PART II

Investment/Performance Analysis

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Introduction

Chapters 7 through 10 present and analyze future capital investment scenario estimates for highways, bridges, and transit. These chapters provide general investment benchmarks as a basis for the development and evaluation of transportation policy and program options. The 20-year investment scenario estimates shown in these chapters reflect the total capital investment from **all sources** that is projected to be required to achieve certain levels of performance. **They do not, however, directly address which revenue sources might be used to finance the investment under each scenario, nor do they identify how much might be contributed by each level of government.**

These four investment-related chapters include the following analyses:

Chapter 7, **Capital Investment Scenarios,** provides estimates of future capital investment under different scenarios. The "Cost to Maintain" scenarios for highways and bridges and for transit are designed to show a level of investment estimated to be sufficient to keep future indicators of conditions and performance at current levels. The "Cost to Improve" scenarios for highways and bridges and for transit are intended to define the upper limit of appropriate national investment based on engineering and economic criteria. **The benchmarks included in this chapter are intended to be illustrative and do not represent comprehensive alternative transportation policies.**

Chapter 8, **Comparison of Spending and Investment Scenario Estimates,** relates the estimates presented in Chapter 7 to current and anticipated highway and transit capital expenditures in the United States. The chapter identifies "gaps" that may exist between current funding levels and future investment levels under different scenarios. It also compares the current mix of highway and transit capital spending by type of improvement (especially rehabilitation and expansion) to the future investment mix suggested by the models.

Chapter 9, **Impacts of Investment,** relates historic capital funding levels to recent condition and performance trends. It also analyzes the projected impacts of different future levels of investment on measures of physical condition, operational performance, and system use.

Chapter 10, **Sensitivity Analysis,** explores the impact that varying travel growth forecasts and some other key assumptions would have on the investment scenario estimates. The investment scenario projections in this report are developed using models that evaluate current system condition and operational performance and make 20-year projections based on certain assumptions about the life spans of system elements, future travel growth, and other model parameters. The accuracy of these projections depends, in large part, on the underlying assumptions used in the analysis. The uncertainty inherent in the estimates is further discussed below.

Unlike Chapters 1 through 6, which largely include highway and transit statistics drawn from other sources, the investment scenario projections presented in these chapters (and the models used to create the projections) were developed exclusively for the C&P report. The procedures for developing the investment scenario estimates have evolved over time, to incorporate new research, new data sources, and improved estimation techniques relying on economic principles. The methodologies used to analyze investment for highways, bridges, and transit are discussed in greater detail in Appendices A, B, and C.

The combination of engineering and economic analysis in this part of the report is consistent with the movement of transportation agencies toward asset management, value engineering, and greater consideration of cost effectiveness in decision making. The economic approach to transportation investment is discussed in greater detail below.

Implications of the Investment Scenarios

The 20-year capital investment scenario projections shown in this report reflect complex technical analyses that attempt to predict the impact that capital investment may have on the future conditions and performance of the transportation system. While the discussion focuses heavily on the impacts of investing in a manner consistent with "Cost to Maintain" and "Cost to Improve" scenarios, these represent only two points on a continuum of alternative investment levels. **The Department does not endorse either of these scenarios as a target level of investment.** Where practical, supplemental information has been included to describe the impacts of other possible investment levels.

This report does not attempt to address issues of cost responsibility. The investment scenarios predict the impact that particular levels of combined Federal, State, local, and private investment might have on the overall conditions and performance of highways, bridges, and transit. While Chapter 6 provides information on what portion of highway investment has come from different revenue sources in the past, **the report does not make specific recommendations about how much could or should be contributed by each level of government in the future.**

This report has traditionally identified the amount of additional spending above current levels that would be required to achieve certain performance benchmarks, without considering the types of revenues required to support this additional spending. The implicit assumption has been that the financing mechanisms would not have any impact on the investment scenario estimates. In reality, however, increased funding from general revenue sources (such as property taxes, sales taxes, income taxes, etc.) could have different implications than increased funding from user charges (such as fuel taxes, tolls, and fares). This is particularly important on the highway side, where such user charges are one of the primary funding sources for capital investment (it is a lesser issue for transit, where farebox revenues are generally used only to fund a portion of operating costs). As discussed in the "Financing Mechanisms and Investment Analysis" section below, however, this edition of the report represents the first attempt to address this issue directly in the highway investment scenarios. The section on "Congestion Pricing and Investment Analysis" further expands on this discussion, noting the inefficiencies associated with current financing mechanisms and their implications for the investment scenario estimates.

Highway and Bridge Investment Scenarios

Future investments in highways and bridges are analyzed independently by separate models and techniques, and the results are combined for the key investment scenarios. The **Cost to Maintain** Highways and Bridges combines the **Maintain User Costs** scenario from the Highway Economic Requirements System (HERS), and the **Maintain Economic Backlog** scenario from the National Bridge Investment Analysis System (NBIAS). The **Maximum Economic Investment** for Highways and Bridges (Cost to Improve) combines the comparable scenarios from HERS and NBIAS.

The costs reported for the two scenarios also include adjustments made using external procedures, allowing elements of system rehabilitation, system expansion, and system enhancement that are not modeled in NBIAS or HERS to be reflected in the estimates. The investment scenario estimates shown should thus reflect the realistic size of the total highway capital investment program that is projected to be required in order to meet the performance goals specified in the scenarios.

Investment scenario estimates are also reported and analyzed in Chapters 7 and 8 by highway functional class and by improvement type. Chapters 11 and 12 also include investment analyses focused on the Interstate System and the National Highway System, respectively.

Investment Scenario Estimates for Capacity Expansion and Highway Resurfacing and Reconstruction

Investments for capacity expansion and the highway resurfacing and reconstruction component of system rehabilitation are modeled by HERS. While this model was primarily designed to analyze highway segments, HERS also factors in the costs of expanding bridges and other structures when deciding whether to add lanes to a highway segment. All highway and bridge investments related to capacity are modeled in HERS; NBIAS considers only investments related to bridge repair, rehabilitation, and replacement.

The Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) requires that this report include information on the backlog of infrastructure needs. It also requires that this report allow for comparability with previous versions of the C&P report. As in the 2004 edition, this report defines the highway investment backlog as all highway improvements that could be economically justified to be implemented immediately, based on the current condition and operational performance of the highway system. An improvement is considered economically justified when it corrects an existing deficiency, and the benefits of making the improvement are greater than or equal to the cost of the improvement (i.e., the benefit-cost ratio [BCR] is greater than or equal to 1). Appendix A includes a discussion of changes in modeling techniques and the impact of such changes on investment analysis.

Two HERS scenarios, related to the "Cost to Maintain" and "Cost to Improve" scenarios, are developed fully in this report: the **Maintain User Costs** scenario and the **Maximum Economic Investment** scenario. Other benchmarks are also identified in Chapter 9. These scenarios and benchmarks were developed by imposing a budget constraint placed on the HERS analysis. Under this procedure, potential highway improvements are implemented (in descending order of BCR) until the funding constraint is reached. The budget constraint can then be varied sequentially to find the funding levels that produce the results consistent with the definitions of the scenarios and benchmarks.

For the **Maintain User Costs** scenario, the funding constraint was lowered until the point where average highway user costs (travel time costs, vehicle operating costs, and crash costs) in 2024 would match the baseline highway user costs calculated from the 2004 data. Under this investment strategy, existing and accruing system deficiencies would be selectively corrected. Some highway sections would improve, some would deteriorate. Overall, average highway user costs in 2024 would match the level observed in 2004.

The **Maintain User Costs** scenario is a performance-based target, corresponding to maintaining conditions and performance as reflected by the impact that this has on highway users via travel time, safety, and vehicle operating costs. **It does not include taxes and tolls**. While such fees can *affect* conditions and performance (by raising the costs of travel to drivers and thus discouraging highway usage), they do not *reflect* conditions and performance, and are thus excluded from the calculation of the target. In economic terms, tolls and taxes are simply considered to be "transfer payments," which are excluded from the computation of user costs in evaluating the benefits of improvements. See the "Financing Mechanisms and Investment Analysis" section below for more discussion of the impact of user fees in the investment scenario analysis.

One concern that has been raised with this scenario is whether the specified performance goal could actually be attained at this level of capital investment. While the **Maintain User Costs** scenario assumes that projects would be carried out strictly in descending order of benefit-cost ratio, this is unlikely to be the case in reality. While the model focuses on engineering impacts and economic benefits, other factors do in fact influence project selection. If some projects with lower BCRs were carried out instead of projects with higher BCRs, then the actual amount necessary to achieve this performance objective would be higher. This issue is discussed in more detail in Chapter 7, in a Q&A box titled "How closely does the HERS model simulate the actual project selection process of State and local highway agencies?"

The **Maximum Economic Investment** scenario shows the highest funding level that could be justified while making investments that HERS deems to be cost-beneficial. While this scenario does not target any particular level of desired system performance, it would address the existing highway investment backlog and other deficiencies that will develop over the next 20 years because of pavement deterioration and travel growth. This scenario was generated by sequentially adjusting the funding constraint in HERS upward until the supply of cost-beneficial improvements evaluated by the model was exhausted. Under this scenario, key indicators such as pavement condition, total highway user costs, and travel time would all improve.

It should be noted, however, that simply increasing spending to the **Maximum Economic Investment** level would not in itself guarantee that these funds would be expended in a cost-beneficial manner. Achieving the projected results for this scenario would require a combination of increasing spending and modifying Federal highway program requirements and State and local government practices to ensure that no project would be implemented unless its estimated benefits exceeded its estimated costs. There may also be some projects that, regardless of their economic merits or impact on conditions and performance, may simply be infeasible for political or other reasons. As a result, the supply of feasible cost-beneficial projects could possibly be exhausted at a lower level of investment than is indicated by this scenario.

It is important to note that simple benefit-cost analysis is not a commonly utilized capital investment model in the private sector. Instead, firms utilize a rate of return approach and compare various investment options and their corresponding risk. In other words, a project that is barely cost-beneficial would almost certainly not be undertaken when compared with an array of investment options that potentially produce higher return at equivalent or lower risk.

Further information on changes in the highway investment methodology is provided in Appendix A.

Investment Scenario Estimates for Bridge Rehabilitation and Replacement

The bridge section of Chapter 7 begins with a discussion of the NBIAS model, now being used for the third time in the C&P report. Unlike previous bridge models, NBIAS incorporates benefit-cost analysis into the bridge investment evaluation.

This section discusses the current investment backlog and two future investment scenarios. As noted earlier, the amounts reported in this section relate only to bridge repair, rehabilitation, and replacement. All investments related to highway and bridge capacity are analyzed using the HERS model.

The investment backlog for bridges is calculated as the total investment that would be required to address deficiencies in bridge elements and some functional deficiencies when it is cost-beneficial to do so. Note that this analysis takes a broader approach to assessing deficiencies and does not focus on whether a bridge would be considered structurally deficient or functionally obsolete by the criteria outlined in Chapter 3.

Under the **Maintain Economic Backlog** scenario, existing deficiencies and newly accruing deficiencies would be selectively corrected such that the total economic backlog of cost-beneficial investments to correct bridge deficiencies at the end of the 20-year analysis period would be the same as the current amount. Under the **Maximum Economic Investment** scenario, all cost-beneficial bridge replacement, improvement, repair, or rehabilitation improvements would be implemented.

Changes to the NBIAS model and other aspects of the bridge investment modeling in this report are presented in Appendix B.

Investment Scenario Estimates for System Enhancement

The FHWA currently does not have a model for analyzing future investment in system enhancement (e.g., traffic control, targeted safety enhancements, and environmental enhancements). As a result, the methodology employed in Chapter 7 assumes that the share of future investment for these types of improvements under each scenario is proportional to their current share of the overall highway capital program. The purpose of this adjustment is to allow the total highway and bridge capital investment scenario estimates to be directly compared with the capital spending data presented in Chapter 6.

A similar procedure is applied to investment on rural minor collectors and rural and urban local roads, which are not included in the data used in the HERS model. Chapter 7 includes more information on the nonmodeled portion of the highway investment scenario estimates.

Transit Investment Scenarios

The transit section of Chapter 7 begins with a discussion of the Transit Economic Requirements Model (TERM), used to develop the investment scenarios for this report. TERM uses separate modules to analyze different types of investments: those aimed at the physical condition of existing assets, those intended to maintain current operating performance, and those that would improve operating performance. The TERM subjects projected investments at each transit operator to a benefit-cost test. Only those with a benefit-cost ratio greater than 1.0 eligible for inclusion in TERM's final investment scenarios. The TERM methodology is presented in greater detail in Appendix C.

The **Cost to Maintain** scenario would maintain equipment and facilities in their current state of repair and maintains current operating performance by accommodating future transit ridership growth. These investments are modeled at the transit agency level on a mode-by-mode basis. The **Cost to Improve** scenario determines the level of additional investment projected to be sufficient to improve the condition of transit assets to an average rating of "good" and to improve the performance of transit operations to targeted levels.

Transit investments are also disaggregated by type of improvement, type of asset, and urbanized area size for both the **Cost to Maintain** and the **Cost to Improve** scenarios.

Comparisons Between Report Editions

The investment scenario estimates presented in Part II are intended to be comparable with previous editions of the C&P report. However, it is important to consider several factors when making such comparisons:

<u>Different Base Years</u>. The future investment scenario estimates are calculated in constant base year dollars. However, since the base year changes between reports, inflation alone will cause the estimates to tend to rise over time.

<u>Changes in Condition or Performance</u>. Changes in the physical condition or operational performance of the highway or transit systems may affect the investment scenario estimates between reports. However, the effects are likely to be different for the "Maintain" and "Improve" scenarios.

Cost to Maintain. The "Maintain" scenarios for both highways and transit are tied to the conditions and performance of the system in the base year. If conditions and performance are deteriorating over time, however, the "target level" of the "Maintain" scenarios will be likewise declining between reports (resulting in a "lowered bar" for these scenarios). As a result, the Cost to Maintain would be likely to decrease over time for this reason alone. Conversely, if system conditions and performance are improving over time, then the "Maintain" scenarios in subsequent reports would represent an increasing standard that is being maintained.

Cost to Improve. If the conditions or performance of the underlying system deteriorates over time, then the models are likely to find more improvement projects to be cost beneficial, or to find more improvements necessary to improve the conditions or performance of the system. As a result, the Cost to Improve would be likely to increase over time. The opposite would be true if system conditions and performance were to improve over time.

Expansion of the Asset Base. As the Nation's highway and transit systems expand over time, the cost of maintaining this larger asset base will also tend to increase. For assets with useful lifetimes of less than 20 years, expansions of the infrastructure will also generate additional rehabilitation and replacement investment under the scenarios.

Changes in Technology. Changes in transportation technology may cause the price of capital assets to increase or decrease over time and thus affect the capital investment scenario estimates.

Changes in Scenario Definitions. Although the C&P report series has consistently reported investment levels for "Maintain" and "Improve" scenarios over time, the exact definition of these scenarios may change from one report to another. Such changes are explicitly noted and discussed in the text of the report when this occurs.

Changes in Analytical Techniques. The models and procedures used to generate the investment scenario estimates are subject to ongoing refinements and improvements, resulting in better estimates over time. The underlying data series used as inputs in the models may also be subject to changes in reporting requirements over time.

The Economic Approach to Transportation Investment Analysis

Background

The methods and assumptions used to analyze future highway, bridge, and transit investment scenarios are continuously evolving. Since the beginning of the highway report series in 1968, innovations in analytical methods, new empirical evidence, and changes in transportation planning objectives have combined to encourage the development and application of improved data and analytical techniques. Estimates of future highway investment requirements, as reported in the 1968 *National Highway Needs Report to Congress*, began as a combined "wish list" of State highway "needs." As the focus of national highway investment changed from system expansion to management of the existing system during the 1970s, national engineering standards were defined and applied to identify system deficiencies, and the investments necessary to remedy these deficiencies were estimated. By the end of the decade, a comprehensive database, the Highway Performance Monitoring System (HPMS), had been developed to monitor highway system conditions and performance nationwide.

By the early 1980s, a sophisticated simulation model, the HPMS Analytical Process (AP), was available to evaluate the impact of alternative investment strategies on system conditions and performance. The procedures used in the HPMS-AP were founded on engineering principles. Engineering standards were applied to determine which system attributes were considered deficient, and improvement option "packages" were developed using standard engineering practice to potentially correct given deficiencies, but without consideration of comparative economic benefits and costs.

In 1988, the FHWA embarked on a long-term research and development effort to produce an alternative simulation procedure combining engineering principles with economic analysis, culminating with the development of the HERS model. HERS was first utilized to develop one of the two highway investment scenarios presented in the 1995 C&P report. In subsequent reports, HERS has been used to develop all of the highway investment scenarios.

Executive Order 12893, *Principles for Federal Infrastructure Investments,* issued on January 26, 1994, directs that Federal infrastructure investments be selected on the basis of a systematic analysis of expected benefits and costs. This order provided additional momentum for the shift toward developing analytical tools that incorporate economic analysis into the evaluation of investment requirements.

In the 1997 C&P report, FTA introduced the TERM model, which was used to develop both of the transit investment scenarios. TERM incorporates benefit-cost analysis into its determination of transit investment levels.

The 2002 C&P report introduced the NBIAS model, incorporating economic analysis into bridge investment modeling for the first time.

Economic Focus vs. Engineering Focus

The economic approach to transportation investment relies fundamentally upon an analysis and comparison of the economic benefits and costs of potential investments. By providing benefits whose economic value exceeds their costs, projects that offer "net benefits" have the potential to increase societal welfare and are thus considered to be "good" investments from a public perspective. The cost of an investment in transportation infrastructure is simply the straightforward cost of implementing an improvement project. The benefits of transportation capital investments are generally characterized as the attendant reductions in costs faced by transportation agencies (such as for maintenance), users of the transportation system (such as savings in travel time and vehicle operating costs), and others who are affected by the operation of the transportation system (such as reductions in health or property damage costs).

Traditional engineering-based analytical tools focus mainly on estimating transportation agency costs and the value of resources required to maintain or improve the condition and performance of infrastructure. This type of analytical approach can provide valuable information about the cost effectiveness of transportation system investments from the public agency perspective, including the optimal pattern of investment to minimize life-cycle costs. However, this approach does not fully consider the potential benefits to users of transportation services from maintaining or improving the condition and performance of transportation infrastructure.

By incorporating the value of services that transportation infrastructure provides to its users, the HERS, TERM, and NBIAS models each have a broader focus than traditional engineering-based models. They also attempt to take into account some of the impacts that transportation activity has on nonusers and recognize how investments in transportation infrastructure can alter the economic costs of these impacts.

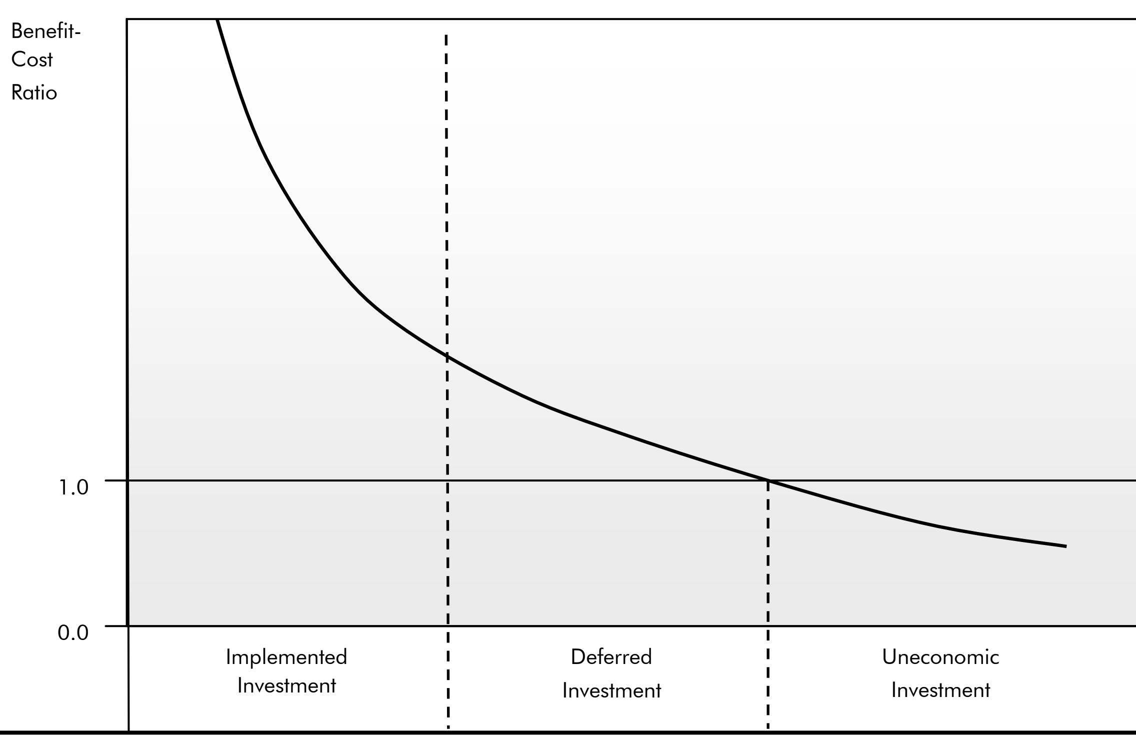
By expanding the scope of benefits considered in their analysis, these models are able to yield an improved understanding of existing and future investment needs for the Nation's surface transportation system.

Using this economics-based approach to analyze potential transportation investment is likely to result in different decisions about the catalog of desirable improvements than would be made using a purely engineering-based approach. For example, if a highway segment, bridge, or transit system is greatly underutilized, benefit-cost analysis might suggest that it would not be worthwhile to fully preserve its condition or to address its engineering deficiencies. Conversely, a model based on economic analysis might recommend additional investments to expand capacity or improve travel conditions above and beyond the levels dictated by an analysis that simply minimized engineering life-cycle costs, if doing so would provide substantial benefits to the users of the system.

The economics-based approach also provides a more sophisticated method for prioritizing potential improvement options when funding is constrained. By identifying investment opportunities in order of the net benefits they offer, economic analysis helps to provide guidance in directing limited transportation capital investment resources toward the types of system improvements that can together provide the largest benefits to transportation system users. Such an approach, which is applied in HERS, is illustrated in *Exhibit II-1.* Projects are ranked in order by their benefit-cost ratios, and are then successively implemented until the funding constraint is reached. Projects that would produce lesser net benefits would be deferred. If the funding level were great enough, it would be possible to implement all cost-beneficial projects. Projects that do not meet this threshold of economic viability (because they do not offer positive net benefits and thus cannot increase total net benefits provided by transportation system infrastructure) would not be selected or implemented, even if sufficient funding were available.

Exhibit II-1

Economically Efficient Investment



Financing Mechanisms and Investment Analysis

As discussed in Chapter 6, highway user revenues (including fuel taxes, motor-vehicle fees, and tolls) are one of the primary sources of funding for highway-related expenditures in the United States. This is particularly true for expenditures funded by the Federal government, which are predominantly drawn from user charges and are devoted primarily to capital outlay, but it is also a significant factor for State and local government expenditures. Private sector investment in highways is also dependent on revenue streams (primarily tolls) from users of the privately financed facilities.

Given the current financing structure, it is thus reasonable to assume that any increases in future highway investment would be funded to a significant degree by increases in highway user charges. By raising the out-of-pocket costs of highway travel to users, these increased charges could also reduce the demand for use of the system, and thereby reduce the amount of additional investment that would be required to achieve a given level of condition and performance, or to exhaust all cost-beneficial investments. The impact would be larger for higher funding levels, which would require greater proportional increases in user charges.

Due to limitations in the modeling techniques used for investment analysis, previous editions of the C&P report did not explore this link between financing mechanisms and the investment scenario estimates. For this report, however, the HERS model has been adapted to allow for this type of feedback between revenues and investment. The analysis assumes that the funding to support any increases in highway and bridge investment above 2004 levels would be financed in a manner consistent with the current financing structure, which is primarily supported by user fees. One implication of this new approach is that total average highway user expenditures (which would include both user costs and the user surcharge) would actually be higher in future years under the "Maintain User Costs" scenario than in the base year since, as discussed earlier, taxes and tolls are excluded from the user cost target in this scenario. Chapter 10 includes a sensitivity analysis showing the impact that this new feature has on the investment scenario estimates.

While the assumption of user surcharges via the current general financing structure draws revenues, investment, and travel demand together, it still falls short of improving the efficiency of the current regime. Travel on uncongested facilities is charged at the same rate as those with significant congestion issues, and thus continues the distortionary effect that the current financing structure has on highway use and investment. This issue is explored in the next section.

Congestion Pricing and Investment Analysis

In addition to raising revenues to fund new infrastructure investments, user fees can be applied to reduce congestion on specific facilities. This type of targeted pricing is called congestion pricing, and may be intended for the principal purpose of congestion mitigation rather than revenue generation.

When highway users make decisions about whether, when, and where to travel, they consider both the implicit costs (such as travel time and safety risk) and explicit, out-of-pocket costs (such as fuel costs and tolls) of the trip. Under normal operating conditions, their use of the road will not have an appreciable effect on the costs faced by other users. As traffic volumes begin to approach the carrying capacity of the road, however, traffic congestion and delays begin to set in and travel times for all users begin to rise, with each additional vehicle making the situation progressively worse. However, individual travelers do not take into account the delays and additional costs that their use of the facility imposes on other travelers, focusing instead only on the costs that they bear themselves. Economists refer to this divergence between the costs an individual user bears and the total added costs each additional user imposes as a *congestion externality*.

Ignoring this externality is likely to result in an inefficiently high level of use of congested facilities, resulting in a loss of some of their potential benefits to users.

To maximize net societal benefits, users of congested facilities would be levied charges precisely corresponding to the economic cost of the delay they impose on one another, thereby "internalizing" the congestion externality, spreading peak traffic volumes more efficiently (but not necessarily eliminating all congestion delay), and increasing net benefits to users. In such a case, the economically efficient level of investment in highways would depend only on the cost of building, preserving, and operating highways; valuations of travel time, vehicle operating costs, and safety; and interest rates. The price signals that such an arrangement would produce would also help guide the location of future investment in capacity expansion toward those areas where it would produce the greatest benefits.

In the absence of efficient pricing, options for reducing congestion externalities and increasing societal benefits are limited. One possibility would be to invest in additional roadway capacity beyond the level that would be "optimal" under efficient pricing, thereby reducing congestion generally and the attendant costs that highway users impose on one another. This is sometimes referred to as a "second-best" solution to the problem of optimal highway investment. One implication of this is that the maximum efficient level of investment in highway capacity would likely be larger under the current system of highway user charges (primarily fees such as fuel taxes that do not vary with congestion levels) than would be the case with efficient, marginal cost pricing of highway use.

In the real world, a number of barriers exist to the implementation of a perfectly efficient congestion pricing system. Calculating and collecting tolls impose costs on both operators and users of a toll facility, and achieving the true optimum would require both a comprehensive knowledge of user demand and the ability to continuously adjust the fees that motorists are charged. However, as these barriers are being reduced, it is becoming increasingly possible to make the current system more efficient through variable road pricing. Significant advances in tolling technology have reduced both the operating costs of toll collection and the delays experienced by users from stopping or slowing down at collection points. Technology has also made it possible to charge different toll rates during different time periods, in some cases even varying the price dynamically with real-time traffic conditions. While many of these technologies require extensive roadway infrastructure (and would thus likely be deployed only on high-volume, limited access roads), other GPS-based, in-vehicle technologies are being developed that could make it possible to assess fees on virtually any roadway (though such technologies would have their own issues and limitations that could inhibit widespread adoption and use). To the extent that such charges reflect the underlying external costs, they can reduce the welfare loss due to the underpricing of road capacity. The economically efficient level of infrastructure investment under a regime of partial pricing could also be reduced accordingly.

For this report, the HERS model has been adapted to provide quantitative estimates of the theoretical impact that more efficient pricing could have on the future highway investment scenario estimates. This illustrative analysis, presented in Chapter 10, assumes that congestion pricing would be implemented universally on all congested roads. Importantly, it does not account for the considerable costs that could be associated with implementing such a comprehensive pricing system, which could vary widely depending on the type of technology adopted to collect them. It also does not fully address the network effects associated with drivers diverting to other roads. The methodology used for this analysis is presented in greater detail in Appendix A. The "Pricing Effects" section in Part IV of this report also provides a further discussion of other ongoing research activities in this area that will be reflected in future editions of this report.

While the above discussion focuses on highway pricing, the same considerations may apply to transit investments in some cases. While most transit routes have excess capacity (measured either in terms of passengers per vehicle or vehicles per route mile), some heavily used lines in major metropolitan areas do approach their passenger-carrying capacities during peak travel hours, with commensurate deterioration in the quality of service. As with highways, some of this overcrowding relates to the underpricing of transit service during rush hours. These overcrowded transit lines are often in corridors with heavily congested highway service, making a joint solution to the pricing problems on both highways and transit not only more important to impose, but also more complicated to analyze, devise, and implement.

Multimodal Analysis

The HERS, TERM, and NBIAS all use a consistent approach for determining the value of travel time and the value of reducing transportation injuries and fatalities, which are key variables in any economic analysis of transportation investment. While HERS, TERM, and NBIAS all utilize benefit-cost analysis, their methods for implementing this analysis are very different. The highway, transit, and bridge models each rely on separate databases, making use of the specific data available for only one part of the transportation system and addressing issues unique to each mode.

These three models have not yet evolved to the point where direct multimodal analysis would be possible. For example, HERS assumes that, when lanes are added to a highway, this causes highway user costs to fall, resulting in additional highway travel. Some of the increased use of the expanded facility would result from newly generated travel, while some would be the result of travel shifting from transit to highways. However, HERS is unable to distinguish between these different sources of additional highway travel. At present, there is no direct way to analyze the impact that a given level of highway investment would have on the transit investment scenarios (or vice versa). Opportunities for future development of HERS, TERM, and NBIAS, including efforts to allow feedback between the models, are discussed in Part IV.

Uncertainty in Transportation Investment Modeling

The three investment analysis models used in this report are deterministic rather than probabilistic, meaning that they provide a single projected value of total investment for a given scenario rather than a range of likely values. As a result, it is only possible to make general statements about the limitations of these projections, based on the characteristics of the process used to develop them, rather than giving specific information about confidence intervals.

As in any modeling process, simplifying assumptions have been made to make analysis practical and to meet the limitations of available data. While potential highway improvements are evaluated based on benefit-cost analysis, not all external costs (such as noise pollution) or external benefits (such as the favorable impacts of highway improvements on productivity and competition in the economy) that may be considered in the actual selection process for individual projects are reflected in the investment models. Across a broad program of investment projects, such external effects may fully or partially cancel each other out, but to the extent that they do not, "true" level of investment required to achieve a particular goal may be either higher or lower than those predicted by the model. Some projects that HERS, TERM, or NBIAS view as economically justifiable may not be after more careful scrutiny, while other projects that the models would reject might actually be justifiable if these other factors were considered.

While it is not possible to present precise confidence ranges for the estimates found in this report, it is possible to examine the sensitivity of the estimates to changes in some of the key parameters underlying the models. Such an analysis is presented in Chapter 10.