Part II

Investment/Performance Analyses

Introduction

Chapters 7 through 10 present and analyze estimates of future capital investment requirements 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 requirement estimates shown in these chapters reflect the total capital investment required from **all sources** to achieve certain levels of performance. They do not, however, directly address which revenue sources might be used to finance the investment required by 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 Requirements,** provides estimates of future capital investment requirements under different scenarios. 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 Cost to Maintain scenarios for highways, bridges and transit are designed to show the investment required to keep future indicators of conditions and performance at current levels. 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 Requirements,** relates the estimates presented in Chapter 7 to current and anticipated highway and transit capital expenditures in the U.S. The chapter identifies any "gaps" that may exist between current funding levels and future investment requirements under different scenarios. It also compares the current mix of highway and transit capital spending by type of improvement (especially preservation 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 conditions, 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 investment requirements. The investment requirement 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 involved in the estimates is further discussed in this introduction.

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

The move from a purely engineering approach to one incorporating economic analysis 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.

Highway and Bridge Investment Requirements

Estimates of investment requirements for highways and bridges are generated 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 Backlog** scenario from the National Bridge Investment Analysis System (NBIAS). The **Cost to Improve** Highways and Bridges combines the **Maximum Economic Investment** scenario from HERS, and the **Eliminate Deficiencies** scenario from NBIAS.

As in the 1999 C&P report, the costs reported for the two scenarios also include adjustments made using external procedures. By doing so, capital investment requirements for elements of system preservation, system expansion, and system enhancement that are not modeled in NBIAS or HERS can be estimated. The investment requirements shown should thus reflect the realistic size of the total highway capital investment program that would be required in order to meet the performance goals specified in the scenarios.

Investment requirements are also reported and analyzed in Chapters 7 and 8 by highway functional class and by improvement type.

Investment Requirements for Highway Preservation and Capacity Expansion

Investment requirements for highway preservation and capacity expansion 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 investment requirements related to capacity are modeled in HERS; NBIAS considers only investment requirements related to bridge preservation and bridge replacement.

The Transportation Equity Act for the 21st Century (TEA-21) required that this report include information on the investment requirement backlog. It also required that this report provide greater comparability with previous versions of the C&P report. As in 1999, 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 its benefit/cost ratio (BCR) is greater than or equal to 1.0; i.e., the benefits of making the improvement are greater than or equal to the cost of the improvement. Appendix A includes data showing the separate effects of changes in modeling techniques and changes in the underlying data on the investment analysis.

Two HERS scenarios related to the Cost to Improve and Cost to Maintain scenarios are developed fully in this report: the **Maximum Economic Investment** scenario and the **Maintain User Costs** scenario. The investment required to **Maintain Physical Conditions** and **Maintain Average Speed** are also identified, as separate benchmarks.

The **Maximum Economic Investment** scenario would correct all highway deficiencies when it is economically justified. This scenario would address the existing highway investment backlog, as well as other deficiencies that will develop over the next 20 years due to pavement deterioration and travel growth. This scenario implements all improvements with a BCR greater than or equal to 1.0. At this level of investment, key indicators such as pavement condition, total highway user costs, and travel time would all improve.

The **Maintain User Cost** scenario shown in Chapter 7 and the **Maintain Physical Conditions** and **Maintain Average Speed** benchmarks shown in Chapter 9 were developed by progressively increasing the minimum BCR cutoff point above 1.0 so that fewer highway improvements would be implemented, until the point where these key indicators would be maintained at current levels, rather than improving. For the **Maintain User Costs** scenario, the minimum BCR cutoff point was raised until the point where highway user costs (travel time costs, vehicle operating costs, and crash costs) in 2020 would match the baseline highway user costs calculated from the 2000 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 2020 would match that observed in 2000. The **Maintain Physical Conditions** benchmark shows the level of investment required so that the projected average pavement condition at the end of the 20-year analysis period matched the current 2000 values. The **Maintain Average Speed** benchmark indicates the investment necessary to hold average highway operating speeds at their 2000 levels.

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

Investment Requirements for Bridge Preservation

The bridge section begins with a discussion of the NBIAS model, which is used for the first time in this C&P report. Unlike previous bridge models, NBIAS incorporates benefit cost analysis into the bridge investment requirement evaluation.

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

The investment backlog for bridges is calculated as the total investment 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 **Eliminate Deficiencies** scenario, all existing bridge deficiencies, and all new deficiencies expected to develop by 2020, would be eliminated through bridge replacement, improvement, repair, or rehabilitation, if it is cost-beneficial to do so. Under the **Maintain Backlog** scenario, existing deficiencies and newly accruing deficiencies would be selectively corrected. At the end of the 20-year analysis period, the total backlog of cost-beneficial investments required to correct bridge deficiencies would remain the same as the current amount.

The NBIAS model and other changes in bridge investment requirements modeling in this report are presented in Appendix B.

Investment Requirements for System Enhancements

FHWA currently does not have a model for estimating requirements for future investment in system enhancements. As a result, the methodology employed in Chapter 7 assumes that such investments will remain constant in the future as a share of the overall highway capital program, increasing or decreasing with the level of investment in system preservation and expansion. The purpose of this adjustment is to allow the total highway and bridge capital investment requirements to be directly compared to 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 estimation on non-modeled highway investment requirements.

Transit Investment Requirements

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

The **Cost to Maintain** scenario maintains equipment and facilities in their current state of repair, and maintains current operating performance while accommodating future transit growth. These investments are modeled at the transit agency level and on a mode-by-mode basis. The **Cost to Improve** scenario determines the additional investment requirements to improve the condition of transit assets to a "good" rating and improve the performance of transit operations to targeted levels. A cost-benefit analysis is performed on these investments on an urbanized area basis.

Breakdowns of transit investment requirements by type of improvement, type of asset, and urbanized area size are also presented for both the **Cost to Maintain** and the **Cost to Improve** scenarios.

Comparisons between Reports

The investment requirements 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:

- Different Base Years. Future investment requirements 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.
- Changes in Condition or Performance. Changes in the physical condition or operational performance of the highway or transit systems may affect the estimates of investment

requirements between reports. However, the effects are likely to be different for the Maintain and Improve scenarios:

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

- 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, future expansions will also affect the 20-year investment requirements estimates.
- Changes in Technology. Changes in transportation technology may cause the price of capital assets to increase or decrease over time, and thus affect the estimates of capital investment requirements.
- Changes in Scenario Definitions. Although the C&P report series has consistently reported investment requirements for Improve and Maintain 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 requirements 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 Investments

Background

The methods and assumptions used to estimate future highway, bridge, and transit investment requirements are continuously evolving. Since the beginning of the highway report series in 1968, innovations in analytical techniques, new empirical evidence, and changes in transportation planning objectives have combined to encourage the development 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 "wish list" of State highway "needs." Early in the 1970s the focus changed from system expansion to management of the existing system. National engineering standards were defined and applied in the identification of system deficiencies. By the end of the decade, a comprehensive database, the HPMS, had been developed to monitor system conditions and performance.

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. This procedure was founded on engineering principles: engineering standards defined which system attributes were considered deficient and the improvement option "packages" assigned to potentially correct given deficiencies were based on standard engineering practice.

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. The culmination of this effort was the development of the Highway Economic Requirements System (HERS). HERS was first utilized in the 1995 C&P report to develop one of the two highway investment requirement scenarios. In subsequent reports, HERS has been used to develop all of the highway scenarios.

Executive Order 12893, "Principals for Federal Infrastructure Investments," issued January 26, 1994, directs that Federal infrastructure investment be based on a systematic analysis of expected benefits and costs. This order provided additional momentum for the shift toward developing investment requirement analytical tools that would perform economic analysis.

In the 1997 C&P report, FTA introduced the Transit Economic Requirements Model (TERM), which was used to develop both of the transit investment requirement scenarios. TERM is based on extensive engineering surveys of transit asset conditions and data from the National Transit Database. TERM incorporates benefit cost analysis into its investment requirements analysis.

The FHWA has recently developed the National Bridge Investment Analysis System (NBIAS), which incorporates economic analysis into bridge investment requirements modeling for the first time. The 1999 C&P report introduced NBIAS, though it was not then used to generate estimates of bridge investment requirements. In this report, NBIAS is used for all bridge investment scenarios.

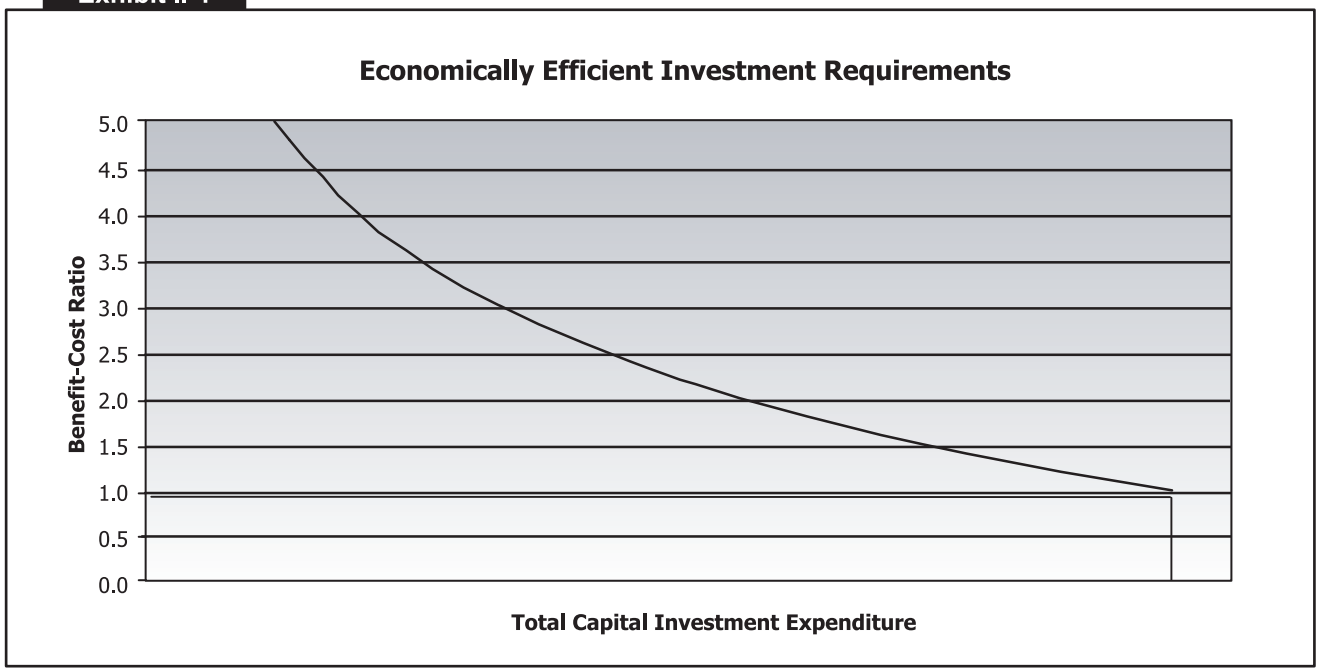
Economic Focus versus Engineering Focus

The economic approach to transportation investment is fundamentally an analysis of the economic benefits and costs of that investment. Projects with "net benefits" (benefits greater than costs) increase societal welfare, and are thus "good" investments from a public perspective. The cost of an investment 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 travel time and vehicle operating costs), and others who are affected by the operation of the transportation system (such as environmental costs).

Traditional engineering-based analytical tools focus mainly on transportation agency costs and the 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 investment from the agency perspective, predicting the optimal pattern of investment to minimize life-cycle costs. However, this approach does not fully consider the needs of the consumers of transportation services.

The HERS, TERM, and NBIAS models have a broader focus than traditional engineering-based models, looking at the service that the transportation system provides to its users. They also attempt to take into account some of the impacts that transportation investment has on non-users. By expanding the scope of benefits considered in the analysis, the models are able to yield an improved understanding of existing and future investment needs.

Exhibit II-1



One way to conceptualize the goal of the HERS, TERM, and NBIAS models is shown in Exhibit II-1. For some projects, the benefits of transportation investment greatly exceed the costs of that investment, resulting in a high benefit-cost ratio (BCR). As additional projects are considered and implemented, however, the gap between benefits and costs of subsequent projects diminishes, reducing the BCR and eventually reaching a point where further investments will no longer increase net benefits (at a BCR of 1.0). Projects that do not meet this threshold of economic viability will not be implemented by any of the three models.

Using an economics-based approach to transportation investment may result in different decisions about potential improvements than would occur 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 address its deficiencies. Conversely, an economics-based model might recommend additional investments to improve system conditions above and beyond the levels dictated by an engineering life-cycle cost analysis, 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. This helps provide guidance in directing limited transportation capital investment resources to the areas that will provide the most benefits to transportation system users.

Multimodal Analysis

HERS, TERM, and NBIAS all use a consistent approach for determining the value of travel time and the value of life, which are key variables in any economic analysis of transportation investment. However, 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 build off separate databases that are very different from one another. Each model makes use of the specific data available for its part of the transportation system, and addresses 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 this would be newly generated travel; some would be the result of travel shifting from transit to highways. However, HERS does not 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 transit investment requirements (or vice versa). Further development of HERS, TERM, and NBIAS will include efforts to allow feedback between the models.

Uncertainty in Transportation Investment Requirements Modeling

The three investment requirements models used in this report are deterministic, rather than probabilistic, meaning that they provide a single projected value rather than a range of likely values. As a result, it is only possible to make general statements about the limitations of the 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. Potential highway improvements are evaluated based on a benefit/cost analysis. However, this analysis does not include all external costs (such as noise pollution) or external benefits (such as the favorable impacts of highway improvements on the economy) that may be considered in the actual selection process of individual projects. Some of these limitations are discussed further in Chapter 15. To some extent, such external effects cancel each other out, but to the extent that they don't reveal the "true" investment requirements 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 in reality, while other projects that the models would reject might actually be justifiable, if all factors were considered.

While it is not possible to present precise confidence intervals 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.