Least-Cost Planning: Principles, Applications and Issues

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Abstract

Work sponsored by the federal government, including this report, is exploring ways that the evaluation and selection of alternative transportation projects and policies can be rationalized and simplified. This report summarizes existing research that relates to how public entities making transportation investment decisions should attempt to identify, quantify, value, and sum the benefits and costs of alternative transportation programs and projects. It is funded by the Federal Highway Administration (FHWA), which has an obvious interest in seeing the policies of ISTEA implemented.

The report results from FHWA's desire to look at an emerging transportation planning concept called *least-cost planning*. Least-cost planning embodies both a planning process and specific analytical techniques. It attempts to meet a given set of transportation objectives with a combination of improvements, policies, and programs that is less expensive than any other combination. Among the principles of least-cost planning are:

- Application of benefit-cost techniques to the evaluation of alternative transportation systems and projects
- Consideration of policies and investments to reduce demand for transportation facilities on equal footing with those that increase the supply of those facilities
- Evaluation of the uncertainties in forecasts of future travel demand and the performance of different alternatives
- Involvement of the public in the development of alternatives and their evaluation
- Coordination among different agencies and jurisdictions of a system-wide planning effort that regularly updates plans to reflect new information about those measures that are most cost-effective.

For planners at state departments of transportation or Metropolitan Planning Organizations (MPOs), this report provides a general framework (both planning concepts and analytical techniques) for evaluating transportation projects, and ideas on how to shift from current practices toward the type of analysis recommended.

The chief value of a framework for project evaluation based on the principles of benefit-cost analysis or least-cost planning is that the debate about transportation investments is better informed by estimates of their likely benefits and costs. It remains, however, a debate. People can reasonably differ on assumptions about what benefits and costs to include, how they should be measured, and what the best estimate of their values should be. Resolving those differences is beyond the scope of this report, and of most of the reports that this one cites. We believe that this report would do more harm than good if its message were that states and MPOs should simply adopt some standardized cost estimates and computational routines to

estimate the full benefits and costs of alternative transportation projects. This report is a primer on concepts, not a step-by-step manual of techniques.

All of what is important about the framework has already been written. The problem is not primarily a lack of clear theory about project evaluation; though much remains to be done on measurement, much has already been completed and left unused. The problem is the gap between theory and practice: dozens of thoughtful reports have yet to provide to states and MPOs workable techniques and compelling reasons to use them. It is our belief that until the concepts of project evaluation described in this report are debated, modified, and moved into the mainstream, it is idle to work out the details of the measurements for MPOs to apply in a cookbook fashion.

Least-cost planning is a strategic planning process that uses the principles of benefit-cost analysis as its underlying evaluative framework. This report describes in greater detail what those principles are and how they could be applied to transportation.

Preface

This report describes how the concepts of *Least-Cost Planning* could be applied in metropolitan areas to assist in evaluating and selecting among alternative transportation projects and programs. Least-cost planning is one way for metropolitan planning organizations (MPOs) to meet federal and state requirements for a full and balanced evaluation of all relevant alternatives when considering major transportation investments.

This report was funded by the Federal Highway Administration. ECO Northwest wrote the report (Terry Moore, Daniel Malarkey, Randy Pozdena, and Paul Thorsnes). Parsons Brinckerhoff (Sam Seskin) reviewed and commented on drafts of the report. The report was funded through an on going contract for services with COMSIS (Bob Winick).

Since this report is largely a review and summary of other work on least-cost planning and benefit-cost analysis, the authors have drawn heavily on the work of other researchers. The bibliography of this report notes their collective contributions. ECONorthwest was fortunate to be working with the Puget Sound Council of Governments in Seattle on a related evaluation of least-cost planning to transportation. That project started with a draft of this report as a base, and then improved on it. In particular, the following people were on a panel of reviewers that commented extensively on the draft:

Kiran Bhatt, president, K.T. Analytics, Inc.

Paul N. Courant, professor, economics and public policy, University of Michigan

Steve Fitzroy, director of research and forecasting, Puget Sound Regional Council

David Forkenbrock, Public Policy Center, University of Iowa

José (Tony) Gómez-Ibáñez, Derek Bok professor, urban policy and planning, Harvard's Graduate School of Design and John F. Kennedy School of Government

Greig Harvey, principal, Deakin, Harvey, Skabardonis

Charles Howard, Washington Department of Transportation

John Kain, Henry Lee professor, economics, Harvard University

Doug Lee, senior transportation planner and principal investigator, Volpe National Transportation Systems Center

Todd Litman, transportation analyst

Don Pickrell, senior economist, USDOT Volpe Tranportation Center

Anthony Rufolo, professor, urban studies and planning, Portland State University

Scott Rutherford, professor, University of Washington

Kenneth Small, chair, Department of Economics, University of California at Irvine

Cy Ulberg, research associate professor, Washington State Transportation Center

Dick Watson, executive director, Northwest Power Planning Council

We got useful comments on an early draft of this report from Dick Nelson and Don Shakow of ITR, and Dan Dodds and Gilbert McCoy from the Washington State Energy Office. A special acknowledgment is due Patrick DeCorla-Souza, FHWA's project manager for this research.

Though the help we received substantially improved this report, any errors remain ours. The views expressed are not necessarily those of FHWA.

Chapter 1

Introduction

1.1 BACKGROUND

Deciding on surface transportation programs and projects gets harder every year. Fifty years ago, the direction for transportation investment was clear technically and politically: build highways. But the farther technicians and politicians pursued this solution to traffic congestion, the less effective it became. Urban renewal with neighborhood relocations got more complicated. Land values in urban areas increased. Each new lane was harder to build and did less to reduce congestion. Many groups became vocal about the impacts of transportation projects on the environment (especially air quality) and on urban form.

The process for decision-making about transportation projects and programs evolved. Federal and state transportation agencies in the 1950s and 1960s wielded great power—they pursued a system of interstate highways and urban freeways with little internal evaluation and public scrutiny. In the 1970s and 1980s, Environmental Impact Statements required a description of the impacts of these projects, but did nothing to integrate those descriptions into a comprehensive evaluation of the efficiency of alternative transportation options. By the 1990s, most transportation planners acknowledged that "we cannot build our way out of congestion," though most continued to pursue capacity solutions to congestion problems (now with the addition of demand-side solutions).[1]

The federal Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) and related legislation at both the federal and state level formally recognized the general shift toward the identification, quantification, and valuation of *all* impacts for *all* transportation options.

Among other things, ISTEA gave more flexibility to state and metropolitan governments regarding the expenditure of federal funds for transportation projects. That local discretion has advantages, but it also makes choices that were once easy much harder. For example, local jurisdictions will be less likely to build a freeway when the money they use to build it is the same money they could be using for transit, pedestrian, or demand-management projects. Moreover, the desirability of and requirement for cross-modal evaluations means that standardized or, at least, comparable methods and data be used to evaluate the benefits and costs of different modes.

[1]As with all quick histories, this one ignores the occasional efforts to swim against the main current. For example, *A Manual on User Benefit Analysis of Highway and Bus-Transit Improvements* published by the American Association of State Highway and Transportation Officials (1977) emphasized a theme that permeates this report: any good evaluation of alternative transportation investments requires a clear understanding of and accounting for their benefits and costs.

If the advantages of evaluating transportation options is not compelling enough, ISTEA's implementing regulations give more incentive by requiring that "...major investment [corridor and subarea] studies shall evaluate the effectiveness and cost-effectiveness of alternative investments or strategies... The analysis shall consider direct and indirect costs of reasonable alternatives..."[2] A major investment study (MIS) is required for a "highway or transit improvement of substantial cost that is expected to have a significant effect on capacity, traffic flow, level of service, or mode share at the transportation corridor or subscale level." This general requirement is made more specific by examples given in the regulations, which suggest that any highway improvements on a partially controlled principal arterial that expand capacity, and any fixed guideway for transit, will trigger the MIS requirement. As amended by ISTEA, the Federal Transit Act now states that fixed guideway systems must consider "...direct and indirect costs of relevant alternatives; ...all associated ancillary and mitigation costs."[3]

Executive Order 12893 (January 1994) describes principles for federal infrastructure investments with which the Federal Transit Administration (FTA) and the Federal Highway Administration (FHWA) must comply. Those principles include "Systematic analysis of expected benefits and costs...[which are] quantified and monetized to the extent practicable..." Other terms in the Order sound like they are straight from a text on least-cost planning: "market and nonmarket ...discounted ...recognize uncertainty ...comprehensive set of options..."

Work sponsored by the federal government, including this report, is exploring ways that the evaluation and selection of alternative transportation projects and policies can be rationalized and simplified. For example, FHWA currently offers a training course[4] for state departments of transportation and metropolitan planning organizations (MPOs) showing sketch planning techniques for identifying and quantifying the benefits and costs of transportation alternatives. Such screening may precede or be incorporated into a full fledged investment MIS.

Some states have reinforced the federal mandates. The state of Washington, for example, passed legislation requiring regional transportation planning organizations to use least-cost planning methods to identify the most cost-effective facilities, services, and programs.

State and federal mandates are pushing MPOs to where their self-interest might take them anyway. Transportation investment decisions are moving from political decisions based on engineering data about the costs and performance of different highway configurations, to an explicit quantification of effects and balancing of tradeoffs.

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[2]23 CFR, Section 450.118. Joint regulations issued 28 October 1993 by FTA and FHWA implementing changes made to the Federal Transit Act and Title 23, USC by ISTEA regarding statewide and metropolitan planning.

[3]Section 3(i)(2)

[4]National Highway Institute Course No. 15257, "Estimating the Impacts of Transportation Alternatives".

This idea is as old as formal writings about policy analysis. It is hard to disagree with the idea that the nation and metropolitan areas should make intelligent decisions about transportation investments; that intelligent decisions require good information and analysis; and that good analysis means, fundamentally, showing all the costs and benefits of alternative programs and projects to the extent that the data allow so that the program with the greatest net benefits can be identified and chosen.

This report summarizes existing research that relates to how public entities making transportation investment decisions should attempt to identify, quantify, value, and sum the benefits and costs of alternative transportation programs and projects. It is funded by the Federal Highway Administration, which has an obvious interest in seeing the policies of ISTEA implemented.

The report is a result of FHWA's desire to look at a planning concept emerging in transportation discussions called *least-cost planning*. Least-cost planning embodies both a planning process and specific analytical techniques. As we discuss later, our investigation of least-cost planning methods led to a broader framework for evaluating transportation policies and projects. That framework, which we prefer to call *integrated transportation planning*, includes both a planning process (like the one described for least-cost planning) and analytical techniques that have been extensively developed over decades in applications of the principles of benefit-cost analysis to transportation.

For planners at state departments of transportation or MPOs, this report provides a general framework (both planning concepts and analytical techniques) for evaluating transportation projects, and for meeting the requirements for an MIS. It also provides ideas on how to shift from current practices toward the type of analysis recommended.

This report is a primer on concepts, not a step-by-step manual of techniques. The scope, schedule, and budget for this project limited it to a review of existing literature. Moreover, for both technical and political reasons, we believe it is risky to move too quickly from the concepts to the details of the analysis. There are dozens of fundamental assumptions necessary to permit the kind of evaluation techniques this report describes. Many of those assumptions are unstated in the typical state or MPO evaluation process today, and some are at odds with the direction of existing plans.

The chief value of a framework for project evaluation that is based on the principles of benefit-cost analysis or least-cost planning is that such assumptions are made explicit and quantified where possible, and that the debate about benefits and costs moves beyond rhetoric and politics. It remains, however, a debate. People can reasonably differ on assumptions about what benefits and costs to include, how they should be measured, and what the best estimate of their values should be. Resolving those differences is beyond the scope of this report, and of most of the reports that this one cites. We believe that this report would do more harm than good if its message were that states and MPOs should simply adopt some standardized cost estimates and computational routines to estimate the full benefits and costs of alternative transportation projects.

Thus, the purpose of this report is to summarize current thinking on a framework for evaluating alternative transportation projects and developing integrated transportation plans. It provides little new research; much of what is important about how to evaluate such projects has already been said. Our review of technical reports and scholarly articles convinces us that federal policy analysts and academicians are well aware of the analytical principles that least-cost planning embodies.

The problem is not primarily a lack of clear theory about project evaluation; and though much remains to be done on measurement, much has already been completed and left unused. The problem is the gap between theory and practice: the thoughtful reports have yet to provide to states and MPOs workable techniques and compelling reasons to use them. It is our belief that until the concepts of project evaluation described in this report are debated, modified, and moved into the mainstream, it is idle to work out the details of the measurements for MPOs to apply in a cookbook fashion.

Though we tried to be general about approaches, some of concepts and techniques we describe in this primer are likely to be understood and applied only in states and MPOs, and probably only in large MPOs.[5] One of the problems our research identified was the difficulty of creating simple sketch planning models that can be applied in jurisdictions without complicated models and modelers. It is not primarily a problem of creating the algorithms for such sketch planning, but rather one of the variability of generic estimates from extant case studies, and the difficulty of adjusting those estimates to make them appropriate for local conditions. Transportation systems are complex and highly dependent on local conditions. Least-cost planning must incorporate the particular characteristics of the transportation system and the likely effects of investments and policies that are proposed to improve its performance.

1.2 METHODS

The scope of work for this primer was limited to summarizing existing work on least-cost planning. That summary included:

- A synthesis of recent articles and reports in the professional literature on least-cost planning and on project evaluation for transportation.

[5]That said, there is nothing in the principles or techniques that precludes the application of the framework we describe by a single analyst in a small city. Given that the results of even the most sophisticated models often get fed into an evaluation process that makes fundamental conceptual errors about benefits and costs, it is entirely possible that a single analyst working with the right principles and a four-function calculator can produce a more realistic evaluation.

We did not attempt a comprehensive review of the literature. Rather, we turned to recent articles by recognized experts summarizing the state of the art.

- A summary of recent efforts in the Northwest (Oregon and Washington) to apply least-cost planning principles to transportation. Our objective was to be illustrative, not definitive. *A priori* the Northwest seemed a good place to start, not only because we were familiar with all the transportation planning efforts in the region, but also because (1) least-cost planning has strong roots in the Northwest, particularly in the electric utilities, (2) Oregon and Washington are considered leading states in integrating land use and transportation planning, and (3) preliminary interviews with national experts suggested that the Northwest was ahead of other regions in its discussions of the applicability of least-cost planning to transportation.
- A review by a panel of national transportation and economic experts. Their comments on an earlier draft of this report substantially improved its organization and helped refine the descriptions and distinctions we make in our definition of least-cost planning for transportation.

1.3 LEAST-COST PLANNING AND BENEFIT-COST ANALYSIS

The term *least-cost planning* developed out of the electric utility industry as a method for selecting the most cost-effective measures for meeting projected increases in demand for electricity. There are some obvious parallels between the electricity and transportation facilities that suggested that the recent advances in the planning approaches taken by utilities could improve the planning and decision-making for transportation investments. Electric utilities and transportation agencies both make large capital investments in facilities that often have characteristics of natural monopolies and that are owned, operated, or closely regulated by the public sector. Both utilities and transportation agencies provide vital services to the economy. Both have been criticized by their detractors for over-investing in capacity at great cost to the tax (rate) payer and the environment.

Whether least-cost planning is a new and better planning tool for transportation, or an old and inferior one, depends on perspective. We will risk oversimplification to make the point clear: consider the typical views of technical analysts versus public-process specialists, or, for an even greater stereotype, economists versus planners. Economists (and we place ourselves in this category) tend to equate least-cost planning with *cost-effectiveness analysis*, a subset and simplification of a complete analysis of benefits and costs that is appropriate when an analyst can assume, as a rough approximation, that benefits remain constant across alternatives. If all alternatives provide the same benefits, then benefit-cost analysis reduces to determining the project with the least cost. From that perspective, there is nothing new about least-cost planning: it is a subset of benefit-cost analysis.

As economists, that was the perspective we sketched in the draft of this report. Some reviewers quickly and clearly pointed out that another perspective was possible. Many utility planners who use least-cost planning think of it not as a subset of benefit-cost analysis, but as just the reverse. They view least-cost planning as an overarching planning *process*. As such, it includes the techniques of benefit-cost analysis, but it also includes more. Least-cost planning is a process that includes the ideas of public involvement; expansion of alternatives to include serious evaluation of no-build alternatives like demand management; inclusion of all costs, including those difficult to quantify like environmental damage and risk; an explicit treatment of uncertainty; a portfolio of options from which solutions can be pulled in response to changing conditions.

Our response, again as economists, was that the standard texts on benefit-cost analyses address all the points on which the utility planners say least-cost planning breaks new ground. While that point is correct in theory, we admit that it is often ignored in practice. In practice, benefit-cost analysis has often been applied as a technique for estimating *direct* and *measurable* benefits and costs. Its practitioners, despite the admonishments of the professional literature, have often used it as if it were a purely technical process that is only confused by the inclusion of a non-technical public.

Our conclusion is that it is useful to understand the two different perspectives because then one can justifiably get past what will almost surely be unproductive caviling about definitions. Whether called least-cost planning or benefit-cost analysis, this report is about a framework for addressing transportation problems and evaluating transportation solutions that is both technically and politically sound. That framework must recognize that complex systems like metropolitan transportation require abstraction and quantification if they are to be made understandable and tractable. It must also recognize that some issues of importance to the public and policy-makers defy quantification, and that public and political opinion is often determined by more concerns than system efficiency.

Since our charge from FHWA was to evaluate least-cost planning as an approach for transportation policy analysis and investment decisions, we will stay with that term in this report.[6] The key principles of least-cost planning include the:

- Application of benefit-cost analysis to the evaluation of alternative transportation systems and projects
- Consideration of policies and investments to reduce demand for transportation facilities on equal footing with those that increase their supply

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[6]As we discuss later in more detail, the major problem with the term is that it implies that the benefits of different transportation alternatives can somehow be held constant while costs are minimized: they cannot. The chief advantage of the term is political currency: it may be a more palatable coating to the distasteful medicine of benefit-cost analysis.

- Evaluation of the uncertainties in forecasts of future travel demand and the performance of different alternatives
- Involvement of the public in the development of alternatives and their evaluation
- Coordination among different agencies and jurisdictions of a system-wide planning effort that regularly updates plans to reflect new information about those measures that are most cost-effective.

Least-cost planning is a strategic planning process that uses the principles of benefit-cost analysis as its underlying evaluative framework. The rest of this report describes in greater detail what those principles are and how they could be applied to transportation.

1.4 ORGANIZATION OF THE REPORT

Chapter 2 describes what least-cost planning is, where it came from, and why it is a logical and potentially useful framework for evaluating transportation investments. To make these points, it draws parallels from electric utilities, where the least-cost approach has been most thoroughly developed and applied. *Appendix A* describes the experience of electric utilities in more detail. *Appendix B* describes the link between the under-pricing of the services some utilities provide and the ability of least-cost planning to redress some of the allocation problems that under-pricing engenders.

Chapter 3 describes the analytic principles of benefit-cost analysis as applied to transportation project evaluation. It starts with an overview of general principles, and then moves to the specifics of transportation evaluation. It divides benefits and costs into three principal categories: benefits to users (decreases in travel time, operating cost, and accidents); costs to society (design, construction, operation, and maintenance for projects; administration and compliance for programs and policies); and external benefits and costs (pollution, regional economic impacts, and land use). *Appendix C* provides more detail on issues relating to the valuation of external environmental costs. *Appendix D* provides an example of applying benefit-cost principles to a system level evaluation of alternatives.

Chapter 4 describes the broader planning process encompassed by least-cost planning. It puts least-cost planning in the context of strategic planning in the public sector and describes a planning model that is consistent with current federal requirements for Metropolitan Transportation Plans and Major Investment Studies.

Chapter 5 suggests how the proposed least-cost planning framework might be applied by MPOs, and about additional research that could assist with the acceptance and implementation of the framework.

Appendix E is a bibliography.

Chapter 2 The Case for Least-Cost Planning

2.1 LEAST-COST PLANNING IN THE UTILITY INDUSTRY

Least-cost planning (LCP)[1] is a process for choosing the lowest-cost method for providing a given level of service (i.e., benefit). The details of the process are many and occasionally complex. To understand the methods of LCP, it helps to understand how it developed. Because most of LCP methods now being discussed by transportation planners were developed in electric utilities, we focus our discussion on the recent history of LCP in electric utilities.[2]

2.1.1 WHAT MOTIVATED LCP FOR ELECTRIC UTILITIES?

LCP developed in the 1970s in response to concerns about planning and investment in electric utilities. The electric utilities worried that the conventional planning process provided little insight into the sensitivity of proposed projects to difficult-to-foresee changes in demand, input prices, and government regulations. In the 1970s and early 1980s most utilities failed to forecast the rise in the price of fossil fuels, the increased competition in the supply of electricity, and the slow growth of demand for electricity. Those that had invested in large-scale fossil fuel and nuclear generating plants suffered. In response, an important component of LCP evolved: methods to evaluate the effects of a variety of changes in market conditions on the performance of alternative projects.

A second concern of electric utilities arose from the increasing competition in electricity generation. Changing technologies had increased the number of ways to generate electricity at relatively low cost. Because those technologies were likely to continue to improve, utilities developed a second component of LCP: identifying and evaluating *all* the options for supplying a given amount of electricity.

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[1]Within the utility industry the term *least-cost planning* is falling out of favor and the term *integrated resource planning* is ascendant. Though an occasional debate in the utility planning literature about the differences between LCP and IRP still surfaces, for practical purposes they are the same. IRP is becoming the more popular term because it avoids implying that cost is the only criterion for decisions. We retain the term least-cost planning for this report because it is the term currently used by proponents of applying this planning method to transportation. Should the approaches described in this paper come in to broader use, we favor adopting the term Integrated Transportation Planning.

[2]See Appendix A for a more detailed discussion of the development of LCP, its application in other utilities, and references.

A third concern about environmental quality motivated expansion of the list of alternatives from its focus on the supply side to consider demand-side alternatives. Increasing the supply of electricity typically meant building more fossil-fuel or nuclear generating facilities. Operating these facilities has potentially serious adverse consequences for the environment. Environmental advocates argued that conservation measures could allow an increase of the end uses to which electricity is an input (e.g., running machinery, heating houses) without increasing the demand for electricity itself. For example, more buildings can be heated with the same amount of electricity if the buildings are better insulated. The focus of planning changed from the production of electricity per se to the production of the various uses into which electricity is an input.

As utilities and regulators increased the range of alternatives considered, the need to interact with other utilities and governmental agencies increased. For example, in the Northwest, where hydroelectric power is a significant component of the electricity supply system, a careful evaluation of the impacts of electricity-supply decisions includes an analysis of water-use issues and engages many agencies. The development of LCP fostered greater coordination among firms and agencies that had historically worked independently.

A fourth concern of electric utilities was the large share of the blame they took for poor decisions made in conjunction with public utility commissions. In an effort to share responsibility for investment decisions and to improve the decision-making process, planners began to work harder to get input from the public. Public involvement in the decision-making process became an important component of LCP.

In sum, electric utilities turned to LCP because it offered the hope of providing an integrated method for evaluating a variety of alternatives in terms of both cost and reliability. It attempts to look at the full costs of providing a given amount of service. Full costs mean not only the direct costs of planning, construction, operation, and maintenance, but also external costs like pollution, threats to species, and loss of habitat and recreation opportunities. It is more explicit about risk, uncertainty, and the need for a flexible, responsive planning approach to deal with them. It attempts to put demand-side and supply-side solutions on equal footing. It increases the role of the public in planning decisions and fosters greater coordination between institutions and agencies involved in service provision.

2.1.2 EVALUATING ENERGY ALTERNATIVES

The underlying economic analysis of alternatives for electric utilities was made easier by the homogenous nature of the end product. A kilowatt hour is essentially the same whether it is produced using power from water, wind, natural gas, oil, or a nuclear reaction. With proper accounting for all costs, a consistent measure—cost per kilowatt hour—can be used to compare any method of generating electricity. Utilities are able to compare alternatives whose costs and output occur in different time periods by calculating "levelized costs." This procedure discounts all the costs and the output of a facility and expresses a present value cost per unit of output (usually, cost per kilowatt-hour).[3]

Utilities use the same measure of cost per unit of output measure to evaluate alternatives that reduce demand. Consider a conservation program that subsidizes the installation of energy-efficient lighting and heating systems in commercial buildings. With the program the utility's customers consume less electricity than they would have without the subsidy. By dividing the present value cost of the program by the amount of energy saved, the utility can compare the unit costs of conservation with the costs of new sources of supply .

In theory all costs should be included in this economic representation of facility and program options. Electric utilities like the Bonneville Power Administration sponsored significant amounts of research into methods for quantifying and monetizing (placing dollar values on) environmental costs like air pollution, loss of habitat, and aesthetic changes. In practice, however, judgment must augment the quantitative process to incorporate intangible costs and benefits. The point here is not the one often attributed to economists: that they think everything can and should be measured in dollars. Rather, it is that agencies cannot ignore some significant costs just because they cannot measure them. The least-cost framework reminds and requires analysts to identify those costs, and to quantify and monetize them to the extent possible.

The cost-comparison approach used in least-cost planning is essentially a cost-effectiveness analysis. It compares the costs of a single, homogenous measure of output that the public policy process has determined desirable. It was originally applied to national defense and then extended to other aspects of public policy. Cost-effectiveness analysis in the electric utility industry meant identifying the least-cost mix of resources (both facilities and programs) that would deliver sufficient kilowatt hours without unplanned interruptions to all customers.

Utilities integrate the information about the cost effectiveness of different alternatives with some insights from asset allocation in the field of investing to develop their plans for meeting projected increases in demand. Rather than depending on any one large investment to produce new supply, least-cost plans are likely to include a broad "portfolio" of different supply and demand measures. Investment portfolios are typically constructed to diversify risk. Energy portfolios also diversify risk by including a range of measures that may perform more or less well depending on future market conditions. A least-cost energy portfolio is developed through the following steps:

- Estimate the costs of all resources in comparable terms (cost per unit of output)

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[3]The theory and mechanics of discounting are discussed in Chapter 4.

- Identify and screen alternative programs and facilities to eliminate obviously inferior ones
- Bundle resources into competing portfolios
- Compare, rank, and select the portfolio that minimizes cost given the uncertainty in demand and cost estimates.

The cost-effectiveness analysis in least-cost planning is thereby integrated into an explicit evaluation of future uncertainty. As more is learned about the performance of a particular measure, plans are changed to reflect new information. The cost-effectiveness analysis and evaluation of uncertainty are the core analytic principles that provide key information within the broader context of least-cost planning.

2.1.3 WEAKNESSES OF LEAST-COST PLANNING

Least-cost planning continues to evolve as its practitioners gain insight and experience. Two weaknesses in the way LCP is typically applied are worth noting for their implications in applying the approach to transportation.

The first has to do with the balancing of supply-side and demand-side programs. Requiring electric utilities (suppliers of electricity) to consider demand-side methods for reducing the growth in demand while accommodating the demand for the end uses for which electricity is an input is touted as a fundamental advancement of LCP. For example, the subsidies that utilities provide for adding insulation to existing buildings is seen as critical in delaying the construction of expensive new generating facilities.

These programs may have reduced the quantity of electricity demanded at current electric rates. But, strictly speaking, none of these programs represent the least-cost method of reducing the quantity of electricity demanded. That method requires proper pricing. If rates are set to include the full social cost of supplying the electricity, then consumers will adjust their demand in the most efficient way possible. They may choose to insulate, to use other conservation measures, or to continue current consumption patterns and pay the bill.[4]

The second weakness in the way LCP has been practiced has to do with the way planners calculate the costs and benefits of a proposed project. Borlich (1994) details the distortions in cost-benefit analyses that occur when planners ignore the effects of consumers' response to changes in prices. The context is a case in which a utility implements a demand-side management (DSM) program (e.g., subsidizing purchase of energy-conserving lighting), and pays for the program with a rate increase. If no other effects occur, society is better off because the end use—lighting—is (approximately) the same, and has been achieved using a lower cost-resource (replace bulbs

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[4]Appendix B discusses some of the close parallels between the mispricing of electricity and transportation and why mispricing requires consideration of programs that affect the demand for electricity and transportation services.

instead of new generating facilities). Although planners recognize that consumers respond to the increases or decreases in price that result from implementing a DSM measure (an effect referred to as "snap back"), they typically view it as undesirable.[5] In reality, consumer response to changes in price is the primary source of benefit in a market system. In the example, the net benefits of the DSM project increase when the consequences of the changes in behavior caused by the rate increase are considered. The main source of the increase in net benefit is that the rate increase unintentionally brings rates closer to marginal social cost.

2.2 APPLYING LCP TO TRANSPORTATION

If the objective for public policy is to choose among alternative actions the one that provides the greatest net social benefit—an objective very difficult to argue with—then estimates of all costs and benefits associated with each action are required. The principal motivation for the development of LCP in electric utilities in the 1970s was the desire to better compare costs across as wide a range of alternatives as feasible and better assess the consequences of uncertainty in energy markets on each alternative. As in energy, in transportation the range of options and of social costs and benefits is large. Because the costs and lifetimes of transportation infrastructure are large, so are the costs to society of poor investment decisions. Common sense and recent legislation agree: a thorough evaluation of these projects is prudent and required.

The analytic process for evaluating transportation alternatives, however, differs in a key respect from the utility experience. In transportation, alternatives analysis must include explicit accounting for the benefits to users. There is no kilowatt-hour equivalent in transportation. Electricity and natural gas are homogeneous commodities, whereas trips are not. The traveler's perception of a trip on transit differs substantially from the same trip made by automobile.

A simplistic evaluation of cost per trip without explicitly accounting for the benefits to travelers could result in least-cost plans that leave travelers worse off.[6] For example, a policy of requiring even and odd numbered license plates to drive on alternate days might be the "least-cost" way (from the perspective of governments who must otherwise build and pay for new capacity) to lower the total social and environmental cost per trip within a region, but such a policy would substantially reduces the benefits to those who want to drive but can't.

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[5] The issue is analogous to the way transportation planners react to the response of drivers to new road capacity, who take advantage of the now lower-cost travel to reintroduce some of the congestion the new capacity was designed to eliminate. If not for this form of "snap-back," the new capacity would have provided congestion-free travel.

[6]Analysis of costs per trip can be useful in screening some types of alternatives (e.g. , transit service through a particular corridor), but alternatives should eventually be analyzed through full benefit cost analysis.

Transportation differs from utilities in other ways that are relevant to the application of least-cost planning.[7] Users of transportation services can choose among different modes and supply many important inputs for some of these modes (e.g., time, vehicles); thus, important aspects of the decision-making and planning are more decentralized than with utilities. Furthermore, transportation systems must be in local as well as global equilibrium. Output cannot be inventoried or moved around the network. Thus, while system-level planning is important to transportation, it is more limited in the extent to which it can influence the behavior of producers and consumers and correct mismatches between demand and supply. Least-cost plans must account for the preferences and behaviors of travelers at a particular location at a particular time.

One may object that, in practice, estimating all the benefits and costs of a proposed project accurately is impossible. A wide range of spillover costs and benefits of transportation facilities and programs have yet to be estimated reliably. Moreover, it is very difficult to foresee changes in transportation, land use, and energy markets that could have profound effects on the performance of different components of the transportation system. We agree. But those facts do not make the need for evaluating benefits and costs go away—they only make it more difficult to meet. The framework and tools of LCP provide the best hope for meeting the need.

While the evaluation of transportation alternatives requires a more complete evaluation of benefits than has been the practice in the utility industry, many of the other principles that guide LCP are appropriate for transportation planning. We listed those principles Chapter 1 and will discuss many of them more fully in Chapter 3.

Among the principles is an explicit consideration of risk and uncertainty. Some of the approaches energy planners use to cope with uncertainty are readily transferable to transportation. Sheets and Watson (1994) describe how the methods used by the Northwest Power Planning Council to evaluate the effects of uncertain growth in demand for electricity have influenced investment decisions. For example, energy utilities have found that staging the development of new facilities can reduce risk.

Least-cost planning for transportation folds benefit-cost analysis into a good strategic planning process for the key agencies and stakeholders. It identifies the most cost-effective alternatives within a planning context that builds support for the chosen plan. The plan is revised as better information becomes available about future conditions and the performance of different alternatives.

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[7]In part because of legislative mandates, the state of Washington has spent considerable effort over the last two years investigating how LCP could be applied to transportation. The Washington State Energy Office has produced several reports, including one (Dodd 1994) that does a thorough comparison of energy operating characteristics and management concepts to those of transportation. See Appendix E for other sources including Dodd (1994), Ulberg (1994), and McCoy, et al. (1994). Reports can be ordered from the Washington State Energy Office, (206) 956-2000.

2.3 CONCLUSIONS

The interest of transportation planners in least-cost planning is appropriate. For many people involved in planning and decision-making for transportation improvements, LCP offers a new paradigm for evaluating those improvements. It encourages a more rigorous evaluation of *all* the benefits and costs of the proposed alternative, and of *all* reasonable alternatives to the improvement.

But for transportation analysts familiar with standard techniques of benefit-cost analysis as applied to transportation, there is little new in LCP. It represents the melding of good strategic planning and public involvement with benefit-cost analysis. The core analytic principles have been discussed in the transportation literature for decades. The requirements of ISTEA have stimulated a spate of reports at the federal level on how to apply benefit-cost principles to multi-modal evaluation of transportation improvements.[8]

These principles, however, are only occasionally applied in decisions about state and metropolitan transportation projects. They are not well understood to begin with, and agencies that rely more on political judgments and the requirements for federal funding than on technical analysis have little incentive to understand them better.

The primary value of LCP is not that it introduces new concepts or techniques. Rather, it is that it generates new interest in old but solid ideas by presenting them in a contemporary vernacular. Focusing on the services of transportation rather than on the inputs, providing those transportation services efficiently (at least cost)—these ideas make sense to transportation planners, transportation and environmental interest groups, and the public.[9]

Thus, in the rest of this report we explain how the principles of benefit-cost analysis can be applied to the evaluation of transportation investments and policies, and how that analysis could be included in a least-cost planning process for transportation.

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[8]See, for example, FTA (1994) *Revised Measures for Assessing Major Investments* (draft); Grant (1994a) *A Methodology for Evaluating Cross-modal Transportation Alternatives*; Parsons Brinckerhoff Quade & Douglas (1994) *National Transit Institute Training Program on Major Investment Studies, Reference Manual* (Draft). Others will certainly be in the works by the time this report is published.

[9]The caveat is that LCP brings with it some baggage that is not helpful to transportation analysis: the implication that demand (benefits) can be held constant and transportation investments and policies then structured in a way to minimize their cost. This aspect of a strict LCP approach is *not* applicable to transportation investment decisions.

Chapter 3 Evaluating the Benefits and Costs of Transportation Alternatives

This chapter describes the central technical component of least-cost planning in transportation: the application of benefit cost analysis to the evaluation of alternatives.[1] It starts with a description of the key concepts of a benefit-cost framework for evaluating transportation investments and policies. It then looks in detail at how those concepts get implemented. The main benefits are reductions in travel costs to users of transportation systems (time, operation, and accidents). The direct costs are those associated with the project or policy that generates the benefits. These include the costs of the design, construction, operation, and maintenance of transportation improvements, and the administration of and compliance with transportation policies. There may be other costs and benefits as well, including changes in environmental quality, and any efficiencies gained from changes in regional economic conditions and patterns of land use.

We recognize that some of the methods we describe in this and the next chapter are difficult to implement in the real world. In Chapter 5 we drop back from the comprehensive evaluation and planning approach advocated here to describe the initial steps that the federal government, states, and MPOs might take to further the implementation of least-cost planning.

3.1 OVERVIEW OF KEY ANALYTICAL PRINCIPLES

Every investment decision, whether in the public sector or the private sector, should attempt to maximize the excess of benefits over costs (net benefits). In the private sector, net benefits to firms are measured through profits (net revenues): firms make decisions about what type and quantity of goods or services to produce based on their predictions of how much of those products consumers will buy at a given price, and how much it will cost to produce those goods.

The optimization of private investment decisions can be measured approximately by profits. The public sector, however, has other objectives beyond what can be stated in terms of net revenues. Benefits might be the decreased travel costs to commuters that results from a new HOV lane; decreased air pollution for people living and working near highways; or a feeling of stewardship enjoyed by some people when the government enacts policies to discourage sprawl and increase transit ridership.

[1]Chapter 4 describes how this analytic approach fits into the broader context of planning for large, multimodal transportation systems.

Benefit-cost analysis (BCA) is the general term used by policy analysts to refer to both a logical framework and specific techniques for measuring and comparing all the significant benefits and costs of a public policy.[2] In a narrow sense, some texts and critiques of BCA refer to it primarily as a technique for calculating the net present value of a future stream of direct, quantifiable, monetary benefits and costs. In the fuller sense that we use here, it is a framework that helps analysts and decision-makers (1) identify and quantify all benefits and costs of a proposed action, (2) avoid omitting or double-counting benefits or costs, (3) determine how future benefits and costs should be valued today, and (4) estimate how benefits and costs are distributed among different groups.

The rationale of benefit-cost analysis is economic efficiency; it aims to ensure that resources are put to their most valuable use. Its *fundamental rule* is:

> "In any choice situation, select the alternative with the greatest net social benefit." (Stokey & Zeckhauser, 1978)

Any choice is evaluated in relation to a no-action (or, rather, a business-as-usual) alternative—if the no new action (policy) yields greater net benefits, then the best policy is to do nothing. Benefit-cost analysis recognizes that policy alternatives may make some people better off and others worse off. Such distributional changes are inevitable. But the fundamental rule at least requires that in the aggregate there is more value after the action than before. In theory, those who benefit from the change could compensate the losers leaving everyone better off. Whether the losers do, in fact, get compensated is part of the evaluation of the equity impacts of a policy that policy-makers must consider along with the evaluation of net social benefits.

BCA consists of the following steps:

1. **Select alternatives for evaluation.** This is a key step in the process that is discussed in greater detail in Chapter 4. The essential point is to develop honest alternatives that provide real choices for policy-makers.

2. **Describe the path of cause and effect by which the new action is expected to change the future from what it would have been in the absence of the action.** BCA only looks at *changes* in social welfare, since it is very difficult to measure current *total* welfare. Thus, project benefits and costs are measured as *differences* between what the world is forecast to be like without the action, and what it is forecast to be like

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[2] Many texts and documents explain the principles of BCA. For a good general introduction see Gramlich (1981), Thompson (1980) , Mishan (1982), and Stokey & Zeckhauser (1978). For the general application of BCA to transportation, see AASHTO (1977), Lee (1994), and Greene & Jones (1995). For specific applications of BCA to transportation, see Lee (1995a), and Wilbur Smith Associates & Howard Needles Tammen Bergendorff (1994). Key federal guidance is cited in the bibliography of this report.

with the action. For choosing among alternative actions, it is sufficient to know how their effects (impacts) are different.

3. **Identify which benefits and costs can be quantified and, of these, which can be monetized, and how**. An accurate measurement of changes in benefits to consumers and changes in resource use (production cost) is crucial to the accurate rendering of the benefit-cost analysis. Some impacts can be *quantified*:: e.g., pounds of pollution, hours of travel time, and stated satisfaction by consumers. Some impacts are very difficult to measure, or even to express in terms that could theoretically be measured: e.g., changes in civic pride. Of the impacts that can be quantified, many can be *monetized* (expressed in terms of dollars) easily, others only with difficulty. The monetization of impacts may be done with market prices or *shadow prices*. Shadow prices are implicit prices for goods and services that are not actually traded in the marketplace. They are inferred from either behavior other than direct purchases of a good or service, or from surveys in which people state what they would pay to reduce the impact or be willing to accept to allow it to occur.

4. **Estimate and assign changes to benefits and costs to the time period in which they occur**. For most investments, including transportation improvements, costs occur up-front to get benefits that occur later. The timing of these costs and benefits has a large influence on a project's desirability. Obviously if two projects are otherwise identical in benefits and costs except that the benefits of the second occur 10 years later than the benefits of the first, the first project is preferable. Since the effects of a particular project or policy are usually composed of a *stream* of impacts that play out over a long period of time, care must be taken to properly time-weight the various elements of that stream of impacts in rendering the overall estimate of net benefits

5. **Discount changes in quantifiable benefits and costs to account for the time value of money**. The proper way to deal with benefits and costs that occur in the future is to discount them. Otherwise, in the example in point 4 above, one would be indifferent between the two projects, which is typically not the case. All quantifiable benefits and costs should be discounted.

6. **Sum discounted benefits and costs to establish their present value**. Subtract the present value of the monetizable costs from the present value of the monetizable benefits to determine the *net present value* of the net change in benefits (or costs) attributable to the proposed transportation improvement or program

7. **Describe other non-monetizable benefits and costs.** Some important costs and benefits may be difficult to monetize. Hence, one may end up with a multi-dimensional measure of a project's impact: the present value of monetized benefits and costs, and descriptions of other impacts that analysts and decision-makers are unable to quantify.

8. **Describe the distribution of all benefits and costs (both priceable and unpriceable): who benefits and who pays?** Benefit-cost analysis requires aggregating impacts across individuals who may be dissimilar in important ways (for example, in the value they place on time). Even if all impacts were monetizable, it is not necessarily the case that the best project is the one for which the net present value of the benefits is the greatest. How those benefits are distributed is also important. For example, how does the action look when evaluated from the perspective of drivers versus that of transit users; of high income households versus that of low-income households; of commuters versus other trip-makers; of urban residents versus rural residents; and so on?

9. **Perform sensitivity analyses.** Risks and uncertainties should be described and quantified to the extent possible for all steps of the analysis. The analysis must describe how results vary in response to changes in values for the magnitude of benefits and costs, the discount rate, length of planning period, and degree of risk associated with the project. For transportation projects, for example, there is substantial uncertainty about travel demand response.

10. **Integrate the results into the least-cost planning process.** Chapter 4 discusses how the results of BCA used to inform the planning and decision-making process in least-cost planning.

The overarching strength of BCA is the framework it provides for identifying and discussing benefits and costs. It facilitates a comparison of different types of benefits and costs occurring at different times and affecting different people. BCA focuses on comparing the real resources available before the project with the real resources available after the project. If done correctly, it considers not only direct dollar costs (like labor and materials) but also costs and benefits not usually measured in dollars (like environmental damage and decreased congestion) and the distribution of all benefits and costs. Thus, in contrast to critiques of BCA that assert that it only looks at dollar costs, BCA provides a useful framework for a comprehensive analysis of all the benefits and costs attributable to a project, whether they are measurable in dollars or not, and to some degree, even if they are not quantifiable.[3]

[3]For a thorough discussion of the strengths and weaknesses of BCA, see Campen (1986).

If properly performed, BCA can eliminate three sources of error that one often finds in less rigorous analyses: a confusion about (1) *what* resources count, (2) how a project or policy *changes* the amounts of society's various resources, and (3) *whose* resources count.

The sections that follow discuss several economic concepts at the foundation of BCA that are critical for any good evaluation of any public investment, including major transportation impacts.

3.1.1 EVALUATING *ALL* SIGNIFICANT BENEFITS AND COSTS

Many of the costs of transportation projects can be measured by adding up the market costs of the resources those projects use up. Freeways take labor (planning, design, construction), concrete, steel, machinery, and so on. The costs can be added and expressed in dollars. Many of the benefits and costs of public projects, however, 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 since 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 (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.

An extensive literature exists in policy analysis in general, and in transportation in particular, on issues relating to identifying and valuing benefits and costs.[4] It is not the purpose of this report to go into all of the details of benefit-cost analysis as it applies to transportation. It is our opinion, however, that without an acquaintance with the fundamental concepts and methodological issues associated with benefit-cost analysis, planners and policy-makers will be unable to take the first steps towards a more comprehensive evaluation of alternative transportation investments and policies. Some of the main concepts and issues are:

[4]See footnote 3 above, and the bibliography. During our research we were surprised to find a study done by the Oregon State Highway Department in 1937 ("The Economics of Highway Planning") that gave a thorough description of a benefit-cost framework for evaluating highway projects. As we note several times in this report, the problem is not an inability to articulate how to evaluate alternative highway investments—it is that, for reasons we describe in this report, technicians and politicians are often not using the theoretically correct techniques.

- *Costs are real economic resources used by a policy or project.* Money facilitates the exchange of useful resources, but is not a resource itself. Steel, concrete, labor, driver time, and gasoline, *are* real resources that get used up 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 hadn't 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 measure the value of many benefits and costs.[5] 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 whenever, and only when, resources are used up.

  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 up 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.* While this may be good politics, it is not good policy analysis. A related point is that what are often listed and added as either benefits and costs are really *transfers.* Taxes and grants are usually transfers (see the note following on *perspective*): money may move from one place to another, but no resources are used up.

- *Benefits are negative costs; costs are negative benefits.* Many of the benefits of transportation improvements are best expressed as reductions in the 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, which we follow in this report, is to talk about these decreases as *user benefits*, even though it is certainly true that for some users some of these factors may increase (e.g., an increase in travel time is a negative benefit). The convention derives from the reasonable assumption that for any transportation improvement to merit consideration, these factors must have a very high probability of decreasing, in the aggregate,[6] and the reductions in costs are benefits for the users.[7]

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[5]Assuming there are no significant external costs, a rebuttable assumption to which we will return later in this chapter.

[6]The logic here is that the predominant category of cost usually considered in a transportation improvement is the direct costs of construction, operation, and maintenance. The investment decision is usually based on an evaluation that compares (not usually according to the principles described in this report) those costs to the user benefits. If the user benefits were likely, in the aggregate, to be negative (i.e., to be user costs), there would be no point in conducting the evaluation: society would be spending money to make users worse off.

[7]Whether something is categorized as a benefit or a negative *can* be important, however, if one is making decisions based on the ratio of benefits to costs. The reason is that additions to the numerator of the ratio (benefits) will have a different impact on the ratio than an equivalent subtraction (negative costs) from the denominator.

- *Benefits and costs must be defined in a way that is both comprehensive and mutually exclusive.* Clearly, accounting for all benefits and costs requires identifying a comprehensive list of all (or at least the significant) benefits and costs. Otherwise some will not be counted. It also requires, however, that the categories not overlap, or else some will be counted twice. For example, transportation evaluation typically counts (as it should) reductions in travel time as a benefit. Many evaluations, however, go on to count as benefits increases in property values and tax revenues that such reductions in travel time stimulate, double- and triple-counting the benefit (Mishan 1978, 67).
- *Consumer benefits are measured using information on consumer demand.* The difference between what consumers are willing to pay to make a trip and what they actually do pay is known as *consumer surplus.* The concept of consumer surplus is central to evaluating transportation investments. It is, in concept, a measure of net benefits (the benefit being what a consumer would pay, the cost being what a consumer did pay). Much of this report aims at describing components of that surplus; i.e., the net benefits that users derive from the transportation improvement or program.
- *Measuring all benefits and costs means considering some that do not have obvious market prices.* The most obvious example is loss of environmental quality from pollution (e.g., from tailpipe emissions). Less obvious is the loss of time because of congestion. Though air quality and travel time are not traded in any established market, they still are real impacts that must be considered in any full evaluation of the impacts of transportation investments. We discuss them in detail later in this chapter.

This emphasis on accounting for all costs is not a call for an academic refinement of current practice. A full accounting framework would substantially change the results of current transportation investment analyses. In all cases it means describing what resources it takes to allow a trip to be made. Consider:

- *Highways.* It takes more than cars, gas, and roads. The costs of vehicle travel include disruption costs during construction, additions to connecting roads, sidewalks and lighting, parking at origins and destinations, police and emergency services, air pollution, and benefits and costs to users as they shift modes or take more or fewer trips.
- *Transit.* It takes more than buses, rail, electricity, and labor. Transit has the same *type* of additional costs as highways, though some of them manifest themselves differently. For light rail, for example, the air pollution cost occurs at the power plant, not on the highway. As transit service changes, so do the benefits to both transit and highway users as they shift modes.

- *Transportation Demand Management.* Policies do not have construction costs, but they are not free. The costs and benefits include the thousands of hours of time that technicians, politicians, and citizens spend designing and debating the policies; administration, monitoring, and enforcement; employer costs (e.g., administration) and benefits (e.g., reduced parking costs and absenteeism); changes in user benefits; and reductions in auto-related infrastructure.

The main points are easily summarized: (1) all significant effects of a project—whether priceable or not, whether quantifiable or not—must be considered in the decision-making process, and (2) the effort is worth it, to facilitate efficient decision-making.

3.1.2 PERSPECTIVE: BENEFITS AND COSTS FROM WHOSE POINT OF VIEW?

Not only must all effects be considered, but they should also be considered from all important perspectives. For example, a grant from the federal government to an MPO is an expenditure for the U.S., a revenue for the region the MPO serves, and a transfer from the perspective of net social (national) cost. The distinction between a regional perspective and a local perspective is essential for two reasons.

First, net benefits to a region as a whole do not ensure net benefits to every subset of the region. For example, though a project to develop new highway capacity may provide net benefits to the region considered as a whole (i.e., the costs, including costs to local neighborhoods that are not easily quantified, are more than offset by the benefits of decreased travel time and increased safety), local residents very near the project may oppose it because they genuinely believe that they will be worse off (for example, because they lose their land, privacy, or quality of life). It is easy to imagine that situation in the case of a limited access highway or new high-speed rail system.

Second, the recommendation that BCA consider not just gains in economic efficiency but also how those gains are distributed is another way of saying that it must consider different perspectives. In the previous example, an analysis done from the perspective of the residential neighborhood would have shown net losses if all external costs had been counted.

Third, the issues of transfers cannot be ignored if governments are to make efficient investments in transportation. Local governments are right to consider earmarked federal funds as benefits, or at least to ignore them as costs. Projects with 80% federal funding will usually look good to local governments: they are, after all, receiving real resources that they can use to their benefit. But the federal government is also right to hold local governments to a more restrictive standard when it hands out discretionary funds. From the federal perspective (which arguably represents all U.S. citizens and taxpayers, and, hence, is the perspective of society as a whole) giving funds to one local government has the real opportunity costs that those funds are not available for another project elsewhere. The concern should be primarily for the efficiency of projects based on total resource costs.

These two perspectives, local and national, are both legitimate and inherently in conflict. The conflicts can be reduced by (1) being clear that the differences exist; (2) being clear about the criteria that the federal government will use to evaluate projects (which would probably not give much weight to the value of the federal transfer to the local economy); and (3) shifting (as ISTEA does) from earmarked funding to flexible funding that will encourage local governments to use that funding efficiently.

In practice, few benefit-cost analyses provide rigorous evaluations of how benefits and costs fall on different groups.[8] Part of the reason for the absence of equity analysis is that it can often be difficult to determine to whom the benefits of a policy decision ultimately accrue. Market forces tend to shift benefits and costs from the nominal recipients or payees to others. For example, the time savings benefit from a transportation project initially goes to users, who presumably are local, but may eventually be captured or shifted to landowners, who could be non-local, in the form of higher rents.

There is no economic or mathematical solution to the problem posed by distributional issues except in the instance when all groups are clearly better off under one alternative than another. All a careful analyst can do is describe the likely impacts on different groups to try to help the decision-maker select among alternatives. In our opinion, however, given the magnitude of investment and the likely federal contribution for major transportation investments, the appropriate social perspective for an analysis of project *efficiency* is the national one, with inter-governmental transfers identified as just that: transfers, not wealth generation.

3.1.3 MARGINAL ANALYSIS: FOCUSING ON DIFFERENCES AMONG ALTERNATIVES

Project evaluation can be simplified by looking at *differences* between what the world is forecast to be like without the project, and what it is forecast to be like with the project. If, for example, all the relevant transportation alternatives being considered are estimated to have roughly the same impacts on the regional economy, then one can skip spending time trying to estimate those effects: they net out and make no difference to decision-making. For choosing among alternative actions, it is sufficient to know how their effects (impacts) are different.

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[8]A good example of an exception is *Efficiency and Fairness on the Road* by Cameron (1994). It provides a clear illustration of how an analysis of transportation projects and policy can consider differences in effects on different income groups. That report on the fairness and efficiency of highway policy in the Los Angeles area also illustrates many other concepts and analytical techniques we describe in this report.

Some evaluations of transportation investments miss this critical point. For example, sometimes the base case (the "without new policy" world) is simulated as a simple extrapolation of trends, with the result that congestion goes to level of service F on many major corridors. Any projects (the "with new policy" worlds) look good by comparison. The problem is that the base case is a fiction that would never occur. The models that would predict how travelers would respond to that level of congestion (in the short run, with changes in route, travel time, or mode; in the long run, with changes in vehicle type, and residential and employment locations) are either not available, not acceptable, or not used. The need to estimate net impacts means better predictive models must be developed and used.

In all cases the concern should be with reasonable estimates of the *additional (marginal) costs and benefits* resulting from a proposed action.

3.1.4 DISCOUNTING TO PRESENT VALUE

Assume that all costs and benefits have been identified, categorized properly to avoid double-counts and transfers, quantified, and monetized. 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 accounts for 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 $1000, most people would choose the note: they would accept the postponement of gratification, the erosion of inflation, and the risk that, for whatever reasons, that payment in a year will end up being less than $1000. At some point in between they would be indifferent. 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 can get involved.[9] The experts who reviewed an early draft of this report recommended real discount rates between 2% and 7%. ("Real" in this context means taking out the effects of inflation.) A real discount rate of 5% combined with an expectation that the average rate of inflation will be 4% yields a "nominal" discount rate—the rate that a lender might quote—of

[9] For a good discussion of selecting discount rates see General Accounting Office (1991).

about 9%.[10] We recommend using this range of discount rates to test whether the relative rankings of the alternatives under consideration change within this range. In most instances, the relative rankings of projects will not change over this range of discount rates. If rankings do flip with changes in the discount rate, policy-makers should consider the arguments for the higher or lower end of the range.

3.1.5 SUMMARY OF THE LIMITATIONS AND ADVANTAGES OF A BENEFIT-COST FRAMEWORK

This brief overview shows that benefit-cost analysis always involves estimates of values, assumptions about the present and future, and other sources of uncertainty. The results of the method depend upon these estimates and assumptions. Benefit-cost analysis is only as good as the data and assumptions that go into it. There are several areas in BCA where problems often arise.

- *Selecting Alternatives.* The first step is in many ways the most crucial. All analysis is relative, of course—one can't say whether something is good or bad without knowing what the alternative is. Moreover, straw men or poorly considered alternatives are among the most common pitfalls in transportation project evaluation. The next chapter offers some suggestions for public involvement and approaches to developing alternatives that will insure all reasonable alternatives are considered.
- *Predicting Consequences.* Benefit-cost analysis depends on the ability to predict how travelers will behave over time with and without the proposed alternatives. While the models for forecasting travel behavior and land use changes have advanced in recent years, they are still unable to evaluate many alternatives that agencies should consider in a least-cost planning process. The models are also mathematically complex and vulnerable to manipulation by agencies that want to steer the analysis in favor of a preordained outcome.
- ***Counting Jobs as Benefits.*** Strictly speaking, jobs are not a benefit from a major transportation project. Evaluations done by government agencies will often claim that projects offer enormous benefits by creating jobs or by increasing regional incomes. In fact, if the money were not spent on the transportation project it would support jobs and regional income in whatever alternative use to which the money is put. Those alternative uses may have different distributional consequences but the equity issues should be kept distinct from the estimation of net social benefits.

[10]"About" 9% because adding the real discount rate and the inflation rate only approximates the nominal discount rate. The exact relationship is: real discount rate = [(1 + nominal discount rate) / (1 + inflation rate)] -1.

- *Valuing Environmental Impacts and Other External Effects.* While there is considerable agreement among transportation economists on how to value certain non-market effects such as changes in travel time, many environmental effects are much less amenable to valuation.[11] Analysts should be careful of assigning extremely high environmental costs to some alternatives (e.g., auto travel) and ignoring the environmental costs of others (e.g., rail transit). Environmental impacts are often best left at estimates of the differences in their physical effects without making the final step to valuation.[12]

These analytic pitfalls can be difficult to avoid because of the political context in which transportation project evaluation occurs. Powerful interests can influence the outcome of an analysis; the preceding areas are particularly susceptible to manipulation. The least-cost planning process should encourage the independent evaluation of alternatives in a way that is insulated from political pressures. Once the analysis in complete, it can be integrated into a political process that accounts for the distributional impacts of different alternatives and the political interest of key constituencies. Chapter 4 offers some suggestions on how to do that.

Developing good alternatives and modeling their likely consequences is part of the craft of transportation project evaluation. It is easy to get it wrong. The following sections provide some directions for getting it right, but analysts must remain watchful of the rocks on which benefit-cost analysis can founder.

There are no simple solutions to these problems. But the problems do not disappear or become less important by using an evaluation method that ignores them. A benefit-cost framework is logical, rigorous, and relatively transparent. It monetizes where it can, quantifies where it cannot, and describes where even quantification is beyond our data and methods. It is explicit about efficiency, about the tradeoffs between efficiency and equity, about the timing and value of benefits and costs, and about uncertainty.

Benefit-cost analysis is an analytic technique; it does not make decisions. It is the right framework for thinking about the complexities of the impacts of transportation investments—a framework for getting complex issues into a format such that they can be understood and debated by decision-makers and the public they represent.

[11]The debate is even deeper than measure—there is still a debate about what, in theory, should be classified as external benefits and costs. See Greene and Jones (1995).

[12]One of the best examples of a rigorous attempt to estimate the costs of changes in air quality is Small and Kazimi (1995).

3.2 IDENTIFYING, QUANTIFYING, AND VALUING ALL SIGNIFICANT BENEFITS AND COSTS

Some recent studies have categorized costs with the aim of illustrating the percentage full cost paid by some user group (typically, drivers).[13] However, benefit-cost analysis should be oriented to a *social perspective*, which means defining and organizing costs and benefits in a way most suitable to answering the question:

> What would be the net benefits of a particular transportation improvement to the citizens of a metropolitan area if they were required to pay the costs of all the resources that would have to be committed to building, operating, and maintaining that improvement?

An implication of this perspective is that the technical evaluation of big transportation projects should start with a national perspective, not counting as benefits the funds that a metropolitan area might enjoy from transfers from the federal government.

The issue of perspective raises an important point related to interpreting the research to date on transportation costs. Much of the recent research on transportation evaluation has focused on demonstrating that drivers of automobiles do not pay the full costs of their automobile trips, and on trying to allocate full costs between drivers and the rest of society. For a calculation of full benefits and costs to society, such allocations are not necessary. It is enough to know, for example, that accidents cause a certain amount of damage and that such damage has a certain value—what amount of damage drivers pay for through insurance or loss of income is not relevant to the benefit-cost calculation. This is not to say that the calculations of full costs are unimportant, however, because if users fail to perceive full costs because of pricing failures, the usage of the improvement may be distorted away from the social optimum.

Thus, the issue of whether a benefit or cost is internal or external to a particular group of users is not of primary importance in the simple, accounting approach to benefit-cost analysis. What is important is whether it occurs as a result of the transportation investment under investigation, that it gets counted once and only once as a benefit or cost to society, and that travel demand estimates treat the incidence of the costs correctly.

This perspective leads to another important clarification. We interpret the federal and state mandates for LCP and major transportation investment analysis to acknowledge that the full benefits and costs of transportation investments have not been adequately evaluated in the past. The evidence suggests that *all* transportation—both highway and transit— is underpriced. If this is true, then a proper investment analysis is likely to find that many investments for which there appears to be a "need" are uneconomic. Why?

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[13]See Litman (1994b) and Lee (1994).

The reason is that, by definition, today's trip-makers are willing to pay what they are charged to travel, but many are probably not willing to pay what it costs. They are probably not willing to pay what new transportation investments will cost to reduce congestion. Thus, we expect the benefit-cost framework we propose to collide with the politics of transportation investment decisions. The benefit-cost framework will answer the question about the effectiveness of transportation investment under the assumption that society wants to get the prices right. The answer will be quite different from the answer one would get starting, as most analyses of transportation investment now do, from the assumption that need can be properly estimated despite incorrect pricing.

Table 3-1 presents a framework for identifying impacts as benefits or costs. Because benefits can be measured as negative costs (and vice versa) any type of impact can be stated as a benefit or cost depending on whether it decreases or improves welfare (e.g., the benefit of a transportation investment is to reduce the cost of congestion, measured as a reduction in travel time). The impacts to society, for example, are either a cost or a benefit depending on how they change the situation relative to a base case. Benefits and costs are subdivided based on who they fall on (users or society[14]) and how they are evaluated (through market transactions or some other way).

Assuming that users bear all costs, one would hope that any proposed transportation policy would lower the long-run total costs to users (the present value of time and out-of-pocket costs including any new burdens of transportation infrastructure and operating costs). Even when this is true, however, it is certainly possible that total user costs for some users increase. Thus, it is possible to think of one of the costs of a transportation investment as increases in travel time. While a full benefit-cost analysis would require a forecast of travel times on different links at different times of day, the decision on net benefits is usually made on the aggregation of the value of those travel times. The losses for some travelers are presumably offset by the gains of others, for a net reduction in travel time (a benefit).

As soon as one tries to apply the logic of Table 3-1 in the real world, its crisp definitions go quickly fuzzy. It is here that a benefit-cost framework gets its heaviest criticism. While there are certainly debates about the concepts, most analysts agree that good decisions are generally ones that look at all the benefits and costs, priceable and nonpriceable, present and future, for all relevant alternatives, to determine which alternative provides the greatest present value of net benefits, allowing for adjustments for other (less priceable) considerations like equity. The typical critique is that this decision rule, impeccable in theory, cannot be applied in a complex region with millions of citizens and interests, and inadequate data and models.

[14]Users may also pay as members of society; for example, through federal, state, and local taxes that are used to support highway services and pollution control. In Figure 2-5 and elsewhere we use *user charges* to mean the costs users pay as users.

Table 3-1: Classification of Benefits and Costs Used in This Report

	Type of Benefit or Cost	
Who Benefits or Pays?	Observable Market Prices	No Direct Market Prices
Users of the Transportation Improvement	Operating costs (direct auto capital and operating expenses, auto insurance, parking charges, gas and excise taxes paid by users, transit fares, etc.) Benefit: decrease Cost: increase	Travel time (during construction and operation) Benefit: decrease Cost: increase Quantity or severity of accidents (beyond what is covered by insurance, a priced operating cost) Benefit: decrease Cost: increase
The Rest of Society	Capital, operating, and maintenance costs of proposed transportation improvement (including right-of-way acquisition and relocation, and other opportunity costs) Benefit: decrease Cost: increase Capital, operating, and maintenance costs of other facilities and services the new improvement requires (e.g., parking, transit, sidewalks, lighting, police and emergency services) Benefit: decrease Cost: increase Regional economic output Benefit: increase Cost: decrease	Human morbidity and mortality (primarily from airborne emissions and road dust) Visibility (emissions and road dust) Visual and audio (aesthetics and noise) Quality and sustainability of agricultural crops, timber, and livestock Water quantity and quality (loss of wetlands, storm water runoff) Vibration damage Global climatic conditions Land use patterns Social impacts Benefit: Improve Cost: Worsen

We acknowledge that critique, but suggest that it is incomplete until one considers the alternative. The complexity does not disappear by choosing not to try to sort out, quantify, and price the benefits and costs. It is simply dealt with implicitly. For example, one assumes that new highway capacity is beneficial if there is congestion, or that the costs of air pollution associated with induced travel can be safely ignored. Those assumptions might be correct. Our position in this report, however, is that before one can have any confidence in those assumptions one must understand what the possible impacts of transportation investments are, how they interact, and how people value them. That is exactly what a benefit-cost framework attempts to do.

In the rest of this section we discuss briefly the major impacts identified in Table 3-1. In concept, we are looking to estimate how:

- Consumer surplus changes in reaction to a transportation facility or program
- Consumer resources change as the result of changes in time resources used
- Consumer resources change as the result of changes in consumer operating expenditures (gas, oil, etc.)
- Resources change for other producers (such as a road or transit authority)
- Resources change as the result of external effects (externalities).

Our purpose in this report is to provide an overview of the benefits and costs that a full evaluation of major transportation investments should include. We are focusing on describing why these costs and benefits are real and how they can be measured, not on specific estimates for each category of benefit and costs.

The recent studies that we reviewed typically looked at the full benefits or costs of transportation investments with the purpose of demonstrating that automobile drivers do not pay the full costs of their trips. We agree with that conclusion (at least for peak-hour transportation in metropolitan areas); Appendix B shows some typical estimates. But in many cases, the impacts (e.g., per vehicle-mile) were calculated by taking estimates of total costs for all the U.S. for a year and dividing by the U.S. base for the year (e.g., vehicle miles). That works for the purposes of showing that, on average, the auto does not pay its way. It is not a very reliable estimate, however, of the marginal cost of a particular trip in a particular city at a particular time of day. In other words, one cannot simply apply these aggregated numbers to estimate the benefits and costs of marginal changes in a particular corridor.

Moreover, the purposes of those studies led them to focus on showing that external costs existed and were significant. For example, they would treat congestion costs under the heading of externalities. In this report, we are less concerned with the total external costs per se than we are with accounting for all costs within the benefit-cost framework we have outlined. Thus, we treat external congestion costs under the heading of user benefits (with the transportation investment leading to a negative cost—a reduction in the external congestion cost).

3.2.1 BENEFITS TO USERS[15]

We described above the convention of using the term *user benefits* to apply generally to changes the users see as a result of a transportation investment: in travel time, operating cost, and safety. While trying to

[15]For a good description of user benefits as they apply to highway projects see AASHTO (1977).

measure all the attributes (benefits and costs) of a trip is a tricky job for an analyst, for trip-makers it is done quickly, intuitively, and holistically. They do not decompose every trip possibility (a combination of destination, mode, time of day, and route) into its attributes (travel time, amenity, operating cost, risk) and then compare their willingness to pay to the cost for each possibility. They do it all in their heads, based primarily on knowledge they are not consciously aware of having acquired as a result of making several trips a day for a lifetime.

These trip-makers do not have to construct their demand curves, though their decisions implicitly define it. All they have to decide is that one trip is better than the alternatives, however they decide it. Transportation analysts can observe trips and assume that people wouldn't make them if they felt they cost more than they were worth. They cannot observe, however, what is central to making the right investment decision for the collectivity of all those trip-makers: how much *consumer surplus* does each enjoy now and how would it change as a result of a new investment. It is consumer surplus that defines the value—the benefits—of the investment.[16]

Measuring the benefits of a transportation improvement means measuring changes in consumer surplus, which requires an understanding of the nature of demand relationships. In short, it requires an understanding of economics. This conclusion may seem overstated to some transportation planners. But the economic realities and legal mandates of the 1990s make the conclusion inescapable. If MPOs, as the mandates for major transportation investments require, are going to evaluate and compare alternative projects and programs based on cost-effectiveness, than they must (by definition) be comparing the effectiveness of the investment to the costs. But for major investments the effectiveness cannot be adequately evaluated without forecasting how travel patterns will change as a result of the improvement. In major metropolitan areas, those changes are the result of millions of individual decisions daily. The only way MPOs can forecast those changes is to model travel behavior: how people with different characteristics will respond to changes in the characteristics of their travel options, which depends on how they value the attributes of the options. Without some specification of the shape of the demand curve, the models cannot solve for a new travel equilibrium. They cannot, among other things, deal well with latent demand, the growth in trips that results from the decrease in travel cost that the new investments provide.

The measurement process is made somewhat easier, however, because it is only *changes* in excess willingness to pay that need be inventoried to measure the change in consumer surplus. Therefore, if the effect of a policy or project change is to decrease the price paid by some group of consumers, it is not difficult to calculate the change in consumer surplus for *those*

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[16]Consumer surplus is the difference between the amount a traveler actually pays for a trip in time, money and accident costs and the largest amount they are willing to pay to make the same trip. Any introductory economics text will provide a discussion of the topic of consumer surplus, as will introductory texts on benefit-cost analysis listed in footnote 3.

consumers that were consuming originally at the higher price, because their increase in consumer surplus is exactly equal to the reduction in price times the amount they were consuming previously. For *those consumers who are induced to consume by the now-lower price*, the calculation is a bit trickier. For individual consumers, however, the smallest increase in consumer surplus will be is zero, and the most is the total reduction in price. As a practical matter, aggregate changes in consumer surplus resulting from induced consumption can be approximated reasonably accurately by taking one-half of the change in price times the amount of induced consumption.[17] Without an accounting of consumer surplus, at least in concept, evaluations of transportation improvements ignore the additional benefits that accrue to new drivers that the improvement allows to enter what was previously a congested roadway.

Travel models must therefore account for the demand-supply-price relationships that determine trip choice. The complexities of these relationships (which are sensitive to origin-destination pair, mode type, variations in trip attributes within mode, time of day, trip-maker values, and so on) require modeling to do any rigorous evaluation of net benefits. For example, as we pointed out in Chapter 2, the simple version of LCP as applied by electric utilities did not address the issue of latent demand (induced consumption) that results in more consumption as the relative price of end-uses decreases. Simple addition or graphic analysis cannot estimate this change in consumption: it must be estimated in a computer model that captures the major interactions among the routes, modes, travel times, and so on, and tallies aggregate changes in benefits and costs.

This conclusion may be a disappointing one for transportation planners and decision-makers. It implies that technocrats in general, and transportation modelers and economists in particular, hold sway in decisions about transportation investments, and that the public and their representatives must rely on black boxes and mathemagic for decisions. We address this issue in the next chapter of the report. For now, we will state again that the technical analysis can aid decision-making, but cannot make decisions. Ultimately, the public and their representatives will decide. It is our hope and belief that a correct analysis, despite the challenge of making it understandable to a lay audience, is more valuable than a flawed one that is simply explained. We offer ideas later on how to use the results of the modeling in a political decision-making process, and how MPOs might be able to shortcut some of the detailed modeling without violating the basic principles of the benefit-cost framework.

We now turn to the major components of transportation user costs whose reduction accounts for most user benefits: travel time, vehicle operating costs, and accident costs. Other attributes of trips also influence the choices that travelers make. These include comfort, reliability, schedule

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[17]This application of the "Rule of One-Half" assumes that the demand curve is linear. This is a reasonable assumption for small changes in demand. For large changes in trip making, the shape of the demand curve used in the travel demand model may be more appropriate.

convenience, flexibility in routing, and the ability to link trips for different purposes. While we do not discuss these attributes explicitly in the following sections, they are reflected in the mode choice components of travel demand models. If properly estimated, the demand curves for different trip types reflect their particular mix of attributes. By focusing on changes in the major cost components and having accurate demand models to predict changes in quantities of different trip types, analysts can calculate the benefits to users of proposed investments and policies.

3.2.1.1 TRAVEL TIME

Since one of the primary benefits of many roadway improvement projects is the reduction of congestion burdens, the value of time saved by various classes of travelers is a central element in the analysis. Although some decision-makers and courts have difficulty with the idea that unpaid time has monetary value, the theory and empirical evidence is sufficiently well developed that one cannot ignore the value of travel time savings or losses if one hopes to do a rigorous evaluation of alternative transportation investments.[18]

The idea that travelers benefit from reduced travel times is straightforward, but measuring that benefit with accuracy is not. There are two practical issues to deal with: (1) travelers with different characteristics (e.g., income, type and purpose of trip, length of trip, mode of travel) value time differently; and (2) a project that reduces travel times on one segment of roadway induces new trips and diverts trips from other routes.

Considerable research has been conducted over the past two decades concerning the value travelers place on time spent traveling. Researchers continue to debate, however, the precise measures that should be assigned to various types of time savings or costs, across individuals who differ in their personal characteristics and trip purpose. The conclusions of Small (1992) in his book on urban transportation economics summarize the current state of the art from revealed preference studies:

- The average value of in-vehicle time for the journey to work is 50 percent of the gross wage rate, with a range of 20 to 100 percent across the various studies
- The average value of waiting and walking time is two to three times that of in-vehicle time
- There is ambiguity in the data as to whether business-related trips and recreational trips display the same or different implicit time valuations

[18]See, for example, Train and McFadden (1978, 349-53) for an exposition of the issue in the context of transportation demand.

- The marginal value of time (i.e., the value of time per hour) of various types of trips tends to rise with the length of the trip. Thus, longer walks may have implicit per hour values that are greater than short walks, and longer commutes may be more burdensome per hour than short commutes.

If enough is known about the characteristics of the people traveling, and about how they react over time to changes in travel times, it is possible to compute reasonable estimates of the value of time saving. Information about the characteristics of travelers is typically available to MPOs through metropolitan household travel surveys and surveys conducted by the U.S. Census Bureau. The trickier part is obtaining reliable estimates of the changes in travel patterns induced by the roadway improvement.

Most MPOs operate some form of computer model that simulates traffic flows throughout the transportation network throughout the day. These models are useful for simulating the changes in travel patterns that would result from an increase in travel speeds on one segment of the transportation system. In particular, the models show, with reasonable accuracy, how proposed roadway improvements would attract travel from other routes during peak periods, given that the overall volume of travel on the system remains largely unchanged. Given knowledge of the characteristics of travelers, how they value time, and how travel times change throughout the system, an analyst can estimate the value of the time savings.

Critics of transportation modeling assert that a major problem with most of the models currently in use is that they cannot accurately predict the additional trips induced by the improvement, especially over the long term as land use changes and other reactions to the improvement occur. It follows, they argue, that models cannot estimate benefits with any degree of accuracy into the future. It is certainly true that the current generation of models operated by most state and MPOs have difficulty capturing all of the likely land use and transportation interactions over a 20-year planning horizon. This difficulty is especially evident in the evaluation of certain demand management policies such as congestion pricing. If properly applied, however, the current models are able to account for how additions to road and transit capacity will influence travel time over the near and long-term[19]. The uncertainty associated with these estimates should be factored into the analysis but it is not a reason to abandon the models altogether. Chapter 5 recommend areas in travel demand modeling that need to be improved to take full advantage of the least-cost planning approach.

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[19]This statement is true for most states and MPOs, which have good transportation models. For those with limited modeling capacity, any calculations of user benefits (the area under the demand curve and above price) will be very rough. For example, one might approximate latent demand (induced trips) on highways by examining historical traffic count data to estimate the rate at which traffic volumes grow on an improved segment of highway. Based on those data, one could graph a relationship between the percent of new capacity that gets used up and time. Casual observation suggests that generated traffic rises steeply immediately after the new capacity is added, and then flattens. The rate would depend on all the factors that create demand for highways (e.g., density of development).

A less frequently treated issue is the time-value of commodities and drivers in freight transit. Clearly, delays in the shipping of commodities, and delays imposed upon freight rigs and drivers, have significant economic value. Delay of goods in transit imposes an inventory cost that is roughly equal to the hourly interest rate times the value of the shipment (at a nominal interest rate of 10 percent, that is roughly 0.0011 percent per dollar per hour, or about $1.60 per hour for a $140,000 truck shipment[20]). Commodities with different values, or perishable characteristics, of course, will have different inventory time costs. In addition, it is appropriate to incorporate the value of the driver's gross, benefit-loaded wages at full value.[21]

3.2.1.2 VEHICLE OPERATING COST

A variety of roadway improvement projects and policies cause changes in vehicle operating costs (for cars, trucks, and transit) that should be included in the benefit-cost analysis. These costs include fuel consumption, tire wear, maintenance and repair, and depreciation.[22] For example, fuel cost increases as vehicle speed increases, as the grade of the roadway increases, and as the amount of stopping and waiting at traffic-control devices increases.

Many studies have estimated these costs. AASHTO (1977) presents a thorough analysis, but the numbers are now 20 years old. More recent estimates are found in Jack Faucett Associates (1991), the American Automobile Manufacturer's Association (1993), Apogee (1994), and Litman (1994). The fixed costs for a typical car, annualized and averaged over average annual vehicle miles, work out to around 20 cents per mile. The variable operating costs paid by the vehicle owner, using a similar method, work out to 10-20 cents per mile. These numbers vary substantially depending on type of vehicle, area of travel (urban/rural), and time of travel (congested/uncongested), but they give a rough idea of costs. For trucks and buses, the per-mile costs are greater. To make the costs of transit vehicles comparable to those of an automobile, the costs of purchase and operation are often expressed as dollars per *passenger-mile* instead of dollars per *vehicle-mile.*

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[20]This is an estimate reported by the Bay Area Economic Forum (1990b). In any given setting, specific estimates may vary. Some recent research by the Puget Sound Regional Council on freight mobility suggests that reliability is highly valued by freight shippers.. They may prefer reductions in the standard deviation of travel time over a particular link rather than a reduction in the mean travel time, especially given the recent shift toward "just-in-time" manufacturing. The benefits that shippers derive from different trip characteristics is one area deserving further research.

[21]Unlike for private commuting, drivers of freight vehicles are being compensated at a rate that is already reduced by any non-pecuniary benefits of their travel.

[22] Operating costs not affected by the design of the roadway should not be included in the analysis.

3.2.1.3 SAFETY

The third of the primary benefits of many roadway improvement projects is a reduction in the accident rate. A proper benefit-cost analysis requires that a value be put on the reduction in the number of accidents by alternative. That valuation requires two estimates: (1) the change in the number of accidents by type (fatality, injury, property); and (2) the cost to society of each type of accident. Moreover, as with travel time and operating costs, the estimates must account for any induced or discouraged trips by mode.

Assigning costs to fatalities and injuries is politically difficult because it requires the transportation agency to specify the dollar value to society of saving a life or preventing an injury. Many people oppose specifying such values, some arguing that not only is there no way to estimate them, but also that the value of human life infinite. While the value of the life of any individual may be infinitely precious to him or her, society does implicitly place rough values on random injury and death to a statistical abstraction of an individual. Many activities entail some risk of injury or death. Because eliminating these risks completely is usually extremely expensive, businesses and individuals take cost-effective measures to reduce these risks, but stop short of eliminating them. The transportation agency should do the same, and the only way to do so is to explicitly consider the value of lower accident rates.

The first step in the analysis entails estimating the change in accidents by type for each link in the network. Accident rates depend on the characteristics of the roadway and the volume of traffic. The problem of estimating future traffic volumes was discussed previously in the context of valuing changes in travel times. Given these estimates, accident rates can be estimated using national data,[23] possibly revised for local conditions (e.g., weather) as indicated by local accident data. Forkenbrock, Foster and Pogue (1994) reviewed the current practices of states and recommended the adoption of better predictive models using regression analysis to assess the accident rates of different types of facilities. Recent work on the topic is being conducted by Ted Miller. For example Miller et al. (1991) estimate the comprehensive costs of accidents to be in the neighborhood $1,500 per year (1995 dollars) per car or passenger van, the equivalent of an average of about 15¢ per mile. Their estimates of relative accident costs are instructive. Compared to the car, the annual accident cost per vehicle is, on average, about four times greater for motorcycles, and ten times greater for a combination truck.

The second step of the analysis places dollar values on the changes in accident rates for each alternative. The estimates of the cost of each type of accident varies depending on the methods of the researchers. Forkenbrock, et al. reviewed the costs that different states apply to accidents and

[23] Accident rates can be obtained, for example, from The Highway Performance Monitoring System Analytical Process, Vol. 2, Version 2.0, U.S. D.O.T., January 1986, Appendix J.

recommended that many consider raising their values to reflect current research.[24] Analysts must also be careful not to double count accident costs with the operating cost of insurance.

3.2.2 COSTS TO SOCIETY

Under this heading we include what most people think of first when one talks about the costs of a transportation project: what does it cost to build it and operate it? But other direct costs must also be considered. For example, increased highway capacity creates the need for additional resources to be allocated to police, safety, and traffic courts. Moreover, for programmatic transportation options the construction and operation and maintenance cost may be trivial: the big cost to society is in program administration and, more important for many programs, compliance (where the private sector must incur costs to comply with regulations—for example, trip reduction ordinances that require companies to fund transportation coordinators).

3.2.2.1 CAPITAL AND OPERATION COSTS FOR PROPOSED IMPROVEMENT

3.2.2.1.1 The improvement itself

Accounting for these direct costs is an intuitively obvious and methodologically straightforward part of the analysis. Engineers, planners, and policy-makers have plenty of experience with identifying, estimating, and interpreting these costs. To the extent that market prices for the labor and materials that go into transportation improvements can be taken as the true value of the resource (a reasonable assumption in our opinion), the calculation of costs is straightforward. Rather than dwell on obvious points, we will simple provide a check list of how the analysis typically proceeds:

- Engineers usually do most of the cost estimates based on the project specification
- Costs of right-of-way acquisition are usually included, but the opportunity cost of public land is usually not. It should be. A debatable case is a widening or land addition where the right-of-way has already been acquired and would remain vacant but for the improvement. In that case, the land should probably be valued as lost open-space.
- Costs are best specified in real (constant) dollars: e.g., 1994 dollars. See the discussion of discounting earlier in this chapter.
- Estimates of costs are uncertain. Engineers often use contingencies of 40% or more and still underestimate project costs. Sensitivity analysis must acknowledge and account for this tendency.

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[24]The value of fatalities used by different states ranged from $500,000 to $2.7 million.

- Decommissioning costs are never considered—they probably should be. Electric utilities understand this point, but they still cannot deal with it. A cost of nuclear power is storing spent fuel and control rods. After 20 years and billions of dollars of just study costs, the U.S. still seems a long way from a solution. An analogy in transportation is the cost of demolishing structurally or economically obsolete freeways like the Embarcadero in San Francisco. Given the likely life of most transportation improvements, however, and the effects of discounting, these costs can probably be ignored or only roughly estimated.

3.2.2.1.2 Related improvements and services

The mechanism of public finance for some of the public services enjoyed by users of transportation services obscures the relationship between changes in transportation activity and the cost of these services. Services such as police, fire, and ambulance are important to transportation activity, but the associated costs are not always financed through direct charges on the users of transportation services. Consequently, changes in the amount of travel, or the service characteristics of the modes (such as the speed of automobile traffic), can result in changes in the burden of public services.

Like social costs associated with emissions, these changes in public service burdens must be tallied and incorporated in benefit-cost analyses. The method of measuring these impacts depends importantly on the particular fiscal mechanisms that are in place in a community, and thus vary considerably from place to place. For example, in some jurisdictions, ambulance costs are billed fully to the affected parties in an accident. In such cases, it is relatively easy to obtain historical tallies of these costs, and to associate them with traffic volume or other measures. In other cases (and this is typically the case for highway patrols and other police services) the source of finance is general revenue sources and it can be difficult to separate the transportation-related expenses from other factors affecting the cost of these services. Conceptually, however, measurement of such impacts is straightforward: identify the incremental public service costs associated with the project and include them in the project evaluation.

3.2.2.2 PROGRAM ADMINISTRATION AND COMPLIANCE[25]

Compared to the costs of building large highway and transit projects, the costs of many transportation programs and policies seem small. Anyone who has worked on developing, adopting, and implementing state and regional transportation policies, however, knows that such processes consume a lot time. Certainly there is the direct cost of public sector staff time. There is

[25]For an example of how this category of costs can be estimated in a benefit-cost framework see Comsis, et al. (1993).

also, however, the value of donated time from stakeholders from business, interest groups, and neighborhoods.

Commuter trip reduction ordinances provide a good example of the kinds of costs that must be considered to get a full accounting. Developing, debating, and adopting such an ordinance at a regional level could easily take a year or two. Considering all the interest groups, staff, and consultants involved, that process would require many thousand hours of time, even a few tens of thousands of hours in large jurisdictions.

Once adopted, however, the costs of gaining the benefits the ordinance purportedly produces are significant. Obviously there are the public sector costs: program administration, public information, monitoring and reporting, and enforcement. More important in this example, however, may be the private sector costs. A typical ordinance might require all employers with more than 100 employees to have an employee take on the functions of transportation coordinator; to provide guaranteed rides home; to cash-out parking. Some of these actions may have countervailing benefits (e.g., reduced parking requirements) that must also be accounted for.[26]

3.2.3 EXTERNAL BENEFITS AND COSTS TO SOCIETY[27]

To the extent that producers of a service do not pay for everything they use (clean air, for example), accounting for the private producer costs alone can underestimate the costs of producing the good or service.[28] These costs are external to market transactions; hence, they are referred to as *externalities*. To make a judgment about the net benefits of a transportation investment, they must be accounted for as if they were part of private accounting system. Thus, changes in external costs (which may be positive or negative) that result from the policy also must be estimated. The calculation is the same as with private producer resource use; that is, the externality burden that must be assigned to the policy should equal the change in total external costs that results from the policy change.

External costs have typically not been accounted for in the evaluation of transportation alternatives. The AASHTO manual on user benefits (1977) acknowledges that non-user social, economic, and environmental effects are frequently of crucial importance, though outside the scope of the manual.

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[26]The anecdotal evidence from Measure XV in the Los Angeles region is that most employers found the costs much greater than the benefits.

[27]For a good description and estimate of these costs see Apogee (1994), Battelle (1994), and Litman (1994b). Parts of this section are taken from previous work by ECONorthwest (1994). Appendix C of this report provides more detail on the theory.

[28]Symmetrically, there may be benefits that producers generate that they cannot charge for because they cannot exclude consumers from them. The magnitude of uncharged benefits is probably much less than the magnitude of unpaid costs.

The absence of markets for external effects means analysts must turn instead to non-market analytical techniques that may not be as precise or accurate as the market techniques. There is a substantial professional literature in natural resource and environmental economics regarding the techniques for valuing these external effects and the limitations of those techniques.

In the sections that follow we limit ourselves to summarizing briefly information about the major categories of externalities associated with transportation improvements. Readers are warned that the numbers presented here are illustrative not definitive. They cannot be interpreted outside of the context of the study that generated them. Appendix E of this report, Concepts for Valuing External Effects, discusses in more detail some of the reasons for this caution.

Battelle (1994) presents the most rigorous analysis we found of environmental costs associated with transportation. That report is an interim one for FHWA. When completed, the project will update and extend the analysis of external costs of highway operations reported in *The Final Report on the 1982 Federal Highway Cost Allocation Study.* It will contain not only disaggregated estimates (by vehicle type, weight, highway type, and state) of the external costs of congestion, accidents, noise, and air pollution, but also a computerized system for making local calculations of project cost.

3.2.3.1 PARKING AND ACCIDENTS

Under the heading of *Benefits to Users* previously in this chapter, we discussed the benefits of decreases in travel time, operating costs (including the costs of parking), and accidents. To a large extent, the benefits of new transportation investment redound to users. For example, because of the absence of congestion pricing, the marginal driver entering a congested freeway does not recognize the congestion costs he imposes, even though drivers as a group do not avoid those costs. Thus, we believe that changes in travel time from transportation improvements or policies can and should be treated as part of benefits to users. This logic applies not just to drivers, but to all trip-makers. If, for example, a new highway makes travel *worse* for pedestrians and cyclists (by cutting off routes, say), then the value of their lost travel time should be included as a user *dis*benefit.

For parking, it is easy to imagine a connection between highway improvements and the perceived need in a city to build more parking structures, which it chooses to subsidize with general fund (non-user) revenue. To the extent that such parking is necessary to the successful functioning of the transportation improvement (or even contributes marginally to its full functionality), its costs should be included in the investment analysis.[29]

As with most of the measurements of benefits and costs for transportation, parking gets messier as it gets more detailed. Though drivers may not pay directly for parking at work or retail stores, most of them do pay indirectly extent for off-street parking, to greater or lesser extent, through property taxes or other contributions to the municipal general fund. Employers and retailers almost certainly pass on to parkers some, if not most, of the costs of the free parking. As with congestion, the external cost of parking is sensitive to time and location: it is probably much greater in central cities of metropolitan areas than in suburbs.

For accidents most of the costs are already covered as part of user benefits (costs). Drivers who live through an accident pay a deductible and incur some costs for uncompensated lost time, inconvenience, and any uncompensated injuries. Drivers and passengers who die have medical and funeral costs, their dependents may lose income and services, and their friends suffer a loss.[30] The drivers' insurance companies pay part or all of the rest of vehicle damages, medical bills, lost income, and (perhaps) mental suffering. The question is whether there remain additional costs of accidents that society bears.

Many studies believe that there are and provide estimates. One must be careful in interpreting these estimates, however, since they are often organized to show the costs that drivers do not pay. While that point can have important implications for politics and policy, it is not essential to a transportation investment analysis. As we discussed in the section on Safety above, it is enough to estimate the total impacts on society of accidents. Disaggregating them to separate the costs that drivers pay (internal costs) from those they do not (external costs) is not necessary unless one believes that such analysis will have implications for the decision because of its equity effects.[31]

3.2.3.2 POLLUTION AND ENVIRONMENTAL QUALITY

The obvious environmental problems of transportation are those of operation: air pollution and noise. But transportation improvements can

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[29]Parking costs can be a significant component of total trip cost and, therefore, whatever assumptions are made about changes in parking supply and the relative costs between travelers and the public entities should be consistent between the travel demand forecast and the allocation of publicly subsidized parking costs to a new road project.

[30]A thorough accounting would require that some of these losses be offset, one hopes modestly, by benefits to their enemies.

[31]The perception and allocation of risk of injury or death for travelers on particular mode over a particular link may influence behavior in a way that either increases or decreases the likelihood of accidents. It is enough for analysts to know how travelers will behave under the current allocation of risk and calculate the total changes in accident costs. The allocation of the those costs among insurers, travelers, and the rest of society is principally a question of distribution.

cause the full range of environmental problems. During construction, major transportation investments can degrade habitat with the best of them: wetlands can be lost, species endangered, ground water polluted, historical buildings and cultural sites demolished or degraded, and so on.

It is optimistic but not unrealistic to assume that for a majority of projects the federal process of environmental assessment and impact statements will prevent the worst of the damage from occurring. For most projects, however, some degradation of these resources will almost certainly occur.[32]

Obviously a benefit-cost framework of the type we have described requires an assessment and, to the extent possible, quantification and monetization of all the environmental impacts that are attributable to the transportation improvement or policy. But rather than describing techniques for valuing a full range of impacts, any of which might occur during the construction of any particular improvement, we focus on the more common environmental externalities that are an inevitable part of the operation of most surface transportation facilities.[33]

Our general recommendations is that analysts not try to include estimates of these environmental costs in a benefit-cost framework. In most cases, analysts in states and MPOs should limit themselves to estimating the physical changes in air quality using the existing air quality modeling techniques. Policy-makers can consider these estimates with the data on monetized benefits and costs. Alternatively, analysts can test a range of external costs per VMT and see if changes within that range flip the ranking of different projects.

3.2.3.2.1 Emissions

Transportation technologies, especially those based on internal combustion engines or remotely-generated electric power, generate emissions that decrease air quality with consequent impacts on human health, plant material, industrial processes, building maintenance, and other activities. Since most of these impacts are negative (i.e., they impose unavoidable costs on others or they require costly remediation efforts), strictly private accounting of resource costs underestimates total system costs.

Epidemiological studies have estimated the impacts on health from auto emissions but there remain considerable gaps between documenting health effects and measuring economic costs. There is uncertainty attendant with most estimates of the economic costs of emissions and those estimates vary

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[32]The analysis contained in environmental impact statements (EISs) rarely supplies the type of benefit-cost framework we are describing in this reports. EISs are often little more than descriptive lists of potential impacts whose primary function is to satisfy legal and political requirements, not analytic ones.

[33]Both this chapter and Appendix C give references to research that attempts to quantify and value these other impacts.

considerably depending on the particular location under evaluation (Small and Kazami 1995). That said, air pollution has been studied by scientists and economists extensively, and most estimates tend to be in the range of 1¢ to 5¢ per passenger mile. We report this range not to encourage use of numbers from it as a defaults in local analyses of air pollution impacts, but to suggest the magnitude of the cost.

In densely populated urban areas the Clean Air Act is the binding constraint on many proposed transportation plans. MPOs in these regions must develop plans that conform with federally established air quality standards. Practically, in is sufficient to determine whether a particular project or system plan conforms with Clean Air Act requirements without estimating the dollar benefits or costs of changes in air quality.

The air quality models also have a high degree of uncertainty that analysts should reflect in their presentation of results. Spurious precision may make one alternative appear superior in terms of air quality when in fact, its performance is indistinguishable from another.

3.2.3.2.2 Noise

Transportation activity produces noise, a negative externality that imposes direct costs or remediation costs on individuals external to the transportation marketplace. The valuation of noise impacts is not as difficult as the valuation of air quality impacts because the phenomenon is relatively localized, and can be studied more easily using hedonic price analysis of affected real estate.[34]

3.2.3.2.3 Energy consumption

If the price of energy used to build and operate transportation vehicles and services is, itself, fully representative of the total cost of producing energy, then there are no externalities associated with energy consumption and, hence, the private accounting of energy costs is all that need be tallied in the benefit-cost analysis. (See the analysis below concerning double-counting of costs.) If, in contrast, energy production or consumption imposes other costs (the burdens associated with the so-called "greenhouse" effect are one such externality concept), then the private costs represent an incomplete accounting of the full costs of the activity. Attempts to quantify greenhouse effects and economic impacts associated with fossil fuel, hydroelectric, and nuclear power production are, at best, in their infancy.[35]

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[34] Hedonic price analysis uses actual transactions data on, for example, home sales, to measure the impact of various levels of noise exposure on the value of the affected real estate. Hedonic price studies rely, however, on the assumption that individuals buying or selling real estate themselves value fully the effects of exposure to noise. If individuals poorly estimate these effects (long-term health effects, for example), then epidemiological studies also are required. An example of an economic study of noise impacts is O'Byrne, Nelson, and Seneca (1985).

[35] A survey of these empirical studies is in Hoeller, Dean, and Nicolaisen (1991).

3.2.3.3 REGIONAL ECONOMIC IMPACTS

The reason to suspect that transportation investments could have impacts on the economy is straightforward. If the investments lead to user benefits, then businesses will have lower transportation costs, which will (1)encourage them to invest their savings and expand, and (2) encourage new businesses to move in from other places. Though, at the margin, these effects are theoretically possible, they probably do not contribute significantly to net benefits from a social perspective for several reasons.

First, the contribution of surface transportation costs to the total production function of most firms is relatively small. Marginal changes in transportation cost are not likely to make or break many firms, or to cause them to expand or shelve expansion plans. Second, literature on how firms make new location choices is clear that the considerations are multiple. Again, the impacts of marginal improvements to surface transportation would be small. Third, from a national social perspective, almost any new businesses moving into the region could legitimately be considered a transfer rather than a benefit. If they had not moved to one region, a different region would have benefited from their expansion.

There may be a case to be made for adding regional economic benefits to the benefits of a transportation investment when that improvement alters significantly the production possibilities of the region's economy. That is, there may be a macroeconomic impact of the investment that transcends the aggregation of the individual user benefits. There are virtually no good models for analyzing this impact; the input-output models that are frequently used to measure project impact, for example, are unable to capture changes in production possibilities. Given the extensive transportation system that already exists in every MPO, this type of effect is probably fairly small for all but a break-through type investment (e.g., the Panama Canal).

A related issue is the common practice of counting the expenditures on construction as a benefit of income to workers, and to count job creation as a benefit. As we noted above, this practice is clearly inappropriate. From the perspective of social welfare, the creation of jobs has a value only when unemployment is chronically excessive. In general, we recommend that regional economic impacts *not* be included in the benefit-cost framework.

We examine the possibility that major transportation investments can have impacts on the regional economy through impacts on the pattern of land use in the next section.

3.2.3.4 LAND USE

One needs to be careful about what effects get counted under the heading of land use. There are at least three different types of effects that may find their way into benefit-cost analysis:

- The costs of land used for a new transportation project
- Increases in land prices in areas that benefit from transportation investment
- Long-term changes in the location of households and firms within a region.

Land costs associated with acquiring right-of-way and buying out adjacent property owners in lieu of impact mitigation should be included under direct costs to society. Lee (1994) points out that the opportunity cost of land is usually ignored when transportation agencies already own the right-of-way: it should not be. If counted, it is covered under the heading of Cost to Society, Construction Costs, which we covered above, and is not an external cost.

Thus, to the extent that the land is paid for, we see no external cost. Land markets work well to determine land value. If the transportation improvement pays for the land at market value, it has paid the present value that the marketplace puts on the future stream of revenues expected from the land.

A complication arises, however, because the transactions prices used in condemnation proceedings (at which the price government pays for right of way is determined) are usually for privately-owned land which faces a (perpetual) tax obligation (and benefits from, arguably, the public spending in return). On balance, the market values of such private land may be greater or less than the market value of land without these encumbrances or benefits. Hence, to be perfectly accurate, the market value of the land condemned for public right of way and taken off the tax roles may be higher or lower than the observed market prices on privately traded properties. (This is a minor correction that can probably be safely ignored.)

It is clear, however, that the lost government revenues themselves are not a net cost to a project. Though tax revenues may drop in the short run, in the long run state and municipal governments have a variety of means to raise revenues (including increasing the tax rate). Lost tax revenues should probably not be counted as a cost of the transportation improvement.

Changes in land value are sometimes counted as non-user project benefits. Because of the intimate relationship between transportation costs and land values, disturbances in the pricing and service quality of the transportation system feed back on land value and land use in the affected region. For at least 30 years economists have argued that such changes are primarily a capitalization into land value of the transportation improvements. As such, they are a double-count on the user benefits of decreased travel time. To the extent that these effects are simply capitalization of the transportation benefits or disbenefits of a policy, they need not be accounted for except for considerations of equity and to derive mechanisms of compensation.

More recently, planners have begun to worry about the impact of transportation investments on *land-use patterns*. It is possible that there are externalities associated with abrupt, significant changes in the viability of particular locations that must be accounted for. In particular, many believe that the underpricing of highway travel is a subsidy that encourages decentralization (urban sprawl), and that such a pattern of development has external costs. They argue, for example, that decentralization causes the costs of other services (like sewer, water, and fire service) to be higher, that such costs are not recovered from users, and that land valuable for farming and open-space gets used up faster than it should.

To the extent that one can identify true external costs that in the absence of the transportation investment would not have existed, they are appropriately attributed to the investment. But one must be careful not to attribute costs to the transportation investment or policy that are not costs or not fully their responsibility. Clearly other land use policies, federal tax policy, and utility pricing also play significant roles in promoting sprawling development patterns.

Furthermore, sprawl may provide benefits that far exceed the extra administrative costs. As in other areas of benefit-cost analysis, it is only net changes in social benefits and costs that matter to such an accounting. Hence, a policy that, say, encourages sprawl is only imposing external *costs* to the extent that the *net* of benefits and costs of such an impact are negative. It is theoretically possible that the encouragement of sprawl results in net external *benefits* on balance. Lee (1994, 26) makes exactly this point, noting that in a functioning land market consumers make tradeoffs between travel costs and the amenities provided by housing type and location, and that the costs of sprawl "are balanced by consumer benefits that are probably impossible to measure comprehensively (private space, housing, open space, crime, sense of community, aesthetics)."

In summary, we recommend that analysts fully account for costs of any land used for transportation project, avoid counting increases in land values as benefits since they are already part of the user benefit calculation when measured as savings in travel time, and proceed very cautiously when assigning costs to sprawl. The potential influence on urban form is one aspect of transportation investments that policy-makers may want to consider, but the state of the art is such that any estimates of the value of the future benefits of a "better" urban form will be highly speculative: they are probably better dealt with as unquantifiable effects and argued on the basis of theory.

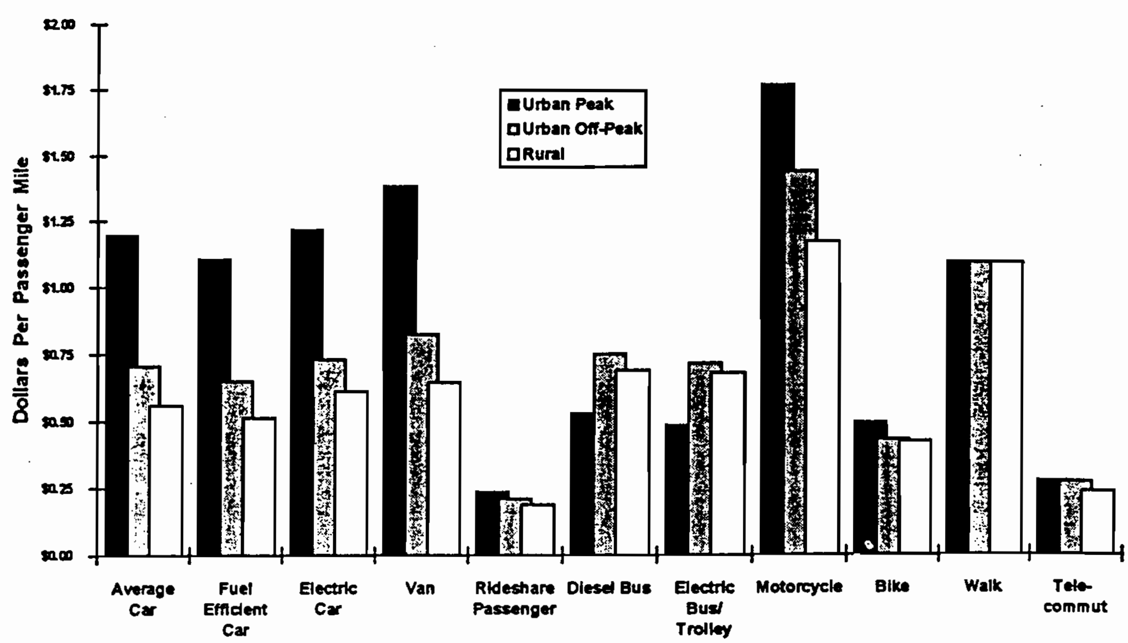
3.2.4 SUMMARY OF ESTIMATES OF BENEFITS AND COSTS

In this report we have focused on the logic of the analysis, not on providing costs estimates that states and MPOs can use in their analyses of major transportation investments. That said, we are well aware that if an analysis of transportation investments is to follow the principles of the benefit-cost framework we present in this report, it will eventually need to generate estimates of the benefits and costs. More important, if MPOs are to adapt the principles into a simpler method that fits with the limitations of time, budget, methods, and data, they need to have a sense about which impacts are likely to be quantitatively important, and which can be safely ignored. To that end, we present summaries of cost estimates.

The most recent studies that we reviewed on the costs of transportation investments are Litman (1994b), Apogee (1994), Battelle (1994), Lee (1994), and Delucchi (1995, forthcoming). Of these, Litman is the most comprehensive; Battelle provides the most detail on economic studies to estimate the value of environmental effects; and Delucchi is the most rigorous in applying microeconomic principles to minimize double counting. Figure 3-5, taken from Litman, provides an illustration of the magnitude of the costs estimated. His estimates of external costs are generally on the high side of the range, in part because he is more likely to classify impacts as externalities than other studies, and in part because he is more willing to report values where other researchers have argued for more research before doing so.

Litman divides all trips into three categories—urban peak, urban off-peak, and rural—and estimates costs per vehicle mile for each cost category. In the framework of this report, his first six categories (vehicle ownership to internal parking) plus his eighth category (congestion) are what we covered under the heading of *Benefits to User* (travel time, operating cost, and safety). His categories for road facilities and municipal service are what we covered under *Costs to Society*. All the rest of his categories fit under our heading of *External Benefits and Costs to Society.*

Figure 3-5: Costs for Average Automobile Under Three Travel Conditions



Source: Litman (1994b)

We present the numbers in Figure 3-5 only to provide a rough idea of the types and magnitudes of effects that researchers in this field are finding. *These numbers should not be used for local analysis of external transportation effects on the basis of this report alone.* They are only an illustration, not a recommendation for values that states or MPOs should use in estimating the full costs and benefits of specific transportation projects or policies.[36] We encourage transportation analysts in state agencies and MPOs to consult the full reports that we cite. We see the main benefit of this figure and others like it being a clarification of *relative* contributions to total cost. For example, the cost of travel time is one of the single biggest costs of transportation: depending on what gets counted, it might account for a quarter to a third of the total costs of surface transportation; it is two to four times greater than the costs of building and maintaining highways. Vehicle ownership and operating costs are similarly large.

The estimates in Figure 3-5 and our review of the quality of data available to analysts suggests a hierarchy in the effects that analysts should attempt to monetize. Returning to the descriptions of effects presented in Table 3-1, we recommend that analysts begin by accurately estimating the capital and operating costs of the improvement and related facilities to the public sector. Analysts should also try to estimate in dollar terms all of the benefits and costs that accrue to users of the transportation improvement including changes in travel time, operating costs and safety. Properly estimating these costs and benefits will substantially improve the quality of information available to policymakers about the cost-effectiveness of proposed facilities. The data and procedures for estimating costs and benefits of changes in air quality and other external effects are less well developed and are too speculative for some of the national experts who reviewed this document. Analysts should certainly describe all of the external effects to the extent they are known but proceed carefully with any efforts to monetize them. Given the recent interest in estimating the external costs that automobiles impose, it is reasonable to test a range of external costs per vehicle mile traveled to see if the relative rankings of projects under consideration change. If the rankings of projects or policies are sensitive to external cost estimates, analysts should avoid using high estimates of external costs to justify choosing one project over another without solid data that is specific to the improvement and local conditions. The general principle here is that analysts should know the reliability of the different elements of the benefit-cost calculation and avoid presenting uncertain information without sufficient disclosure about its reliability. This principle hold with travel demand forecasts as well as estimates of external effects.

This chapter outlined an approach for applying benefit-cost analysis to transportation choices. Least-cost planning uses the insights and information from benefit-cost analysis to develop plans, make decisions, and adjust plans as more is learned about the actual performance of a transportation system. In the next chapter we describe the broader least-cost planning process within which benefit-cost analysis takes place.

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[36]Several reviewers noted that many estimates for external costs are controversial and should be used with caution.

Chapter 4

The Least-Cost Planning Process

4.1 LEAST-COST PLANNING PRINCIPLES

The last chapter focused on the analytic methods central to least-cost planning in transportation; namely, benefit-cost analysis. The results of benefit-cost analysis must be used by policy-makers and the public as part of a planning process that builds political agreement on appropriate transportation policies. As we noted in the introduction, there are other key principles to least-cost planning that place benefit-cost analysis in a broader planning context. These other principles include:

- An emphasis on developing system-level plans (e.g. regional or MPO level plans) to explore policies that can only be fully evaluated at that level
- Consideration of all alternatives, including demand management approaches
- Explicit accounting for uncertainty in the estimation of benefits and costs
- Public involvement in the decision-making process
- Coordination among jurisdictions
- Monitoring and updating plans to reflect new information about demand for different for facilities and the cost-effectiveness of different approaches.

In this chapter we provide an overview of a planning process that is consistent with least-cost planning principles and federal mandates. Federal regulations require MPOs to consider fifteen elements in the development of their metropolitan transportation plans. These elements closely parallel the principles of least-cost planning. The following list highlights some of the federal requirements that say , in essence, "Do least-cost planning." The numbers correspond to their listing in the federal guidelines:[1].

(1) Meet "...transportation needs by using existing facilities more efficiently."

(3) Use "...travel demand and reduction and operation management strategies."

(4) Include "...projections of ...economic, demographic, environmental protection, growth management, and land use activities.."

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[1] Federal Register §450.316, Vol. 58, No 207)

(6) Consider "... the effectiveness, cost effectiveness, and financing of alternative investments in meeting transportation demand..."

(10) Preserve "...rights of way for construction of future transportation projects."

(11) Enhance "...the efficient movement of freight."

(12) Consider "...operating and maintenance costs ... in analyzing transportation alternatives."

(13) Consider the "...overall social, economic, energy, and environmental effects of transportation decisions."

These regulations also identify key components of the planning process which Metropolitan Planning Organizations must adopt. These process requirements include a twenty-year planning horizon, projections of future travel demand for people and goods, consideration of a full range of new supply and travel demand management options, and an active program of public involvement. By complying with federal requirements, many MPOs are already making substantial progress toward incorporating some least-cost principles into their planning processes.

This chapter provides a framework for thinking about a comprehensive least-cost planning process.[2] The framework is consistent with federal requirements for developing Metropolitan Transportation Plans and performing Major Investment Studies on significant subarea or corridor level investments. It shows how the analytic elements of transportation project and policy evaluation could fit into a broader planning process. It suggests approaches that states and MPOs could adapt to their particular agency and political environment.

Most economists would agree that public agencies should apply benefit-cost principles and analysis to major investment decisions; we suspect that most would also agree that the application should occur approximately in the way described in the preceding chapter. It is much more difficult, however, to get agreement on how that information can best be integrated into a political process in a way that offers the best prospect for efficient and fair decisions. We offer an overview of what federal regulations require and what, in our experience, works. The final design of the process, however, must reflect the particular policy and political environment in which least-cost planning will occur.

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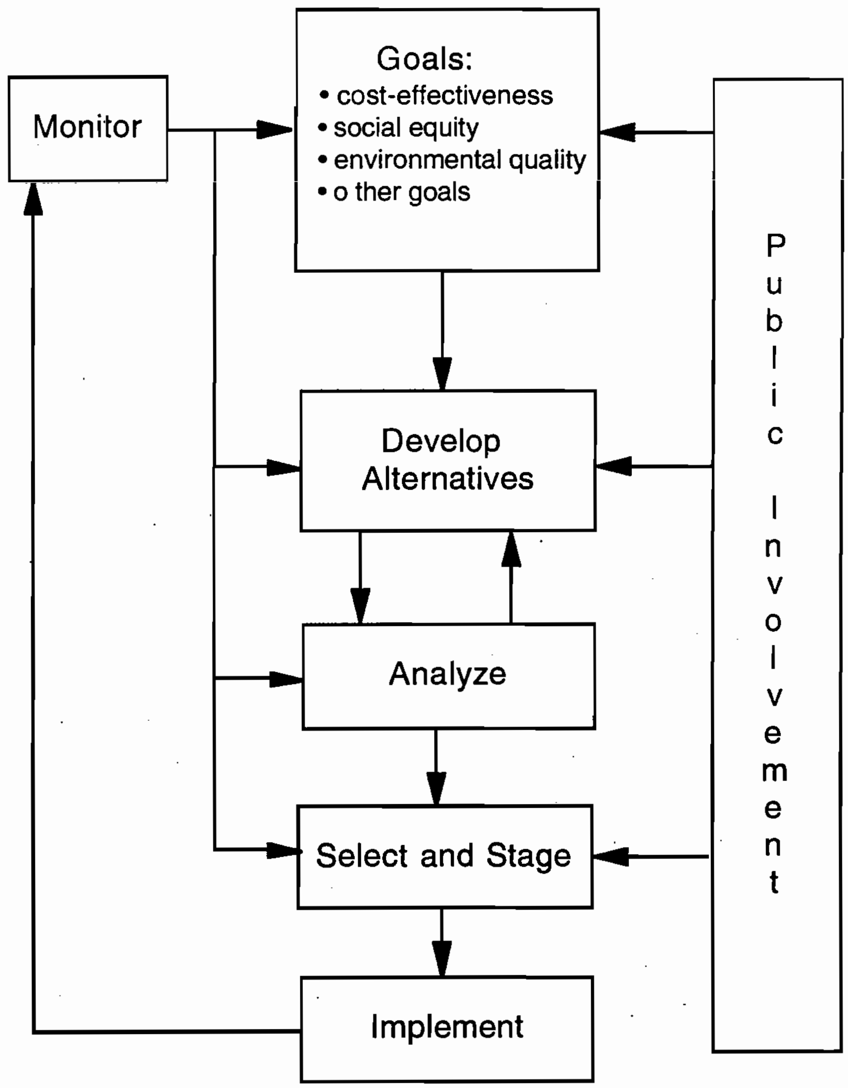
[2]It is our belief that there is little in the *process* of least-cost planning that differs significantly from what planners have been writing about planning processes for years. The names change (least-cost planning, strategic planning, comprehensive planning, integrated resource planning), but the basic ideas about what constitutes good analysis, substantive public involvement, and a politically productive process remain the same. The steps of that process have been recounted in numerous books, articles, and reports, including this one.

4.2 A PROPOSED PROCESS FOR LEAST-COST PLANNING

4.2.1 OVERVIEW OF THE PROCESS

Figure 4-1 presents an overview of the least-cost planning process.[3] It represents an adaptation of some of the strategic planning models to meet the special requirements of transportation planning. It also incorporates least-cost planning's emphasis on identifying cost-effective alternatives.

Figure 4-1: Overview of a least-cost planning process



[3]This figure and many of the ideas in this section were developed by ECO Northwest for the Puget Sound Regional Council and are described in "Technical Memorandum Regarding Procedural and Methodological Issues in the Implementation of Integrated Transportation Planning," June 1995.

In the rest of this section we describe in more detail each of the major steps.

4.2.2 SETTING GOALS

Goals are the driving force for the planning process. Least-cost planning provides a consistent framework for simultaneously considering a number of seemingly diverse goals: e.g., a cost-effective transportation system, social equity, and environmental quality. Least-cost planning, by definition, usually starts with cost-effectiveness at the top of the list of goals. It places special emphasis on directing public resources in ways that achieve the maximum social benefit for a given investment.

LCP also recognizes that goals such as social equity and environmental quality are often not amenable to quantification in the benefit-cost framework but are nonetheless legitimate criteria for evaluating alternatives. It balances the cost-effectiveness criterion with other policy goals and gives policy-makers a framework for weighing tradeoffs.

4.2.3 PUBLIC PARTICIPATION

Public participation is crucial to several key elements of the least-cost planning process. It is necessary for the articulation of goals, especially those that cannot be easily monetized or quantified. Public participation is required to develop a full range of alternatives that collectively address all goals. It is also a key factor in the selection of alternatives to be implemented, because this is the stage in the process where tradeoffs among goals must be made.

We recommend that the public be involved from the beginning of the least-cost planning process, especially the formulation of goals and the development of alternatives. Public involvement with the development of alternatives is important for several reasons:

- The public is likely to have diverse views on which alternatives are desirable. Including these views helps demonstrate that a full range of alternatives has been considered.
- As discussed later, an important test of alternatives will be to see how well they perform under different future scenarios. Development of scenarios will require public agreement on things such as land development and population densities in the region. Public involvement will ensure that at least some of the scenarios are politically acceptable.[4]

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[4]But if the range of scenarios is to be broad enough to bracket all possible future conditions, there may be some scenarios that the public does not consider desirable. Nevertheless, these should be included in the analysis to allow testing the alternatives for robustness, and to provide policymakers and the public on which alternatives perform best should the "undesirable" scenarios actually occur.

- When alternatives are being analyzed, the first phase of the analysis will consist of screening all alternatives. The methods of analysis used for screening will be more transparent than the detailed modeling process used in the second phase. Thus, it will be easier to explain the screening process to policy-makers and the public; in particular, why planners recommend that some alternatives not be considered any further.
- Planners may recommend screening out some alternatives that the public would like to see analyzed further. In that case, it may be necessary to include one or more of these in the detailed analysis if the planning process is to be perceived as legitimate by the public.

4.2.4 DEVELOPING ALTERNATIVES

For system-level planning such as that required for Metropolitan Transportation Plans, the alternatives consist of broad, region-wide policies; the policy that is selected will determine the context for carrying out more detailed planning analyses at the project level System-level alternatives are likely to include not only modal alternatives (e.g., highway emphasis vs. transit emphasis), but other types of policies such as system management alternatives (e.g., demand-side management, road pricing) and land use alternatives (e.g., land-use restrictions favoring higher density vs. no limits on land development). Most system-level alternatives will involve some changes to the supply of transportation, and therefore to the transportation network. But the level of network detail required for defining system-level alternatives will very likely be less than that required for corridor-specific or project-specific analysis.

For project level analysis of the type required for Major Investment Studies, the alternatives will consist of discrete projects that must be compared to each other (e.g., adding HOV lanes in a corridor, increased transit capacity and operating frequency, adding mixed-use lanes). The range of projects to be considered may be constrained to those that support the alternatives selected at the system level. For example, if the region were to select system policy that consisted of a combination of improving transit service and pricing with no further significant additions to highway capacity; then the project-level alternatives could be constrained to projects such as specific transit service additions or implementation of road pricing on specific routes. In other contexts, however, project level analysis should include alternatives that are not in the current system plan as a means for developing data about supply or demand management options that could be added to future revisions to the system plan.

Regardless of the planning level, the key aspect of developing alternatives for least-cost planning is that *a full range of alternatives must be considered*. Two elements are crucial to defining alternatives in order to carry out least-cost planning effectively at the project, corridor and system level:

- *Develop as many alternatives as possible to enable evaluation of all potential policy directions.* It frequently happens that planning resources are limited, forcing a tradeoff between the number of alternatives considered and the depth of analysis that can be applied. Impoverishing the alternatives places a limit at the outset on the information that least-cost planning can provide to decision-makers.
- *Design each alternative to be as cost-effective as possible.* In order to fairly compare alternatives, each should be designed for its optimal cost-effectiveness. This means, for example, that a highway alternative should be designed to maximize user benefits; or that a transit alternative should be designed to provide the most cost-effective service. Least-cost planning cannot provide good information to decision-makers if one approach is designed for optimal efficiency while other approaches performs badly because of flawed design. Honest comparisons require optimal designs for each alternatives and the use of realistic and consistent assumptions to evaluate them.

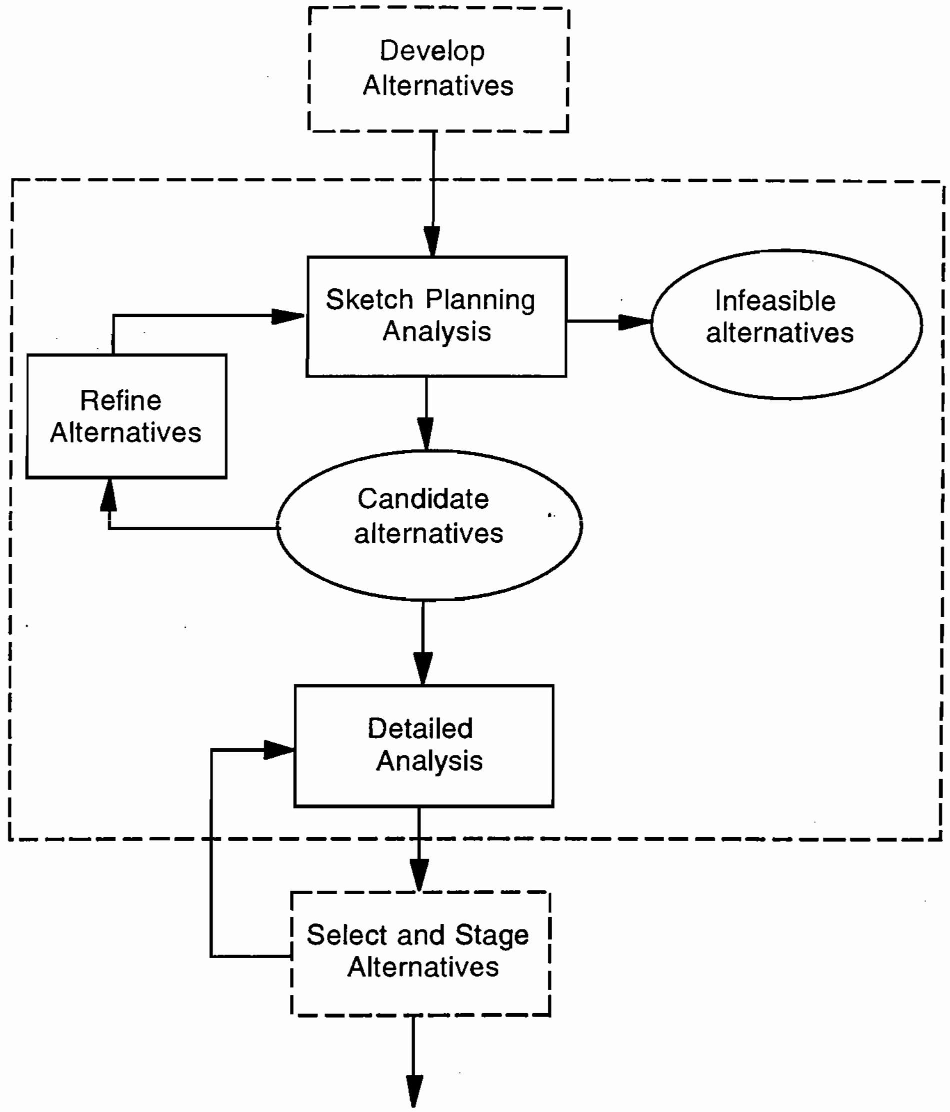
4.2.5 ANALYSIS

Figure 4-2 shows the relationships among the analytic elements of the least-cost planning process. These divide into two phases: (1) initial development and screening of alternatives, and (2) detailed analysis of candidate alternatives that remain after the first phase. Details of the process will vary according to the scope of the analysis (e.g., system level, subarea level, corridor level, project level), but the general procedures will apply regardless of the scope.

4.2.5.1 SKETCH PLANNING ANALYSIS

The initial number of alternatives is likely to be quite large, especially when carrying out a system-level analysis. It is unlikely that the resource capabilities of planning agencies are sufficient to model all the alternatives in detail. Sketch planning techniques should be used to screen out those alternatives that perform significantly less well than others being considered. Using sketch planning methods rather than full-scale application of traditional travel forecasting models makes it feasible to consider a sufficiently broad range of alternatives.

Figure 4-2: Analytic elements of least-cost planning process



"Sketch planning methods" has been used as a term by transportation planners to describe analytic methods that range from simple rules of thumb, to "back of the envelope" analyses, to simplified models that can be implemented on a spreadsheet, to special-purpose computer packages. For purposes of this discussion, the term "sketch planning methods" is used to refer to any analysis method up to (but not including) the full four-step transportation models used by most planning agencies. Sketch planning analysis may make use of any one of several different methods. Existing network data can be useful for providing level-of-service estimates for micro-simulation models such as STEP, which provides results at a relatively greater level of detail than most sketch planning models.[5] Some studies of broad, regional-level policies have used sketch planning models that represent the transportation network at a more abstract level than that used in the four-step process.[6] Economic studies are available that provide information on the cost-effectiveness of various modal alternatives.[7] Documented experience with changes to the transportation system can also provide useful information on the likely effects.[8]

Whatever method is used, the sketch planning analysis should be done in sufficient detail to accomplish the following:

- Estimate the major effects of the alternatives (e.g., construction and operating costs, user costs, air quality effects)
- Provide sufficient detail to distinguish among most of the alternatives. (Some alternatives may perform so poorly that not much analysis will be required to screen them out.)
- Test the sensitivity of the alternatives' relative performance to changes in underlying assumptions

The initial analysis may reveal that some alternatives would perform significantly better if they were redesigned. For example, a transit-based policy alternative that is being considered may overemphasize line-haul service at the expense of collector service. If this occurs, the appropriate alternatives should be refined to make them more cost-effective so that the sketch planning analysis can provide a fair assessment of which alternatives deserve more detailed analysis.

4.2.5.2 DETAILED ANALYSIS OF ALTERNATIVES

The result of the initial phase of the process will be a set of candidate alternatives that are selected for additional analysis. In general, these will consist of alternatives for which the sketch planning process estimated greatest net social benefit. There may, however, be one or more additional alternatives that are included as a result of public involvement.

Analysis of the candidate alternatives will be done at a greater level of detail than for the full set of alternatives considered in the first phase. Because those alternatives that survive this far are determined to be cost-effective, a greater depth of analysis will be needed to distinguish between them. Analysis of these alternatives will require full-scale application of the

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[5]The STEP model is described in Harvey (1979). An abridged description of the model is contained in Cameron (1994).

[6]An early example is the Boston transportation planning review, described in Gakenheimer (1976).

[7]See, for example, Fisher and Viton (1974).

[8]A good example of documentation of past experience is Pratt (1981).

regional land use, travel forecasting, and air quality models to capture network effects that are absent from most sketch planning techniques.

A key aspect of this phase is to account as well as possible for the uncertainties in the results. This requires estimation of uncertainties in the components of the benefits and costs, and numerical simulation to estimate overall uncertainties in the net social benefit for each alternative.[9]

4.2.6 REFINEMENT AND STAGING OF IMPLEMENTATION

The analysis in this phase may uncover specific flaws in some alternatives that cause them to perform less well than they otherwise might. In those cases, the designs of these alternatives should be modified before completing the analysis.

The final stage of the analysis should include specifications of the projects that go into each alternative, including the staging of the projects and their lead times. The least-cost planning process is dynamic, responding to changing future conditions. Periodic environmental scans may reveal that exogenous conditions are changing differently than forecast, changing the relative cost-effectiveness of some alternatives. Hence, it is important that decision-makers know the key decision points for each alternative in order to make policy and implementation decisions in a timely manner. The lead times for these projects are crucial to identifying when key decision points will occur.

Under federal requirements Metropolitan Transportation Plans get revised on a three-year cycle. This schedule permits regular review of forecast data, evaluation of cost effectiveness, and adjustment to long-range plans to account for new information.

4.2.7 MONITORING

There are two aspects of monitoring in the least-cost planning process:

- *Environmental scanning.* This consists of identifying key factors and trends that are important for the future, and determining how external forces will influence the environment within which alternatives will be implemented.
- *Project monitoring and evaluation.* Least-cost planning requires careful monitoring of the actual costs and performance of transportation projects and policies that are implemented. Feedback from how projects actually perform provides better information on cost-effectiveness and improves the models used to predict travel behavior. Least-cost planning should involve constant reevaluation of which measures work and corresponding adjustments to long-term

[9] For a more detailed discussion of the sources of uncertainty in travel demand models and methods to account for it, see ECONorthwest (1995).

strategies. Hence, implementation of a plan or project should include the establishment of an ongoing evaluation process to provide the necessary monitoring information.

4.3 INCORPORATING TECHNICAL ANALYSIS INTO THE POLITICS OF DECISION-MAKING

At the Select and Stage phase in the planning process show in Figure 4-1, policy-makers must make a decision. They must choose one transit system rather than another; they must decide whether to add another lane to a freeway or not. There are three general options for presenting information to policy-makers so they can make decisions.

The first option assumes that the dominant decision-making criteria is the one that underlies a benefit-cost framework. After describing the streams of benefits and costs that a policy or project engenders, the gross benefit and cost streams are discounted, and the present value of benefits and the present value of all resource costs including externalities are calculated. Since the goal of efficient project selection is to maximize social welfare, the investments chosen should be those that maximize the net of benefits, in present value terms. This is what we referred to previously as *the fundamental rule.*

The only qualification of the fundamental decision rule is that the evaluation of distributional impacts or risk may cause projects that are only marginally beneficial to be rejected. But in general, if the analysis shows net benefits and no significant inequities (one unworthy subgroup gets most of the benefits while a worthy subgroup pays most of the costs), the investment should be made.

The second option responds to a fundamental critique of the fundamental rule: that decision-makers are not comfortable with a single decision rule. After all the math and modeling is done, the critique goes, decision-makers simply will not believe that all the complexities of transportation, land use, regional economic policy, social welfare, and politics are captured in net present benefits. Thus, they will want to see other criteria.

This critique is persuasive because the situation it describes is pervasive. Any analyst with experience in helping elected bodies make complex decisions has certainly seen, and probably used, what is the most common means of evaluating public policy, a process which goes through the following steps:

- List criteria
- Weight criteria
- Measure criteria
- Rank alternatives based on the sum of the weighted measurements.

In this method, net benefits, if mentioned at all, is only one of several criteria. More likely, net benefits gets subsumed in a criterion like *efficiency* or *cost effectiveness.*

For example, in the fall of 1994 the Seattle Chamber of Commerce assembled over 200 political and business leaders for a three-day retreat to examine the region's transportation options. In preparation for that event, staff from various local and state agencies work to define alternative investment packages (each with a different emphasis: e.g., expanded bus, rail, congestion pricing) and criteria for evaluating them:

- Cost effectiveness
- Impact on mobility
- Breadth of impact
- Environmental impacts
- Land-use impacts
- Administrative/institutional capacity
- Political feasibility.

The criterion of cost-effectiveness comes closest to the idea of net benefits. *But note the double counting that occurs.* If changes in travel efficiency, mobility, and environmental quality have already been properly accounted for in the benefit-cost analysis (the cost-effectiveness criterion), the separate tallies of impacts are redundant. While these tallies may be interesting, they should not be used to second-guess the implications of the benefit-cost analysis. To do so would double count their impacts.

The multi-criterion method is a response to the critique that there is no way to assign a reasonable value, or range of values, to a particular resource, or that the range of estimates is so wide as to render the resulting benefit-cost estimates useless for investment evaluation. There is an extensive literature on how to conduct multi-criteria analysis which is beyond the range of our discussion here.[10]

A multi-criterion method also has the advantage of compatibility with the language of the federal mandates we cited in Chapter 2, which require an evaluation of a list of attributes that looks similar to the one used in Seattle: for example, cost-effectiveness, mobility improvements, operating efficiencies, environmental benefits, and transit-supportive land-use policies and future patterns.

If the multi-criterion method is used, analysts should make every effort to avoid double accounting. One approach is to disaggregate the components of the benefit-cost calculation so decision-makers can see that it encompasses improvements in travel time, safety, vehicle operating costs

[10] See, as an example of such analysis, Saaty (1980).

and so on. In addition to the quantifiable benefits and costs, the non-monetized elements of the analysis can then be listed out and described as accurately as possible. This approach avoids the potential danger of listing one benefit-cost number and a long list of non-quantifiable effects. It has a countervailing disadvantage, however: the longer the list of criteria, the less important the efficiency criterion will become. There is a natural tendency for decision-makers to weight criteria evenly. For example, if criteria are selected to assure that every environmental problem is covered (e.g., water quality, water quantity, particulates, VOC, fish habitat, etc.), it will probably be the case that the sum of the environmental quality parts will be greater than a single "environmental quality" criterion would have been. If the multi-criterion approach is used, analysts must make every effort to disaggregate the benefit-cost components and to make the remaining criteria mutually exclusive to avoid double counting.

Policy-makers should also be given some sense about the level of uncertainty associated with the predicted effects. The should know, for example, that the estimates of user benefits are fairly robust but that predictions about future land-use impacts are uncertain because of their dependence on other external policies (e.g., interest rate and tax policy).

The third option moves yet one step farther from quantification. It suggests simply displaying graphically a general sense of the performance of alternative transportation investments on different criteria. A typical summary of the evaluation might look like a page out of the *Consumer Report* evaluation of automobile performance, which shows a matrix with criteria as row headings, alternatives as column headings, and circles in the cells of the matrix thus created. The amount and tint of the shading of the circles gives a quick visual impression of performance.

A recent study by the Federal Transit Administration (1994) investigated these three methods and concluded that: (1) a benefit-cost framework is the correct one for doing major transportation investment analysis, and (2) such a framework has some practical problems (e.g., difficult to understand and explain, to express all benefits and cost in dollars). The study concluded that "...the theoretical elegance and integrity of social cost-benefit analysis will not guarantee uncritical acclaim for, nor even the validity of, its findings." (page 21). The study recommended modify FTA's "...Major Investment Policy to utilize a multiple measure method [the third option we described above], based on the tenets of social cost-benefit analysis." (page 25). It goes on to describe how the criteria in the mandates would be measured. Though written just for transit projects, they provide a good illustration of what such measurements would probably look like:

- *Cost-effectiveness:* incremental cost per new transit rider, incremental cost per new transit passenger mile.
- *Mobility*: value of travel time savings, and number of zero-car households within 1/2 mile of the new facility.

- *Operating efficiencies*: change in operating costs per vehicle service e hour (or mile), change in passengers per vehicle service hour (or mile), and change in passenger miles per vehicle service hour (or mile).
- *Environmental benefits*: dollar value of net pounds of particular pollutants, barrels of petroleum saved per year, change in the consumption of fuels of different types.
- *Transit supportive land use polices and future patterns*: several measurements of the degree to which local governments have taken the measures needed to assure that the transit project is surrounded by supportive land use patterns and densities.

The counter to the multiple-measures argument is made strongly by Doug Lee (1995) in his comments on a draft of this report. He notes that the scoring and weighting of multiple measures "avoids the discipline of exhaustive enumeration of benefits and elimination of all doublecounting, and makes the unit valuations inscrutable in dollar terms" and that it is "worse than unsatisfactory for selecting among public investment alternatives" except in situations where "the only basis for choice is expert judgment and the participants fully understand how scoring and weighting can be manipulated to mislead the unsophisticated." To summarize a much longer argument, Lee believes that a comparison of the efficiency of transportation improvements (i.e., the net present discounted value of all significant benefits and costs) taken from the perspective of society as a whole captures most of what is important to transportation, and does it without doublecounting (an analysis of the distribution of benefits and costs captures most of the rest).

Technically, we think Lee is right. The question is whether states and MPOs are ready, technically and politically, for a benefit-cost approach. Lee allows that many are not: "agencies with complex participatory political environments and weak technical staff will go for scoring and weighting, while the reverse will favor benefit-cost analysis. Many agencies will assert that they are doing benefit-cost analysis when in fact they are doing mostly scoring and weighting."

Our experience leads us to conclude that a large majority of states and MPOs will continue to make decisions about major transportation investments based on the scoring and weighting of multiple measures, or even less appropriate analytical techniques. We hope, however, that the case we have presented in this report for benefit-cost principles encourages transportation analysts in states and MPOs to push their organizations and decision-makers toward using them. Where scoring and weighting approaches are used alone or in combination with benefit-cost analysis, analysts should make every effort structure the evaluative criteria in way that is fair to all the alternatives and avoids double-counting.

Section 5

Steps Toward Implementing Least-Cost Planning

5.1 EMERGING SUPPORT FOR A BENEFIT-COST FRAMEWORK

An optimistic interpretation of our research that we considered is that federal regulations, state actions, and transportation experts are converging on an analytic framework for evaluating transportation investments similar to the one we describe in this report. Most of the citations in this report support that interpretation. As we described in Chapter 1, ISTEA and related federal regulations strongly suggest a requirement for the type of benefit-cost framework we have described. Moreover, as we showed in Chapter 3, that framework is not a new one. Many experts have done substantial research on the full costs of transportation, on the techniques for comparing alternatives, and on estimating values for benefits and costs in specific case studies.

There is also, however, a pessimistic interpretation. A temptation after reviewing what the top economists and policy analysts have said for the last 20 years about evaluating transportation projects is to conclude that there is great agreement on how to conduct such evaluations. That agreement, however, exists only among academics, consultants, federal policy analysts whose work focuses on the topic. It does not extend to the practices of states and MPOs who are actually making the decisions about major transportation investments. The fact that our research demonstrates that a benefit-cost framework for evaluating projects is not a new idea leads to the obvious question, So what keeps it from being used? The answers are both technical and political.

Comprehensive benefit-cost analysis that includes quantification of all environmental externalities is usually beyond the grasp of even well-funded academic research. Certainly most states and MPOs cannot do it. Though the full analysis is the right foundation for thinking about transportation investment, states and MPOs need something simpler. But making things much simpler leads potentially to the problem of making them simpleminded. No one has developed a simplified but rigorous technique for sketch planning that has gained general acceptance.[1]

[1]This fact does not necessarily result from the failure of such models (though some we have reviewed are flawed in relation to the concepts we have described in this report). A large part of the problem is that there has been, at least until recently, little demand for such models, and little effort by experts to develop, review, refine, and standardize them. Moreover, though no such simplified but rigorous techniques have been generally accepted, there are certainly examples to point to. Lee (1995), for example, presents an application of a benefit-cost evaluation to investment decisions in a prototypical highway corridor in 27 pages.

Moreover, states and MPOs have not really wanted such models for several reasons. Transportation modelers have focused on forecasting traffic. Comparisons across modes and programs have, when they occur, focused on changes in level of service without examining underlying costs and benefits. When federal funding was flush for freeways and later for some rail projects, there was little incentive to show that such projects were inefficient from a national perspective. Evaluations aimed at justifying projects, not rejecting them.

Finally, as we note elsewhere in this report, the complicated interactions among transportation, land use, other public facilities and policies, and urban growth in metropolitan areas makes even a sketch analysis of benefits and costs difficult for nontechnicians to comprehend or accept. A key concept for estimating benefits, consumer surplus, is not part of the vocabulary of most citizens and politicians; the interpretation of an investment analysis based on consumer surplus is not intuitively obvious to most people. Moreover, for politicians a technical analysis can get in the way of a more pragmatic means for deciding on projects: political negotiation that ends up giving something to every jurisdiction so that something (whatever its technical merits) can proceed.

The pessimistic view leads logically to a rejection of all the new mandates for evaluating transportation investments and most of the ideas contained in this report. If one believes that the only criterion for making state and metropolitan decisions about transportation projects and policy is political acceptability, and that a technical evaluation of the benefits and costs of the investment alternatives can have but little influence on the outcome of that political process, then the transportation planning departments in states and MPOs should be pruned and the growth of transportation systems left to run where it may.

It is not enough, in our opinion, to refer to the mandates we have cited and assume that the requirements of ISTEA and its implementing regulations for states and MPOs to conduct MISs according to the principles described in this report will force them to do such research. It is not clear how the U.S. Department of Transportation will monitor performance and enforce such requirements. It is not hard for us to imagine states and MPOs ignoring the mandates for budgetary, technical, or political reasons.

Despite all these problems, we lean toward the optimistic interpretation. We have hopes that policy can be made better than it is. In the rest of this section, we describe some immediate steps that states and MPOs might take to move toward a decision-making framework more likely to result in efficient transportation investments.

5.2 STEPS STATES AND MPOs CAN TAKE

5.2.1 EDUCATE POLICY-MAKERS ON THE NEED TO DO IT

For some decision-makers, the possibility that a benefit-cost framework will lead to better investment decisions—ones that are more efficient and more fair—will be enough to attract them to it. The technical advantages notwithstanding, there are legal mandates for using the principles described in this report. States and MPOs may find their plans subject to legal challenge if the ignore these principles.

More importantly, the U.S. Department of Transportation and each of its modal agencies is committed to informing a wide audience about ISTEA mandates. Through the National Transit Institute, for example, several dozen training programs are underway and planned, dealing with the conduct of major investment studies by states and MPOs. Policy-makers need to understand how and why these studies are to be done.

5.2.2 BUILD AGREEMENT ON THE FRAMEWORK AMONG POLICY-MAKERS, PLANNERS, TECHNICIANS AND INTEREST GROUPS

The literature we reviewed makes it clear that professional researchers working on how to evaluate transportation investments understand the central ideas of a benefit-cost evaluation framework. It is likely, however, that while most practicing planners at states and MPOs have a good understanding of their particular component of the transportation system (e.g., highways, buses, trip reduction ordinances), few have had the time or inclination to become conversant in the details of the framework. It will take time to build agreement about the framework and to accept its results. Policy-makers like the rhetoric of cost-effectiveness analysis but can abandon it when it fails to support projects that have strong constituencies.

5.2.3 DEVELOP COOPERATION AND AGREEMENT ON THE FRAMEWORK AMONG JURISDICTIONS

A patchwork of jurisdictions have responsibility for making street, highway, transit, and land-use decisions, all of which affect travel demand. With separate sources of funding, different legal mandates, and sometimes competing political leadership, it is difficult to accommodate the kind of rational, dispassionate analysis of alternatives implicit in a benefit-cost framework.

Two factors may encourage closer cooperation. First, ISTEA has strengthened the role of states and MPOs in making transportation investment decisions. Second, resources are increasingly scarce, so there will be greater incentive to do what's most efficient and economical.

5.2.4 TAKE INCREMENTAL STEPS

For both technical and political reasons, shifting from existing methods for project evaluation and selection to ones based more on the benefit-cost principles described in this report can probably only occur in small steps. Many gaps on the technical side—gaps in data and methods—may best be filled by federally sponsored research and demonstration projects. Similarly, one cannot expect the process that states and MPOs now use to select projects to change quickly. The principles of benefit-cost analysis implied by the new federal mandates will be incorporated little by little, not all at once.

A good place to start a change in the evaluation process is with benefits and costs that are easy to understand conceptually and relatively easy to measure. Most transportation evaluations that we reviewed done by states and MPOs did an adequate job of addressing direct costs of proposed projects: design, construction, and maintenance. But few contained a proper conceptualization and calculation of the most basic user benefits: decreases in the costs of travel time, operation, accidents. Existing travel demand models provide rough estimates of the variables necessary to make these calculations. Just getting the user benefits and the project costs accounted for correctly will go along way towards helping make better informed decisions.

Though many states and MPOs may not be ready to conduct a full analysis of benefits and costs, but they could substantially improve their estimates of benefits with little extra data collection. Most have travel-demand models that already estimate changes in travel time. Using readily available information on demographic characteristics, some crude estimates of average driver characteristics and time value can be made. A more sophisticated analysis might follow the format of the study by Cameron (1994), where travelers are disaggregated by income. If, as is typical, the demand model only allocates trips to two modes (auto and transit), the non-auto trips can be further disaggregated outside the model in a spreadsheet.

Even this simple analysis would add a lot of information to the process. For regional, subarea, or corridor planning, this type of analysis would provide an initial, rough estimate of whether a particular project, corridor, and combination of projects and corridors could be expected to provided user benefits in excess of direct costs. We believe that such analysis would show many projects now getting built to be such poor performers that alternatives would have to be considered. For projects where user benefits and direct cost are within striking distance of each other (e.g., within 50-100%, not 500-1000%) more detailed analysis could be undertaken, and external costs and benefits might be considered in a multi-criterion evaluation.

States and MPOs need not wait for more direction from the federal government before pursuing such an analysis. The principles on which such an analysis would be based are described in this report and many of the reports it references. States and MPOs might join with a state department of transportation to develop a common procedure.

Appendix A

Concepts of Least-Cost Planning as They Apply to Public Utilities

A.1 WHAT MOTIVATED THE DEVELOPMENT OF LEAST-COST PLANNING?

Electric utilities pioneered least-cost planning (LCP) beginning in the mid-1970s. Wisconsin Electric Power Company, for example, adopted least-cost planning concepts in 1976. Bonneville Power Administration began developing a Cost-Effectiveness Methodology in 1980 (BPA 1986). Water and wastewater treatment utilities began to consider least-cost planning practices in the early 1980s.[1] The experience of electric utilities illustrates the concepts of LCP and their evaluation.

LCP developed out of a need for electric utilities, and the government agencies that regulate them, to adapt to significant changes in market and regulatory conditions. Until the early 1970s, several factors influenced the way planning was conducted:

- *Economies of scale.* Electricity could be produced at the lowest unit cost by large generating facilities; scale economies extended over a wide range of output. Thus, a single, large company could produce, transmit, and distribute electrical energy for a region at lower cost than could several smaller companies.
- *Government regulation.* The fact that the technology of energy production tends to result in a few large producers leads to what economists refer to as a natural monopoly, which in turn leads to the recognition of electric utilities as legal monopolies. In an effort to prevent electric companies from charging rates in excess of costs, public utility commissions (PUCs) regulate rates. The objective is to set rates high enough that a utility can cover its costs and earn a normal profit, but not so high that the utility earns excessive profits.
- *Falling unit price.* Growing demand for electricity allowed utilities to exploit economies of scale, which allowed utilities to charge lower rates. Improvements in technology, while leaving the efficient scale of production relatively unaffected, also allowed generation at lower cost.

[1] In the 1990s, solid waste utilities began to incorporate least-cost planning into their decisionmaking. This appendix focuses on the experience of electric utilities because that experience is relatively involved.

- *Less concern about environmental externalities.* Over most of the period in which the electricity industry developed, concerns about economic development dominated most other concerns, including concerns about environmental externalities and equity. Electric utilities were not required to pay much attention to the external costs of their operation. Nor were they required, in a time of generally falling prices, to concern themselves much with how changes in prices affected different parties.

That utilities operated as legal monopolies in a growing market encouraged a relatively simple planning process. Analysts forecasted the demand, or the growth in demand, for electricity. Demand and its rate of growth were taken as given; the only influence the utility could have on demand was through price. The main concern was with how the utility could most cost effectively deliver the amount of electricity forecast. The issue typically revolved around how many and what kind of large generation facilities to build (fossil fuel, nuclear, or hydro).

Conditions changed so dramatically in the 1970s and 1980s that the decisions of electric utilities, and the PUCs that regulate them, came under intense public scrutiny. These changes included:

- *Rising production costs.* The rise in the cost of fossil fuels in the 1970s increased the cost of fossil-fuel generation. Concern about the rising cost and future availability of fossil fuels encouraged consideration of other methods of generation. Nuclear generation appeared to be the most promising long-run approach to decreasing dependence on imports of fossil fuels.
- *Decreases in the growth rate of demand.* The decades-old trend of growth in the demand for electricity led to forecasts of continuing growth in demand. These forecasts, combined with higher fossil-fuel prices, encouraged electric utilities and PUCs to invest in nuclear power plants. The unexpectedly low rate of growth in demand, however, forced the utilities that invested in nuclear power plants to raise rates far more than anticipated.
- *Shrinking scale economies.* While many utilities invested in nuclear power plants, which require very large-scale production to minimize production costs, technological innovations were reducing both the costs and minimum efficient scales of production facilities using other fuels. Relatively small-scale power plants based on non-traditional fuels—gas, hydro, wind, geothermal, solar, methane—were becoming competitive with large-scale coal, oil, and nuclear energy production.
- *Growing concern about externalities.* Increasing incomes, combined with increasing air and water pollution led to growing concern in the 1960s and 1970s about the long-term social effects of environmental degradation. Electrical power plants contributed to the problem. Coal plants potentially contributed to acid rain. Coal and oil contributed to the general problem of air pollution. The specter of a nuclear disaster, and the accumulation of nuclear waste, caused public concern. The resulting regulatory changes designed to ensure

nuclear plant safety contributed to the high cost of nuclear power, and the need to increase electricity rates.

- *Political movement toward deregulation.* The decade of the 1970s saw the beginnings of the now-prolonged movement toward deregulation of industry by government. The Public Utility Regulatory Policies Act of 1978 required distributors of electricity (who were typically also producers) to purchase power generated by small producers. The motivation of the legislation was the idea that competition in the production of electricity would increase efficiency and reduce costs. Though the legislation had the desired effect on production costs, it further eroded the ability of large utilities to use nuclear plants at efficient scale.

In sum, the conventional process of planning and regulation, combined with unforeseen changes in the technology of electrical generation and in the general political sphere, created problems approaching a crisis for many electric utilities. The failure of investments in nuclear plants placed the most pressure on large utilities and PUCs to change planning policies and practices.

A.2 IN WHAT WAYS DOES LCP DIFFER FROM TRADITIONAL PLANNING?

For electric utilities, LCP developed in response to the crisis they experienced in the late 1970s and early 1980s. The principal changes in planning stem from the perceived weaknesses in the way planning was conventionally conducted. LCP increased the emphasis on:

- *Services, not on products.* Traditional planning focused on supplying a given amount of electricity at least cost to the utility. LCP focuses on providing at least cost the services into which energy is an input. LCP recognizes, for example, that users of electricity demand a comfortable room temperature. Room temperatures can be raised either by using more electricity or by using the same amount of electricity and improving the building's insulation. The objective of LCP is to reduce the cost of heating the room, not just providing the electricity.
- *Demand side factors.* Traditional planning took demand as given (including the responsiveness of demand to changes in price) and concentrated on the generation capacity needed to meet that demand. LCP requires that the utility pay attention to alternatives to increased generation to meet demand for energy services (e.g., investment in conservation measures).
- *Full social costs, not just private costs.* Generation of electricity typically involves external costs—people other than the utility and the rate payers are affected by the process of generating electricity. Large hydro-electric projects, for example, impede the movement of salmon, which reduces the benefits from use (e.g., commercial and sport fishing) and non-use (e.g., the knowledge that a species and

ecosystem has been preserved) of the salmon. Fossil-fuel generation releases potentially harmful emissions into the air, and increases reliance on imports of fossil fuels. LCP methods attempt to quantify the costs of these non-market impacts of electricity production.

- *Alternative methods of increasing the supply of electricity.* LCP attempts to identify and evaluate all options for maintaining or increasing supply. Rapid change in technology, public sensitivity to environmental concerns, and increasing competition motivate utilities to look carefully at all supply alternatives. These include consideration of maintaining existing resources, using renewable resources, and purchasing power from non-utility resources.
- *Risk and uncertainty.* Electric utilities have long been concerned with providing reliable service. With volatility in fuel prices, uncertainty in demand forecasts, and the potential for significant change in regulatory constraints, utilities are increasingly concerned about reducing risk and uncertainty. An important aspect of LCP is the analysis of the sensitivity of alternative resources (both new supply and demand-management programs) and resource portfolios (logical combinations of supply and demand resources) to changes in key variables. Planners test the impact on costs and reliability of a variety of plausible changes in input prices, consumer demand, and regulations.
- *Public involvement in decision-making.* Rising electricity rates in the 1970s and the failure of expensive nuclear power plants increased the interest of ratepayers in the activities of utilities and PUCs. An important aspect of LCP is public participation in the planning process. The process potentially benefits the public and the utility; the utility can better assess consumer needs and responses (e.g., to DSM measures, environmental projects), and the public is better informed of, and shares some of the responsibility for, utility actions.
- *Inter-agency coordination.* LCP is also a tool for coordinating activities across service providers and governmental agencies. In the water industry, for example, water suppliers typically paid little attention to the impacts of their projects on wastewater treatment facilities. LCP includes an effort to coordinate investments across agencies.

In sum, the objective of LCP is to reduce the cost and increase the reliability of providing end uses. LCP attempts to balance consideration of the supply and demand sides of the market. It provides an integrated method of evaluating a variety of projects in terms of both cost and reliability. It attempts to look at the full costs of providing a service (e.g., electricity), which include not only the direct costs of planning, construction, operation, and maintenance, but also external costs like pollution, threats to species, and loss of habitat and recreation opportunities. It increases the role of the public in planning decisions and fosters greater coordination between institutions and agencies involved in energy provision.

A.3 WHAT ARE THE KEY CONCEPTS OF LCP?

The literature in LCP contains technical concepts that may not be familiar to transportation planners and policy-makers. This section describes these key concepts. This section is largely redundant to Chapter 3 of this report. It is presented again so that this appendix can stand alone as a summary of LCP.

A.3.1 FULL SOCIAL COST

Public concern about the damage electricity generation, transmission, and distribution motivates one of the key characteristics of LCP: consideration of all the costs of a proposed project, rather than just the costs borne by the utility. LCP typically breaks full social costs into its components:

- *Direct costs to the utility.* These are the costs the utility bears directly: planning, construction, operation, and maintenance. These costs are usually quantifiable, though the reliability of estimates may vary considerably due to changes in input prices or government regulation that are difficult to foresee.
- *External costs and benefits.* Typically more difficult to quantify are the costs and benefits of the generation, transmission, and distribution of electricity that spillover onto people that are uncompensated for harm incurred and that do not pay for benefits received. For example, a large hydro project involves potentially large spillover costs and benefits. The dam alters the river ecosystem and inhibits the movement of migratory fish, which affects both the users of fish and non-users who value the existence of a healthy ecosystem. Obviously, the full extent of these costs is difficult to estimate. The project also provides spillover benefits to recreational users of the reservoir. Again, these benefits are difficult to quantify. Though external costs and benefits may be difficult to quantify, they often are large. LCP requires that external costs and benefits be considered in the planning process.
- *Social costs.* The cost to society of a proposed project include both the direct cost to the utility and the costs and benefits that spillover onto other members of society. From the standpoint of economic efficiency, the social cost of the project is the appropriate evaluation of the project's cost. LCP attempts to minimize the social cost, rather than the direct (private) cost, of a proposed project.

A.3.2 COMPARABLE FULL-COST TREATMENT OF RESOURCES

A key aspect of LCP is a balanced consideration of both the demand and supply sides of the market. Conventional planning focused on the supply side—analyzing how to produce at least cost the quantity of electricity demanded—taking demand as given. LCP requires that utilities consider ways of reducing the quantity of electricity demanded in addition to ways of generating larger amounts of electricity. If demand can be reduced at lower cost than supply can be increased, the demand-side solution is preferred.

- *Supply side management.* An important aspect of LCP is the consideration of the complete range of options for generation. Given a forecast of increasing demand, conventional planning revolved around the decision of what kind of large generating facility (e.g., natural gas or nuclear) to build. It was taken as given that increasing demand must be supplied. The principal changes in supply-side management in LCP are (1) a consideration of a wide range of alternative sources of power (e.g., smaller facilities, non-conventional fuels, purchase from other generators); and (2) a consideration of all the costs of production, including costs external to the utility (e.g., pollution, loss of wildlife habitat).
- *Demand side management.* The focus on end-use, rather than electricity per se, allows a consideration of alternatives to increasing electricity production when demand for the end-use increases. For example, better insulation allows space heating with less electricity. A demand-side analysis may reveal that the demand for space heating (as opposed to electricity) can be more cost-effectively met by insulating the consumers' building than by building additional generating capacity. Under LCP, the utility must weight these demand-side management (DSM) techniques equally with supply-side solutions.
- *Pricing.* Pricing is often considered a technique of demand-side management, but is rarely allowed to play the role it does in the markets for most commodities. In competitive markets, prices adjust with changes in cost; as the marginal cost increases or decreases, so does price. Consumers adjust their consumption in response to changes in price. Economists consider these adjusts to take place in a highly efficient manner. Utility rates, however, are set by PUCs, and their structure typically results as much from political as from market forces. For example, the marginal cost of production is typically greater during peak periods (because relatively high-cost generators are brought on line) than during non-peak periods, but rates seldom reflect this difference. In addition, rates often reflect only the direct costs of production and not the external costs. If rates accurately reflected marginal production costs, consumers could be expected to efficiently conduct their own demand-side management.

A.3.3 FORECASTING

Accurate forecasting of the characteristics of future demand for and supply of electricity is critical to sound planning. Some decisions to build nuclear power plants in the 1970s resulted in large part from optimistic forecasts of the growth in demand for electricity, and of the cost of construction and maintenance of the nuclear facilities. The result has been refinement in the way planners forecast demand, and in the consideration of the uncertainty in those forecasts.

- *Forecasting methods.* Hirst (1992) describes the forecasting methods that utility planners typically employ. An econometric forecast uses historical trends and economic theory to produce a statistical forecast of the value of important variables into the future. Some utilities take a more disaggregate (and, therefore, more expensive) approach by looking in detail at the way different types of consumers use electricity, and how those uses are changing. More sophisticated forecasting techniques integrate these two approaches.
- *Risk and uncertainty.* A critical part of LCP is to include in the evaluation of alternative proposed projects an analysis of the impacts of unexpected changes in important variables (e.g., fuel prices, government regulations). This is usually done by performing a *sensitivity analysis.* The stream of future costs and revenues depends on the values of many variables, each of which must be forecast. The expected net benefits (or total costs) of one propose project may vary more with unexpected changes in important variables than other proposed projects. LCP includes this risk in the overall evaluation of the project. Though not typically done, the effects of greater risk can be quantified by giving riskier projects a higher discount rate.

A.3.4 PROPER TREATMENT OF ALL COSTS OVER TIME

The costs that LCP evaluates for different resources can occur in different years and can fall on different people. To find a way to treat those costs consistently across alternative resources, LCP uses:

- *Discounting.* A payment made or received in the future is worth less than the same payment made or received today for three reasons: (1) inflation reduces the purchasing power of the future payment; (2) a payment received today will earn interest over time; and (3) there usually exists some uncertainty that a payment will in fact occur at the future time. For these reasons, people prefer to receive a given nominal payment today, rather than in the future. In other words, they discount the value of the future payment. Because most projects involve a stream of revenues and costs into the future, it is critical that these revenues and expenditures are discounted appropriately. The present value of those discounted costs can also be *levelized* (spread out into a stream of even payments, like a mortgage) to make comparisons among alternatives easier.
- *Marginal cost.* A key characteristic of both BCA and LCP is that only differences from some base case (usually the status quo) need be considered. That is, an analyst does not need to know the total net benefit enjoyed from a project, only how much better the project is from the base case. This is referred to as the *marginal* benefit of the project. In LCP, the same notion is often referred to *as avoided cost*; a project has a net marginal benefit if it avoids some of the costs of the base case. For example, one project may provide a given amount of electricity while producing fewer emissions, thereby avoiding some of the cost to society of those emissions.

- *Different perspectives.* An important aspect of BCA and LCP is that the proper perspective for decision-making is the impact of the project on all of society, not just the utility and its ratepayers. This drives, for example, the concern about externalities. But perspective is also important to consider when considering the way a project is financed. For example, part of the costs of construction may come from the federal government. The net benefits of a project are higher if the utility ignores the costs paid for with federal money. Projects may be undertaken that have negative net benefits to society as a whole. An important aspect of BCA and LCP is that the project be evaluated in terms of the net benefit to all of society (including taxpayers from other regions). A related point is that different groups (e.g., of users, or special classes) may be affected differently: by taking their perspectives, LCP can show how proposed projects impact them.

Borlich (1994) argues that LCP often differs from BCA *in practice* because analysts fail to consider fully the costs and benefits of consumers' response to changes in price. For example, the benefit from a decrease in price is greater than current consumption times the change in price. Consumers respond to the lower price by consuming more. BCA takes that response into account, whereas LCP often does not.

A.3.5 STRATEGIC PLANNING AND PUBLIC INVOLVEMENT

Most of the LCP processes run by public utilities include programs to involve stakeholders (e.g., other agencies, local governments, users, and so on) and the public in decision-making. The process parallels the one typically described in the literature of strategic planning: the LCP is a strategic plan that talks about goals, resources, and uncertainty.

A.4 WHAT IS THE LIKELY FUTURE FOR LCP?

From an economic standpoint, the key weaknesses of LCP are its implicit assumption of constant benefits and tendency to skip over efficient pricing as a policy. Utilities and PUCs that have adopted LCP have done so in an effort to respond to the changes in market and political conditions that left conventional planning wanting. The focus of LCP has been on more thorough consideration of supply- and demand-side resources. From the standpoint of economic efficiency, producing at least cost is essential. But the behavior of both producers and consumers depends on prices. Yet "rates are typically designed or modified on the basis of equity considerations and/or political acceptability. Economic efficiency is considered as an afterthought—if at all." (Borlich 1994, 28).

For the price system to function effectively, prices (in the case of electricity, rates) should be set at the cost of producing the marginal (i.e. last increment) of output. LCP focuses on reducing the social cost of producing that last unit, a step necessary for economic efficiency. That cost should be communicated to consumers in the form of prices, but typically isn't. For example, the cost of producing additional electricity during peak hours typically increases as higher-cost generators are brought on line. The price of electricity should, therefore, rise during peak periods, but it typically doesn't. As another example, LCP includes a consideration of external costs in making supply- and demand-side decisions. But external costs should also be included in the rate to guarantee that the marginal benefit consumers receive exceeds the marginal social cost of provision.

Borlich (1994) gives an example of the distortions in cost-benefit analyses caused by planners ignoring the effects of the consumer's response to changes in prices. Suppose an electric utility implements a DSM program (it subsidizes purchase of energy-conserving lighting), and pays for it through a rate increase. Although planners recognize that consumers respond to the increases or decreases in price that result from implementing a DSM measure (an effect referred to as "snap back"), they typically view it as undesirable. In reality, consumer response to changes in price is the primary source of benefit in a market system. In the example, the net benefits of the DSM project increase when the consequences of the changes in behavior caused by the rate increase are considered. The main source of the increase in net benefit is that the rate increase unintentionally brings rates closer to marginal social cost.

Buchanan (1994) describes how increasing competition in wholesale and retail markets for electricity will force utilities to improve pricing. Despite the technological and regulatory changes in the 1970s that motivated the development of LCP, the monopoly status of utilities did not change. As LCP developed, utilities encountered increasing competition in electric generation, but they retained a monopoly in transmission and distribution. More recent changes indicate greater competition in retail markets is evolving as well. "New end-use technologies, end-use efficiency measures, wholesale wheeling, self-generation, unbundled utility products and services, and the prospect of retail wheeling all will affect dramatically the role of [LCP] in the future" (Buchanan 1994, 4).

Increased competition will not only affect how utilities plan, but in how they price. Currently, utilities pay for DSM projects through increases in rates. The rate increases influence the behavior of consumers (though the net effect differs between participants in the DSM program and non-participants). As long as the utility has monopoly power, however, the rate increases do not affect profitability. In a more competitive market, however, consumers will be able to respond more strongly to increases in price, and utilities may not be able to maintain profitability while paying for DSM measures through increases in rates. "Eventually, utilities will be unwilling to undertake investments that raise rates because competition in retail markets will not allow them to." (Buchanan 1994, 8).

Increased competition potentially has significant implications for LCP. Competition will force utility planners to take into account an even broader array of production, distribution, and pricing options than they currently consider. Competition will put them in a position similar to that of corporate planners in a relatively competitive industry. The consumer benefits from generally lower prices and greater choice. Society benefits to the extent that prices reflect marginal social costs. The potential benefits are analogous to those obtained from deregulation of, and increased competition in, the airline and telecommunications industries.

Connors (1994) agrees that increased competition will influence the LCP process, directing its focus more toward control of environmental problems, and toward promoting industry coordination. Connors foresees technological and institutional improvements that will encourage competition at each stage of production: generation, transmission, distribution, and end-use. The competition will force utilities toward least-cost production. It will also discourage costly efforts to reduce environmental damage. Thus, the planning and regulatory process should evolve toward the creation of institutions that encourage all energy providers to consider environmental externalities in their production decisions.

In sum, increasing competition that results from changes in technology, regulation, and market institutions has the potential to influence the planning processes used by utilities and PUCs. In general, the increased competition will be good for consumers: prices will decrease and choices will increase. Competition, however, increases the pressure on utility planners to recommend sound investments in a more complex economic environment. Moreover, increased competition will reduce private incentives to fully consider environmental externalities.

Appendix B

Mispricing in Electric Utilities and Transportation

B.1 OVERVIEW

Least-cost planning in electric utility planning evolved in a way that highlights the importance of the relationship between consumer prices and producer costs in efficiently providing electricity. Initially, electric utilities and public utility commissions (PUCs) adopted LCP as a way to better evaluate a wider range of alternative methods for supplying electricity. Public concern about the quality of the environment led utilities and PUCs to include environmental costs in their supply-side analyses, and to consider demand-side programs—conservation programs that reduce the amount of energy required to produce a given end use—as well as supply-side alternatives. Along the way, it became apparent that consumers respond strongly to changes in the prices of electricity and of conservation measures. Utilities and PUCs became more sensitive to the role of pricing in the efficient production and consumption of electricity.

Economists have long held that inefficiencies in a variety of markets occur when price diverges from marginal cost. Price is the key signal to producers and consumers that guides resources to their highest valued uses.

Experience with LCP helped convince electric utilities, and the PUCs that regulate them, of the importance of pricing. Though the trend is toward better pricing, many electric rates continue to diverge significantly from marginal costs (the cost of supplying an additional amount of power, given the existence of the current power-supply system). Improper pricing leads to an inefficient allocation of resources, and a loss of net social welfare. There are two fundamental economic reasons for mispricing in the markets for electricity: natural monopoly and externalities.

The primary motivation for the regulation of electric utilities is the prevention of monopoly pricing (pricing above average cost). Historically, the technology of generating, transmitting, and distributing electricity allowed big providers to deliver electricity at lower cost per kilowatt than smaller providers.[1] The big producer could spread the high costs of plant and equipment over a larger amount of output, decreasing the average cost of production. Because they have lower average costs, the big firms can underprice their smaller competitors, forcing the smaller firms out of business. With the competition eliminated, the one remaining firm can raise

[1] Recent technical innovations have decreased the extent of scale economies in the generation of electricity; smaller plants can produce at relatively low average cost. Some analysts (see, for example, Buchanan (1994) and Connors (1994)) predict that further improvements in technology (and regulation) will improve opportunities for competition in the transmission and distribution of electricity as well.

price above cost to maximize profit. Net social benefit is not maximized when price exceeds cost. PUCs were formed to regulate these natural monopolies.[2] PUCs attempt to set rates so that utilities can cover costs and provide a reasonable (not excessive) return to their shareholders.[3]

A second source of mispricing in electric utilities are the external costs associated with generation of electricity—people other than the utility and the rate payers are affected by the process of generating electricity. Large hydro-electric projects, for example, impede the movement of salmon, which reduces the benefits from use (e.g., commercial and sport fishing) and non-use (e.g., the knowledge that a species and ecosystem has been preserved) of the salmon. Electric generation using fossil fuels releases potentially harmful emissions into the air, and increases reliance on imports of fossil fuels. To the extent that PUCs fail to include these external costs in their calculations of electric rates, electricity is underpriced.

For example, suppose that an electric utility is able to ignore the costs it imposes on society when it pollutes the environment in the course of generating electricity. This affects the quality of the environment in two ways. First, the utility has no incentive to use pollution-abating technology; the level of pollution is inefficiently high at each level of output. Second, because the utility is willing to charge a price for the product that is less than the full *social* cost of its production (it is only concerned with covering its own *internal* costs), consumers demand more of the product than they would if the price was higher. Thus, not only is the utility polluting too much per unit of output, it is also producing too much output. If the utility had to pay to pollute, price would rise, and both the utility and consumers would have incentive to reduce the activities that cause the pollution. If price equals marginal social cost, net social benefit is maximized without further government involvement.

Electricity is also mispriced for political reasons. External costs are often ignored because raising rates to protect the environment potentially discourages the location of new industry in the area.[4] Politics also has prevented PUCs from adopting the time-of-day pricing common in unregulated industries such as telecommunications, airlines, and even movie theaters.

Failing to adjust rates as demand for electricity changes over the course of the day and year is an important source of inefficiency in the provision of electricity. For a typical utility, the cost of an additional kilowatt of power (i.e., the marginal cost) increases as the total amount generated increases.

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[2] These monopolies are termed "natural" because the economies of scale enjoyed by larger firms allows them to do no more than price at cost to eliminate smaller competitors. This contrasts with monopolies that have formed in industries in which the monopoly producer has no cost advantage over its competition.

[3] The issues in the pricing of public utilities are too many to discuss here. We focus on issues of relevance to transportation.

[4] Of course, poor environmental quality also discourages economic development.

The utility provides base power with its lowest-cost facilities (e.g., hydro). To accommodate increased demand for power during peak periods, the utility sequentially brings higher-cost resources (e.g., natural gas generators) on line.[5] Though peak-period energy costs more to generate, in the absence of a tiered pricing system, consumers do not perceive these higher costs. The single price for electricity induces too little consumption during off-peak periods (because the price is above marginal cost), and too much consumption during peak periods (because the price is below marginal cost). The need for new generation facilities would be reduced if peak-period pricing reflected the marginal cost of supplying that power.

B.2 EVIDENCE ON THE MISPRICING OF TRANSPORTATION

Mispricing in surface transportation occurs, for the most part, for reasons analogous to those in utility pricing.

Part of the problem is economic. The primary motivation for government provision of roads and highways is the difficulty of charging drivers for their use of the road. If a private company could easily charge travelers, the roadway system would have the characteristics of a natural monopoly. Private producers could operate the system and charge tolls approved by the government. Some privately owned and operated toll highways do exist. For the most part, however, the government has taken over construction, operation, and maintenance of the highway system.

Drivers are charged for their use of the road indirectly through a per-gallon tax on fuel and a variety of other taxes and fees (e.g., excise taxes on tires, vehicle registration, and license fees). The fuel tax, which provides the bulk of revenues, may seem a sensible payment mechanism because miles driven is closely correlated with gallons of fuel consumed. Moreover, a fuel tax is much less costly to collect than road tolls.

Closer examination, however, reveals that the typical fuel tax (combined with the other various taxes and fees) does not come close to recovering the full social costs auto travel. To illustrate this, Table B-1 lists estimates of the major costs of highways and driving in the U.S. in 1991, as compiled by Lee (1994). The figures come from a variety of existing estimates of costs applied to the accounting framework Lee develops, which based on standard business practices. Estimates of many costs vary substantially from study to study, but those in Table B-1 are representative and, given the author's extensive knowledge of the theory of benefit-cost analysis and full-cost pricing, probably better than most. Our point is not to debate any particular estimate, but to give a rough idea of the relative magnitudes of costs.

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[5] For a given generation facility, the cost per kilowatt decreases as output increases as fixed costs are spread over a larger amount of output. That is, scale economies exist. If demand can be satisfied by a single large generating facility, the marginal cost of supply decreases during peak periods. Typically, however, satisfying even off-peak demand requires multiple generating facilities, and satisfying peak demand requires bringing relatively high-cost facilities on line.

The figures in the table indicate that drivers, as a class, avoid paying directly an average of about 14.5 cents per mile traveled in 1991 (assuming 2.17 trillion vehicle miles traveled in 1991).[6] This is nearly five times the total amount spent by all units of government on highway infrastructure and services, and 7 times total receipts from tolls and taxes on fuel and vehicles.[7] Given no effect on travel behavior, it would require an increase in fuel taxes of over $3.00 per gallon to impose the full cost of travel on drivers (assuming average mileage of 20 mpg). That is, in addition to the costs they cover directly (through market purchases of vehicles, equipment, gas, insurance and so on, and through gas taxes to pay for public infrastructure and other social costs of the highway system) drivers are responsible for over $300 billion of costs on society.[8]

Table B-1: Estimates of U.S. highway costs not recovered directly from users in 1991

Component of cost	Cost per mile (cents)	Total cost ($ billions)	Percent of total
Roadway construction and repair	6.61	143.5	39.1%
Roadway maintenance	0.94	20.4	5.6%
Related services (police, etc.)	0.68	14.7	4.0%
Parking	2.44	53.1	14.5%
Pollution	3.19	69.3	18.9%
Accidents	0.66	14.4	3.9%
Fuel and Oil	0.62	13.4	3.7%
Social Overhead (foregone taxes)	1.75	38.1	10.3%
Total Costs	16.9	366.9	100.0%
Current User Revenues	2.4	52.1	
Cost unrecovered directly from users	14.5	314.8	

Source: Lee (1994), with minor modifications by ECONorthwest

[6]Given the magnitude of the costs reported in Table 1, the reliability of the estimates and soundness of the accounting system are important. See Lee (1994) for details. Lee draws on estimates of costs developed or cited in other sources, including Apogee Research (1994), Litman (1994), MacKenzie, Dower, and Chen (1992), and Small (1992).

[7]FHWA, 1991. *Highway Statistics, 1991*, Washington, D.C.: Federal Highway Administration.

[8]Obviously, drivers as taxpayers and property owners foot much of this bill. Paying the bill through general taxes, however, has much less influence on driving behavior. That is, if drivers, as drivers, had to pay the full cost of their travel, their travel behavior would probably change significantly, even though their total expenditure on travel (through user fees plus other taxes) would change relatively little. It is important to note that the estimates reported are average costs for drivers as a class. The important costs for decision-making are the marginal costs to *individual* drivers, which may be quite different from these average costs.

Though a substantial increase in the fuel tax would increase the average amount drivers pay for travel, it would be an inefficient way to treat the most tenacious of transportation problems: congestion. Conceptually, the congestion problem is analogous to the peak-load problem in electricity. During non-peak periods, drivers use the lowest-cost facility: usually an uncongested freeway. As the number of drivers grows, drivers bring higher-cost facilities on line; some drivers shift to unlimited-access highways and arterial streets.

The congestion problem is usually analyzed as an externalities problem. When additional drivers enter a congested highway, they cause a general reduction in travel speeds. Thus, the most important component of travel costs—travel time—increases. To the extent that drivers fail to consider the costs they impose on other drivers, they fail, on the margin, to make travel decisions that increase net social benefit. Specifically, the value of the trip to many of the drivers on a congested highway is less than the cost they impose on all of the other drivers on the highway, collectively. In the absence of congestion tolls, trips on congested highways are substantially underpriced.

Peak-period travel is underpriced mainly for political reasons. The technology now exists to charge tolls on freeways without adding to the congestion problem by forcing cars to stop at toll booths. Electronic toll systems that protect the privacy of the driver have been tested and are in operation on a number of limited access highways in the U.S. and Europe.[9] Carefully designed and priced area permits can effectively control congestion on urban street systems. While consumers have already accepted tiered pricing for other goods and services (e.g., higher peak telephone charges, airline prices, theater prices) transportation policy-makers fear voter reaction from charging tolls on traditionally unpriced roadways.

While pricing policies could generate substantial improvements in total social welfare, the distribution of the benefits depend how the revenues are used. While it is theoretically possible that the revenue raised could be used to compensate any losers from the pricing, such a policy is difficult to put into practice. In all likelihood some auto drivers will be made worse off by road charges and they will oppose the use of road fees. The benefits of pricing will also be limited if the revenue raised is dissipated on public projects and programs that don't yield a dollar for dollar benefit. Pricing policies could substantially improve the efficiency of the road system but its implementation poses significant political challenges.

[9] See Fielding and Klein (1993) for details. The tolls collected on these highways are intended to pay for the highway and do not vary by time of day as would an efficient congestion toll. From the standpoint of economic efficiency, congestion tolls are a more appropriate way to pay for the highway because the capacity of the highway is determined by peak demand.

B.3 POLICY RESPONSES TO MISPRICING

Analysts in both electricity and transportation have proposed ways to improve resource allocation in the absence of efficient pricing. A variety of demand-management programs, for example, attempt to reduce traffic congestion, including transit subsidies, peak-period parking fees, and ride-sharing programs. These and other programs succeed to varying degrees in reducing peak-period traffic congestion. Unfortunately, none of these methods approach proper pricing in impact or effectiveness.

The fundamental problem is illustrated by efforts to reduce air pollution. The typical regulatory approach is to set a target for reduction of emissions of each pollutant. Though difficult, setting the target is easy compared to the next step: deciding who should reduce emissions by how much. The simplest way to achieve a target reduction in emissions of, say, 20% is to require that all polluters reduce emissions by 20%. Some polluters can comply with relative ease; for them it costs relatively little to purchase less polluting equipment, or to adjust production methods to reduce pollution. For other polluters, however, reducing emissions even a little is extremely expensive. This apparent unfairness breeds controversy, and often results in complex changes in regulations that are costly to administer and that reduce the effectiveness of the program.

For this reason, agencies that have strong public support for reducing air pollution have begun using market-based approaches. One option is simply to charge an emissions toll: the polluter receives a bill for each unit of pollutant emitted (much like the bill received for purchase of other inputs). Polluters that can reduce emissions easily do so to reduce their emissions charge. Other polluters make fewer changes in behavior and pay the toll. Two disadvantages of this system from a political standpoint are that it is difficult to estimate accurately the appropriate toll, and the government earns windfall tax payments. An alternative is to issue tradable emissions permits. If, for example, the target is to reduce overall emissions by 20%, each polluter is issued a permit to produce 80% of current emissions. If the cost of reducing emissions is high for a given polluter, the polluter can purchase emissions permits from other polluters better able to reduce emissions. With either emission charges or tradable emissions permits, pollution is reduced to the target level efficiently; that is, at the least cost to society. A planning agency cannot directly regulate emissions with similar efficiency.

The same is true in transportation. Consider, for example, the problem of congestion. Current peak travel volumes are too high: the benefit some of the drivers on the highway enjoy from the trip is less than the total costs their trip imposes on society. One may even be able to get a reasonable estimate of the number of drivers who should not be on the road. The hard part is deciding who should not be on the highway. Only the drivers themselves know how much they value the trip. Some form of marginal-cost pricing is required to induce them to reveal that valuation.

Most attempts at LCP start from the assumption (or quickly arrive at it) that marginal cost pricing cannot be implemented for political reasons. The LCP exercise then becomes one of finding other measures that move the consumption (e.g., of electricity or transportation) to more efficient levels—that is, closer to where analysts think it would be if marginal costs were paid. From an efficiency standpoint, it is critical to evaluate all the costs and benefits of these programs. A program that provides the benefit of lower peak travel volumes may distort incentives in ways that create serious costs. For example, additions to road capacity may reduce traffic congestion. But they further reduce travel costs, which are already inefficiently low, and contribute to the inefficiently large amount of resources devoted to travel. LCP provides a framework in which to evaluate all the costs and benefits associated with demand-side management techniques used in place of efficient pricing.

Appendix C

Concepts For Valuing Environmental Resources[1]

C.1 OVERVIEW

Economists prefer to estimate value based on willing exchange. For any particular good or service, as numerous individuals and firms make countless transactions, the value of that good or service relative to the values of all other goods and services is established. If the parties use a currency to make the transactions proceed more smoothly than would occur through barter, and if there is no price discrimination, then the process quickly establishes a monetary price as the representation of the value of each good or service relative to all others.

Most economists believe that this market system of exchange identifies the marginal value society places on the goods and services traded in the market, at least when some basic conditions are met. These conditions include many parties making numerous trades in which they transfer exclusive ownership of the good or service being traded; each party knows the characteristics of each good or service; and there are no third parties subsidizing either of the parties making the trade. Under these conditions markets are in equilibrium so that, at the margin, when a buyer and seller agree to a trade, both parties place the same value on the good or service being traded.

These conditions are violated, however, to the extent that producers of a service do not pay for everything they use (clean air, for example). Accounting for the private producer costs alone can underestimate the costs of producing the good or service.[2] These costs are external to market transactions; hence, they are referred to as *externalities*. To make a judgment about the net benefits of a transportation investment, they must be accounted for as if they were part of private accounting system. Thus, changes in external costs (which may be positive or negative) that result from the policy also must be estimated.

The absence of markets for external effects means analysts must turn instead to non-market techniques that may not be as accurate or reliable as the market techniques. That analysis is complicated by ambiguity regarding who possesses property rights in the affected environmental resources. Our legal structure does not allow, for example, a household to own the clear,

[1]This appendix draws heavily on previous work by ECO Northwest contained in *Environmental Externalities and Electric Utility Regulation* (ECO 1993).

[2]Symmetrically, there may be benefits that producers generate that they cannot charge for because they cannot exclude consumers from them. The magnitude of uncharged benefits is probably much less than the magnitude of unpaid costs.

high-visibility air in an airshed and to sell it to a utility. With no actual transactions involving the transfer of ownership of property rights from one party to another, analysts must conduct the evaluation considering hypothetically how the parties to the externality would behave if transactions were possible.

A major category of external costs is environmental externalities. The production and consumption of transportation facilities entails some costs to society that are external to the decisions of the utility and the consumer. One way to include these externalities in decisions about transportation investments is to adopt policies that internalize them; that is, that force producers and consumers to see and respond to marginal prices that equal the sum of the marginal private and marginal environmental costs. Alternatively, one can try to estimate the value of these impacts and add them into a benefit-cost analysis.

Including external environmental costs in an analysis of alternative transportation projects is not just, and not initially, a valuation exercise. It must start with a physical description of what the environmental effect is, and what is its *damage pathway*. For example, the impacts of automobile travel on air quality start with emissions (both at the pump and at the tailpipe). But those emissions undergo chemical or physical transformations. They get dispersed. They cause changes in ambient concentrations. Those changes affects different receptors in different ways (the dose response to the exposure): humans (morbidity and mortality, visibility), plants (loss of crop value), and materials (deterioration of buildings and clothes). It is only after that pathway is understood and quantified that one can move to the question of valuation.[3]

Even if the damage pathway could be specified and measured with some certainty, there would remain several issues that complicate the problem of assigning value to the physical impacts on receptors caused by pollution. We discuss several of these general issues before discussing the estimates of specific environmental impacts for transportation investments: (1) whether values should be on willingness to pay or willingness to accept compensation (which gets into an issue of property rights), (2) whether environmental costs should be measured as the costs of prevention, clean-up, or damage, (3) whether damage estimates should be marginal or average, and (4) whether one should consider non-use values.

C.2 WILLINGNESS TO PAY VERSUS WILLINGNESS TO SELL

The value of a change in an environmental good or service stems from what society would be willing to exchange for it. One can approach this exchange from either of two perspectives: as buyer or as seller. From the buyer's perspective, the value of a good or service is the amount the buyer is willing to pay (WTP) to acquire ownership. From the seller's perspective, its

[3]We have worked on issues of environmental valuation for the last 15 years. It is our experience that the physical effects on receptors are usually more uncertain than the estimate of the value of a unit effect.

value is the amount the seller is willing to accept (WTA) as compensation in return for giving-up ownership.

When market conditions prevail, the WTP for a good or service equals the WTA, and both equal the market-clearing price. The equality of WTP and WTA is a cornerstone of economic theory for market-based goods and services, and, until recently, economists theorized that it also applied to non-market situations. But empirical studies consistently find that WTA frequently is 2 to 10 times larger than WTP even for goods commonly traded in markets, and theoreticians are debating the source of the discrepancy. Is it an artifact of empirical techniques that will disappear as these techniques are refined, or a bona fide difference in value?

The issue has important implications the evaluation of transportation investments. Whenever there is a discrepancy between WTP and WTA, whether real or an empirical artifact, adoption of one or the other as the value of an environmental externality will embody a statement about who owns the affected environmental good or service. Consider, for example, a hypothetical new highway that induces substantially more auto trips, which increase air pollution in general and in the neighborhood through which the highway runs in particular. If an MPO investment analysis seeks to internalize the cost of that air pollution using a WTP approach, it implies that it has rights to build and use the airshed, and that damaged parties must pay to maintain air quality. The amount they are willing to pay indicates the value of the change in air quality. Alternatively, if the MPO adopts a value developed using a WTA approach, it is saying that society owns the airshed and the MPO (and the trip-makers it represents) must pay society for permission to degrade the resource, and the amount society demands in return indicates the value it places on the change in air quality.

In short, the choice of WTP or WTA entails an assumption about who ultimately possesses the property rights to the nation's environmental resources. The resolution of this decision can come only from the political process. Historically, economists have tended to focus on analytical methods that ascertain society's willingness to pay to avoid degradation of environmental resources, but future studies are likely to focus increasingly on investigating the conditions under which WTP differs from WTA, and by how much.

C.3 DAMAGE COST VERSUS CONTROL COST

The second complication also relates to how potential damages should be valued. When the production and consumption of transportation services reduces, or damages, the value of goods and services associated with the natural environment, these impacts are categorized as economic costs and, to the extent that producers and consumers have not already internalized these costs, they are categorized as environmental externalities. The most direct way to measure the value of the external costs is to determine the amount society would be willing to pay to avoid the damage or willing to accept as compensation for the damage. This strategy is known as the *damage-cost approach*. Most, if not all, economists agree that the damage-cost approach is the theoretically appropriate way to measure the value of environmental externalities. Successfully completing the damage-cost approach often is difficult, however, given that most of the valuation methods for directly estimating the value of non-market goods and services are cumbersome, time-consuming, and unfamiliar to the general public.

Some analysts, while conceding that the damage-cost approach is theoretically the most appropriate, have sought alternatives that are more expedient. They have pursued *control-cost approaches*. The argument is that since damage estimates are uncertain and likely to fail to identify or quantify important costs, and that politically set targets for damage levels (e.g., levels of air pollution) take these uncertainties into consideration. (Whether, with perfect measurement, the costs of control would be greater than the costs of damage is an empirical question that depends on levels of pollution, technologies, and so on.) There are three categories of control-cost approaches.

In the first, a *mitigation-cost approach*, a state or MPO could take actions elsewhere that mitigate the environmental damage from its new facilities. Wetland offsets are a typical example. In such a situation, proponents of the mitigation-cost approach equate the value of the externalities from the utility's facilities with the costs of mitigating the externalities through some separate action.

A difficulty with this approach is that there is no necessary linkage between the cost of a mitigation program and the value of the damages caused by the externalities the program is trying to mitigate. Another potential problem is that the distribution of benefits may not accrue to the individuals who are affected by the policy. A beautification project in a city center as an offset to a new highway corridor at its fringe would mitigate few of the adverse land-use impacts on landowners adjacent to the corridor, and the cost of the central-city project need not correspond to the damages.

In the second control-cost approach, a *regulation-cost approach*, a state or MPO might be forced by federal regulatory agencies to install equipment and take measures to curtail environmental damage. Noise barriers on highways provide a good example. It is possible that the regulatory actions stem from public hearings and other decision-making processes wherein society as a whole fully weighed the costs of implementing alternative regulatory actions against the costs of not doing so and chose the action that just balanced the benefits of the last action against its costs. If such an outcome occurred, then the control-cost of accomplishing the last unit of environmental protection would seem to be a reasonable proxy for the value of the associated goods and services.

Many economists and political observers conclude, however, that most mitigations and regulations reflect numerous other factors, such as the political power of individual legislators and lobbying groups, rather than an impartial weighing of the marginal costs of controlling environmental damages against the marginal costs of not doing so. To the extent that they are correct, these methods will arrive at an efficient outcome—i.e., the marginal cost to an MPO and the trip-makers it serves of controlling environmental impacts will equal the marginal benefit—only by chance. To the extent that they are not correct, one will arrive at an inefficient outcome and, the greater the inefficiency, the louder the calls for less environmental regulation.

The third variation on the control-cost approach is a *risk-management strategy*. It could be used if a state or MPO were concerned that the cumulative impact of protracted failure by the transportation sector and others to internalize environmental impacts eventually will yield a strident, perhaps Draconian, response. There are numerous indicators of future tightening of environmental regulation in the U.S.—such as international agreements to restrict some airborne emissions—so that it might seem prudent for a risk-management policy to incorporate the liabilities implied by these indicators. In doing so, it might estimate the present value of these potential future liabilities and use this control-cost value as the basis for weighing the environmental characteristics of various facilities.

Which approach, damage-cost or control-cost, should be used? The damage-cost approach dominates the several control-cost approaches in its theoretical footing. But electric utilities have sometimes found it infeasible in practice, leading several public utility commissions to adopt one or another form of the control-cost approach. In transportation, for example, it is easier to estimate the cost of reducing tailpipe emissions by requiring, say, new catalytic converts, than it is to measure the cost on humans, crops, and ecological systems of global warming and the effects that might accompany it. In such instances, analysts should be careful not to conclude that the control-cost approaches yield the correct values simply because they yield the only values. Where transportation policy choices are being made that can be reasonably linked to new damage (costs), the damage-cost approach is more appropriate. In summary, analysts should anticipate that all the available techniques are less than ideal and that the products from them provide insights, not answers.

C.4 MARGINAL VALUES VERSUS AVERAGE VALUES

Whatever the approach to estimating the value, one must remember that this value applies to a *change* in an environmental resource, not to the entire resource itself. In general, the marginal value associated with this change in opportunities will differ from the average value derived in a broader context. The average cost of reducing airborne or waterborne emissions for a specific transportation facility in the past will equal the marginal cost of achieving an additional reduction in the future only by chance. The distinction between average and marginal costs becomes even more important when one uses control-cost values as proxies for damage-cost values. One cannot necessarily conclude that the average, historical cost of controlling a specific type of emission, for example, equals the marginal value of the damages associated with a future, incremental change in the remaining emissions. For several important transportation costs, especially the costs of congestion, marginal costs exceed average costs.

The distinction between marginal and average cost is particularly important in transportation. Common sense and empirical evidence argue that the social costs of a vehicle-mile of travel at peak hour in congested metropolitan areas are greater the social costs of a vehicle-mile of travel at in an off-peak hour in a rural area. Yet many studies of the cost of automobile travel focus (primarily because of data limitations) on average cost: for example, they divide the portion of total air pollution costs in the U.S. attributable to auto emissions by the total annual vehicle-miles traveled (3 trillion) to get an estimate of, say, 3¢ per vehicle-mile traveled. Numbers generated in that manner cannot be applied in any specific project evaluation.

C.5 USE VALUES VERSUS NON-USE VALUES

While in some cases external impacts of transportation improvements affect goods directly (e.g., air pollution deteriorates building facades), their more common effect is on services consumers derive from natural resources. For example, if a new beltway would destroy wildlife habitat, the analysis of the economic value of the impact would focus not on the habitat itself, nor on the wildlife it supports, but on the services consumers derive from the habitat and wildlife. It would focus, for example, on the fishing, not on the fish.

Economists have separated the services consumers derive from natural resources into three categories: consumptive-use, non-consumptive-use, and non-use services. Consumptive-use services are on-site activities, such as hunting and fishing, that reduce the quantity or quality of these services for others. Non-consumptive-use services are on-site activities, such as bird-watching, that are more passive. Non-use services refers to the fact that many people derive benefits from natural resources, even when they are not on-site, when they are pleased that the preservation of a distant and isolated ecosystem will prevent extinction of a species or have some other environmental effect they consider to be positive.[4]

The distinctions among the categories of services consumers receive are important because one must use different techniques to calculate their societal values. Some consumptive-use services can be valued using techniques similar to those applied to market goods, since the individual consumes (in other words, obtains exclusive ownership of) the environmental resource. The value the successful angler places on the nutrition obtained from the fish she catches and takes home for dinner is similar, for example, to the value the unsuccessful angler places on the nutritional content of the groceries he must obtain from the market on the way home.

[4]There has been considerable controversy over both the definition of non-use values and the techniques for measuring them. For a recent entry in the literature on the definition of non-use values, see Bishop and Welsh (1992).

Non-consumptive-use services generally do not entail acquisition of exclusive ownership rights and can be enjoyed by more than one person at once. They are valued as the sum of the values of all those who want to use it today, plus the present values of all those who want to use it in the future.

Non-use services require an even broader approach. Everyone in the population might place a finite value on the protection of a particular resource, such as a national historic building. Even though the amount per individual is small, if the number of individuals holding this value is large, non-use value can become very large. This is the arithmetic that can cause environmental externalities to become compelling economic considerations.

C.6 CONCLUSIONS

The preceding discussion makes apparent the difficulty of estimating the value of many environmental externalities. There is general agreement that the damage-cost approach is theoretically correct, but for most externalities it has not produced off-the-shelf estimates of value, or even facile, unambiguous techniques for estimating value.[5] Thus, it is not surprising that some of the literature on valuing environmental externalities suggests that the attempts at quantification and valuation are uncertain, academic, and irrelevant.

Some analysts have suggested substituting a political, or dispute-resolution, process for the economic-valuation exercise by enlisting interested parties in a political process expressly focused on environmental decisions, such as determining which facilities should be included in a utility's system plan, what level of externalities should be allowed, and who should pay the costs of avoiding additional externalities. But most economists probably would respond to this suggestion by observing that, although such a process might make the debate over an MPO's decision-making less contentious, eventually the MPO cannot avoid making valuative assessments.

Dispute-resolution processes can take several forms, such as weighting and rating methods, systematic qualitative assessments, and multi-attribute methods. In general, they entail (1) identifying the multiple attributes, or evaluative criteria, that decision-makers want to take into account as they weigh resource alternatives; (2) assembling alternative resources into packages, or resource-management strategies, and (3) and ranking the packages according to the attributes under several scenarios depicting potential future conditions. The process is especially useful when, without it, decision-makers would be distracted by alternatives that, although clearly inferior to others, are not easily set aside in the absence of the disciplined multiple-attribute approach.

[5]The most recent sources we found that summarizes and evaluates a range of values for environmental externalities in transportation are Litman (1994b) and Apogee (1994).

Decision-makers usually turn to a political or a multiple-attribute process when they are wrestling with impacts, environmental or otherwise, that do not lend themselves to economic valuation. Indeed, some parties to the process might find abhorrent the very notion of assigning values to some impacts, such as increasing the probability of human mortality or rendering a species extinct.

Economists are adamant, however, in asserting that one cannot make a decision about the appropriate level of externalities without, eventually, estimating the value of those externalities relative to the cost of curtailing them. Political processes employ the evidence and political prowess of the participants as substitutes for determining the value of externalities in the absence of market mechanisms that do so. The end result, though, is that the decision-makers must weigh the value of those externalities relative to the cost of curtailing them. A decision not to act on externalities implicitly says the value of the marginal damage they cause is less than the marginal cost of curtailing them. A decision to curtail externalities says the reverse. S. David Freeman (1992) offers another expression consistent with this conclusion that, ultimately, one must confront valuation issues when making decisions about environmental externalities:

> "Your adders [the amount added to the costs of a facility or program to estimate the cost of environmental impacts] will be large numbers if your judgement and values tell you that the risks of a particular technology are great (global warming from fossil-fuel emissions is a good example). And you will oppose any add-on if you aren't concerned. We can look to scientists for factual information and to economists for the economic impact of various scenarios—but in the end, the quantification of externalities will depend on political decisions based on our collective fears, values, and options."

Appendix D

A Simplified Example of Applying Benefit-Cost Analysis to System-Level Alternatives

Estimating the present value of every benefit and cost that might result from a major transportation investment (and counting it only once) is a daunting undertaking. Analysts must contend with uncertainty about how policy alternatives will effect physical measures of transportation and environmental performance and additional uncertainty about how to value some of those effects. The valuation of costs and benefits must then be assigned to a matrix which includes dimensions of time, modes, user groups, and income categories with careful attention to avoid double counting. An analyst can quickly feel as if she must construct what one of the authors refers to as the all-by-all, eye-of-God matrix. Fortunately, better transportation investment decisions require neither omniscience nor omnipotence on the part of analysts and policymakers. While we cannot eliminate uncertainty from decision-making, there is much agreement on the essential framework and many of the most important benefits and costs can be estimated with a reasonably high degree of confidence.

In this section we propose a simplified analysis. It focuses on the benefits to users, and the direct costs that society must pay to produce these benefits. It also tests a wide range of possible environmental costs to see how it changes the results of the analysis. This example does not evaluate the distributional impacts of the alternatives under consideration.

We admit this method is incomplete, but defend it here for two reasons. First, it allows us to simplify the analysis so that its main steps can be more easily presented and understood. Second, we believe that there is a good case to be made that transportation investment could be substantially improved just by being careful in the assessment of user benefits and the direct costs of the investment (design, construction, operation, maintenance, administration, and compliance).

The example is intended to serve several purposes. First, it demonstrates the kinds of information and assumptions required to perform this type of analysis. Second, it provides an opportunity to review some of the issues raised in Chapter 3 and discuss their implications with a practical example. Finally, by providing a cursory scan of the process of benefit-cost analysis, it is intended to stimulate further thought and research on application of the framework to real world situations.

The example evaluates three alternatives for a large metropolitan transportation system level: do-nothing, adopt congestion pricing or build HOV lanes. Most benefit-cost analysis in transportation, if done at all, is applied to projects within a particular corridor. The example reinforces the need for policymakers to consider the benefits and costs of major policy decisions at the system level.[1] The example presented here makes some necessary simplifications (e.g., it does not disaggregate different trip types and travel by time of day) but it does illustrate the basic principles involved in applying benefit-cost analysis to transportation policies.

The presentation assumes a familiarity with the output of travel demand forecasting and the concepts of benefit costs analysis. Readers interested in a more detailed discussion of the theory and application benefit cost analysis to transportation projects should review any of several works cited in the bibliography including Lee (1995) and Wilbur Smith Associates and Howard Needles Tammen Bergendorff (1994).

Our example is for an MPO[2] with a population of 2.7 million in 1990 that is projected to grow to 4.1 million in 2020. Twenty-seven percent of the freeway system experiences congestion during peak periods and that percentage is expected to grow to 45% in 2020 with no change in policy. The region is trying to determine whether or not to proceed with a $3.0 billion HOV (High Occupancy Vehicle) network for the regional highway system, which would benefit both car and transit riders. In response to the ISTEA mandate to evaluate "the cost-effectiveness of alternative strategies and investments", the MPO has decided to examine the effects of implementing congestion pricing on it's existing highways as an alternative. Thus the analysis is between a supply

The 1977 AASHTO manual on user benefits analysis describes seven steps in calculating user benefits from transportation facilities. We have adapted the AASHTO approach and apply the following steps in this example:

1. Select study features.
2. Describe the projects characteristics and costs.
3. Model travel demand and calculate user costs.
4. Calculate user benefits
5. Estimate environmental costs
6. Estimate residual value
7. Determine present value
8. Conduct sensitivity analysis
9. Select preferred project

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[1]In the fall of 1995, ECONorthwest will conduct a case study for the Puget Sound Regional Council to evaluate the benefits and costs of the types of system level alternatives the agency considered in the development of its 1995 Metropolitan Transportation Plan. One issue that case study seeks to resolve is whether the travel demand modeling is reliable enough to distinguish among significantly different system level alternatives such as no-action, substantial new investments in highways, and no new highways with major investment in rapid rail transit.

[2]Some of the data used in this example describe the Puget Sound region in Washington state and were developed by the Puget Sound Regional Council. Other inputs are pure fabrication. This example is for illustrative purposes only and does not represent a formal evaluation of these alternatives in that particular geographic context.

D.1 SELECT STUDY FEATURES

The analyst needs to determine the relevant time period for the evaluation (in most cases it is the useful life of the proposed facility) and the study years for the travel demand modeling. The travel demand response to the proposal is usually modeled for only a few years at the beginning, middle and end of the entire analysis period. It is then interpolated between the study years. The analyst also needs to select the discount rate and the value of travel time used in calculating user benefits.

The period of analysis for the HOV system evaluation is thirty years which is roughly equal to the useful life of the facility. To keep things consistent we analyze the congestion pricing alternative over the same period. For simplicity's sake, we model travel demand in year 0 and year 30 and make a straight line projection between the two estimates. A more thorough analysis would estimate travel demand in year 10 when the facility is completed and in year 20 to reflect some of the non-linearity in travel demand response over time.

All the costs and benefits in this example are expressed in constant dollars and therefore a real discount rate (with the inflation component removed) is applied. The example uses a discount rate of 3% and tests a range from 1% to 10% in the sensitivity analysis. We use a value of time of $10.00 per hour for in-vehicle time and $20.00 per hour for walking and waiting time. The example uses a regional average value of time and does not break down travel demand response by different income groups with different time values. While absent in this example, such detail is necessary for precision in demand forecasting as well as analyzing the equity impacts of policy alternatives. A more complete analysis would show the allocation of benefits and costs between different income groups as well as different travel modes.

D.2 DESCRIBE PROJECT CHARACTERISTICS AND COSTS

The project must be defined in sufficient detail to allow the travel demand modeling and to allow estimates of some of the environmental costs. The capital costs of the project including the opportunity costs of all public resources committed to the project must be estimated and assigned to a particular year. The maintenance and operating cost must also be estimated for each year during the analysis period.

The HOV system will add 100 miles of HOV lanes to the existing highway system for the exclusive use of transit vehicles and passengers cars with two or more occupants. The HOV system will cost a total of $3.0 billion including the value of the right of way committed to the project. The project will be completed over 10 years with an equal amount expended in each year of construction. The annual operating and maintenance costs are equal to 5% of the capital costs.

The congestion pricing alternative uses automatic vehicle identification to charge road fees which vary by location and time of day. The fee averages \$0.12 per mile with a range from \$0.00 per mile on some roadways during the off peak to \$1.25 per mile on the most congested corridors during peak periods. The fees are set at a level so that average travel speeds along any corridor don't fall below 45 miles per hour. The congestion pricing system has a capital cost of \$200 million and annual operating costs of \$20 million.

D.3 MODEL TRAVEL DEMAND AND CALCULATE USER COSTS

For each study year travel demand must be accurately forecast. One of the weaknesses of many studies used to justify transportation investments is the failure to properly model the no build scenario. Travel models may show the entire highway network going to Level of Service F when, in fact, such a result is highly unlikely. As congestion increases, drivers change their behavior to avoid congestion by either not driving or making their trips at different times or taking different routes. It is important that the baseline forecasts include the feedback effects of increased congestion as travel demand grows.

Of equal importance are accurate forecasts of travel demand on the proposed facility. In the past, because modeling did not take into account the impact of the failure to price roadways properly, traffic engineers underestimated how quickly latent travel demand for new highway facilities will result in renewed congestion at peak travel times. If highway planners have tended to underestimate the travel demand on proposed facilities, transit agencies have had the opposite problem. The experience in many parts of the country has been for transit agencies to make overly optimistic projections of travel demand for new transit facilities (especially rail, see Pickrell (1989)). Regardless of the type of facility or policy being contemplated, estimates of user benefits are only as good as the travel demand forecasts on which they are based.

The Table D-1 shows the hypothetical results of a modeling run for the proposed HOV alternative. For the purposes of the analysis we need to compare traffic conditions with and without the proposed policy. Reading the second to last column under Change/Amount, we note that the creation of the HOV lanes has had no effect by Year 30 on the vehicle miles traveled (VMT) by single occupant vehicles (SOVs). Those travelers who moved from SOVs to HOVs have been replaced by new travelers on the regular highway lanes. HOV traffic (cars with more than 2 occupants) on the new lanes has increased by 2 million miles per day. The number of HOV person trips has increased by 500,000 per day and the number of bus trips has increased by 30,000. As a result of the improved travel times the new lanes offer, the time costs for riders in HOVs drop \$0.19 per trip in Year 30. Bus riders also enjoy faster travel times and reduced waiting time from improved bus service generating time saving of \$1.40 per trip.

The travel demand modeling for congestion pricing in Table D-2 shows a 12% reduction in the vehicle miles traveled by SOVs. Many of these travelers move to HOVs raising that mode's VMT by 5 million miles per day. However, pricing does generate an overall decrease in VMT of about 3%. Because of the reduced congestion automobiles operate more efficiently reducing automobile operating costs by $0.02 per mile. However, autos pay an average of $0.12 per mile in a road pricing fee that they did not pay before. The reduced congestion creates time savings for all modes with time costs per person per trip reduced by $0.36 for HOVs and SOVs and $2.00 for bus riders. The net effect of these changes in the components of total trip costs is that SOV user costs increase in cost an average of $0.64 per trip, HOV user costs increase by $0.04 per trip, and bus user costs drop by $2.00 per trip.

Table D-1: HOV Network Travel Demand

Travel Demand Modeling (all non-dollar figures in millions per day)	Baseline		HOV Network	Change	
	Year 0	Year 30	Year 30	Amount	%
SOV VMT	43.00	67.00	67.00	0.00	0%
HOV VMT	18.00	32.00	34.00	2.00	6%
Avg SOV operating cost/mile	$0.30	$0.30	$0.30	$0.00	0%
Avg HOV operating cost/mile	$0.30	$0.30	$0.30	$0.00	0%
Avg CP fee/mile	$0.00	$0.00	$0.00	$0.00	
SOV Trips	4.30	6.70	6.70	0.00	0%
HOV: Person trips	4.50	8.00	8.50	0.50	6%
Bus: Person Trips	0.25	0.44	0.47	0.03	7%
SOV Trip Operating cost	$3.00	$3.00	$3.00	$0.00	0%
HOV Trip Operating Cost	$3.00	$3.00	$3.00	$0.00	0%
SOV/HOV road fee per trip	$0.00	$0.00	$0.00	$0.00	
Per trip cost to transit users	$1.00	$1.00	$1.00	$0.00	0%
Total SOV Travel Time (hrs)	0.96	1.91	1.91	0.00	0%
Total HOV Travel Time (hrs)	1.00	2.29	2.27	-0.02	-1%
Total Bus Travel Time (hrs)	0.08	0.22	0.19	-0.03	-15%
Total Bus Wait & Walk Time	0.06	0.11	0.11	0.00	-2%
SOV time costs per trip	$2.22	$2.86	$2.86	$0.00	0%
HOV time costs per person trip	$2.22	$2.86	$2.67	($0.19)	-7%
Bus time costs per person trip	$8.30	$10.00	$8.60	($1.40)	-14%
Total SOV user costs per trip	$5.22	$5.86	$5.86	$0.00	0%
Total HOV user costs per PT	$3.42	$4.06	$3.87	($0.19)	-5%
Total bus user costs per PT	$9.30	$11.00	$9.60	($1.40)	-13%

Table D-2: Congestion Pricing Travel Demand

Travel Demand Modeling (all non-dollar figures in millions per day)	Baseline		Congestion Pricing		
				Change	
	Year 0	Year 30	Year 30	Amount	%
SOV VMT	43.00	67.00	59.00	-8.00	-12%
HOV VMT	18.00	32.00	37.00	5.00	16%
Avg SOV operating cost/mile	$0.30	$0.30	$0.28	($0.02)	-7%
Avg HOV operating cost/mile	$0.30	$0.30	$0.28	($0.02)	-7%
Avg CP fee/mile	$0.00	$0.00	$0.12	$0.12	
SOV Trips	4.30	6.70	5.90	-0.80	-12%
HOV: Person trips	4.50	8.00	9.25	1.25	16%
Bus: Person Trips	0.25	0.44	0.66	0.22	50%
SOV Trip Operating cost	$3.00	$3.00	$2.80	($0.20)	-7%
HOV Trip Operating Cost	$3.00	$3.00	$2.80	($0.20)	-7%
SOV/HOV road fee per trip	$0.00	$0.00	$1.20	$1.20	
Per trip cost to transit users	$1.00	$1.00	$1.00	$0.00	0%
Total SOV Travel Time (hrs)	0.96	1.91	1.48	-0.44	-23%
Total HOV Travel Time (hrs)	1.00	2.29	2.31	0.03	1%
Total Bus Travel Time (hrs)	0.08	0.22	0.26	0.04	20%
Total Bus Wait & Walk Time	0.06	0.11	0.13	0.02	20%
SOV time costs per trip	$2.22	$2.86	$2.50	($0.36)	-13%
HOV time costs per person tri	$2.22	$2.86	$2.50	($0.36)	-13%
Bus time costs per person tri	$8.30	$10.00	$8.00	($2.00)	-20%
Total SOV user costs per trip	$5.22	$5.86	$6.50	$0.64	11%
Total HOV user costs per PT	$3.42	$4.06	$4.10	$0.04	1%
Total bus user costs per PT	$9.30	$11.00	$9.00	($2.00)	-18%

D.4 CALCULATE USER BENEFITS

User benefits are calculated in the study year using the following formula:

User Benefits = $(U_0 - U_1)(V_0 + V_1)/2$

where:

U_0 = the user cost per trip without the improvement

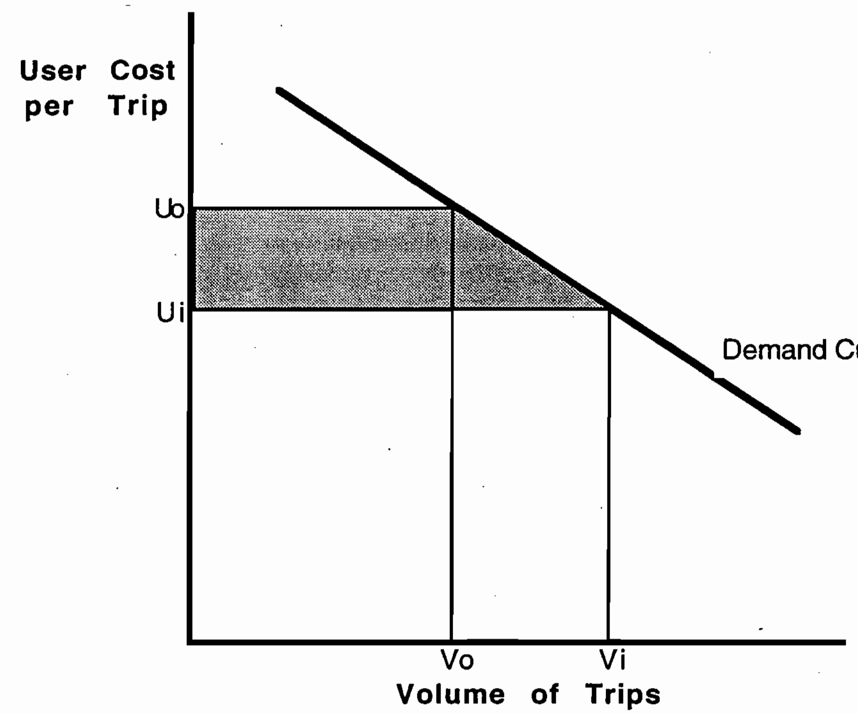
U_1 = the user cost per trip with the improvement

V_0 = the volume of trips without the improvement

V_0 = the volume of trips with the improvement

A transportation improvement lowers the user costs for a trip from U_0 to U1 which results in an increase the volume of trips taken from V_0 to V_1 (this is the essence of "latent demand"). The benefit to users of the new facility is the increase in consumer surplus show by the shaded area in Figure D-1.

Figure D-1: User Benefits From Transportation Improvements



For the HOV improvement the benefits accrue to HOV users and bus riders. Using the data from Table D-1 the daily user benefits to HOV users and bus riders are as follows:

User Benefits_{HOV} = (\$4.06 - \$3.87) (8.0 + 8.5)/2 = \$1.57 million

User Benefits_{Bus} = (\$11.00 - \$9.60) (0.44 + 0.47)/2 = \$0.64 million

The change in user benefits (positive or negative) are calculated using this formula for each mode in the study year. The results of the user benefit calculation for each mode for the HOV and Congestion Pricing examples are summarized in the subsequent section on net present value.

D.5 ESTIMATE ENVIRONMENTAL COSTS

The environmental costs associated with the transportation investments are the least amenable to ready calculation. They are unique to a particular location and transportation technology and vary considerably with different types of projects. Analysts need to make the best possible estimates of the major environmental effects and then test a reasonable range of values in the sensitivity analysis.

Our example includes the environmental costs of air pollution estimated at $0.08 per vehicle mile traveled, the average cost reported by Litman (1994b). In a rigorous study for the Los Angeles area, Small reported[3] impacts closer to $0.03 per vehicle mile traveled. In fact, pollution response is highly non-linear and policies such as congestion pricing result in air quality improvements that are greater than the proportional reduction in vehicle miles traveled because the improved operating speeds raise engine efficiency and reduce emissions. For this sensitivity analysis we test environmental costs over a very wide range, between $0.01 and $.20 per VMT, to see if it changed the relative rankings of the alternatives. As will be seen in the sensitivity analysis, it did not.

D.6 ESTIMATE RESIDUAL VALUE

Transportation projects often retain value beyond the analysis period. The present value of the future worth of those assets needs to be included as a benefit at the end of the analysis period. The HOV network is assumed to retain a value equal to half of its construction costs or $1.5 billion at the end of year 30. The capital of the congestion pricing system is assumed to have no residual value.

D.7 DETERMINE PRESENT VALUES

The stream of benefits and costs must be projected out over the analysis period and then expressed in present value terms using the selected discount rate. Figure D-2 shows the pattern of benefits and costs from the HOV network. Costs are highest in years 0 through 10 while HOV lanes are under construction. For years 11 through 30 the maintenance and operation costs remain constant. The benefits increase in a straight line from year 0 to year 30 because benefits are assumed to increase at a constant rate to the study year. More detailed modeling of years 5, 10, and 20 would likely yield a different shape to the benefits. The large benefit in the final year reflects the addition of the residual value of the project in year 30.

The present value of the stream of benefits and costs from the HOV system is presented below in Table D-3. The net present value of the benefits of the project are slightly over five billion dollars. The annual user benefits to HOV users and bus riders is offset by a decrease in air quality. The increase in vehicle miles traveled induced by the additional HOV lanes diminishes air quality generating a negative social benefit. We could just as easily call this a social cost but we leave on the benefit side for consistency with the congestion pricing example which follows. The present value of the stream of costs is $4.9 billion yielding a net present value of $180 million.[4]

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[3]Presentation at USDOT, December 1994.

[4]This example excludes several important potential costs including the increased public transit operating costs from more bus usage that is not covered by fares.

Figure D-2: HOV System: Projection of Benefits and Costs

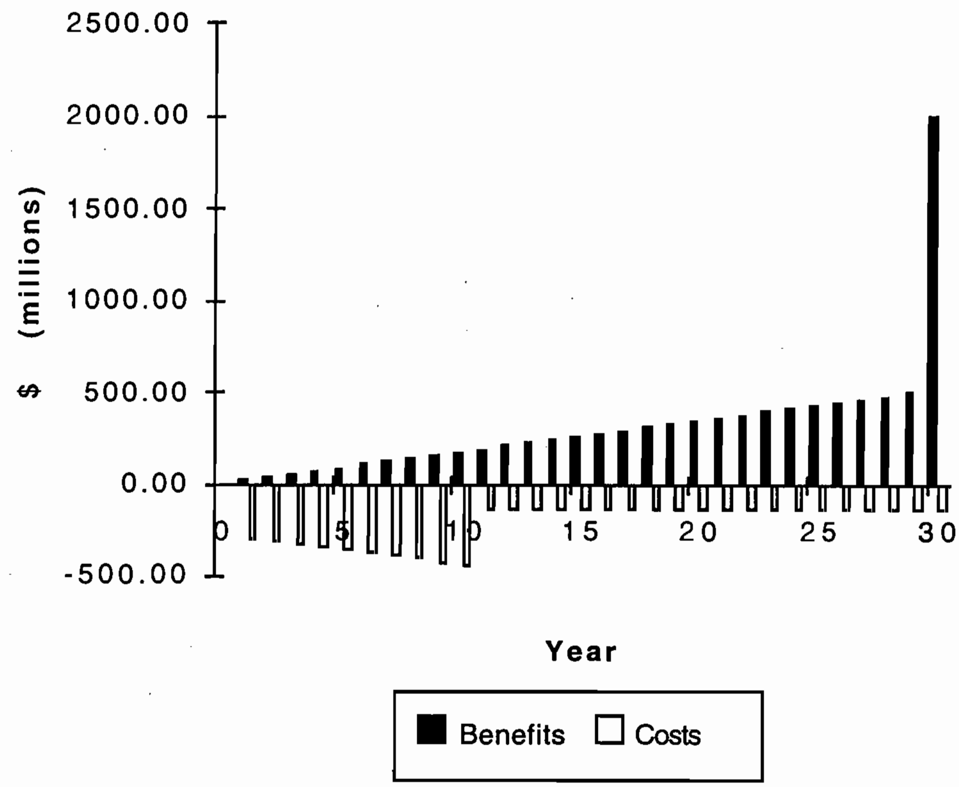
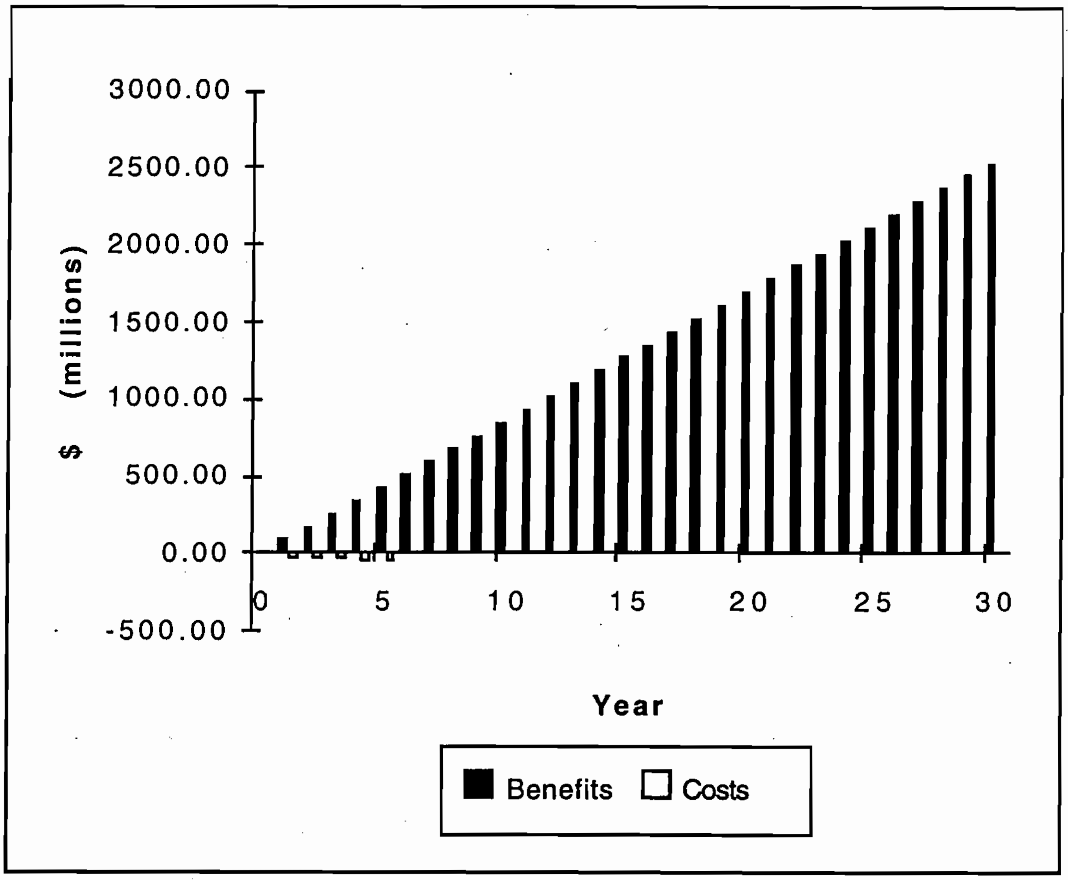


Table D-3: HOV Network: Present Value of Benefits and Costs

Present Value (millions)		
Benefits		
User Benefits	**Year 30**	
SOVs	0.00	
HOVs	392.86	
Bus Riders	159.25	
Social Benefits		
Air Quality	(40.00)	
Congestion Pricing Revenue	0.00	
Total	512.11	
Present Value of Benefits		**$5,073**
Costs		
Social Costs		
Total Capital Cost (10yr buildout)	3,000.00	
Annual Maintenance at year 10	150.00	
Present Value of Costs		**$4,892**
Net Present Value of Project		**$180**

Figure D-4 shows the pattern of benefits from congestion pricing. The benefits are projected to grow in a linear fashion from zero in year 0 to $2.5 billion in year 30. Again with more detailed modeling in some of the intermediate years a different pattern of benefits would likely appear. The costs associated with congestion pricing are quite small relative to the benefits since the policy does not require extensive capital investment.

Figure D-4: Congestion Pricing: Projection of Benefits and Costs



The benefits section of Table D-4 deserves a close look. Note that the user benefits for both SOVs and HOVs is negative. Raising the costs of driving has made those users worse off because of the additional road fee they must pay. Recall from Table 3-3 that while the time costs of trips went down for HOVs and SOVs total trip costs went up. It is this increase in total costs that encourages people to reschedule their trips or move to a less expensive mode. It is only when the revenue from the congestion pricing is included in the benefit calculation that total benefits become positive.[5] To realize the full benefits of the policy the revenue must be returned to users in a form that generates a dollar for dollar benefit. This is most easily done by returning money to people through tax reductions or rebates. The social

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[5]More detailed modeling that accounts for variations in time values would show that many high time value people are in fact made better off after paying the road fee even without receiving any of the road pricing revenue back. The value of time saved by these people exceeds the dollar cost of what they must pay in congestion prices.

benefits are also preserved if the revenue is spent on worthwhile public projects that yield a dollar of public benefit for each dollar expended.

The benefits section also shows a positive social benefit from improved air quality brought about by the reduction in total vehicle miles traveled. The net benefits of the policy are over $22 billion after subtracting out the present value of the capital costs.

Table D-4: Congestion Pricing : Present Value of Benefits and Costs

Present Value (millions)		
Benefits		
User Benefits	**Year 30**	
SOVs	(1,215.00)	
HOVs	(110.89)	
Bus Riders	330.00	
Social Benefits		
Air Quality	72.00	
Congestion Pricing Revenue	3,456.00	
Total	2,532.11	
Present Value of Benefits		**$22,026**
Costs	**Total**	
Social Costs		
Total Capital	200.00	
Annual Maintenance at Completion	20.00	
Total		
Present Value of Costs		**$537**
Net Present Value of Project		**$21,489**

D.8 CONDUCT SENSITIVITY ANALYSIS

There is always uncertainty about key assumptions in any analysis. The advent of computer spreadsheets makes it easy to test how changes in key assumptions affect the results of the analysis. Testing whether changes key assumptions within a reasonable range change the outcome of the analysis gives policymakers some indication of how robust is the estimate of net benefits.

For each of our proposed policies we test how sensitive the net benefit result is to changes in two assumptions, the discount rate and the environmental costs per vehicle mile traveled. Table D-5 shows that at a discount rate of 1%, the HOV network yields benefits for along the entire range of environmental costs but at a 3% discount rate the benefits are positive if the environmental costs are $0.01 and $0.10 per mile but at $0.20 per mile they turn negative. At a discount rate of 5% or higher, the present value of the costs exceed the present value of the benefits across the entire range of environmental costs. The feasibility of the HOV project changes within a reasonable range of assumptions. There are several implications of such a result. The first is to evaluate how all the alternatives perform over the same range of assumptions. It may be that one alternative clearly dominates the other regardless of the assumptions made and that no additional research is needed. On the hand several alternatives may be close enough that it is sensible to go back and get better information to narrow the range of reasonable assumptions.

Table D-5: HOV Network: Sensitivity Analysis of Project's Net Present Value

		Environmental Cost Per VMT		
		$0.01	$0.10	$0.20
Discount Rates	1%	1,996	1,425	790
	3%	485	93	(341)
	5%	(352)	(628)	(935)
	10%	(1,108)	(1,237)	(1,382)

The congestion pricing alternative retain positive net benefits across all the discount rate and environmental assumptions. In the case of this example, the congestion pricing alternative dominates the HOV alternative regardless of the changes in these key variables.

Table D-6: Congestion Pricing : Sensitivity Analysis of Project's Net Present Value

		Environmental Cost Per VMT		
		$0.01	$0.10	$0.20
Discount Rates	1%	30,671	31,699	32,842
	3%	20,941	21,645	22,428
	5%	14,699	15,196	15,748
	10%	6,813	7,046	7,306

D.9 SELECT PREFERRED PROJECT

Economic theory supports the completion of all projects with a net present value greater than zero. If several projects have positive net benefits, then policymakers should start with the projects with the highest benefit-cost ratios move down the list until they either run out of money or reach a project with a ratio of less than one. Several small projects with high benefit-cost ratios may provide more total net benefits when added together than does a single large project, even if each small project by itself has a smaller net present value than the large project. The benefit-cost ratio serves as a ranking mechanism for those kinds of competing projects.[6]

After all the quantitative analysis, transportation investment decisions are ultimately made in a political environment. Policymakers will evaluate information about benefits and costs along with other factors such as political feasibility and impacts on particular constituencies before making a final decision. Benefit-cost analysis provides insights that can help guide more intelligent resource allocation decisions but ultimately other non-economic factors will come to bear.

In our example, congestion pricing offers the highest benefit-cost ratios and the greatest net benefits. Policymakers would no doubt want much more information about the impacts on how the policy effects different income and user groups. The congestion pricing revenue offers the opportunity to compensate those made worse off by the policy and decision-makers would certainly want clarity on how those negative effects would be mitigated.

If policymakers decided that congestion pricing was too difficult politically, they may turn to the HOV alternative. However, the sensitivity analysis shows that at a discount rate of 5% or more, the project has costs which exceed its benefits. If policymakers apply discount rates close to those earned by investments in the private sector, then the proposed HOV program is not worth doing. After an analysis such as this one, the HOV project designers may want to go back and see if they can redesign the proposal to reduce costs and increase benefits. Benefit-cost analysis should be part of an iterative process that improves project design and gives policymakers information to integrate into their overall planning process.

[6]The fundamental decision rule for economic efficiency is to select the set of projects and policies that yield the greatest net present value. Procedures for selecting projects and policies in order to maximize NPV vary according to the nature of budget limitations and the independence or mutual exclusivity of projects. See Appendix C of AASHTO (1977) for examples of these different procedures.

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