex, religion, physical limitations, or other characteristics.

Transportation obviously has a big effect on people's access to opportunity. In a world of ubiquitous transportation choices among multiple modes and prices from all locations and adequate income for all to access at least one of these modes, transportation might not be a big factor in the equity of opportunity. To the extent these conditions are not met, however, society may decide to give special consideration to groups with special needs. Such special consideration gets implemented though federal, state, and public policies, and decisionmakers adopting such policies usually require evidence that certain groups are being treated differently (and, by implication, unfairly) or otherwise are enduring some transportation hardship. Thus, the analyst must often address the distribution of impacts.

For this reason, some transportation is often considered to be a "merit good"[5] and even a right.[6] "Basic mobility" consists of trips that are considered valuable to society (they provide external benefits), such as access to education, employment, and basic services (stores, medical care, and civic activities), and, to a lesser degree, social and recreational activities. It is these trips that are most often considered to deserve community subsidy, while other types of travel (luxury travel) are usually expected to be self-supporting.

To this point we have focused on different ways to subdivide households primarily with respect to travel impacts. Another perspective that a distributional analysis could take is a financial one: who is paying for the transit improvement and are benefits roughly in proportion to costs?

For example, the cost of a transit project may be funded by a mix of federal grants and local funds. Since federal grants are funded by taxpayers nationwide, the cost impact is borne by those taxpayers. Local citizens will probably consider a federal grant as a benefit because it is primarily funded by people who live outside the local region. Or, if the local funds are from bonds financed by property tax revenue, then the impact will affect local property tax payers. The distribution of costs paid by local funds depends on who pays for that funding.

Chapter 5 discusses the important issues with respect to sources of funds in more detail. Its main point is that sources

[5] P.B. Goodwin, "Demographic Impacts, Social Consequences, and the Transport Policy Debate," *Oxford Review of Economic Policy*, Vol. 6, No. 2, Summer 1990, pp. 76-90.

[6] John Hamburg, Larry Blair, and David Albright, "Mobility as a Right," *Transportation Research Record1499*, 1995, pp. 52-55. A. Hay and E. Trinder, "Concept of Equity, Fairness, and Justice Expressed by Local Transport Policy Makers," *Environment and Planning C*, Vol. 9, pp. 453-465. This survey also identified horizontal equity (the authors call it "formal equity") as a priority in transport equity.

of funds may be important for evaluating *financial* feasibility and *political* feasibility (Who gains and who loses; who will support and who will oppose?), but estimates of revenues are not directly additive to the benefits of a benefit-cost evaluation.

The links between who is actually contributing funds to build and operate projects (the revenues) and who is enjoying the benefits of that operation are hard to disentangle. Any attempts to do so necessarily move an analyst into the fuzzy area of *equity*: What's fair? How do we know? How do we place a value on the fairness that can be included in the benefit-cost analysis?

For transit projects, one can think of revenues as coming from three big categories of sources: user fees (typically fares), other local sources (e.g., employer taxes, property taxes), and other non-local sources (e.g., state and federal funding). Reporting costs against revenues, by source of funds, is relevant to decisionmaking: where are funds coming from (who pays), and will they be sufficient to pay for the construction and operation of the project? Table 5-7 in Chapter 5 shows what that kind of analysis would look like.

> *Key point: Although there is no universally accepted definition of "fairness" (it remains a value judgment), impacts are usually assessed in the context of horizontal and vertical equity. Some groups may warrant special consideration or investment if it can be shown that their basic transportation needs are not being met.*

DATA AND ANALYSIS

Chapters 3, 4, and 5 cited literature and conducted original research to estimate coefficients that local transit analysts might use to estimate certain aspects of transit's benefits and costs. It is our conclusion that no such coefficients can be specified with any rigor that would apply across classes of agencies and projects. That conclusion derives directly from points made in the "Framework" section above. There are too many different ways to define groups and too much variability in their size, location, and travel characteristics for this guidebook to supply such coefficients.

Thus, the focus in this section is on data sources, not analysis. The analytical techniques are largely descriptive (what impacts, on what groups, where?). For agencies with the capabilities, the applicability of Geographic Information Systems (GIS) data and techniques will be obvious.

The distribution of benefits and costs of transit projects can be described with data from a number of sources. The analysis of benefits and costs itself will identify some of the distributional aspects. For example, a typical analysis of the travel impacts of a transit project will identify impacts by mode (e.g., travel-time savings of a transportation investment to auto travelers versus transit travelers). It may also seek to identify impacts by income or by location. To examine the distribution of travel impacts by income and location, the analyst will need information that associates mode with income and location.

> *Key point: Travel behavior and impacts by population subgroup vary too much across local areas to permit the analyst to rely on any general or average values. Analysts should instead refer to local travel models, census data, travel surveys, and private vendor data to measure the distribution of travel benefits and costs by mode and population subgroup.*

Table 8-1 describes data sources for measuring the distribution of benefits and costs by mode, income and ethnicity, and location.

The impact categories in Table 8-1 overlap: double-counting certainly occurs. But distributional analysis is, by definition, a double-count: it disaggregates impacts in Chapters 3 through 7 by population subgroups. This table shows a pattern for data on the distribution of impacts:

- The *transportation demand* model is the primary source of data on impacts by mode.
- The *Nationwide Personal Transportation Survey (NPTS)* or similar local surveys of transportation choices and travel patterns constitute a primary source for translating impacts by mode to impacts by income, ethnicity, and location.
- *Census data*, including the American Community Survey and Public Use Microsample (PUMS) data, can be used to identify the income, ethnicity, and other characteristics of impacted areas. A subarea description of demographic characteristics overlaid on a map of travel benefits and expected environmental impacts (pollution, noise, neighborhood disruption) can provide insights into distributional impacts.
- *Private vendor data*, such as Claritas, reports income, ethnicity, and other demographic characteristics similar to those included in Census data, but may be more up-to-date or for smaller areas than available Census data.
- A *regional econometric model*, such as REMI or IMPLAN, can describe the distribution of economic development impacts at a regional or county level.
- *Existing models* like STEP and STEAM 2.0 can provide some disaggregation of impacts that can be used to address distributional issues.
- *Transit agencies* should be able to provide analysis of funding for transportation facilities as needed to identify the distribution of impacts that affect public revenues and expenditures. This analysis is necessary to answer who is paying the direct costs of the transportation improvement.
- *Other local public agencies*, such as school districts, housing authorities, and health departments, may have useful information.

TABLE 8-1 Impacts and potential data sources for distributional analysis

	Mode	Income and Ethnicity	Location
User Costs & Benefits			
Travel Time Monetary Costs Accidents	Travel demand model will identify travel time, out-of-pocket costs, and accident impacts by mode.	NPTS or local surveys can identify the income range and ethnicity of all travelers by mode; to identify income & ethnicity of those impacted, analysts may need to identify affected locations from travel demand model and use Census or private vendor data to describe income & ethnicity of those areas.	Travel demand model may identify locations impacted by changes in travel time, monetary costs, and accidents.
Environmental Externalities			
Air Quality	Impacts spread across society; impacts by mode not relevant.	Impacts are primarily region-wide, but there may be some localized impacts in areas near roadways or transit corridors. Census, private vendor, and local source data can be used to identify the income and ethnicity of residents in impacted locations.	
Noise	Impacts accrue primarily to residents and workers next to roadways and transit corridors. Impacts by mode probably not relevant. Travel Demand Model should allow description of the locations where noise impacts occur. Census, private vendor, and local source data can allow a description of income and ethnicity of impacted areas.		
Water Quality	Impacts spread across society; impacts by mode not relevant. Impacts may affect people that live near impacted waterways or that rely on impacted waterways for food or recreation. Census, private vendor, and local source data can allow a description of income and ethnicity of populations near waterways; surveys of recreational use will be necessary to identify characteristics of recreational users.		
Direct Costs			
Fares	Travel Demand Model will allow description of fare impacts to transit riders.	NPTS and local transportation surveys can help identify income, ethnicity, and location of transit riders in general. If fare impacts are localized, Census, private vendor, and local sources can identify the income and ethnicity of area residents.	
Construction & Operating Costs	Analysis of who pays for funding sources for construction and operating costs is needed to identify impacts by mode, income, ethnicity, and location. Additional data from the NPTS, Census, private vendor, and local sources may be needed to identify the characteristics of groups who pay for funding.		
Other Impacts			
Land Use	Impacts complex and spread across society. Integrated transportation/land use models may allow description of land use impacts (for example, TELUS estimates impact on property value) and may help identify location of impacts. Census, private vendor, and local source data will be needed to identify the income and ethnicity in impacted areas.		
Economic Development	Benefit spread throughout economy; benefits by mode probably not relevant.	Input/output model of regional economy (such as IMPLAN) can identify impacts by industry. Employment and payroll data can be used to translate impacts by industry to income groups and location. Census and local surveys may identify employment distribution by industry for ethnic groups.	

Source: ECONorthwest.

The rest of this chapter describes each of these sources in more detail.

Travel Demand Models

Basic travel demand models have a "mode-choice" component; some are more sophisticated than others. Sophisticated ones may have logit specifications and feedbacks to demographics, auto ownership, and even land use (e.g., changes in density may affect rates of auto ownership by analysis zone). Simple ones may simply specify a ratio of auto trips to total trips. In any case, for an agency with a travel demand model, the specification of the mode choice component is the place to start any investigation of impacts by modes. The travel demand model should provide estimates for aggregate travel-time savings by, at least, auto and bus. One can then compare those savings (or the user benefits that derive from those savings, as described in Chapter 3) in order to answer questions about the distribution of those benefits.

Travel demand models will also allow some rough estimates of user benefits by location, but the computational difficulties increase. The models should estimate which *links* are improving and which are deteriorating. But links do not relate directly to areas or people who live in those areas. One solution is to create some type of accessibility matrix that is measured before and after a transportation improvement: for example, number of jobs (or number of housing units) within 30 minutes of the centroid of each traffic analysis zone. Zones accessible to more jobs or households have become more accessible.

Some travel demand models deal with income, none with ethnicity. The Portland metropolitan region, generally recognized as having one of the most advanced travel demand models in the country, divides modes into user classes (e.g., low-income auto users, middle-income auto users, high-income auto users). In general, most jurisdictions will find that, to address income and ethnicity, they will have to work with summary demographic data by transportation analysis zone (TAZ): for example, this TAZ, with 50 percent low-income households, got 2 percent of the user benefits, while the TAZ, with 50 percent high-income households, got 20 percent of the benefits.

Nationwide Personal Transportation Survey (NPTS)

One source that will allow an analyst to make associations between mode, income, and location is the Nationwide Personal Transportation Survey (NPTS).[7] The 1995 NPTS provides information to assist transportation planners and others who need comprehensive data on travel and transportation patterns in the United States. The 1995 NPTS updates information gathered in similar studies in 1969, 1977, 1983, and 1990. Publicly available NPTS data files are micro-data data sets that contain records of each interview (with information deleted that would identify the specific person or household). The NPTS provides data on personal travel behavior, trends in travel over time, trip generation rates, national data to use as a benchmark in reviewing local data, and data for various other planning and modeling applications.

The 1995 NPTS data set includes the following:

- Data on households, including education level, income categories, housing characteristics, and other demographic information;
- Motor vehicle information, including year, make, model, and odometer readings, converted to annual estimates;
- Information on the availability of public transportation;
- Data about drivers, including information on travel as part of work;
- Data about one-way trips taken during a designated 24-hour period (the household's travel day), including the time the trip began, length of trip, composition of the travel party, mode of transportation, purpose of the trip, and specific vehicle used (if a household vehicle);
- Information to describe characteristics of the geographic area in which the sample household and workplace of sample persons is located;
- Data on telecommuting;
- Data on people who use transit occasionally;
- Public perceptions of the transportation system; and
- Reasons for not car-pooling or using public transit for the work trip.

Transportation researchers, including academics, consultants, and the government, use the NPTS extensively to examine travel behavior at the individual and household level and the relationship between demographics and travel, including the characteristics of travel (such as trip chaining), use of the various modes, amount and purpose of travel by time of day and day of week, vehicle occupancy, and a host of other attributes.

Census Data

Decennial Census

The decennial Census is a primary source of information about the characteristics of residents in geographic areas ranging from the neighborhood level (block groups) to cities, counties, states, and the United States as a whole. Characteristics in the decennial Census that are relevant to this report include means of transportation to work, mobility limitation status, occupation, place of work, travel time to work, vehicles per household, private vehicle occupancy, poverty status, and race.

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[7] Research Triangle Institute and Federal Highway Administration. 1997. User Guide for the Public Use Data Files: 1995 Nationwide Personal Transportation Survey. Washington D.C.: U.S. Department of Transportation. FHWA-PL-98-002. http://www-cta.ornl.gov/npts/1995/Doc/userguide.pdf

Unfortunately, the decennial Census occurs only once every 10 years, so the data can quickly become too dated to rely on it for analysis of transit projects. The Bureau of the Census is developing the American Community Survey (ACS) as a way to provide the data communities need every year instead of once in 10 years. The ACS is an ongoing survey that is intended to replace the decennial Census long form in the 2010 Census.

American Community Survey (ACS)

The American Community Survey will provide estimates of demographic, housing, social, and economic characteristics every year for all states, as well as for all cities, counties, metropolitan areas, and population groups of 65,000 people or more. For smaller areas, it will take 2 to 5 years to accumulate sufficient samples to produce data for areas as small as census tracts. For example, areas of 20,000 to 30,000 can use data averaged over 3 years. For rural areas and city neighborhoods or population groups of less than 15,000 people, it will take 5 years to accumulate a sample data set that is similar to that of the decennial Census. These averages can be updated every year, so that eventually the ACS will be able to measure changes over time for small areas and population groups. Full implementation of the ACS in every county of the United States is scheduled for 2003.

Public Use Micro-data Sample (PUMS) Files

The Public Use Micro-data Sample files (PUMS) are a sample of the actual responses to the American Community Survey and include most population and housing characteristics that are in the ACS. The primary advantage of PUMS data is that it allows cross tabulations of characteristics—for example, the income distribution of households that do not own a car. PUMS records have been edited to protect the confidentiality of all individuals and of all individual households.

Private Vendor Demographic and Marketing Data

Several private vendors sell demographic and marketing data that may be useful for an analysis of the distribution of impacts. Private vendors of demographic and marketing data include Claritas and CACI's Marketing Systems Group. The primary advantages of private vendor data is that it often reports more recent data than the Census or other sources, and it can be generated for user-defined areas (such as a radius around a point in addition to the standard Census geographic units of block group, tract, place, county, state, and nation). Private vendor data also may report characteristics that are unavailable in small geographic units from the Census or other sources, such as household wealth (which is more inclusive than household income).

A limitation of private vendor data is that it is frequently based on an extrapolation of trends applied to decennial Census or other data to produce data for the current year. For example, the current-year income distribution for an area may simply be the distribution reported by the previous decennial Census applied to an estimate of the current-year population. It may be difficult to determine how some estimates were made. Given the need for information to answer the kinds of questions policymakers ask, the temptation for analysts is to accept any estimate that has an aura of authenticity uncritically.

Regional Econometric Models

Regional econometric models, such as REMI Policy Insight™, model regional economies by estimating mathematical relationships between industries and sectors of the economy. Econometric models allow an analyst to describe the distribution of impacts by industry because they can estimate the impacts in terms of changes in employment and income by industry.[8]

Transit Agencies

Both the Framework section of this chapter and Chapter 5 have explained the issues related to sources of funds. In sum, they are transfers and, therefore, double counts, but they are relevant to decisionmaking because they relate to a project's financial and economic feasibility.

Transit agencies should be able to make reasonable judgments about the direct funding for their projects to complete a rough approximation of Table 5-7. The analysis can get increasingly complicated as one tries to determine the ultimate source of the funding. Funding via fares is relatively easy: transit riders are paying for part of the transit benefits they enjoy. But what about funding from a gas tax or a business tax: who is ultimately paying? The basic principle for such an analysis is clear: try to estimate whose resources are being used up. For taxes, that is logically and usually interpreted to mean that it is the payer of the tax who pays most of the cost (though some, or sometimes most, of the burden can fall on the producer of the thing being taxed).

Gas taxes illustrate the complications. Both federal and state governments collect gas taxes; in some places municipal governments collect them also. Federal gas taxes fund both highway and transit improvements. Increasingly, states get approximately their fair share of federal taxes returned for local projects of all types. But some large projects can get states, at least for many years running, more than their fair

[8] See "Policy Analysis Applications of REMI Economic Forecasting and Simulation Models," International Journal of Public Administration, 18(1), pp. 13-42 (1995).

share. In other words, projects in one state get contributions beyond what that state has paid in gas tax (so other states get less). At the state level, gas tax may also be a transfer from one state to another. A state like Nevada, on the one hand, probably collects a disproportionate amount of revenue from non-residents; on the other hand, a disproportionate amount of the use of its transportation system is probably from non-residents as well. Moreover, the debate about the use of gas taxes ("highway funds") for transit is not over in all states.

Other Local Data

A variety of local agencies may have additional data that is useful for analysis of the distribution of impacts. Examples include the following:

- School districts will have data on enrollment by school; these data may identify the number of students in very small areas such as Census tracts. Districts will also have data on the number of students receiving free/reduced lunches, which may be an indicator of poverty conditions.
- Health departments may have data on the number of people with certain health conditions, including respiratory conditions that could be affected by changes in air pollution. Health departments may also have data on the number of people receiving public health assistance, which may be an indicator of poverty conditions.
- Housing departments may have data on the number of households receiving public housing assistance, which may be an indicator of poverty conditions.
- Planning agencies may have updated population, housing unit, employment, and commercial development data based on building permits and field surveys. In the absence of this data, an analyst may be able to conduct his or her own update of these characteristics using building permit data.

The availability and applicability of local data will vary by jurisdiction.

SECTION IV:

SYNTHESIS

Sections II and III (Chapters 3 through 8) provide all the details about the theory and measurement of transit benefits and costs. This section illustrates how the recommended procedures could be applied to a real decision that transit agencies might face. It consists of a single chapter (Chapter 9) that goes step by step through the calculations for a hypothetical transit improvement: adding express bus service between a central city downtown and a suburban center.

CHAPTER **9**

AN EXAMPLE

OVERVIEW

This chapter applies the ideas of Chapters 3 through 8 to a hypothetical transit improvement (adding a bus line). The improvement is relatively simple so that the application of the techniques is not obscured. The steps and general principles would be the same for more complicated projects.

Chapters 3 through 8 are organized by *type of impact*. The evaluation of a transit project, or any public policy, does not occur sequentially by type of impact. Rather, the evaluation begins with a definition of problems, potential solutions (transit improvements), and evaluation methods. Then the analyst gathers data and conducts analysis and then presents the analysis to decisionmakers and the public. This chapter roughly follows that organization. In other words, it is organized to conform to the way an evaluation project typically would occur.

This chapter presupposes that a legitimate transportation problem has already been identified and that a transit improvement has been proposed to help solve it. The steps that must be taken to evaluate the transit improvement are then grouped into four sections:

- **Defining study features**. Before any analysis can begin, its parameters must be clearly defined. Most obviously, one must be able to describe what the proposed transit improvement is, that is, what type of service will be offered, where, and when. Other items requiring careful definition are the time horizon, the study area, the point of view of the analysis, the base case, the audience, and the resources and schedule.
- **Estimating impacts.** This step has been the focus of this guidebook. This section is organized per the guidebook—first addressing basic benefits and costs (user, secondary, and direct monetary impacts) and then addressing other impacts (land use, economic development, and equity).
- **Dealing with time and uncertainty.** Chapter 2 described why the timing of benefits and costs is important. But to keep the discussion in Chapters 3 through 8 focused on the measurement of types of impacts, the timing of those impacts was not addressed in any detail. This section shows how the timing of impacts is handled, and discusses uncertainty about the impacts.
- **Presenting the results**. The results must be communicated to decisionmakers so that they find the results useful, that is, in a way that facilitates decision-making.

SAMPLE ANALYSIS

For this example, we assume a central city of about 400,000 people in a metropolitan area of 1,000,000 people. Several cities are located around the central city, as are areas of extensive suburban development occurring on county land outside any city boundaries. There are no significant topographic features.

The central city is healthy, with substantial office employment, retail specialty shops, restaurants, entertainment, and evening activity. Some housing exists in the downtown, but it is limited. The largest suburban city has some large offices and flexible, high-tech space in a business park setting adjacent to its freeway interchange.

The primary mode of transportation is the automobile. East-west and north-south freeways intersect close to the center of the central city; various freeway connectors and by-passes also exist. The freeways are three-lanes in each direction: one of the lanes is marked for high-occupancy vehicles (HOV), including vehicles with two or more people in the AM and PM peaks. The metropolitan area has a grid of arterial streets spaced roughly a mile apart and is served by a transit agency that operates buses. There is no heavy- or light-rail transit.

The metropolitan area has grown rapidly. Congestion has increased, particularly on freeways connecting the central city downtown to large suburban centers. Most of the “easy” freeways and highways have been built: new highway capacity will be more expensive in real terms than it has been in the past. The Metropolitan Planning Organization (MPO) (a Council of Governments) has used a travel demand model to forecast deteriorating level of service on highways, even with hoped for capacity improvements (not all of which are funded). In that context, the MPO is working with the transit agency to increase transit service.

Among the transit improvements proposed is an express bus service between the largest suburban city (population 50,000) and the central city. The suburban city is 12 miles from the downtown of the central city and is located along the east-west freeway. The express buses would leave from a new park-and-ride area to be located adjacent to a freeway interchange. It would run on weekdays only.

The transit agency wants to evaluate this project (and others that will not be discussed in this example). How does it apply the principles discussed in this guidebook to do that evaluation? The rest of this chapter answers this question.

Selecting Study Features

Project Description

The project would purchase six new buses (five in use at any one time, one in reserve). The transit agency estimates the following ridership (from a combination of a travel demand model and the results of interviews with planners at other transit agencies that have implemented somewhat similar projects). The estimates are for Year 5 of operation—to simplify the calculation the analyst assumes that lower ridership before Year 5 is offset by higher ridership after Year 5. Thus, the estimates are for an average year of operation:

- Morning peak (7 A.M.–9 A.M.): 18 buses × 50 riders = 900 riders
- Mid-day non-peak (9 A.M.–4 P.M.): 41 buses × 30 riders = 1,230 riders
- Evening peak (4 P.M.–6 P.M.): 18 buses × 50 riders = 900 riders
- Evening off-peak (6 P.M.–9 P.M.): 16 buses × 20 riders = 320 riders
- Total of 3,350 daily ridership

The park-and-ride lot in the suburban city is designed to accommodate 200 vehicles in surface parking. It has a covered waiting area, restrooms, and good landscaping. In addition to the park-and-ride facility, local walk-up traffic from the surrounding neighborhood is also expected to contribute significantly to the express bus ridership. The transit agency already owns the land. Local plans and public opinion support the express-bus project. Buses will go to an existing downtown bus facility that has adequate capacity to accommodate them.

Audience for the Analysis

Any significant investment in transit in any metropolitan area is going to have the full range of audiences: technical analysts at federal, state, and local agencies (transportation, land use, economic development, environmental quality); decisionmakers at those agencies, including municipal governments; interest groups (highway, transit, land use, environmental); and the general public. The implication is that any analysis has to be able to be presented at different levels and that different levels of detail will be needed.

For this project, the primary audience is the transit agency board, the members of which ultimately have the responsibility for the decision.

Resources and Schedule

The addition of a new line is entirely under the jurisdiction of the transit agency. It does not require any highway improvements. Thus, the agency would like to move quickly to a decision: no more than 6 months. The agency has a planner available to assemble the analysis and other specialized staff to assist with aspects of the analysis. The MPO has agreed to model the new line in its travel demand model.

Time Horizon

Because the agency is not proposing an extremely expensive capital facility with a long life, because it can probably sell the park-and-ride lot later to a developer for office space if the express-bus project is not successful, and because it can move its rolling stock to other places later, it chooses a relatively short time horizon for the evaluation: 10 years.

A related point is that the agency decides to estimate all costs in *constant, year-2000 dollars*. Implicitly, it assumes that any increases in future costs and benefits will be at the same rate of inflation. That assumption simplifies the cost analysis and means that any discounting of the stream of benefits and costs can be done using a *real discount rate*, which obviates the need for a forecast of future inflation. This general assumption does not preclude the agency from adjusting operating costs for expected real increases in price. For example, the agency may believe that the evidence is strong that the real price of gasoline will increase over the planning period: that increase can be handled in the specification of the user costs that happens later in the analysis.

Study Area

The key part of the study area is obvious: it is the freeway link between the suburban city and central city. It is here that the great majority of the travel impacts accrue. Impacts are measured on the travelers on that link, independent of their point of origin. It is possible, but more difficult and less logical, to define some travel-shed around each origin and destination. A study area defined in that way would not, for example, handle the travel-time savings to through travelers.

For non-travel impacts, the transit agency simplifies the analysis by noting that the proposed transit improvement is an express bus service on an existing, limited-access highway. The agency assumes that there are few impacts along the route because the highway and HOV lane already exist and because the express buses will not stop anywhere along the route. (There are potentially changes in air quality and noise along the route, but these changes are likely to be small for reasons discussed later.) Impacts to people not living near either trip end will thus be primarily travel time savings for travelers who use the freeway, which the transit project makes less congested.

Thus, most of the impacts occur at the trip ends. At the downtown end, the area of impact for non-travel effects is likely to be rather small: a radius of a few blocks around the transit center. At the suburban end, there are construction impacts and potential land use and economic development impacts around the park-and-ride, around the interchange, and (potentially) at the suburban city center.

Point of View

The transit agency accepts the argument made in Chapter 2 that the correct point of view is a broad, social one that evaluates the project in terms of its efficiency, independent of funding sources. The fact that the agency may get some federal funding for the park-and-ride or new buses is a consideration that can occur after the basic evaluation.

Base Case

The funds that the agency uses for this project could be used for other projects instead. One option (which we do not illustrate in this example) is to use some type of preliminary screening to get to a short list of projects, evaluate each using the methods of this guidebook, and then select the projects that perform best within the budgetary constraints. For this example, however, we simplify by assuming that the agency is considering only two options: the no-build base case of no new transit project versus the transit project. Thus, the analytical challenge is to describe what the world would be like in the future with and without the project, holding all else constant. Any differences in the results can then be attributed to the transit improvement.

ESTIMATING IMPACTS

Basic Benefits and Costs

User Benefits and Costs

Chapter 3 describes how to calculate user benefits. For this particular project, the transit agency had access to a travel demand model and proceeded as follows.

Refine the Model's Specification of Generalized Travel Cost (User Cost) for All Relevant Travel Modes. For this project evaluation the agency assumed only three relevant modes: auto, bus, and truck. Because of the long-haul nature of the express bus, the agency believed that impacts on bike and walking trips would be too small to have an influence on the investment decision. In addition, since most of the auto traffic to the park-and-ride facility would be local, auto operating costs for those who drive to the facility were assumed to be minimal by the analyst (i.e., auto operating costs are not estimated). In other cases where more auto traffic from longer distances would be involved, these access costs should be incorporated into the analysis. Models such as SPASM have the ability to incorporate access costs in these applications. The section of Chapter 3 on *Measuring User Costs* provides the framework for the cost estimations in this example.

For each transportation mode, the user cost specification must include any changes that are anticipated to change user cost components in project out-years. The point is that components of user cost may change as a result of (1) the project itself (e.g., a transit project may change the cost of parking) or (2) external events that change the relative costs of auto versus transit trips (e.g., an analyst might expect or otherwise want to model the effect of a real increase in the price of gasoline). Potential factors the analyst should consider are summarized in Table 9-1. In all cases "inflation" means an increase in the real price of a good or service relative to the average rate of inflation (the general rate of inflation is already handled by the use of constant dollars and a real discount rate).

For example, changes in the inflation rate (beyond an expected average rate of inflation already accounted for in the discounting) need to be considered. Increases in inflation will potentially affect wages and operating costs as the costs of maintenance increase. The future effect of inflation on tolls, fares, and parking should also be evaluated. In addition, equipment or highway degradation may also have an impact on operating costs in project out-years as maintenance increases with age.

The analyst also needs to evaluate if the project itself will impact user costs. For example, if the project increases the use of public transportation and decreases the demand for parking, parking fees may decrease as lot owners attempt to attract more business. The analyst should consider whether the project will have similar effects on tolls and fares in the project area.

Table 9-2 shows the user cost calculations for the A.M. peak traffic time (7 A.M. to 9 A.M.) for bus transit. For the A.M. peak period, the addition of the five express buses reduces ridership on the existing surface-street buses. The express buses also come more often during the peak periods, every 8 minutes rather than every 15 minutes for the buses on the surface-street routes. Since the express buses are using the HOV lane on the freeway (rather than surface streets), the travel time is significantly lower than the existing bus options.

TABLE 9-1 Out-year cost considerations

User Cost Components	Possible future effects
Operating costs	Inflation, degradation
Wages	Inflation
Gasoline	Inflation
Tolls	Inflation, project impact
Fares	Inflation, project impact
Parking	Inflation, project impact

TABLE 9-2 User cost calculations—bus transit (A.M. peak demand)

Data Type	Units	Ch. 3 Ref. Table	Bus Transit Base Case	With Project Surface	With Project Express
Corridor length	miles		12	12	12
Passengers per vehicle	number		45	20	50
Speed	miles per hr.		35	37	50
Travel time, walking	min./pass.		5	5	3
Travel time, waiting	min./pass.		15	15	8
Travel time, in-vehicle	min./pass.		21	19.46	14.4
Transfer time	min./pass.		0	0	0
Fares	cents/pass.-mi.	3-6, 3-7	5	5	5
Tolls	cents/veh.-mi.		0	0	0
Operating costs paid by pass.	cents/veh.-mi.		0	0	0
Value of travel time, walking	dollars/hour	3-1 - 3-2	18	18	18
Value of travel time, waiting	dollars/hour	3-1 - 3-2	18	18	18
Value of travel time, transfers	dollars/hour	3-1 - 3-2	18	18	18
Value of travel time, in vehicle	dollars/hour	3-1 - 3-2	9	9	9
Intermediate Calculations of Perceived Costs					
Cost of walk, wait, transfer	cents/pass.-mi.	3-16	50.0	50.0	27.5
Cost of in-vehicle time	cents/pass.-mi	3-16	25.7	24.3	18.0
Out-of-pocket cost	cents/pass.-mi.	3-16	5	5	5
Total perceived user cost	**cents/pass-mi.**	**3-16**	**80.7**	**79.3**	**50.5**

Source: ECONorthwest.

Commuters also switch from automobiles to the express bus, thereby decreasing congestion and increasing average travel speeds for all modes. In addition, travel time spent walking and waiting are reduced on average for passengers on the express buses with the addition of the buses and the new parking facility. Overall, the addition of the new buses decreases perceived user costs from 80.7 to 79.3 cents per passenger-mile for bus transit passengers who are not using the new express buses. For the express bus passengers, the perceived user cost is 50.5 cents per passenger-mile.

The same user-cost calculations are done for automobiles and trucks for both alternatives, with the results shown in Table 9-3. For both modes, there is a reduction in perceived user costs because of less congestion, resulting in slightly faster travel speeds and lower travel times along the highway link.

Tables 9-2 and 9-3 show the changes in perceived user costs by transportation mode for the AM peak traffic period only. Operating costs are determined by the analyst based on data on out-of-pocket driving expenses for the population in the area. Changes in speed are calculated by the analyst using a volume-delay equation that relates highway congestion and traffic volumes to travel speed for different vehicle types. The congestion-speed relationship is also calculated automatically in some modeling tools, such as IMPACTS and STEAM.

Similar calculations need to be done for the other drive periods to get an estimate of the total user costs for an entire day. Table 9-4 shows the results of these calculations for each driving period. Across all time periods, the addition of the express buses decreases the user costs for each transportation mode for this particular project. These user costs are then used to estimate travel demand for each mode for each daily driving period.

Run the Travel Demand Model. The transit agency models the Express/HOV lane as a separate parallel link to the freeway, with a different impedance (because of restrictions on use). Thus, express buses can travel faster than autos on center-to-center line haul during peak periods (the full-trip travel time cost could still favor the auto because of collection, walking, and waiting times).

Table 9-5 shows the results of the travel demand model in terms of passenger-miles for each drive period. Note that the results of the model depend on the specification of the parameters used to estimate the generalized costs in the previous step: it is the relative savings in perceived travel cost that the project creates that causes travelers to change travel behavior. In this instance, the addition of the buses decreases the travel volume for automobiles by less than 5 percent. This decrease in volume results in an increase in travel speed for autos remaining on the freeway after the express bus system is implemented.

Other modes also see changes in volumes with the addition of the express bus. For the surface-route buses, passenger volume decreases by half as riders switch to the express

TABLE 9-3 User cost calculations—automobiles and truck traffic (A.M. peak demand)

			Autos		Trucks	
Data Type	**Units**	**Ch. 3 Ref. Table**	**Base Case**	**With Project**	**Base Case**	**With Project**
Corridor length	miles		12	12	12	12
Passengers per vehicle	number		1.2	1.2	1.0	1.0
Speed	miles per hr.		45	47	35	37
Travel time, walking	min./pass.		5	5	5	5
Travel time, waiting	min./pass.		0	0	0	0
Travel time, in-vehicle	min./pass.		16	15.3	21	19.5
Transfer time	min./pass.		0	0	0	0
Fares	cents/pass.-mi.		0	0	0	0
Tolls	cents/veh.-mi.		5	5	5	5
Operating costs paid by pass.	cents/veh.-mi.		20	19	35	30
Value of travel time, walking	dollars/hour	3-9 - 3-12	22	22	0	0
Value of travel time, waiting	dollars/hour	3-9 - 3-12	22	22	0	0
Value of travel time, transfers	dollars/hour	3-9 - 3-12	22	22	0	0
Value of travel time, in vehicle	dollars/hour	3-9 - 3-12	11	11	30	30
Intermediate Calculations of Perceived Costs						
Cost of walk, wait, transfer	cents/pass.-mi.	3-16	15.3	15.3	0.0	0.0
Cost of in-vehicle time	cents/pass.-mi	3-16	24.4	23.4	85.7	81.1
Out-of-pocket cost	cents/pass.-mi.	3-16	21	20	40	35
Final Calculations of Perceived Costs						
Total perceived user cost	cents/pass-mi.	3-16	60.6	58.7	125.7	116.1

Source: ECONorthwest.

bus during all time periods. Truck traffic increases by 10 percent, due to lower congestion decreasing the perceived user cost as a result of the project.

Calculate User Benefits. Table 9-6 shows the total annual direct benefit calculations for all modes in the AM period only. These calculations follow the procedures discussed in Chapter 3 and summarized in Table 3-20. For each transportation mode and time period, benefits are calculated by taking the difference in user costs ($U_0 - U_1$) and multiplying this by the average passenger volume $(V_0 + V_1)/2$ that results from the project.

One additional step is needed in the calculation used in this example. For the express bus, there is no base case user cost, since, in the base case, there is no express bus service. In this situation, the appropriate base case user cost is the cost of the travel mode alternative that a passenger would have taken. With a travel model based on observed behavior, one would have detailed information on the costs of transportation alternatives for all passengers included in the model. For purposes of this example, these costs are estimated from the average perceived user costs for the alternative transportation modes.

As shown in Table 9-5, of those passengers observed to switch to the express bus from other transportation modes, about twice as many switch from automobiles as from surface street buses (67 percent and 33 percent, respectively). If one assumes that this proportion holds true for all riders, then the base case user cost for the express bus is a weighted average of the base case user costs for automobiles and surface buses without the express bus in place. Given the base case user

TABLE 9-4 User costs for all models and times (¢ per passenger-mile, per weekday)

	Autos		Bus Transit			Trucks	
Total perceived user cost	**Base Case**	**With Project**	**Base Case**	**With Project: Surface**	**With Project: Express**	**Base Case**	**With Project**
A.M. Peak	60.6	58.7	80.7	79.3	50.5	125.7	116.1
Midday	56.1	54.6	90.0	88.9	55.5	106.7	98.8
P.M. Peak	60.6	58.7	80.7	79.3	50.5	125.7	116.1
Evening	56.1	54.6	90.0	88.9	55.5	100.0	92.7
Total	233.3	226.5	341.4	336.5	212.0	458.1	423.7

Source: ECONorthwest.

TABLE 9-5 Travel volume by transportation mode (passenger-miles)

Total Travel Volume (Passengers x Miles)	Autos: Base Case	Autos: With Project	Bus Transit: Base Case	Bus Transit: With Project: Surface	Bus Transit: With Project: Express	Trucks: Base Case	Trucks: With Project
AM Peak	172,800	165,600	4,320	1,920	10,800	1,200	1,320
Midday	129,600	126,720	7,560	4,032	14,760	1,200	1,320
PM Peak	172,800	165,600	4,320	1,920	10,800	1,200	1,320
Evening	72,000	70,560	2,160	1,080	3,840	1,200	1,320
Totals	**547,200**	**528,480**	**18,360**	**8,952**	**40,200**	**4,800**	**5,280**

Source: ECONorthwest.

costs from Table 9-3 for the AM peak period (for example) and the weights given above, this calculation is as follows:

$$\text{Express Bus Base Case User Cost} = (0.67) \times 80.7 + (0.33) \times 60.6 = 74.1$$

As shown in Table 9-6, the daily benefit for the AM peak period for all modes is $4,652 with the addition of the express bus. Most of these benefits accrue to auto passengers ($3,215) followed by express bus riders ($1,273), trucks ($121) and surface bus passengers ($44). Assuming 250 workdays in a year (50 weeks times 5 days per week), the total annual benefit from all modes is $1,163,015 for the AM peak period. The same calculations are done for the other three travel time periods (results not shown). In this example, the total annual benefit for all modes for all time periods is $3,684,230.

Secondary Benefits and Costs

Chapter 4 describes how to estimate these costs and benefits, dividing them into three distinct categories: option value, environmental externalities, and other impacts (primarily unperceived accident costs).

Option Value

The express bus service gives a new option to all travelers between the central city and suburban locations. This option has value in the sense that people who do *not* use the bus might be willing to pay some small amount to make sure that the service is available to them in special situations (car problems, bad weather, and so on). The information used for calculating the option value is shown in Table 4-1. For this project, the standard deviation of the expected price of an automobile trip (σ) was relatively high at $2.00. From the information on user costs for automobile trips, we know that with the project the perceived cost of an automobile trip is $0.61 per passenger-mile for peak periods, or $7.20 for the 12-mile trip. Assuming two options per year and using $7.00 as the cost of the trip, the option value is set at $2.22 per option or $4.44 per year per passenger. To get a total value for these annual options, the yearly value of $4.44 is multiplied by the 44,786 passengers[1] still using automobiles or the surface bus route after the express busses are in place, yielding a total annual option value of $198,850. As discussed in Chapter 4, option values should be assigned to those potential users who have some likelihood of choosing the express bus over other transportation modes. In this example, the freeway section is the primary route connecting the city with the suburb, and potential delays caused by accidents, weather, and construction make it reasonable to assume that all users will value the chance to have the express bus available to them at some point during the year. Given these conditions, the analyst decides to assign all potential users an option value.

Environmental Externalities

Environmental impacts are primarily a function of the change in vehicle-miles traveled by vehicle type. The travel volume data for autos and trucks in Table 9-5, which is in passenger-miles, must be converted to vehicle-miles by dividing by the average number of passengers per vehicle shown in Tables 9-2 and 9-3. This conversion shows the project decreases daily auto vehicle miles by 15,600 and increases truck vehicle miles by 480 miles. The increase in express bus vehicle miles can be calculated from the project description—93 daily bus trips times 24 miles (12 route miles + 12 deadhead return miles) equals an increase of 2,232 bus vehicle miles.[2]

To calculate air pollution costs, the analyst runs the MOBILE5B and PART5 models following the methodology for calculating mobile source emissions described in Chapter 4. Autos are assumed to be light vehicles burning gaso-

[1] The total number of passengers is calculated by dividing the passenger miles shown in Table 9-5 for autos and surface bus (with the express bus in place) by the length of the corridor (12 miles).

[2] The number of buses and route mileage on surface roadways would not change with this project.

TABLE 9-6 User benefits—A.M. peak period, all modes

Mode	Avg. Volume (pass-miles) $(V_0+V_1)/2$	Change in User Cost (cents/pass-mile) $(U_0 - U_1)$	User Benefit (Dollars)
	Data from Table 9-5	Data from Table 9-4	
Auto	169,200	1.9	$ 3,215
Bus - Surface	3,120	1.4	$ 44
Bus - Express	5,400	23.6	$ 1,273
Trucks	1,260	9.6	$ 121
Total Daily Benefit			$ 4,652
Total Annual Benefit			$ 1,163,015

Source: ECONorthwest.

line, buses and trucks are heavy vehicles burning diesel, and before and after travel speeds are used from Tables 9-2 and 9-3. The models will use the national default cold and hot start percentages.

Based on this information, annual air pollution costs for health, visibility, and crop damage are estimated to increase by $5,800 to $75,000 (the models calculate a range), and the analyst chooses a middle value of $40,000.

Table 9-7 illustrates how other environmental costs are estimated. Noise costs per 1,000 vehicle miles are shown in Table 4-7; we used the "other freeway" costs of $4.25 for autos, $9.77 for buses, and $30.80 for trucks. We assume water pollution costs were $0.01 per vehicle-mile for each mode. Daily environmental benefits and costs were converted to annual figures by multiplying by 250 days/year. The resulting annual change for these other environmental benefits is positive ($55,575) for autos, and negative ($11,048) for bus transit and ($4,896) for trucks, for a combined benefit of $39,631. Net environmental benefits, however, are assumed to be close to zero, however, when $40,000 is subtracted for the increased air quality costs.

Other Secondary Benefits and Costs

This category covers other benefits and costs that are probably (1) not double counts, and (2) not perceived by travelers as part of the costs of traveling. The biggest category is costs related to accidents. Chapter 3 argued that some or most of the costs of accidents are probably part of the long-run perceived

TABLE 9-7 Other environmental benefits (costs)

	Auto	Bus Transit	Trucks
Change in daily passenger-miles	(18,720)	40,200	480
Passengers per vehicle	1.2	20-50	1
Change in daily vehicle-miles	(15,600)	2,232	480
Noise costs per vehicle-mile	($0.0043)	($0.0098)	($0.0308)
Daily noise benefit (cost)	$66	($22)	($15)
Water pollution cost per vehicle-mile	($0.01)	($0.01)	($0.01)
Daily water pollution benefit (cost)	$156	($22)	($5)
Total daily environmental benefit (cost)	$222	($44)	($20)
Total annual environmental benefit (cost)	$55,575	($11,048)	($4,896)
Grand total environmental benefit (costs)			**$39,631**

Source: ECONorthwest

costs and are covered by insurance costs. It also noted, however, that some of the costs would not be perceived.

Chapter 4 made some rough estimates of these costs. For this project the analyst accepts without further research its recommendation that 40 to 80 percent of accident costs are perceived. The analyst notes that the addition of express buses is accompanied by no change in highway geometrics, so there are no specific accident hot spots that the project is going to correct. Rather, at the margin, the reductions in auto travel predicted by the travel demand model are assumed to reduce accidents proportionally. Based on these considerations, the analyst assumes an average value: that 60 percent of accident costs are perceived (and included in the user benefits calculation above) and that 40 percent are unperceived and need to be calculated and added.

The analyst uses national data from the National Highway Traffic Safety Administration to make assumptions about the accident rates for the transit project. The demand model predicts that, although auto volumes will decrease, truck volumes will increase. Since the express bus is carrying most of its passengers during the AM and PM peaks, the analyst assumes that the ratio of truck-to-auto accident costs is 3 to 1. The evidence on bus accident costs per vehicle-mile is mixed, with the ratio of bus-to-auto costs varying from 1 to 1, to 3 to 1. The analyst considers the project: on the positive side, it uses big buses in dedicated, less-congested HOV lanes. On the negative side, the buses are traveling at freeway speeds and have to merge across congested lanes at both ends of the route. The analyst chooses a 1-to-1 ratio for this project, but other projects may have a higher ratio of bus-to-auto accident costs.

Table 9-7 shows the change in VMT for the three modes. For accident costs, additional bus miles are a 1-to-1 offset against reduced auto miles. Additional truck miles are a 3-to-1 offset against reduced auto miles (every truck mile added offsets the savings of three auto miles eliminated). Thus, the net change of the transit option over the base case is the equivalent of 3.26 million annual auto miles. The analyst assumes costs of 3¢ per vehicle-mile and unperceived costs equal to 40 percent of the total. The result is an annual (unperceived) accident cost savings of about $39,000.

Direct Costs (Construction, Operation, and Maintenance)

Direct Costs of Transportation Improvements to Transportation Agencies (Construction, Operation, and Maintenance)

Chapter 5 describes how to estimate these costs. The obvious changes in costs if the project is implemented are for new buses, a park-and-ride facility, and new operating costs (drivers, fuel, maintenance, and other for the new buses). Table 9-8 shows the estimates.

All costs of the park-and-ride facility should be included in the analysis: all resources that get used have an opportunity cost. It is not uncommon for public agencies to not count the value of land that they own under the assumption that they did not have to pay anything (recently) to get the land. In fact, the land has a value. If it is used for the project, it must be counted as a cost, because the agency could sell it and use the money for other purposes. For this example, the land is valued at $5 per square foot, construction is $6 per square foot for a surface lot (which includes modest to good landscaping), cars park at three spaces per 1,000 square feet (implying a site size of about two acres), and restrooms are $100,000.[3] A facility for 200 cars costs roughly $1 million ($420,000 for land, and $600,000 for improvements). Other costs are miscellaneous and contingency, for a total project capital cost of about $2.8 million. Operating cost estimates are shown in the table and add up to $0.5 million per year.

Given the analyst's assumption of a 10-year planning horizon, the analyst further assumes for purposes of evaluation that the agency will shut down the project after 10 years. (This assumption is a methodological convenience that does not have to be a political reality. It is a reasonable and consistent way to get an apples-to-apples comparison across alternatives. One could also assume that the express bus system has an indefinite life, in which case its operational costs and benefits extend longer, and periodic costs for the scrapping and replacement of buses and other equipment are required.) Some of the bus investment has a salvage value. The agency assumes that the buses will be well maintained and can sell for 15 percent of their initial purchase price (in constant dollars), that the land will have increased in value in real terms by 40 percent (to a real value of $7 per square foot), and that the residual value of any improvements (primarily a paved parking area) is approximately offset by demolition costs. Thus, the salvage value, in year 10, is approximately $0.8 million ($580,000 for land; $225,000 for buses).

Other Direct Costs

Chapter 5 provides the background for evaluating these costs.

Transportation-Related Agencies

An additional operating cost that could be affected by the bus service is traffic policing and courts. Again, the effect on auto trips, and thus on policing and courts, is small for this single transit improvement, but the direction of the effect is still clear (fewer vehicles on the highways eventually mean less need for policing and courts). Thus, in theory, one should be able to scale cost reductions to reductions in vehicle travel. These calculations may be more hypothetical than real for a

[3] The restrooms are optional.

TABLE 9-8 Direct costs: capital and operation

Capital (Total: Year 0)		Operating (Annual: Year 1–10)	
6 New Buses @ $250,000 ea.	$1,500,000	Operator @ $25,000 per (operating) bus	$125,000
Park-and-ride facility (200 spaces)	1,000,000	Fuel and Maintenance @ $50,000 per (operating) bus	250,000
Other Costs	250,000	Other Operations @ $25,000 per (operating) bus	125,000
TOTAL	$2,750,000		$500,000 Per year

Source: ECONorthwest.

particular project, but calculating them is consistent with a long-run notion of evaluation.[4]

The analyst uses the generic cost-per-vehicle-mile estimate, from Chapter 5, of 1¢ and multiplies that by the net change in total VMT calculated from Table 9-7 (3.2 million VMT per year) to get cost savings of $32,000.

Parking

The express bus, by reducing auto trips (especially in the downtown direction), will reduce the need for parking in the downtown, other things being equal. The magnitude of the reduction could be very small; given the excess parking capacity in the downtown, it may be that there is no noticeable difference in parking construction. But over the long run, every reduction counts, and credit should be given.

The analyst uses the steps suggested in Chapter 5.

The analyst assumes no significant parking reductions in the suburban city because there are no parking constraints or charges at the suburban office centers, and available evidence from major employers suggests that few employees come from the central city downtown out to the suburban offices.

In the other direction, the analyst assumes that (1) 80 percent of the AM peak ridership is from people who would otherwise have driven cars and (2) there are 1.2 people per auto, which leads to an estimate of 600 fewer autos needing parking during the peak period.

There are few surface lots in the downtown. The analyst uses information in Chapter 5, corroborated by downtown parking owners (private and public), about the cost of parking to estimate average parking costs. The average annual cost per stall is $1,400 (land, capital, and operation). There is no "free" public parking in the downtown. Retailers will validate parking for 2 hours. A recent survey of downtown employers suggests that about one-half of the employees in the downtown get some contribution from their employers to defray parking costs. Based on these considerations, the analyst estimates that, on average, weekday drivers to the downtown perceive 60 percent of total parking costs, with the remaining 40 percent paid by employers.

Finally, the analyst calculates the value of the parking cost savings that the transit alternative creates over the base case because fewer cars need parking. The perceived costs (60 percent of total parking costs) are already incorporated into the user cost estimates. For the remaining unperceived costs that will be saved with this project, the analyst's estimate is $336,000 per year (600 fewer peak auto trips × $1,400 × 40%).

Other Social Services

For reasons given in Chapter 5, the analyst assumes that there are no net benefits that are additive to the basic benefit cost calculation. In further support of this assumption, the analyst notes that there is little commuting from the suburban city to the downtown for social services and none from downtown to the suburban city.

Other Benefits and Costs

Land Use

Chapter 6 discusses these potential impacts. It argued that land use impacts often represent different ways of measuring basic travel benefits, that relatively large transit projects are probably required to obtain measurable effects, and that the effects are most often measured as changes in property values.

For the express bus project, the one obvious land use change is that vacant land in the suburban city becomes a park-and-ride facility. That type of change is not typically the focus of a land use analysis, but it should be considered. The relevant

[4] It is assumed for this example that policing one bus mile has the same costs as policing one auto mile, since there is no difference in enforcing speed limits across vehicle types. One could argue, however, that since there are more passengers in a bus than in a car, policing a bus mile would cost more than policing an auto mile.

question for the analysis is, “What happens to the property during the 10-year analysis period in the absence of the project?” For this project the analyst determined that the property was already owned by the City and that the City had no immediate plans for its development. It probably would remain vacant for at least another 5 years. After 5 years, the disposition of the property would be uncertain: development as a park, city maintenance facility, or sale or transfer to the private sector would all possible.

Thus, for simplification, the analyst assumes that the differences in land uses around the park-and-ride under the two alternatives are constant for the entire 10 years: a park-and-ride under the transit alternative, and a vacant parcel owned by the municipality under the base case. The analyst assumes no measurable change in land use type or intensity at the downtown end because bus transfer facilities already exist there and the increment of the express bus ridership to total ridership is insignificant.

The analyst considers two ways to describe the land use impacts around the park-and-ride. One is to tell a story about how land uses will change around the parcel over a 10-year period under the two alternatives. Based on a review of other studies, calls to other transit agencies that have built park-and-rides in suburban areas at freeway interchanges for express bus service, and discussions with local developers, the analyst decides that the park-and-ride lot will have no noticeable impact on the rate of development of surrounding property, which is being driven by market forces for suburban office space. (Such development is unlikely to be affected by the few commuters going in both directions on the express bus.)

The interviews also lead the analyst to note that the original assumption of no development for 10 years in the absence of the park-and-ride is debatable. Developers believe that if the city’s site near the interchange is not used for a public purpose, such as a park-and-ride facility, it would be attractive for office development that could occur within 5 years. Moreover, such uses would do more to increase the value of surrounding properties than the park-and-ride facility. Thus, the analyst notes that the previous assumption may understate the land use and property value impacts of the base case alternative.

The analysis to this point is descriptive, but not quantitative. In sum, the analyst concludes that there are no measurable land use impacts at the downtown end of the project, but that some changes are possible at the suburban end. The biggest difference is at the City’s site, which would have different land uses under the two alternatives. Moreover, those differences in land use could cause changes in the site and surrounding property values: those effects are discussed in the next section.

Economic Development

Chapter 7 describes how to estimate these impacts. Some of these impacts can be quantified, and others allow only a qualified discussion.

Increases in Regional Productivity, and Benefits of Urbanization and Agglomeration. A reduction in highway congestion as a result of the new bus service could result in efficiency gains by businesses, households, government, and the overall workings of the regional economy. The expanded bus service may also encourage residents and businesses to locate closer to the transit stations as a result of this new capacity.

For this project, the analyst skipped an evaluation of this issue because it is difficult, speculative, without agreed-upon techniques for measurement, and likely (in theory) to show small effects.

Enhanced Employment Accessibility. The suburban center is a thriving center of economic activity, with a growing commercial and retail base. The unemployment rate for the area is below 2 percent and even lower for certain jobs, particularly retail, consumer services (such as hotel employment), and clerical office occupations. Minimum wages are $10.00 or more per hour for many jobs, compared with wages of $6.00 per hour in other parts of the region. In the central city, in contrast, unemployment is high in certain pockets–as high as 20 percent for some distressed areas. In these areas, many residents do not have access to an automobile and rely on public transportation.

Because there is no existing bus service, it is not possible to conduct the type of survey outlined in Chapter 7 to estimate the magnitude of potential accessibility benefits. Supporting this assessment is a recent commuter survey of the suburban city’s largest employers, which finds a growing share of workers driving from the central city for the very jobs where there was the greatest demand. Moreover, it finds that 45 percent of the clerical and retail/service employees live within a 10-minute walk of bus service.

Based on this information, the analyst makes the qualitative assessment that the expanded bus service will give some unemployed or underemployed persons in the central city area greater access to the employment opportunities in the suburban center, where there is a labor shortage for workers possessing the skills of the inner-city residents.

So, again, from a qualitative assessment, one could make a reasonable argument that the new bus service could likely facilitate both the meeting of the labor supply restrictions in the suburban area and the addressing of the underemployment problems of some of the central city areas.

Impacts on Property Values. There are two main sources of property value impacts with a transit project: (1) direct impacts associated with right-of-way and construction impacts and (2) accessibility and agglomeration impacts. For the express bus project, there are no right-of-way or construction impacts along the bus routes: they occur only at the park-and-ride station facility. The direct property value impacts around the park-and-ride facility include the costs of acquisition and any negative impacts on adjacent parcels as a result of the construction of the facility. Because the agency already owns the land for the park-and-ride, there are no right-of-way, or takings, costs. Because the park-and-ride facility is in the urban area, there may be some short-term construction period impacts on property owners and their tenants. An appraiser has determined it may reduce rents by 10 percent during the 1-year construction period for four retail and office properties in the immediate vicinity of the facility. In actuality, this has a minimal effect on overall property value, as it mainly affects the establishment of market rents for new tenants seeking space in these adjacent facilities. The analyst considers this amount negligible.

Longer term impacts on property value would be associated with the accessibility and agglomeration impacts around the park-and-ride. The greater availability of bus transit to serve both directions (i.e., residents in the suburbs commuting to the central city and potential commuters in the central city to work in the growing suburban center) leads to the potential for increases in value. There are few to no empirical studies evaluating the property value impacts of bus stations of this type. It is likely that there would be some positive impact, though not anything like those sometimes found with commuter or even light rail. Based on the studies reviewed in Chapter 7, the analyst makes a judgment that values in the direct vicinity of the station may increase up to 5 percent after construction. For a more detailed study, the agency would want to consult an appraiser to provide specific comparable sales and assessments.

Employment, Output, and Income Effects Due to Construction and Operations of Transit Project. The investment in new buses, construction of the stations, and park-and-ride facility will have a net impact on the regional economy through a multiplier effect, as 30 percent of the project's funding derives from federal sources. Because the metropolitan area represents a high proportion of the state's population, money from state sources of revenue is not included in the multiplier analysis.

Tables 9-10 and 9-11 show the calculations for both the construction and operation impacts. The multipliers applied are based on both the ranges provided in Chapter 7, as well as state-level multipliers from IMPLAN supplied by the state economist.

Construction will take 1 year. During that period there will be \$0.65 million of new output, \$0.25 million in labor income, and 6.7 new jobs generated in the regional economy due to direct and indirect impacts. Once operational (after the year of construction), there will be an annual impact of \$0.29 million in output, \$0.12 million in labor income, and more than five new jobs attributable to the ongoing operations on an annual basis.

Equity

Chapter 8 discusses these impacts. The analyst notes that (1) in general, previous studies show that the average income of bus riders is less than the average for drivers; (2) the transit project will benefit both transit riders and drivers; (3) the express nature of the bus suggests that its ridership will have a higher average income (at least in the downtown direction) than the average for all bus riders; and (4) the evaluation in the previous section suggests that some central city residents with lower average incomes and, perhaps, no job may now find jobs in the suburban city.

The analyst finds no evidence to suggest that any special income or ethnic group will be disproportionately disadvantaged. There is no business or residential displacement associated with construction: the only construction occurs on vacant property already owned by the suburban city. There is no construction along the line (the HOV lane exists) or at the downtown end (the transit station exists and has capacity to handle the express buses).[5] There is no evidence that existing bus service will get worse because the express bus service will capture its current riders.

In short, all of the evidence suggests that the project, if it has disproportionate benefits at all, is likely to be progressive: lower income households are likely to have proportionately more net benefits than higher income households. For this project, the analyst was not concerned with estimating more precisely the possible equity effects. If the analyst had been so concerned, however, information on the distribution of income for all of the travelers included in the analysis would have been needed. Using the income information, travelers could be categorized into separate income groups, either by annual income levels or into broader categories such as "high income," "medium income," and "low income." The benefit and cost calculations would be calculated separately for each income group and then aggregated across all income groups to get total net benefits for the project. With benefit and costs estimated separately for each group, the analyst could determine how project net benefits are being distributed across income levels.

DEALING WITH TIME AND UNCERTAINTY

Discounting

The benefits and costs described thus far in the analysis occur in different years. For example, construction and bus

[5] As with other types of impacts, one could argue that the current excess capacity is relevant in the short run, but not for a long-run evaluation. At some time, the current facility will have to be expanded or replaced, and the new express bus service, though a small part of total station activity, will have contributed to that cost and should, therefore, be debited for its share. The analyst assumes that an expansion or new facility is at least 10 years off and, therefore, outside of the evaluation horizon for this project.

TABLE 9-9 Summary of property value impacts

Type of Impact	Amount/Direction	Basis
Direct impacts		
Right-of-Way Costs	None	Owned by agency
Construction Impacts	Minimal	Appraiser opinion
Accessibility and agglomeration impacts		
Long-term Increase in Property Values Around Park-and-Ride Station	Mainly positive, up to 5% increase in values of properties in the immediate vicinity of the station	Judgment, based on rail stations, adjusted downward

Source: ECONorthwest.

TABLE 9-10 Calculation of construction expenditure impacts

Category	Budget	% Federal Funds	% Spent Locally	Direct Expend.	Output	Labor Income	Emp.
Bus Purchases	$1.50M	30%	0%	---	---	---	---
Station and Park-and-Ride Const.	$1.00M	30%	100%	$0.30M	(Mult. = 1.9) $0.57M	(Mult. =0.7) $0.21M	(Mult. = 19.0) 5.70
Other	$0.25M	30%	50%	$0.04M	(Mult. = 2.1) $0.08M	(Mult. = 0.9) $0.04M	(Mult. = 25.0) 1.00
TOTAL					**$0.65M**	**$0.25M**	**6.70 jobs**

Source: ECONorthwest.

acquisition occur at the beginning of the project, while other benefits and costs are realized subsequently during operation. For reasons described in Chapter 2, it is not appropriate to simply add all the benefits and costs year by year: one must *discount the stream of benefits and costs to a present value.*

Table 9-12 shows how the discounting occurs for the basic benefit-cost calculation. The analyst runs the analysis using a 5 percent real discount rate. The annual transit fare revenue ($502,500) is included both as a benefit as fare revenue and as a cost in the user benefit calculation. The net effect of these revenues is neutral, as this is simply a transfer of funds from bus users to the transit agency. Assuming that the agency uses them productively, the net effect of fare revenues in the final benefit-cost calculation is zero.

The net present value of the monetizable benefits of the project are approximately $31 million.

Annualized Values

The present value estimate in Table 9-12 is often easier for the public and decisionmakers to comprehend if it is con-

TABLE 9-11 Calculation of operation expenditure impacts

Category	Budget	% Federal Funds	% Spent Locally	Direct Expend.	Output	Labor Income	Emp.
Vehicle Operations	$0.13M	30%	100%	$0.04M	(Mult. = 1.8) $0.07M	(Mult. = 0.8) $0.03M	(Mult. = 65.0) 2.60
Maint. & Repair	$0.25M	30%	100%	$0.08M	(Mult. = 1.7) $0.14M	(Mult. =0.9) $0.07M	(Mult. = 25.0) 2.00
Other Operations	$0.13M	30%	100%	$0.04M	(Mult. = 2.0) $0.08M	(Mult. = 0.6) $0.02M	(Mult. = 20.0) 0.80
TOTAL					**$0.29M**	**$0.12M**	**5.40 jobs**

Source: ECONorthwest.

TABLE 9-12 Basic benefit-cost calculation, 5% real discount rate

	Benefits (Costs) by project year (in thousands of Year 2000 $)										
Impact Type	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
User Benefits		3,684	3,684	3,684	3,684	3,684	3,684	3,684	3,684	3,684	3,684
Transit Fare Revenues		503	503	503	503	503	503	503	503	503	503
Option Value Benefits		199	199	199	199	199	199	199	199	199	199
Environmental Costs		0	0	0	0	0	0	0	0	0	0
Accident Costs		39	39	39	39	39	39	39	39	39	39
Construction	(2,750)										
O&M Costs		(500)	(500)	(500)	(500)	(500)	(500)	(500)	(500)	(500)	(500)
Transportation Support Costs		32	32	32	32	32	32	32	32	32	32
Parking Costs (Unperceived)		336	336	336	336	336	336	336	336	336	336
Salvage Value											800
Present Discounted Value (PDV)	(2,750)	4,089	3,894	3,708	3,532	3,364	3,204	3,051	2,906	2,767	3,127
Net PDV	$ 30,891										
Annualized Net PDV	$4,000										

verted to an annualized value. In essence, discounting takes an uneven stream of benefits and costs and brings them back to a single present value; annualizing spreads the net present value back out into even annual payments (just as one gets a big loan now and pays for it with a stream of equal monthly payments).

The net present value of $31 million is equivalent to an average annual amount of $4 million (for every year over the 10-year project life, annualized at a discount rate of 5 percent). Based on this annualized number, the express bus is considered an efficient investment.

Sensitivity Analysis

This guidebook has noted repeatedly that uncertainty is part of the state of the art. Many variables could have different values than those used in the base analysis. The transit agency describes and models an optimistic and pessimistic scenario. In the optimistic scenario, the express bus gets more shifts in trips from cars to bus; total capital costs and annual operating costs are 10 percent lower; and air quality, accident, and parking cost parameters are increased by 25 percent. In the pessimistic scenario, the express bus gets less ridership; total capital costs and annual operating costs are 25 percent higher; and air quality, accident, and parking cost parameters are decreased by 25 percent.

At a 5 percent discount rate, the optimistic scenario increases annual net present value from $4 million to $5 million. The pessimistic scenario drops it to $3 million. The analyst could find no reasonable set of assumptions (given the structure of the analysis) that could cause the project to generate less than $2.5 million of net benefits annually.

The analyst also tested the sensitivity of the results to the discount rate. The results proved very stable. On further inspection, the analyst realized that the combination of low initial costs relative to annual benefits and an assumption of invariant benefits and costs in almost every year of operation meant that discounting had relatively little effect on annualized value.

PRESENTING THE RESULTS

Table 9-12 above summarizes the basic benefit calculation, but it does not show the several impacts that are not part of the basic benefit calculation. The analyst realizes that some way to summarize all the impacts for decisionmakers and the public is needed.

Several sources give advice on this topic, both in general and for transportation projects.[6] The essential advice is well accepted: (1) summarize the results in a few pages; (2) use a matrix that cross-tabulates alternatives against impacts (evaluation criteria); (3) use graphics; and (4) have different levels of reporting and documentation for different audiences (full technical appendices for technicians, a report for very interested committee members and the public, a summary [2–8 pages] for most presentations, and an executive summary [1–2 pages]). This guidebook in its entirety is similar in tone, topic, and length to a technical appendix. This example, Chapter 9, is somewhere between a report and a summary.

The analyst for this project uses Table 9-13 to summarize the results, with numbers and text, as appropriate. The analyst adds a row for Financial Feasibility: even though this guidebook discusses revenue sources as a subset of the distribution of impacts, the analyst believes decisionmakers will want to see and discuss it separately. The analyst also adds a row for Public Acceptance, but leaves it blank, noting that (1) no research to quantify how interest groups and decisionmakers feel about the express bus option has been done, and (2) this evaluation will be part of the deliberation on the other impacts the analyst has described in Table 9-13.

[6] For general advice see, for example, Carl Patton and David Sawicki. 1993. Basic Methods of Policy Analysis and Planning. 2nd Edition. Prentice Hall. For specific applications to transportation, see Cambridge Systematics. 1998. Economic Impact Analysis of Transit Investments: Guidebook for Practitioners. Chapter 8.

TABLE 9-13 Summary of impacts: express bus versus base case, annual benefits and costs at full operation

Type of impact / Evaluation Criterion	Express bus relative to base case	Direction of impact	Comments
User benefits less direct costs	$2.93 million	+	Annual user benefits ($3.68 million) less the annualized cost of capital ($285,000) and annual O&M ($500,000) plus the annualized cost of salvage value ($38,000).
Other monetizable impacts	$0.57 million	+	Option value ($199,000), reductions in unperceived parking costs ($336,000), and reductions in accident cost ($39,000).
Land use	Ambiguous	?	Potential benefits at and around park-and-ride, but that facility could also preclude higher value office uses at the site, and reduce the rate of increase and site and surrounding property values.
Economic development	Positive	+	Increases jobs at construction (6.7) and operation (5.4).
Distributional impacts	No obvious negative impacts	0 to +	If normative objective is to make investments that provide disproportionately more benefits to lower-income households, the express bus probably does that, and is unlikely to do the opposite.
Financial feasibility	More difficult	–	Because the bus alternative requires investment and funding, it is by definition more difficult than doing nothing (base case). But federal funds are likely to be available, perhaps to cover up to 80% of the capital costs (park-and-ride and rolling stock).
Public acceptability			For decisionmakers to assess after review of other impacts at their June meeting.

Source: ECONorthwest.

Table 9-13 describes impacts in different units, which means they cannot be added to produce a single measure of project performance. Thus, Table 9-13 shows relative performance only. It does not make a decision about the importance of the differences in performance either within or across criteria.

Fortunately for the analyst, this fact does not create a big problem for this project because most of the non-monetizable impacts are either positive for the transit project, neutral, or ambiguous. The analyst is relatively confident, based on the basic benefit-cost calculations and sensitivity analysis, that the express bus is an efficient project.

In other cases, however, the analysis could be much more complex. It would not be surprising for a transit project to show annual, monetized net benefits as negative. In that case, decisionmakers and the public must make tradeoffs: in particular, they must assess whether other, non-monetizable benefits (less costs) are important (valuable) enough to more than offset the monetizable net costs. When public bodies enter that discussion they inevitably must address the issue of weighting multiple decisionmaking criteria: for example, how much is consistency with a land use plan worth compared with an extra $1 million in annualized cost?[7] For most projects, however, whether formally (through weights and scores) or informally (through discussion and consensus) the relative importance of the impacts and their differences across alternatives must be addressed.

The analyst incorporates Table 9-13 into a short memorandum to decisionmakers that makes the following summary points and contingent recommendations: contingent, because the analyst does not yet know how decisionmakers and the public will assign relative weights to the different impacts:

- From the perspective of economic efficiency, the express bus is expected to generate $4 million annually in net benefits.
- Land use and economic development impacts are not large, but they are not likely to be negative. Moreover, the express bus service and park-and-ride facility is consistent with both regional and local transportation, land use, and economic development policy.
- Similarly, there are no obvious negative distributional impacts.
- The economic efficiency conclusion means that the project creates net benefits, independent of who pays for it (how it is financed): it is a good investment. But many good investments do not get made for lack of ability to access funding. The fact that the region has a good chance of getting federal contributions means that local contributions would be on the order of pennies per driver or per household.
- Given that the express bus project (1) offers substantial benefits to both bus riders and drivers, under a range of assumptions; (2) is a relatively low-cost investment for

[7] This Guidebook does not go into the details of multi-attribute decisionmaking: its focus is on the measurement of the attributes (in dollars where possible), not their relative importance. We note in passing, however, that the problem with most weighting schemes, as they are implemented, is not only that they are arbitrary, but that both decisionmakers and analysts are often unaware of the arbitrariness and its effect on conclusions. For example, in simple scoring schemes, each impact for each project is assigned 1 to 5 (or –3 to +3, or whatever) points based on a qualitative assessment of the direction and magnitude of its impacts. That is an implicit weighting that would only by chance be the one that decisionmakers would agree to if the weights were derived by more rigorous methods.

a transportation project; (3) is likely to be partly funded from non-local sources; (4) uses existing right-of-way and has almost no negative impact on neighborhoods; (5) is consistent with state, regional, and local policy; and (6) is superior to doing nothing on all evaluation criteria (except that it must be funded), it seems likely that public and elected official support for the project could be attained. Once the capital costs are paid, the $1.20 fare is more than enough to cover operating and maintenance costs, and bus passengers decrease their travel times over the “old” bus by one-third.

- Given these considerations, a decision should be made to move forward to the next step toward implementation.

CONCLUDING REMARKS ABOUT THE EXAMPLE AND EVALUATION METHODS

The example illustrates why it would be difficult to make a comprehensive and rigorous decision with much less than what this guidebook describes. In the absence of this framework, any attempt at evaluation quickly gets lost in double counts, anecdotes, and politics. Ultimately, investment in transportation, including transit, is a political decision. The intent of this guidebook is to (1) help transit planners provide better information to that decision-making process and (2) encourage decisionmakers to achieve a higher standard of evaluation and make better (more efficient and more equitable) investments.

SECTION V:

APPENDICES

APPENDIX A

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APPENDIX B

INTEGRATED MODELS FOR CONDUCTING COMPREHENSIVE BENEFIT-COST ANALYSIS

Among the range of software tools available for evaluation of the benefits and costs of proposed transportation investments, two options exist that are both freely available and well suited for evaluating a wide variety of transit investments: the Sketch Planning Analysis Spreadsheet Model (SPASM) and the Surface Transportation Efficiency Analysis Model (STEAM). Although SPASM and STEAM were developed for the Federal Highway Administration by Cambridge Systematics, both are highly flexible tools that can be used to evaluate a range of transportation investments or policies, including transit improvements, land use strategies, highway capacity improvements, travel demand management, intelligent transportation system strategies, and bikeway improvements.

SPASM and STEAM share many attributes, but they were designed for different levels of analysis. STEAM is designed to be used with the output of a four-step travel demand model and is intended to provide a rigorous and thorough evaluation of a proposed project or transportation action. In contrast, SPASM is designed for instances where running travel demand models is either not possible or requires too much effort for the type of evaluation needed. Consequently, SPASM makes some simplifying assumptions to limit the necessary inputs to what is typically available at the screening level of analysis.

Both SPASM and STEAM are generally consistent with the approach to project evaluation outlined in this guidebook. Each calculates user benefits by looking at users' willingness to pay for transit or auto travel and determines benefits based on a calculation of consumer surplus. To complete the calculation of benefits, both SPASM and STEAM then evaluate changes in benefits that are external to users' decision to travel, adding these external benefits to the calculated consumer surplus to arrive at a total benefit figure.

SPASM and STEAM embody project analysis techniques presented in the FHWA course "Estimating the Impacts of Urban Transportation Alternatives," offered through the National Highway Institute (NHI Course No.15257). Both models are available for free download on the STEAM website (http://www.fhwa.dot.gov/steam/). STEAM is a self-contained software program that an analyst can download and install, while SPASM is a spreadsheet-based tool available in either EXCEL or LOTUS 123 format. Users' guides for both models are also available for download at the site, as is an accompanying paper "Using SPASM for Transportation Decision-Making."

Both SPASM and STEAM generate measures of benefits and costs for a typical year based on annualized capital costs combined with the expected operating costs and expected benefits for a single target year. If an analyst would like to evaluate how the net benefits for potential actions would vary over time, he or she will need to run separate analyses for a range of target years, interpolate between those years, and then calculate total net benefits by discounting the expected stream of costs and benefits into present terms.

In the sections that follow, we provide brief descriptions of SPASM and STEAM, touch on strengths and weaknesses of each, and identify issues users of this guidebook might bear in mind should they choose to use either model. For a complete discussion of the SPASM and STEAM approaches to project evaluation, or for detailed instructions on how to begin using either model, analysts should refer to the respective user's guides.

SKETCH PLANNING ANALYSIS SPREADSHEET MODEL

The Sketch Planning Analysis Spreadsheet Model (SPASM) is intended to be an easy-to-use, screening-level tool for project analysis. SPASM allows planners to generate first-cut estimates of annualized public capital and operating costs, employer costs, system-user costs and benefits, air quality and energy impacts, and cost-effectiveness measures associated with a range of potential transportation investments or actions, including the following:

- Transit improvements,
- Highway capacity expansion,
- Intelligent transportation system strategies,
- Bikeway improvements,
- Land use strategies, and
- Travel demand management.

SPASM was designed as a complement for the more detailed Surface Transportation Efficiency Analysis Model (STEAM). While STEAM is designed for use with output from four-step travel demand models, SPASM is designed for instances where running travel demand models is either not possible or requires too much effort for the type of evaluation needed. Consequently, SPASM makes some simplifying assumptions to limit the necessary inputs to what is typically available at the screening level of analysis.

What Does SPASM Do?

A key feature of the SPASM framework is its ability to evaluate a multimodal package of investments and demand management/pricing strategies—all at the corridor level. Provided the relevant data are available, SPASM can evaluate proposed transportation actions that include major capital projects such as transit or highway investments, improved transit service, pricing schemes (tolls, congestion pricing, parking/access fees), transportation demand management (TDM) strategies, and transportation systems management (TSM) treatments.

SPASM analyzes the effects of transportation actions across six transportation modes:

- Automobile
- Truck
- Carpool
- Local bus
- Rail
- Express bus

The model analyzes the effects a given transportation action will have on a transportation corridor, calculating impacts relative to a "base case" for a single analysis year. SPASM then summarizes the dollar value of these effects in terms of the following:

- User benefits,
- Annualized capital costs,
- Vehicle operating costs,
- Other O & M costs,
- Pollution,
- Other external costs, and
- Revenue transfers.

SPASM also further digests the total effects, calculating the net benefit (or cost) of the action as well as its benefit-cost ratio.

SPASM is configured in a single workbook, with ten separate worksheets, four of which are dedicated to intermediate calculations. These intermediate calculation worksheets are protected to prevent inadvertent changes. Model users can control many of the assumptions used in the analysis through a worksheet labeled "Unit Costs." The Unit Costs worksheet lists more than fifty parameters used at various stages in the analysis, and, although the model comes pre-loaded with default values for each, users are free to adjust parameters as they see fit.

A unique feature of SPASM is the model's ability to account for diverted and induced trips that frequently go uncounted in traditional benefit-cost analysis. To do this, the model assumes two things. First, it assumes that initial reductions in travel times on one facility will attract users who previously used another, parallel facility. The strength of this diversion effect is determined by the relative differences in travel times among facilities and an "Exponent for Traffic Assignment" factor, which can be controlled by the modeler. Second, in addition to accounting for diverted trips, SPASM also calculates "new" trips that would be induced within the corridor by improved mobility. The relative strength of this effect is determined by the overall improvement in travel time associated with an action, filtered through a user-controlled parameter called "travel time elasticity" (defined as the percentage change in travel demand as a result of a 1 percent increase in travel time).

SPASM's Strengths and Weaknesses

SPASM is a flexible tool for corridor-level project analysis that could prove useful in evaluating a wide range of transportation actions. The model is described as a "sketch planning" tool for screening level analysis, and, as such, it does not allow project analysis at the level of detail analysts might achieve were they to pursue the approach recommended by this guidebook. SPASM does enable even users with relatively little experience in project evaluation to generate complex, rigorous, and economically sound analyses. SPASM also provides more detail in some aspects than has been presented in this guidebook, such as consideration of different access modes.

As a tool for evaluating transit investments, SPASM has various strengths:

- **Flexibility.** SPASM allows users to evaluate a wide range of multimodal packages of actions/policies and gives users a great deal of control over the host of underlying assumptions necessary in any benefit-cost analysis.
- **Comprehensiveness.** Although SPASM does not account for all of the effects associated with transportation actions or policies, the framework does allow users to account for a wide range of benefit categories. Whether the cost is internal or external and whether it is perceived by the user or not, if the effect can be defined in terms of "cost per mile" or "cost per trip," it can be accounted for in the evaluation.

  Further, an evaluation performed using SPASM looks at effects on an entire corridor, performing complex calculations that would be virtually impossible for any but the most skilled analysts to match. Among other things, these calculations predict the following:
  - Both diverted and induced highway travel;
  - How changes in transportation will affect the number of auto trips people will ultimately choose to make; and
  - How changes in average speeds, the total number of trips, and mode distribution will affect both energy consumption and emissions.

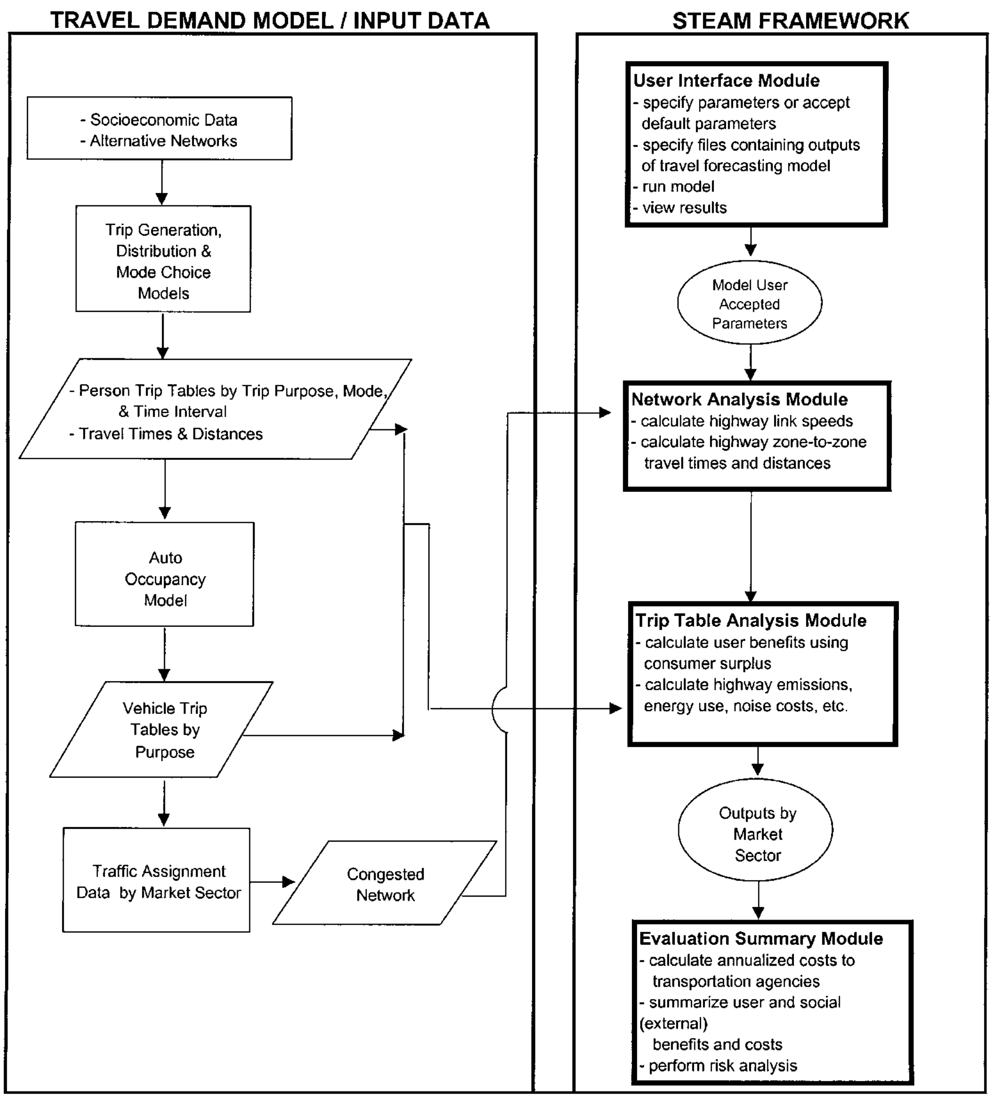
The weaknesses that SPASM brings to project evaluation are largely a function of the limitations associated with its intended use as a sketch planning tool with only limited data requirements. SPASM has several potential shortcomings:

- **SPASM does not provide an accounting of all benefit categories.** SPASM allows users to account for any cost or benefit that can be defined in terms of cost per mile or cost per trip. However, there are some categories of benefits whose values cannot be determined simply by looking at changes in trips (e.g., the option value of transit, the ability of transit to further land use goals, or equity considerations), and inclusion of any of these considerations requires the analyst to augment SPASM's benefit measures.

- **SPASM does not provide a means to include a specific anticipated safety benefit in the analysis.** Within the model's framework, costs associated with accidents must be treated as costs per mile or costs per trip. Under this approach, changes in safety are simply determined by a combination of changes in miles traveled and changes in the modal mix. If an action is anticipated to have a specific impact on safety (e.g., if adding a bus-only lane is expected to reduce the per-mile frequency of accidents on a specific arterial) there is no mechanism within the model to account for that change.
- **SPASM is limited to only a corridor-level analysis.** Many transportation actions that take place in one corridor create effects that reverberate throughout a much larger system. SPASM treats induced travel within the corridor as "new" trips, when, in fact, at least some of these trips might actually be diverted from other corridors.

SURFACE TRANSPORTATION EFFICIENCY ANALYSIS MODEL (STEAM)

As opposed to SPASM, which is a spreadsheet-based model intended for use as a screening-level tool for project evaluation, STEAM is a much more robust, stand-alone software program designed for use with the output of a four-step travel demand model. STEAM was designed to extend and improve SPASM's general analysis framework and is intended to allow rigorous and thorough evaluation of a proposed transportation package's costs and benefits on the basis of system-wide analysis. Figure B-1 shows the structure of the STEAM model framework.



Source: ECONorthwest.

Figure B-1. Structure of the STEAM model framework.

As is true of SPASM, one of STEAM's great strengths is its flexibility and its ability to evaluate a wide range of transportation packages. In evaluating these projects, beyond estimating the costs and benefits associated with a transportation action, STEAM also generates estimates of the annualized cost to the public agency; the action's effect on total transportation cost; system-wide changes in emissions; changes in energy use; changes in noise and other external costs; changes in fatal, injury, and property-damage-only accidents; and revenue transfers resulting from changes in fares or tolls or from changes in fuel tax revenues resulting from overall increases or decreases in fuel consumption. STEAM also allows users to generate an explicit analysis that summarizes the level of uncertainty associated with each evaluation.

It is worth noting, also, that, in its calculation of user benefits, STEAM estimates traffic delays that result from both high traffic volumes *as well as* from incidents. Analysts have traditionally had great difficulty estimating the delays associated with incidents for inclusion in their calculations of user benefits, and, since incidents are believed to be the cause of a substantial share of total freeway delays in urban areas, that failure often resulted in significant underestimation of total delays. STEAM's ability to account for incident-driven delays marks a substantial improvement in project evaluation.

Unlike SPASM, which, although complex, still maintained a degree of transparency thanks to its spreadsheet-based design, STEAM represents much more of a "black box" approach to project evaluation. With STEAM, the user inputs data through a cleanly designed user interface, he or she runs the model, and STEAM generates pages of results. However, for all of its black box feel, STEAM users still maintain a great deal of control over the wide range of assumptions that underlie the analysis.

POTENTIAL ISSUES IN MODEL APPLICATION

Although both SPASM and STEAM are based on a theoretical approach that is broadly consistent with the recommendations of this guidebook, it is important that users read the appropriate user's guide carefully and then review the definition of the model parameters carefully as well, perhaps with this guidebook in hand.

In some cases, for various reasons, the default pre-loaded values for a given parameter in STEAM and SPASM diverge significantly from the values recommended in this guidebook. For instance, both SPASM and STEAM come preloaded with a default value for "Non-fuel Highway User Costs per Mile for Autos" of 3.4 cents per mile. This figure is based on the FTA's CUTS report and deliberately excludes some factors, such as insurance costs and fuels costs. In contrast, when we adjust our recommended user cost for a mid-size car to exclude costs of fuel, we arrive at a cost of slightly more than 40 cents per mile for cars that average 15,000 miles per year.[1] Beyond this relatively large difference, it is also important that analysts using SPASM recognize that SPASM does not provide any dedicated set of parameters for dealing with user-perceived safety costs. Rather, if the analyst believes that there is some perceived safety cost associated with being in a vehicle that is not reflected in insurance payments or in the user's assumed value of time, then that cost must also be included in the "Non-fuel Highway User Costs per Mile." Therefore, the appropriate cost per mile may be even greater than 40 cents per mile. Although the difference between the default and our recommended value for this parameter is probably the most extreme case, the issues under discussion illustrate the importance of reviewing assumptions and having a thorough understanding of what each parameter represents.

FOR MORE INFORMATION

Federal Highway Administration, *STEAM User Manual*, **http://www.fhwa.dot.gov/steam/users_guide.htm**.

Federal Highway Administration, *SPASM User's Guide*, **http://www.fhwa.dot.gov/steam/spasm.htm**.

Federal Highway Administration, *Using SPASM for Transportation Decision-making*, **http://www.fhwa.dot.gov/steam/spasm.htm**.

[1] Most of the difference between the two values is a result of two schools of thought about whether auto ownership costs should be counted as user-perceived costs of driving. For both models, users can easily add additional benefits or costs as model inputs in addition to those already included as default model input parameters.

APPENDIX C

SAMPLE CALCULATIONS

Reviewers of drafts of this guidebook generally thought that transit agencies should be able to provide their own data on travel demand (Chapter 3) and capital and operating costs (Chapter 5). They advised against trying to create complicated look-up tables that would allow an agency of any size, with any existing system, to get a quick estimate of user benefits for any type or size of transit improvement.

We accepted that advice. But we also wanted to give smaller jurisdictions, with smaller projects and perhaps no travel demand model, some idea of what to expect in terms of user benefits. The following worksheets provide a means of estimating how transit trip costs will change with changes in the underlying demand and cost characteristics of simple transit operations. The worksheets are derived from models of optimal dispatch and routing applied to a stylized network.

Each worksheet contains a *starting point estimate* that is calculated using reasonable, but arbitrary, values for the key parameters that determine access time costs and in-vehicle time costs. The *scaling procedure and example* portion of each worksheet shows how to scale the starting point data for an actual project to estimate time cost for the actual project. The shaded cells under "Your Project" indicate where the data for an actual project should be entered. These values are then scaled using the relationship shown under "Factor Effect."[1] After each factor of time cost is adjusted, their values are multiplied and the product is applied to the starting point estimate of time cost.[2] The access time cost and in-vehicle time cost components must be adjusted separately and then added together to derive the total user time cost per trip. Finally, this total is divided by the average trip length to determine the cost per passenger mile. This result can then be used in user benefit calculations.

In Table C-1, the calculation is carried out for a simple bus transit route. The starting point estimate results in a time value cost of 37 cents per passenger mile. After adjusting for a larger number of passengers on the route, higher value of time, and other factors, the scaling example yields a time value cost of 28 cents per passenger mile.

Similar procedures are repeated in Tables C-2 and C-3 for the case of a rail transit route and a bus service that integrates feeder and line-haul services.

It is important to note that the costs tabulated in these worksheets are exclusively the time costs associated with the specified transit service. Information on transit agency costs is used in the worksheet to aid in generating optimized frequencies of service and the resulting wait times, but agency costs are not included in the resulting time costs. Similarly, in Table C-3, the costs of accessing the transit line are also used (to help determine optimal number of routes), but are not included in the travel time cost estimates that result.

These tables provide a useful starting point for characterizing transit user time costs. In evaluating a particular transit improvement, of course, there may be other time costs that must be considered. In a park-and-ride context, for example, there are time costs associated with driving to the park-and-ride lot and time costs associated with walking from the park-and-ride lot to the transit stop. In other cases, the time cost of several transit trips must be combined. A user who takes a bus to a rail transit stop, for example, will experience time costs associated with each trip element. A starting point for estimating these time costs would be to combine information from Table C-1 with information on rail transit from Table C-2.

[1] For example, in Table C-3, the number of passengers on the route is 300 in the starting point estimate and 1,000 under "Your Project" in the example of the scaling procedure. The factor effect is one over the square root of the ratio of the starting point estimate to the value under "Your Project." Hence, the scaling factor equals: 1/(square root (1000/300)) = 0.55.

[2] Each of the scaled factors is multiplied and the result applied to the starting point for time cost. For example, in Table C-3, ($0.55 \times 1.22 \times 0.71 \times 1.41 = 0.67$), which is then applied to the starting point for access time cost ($0.58 per trip) to get an access time cost for the actual project ($0.39 per trip).

TABLE C-1 Calculating user time costs for a simple, bus transit route[3]

Starting Point Estimate			*Scaling Procedure and Example*			
Access time costs			Your Project	Factor Effect		Factor
Passengers on the route/hr.		300	1,000	1/(Sq rt of ratio)		0.55
Value of waiting time/hr.	$	10	15	Sq rt of ratio		1.22
Route length (mi.)		10	5	Sq rt of ratio		0.71
Bus agency costs/bus-mi.	$	2	4	Sq rt of ratio		1.41
				Product of all factors		0.67
Result: Access time cost/trip	$	0.58		$0.58 x 0.67 =	$	0.39
In-vehicle Time Costs						
Average trip length (mi.)		5	10	Ratio		2.00
Average bus speed (mph)		20	25	1/(Ratio)		0.80
Value of in-vehicle time/hr.	$	5	6	Ratio		1.20
				Product of all factors		1.92
Result: In-vehicle time cost/trip	$	1.25		$1.25 x 1.92 =	$	2.40
Result: Total user time costs/trip	$	1.83			$	2.79
Per pass.-mile	$	0.37			$	0.28
Memo: Optimal frequency (bus/hr.)		9				19

Source: ECONorthwest.

Note: Sq rt = Square root.

[3] This worksheet is based on the following formulation of user time costs per passenger trip, in dollars per trip, made up of a waiting time component plus a line-haul time component:

$$\sqrt{\frac{V_w MA}{2Q}} + \frac{LV_v}{S}$$

V_w = value of waiting time ($/hr.)
V_v = value of in-vehicle time ($/hr.)
M = route length (mi.)
A = Bus agency costs ($/vehicle-mile)
Q = number of passenger trips on the route (per hr.)
L = average trip length (mi.)
S = average bus speed (mph)

TABLE C-2 Calculating user time costs for a rail transit route[4]

Starting Point Estimate			*Scaling Procedure and Example*			
Access time costs			Your Project	Factor Effect		Factor
Passengers on the route/hr.		5,000	1,000	1/(Sq rt of ratio)		2.24
Value of waiting time/hr.	$	10	15	Sq rt of ratio		1.22
Route length (mi.)		10	5	Sq rt of ratio		0.71
Rail agency costs/car-mi.	$	4	8	Sq rt of ratio		1.41
Cars per train		10	5	Sq rt of ratio		0.71
				Product of all factors		1.94
Result: Access time cost/trip	$	0.63		$0.63 x 1.94 =	$	1.22
In-vehicle Time Costs						
Average trip length (mi.)		5	10	Ratio		2.00
Average train speed (mph)		30	25	1/(Ratio)		1.20
Value of in-vehicle time/hr.	$	5	6	Ratio		1.20
				Product of all factors		2.88
Result: In-vehicle time cost/trip	$	0.83		$0.83 x 2.88 =	$	2.40
Result: Total user time costs/trip	$	1.47			$	3.62
Per pass.-mile	$	0.29			$	0.36
Memo: Optimal frequency (trains/hr.)		8				6

Source: ECONorthwest.

Note: Sq rt = Square root.

[4] This worksheet is based on the following formulation of user time costs per passenger trip, in dollars per trip, composed of an access time component and a line-haul time component:

$$\sqrt{\frac{V_w MA}{2QN}} + \frac{LV_v}{S}$$

A = rail agency costs ($/train-mile)
S = average train speed (mph)
N = number of cars per train

TABLE C-3 Calculating user time costs for a bus transit route with integrated feeder service[5]

Starting Point Estimate			*Scaling Procedure and Example*		
Access time costs			Your Project	Factor Effect	Factor
Passengers on the route/hr.		300	1,000	1/(Cb rt of ratio)	0.67
Value of waiting time/hr.	$	10	15	Cb rt of ratio	1.14
Route length (mi.)		10	5	Cb rt of ratio	0.79
Bus agency costs/bus-mi.	$	2	4	Cb rt of ratio	1.26
Average length of feeder trip (mi.)		0.50	0.50	Cb rt of ratio	1.00
Cost of accessing the line ($/pass-mi.)	$	1.00	$ 1.00	Cb rt of ratio	1.00
				Product of all factors	0.77
Result: Access time cost/trip	$	0.81		$0.81 x 0.77 =	$ 0.62
In-vehicle Time Costs					
Average trip length (mi.)		5	10	Ratio	2.00
Average bus speed (mph)		30	25	1/(Ratio)	1.20
Value of in-vehicle time/hr.	$	5	6	Ratio	1.20
				Product of all factors	2.88
Result: In-vehicle time cost/trip	$	0.83		$0.83 x 2.88 =	$ 2.40
Result: Total user time costs/trip	$	1.64			$ 3.02
Per pass.-mile	$	0.33			$ 0.30
Memo: Optimal frequency (bus/hr.)		12			31
Memo: Optimal number of routes		2			3

Source: ECONorthwest.

Note: Cb rt = Cube root.

[5] This worksheet is based on the following formulation of user time costs per passenger trip, in dollars per trip, composed of an access time component and a line-haul time component:

$$\sqrt{\frac{c\pi r V_w M A}{2Q}} + \frac{L V_v}{S}$$

c = cost of accessing the transit line ($/pass.-mile)
r = average length of feeder service (mi.)

APPENDIX D

CONVERTING MONETARY COSTS AND BENEFITS TO A COMMON BASE YEAR (CONSTANT DOLLARS)

This guidebook includes references to many prices, wages, and costs gathered at different points in time for various purposes and studies. Because inflation changes the relative value of the U.S. dollar over time, an analyst cannot directly compare costs from different years. Rather, for comparison of costs reported in two or more time periods, the analyst must adjust prices to a common unit that accounts for price differences. The adjustment requires the use of a price index that tracks the value of the U.S. dollar (in terms of what that dollar will buy) from year to year. This appendix provides information on one such index (the Consumer Price Index) and the analytical steps necessary to adjust the prices and costs presented in this report.[1]

The Consumer Price Index (CPI) is a measure of the average change in prices over time in a "market basket" of goods and services. The Bureau of Labor Statistics (BLS) publishes CPIs for two population groups: (1) a CPI for All Urban Consumers (CPI-U), which covers approximately 87 percent of the total population; and (2) a CPI for Urban Wage Earners and Clerical Workers (CPI-W), which covers 32 percent of the total population. The CPI-U includes, in addition to wage earners and clerical workers, groups such as professional, managerial, and technical workers; the self-employed; short-term workers; the unemployed; and retirees and others not in the labor force.

The CPI reflects prices of food, clothing, shelter, fuels, transportation fares, charges for doctors' and dentists' services, drugs, and other goods and services that people buy for day-to-day living. BLS collects prices from 87 urban areas across the country from about 50,000 housing units and approximately 23,000 retail establishments. In calculating the index, price changes for the various items in each location are averaged together with weights, which represent their importance in the spending of the appropriate population group. Local data are then combined to obtain a U.S. city average. Separate indexes are also published for 26 local metropolitan areas. Area indexes do not measure differences in the level of prices among cities—they only measure the average change in prices for each area since the base period.

The index measures price change from a designed reference date—1982–84, which equals 100.0. An increase of 48.2 percent, for example, is shown as 148.2, as in the annual average for 1994 (Table D-1, taken directly from the CPI web site). This change can also be expressed in dollars as follows: the price of a base period market basket of goods and services in the CPI rose from $10 in 1982-84 to $14.82 in 1994.

Decision-makers and analysts may want to express the values of price information in terms of the most recent dollars possible, in order to relate the information to current economic conditions. The last column in Table D-1 has been provided to facilitate conversion of historic price data to dollar values in Year 2000. Use of this table to convert monetary information from tables in this report to Year 2000 dollars requires three steps:

- Identify the year for which the original data were compiled.
- Look up the adjustment factor in Table D-1 that corresponds to that year.
- Multiply the original dollar amount by the adjustment factor.

The result is the same cost, expressed in Year 2000 dollars. Monetary data were presented in the report exactly as the reference source presented the information to avoid confusion. In this way, an analyst can more easily match the price or cost data to the referenced report or data source.

For further details visit the CPI home page on the Internet at http://stats.bls.gov/cpihome.htm.

[1] The federal government publishes two price indexes for the personal consumption of goods and services. One is the CPI; the other is the implicit price deflator for personal consumption expenditures (PCE deflator). The latter is one of several price deflators for the gross domestic product, published by BEA. Other deflators measure changes in price levels for wholesalers and specific industries. For the period under analysis in this report, the adjustments that come from the two indices are identical through three significant digits.

TABLE D-1 Consumer Price Index—All urban customers

Series Id: CUUR0000SA0,CUUS0000SA0

Not Seasonally Adjusted
Area: U.S. city average
Item: All items
Base Period: 1982-84=100

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann Avg	2000 Adjustment Factor
1991	135	135	135	135	136	136	136	137	137	137	138	138	136.2	1.26
1992	138	139	139	140	140	140	141	141	141	142	142	142	140.3	1.23
1993	143	143	144	144	144	144	144	145	145	146	146	146	144.5	1.19
1994	146	147	147	147	148	148	148	149	149	150	150	150	148.2	1.16
1995	150	151	151	152	152	153	153	153	153	154	154	154	152.4	1.13
1996	154	155	156	156	157	157	157	157	158	158	159	159	156.9	1.10
1997	159	160	160	160	160	160	161	161	161	162	162	161	160.5	1.07
1998	162	162	162	163	163	163	163	163	164	164	164	164	163	1.06
1999	164	165	165	166	166	166	167	167	168	168	168	168	166.6	1.03
2000	169	170	171	171	172	172	173	173	174	174	174	174	172.2	1.00
2001	175													

Bureau of Labor Statistics (http://stats.bls.gov/cpihome.htm; accessed March 7, 2001)

The **Transportation Research Board** is a unit of the National Research Council, which serves the National Academy of Sciences and the National Academy of Engineering. The Board's mission is to promote innovation and progress in transportation by stimulating and conducting research, facilitating the dissemination of information, and encouraging the implementation of research results. The Board's varied activities annually draw on approximately 4,000 engineers, scientists, and other transportation researchers and practitioners from the public and private sectors and academia, all of whom contribute their expertise in the public interest. The program is supported by state transportation departments, federal agencies including the component administrations of the U.S. Department of Transportation, and other organizations and individuals interested in the development of transportation.

The National Academy of Sciences is a private, nonprofit, self-perpetuating society of distinguished scholars engaged in scientific and engineering research, dedicated to the furtherance of science and technology and to their use for the general welfare. Upon the authority of the charter granted to it by the Congress in 1863, the Academy has a mandate that requires it to advise the federal government on scientific and technical matters. Dr. Bruce M. Alberts is president of the National Academy of Sciences.

The National Academy of Engineering was established in 1964, under the charter of the National Academy of Sciences, as a parallel organization of outstanding engineers. It is autonomous in its administration and in the selection of its members, sharing with the National Academy of Sciences the responsibility for advising the federal government. The National Academy of Engineering also sponsors engineering programs aimed at meeting national needs, encourages education and research, and recognizes the superior achievements of engineers. Dr. William A. Wulf is president of the National Academy of Engineering.

The Institute of Medicine was established in 1970 by the National Academy of Sciences to secure the services of eminent members of appropriate professions in the examination of policy matters pertaining to the health of the public. The Institute acts under the responsibility given to the National Academy of Sciences by its congressional charter to be an adviser to the federal government and, upon its own initiative, to identify issues of medical care, research, and education. Dr. Kenneth I. Shine is president of the Institute of Medicine.

The National Research Council was organized by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academy's purpose of furthering knowledge and advising the federal government. Functioning in accordance with general policies determined by the Academy, the Council has become the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in providing services to the government, the public, and the scientific and engineering communities. The Council is administered jointly by both the Academies and the Institute of Medicine. Dr. Bruce M. Alberts and Dr. William A. Wulf are chairman and vice chairman, respectively, of the National Research Council.

Abbreviations used without definitions in TRB publications:

AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
IEEE	Institute of Electrical and Electronics Engineers
ITE	Institute of Transportation Engineers
NCHRP	National Cooperative Highway Research Program
NCTRP	National Cooperative Transit Research and Development Program
NHTSA	National Highway Traffic Safety Administration
SAE	Society of Automotive Engineers
TCRP	Transit Cooperative Research Program
TRB	Transportation Research Board
U.S.DOT	United States Department of Transportation

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