PART II

Investment/Performance Analysis

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 directly address specific public or private revenue sources that 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, **Potential Capital Investment Impacts**, analyzes the projected impacts of alternative levels of future investment on measures of physical condition, operational performance, and benefits to system users. Each alternative pertains to investment from 2011 through 2030, and is presented as an annual average level of investment (highway and transit) and as the annual rates of increase or decrease in investment that would produce that annual average (highway only). Both the level and rate of growth in investment are measured using constant 2010 dollars.

Chapter 8, **Selected Capital Investment Scenarios**, examines several scenarios distilled from the investment alternatives considered in Chapter 7. Some of the scenarios are oriented around maintaining different aspects of system condition and performance or achieving a specified minimum level of performance, while others link to broader measures of system user benefits. The scenarios included in this chapter are intended to be illustrative and do not represent comprehensive alternative transportation policies; U.S. Department of Transportation (DOT) does not endorse any of these scenarios as a target level of investment.

Chapter 9, **Supplemental Scenario Analysis**, explores some of the implications of the scenarios presented in Chapter 8 and contains some additional policy-oriented analyses addressing issues not covered in Chapters 7 and 8. As part of this analysis, highway projections from previous editions of the C&P report are compared with actual outcomes to throw light on the value and limitations of the projections presented in this edition.

Chapter 10, **Sensitivity Analysis**, explores the impacts on scenario projections of varying some of the key assumptions. 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 assumptions about future travel growth and a variety of engineering and economic variables. The accuracy of these projections depends, in large part, on the realism of these assumptions. To address the uncertainty concerning which assumptions would be most realistic, Chapter 10 presents sensitivity analyses that vary the discount rate, the value of travel time savings, and other assumed parameter values. Other sources of uncertainty in the modeling procedures are discussed further below.

Unlike Chapters 1 through 6, which largely present 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 recent research, new data sources, and improved estimation techniques. 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 at the end of this section.

Capital 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. These scenarios are intended to be illustrative, and the U.S. DOT does not endorse any of them 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 or the private sector in the future.

In considering the system condition and performance projections in this report's capital investment scenarios, it is important to note that they represent what *could* be achievable assuming a particular level of investment, rather than what *would* be achieved. The models used to develop the projections generally assume that, when funding is constrained, the benefit-cost ratio (BCR) establishes the order of precedence among potential capital projects, with projects having higher BCRs being selected first. In actual practice, the BCR generally omits some types of benefits and costs because of difficulties in valuing them monetarily, and these other benefits and costs can and do affect project selection.

Also, some potential capital investments selected by the models, regardless of their economic merits or impact on conditions and performance, may be infeasible for political or other reasons. As a result, the supply of feasible cost-beneficial projects could be lower than the levels estimated by the modeling assumptions of some scenarios.

Highway and Bridge Investment Scenarios

Projections for future conditions and performance under alternative potential levels of investment are developed independently for highways and bridges in Chapter 7 using separate models and techniques, and then combined for selected investment scenarios in Chapter 8. Investments in bridge repair, rehabilitation, and replacement are modeled by the National Bridge Investment Analysis System (NBIAS); those in capacity expansion and the highway resurfacing and reconstruction component of system rehabilitation are modeled by the Highway Economic Requirements System (HERS). Although HERS was primarily designed to analyze highway segments, it also factors in the costs of expanding bridges and other structures when deciding whether to add lanes to a highway segment. Some elements of highway investment spending are modeled by neither HERS nor NBIAS. Chapter 8 factors these elements into the investment levels associated with each scenario using scaling procedures external to the models. The scenario investment levels are estimates of the amount of future capital spending required to meet the performance goals specified in the scenarios.

Chapter 8 uses consistent performance criteria to create separate but parallel investment scenarios for all Federal-aid highways, the National Highway System, and the Interstate System. Corresponding scenarios are also presented for all roads system-wide, but projections for these scenarios are less reliable because data coverage is more limited off the Federal-aid highways. Although the NBIAS database includes information on all bridges, the Highway Performance Monitoring System (HPMS) database, on which the HERS model relies, includes detailed information only on Federal-aid highways; for the scenarios based on all roads, non-model-based estimates must be generated for roads functionally classified as rural minor collectors, rural local, or urban local. For system-wide and Federal-aid highway investment, Chapter 8 includes an alternative set of scenarios that assume future lower reduce the vehicle miles traveled (VMT) growth forecasts derived from HPMS to match the actual trend in VMT growth from 1995 to 2010.

The **Sustain 2010 Spending scenario** projects the potential impacts of sustaining capital spending at 2010 base-year levels in constant dollar terms over the 20-year period 2011 through 2030. The **Maintain Conditions and Performance scenario** assumes that combined highway capital investment by all levels of government gradually changes in constant dollar terms over 20 years to the point at which selected performance indicators in 2030 are maintained at their 2010 base year levels. For this edition, the HERS component of the scenario is defined as the average of the investment level required to maintain average pavement roughness and the investment level required to maintain the average amount of congestion delay per VMT (the scenario is defined around the average of the investment level required to maintain each); the NBIAS component is defined as the investment level required to maintain the average sufficiency rating for bridges. The investment levels for the **Improve Conditions and Performance scenario** are determined by identifying the highest rate of annual spending growth for which potentially cost-beneficial highway and bridge improvements can be identified. This scenario represents an "investment ceiling" above which it would not be cost-beneficial to invest, even if available funding were unlimited. The portion of this scenario directed toward addressing engineering deficiencies on pavements and bridges is described as the **State of Good Repair benchmark**.

The **Intermediate Improvement scenario** is included in Chapter 8 in recognition that any investment above the level of the **Maintain Conditions and Performance scenario** described above should theoretically improve conditions and performance. The HERS portion of this scenario reflects a level of investment at which all potential improvements with a BCR of 1.5 or higher could be funded (in contrast to the **Improve Conditions and Performance scenario**, which utilizes a minimum BCR of 1.0). The NBIAS portion of this scenario assumes an increase in spending sufficient to achieve, for illustration, half the improvement in the average sufficiency index projected under the **Improve Conditions and Performance scenario**.

Transit Investment Scenarios

The transit section of Chapter 7 evaluates the impact of varying levels of capital investment on various measures of condition and performance, while the transit section of Chapter 8 provides a more in-depth analysis of specific investment scenarios.

The **Sustain 2010 Spending scenario** projects the potential impacts of sustaining preservation and expansion spending at 2010 base-year levels in constant dollar terms over the 20-year period of 2011 through 2030. The scenario applies benefit-cost analysis to prioritize investments within this constrained budget target.

The **State of Good Repair benchmark** projects the level of investment needed to bring all assets to a state of good repair over the next 20 years, defined as asset condition ratings of 2.5 or higher on a 5-point scale (Chapter 3 discusses these ratings). This scenario is focused solely on the preservation of existing assets and does not apply a benefit-cost screen.

The **Low Growth scenario** adds a system expansion component on top of the system preservation needs associated with the **State of Good Repair benchmark**. The goal of this scenario is to preserve existing assets and expand the transit asset base to support projected ridership growth over 20 years as forecast by metropolitan planning organizations. The **High Growth scenario** incorporates a more extensive expansion of the existing transit asset base to support a higher annual rate of growth consistent with that experienced between 1995 and 2010. Both of these scenarios incorporate a benefit-cost test for evaluating potential investments.

Comparisons Between Report Editions

When comparing capital investment scenarios presented in different editions of the C&P report, several considerations should be taken into account:

Scenario definitions have been modified over time. Between the present edition and the 2010 C&P report, the target performance indicators in the **Maintain Conditions and Performance scenarios** have changed. In the 2010 edition, those indicators were average speed for investments modeled by HERS and the backlog of potential cost-beneficial bridge investments modeled by NBIAS. In the present edition, the corresponding indicators are pavement roughness/congestion delay and the average sufficiency rating for bridges. In addition, the expansion of the National Highway System under the Moving Ahead for Progress in the 21st Century Act (MAP-21) means that the scenarios for that system considered in this edition of the C&P report are not comparable to those considered in the 2010 edition.

The scenarios for highway and bridge investment now present alternate sets of projections applying the 15-year historic trend in VMT growth to the assumed rate of future growth, whereas all recent editions of the report have exclusively used the traffic growth forecasts from HPMS. This change makes the highway and bridge investment scenarios more comparable to the transit investment scenarios, which introduced an alternative trend-based ridership growth forecast in the 2010 edition.

The analytical tools and data used in generating the scenarios have been refined and improved over time.

> **Q&A**
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> **Why do the scenarios presented in Part II of this report focus on the NHS as expanded by MAP-21, rather than the NHS as it existed in 2010?**
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> While the data presented in Part I of this report naturally focus on the NHS as it existed in 2010, presenting investment scenarios through the year 2030 for that version of the NHS would provide little value going forward given that MAP-21 significantly expanded the size of the system.
>
> While basing the Part II 20-year investment scenarios on the NHS as expanded by MAP-21 requires readers to be mindful that the 2010 data presented in Part I relate to the pre-expanded system, this approach was deemed preferable to the alternative of simply excluding NHS-based scenarios from this edition entirely.

The base year of the analysis advances two years between successive editions of this biennial report. During this period, changes in many real-world factors can affect the investment scenario estimates. Among these factors are construction costs and other prices, conditions and performance of the highway and transit systems, expansion of the system asset base, and changes in technology (such as improvements in motor vehicle fuel economy). While this issue is relevant to all scenarios, it is particularly significant for scenarios aimed at maintaining base-year conditions.

Selected comparisons of this report's capital investment scenarios for highways with those from previous editions are presented in Chapter 9. Chapter 9 also includes analyses that look back at the highway and bridge scenarios presented in the 1991 C&P Report to see how its projections of future conditions and performance have lined up with what has actually occurred over time, taking into account factors such as changes in capital spending and travel growth.

The Economic Approach to Transportation Investment Analysis

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, improvements in the data and techniques relating to the highway investment scenarios have resulted from innovations in analytical methods, new data and evidence, and changes in transportation planning objectives. 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 HPMS, had been developed to allow monitoring of highway system conditions and performance nationwide.

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

In 1988, the Federal Highway Administration embarked on a long-term research and development effort to produce an alternative simulation procedure combining engineering principles with economic analysis, culminating in the development of the HERS. The HERS model 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, the Federal Transit Administration introduced the Transit Economics Requirements Model (TERM), 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, incorporating economic analysis into bridge investment modeling for the first time.

The Economic Approach in Theory and Practice

The economic approach to transportation investment entails analysis and comparison of benefits and costs. Investments that yield benefits whose values exceed their costs have the potential to increase societal welfare and are thus considered "economically efficient." For such analysis to be reliable, it must give adequate consideration to the range of possible benefits and costs and the range of possible investment alternatives.

Which Benefits and Costs Should Be Considered?

A comprehensive benefit-cost analysis of a transportation investment would consider all impacts of potential significance for society and value them in monetary terms to the extent feasible. For some types of impacts, monetary valuation is facilitated by the existence of observable market prices. Such prices are generally available for inputs to the provision of transportation infrastructure, such as concrete for building highways or buses purchased for a transit system. The same is true for some types of benefits from transportation investments, such as savings in business travel time, which are conventionally valued at a measure of average hourly labor cost of the travelers.

For some other types of impacts, market prices are not available but monetary values can be reasonably inferred from behavior or expressed preferences. In this category are savings in non-business travel time and reductions in risk of crash-related fatality or other injury. As discussed in Chapter 10 (under "Value of a Statistical Life"), what is inferred is the amount that people would typically be willing to pay per unit of improvement, e.g., per hour of non-business travel time saved. These values are combined with estimates of the magnitude of the improvement (or, as may happen, deterioration).

For other impacts, monetary valuation may not be possible because of problems with reliably estimating the magnitude of the improvement, putting a monetary value on the improvement, or both. Even when possible, reliable monetary valuation may require time and effort that would be out of proportion to the likely importance of the impact concerned. Benefit-cost analyses of transportation investments will thus typically omit to value certain impacts that could nevertheless be of interest.

The benefit-cost analyses performed by the models used in this report to evaluate levels of transportation investment—HERS, NBIAS, and TERM—each omit various types of investment impacts. To some extent, this reflects the national coverage of their primary databases; while consistent with this report's focus on the Nation's highways and transit systems, such broad geographic coverage requires some sacrifice of detail to stay within feasible budgets for data collection. In the future, technological progress in data collection as well as growing demand for data for performance management systems for transportation infrastructure will likely yield richer national databases.

In addition, U.S. DOT will continue to explore other avenues for addressing impacts not captured by the suite of models used for the C&P report. One approach is to have the models represent impacts in ways that are sufficiently simplified to demand no more data than are available. This approach was taken to represent within HERS the impacts of traffic disruptions resulting from road construction. Another approach that U.S. DOT will continue to explore for the C&P report is to supplement the findings from HERS, NBIAS and TERM with evidence from other sources. This could shed additional light on various environmental, health, and community impacts of highway and transit investments. Examples include environmental impacts of increased water runoff from highway pavements, barrier effects of highways for human and animal populations, the health benefits from the additional walking activity when travelers go by transit rather than by car, and other impacts related to livability. Another effect not considered by the DOT models, but which may be significant for some transportation investments, is the boost to economic competitiveness that results when travel times among competing producers are lessened. Faced with stiffer competition from rivals in other locations, producers may become more efficient and lower prices.

What Alternatives Should Be Analyzed?

In defining the investment alternatives in a benefit-cost analysis of transportation investments, it is important to make the range of alternatives sufficiently broad. For some transit and highway projects, this would require consideration of cross-modal alternatives. Transit and highway projects can be complements, as when the addition of high-occupancy toll lanes to a freeway creates a demand for bus express services; they can also be substitutes, as when construction of a light rail line lessens the demand for travel on a parallel freeway. In contrast, HERS and TERM each focus on investment in just one mode, and to properly incorporate a cross-modal perspective would require a major increase in the level of detail in their supporting databases that, as was noted above, necessarily sacrifice detail to provide national-level coverage. For the foreseeable future, the best way to address this deficiency in future editions of the C&P report would be through review of evidence obtained from more regionally focused analyses using other modeling frameworks.

Beyond related cross-modal investment possibilities, economic evaluations of investments in highways or transit should also attempt to consider related public choices, such as policies for travel demand management and local zoning, or investment in other infrastructure.

Several previous editions of the C&P report presented the HERS modeling of highway investment combined with system-wide highway congestion pricing. Although this modeling indicated that pricing has potential to substantially reduce the amount of highway investment that would be cost-beneficial, a subsequent review of the methodology found significant limitations, which reflected in large part the lack of transportation network detail in the HPMS database. For this reason, and because the estimated effects of congestion pricing would likely have differed little from that reported in previous editions of the C&P report, the present edition does not repeat this analysis. Also omitted from this edition are HERS analyses of scenarios that adjusted future motor fuel taxes, or other taxes related to highway use, to produce changes in revenue offsetting any increases in highway investment relative to the base year level. The inclusion of this mechanism had minimal effects on the HERS results.

Future editions of the C&P report could further explore the implications for highway and transit investments of congestion pricing and other regionally or locally focused measures with which these investments could be packaged. However, because the databases supporting HERS and TERM lack regional economic and transportation network data, these models are probably not the best vehicles for such analysis. More could probably be learned from regional case studies that use alternative modeling frameworks and databases.

Measurement of Costs and Benefits in "Constant Dollars"

Benefit-cost analyses normally measure all benefits and costs in "constant dollars", i.e., at the prices prevailing in some base year that is normally near the year when the analysis is released. Future price changes may be difficult to forecast, and benefits and costs measured in base-year prices are more comprehensible.

In the simplest form of constant dollar measurement, conversion of any quantity to a dollar value is done at that quantity's base-year price. Future savings in gallons of gasoline, for example, are monetized at the average price per gallon of gasoline in the base year (with the price possibly measured net of excise tax, as in HERS). This approach is still quite common in benefit-cost analysis and was the general practice in pre-2008 editions of the C&P report. It is important to note that this approach does not assume a future without inflation, but simply that ratios among prices will remain at their base-year levels. With relative prices constant, whether a benefit-cost analysis uses actual base-year prices or those prices uniformly inflated at a projected rate of inflation is a purely a presentational issue.

An alternative approach is called for when significant changes in the relative price of a quantity important to the analysis can be predicted with sufficient confidence. What constitutes sufficient confidence is a judgment call, but some predictions carry official weight. The Energy Information Administration's *Annual Energy Outlook* forecasts changes in motor fuel prices relative to the consumer price index (CPI) 25 years out. The 2008 edition of the C&P report incorporated these CPI-deflated forecasts in the highway investment scenarios, a practice that resumes in this edition. The 2010 edition incorporated CPI-deflated forecasts of the marginal damage cost of CO_2 emissions, taken from a 2010 report by a Federal inter-agency working group, into its baseline HERS simulations; the 2013 edition continues this approach (Interagency Working Group on Social Cost of Carbon. February 2010. Social Cost of Carbon for Regulatory Impact Analysis under Executive Order 12866, http://www.whitehouse.gov/sites/default/files/omb/inforeg/for-agencies/Social-Cost-of-Carbon-for-RIA.pdf).

The modeling presented in Part II of the present edition of the C&P report moves allows for still other changes in relative prices. Chapter 10 includes sensitivity tests to examine the effects on some of the modeling results of assuming growth in the real (i.e., CPI-deflated) values of travel time savings and crash reductions, as now recommended under guidance for U.S. DOT analyses issued in 2011 by the Office of Economic and Strategic Analysis under the Assistant Secretary for Transportation Policy. This guidance recommends assuming that these values will grow over time at specified rates that are based on expected growth in real income.

Notwithstanding these allowances for likely changes in prices relative to the CPI, the analysis in this report may be considered to measure benefits and costs in constant 2010 dollars. Office of Management and Budget guidance on benefit-cost analysis defines "real or constant dollar values" as follows:

> Economic units measured in terms of constant purchasing power. A real value is not affected by general price inflation. Real values can be estimated by deflating nominal values with a general price index, such as the implicit deflator for Gross Domestic Product or the Consumer Price Index (OMB Circular No. A-94 Revised, http://www.whitehouse.gov/omb/circulars_a094).

Multimodal Analysis

The HERS, TERM, and NBIAS all use consistent valuations of travel time savings and of reductions in transportation injuries and fatalities, which are key variables in any economic analysis of transportation investment. Although HERS, TERM, and NBIAS all use benefit-cost analysis, their methods for implementing this analysis differ significantly. The highway, transit, and bridge models each rely on separate databases, making use of the specific data available for each mode of the transportation system and addressing issues unique to that 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, highway user costs will initially 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, the models provide no direct way to analyze the impact that a given level of highway investment in a particular location would have on the transit investment in that vicinity (or vice versa). Opportunities for future development of HERS, TERM, and NBIAS, including efforts to allow feedback between the models, are discussed in Appendix D.

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 possible to make only general statements about the element of uncertainty in these projections, based on the characteristics of the process used to develop them, rather than giving specific information about confidence intervals. As was indicated above, the analysis in Chapter 10 of this edition of the C&P report enables statements about the sensitivity of the scenario projections to variation in the underlying parameters (e.g., discount rates, value of time saved, statistical value of lives saved, etc.). As far as possible, the range of variation considered in these tests corresponds to the range considered plausible in the corresponding research literature or to ranges recommended in authoritative guidance. The sensitivity tests address only some of the elements of uncertainty in the scenario projections. In some cases, the uncertainty goes beyond the value of a model parameter to the entire specification of the equations in which the parameters are embedded.

The modeling undertaken for the C&P report is simplified by omitting certain effects. These are effects for which reliable quantification is either unfeasible or would require a modeling or data collection effort out of proportion with their likely significance. In particular, while the modeling uses benefit-cost analysis to evaluate potential investments in transportation infrastructure, some external costs and benefits are omitted.

The omissions include, for example, costs or benefits from impacts on noise pollution and benefits from increased competition when transportation investments improve access to markets. Across a broad program of investment projects, such external effects may fully or partially cancel each other out; to the extent that they do not, the "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.

There are differences in the relative level of uncertainty among different projections made in this report. As already noted, the projections for all roads system-wide are less reliable than those for Federal-aid highways. In addition, the projections for absolute levels of conditions and performance indicators entail more uncertainty than the differences among these levels according to an assumed level of investment. For example, if speed limits were increased nationwide in the future, contrary to the HERS modeling assumption of no change from the base-year speed limits, this might significantly reduce the accuracy of the model's projections for average speed. At the same time, the indications based on these projections of how the amount of future investments in highways affects average speed could be relatively accurate. Although investments in highway capacity expansion increase average speed, the increase will occur mainly under conditions of congestion when average speeds can be well below even the current speed limit. Under such conditions, an increase in the speed limit may have a negligible effect on the congestion reduction benefits from adding lanes.