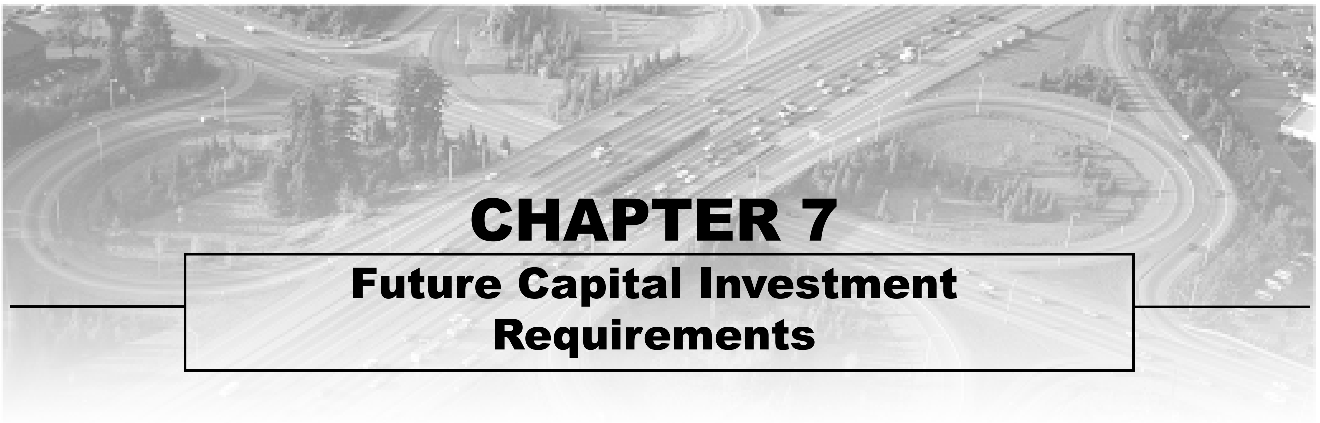


CHAPTER 7

Future Capital Investment Requirements

Introduction

This chapter provides general investment benchmarks as a basis for the development and evaluation of transportation policy and program options. The 20-year investment requirement estimates reflect the total capital investment required from **all sources** to achieve certain levels of performance. This chapter does not directly address which revenue sources might be used to finance the investment required by each scenario. It also does not identify how much might be contributed by each level of government.

The **Maximum Economic Investment** scenario for highways, the **Eliminate Deficiencies** scenario for bridges, and the **Cost to Improve** scenario for transit are intended to define the upper limit of appropriate national investment based on engineering and economic criteria. The lower highway, bridge, and transit scenarios are designed to show the level of performance that might be attained at different funding levels. The benchmarks included in this chapter are intended to be illustrative, and do not represent comprehensive alternative transportation policies.

The investment requirement projections in this report are developed using models which evaluate current system condition and operational performance, and make 20-year projections based on certain assumptions about the life spans of system elements, and future travel growth. **The accuracy of these projections depends in large part on the underlying assumptions used in the analysis.** For example, the highway travel growth forecasts included in previous versions of this report have traditionally been understated. If the highway VMT projections included in this chapter turn out to be too low, then the investment requirements may be understated. Chapter 10 explores the impacts that varying travel growth and some other key assumptions would have on the investment requirements.

The chapter begins with a summary comparing key highway, bridge and transit statistics with the values shown in the last report. The investment requirements for 1996-2015 for bridges and transit used in the last C&P report were based on 1995 data (and stated in constant 1995 dollars). In the second column of this table, these values have been indexed up to constant 1997 dollars, to make them more directly comparable to the new investment requirement projections for 1998-2017, which are based on 1997 data and shown in the third column. The highway investment requirements for 1996-2015 have been revised much more significantly, to incorporate new analytical procedures introduced in this report, and to correct some errors that were inadvertently introduced into the highway database during the preparation of the last report.

The next section contains a general discussion of the economics-based approach to analyzing transportation investments. The procedures for developing the investment requirements have evolved over time, to incorporate new research, new data sources, and improved estimation techniques. This transition to economic analysis is consistent with continued emphasis within transportation agencies toward asset management, value engineering, and greater cost-effectiveness in decision making.

Highway Investment Requirements

The highway section of this chapter begins with a discussion of the Highway Economic Requirements System (HERS), and describes how the model is used to develop future highway investment scenarios. While HERS was primarily designed to analyze highway segments, and the HERS outputs are described as "highway" investment requirements in this report, the model 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; the separate bridge models consider only investment requirements related to bridge preservation and bridge replacement.

The highway investment requirements section of the report has changed significantly from prior years. Since the release of the "1997 Status of the Nation's Surface Transportation System—Condition and Performance" report to Congress (C&P report), the FHWA has conducted a series of outreach meetings with members of the academic community and other transportation professionals on the report and the HERS model. As a result of this process, the FHWA has reevaluated several of the procedures used in the development of previous reports. For example, in earlier reports the analytical model outputs were adjusted using external procedures in an attempt to estimate investment requirements for some types of capital improvements that were not modeled. Some other types of capital improvements, such as system enhancements, were not included in the investment requirements at all. In this version of the report, the external adjustment process has been simplified, and expanded to include all types of highway capital outlay. Therefore, the investment requirements shown 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. The scenarios now attempt to include all elements of system preservation, system expansion, and system enhancement.

The 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. To meet these requirements, HERS has been modified to calculate backlog figures, a new scenario has been added to roughly correspond to the old **Cost to Maintain** scenario in the 1995 C&P report, and the Highway Performance Monitoring System (HPMS) data used to develop the 1995 and 1997 C&P reports have been rerun through the current version of HERS.

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.

Two main highway investment requirement scenarios are developed fully in this report, the **Maximum Economic Investment** scenario and the **Maintain Conditions** scenario. To facilitate comparisons between reports, the **Maintain User Costs** scenario introduced in the 1997 C&P report has been retained, but it is described as a “benchmark” in this report, and is not developed in as much detail as the two major scenarios. The investment required to **Maintain Travel Time Costs** is also identified as a separate benchmark, in response to suggestions received during the outreach meetings on the C&P report and HERS.

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 Conditions** scenario, the **Maintain User Cost** benchmark, and the **Maintain Travel Time** benchmark 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 Conditions** scenario, the minimum BCR cutoff point was raised until the point where the projected average pavement condition at the end of the 20-year analysis period matched the current 1997 values. Under this investment strategy, existing and accruing system deficiencies would be selectively corrected. Some highway sections would improve, some would deteriorate; overall, average pavement condition in 2017 would match that observed in 1997. The **Maintain User Costs** benchmark shows the level of investment required so that highway user costs (travel time costs, vehicle operating costs, and crash costs) in 2017 would match the baseline highway user costs calculated from the 1997 data. The **Maintain Travel Time** benchmark shows the level of investment to maintain only the travel time costs component of the **Maintain User Costs** benchmark.

Bridge Investment Requirements

The bridge section of this chapter 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, and are shown as highway investment requirements.

The investment backlog for bridges is calculated as the total investment required to correct all bridges currently determined to be structurally deficient or functionally obsolete. Under the **Eliminate Deficiencies** scenario, all existing bridge deficiencies and all new deficiencies expected to develop by 2017 would be eliminated through bridge replacement, rehabilitation or widening. 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 investment required to correct all structurally deficient and functionally obsolete bridges would remain the same as the current amount.

This section also contains a brief discussion of the Bridge Needs and Investment Process (BNIP) used to develop the investment requirements for this report, as well as the National Bridge Investment Analysis System (BIAS) which is currently under development. BIAS will incorporate benefit cost analysis into the bridge investment requirement evaluation in future C&P reports.

Combined Highway and Bridge Investment Requirements

The separate highway and bridge sections of this chapter are followed by a combined highway and bridge section. This portion of the chapter breaks down investment requirements by functional class. It contains an analysis of investment requirements for system preservation, system expansion, and system enhancements.

The **Cost to Maintain** Highways and Bridges combines the **Maintain Conditions** scenario for highways, and the **Maintain Backlog** scenario for bridges. The **Cost to Improve** Highways and Bridges combines the **Maximum Economic Investment** scenario for highways, and the **Eliminate Deficiencies** scenario for bridges.

The **Maintain User Costs** benchmark for Highways was not combined with a bridge scenario, because BNIP is not capable of developing a comparable user-oriented investment requirement projection.

Transit Investment Requirements

The transit section begins with a discussion of the Transit Economic Requirements Model (TERM), which was used to develop two 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. All investments identified by TERM are subject to a benefit-cost test, and only those with a BCR greater than 1.0 are implemented. Greater detail on the TERM methodology is presented in Appendix I.

The **Cost to Maintain** scenario maintains equipment and facilities in the 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 makes additional improvements to improve the condition of transit assets to a “good” rating, and improve the performance of transit operations. Investments in performance enhancements are evaluated on an urbanized area basis for TERM forecast investments. The intermediate scenarios of Maintain Conditions/Improve Performance and Improve Conditions/Maintain Performance are also presented.

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

Summary

Exhibit 7-1 compares the 20-year investment requirements in this report with those in the 1997 C&P report. The first column shows the projection for 1996-2015, as shown in the 1997 C&P report, stated in constant dollars. (Note the 1997 C&P report did not contain a comparable scenario to the Highway Maintain Conditions scenario in this report.) The second column restates the bridge and transit values in 1997 dollars, to offset the effect of inflation. The highway values shown in this column have been recalculated using the current analytical procedures. The third column shows new average annual investment requirement projections for 1998-2017.

Exhibit 7-1

Comparison of Highway, Bridge and Transit Investment Requirement Projections with those in the 1997 C&P Report

Statistic	1996-2015 Projection Based on 1995 Data		1998-2017 Projection Based on 1997 Data
	1997 Report	Revised and/or Adjusted for Inflation	
Average Annual Investment Requirements	1995 Dollars	1997 Dollars	1997 Dollars
Cost to Improve Highways, Bridges and Transit			
Highway Maximum Economic Investment scenario	$70.2 bil	$82.6 bil	$83.4 bil
Bridge Eliminate Deficiencies scenario	$ 9.3 bil	$10.0 bil	$10.6 bil
Highway plus Bridge	$79.6 bil	$92.6 bil	**$94.0 bil**
Transit Cost to Improve scenario	$14.2 bil	$14.8 bil	**$16.0 bil**
Cost to Maintain Highways, Bridges and Transit			
Highway Maintain Conditions scenario	N/A	N/A	$50.8 bil
Bridge Maintain Backlog scenario	$5.6 bil	$6.0 bil	$5.8 bil
Highway plus Bridge	N/A	N/A	**$56.6 bil**
Transit Cost to Maintain scenario	$9.7 bil	$10.1 bil	**$10.8 bil**

Transit

The projected average annual transit investment requirements for 1998-2017 are higher than those estimated for 1996–2015 in the 1997 report. While some of this increase is due to inflation, most of the difference is accounted for by the increasing backlog of existing deficiencies, and to certain improvements made to the methodology employed by TERM. Adjusting for inflation, the **Cost to Maintain** increased by 6.9 percent to $10.8 billion, and the **Cost to Improve** scenario increased by 8.1 percent to $16.0 billion.

Bridges

The projected average annual bridge investment requirements for 1998–2017 are higher than those estimated for 1996–2015 from the 1997 C&P report. However, much of this increase is the result of inflation. Converting the values from the last C&P report from 1995 dollars to 1997 dollars reveals that in constant dollar terms, the Bridge **Eliminate Deficiencies** scenario increased by 6.6 percent to $10.6 billion. The Bridge **Maintain Backlog** scenario declined by 3.3 percent in constant dollar terms to $5.8 billion.

Highways

The projected average annual highway investment requirements shown for 1998–2017 are not directly comparable to those shown for 1996–2015 in the 1997 C&P report. The scope of the reported investment requirements has also been expanded to include all types of capital improvements, making it easier to relate them to actual highway capital program levels. Also, during the preparation of the last report, some errors were inadvertently introduced into the highway database that had an impact on the results for the **Maximum Economic Investment** scenario. When these data issues were resolved, it became apparent that they had been masking some undesirable interactions between the new travel demand elasticity features in HERS, and some HERS settings and external adjustment procedures that had previously been in place. To address these problems, a number of changes have been made to the analytical procedures used to develop the investment requirements in this report. These changes are explained in more detail in Appendix G of this report. To facilitate direct comparisons, the 1995 data used to develop the last report have been corrected and reprocessed through the current version of HERS, with the results restated in 1997 dollars.

Under the highway **Maximum Economic Investment** scenario, the projected average annual investment requirements based on 1997 data of $83.4 billion are 1.0 percent higher in constant dollar terms than the restated average investment requirements based on 1995 data. This increase is largely attributable to the growth in highway travel between 1995 and 1997.

The 1997 C&P report did not contain a scenario directly comparable to the highway **Maintain Conditions** scenario in this report. The 1995 C&P report based on 1993 data projected average annual investment requirements of $49.7 billion in 1993 dollars as the Cost to Maintain highways. Reprocessing this 1993 information through the latest analytical procedures results in an estimate of $47.6 billion in 1997 dollars for the highway **Maintain Conditions** scenario. This decline is mainly the result of incorporating the procedures contained in the most recent Highway Capacity Manual (Special Report 209 of the Transportation Research Board) as discussed on page 61 of the 1997 C&P report. The projected average annual investment requirements for the **Maintain Conditions** scenario based on 1997 data are $50.8 billion, 6.7 percent higher than the restated projections based on the 1993 HPMS data, keeping all other factors constant. This is partially the result of the improvement in pavement conditions since 1993, which makes "Maintaining Conditions" at 1997 levels a more stringent standard than maintaining them at 1993 levels was.

Highways and Bridges

The **Cost to Improve** highways and bridges was $94.0 billion in 1997, combining the highway **Maximum Economic Investment** scenario with the bridge **Eliminate Deficiencies** scenario. The **Cost to Maintain** highways and bridges was $56.6 billion in 1997, combining the highway **Maintain Conditions** scenario and the bridge **Maintain Backlog** scenario.

Based on the conditions and performance of the highway system as of 1997, the backlog of cost-beneficial highway investments is estimated to be $166.7 billion. The backlog of bridge investments is estimated to be $87.3 billion in 1997.

Economics-Based 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 is founded on engineering principles: engineering standards define which system attributes are considered deficient and the improvement option “packages” assigned to potentially correct given deficiencies are based on standard engineering practice.

In 1988, the FHWA embarked on a long-term research, development, testing and critical review effort to produce an alternative, economic-based simulation procedure. 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, “Principles 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 incorporates benefit cost analysis into its improvement selection procedures.

The FHWA is currently developing the National Bridge Investment Analysis System (BIAS), which will incorporate economic analysis into the bridge investment requirements in future C&P reports.

Economic Focus Versus Engineering Focus

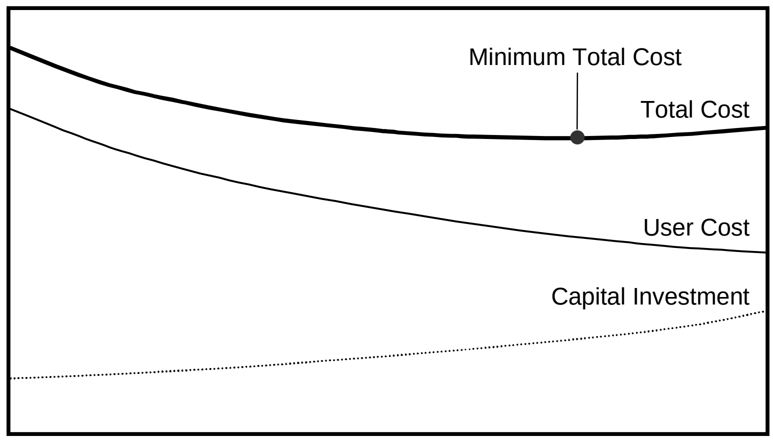
Traditional engineering-based analytical tools focus mainly on transportation agency costs and the resources required to maintain or improve the condition and performance of infrastructure. This type of analytical approach can provide valuable information about the cost effectiveness of transportation 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 BIAS models have a broader focus than traditional engineering-based models, looking at the service that the transportation system provides to its users. The goal of this economic analysis is generally to maximize benefits, and to minimize the combined costs incurred by transportation agencies, transportation system users, and third parties that are affected by the operation of the transportation system.

One way to conceptualize the goal of the HERS, TERM, and BIAS models is presented in Exhibit 7-2. The lines marked "user cost" and "capital investment" indicate that as transportation investment increases, user costs decline. However, at some point the additional increment of investment will fail to result in user cost reductions sufficient to warrant the additional investment. This point is indicated on the "total cost" line as the Minimum Total Cost.

Exhibit 7-2

Economic-Based Approach to Transportation Investments Schematic



Note: This diagram is a general representation that does not fully reflect specific cost and benefits considered by each of the individual models. The lines are not drawn to scale.

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 economic-based approach also provides a more sophisticated method for prioritizing potential improvement options when funding is constrained. This helps ensure that limited transportation capital investment resources are directed to the areas that will provide the most benefits to transportation system users.

Multimodal Analysis

HERS, TERM, and BIAS 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 BIAS 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. As HERS, TERM, and BIAS continue to evolve, it should become easier to integrate their separate approaches.

Highway Investment Requirements

The highway investment requirements shown in this report are developed primarily from the Highway Economic Requirements System (HERS), a simulation model that employs incremental benefit/cost analysis to evaluate highway improvements. The HERS analysis relies on the Highway Performance Monitoring System (HPMS) to provide information on the current conditions and performance and anticipated future travel growth for a nation-wide sample of more than 120,000 highway sections. While HERS analyzes these sample sections individually, the model is designed to provide results valid at the national level, and does not provide definitive improvement recommendations for individual highway segments.

The HERS results are supplemented by external adjustments to account for functional classes not included in the HPMS database, and for types of capital investment that are not currently modeled. This procedure has been streamlined for this report, replacing some old procedures originally developed to supplement the HPMS Analytical Process, that are not fully compatible with the new HERS approach. The external adjustment process has also been expanded to account for all types of highway capital investment. In previous reports, some types of improvements were not included in the reported investment requirements. These amounts derived from these external adjustments are identified separately in this report, since they would be expected to be less reliable than those derived from HERS.

While HERS was primarily designed to analyze highway segments, and the HERS outputs are described as "highway" investment requirements in this report, the model 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; the separate bridge models consider only investment requirements related to bridge preservation.

Q. **What is the reliability of the highway investment requirement projections made in this report?**

A. The HERS model is deterministic, rather than probabilistic, meaning that it provides a single predicted value rather than a range of likely values. Therefore, we can not make specific statements about confidence intervals. However, we can make some general statements about the limitations of the projections, based on the characteristics of the process used to develop them.

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 system reliability, and on the economy. To some extent, such external effects cancel each other out, but to the extent that they don't the "true" investment requirements may be either higher or lower than those predicted by the model. Some projects that HERS views as economically justifiable may not be in reality. Other projects that HERS would reject might actually be justifiable, if all factors were considered.

Highway Economic Requirements System (HERS)

HERS initiates the investment requirement analysis by evaluating the current state of the highway system using information on pavements, geometry, traffic volumes, vehicle mix, and other characteristics from the HPMS sample dataset. Using section-specific traffic growth projections, HERS forecasts future conditions and performance for four 5-year periods. At the end of each period, the model checks for deficiencies in eight highway section characteristics: pavement condition, surface type, volume/capacity (V/C) ratio, lane width, right shoulder width, shoulder type, horizontal alignment (curves), and vertical alignment (grades).

When HERS determines a section's pavement or capacity is deficient, it will identify potential improvements to correct some or all of the section's deficient characteristics. HERS evaluates seven kinds of improvements: reconstruction with more lanes, reconstruction to wider lanes, pavement reconstruction, major widening, minor widening, resurfacing with shoulder improvements, and resurfacing. For each of these seven kinds of improvements, HERS evaluates four alignment alternatives: improve curves and grades, improve curves only, improve grades only, or no change. Thus, HERS has 28 distinct types of improvements to choose from. When analyzing a particular section HERS actively considers no more than six alternative improvement types at a time; one or two aggressive improvements that would address all of the section's deficiencies, and three or four less aggressive improvements that would address only some of the section's deficiencies.

When evaluating which potential improvement, if any, should be implemented on a particular highway section, HERS employs incremental benefit/cost analysis. HERS defines benefits as reductions in direct highway user costs, agency costs, and societal costs. Highway user benefits are defined as reductions in travel time costs, crashes, and vehicle operating costs. Agency benefits include reduced maintenance costs and the residual (salvage) value of the projects. Societal benefits include reduced vehicle emissions. These benefits are divided by the costs of implementing the improvement to arrive at a benefit/cost ratio (BCR) that is used to rank potential projects on different sections. The HERS model implements improvements with the highest BCR first. Thus, as each additional project is implemented, the marginal BCR and the average BCR of all projects implemented declines. However, up until the point where the marginal BCR falls below 1.0 (i.e., costs exceed benefits), total benefits will continue to increase as additional projects are implemented. Investment beyond this point would not be economically justified, since it would result in a decline in total benefits.

Q. **How closely does the HERS model simulate the actual project selection processes of State and local highway agencies?**

A. The HERS model is intended to approximate, rather than replicate, the decision processes used by State and local governments. HERS does not have access to the full array of information that local governments would use in making investment decisions. This means that the models may recommend making some highway and bridge improvements that simply are not practical due to factors the model doesn't consider. Excluding such projects would result in reducing the "true" level of investment that is economically justifiable. Conversely, the highway model assumes that State and local project selection will be economically "optimal" and doesn't consider external factors such as whether this will result in an "equitable" distribution of projects among the States or within each State. In actual practice, there are other important factors included in the project selection process aside from economic considerations, so that the "true" level of investment required to achieve the outcome desired under the scenarios could be higher than that shown in this report.

Q. **Does HERS identify a single "correct" level of highway investment?**

A. No. HERS is a tool for estimating what the consequences may be of various levels of spending on highway condition and performance. If funding were unlimited, it might make sense to implement all projects identified by HERS as cost-beneficial. In reality however, funding is constrained, and highways must compete for funding with other public sector priorities. The investment requirement scenarios in this chapter estimate the resources that would be required to attain certain levels of performance, but are not intended to endorse any specific level of funding as "correct".

Travel Demand Elasticity

The States furnish projected travel for each sample highway section in the HPMS dataset. The HERS model uses these projections as an initial baseline, but alters them in response to changes in highway user costs on each section over time. Travel demand elasticity procedures have been added to HERS to recognize that as a highway becomes more congested, travel volume on the facility is constrained, and that when lanes are added to a facility, the volume of travel may increase.

The basic principal behind demand elasticity is that as the price of a product increases, consumers will be inclined to consume less of it, and either consume more of a substitute product or simply do without. Conversely, if the price of a product decreases, consumers will be inclined to consume more of it, either in place of some other product or in addition to their current overall consumption.

The travel demand elasticity procedures in HERS treat the cost of traveling a facility as its price. As a highway becomes more congested, the cost of traveling the facility (i.e., travel time costs) increases, which tends to constrain the volume of traffic growth. Conversely, when lanes are added and the highway user costs decreases, the volume of travel will tend to increase.

The travel demand elasticity values used in this report are higher than the values used in the 1997 C&P report. This increase further constrains travel growth in congested urbanized areas. This change was made partly to capture some of the effects of Travel Demand Management (TDM) programs that were previously simulated by reducing the HPMS baseline forecasts. The rationale for this change is explained in Appendix G.

Q. **What assumptions does the HERS model make about the travel forecasts in the HPMS dataset?**

A. HERS assumes that the forecasts for each sample highway segment represent the travel that will occur if the level of service remains constant on that section. This implies that travel will only occur at this level if pavement and capacity improvements made on the segment during the next 20 years are sufficient to maintain highway-user costs at current levels. Note that at current funding levels, HERS assumes that VMT will grow more slowly than the HPMS baseline forecasts, particularly in large urbanized areas.

Q. **What are some examples of the types of behavior that the travel demand elasticity features in HERS represent?**

A. If highway congestion worsens in an area, this increases travel time costs. This might cause highway users to shift to mass transit, or it might cause some people living in that area to forgo some personal trips they might ordinarily make. For example, they might be more likely to combine multiple errands into a single trip, because the time spent in traffic on every trip discourages them from making trips unless it is absolutely necessary.

In the longer term, people might make additional adjustments to their life-styles in response to changes in user costs that would impact their travel demand. For example, if travel time in an area is reduced substantially for an extended period of time, some people may make different choices about where to purchase a home. If congestion is reduced, purchasing a home far out in the suburbs might become more attractive, since commuters would be able to travel further in a shorter period of time.

The particular values of elasticity used in this report are within the ranges of the available literature on this subject, and are intended to reflect that the majority of the impact on travel demand will occur in the short term, within 5 years.

For short term elasticity, HERS now uses a value of -1.0. An additional -0.6 (total, -1.6) is used for long-term elasticity. The short-term elasticity is used within the 5-year period being analyzed and long-term elasticity is used in the remainder of the overall analysis period.

For example, if highway-user costs on a given highway facility increased by 10 percent, the model predicts that travel on the facility would decline by 10 percent below the baseline forecast within 5 years, and by an additional 6 percent within 20 years. Conversely, a reduction of user costs would cause a corresponding increase in highway travel on the facility.

As a result of travel demand elasticity, the overall level of highway investment has an impact on the projected travel growth. For any highway investment requirement scenario that results in a decline in average highway user costs,

Q. How do the travel demand elasticity features in HERS reflect the effects of Transportation Demand Management (TDM) programs?

A. To some extent, the HERS elasticity features mimic the effect that transportation demand management programs would be expected to have on the level and location of future travel growth. The elasticity features suppress highway travel growth in areas where widening is not feasible, or congestion is increasing. The model assumes that individual highway users will change their driving patterns and lifestyle choices in response to these factors, which will slow the rate of highway travel growth in large urbanized areas. However, these shifts will not occur at the assumed rate unless these drivers have viable alternatives.

Federal, State and local TDM programs serve to provide these alternatives. The 1990 Clean Air Act Amendments require States and localities to reduce vehicular emissions by implementing transportation control measures to manage travel demand and improve traffic flow. These measures include TDM programs that provide alternatives to single-occupant-vehicle travel such as options for carpooling, transit, and bicycling. These include:

- Bicycle/pedestrian facilities - provision of paths, special lanes, lockers, showers, or other facilities.
- Area-wide ridesharing - a program that provides carpool matching and information services.
- HOV lanes - highway lanes reserved for high-occupancy vehicles, i.e., buses, vanpools, and carpools.
- Park & ride facilities - parking lots or facilities located to provide access to a transit station, HOV lane, bus service, or to encourage carpooling.
- Transit improvements - transit service expansion or improvements.

In addition, the following TDM measures are available for implementation by employers:

- Compressed workweeks - extension of the typical workday in order to reduce the number of days worked, thereby reducing the number of work trips.
- Telecommuting - arrangements allowing employees to work at home or at satellite offices close to home.
- Employer trip reduction - a State or local government regulated program requiring employers, usually above a certain size, to implement plans that encourage employees to reduce vehicle travel to work.

The HERS elasticity values are set at a relatively high level. If the TDM programs listed above are less than fully successful in providing viable transportation alternatives, VMT growth will probably exceed the levels predicted by HERS. If TDM programs are more successful than the elasticity values in HERS imply, then VMT growth could be lower than the level projected by HERS. Chapter 10 explores the effects that different travel growth assumptions would have on the investment requirement projections.

the effective VMT growth rate will tend to be higher than the baseline rate. For scenarios in which high-way user costs increase, the effective VMT growth rate will tend to be lower than the baseline rate. This effect is discussed in more detail in Chapter 9.

Q. **Are the travel demand elasticity values used in HERS appropriate for use in other types of applications?**

A. Since HERS analyzes individual highway segments in isolation, rather than corridors, or the highway network as a whole, the elasticity values need to account for trips that might shift to or from a parallel highway route, as well as trips that might shift to or from other modes of transportation, or that might be induced or suppressed entirely. For network analysis, it would be more appropriate to use lower elasticity values.

Highway Investment Backlog

As defined in this report, the highway investment backlog represents all highway improvements that could be economically justified to be implemented now, based on the current conditions and operational performance of the highway system. To calculate the backlog, HERS has been modified to evaluate the current state of each highway section before projecting the effects of future travel growth on congestion and pavement deterioration. Any potential improvement that would correct an existing pavement or capacity deficiency, and that has a benefit/cost ratio greater than or equal to 1.0 would be considered to be part of the current highway investment backlog. Based on this “Year 0” analysis, HERS estimates that a total of $166.7 billion of investment could be justified based solely on the current conditions and operational performance of the highway system. Note that the backlog represents a one-time cost, rather than an annual value. Note also that this figure does not include rural minor collectors, or rural and urban local roads and streets, since HPMS does not contain sample section data for these functional systems.

Q. **How does the highway backlog cited in this report compare with the value included in the 1993 C&P report?**

A. The backlog cited in this report is lower, primarily due to a change in assumptions about widening. In earlier versions of the C&P report, it was assumed that if a State coded that widening was “infeasible” for a certain HPMS sample section, that any new lanes added to that section would be very expensive. For this report, if a State has indicated that widening is “infeasible” for a section, HERS will not add lanes to the section under any circumstances. [See the discussion of “High-Cost Lanes” in Appendix G.] The implication of this change in assumptions is that some projects involving high-cost lane additions that were included in the backlog in the 1993 C&P report are not included in this report.

The values included in the 1993 C&P report were derived from the HPMS Analytical Process (AP) model. Using the same assumptions about widening feasibility, the AP produces estimates of highway backlog that are similar to the HERS-derived values shown in this report.

Approximately 72 percent of the backlog is in urban areas, with the remainder in rural areas. About 42 percent of the backlog relates to capacity deficiencies on existing highways; the remainder are pavement deficiencies. The backlog figure does not contain any estimate for system enhancements or for the construction of new roads and bridges.

Highway Investment Requirement Scenarios and Benchmarks

The investment requirement scenarios and benchmarks in this report project total investment requirements for period 1998–2017. The **Maximum Economic Investment** scenario would implement all improvements with a BCR greater than or equal to 1.0. This scenario would eliminate the existing highway investment backlog, and address other deficiencies that will develop over the next 20 years due to pavement deterioration and travel growth.

The **Maximum Economic Investment** scenario is of interest mainly because it defines the upper limit of highway investment that could be economically justified. This scenario does not target any particular level of desired system performance. However, by varying the minimum BCR cutoff, HERS can identify the impact that different levels of investment have on certain key indicators. Exhibit 7-3 demonstrates how this approach was used.

The graph shows the impact that varying the minimum BCR cutoff has on the level of investment recommended by HERS. The table shows the impact that the various levels of investment have on average IRI, average total user costs, and average travel time costs. (See Chapter 9 for other impacts of different levels of investment.) Each row in the table represents a different minimum BCR cutoff point, shown in the first column.

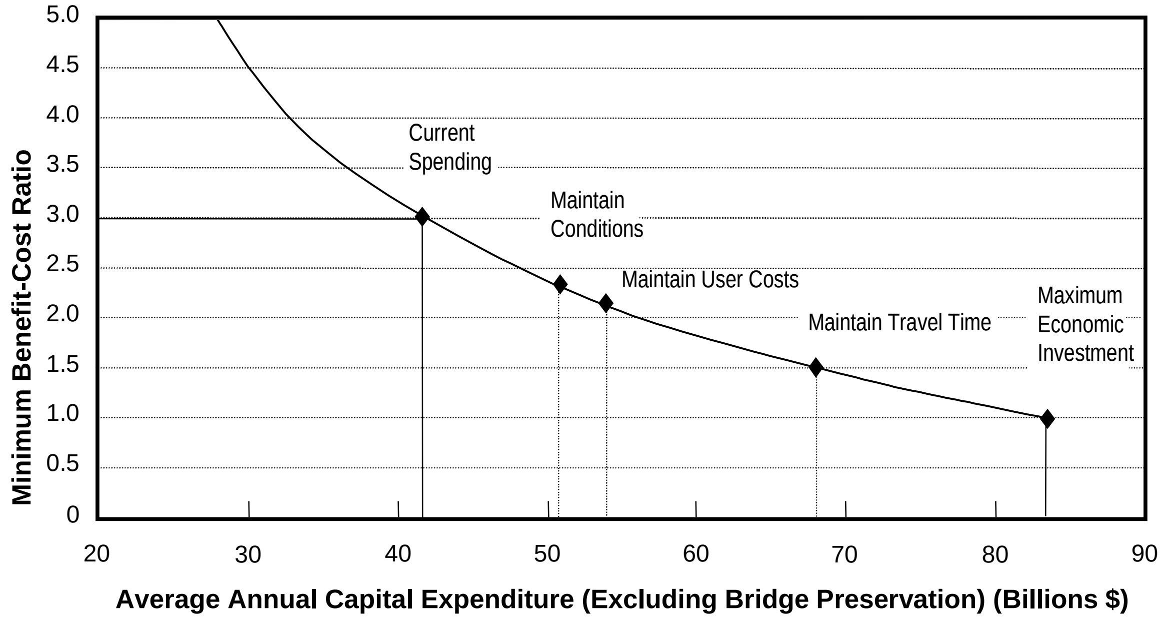
The top row in the table in Exhibit 7-3 represents a minimum BCR of 1.00, and is defined as the **Maximum Economic Investment** scenario, as indicated in the far-right hand column of the table. As shown in the third column, the average annual investment required under this scenario is $83.4 billion. The fifth, sixth, and seventh columns of the table reflect that at this level of investment, average pavement roughness, highway user costs and travel time costs would all improve. Average IRI would decline (improve) 18.3 percent compared to the baseline 1997 level. Average total highway user costs (including travel time costs, vehicle operating costs, and crash costs) would decline by 1.8 percent below the baseline 1997 level in constant dollar terms. The travel time costs component of highway user costs would decline by 0.9 percent below the 1997 baseline. As shown in the second column, at the average investment level required under the Maximum Economic Investment scenario, the average BCR would be 3.67, since many of the projects implemented would have a BCR that is much higher than the minimum BCR cutoff of 1.0. This indicates that an average of $3.67 dollars of benefits would be obtained from every dollar of expenditure.

Although the graph in Exhibit 7-3 has been drawn to include the total highway investment requirements shown in the third column of the table, the minimum and average BCRs reported in Exhibit 7-3 are actually based only on the “Directly Modeled” amounts shown in the fourth column of the table. The total investment requirements shown in the third column include both amounts derived from HERS, and additional amounts added to account for functional classes not included in the HPMS database, and for types of capital investment that are not currently modeled. These additional investment requirements have not been subjected to the same sort of benefit cost analysis as those developed in the HERS model. The external adjustments are discussed in more detail in Appendix G.

The remaining rows in Exhibit 7-3 show the effect of varying the minimum BCR cutoff point. As shown in the fourth row of the table, raising the minimum BCR cutoff to 1.50 would reduce the level of recommended investment to the level required to keep travel time costs constant at 1997 levels. Setting the minimum BCR cutoff to 2.15 (eighth row) would reduce the level of recommended investment to the level required to maintain user costs at 1997 levels. Raising the minimum BCR cutoff point to 2.33 (tenth row) would reduce the level of recommended investment to the level required to maintain average pavement roughness at 1997 levels. The level of total investment shown for the bottom row of the table (minimum BCR = 3.00) approximates actual spending in 1997 for types of improvements that are modeled in HERS.

Exhibit 7-3

Investment Requirements at Different Minimum BCRs



Benefit Cost Ratios		Average Annual Investment Required ($ billions)		Percent Change In			
Minimum	Average	Total	Directly Modeled	Average IRI	Average Total User Costs	Average Travel Time Costs	Funding Level Description
1.00	3.67	83.4	47.9	-18.3%	-1.8%	-0.9%	**Maximum Economic Investment**
1.20	3.98	76.5	44.0	-15.7%	-1.6%	-0.7%	
1.40	4.31	70.7	40.6	-13.0%	-1.3%	-0.2%	
1.50	4.49	67.9	39.1	-12.2%	-1.1%	**0.0%**	Maintain Travel Time
1.60	4.66	65.4	37.6	-10.4%	-1.0%	0.2%	
1.80	5.02	60.8	35.0	-7.8%	-0.6%	0.7%	
2.00	5.40	56.6	32.7	-5.2%	-0.3%	1.1%	
2.15	5.70	53.9	31.1	-2.6%	**0.0%**	1.5%	Maintain User Costs
2.20	5.80	52.9	30.6	-1.7%	0.1%	1.8%	
2.33	6.08	50.8	29.4	**0.0%**	0.4%	2.0%	**Maintain Conditions**
2.40	6.21	49.8	28.8	1.7%	0.5%	2.2%	
2.60	6.62	46.9	27.2	4.3%	0.9%	2.6%	
2.80	7.07	44.2	25.6	7.0%	1.3%	3.1%	
3.00	7.48	41.8	24.3	9.6%	1.6%	3.5%	

Maximum Economic Investment Scenario

As indicated above, based on HERS results and the external adjustment procedures for types of capital improvements not modeled in HERS, the maximum level of highway investment that could be economically justified is $83.4 billion. At this level of investment, average pavement roughness, total highway user costs, and travel time costs would all improve. Additional impacts of investing at the Maximum Economic Investment scenario are discussed in Chapter 9.

Exhibit 7-4 shows the 20-year total and average annual investment requirements under this scenario, broken down by functional class. These totals are further broken down into their system preservation, system expansion, and system enhancement components later in this chapter in the Combined Highway and Bridge Investment Requirements section.

Exhibit 7-4

Highway Investment Requirements 1998-2017
Maximum Economic Investment Scenario
Billions of Dollars (1997 Dollars)

Functional Class	20-Year Total	Average Annual
Rural Arterials & Collectors		
Interstate	$103.1	$5.2
Other Principal Arterial	$167.0	$8.4
Minor Arterial	$95.3	$4.8
Major Collector	$142.6	$7.1
Minor Collector	$29.6	$1.5
Subtotal	**$537.6**	**$26.9**
Urban Arterials & Collectors		
Interstate	$254.3	$12.7
Other Freeway & Expwy	$102.3	$5.1
Other Principal Arterial	$222.5	$11.1
Minor Arterial	$141.2	$7.1
Collector	$77.4	$3.9
Subtotal	**$797.7**	**$39.9**
Subtotal, Rural and Urban	**$1,335.3**	**$66.8**
Rural and Urban Local	$332.5	$16.6
Total	**$1,667.8**	**$83.4**

Source: Highway Economic Requirements System.

Maintain Conditions Scenario

The second major highway investment requirement scenario in this report is the **Maintain Conditions** scenario. As shown in Exhibit 7-3, raising the minimum BCR cutoff point to 2.33 results in fewer improvements being implemented, so that the average pavement condition at the end of the 20-year analysis period is the same as in 1997. The average annual investment required under this scenario is $50.8 billion.

Under this investment strategy, existing and accruing system deficiencies would be selectively corrected; some highway sections would improve, some would deteriorate, but overall, average pavement condition in 2017 would match that observed in 1997. This scenario is roughly equivalent to the Cost-to-Maintain scenario in the 1995 C&P report. The major differences are that the Cost-to-Maintain scenario was not based on economic criteria, and attempted to maintain an index of pavement condition and operational performance for four 5-year intervals. This Maintain Conditions scenario attempts to maintain pavement condition on a 20-year interval; operational performance may improve or decline depending on the mix of improvements implemented at this particular minimum BCR level.

The average BCR under this scenario is 6.08, indicating that an average of $6.08 of benefits would be obtained from every dollar of expenditure. This average is higher than the average under the Maximum Economic Investment scenario, since the Maintain Conditions scenario omits all projects with a minimum BCR between 1.00 and 2.33.

Average highway user costs would rise by 0.4 percent above baseline levels in constant dollar terms under this scenario. The travel time cost component of user costs would grow by 2.0 percent in constant dollar terms. Additional impacts of investing at the Maintain Conditions scenario level are identified in Chapter 9.

Exhibit 7-5 shows the 20-year total and average annual investment requirements under this scenario, broken down by functional class. These totals are further broken down into their system preservation, system expansion, and system enhancement components later in this chapter in the Combined Highway and Bridge Investments Requirements section.

Note that this scenario assumes that investment in system enhancements will continue to occur, and that system expansion will continue where economically justified, so it does not represent the absolute minimum amount required to preserve the existing system.

Exhibit 7-5

Highway Investment Requirements 1998-2017
Maintain Current Conditions Scenario
Billions of Dollars (1997 Dollars)

Functional Class	20-Year Total	Average Annual
Rural Arterials & Collectors		
Interstate	$73.7	$3.7
Other Principal Arterial	$115.8	$5.8
Minor Arterial	$61.5	$3.1
Major Collector	$81.8	$4.1
Minor Collector	$17.9	$0.9
Subtotal	**$350.6**	**$17.5**
Urban Arterials & Collectors		
Interstate	$161.5	$8.1
Other Freeway & Expwy	$59.4	$3.0
Other Principal Arterial	$133.0	$6.7
Minor Arterial	$76.1	$3.8
Collector	$35.2	$1.8
Subtotal	**$465.2**	**$23.3**
Subtotal, Rural and Urban	**$815.8**	**$40.8**
Rural and Urban Local	$200.4	$10.0
Total	**$1,016.2**	**$50.8**

Source: Highway Economic Requirements System.

Maintain User Costs Benchmark

As shown in Exhibit 7-3, setting the minimum BCR cutoff point to 2.15 results in a level of investment sufficient to allow total highway user costs per VMT at the end of the 20-year analysis period match the baseline levels. Highway user costs include travel time costs, vehicle operating costs, and crash costs. The average annual investment required to attain this benchmark is estimated to be $53.9 billion.

The **Maintain User Costs** concept was introduced in the 1997 C&P report to provide a new highway system performance benchmark based on economic criteria and focusing on highway users, rather than the traditional engineering-based criteria, which are oriented more toward highway agencies. The **Maintain User Costs** benchmark is an important technical point that provides insight into the operation of HERS, since the VMT growth rates in the model are partly dependent on changes in user costs, due to the operation of the travel demand elasticity feature. The investment required to maintain user costs is identified as a "benchmark" rather than a

Q. **Why is the investment required to Maintain User Costs treated as a "benchmark" rather than a full-fledged "scenario"?**

A. Recent C&P reports have emphasized two scenarios to illustrate future investment requirements. During outreach meetings following the release of the 1997 C&P report, readers indicated that it would be more useful to have a scenario oriented around maintaining physical conditions rather than maintaining user costs. Also, the current bridge model does not evaluate user costs, so the highway Maintain Conditions scenario is more appropriate for the joint highway/bridge analysis that appears later in this chapter, and in subsequent parts of the report.

Limited information on the investment required to maintain user costs was retained in the report to preserve continuity with the 1997 C&P report.

"scenario" in this report, and is not discussed in as much detail as the two main highway scenarios.

> **Q. What are the strengths and weaknesses of the Maintain User Costs Benchmark?**
>
> **A.** The strength of this benchmark is that it provides a broad way to measure changes that will impact highway users, the consumers of the highway system. This benchmark is more encompassing than a simple measure of pavement conditions, and less arbitrary than a pre-determined index of the value of capacity, pavement, and safety improvements that has been used in some previous reports.
>
> The main drawback with this benchmark is that it is somewhat abstract and hard to visualize. Pavement condition, congestion, and the number of crashes can all be directly observed. User costs, on the other hand, are calculated values. This benchmark may also be more sensitive than others to changes in some of the underlying assumptions of the analysis. For example, while changing the assumed value of time or value of life would have an effect on the benefit/cost analysis for any of the scenarios, it would also change the performance target under this scenario, since these values are used to calculate the baseline highway user costs that the scenario attempts to maintain.

The average BCR for this benchmark is 5.70 indicating that an average of $5.70 of benefits would be obtained from every dollar of expenditure. Pavement condition would improve at this level of investment, as average IRI would decrease by 2.6 percent.

While average highway user costs in 2017 would match baseline levels in constant dollar terms, individual highway user cost components would vary. Travel time costs would increase 1.5 percent, vehicle operating costs would decrease 1.2 percent while crash costs would decline 1.6 percent. This indicates that at this investment level, HERS predicts there would be a relatively greater rate of return on improvements aimed at reducing crashes, rather than those aimed at reducing congestion or improving pavement condition.

The Maintain User Costs benchmark in this report is calculated slightly differently than its equivalent in the 1997 report, maintaining user costs over a 20-year interval rather than four 5-year intervals.

Maintain Travel Time Benchmark

Another point of interest on the curve shown in Exhibit 7-3 is the investment required to maintain travel time. Changes in average travel time per VMT are an indicator of the operational performance of the highway system. This benchmark focuses on one aspect of the Maintain User Costs benchmark, travel time costs. Since travel time costs happen to rise at the investment requirement level for the Maintain User Costs benchmark based on the 1997 data, the average annual investment requirements for the Maintain Travel Time benchmark are higher at $67.9 billion. This would not necessarily always be the case; this benchmark could theoretically be lower in certain circumstances. Maintaining travel time costs requires the minimum BCR cutoff point be set at 1.50, below the level used for the Maintain User Costs benchmark.

Comparison with Previous Reports

The projected average annual investment requirements shown for 1998-2017 in this report are not directly comparable to those shown for 1996–2015 in the 1997 C&P report, due to inflation, data corrections, model enhancements, and changes in the methodology used to develop the estimates. To facilitate direct comparisons between the two reports, the 1995 data used to develop the last report have been corrected and reprocessed through the current version of HERS, with the results restated in 1997 dollars. The adjustments to the 1995 data are discussed in Appendix G.

Exhibit 7-6 compares the investment requirement projection in this report with the original projections reported in the 1995 and 1997 C&P reports, as well as with the values obtained by re-analyzing the older data using the latest analytical procedures.

Exhibit 7-6

Comparison of Highway Investment Requirements 1995, 1997 and 1999 C&P Reports (Billions of Dollars)

	As Reported				Re-analyzed and Converted to 1997 Dollars		
Report Year	Maximum Economic Investment Scenario (1)	Maintain Conditions Scenario (2)	Maintain User Costs Benchmark (3)	Dollar Year	Maximum Economic Investment Scenario	Maintain Conditions Scenario	Maintain User Costs Benchmark
1995 (Avg. Annual 1994-2013)	$65.1	$49.7	N/A	1993	$83.1	$47.6	N/A
1997 (Avg. Annual 1996-2015)	$70.0	N/A	$40.5	1995	$82.6	N/A	$48.2
1999 (Avg. Annual 1998-2017)	$83.4	$50.8	$53.9	1997	$83.4	$50.8	$53.9

(1) Identified as the Economic Efficiency Scenario in the 1995 C&P Report.

(2) Roughly corresponds to the Cost-to-Maintain Highways Scenario in the 1995 C&P Report.

(3) Corresponds to the Maintain User Cost Scenario in the 1997 C&P Report.

Source: Highway Economic Requirements System.

Comparison with 1995 Data Used in the 1997 C&P Report

Keeping all other factors constant, highway investment requirements for the Maximum Economic Investment Scenario based on the 1997 HPMS data are 0.9 percent higher than the restated highway investment requirements based on the 1995 HPMS data. The small increase is largely the result of changes in the composition of highway spending between 1995 and 1997, which affects the external adjustment procedures for non-modeled expenditures as described earlier.

Highway investment requirements for the Maintain User Costs scenario based on the 1997 HPMS data are 11.8 percent higher than those based on the 1995 HPMS data, keeping all other factors constant. Part of this is attributable to the decline in delay discussed in Chapter 4. Travel time costs and total highway user costs are lower in 1997 than in 1995. Therefore "Maintaining User Costs" at their 1997 levels for 20 years is actually a more stringent standard that maintaining them at their 1995 levels for 20 years, and is therefore more expensive to achieve. This is an inherent shortcoming in any of the scenarios that "Maintain" a conditions or performance characteristic, that makes comparisons between reports difficult. As pavement conditions, highway-user costs, and travel time costs change over time, the targets for the Maintain Conditions scenario, the Maintain User Costs benchmark, and the Maintain Travel Time benchmark also change.

Appendix G includes a discussion of the source of the differences between the original investment requirement projections reported in the 1997 C&P report using 1995 HPMS data, and the updated values using the latest analytical approach.

Comparison with 1993 Data Used in the 1995 C&P Report

Keeping all other factors constant, highway investment requirements for the Maximum Economic Investment Scenario based on the 1997 HPMS data are only 0.4 percent higher than the restated highway investment requirements based on the 1993 HPMS data. Highway investment requirements for the Maintain Conditions scenario based on the 1997 HPMS data are 6.7 percent higher than those based on the 1993 HPMS data, keeping all other factors constant. This is partially the result in the improvement in pavement condition since 1993, which makes “Maintaining Conditions” at their 1997 level a more stringent standard. The increase is also influenced by changes in the composition of highway spending between 1995 and 1997, which affects the external adjustment procedures for non-modeled expenditures as described earlier.

The Maintain Conditions projection using the re-analyzed 1993 HPMS data, $47.6 billion in 1997 dollars, is lower than the original projection of $49.7 billion in 1993 dollars for the Cost-to-Maintain scenario in the 1993 C&P Report. This is partially the result of changes in the scenario definition, but mainly the differences are the result of incorporating the procedures contained in the most recent *Highway Capacity Manual* 1994 (Special Report 209 of the Transportation Research Board), as discussed on page 61 of the 1997 C&P report. These reductions more than offset the effects of inflation on the projections.

Bridge Investment Requirements

The bridge investment requirements shown in this report are developed primarily from the Bridge Needs and Investment Process (BNIP). Using the National Bridge Inventory, the process identifies bridge deficiencies, selects improvements, and simulates the costs of these improvements. An engineering ranking scheme is used to prioritize potential actions.

Bridge Investment Backlog

As defined in this report, the bridge investment backlog represents the cost of improving all bridges that are currently deficient. BNIP estimates that $87.3 billion of investment would be required to repair or replace all functionally obsolete or structurally deficient bridges.

More than half of all existing bridge deficiencies are structural deficiencies. If these types of deficiencies are not corrected in a timely manner, further deterioration could require major rehabilitation or bridge replacement. These actions cost significantly more than highway pavement repair on a unit cost basis. In addition, deferred investments on deficient bridges may impose public safety hazards more dangerous than the risks of deferred pavement improvements.

Bridge Investment Requirement Scenarios

The investment requirements scenarios in this report project total investment requirements for the period 1998-2017. The **Eliminate Deficiencies** scenario is the equivalent of the **Cost to Improve Bridge Conditions** shown in previous reports. The **Maintain Backlog** scenario is the equivalent of the **Cost to Maintain Bridge Conditions** shown in previous reports. The scenarios were renamed to clarify their intent, and to emphasize that the bridge investment requirements analyses focus on bridge deficiencies, rather than average bridge conditions.

Eliminate Deficiencies Scenario

This scenario would eliminate the existing bridge investment backlog, and correct other deficiencies that are expected to develop over the next 20 years. The average annual investment required under this scenario is $10.6 billion. Exhibit 7-7 shows the 20-year total and average investment requirements for each functional class under this scenario. This table also contains the number of bridges that would be rehabilitated or replaced during the analysis period.

Q. **HERS is used as an economic tool for roadway investment analysis. Is there a similar tool for bridge analysis?**

A. The national Bridge Investment Analysis System (BIAS) is currently being developed to add an economic component to the bridge analysis. BIAS is based on the optimization procedures of Pontis, a bridge management system developed initially with input from FHWA, several States, the Transportation Research Board, and other interests. Pontis is now supported by the American Association of State Highway and Transportation Officials and is being further enhanced at the suggestion of the States for use as their bridge management system.

Pontis was developed to analyze individual bridges, using data on the condition of a variety of bridge elements. BIAS takes a similar approach to bridge analysis, but relies on the National Bridge Inventory which is less detailed. BIAS can not analyze individual bridges, but can provide information on a more aggregate, national level basis, without requiring all the detailed information that Pontis needs.

Exhibit 7-7

Bridge Investment Requirements 1998-2017 Eliminate Deficiencies Scenario

Functional System	Number of Repaired or Replaced Bridges	20-Year Requirements (Billions of 1997 Dollars)	Average Annual Requirements (Billions of 1997 Dollars)
Rural Arterials and Collectors			
Interstate	30,301	$16.8	$0.8
Other Principal Arterial	25,101	$14.5	$0.7
Minor Arterial	24,476	$9.6	$0.5
Major Collector	59,488	$11.5	$0.6
Minor Collector	31,914	$3.7	$0.2
Subtotal	**171,281**	**$56.0**	**$2.8**
Urban Arterials and Collectors			
Interstate	53,832	$71.6	$3.6
Other Freeway & Expressway	24,020	$22.7	$1.1
Other Principal Arterial	25,554	$25.9	$1.3
Minor Arterial	19,612	$12.5	$0.6
Collector	12,436	$4.9	$0.2
Subtotal	**135,454**	**$137.7**	**$6.9**
Total Non-Local	**306,735**	**$193.7**	**$9.7**
Rural Local	140,906	$12.2	$0.6
Urban Local	16,868	$5.6	$0.3
Total Local	**157,774**	**$17.8**	**$0.9**
Total	**464,508**	**$211.5**	**$10.6**

Source: Bridge Needs and Investment Process.

Maintain Backlog Scenario

Under the **Maintain Backlog** scenario, the bridge investment backlog would be maintained at its current level. Under this scenario, existing deficiencies and newly accruing deficiencies would be selectively corrected, to minimize the investment required to maintain the same backlog of deficient bridges in 2018 that exists in 1998. The average annual investment required under this scenario is estimated at $5.8 billion. Exhibit 7-8 shows the 20-year total and average investment requirements under this scenario, by functional class, as well as the number of bridges that would be rehabilitated or replaced during the analysis period.

It should be noted that the **Maintain Backlog** scenario focuses on deficient bridges, rather than on average bridge conditions. Average bridge conditions would not necessarily be maintained under this scenario.

Comparison with Previous Reports

Exhibit 7-9 contains a comparison of the bridge investment requirements for this report and the previous three reports. The values reported have grown over time for both scenarios, but this is largely due to inflation. In constant dollar terms, the investment required for Maintain Backlog scenario (Cost to Maintain in the 1993, 1995, and 1997 reports) has declined over this time. This is because the number of deficient bridges has declined. The investment required for the Eliminate Deficiencies scenario (Cost to Improve in the 1993, 1995, and 1997 reports) has fluctuated, but remained between $10 and $11 billion annually in constant dollars.

Exhibit 7-8

Bridge Investment Requirements 1998-2017 Maintain Backlog Scenario

Functional System	Number of Repaired or Replaced Bridges	20-Year Requirements (Billions of 1997 Dollars)	Average Annual Requirements (Billions of 1997 Dollars)
Rural Arterials and Collectors			
Interstate	10,330	$8.1	$0.4
Other Principal Arterial	7,130	$6.1	$0.3
Minor Arterial	1,991	$1.6	$0.1
Major Collector	1,314	$0.6	$0.0
Minor Collector	22,459	$2.9	$0.1
Subtotal	**43,224**	**$19.3**	**$1.0**
Urban Arterials and Collectors			
Interstate	30,853	$50.9	$2.5
Other Freeway & Expressway	8,173	$11.8	$0.6
Other Principal Arterial	9,646	$15.0	$0.7
Minor Arterial	3,560	$3.8	$0.2
Collector	737	$0.6	$0.0
Subtotal	**52,969**	**$82.1**	**$4.1**
Total Non-Local	**96,193**	**$101.4**	**$5.1**
Rural Local	105,948	$9.9	$0.5
Urban Local	15,024	$5.3	$0.3
Total Local	**120,972**	**$15.2**	**$0.8**
Total	**217,165**	**$116.6**	**$5.8**

Source: Bridge Needs and Investment Process.

Exhibit 7-9

Comparison of Bridge Investment Requirements 1993, 1995, 1997 and 1999 C&P Reports (Billions of Dollars)

	As Reported			Converted to 1997 Dollars	
Report Year	Maximum Backlog Scenario	Eliminate Deficiencies Scenario	Dollar Year	Maintain Backlog Scenario	Eliminate Deficiencies Scenario
1993 (Average Annual 1992-2011)	$5.2	$8.2	1991	$6.3	10.0
1995 (Average Annual 1994-2013)	$5.1	$8.9	1993	$6.2	10.7
1997 (Average Annual 1996-2015)	$5.6	$9.3	1995	$6.0	10.0
1999 (Average Annual 1998-2017)	$5.8	$10.6	1997	$5.8	10.6

Q. **Are any preliminary results available from the BIAS model?**

A. The National Bridge Investment Analysis System (BIAS) is an analytical system being developed as a bridge investment/performance tool to supplement the Bridge Needs and Investment Process (BNIP) that has been used for a decade to estimate bridge capital investment requirements. BIAS adds economic analysis to this estimation process. This box contains provisional results of BIAS so the reader may become aware of the model and its possible future use to project bridge investment requirements. Please note that future results may differ from the interim results presented here.

BIAS estimates that an annual bridge investment from all levels of government of $6.4 billion for the 20-year period 1999 to 2018 would maintain the same overall backlog amount in 2018 as in 1999. However, this figure cannot be directly compared to BNIP results because the BIAS figure includes some amount of maintenance or minor rehabilitation not included in BNIP. It is estimated that the average benefit cost ratio for the predicted improvements over the 20-year period would be about 4.0, meaning that an average of $4 dollars of benefits would be obtained from every dollar invested. Much of these benefits would derive from trucks not having to detour over a longer route because of deficient bridge load carrying capacity.

An annual investment of $10.7 billion for the same 20-year period is projected to eliminate the backlog for major improvements such as replacement and functional improvements. It would not eliminate the requirement for continued rehabilitation and maintenance. The average benefit cost ratio for this scenario is estimated to be about 2.7. Again, this should be taken as a provisional result.

These BIAS results are tentative and should not be taken as directly comparable to the BNIP results contained elsewhere in this report. Future enhancements to BIAS may incorporate further refinements to relationships contained in the model and information not currently included, such as the benefits to the user of various types of bridge improvements. Such further enhancements may modify the results.

Combined Highway and Bridge Investment Requirements

The highway investment requirement scenarios and the bridge investment requirement scenarios are defined differently, due to the different natures of the models used to develop them. However, it is frequently useful to combine these separate scenarios, to show combined investment requirements for highways and bridges. This is particularly helpful when trying to compare these scenarios to current or projected investment levels, since amounts commonly referred to as "total highway spending" or "total highway capital outlay," include expenditures for both highways and bridges. Chapter 8 compares current highway and bridge spending and the investment requirements outlined in this section.

Of the four highway investment requirements and scenarios laid out earlier in this chapter, the Highway Maintain Conditions scenario corresponds most closely to the Bridge Maintain Backlog scenario. The Highway Maximum Economic Investment scenario corresponds most closely to the Bridge Eliminate Deficiencies scenario.

Backlog

Combining the $188.7 billion highway investment backlog estimated by HERS with the $87.3 billion bridge investment backlog estimated by BNIP results in a combined backlog of $266.0 billion. However, as indicated earlier in the chapter, the two components of backlog are defined differently, and are not fully comparable.

Cost to Maintain Highways and Bridges

Combining the Highway Maintain Conditions scenario with the Bridge Maintain Backlog scenario results in a combined average annual Cost to Maintain Highways and Bridges of $56.6 billion. This total is broken down by functional class in Exhibit 7-10. The investment requirements are classified into three categories, system preservation, system expansion, and system enhancement. System Preservation consists of the investment required to preserve and maintain the pavement and bridge infrastructure. This includes the costs of resurfacing, rehabilitation, and reconstruction. System Expansion includes the costs related to adding lanes to existing facilities, or adding new roads and bridges. System Enhancements include safety enhancements, traffic operations improvements, and environmental improvements.

The investment requirements for urban arterials and collectors total $27.4 billion or 48.3 percent

Q. **How were the investment requirements identified by HERS split between system preservation and system expansion?**

A. All improvements selected by HERS that did not add lanes to a facility were classified as system preservation. For improvements that added lanes, the total cost of the improvement was split between these two categories, since widening projects typically improve the existing lanes of a facility to some degree when adding new ones. Also, adding new lanes to a facility tends to reduce the amount of traffic carried by each of the old lanes, which may extend their pavement life.

To classify these improvements, the HERS analysis for this scenario was rerun with a constraint added to prevent the model from adding any lanes. The difference between these two runs was taken to be the amount attributable solely to system expansion.

HERS does not currently identify investment requirements for system enhancements.

Exhibit 7-10

Average Annual Investment Required to Maintain Highways and Bridges (Billions of 1997 Dollars)

Functional Class	System Preservation			System Expansion	System Enhancements	Total
	Highway	Bridge	Total			
Rural Arterials & Collectors						
Interstate	$2.1	$0.4	$2.5	$1.3	$0.3	$4.1
Other Principal Arterial	$2.7	$0.3	$3.0	$2.8	$0.3	$6.1
Minor Arterial	$2.2	$0.1	$2.3	$0.6	$0.3	$3.2
Major Collector	$3.5	$0.0	$3.5	$0.4	$0.2	$4.1
Minor Collector	$0.4	$0.1	$0.6	$0.4	$0.1	$1.0
Subtotal	**$10.9**	**$1.0**	**$11.9**	**$5.5**	**$1.1**	**$18.5**
Urban Arterials & Collectors						
Interstate	$2.9	$2.5	$5.4	$4.3	$0.8	$10.6
Other Freeway & Expressway	$1.2	$0.6	$1.8	$1.4	$0.4	$3.6
Other Principal Arterial	$3.4	$0.8	$4.1	$2.7	$0.6	$7.4
Minor Arterial	$2.3	$0.2	$2.5	$1.0	$0.5	$4.0
Collector	$1.2	$0.0	$1.2	$0.3	$0.2	$1.8
Subtotal	**$11.0**	**$4.1**	**$15.1**	**$9.8**	**$2.5**	**$27.4**
Subtotal Rural and Urban	**$21.9**	**$5.1**	**$27.0**	**$15.2**	**$3.6**	**$45.9**
Rural and Urban Local	$4.0	$0.8	$4.8	$5.1	$0.9	$10.8
Total	**$26.0**	**$5.8**	**$31.8**	**$20.3**	**$4.5**	**$56.6**

of the average annual Cost to Maintain Highways and Bridges. Investment requirements for rural arterials and collectors total $18.5 billion (32.7 percent), while the investment requirements for rural and urban local roads and streets total $10.8 billion (19.0 percent).

System Preservation

Average annual system preservation investment requirements total $31.8 billion, comprising 56.1 percent of the total Cost to Maintain Highways and Bridges. As shown in Exhibit 7-11, system preservation makes up a much larger share of total investment requirements in rural areas than in urban areas.

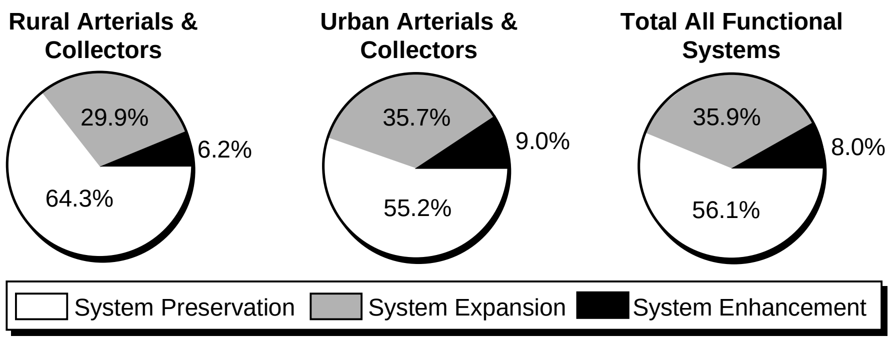
The system preservation investment requirements are derived primarily from the HERS and BNIP models. An adjustment was made to the highway figures, to account for rural minor collectors and local functional class roads which are not included in the HPMS sample section database on which HERS relies.

Q. **Would it be necessary to invest the full amount identified as the Cost to Maintain Highways and Bridges, in order to maintain average pavement condition and the backlog of bridge deficiencies?**

A. No. The $56.6 billion average annual amount specified includes a mix of improvements designed to attain the highest possible level of benefits, including some improvements that do not address the physical conditions of highways and bridges. If all investment requirements for system expansion and system enhancements were ignored, an average annual investment of $31.8 billion of system preservation investment would be sufficient to maintain physical conditions. However, if total highway and bridge capital investment were limited to $31.8 billion annually, the analytical procedures used in this report would suggest that it would be more cost beneficial to split this amount among system preservation, system expansion, and system enhancements, rather than use it all for system preservation.

Exhibit 7-11

1998-2017 Cost to Maintain Highways and Bridges, Distribution By Improvement Type



System Expansion

The $20.3 billion in average annual investment requirements for system expansion represents 35.9 percent of the total Cost to Maintain Highways and Bridges. This includes investment requirements derived from HERS for widening existing highways and bridges. External adjustments were applied to cover types of investment that HERS does not consider, the widening of rural minor collectors and local functional class roads, and the construction of new roads and bridges.

Q. Can highway capacity be expanded without adding new lanes or new roads and bridges?

A. Yes. Highway capacity can be increased by improving the utilization of the existing infrastructure. In many cases, increased investment in intelligent transportation systems may be more cost beneficial than building new roads, double decking roads, or adding new lanes in high cost urban areas. *(See the discussion of High-cost lanes in Appendix G).* Some of the investment requirements identified as for "System Expansion" could also be met through increased investment in types of "System Enhancements" that also increase capacity.

System Enhancements

The $4.5 billion in average annual investment requirements for system enhancements represents 8.0 percent of the total Cost to Maintain Highways and Bridges. Investment requirements for safety enhancements, traffic operation facilities, and environmental enhancements are not directly modeled, so this amount was derived solely from the external adjustment procedures described earlier. Long range plans for the HERS model include expanding its scope to consider some of the ITS and safety improvements included under system enhancements.

Cost to Improve Highways and Bridges

Combining the Highway Maximum Economic Investment scenario with the Bridge Eliminate Deficiency Backlog scenario results in a combined average annual Cost to Improve Highways and Bridges of $94.0 billion. This total is broken down by type of improvement and functional class in Exhibit 7-12.

The investment requirements for urban arterials and collectors total $46.8 billion, or 49.8 percent of the total average annual Cost to Improve Highways and Bridges. Investment requirements on rural arterials and collectors are $29.7 billion or 31.6 percent of the total.

System Preservation, System Expansion, and System Enhancement make up 51.2 percent, 40.8 percent, and 8.0 percent respectively of the Cost to Improve Highways and Bridges. As shown in Exhibit 7-13, system preservation makes up a much larger share of total investment requirements in rural areas than in urban areas.

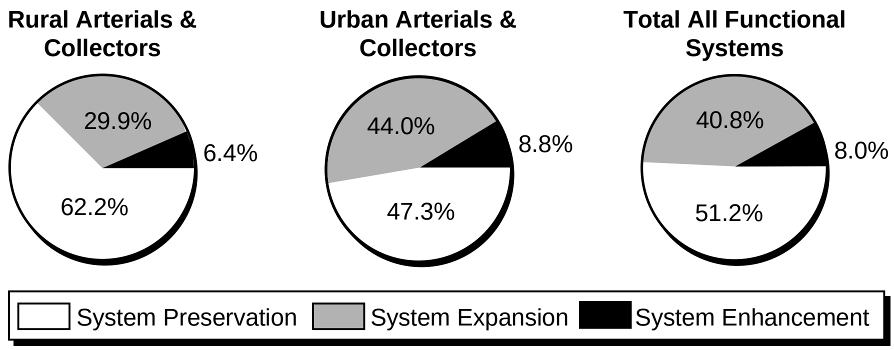
Exhibit 7-12

Average Annual Investment Required to Improve Highways and Bridges (Billions of 1997 Dollars)

Functional Class	System Preservation			System Expansion	System Enhancements	Total
	Highway	Bridge	Total			
Rural Arterials & Collectors						
Interstate	$2.5	$0.8	$3.3	$2.1	$0.6	$6.0
Other Principal Arterial	$3.3	$0.7	$4.0	$4.6	$0.4	$9.1
Minor Arterial	$3.1	$0.5	$3.6	$1.2	$0.5	$5.2
Major Collector	$6.1	$0.6	$6.7	$0.7	$0.3	$7.7
Minor Collector	$0.7	$0.2	$0.9	$0.6	$0.1	$1.7
Subtotal	**$15.7**	**$2.8**	**$18.5**	**$9.3**	**$1.9**	**$29.7**
Urban Arterials & Collectors						
Interstate	$3.4	$3.6	$7.0	$7.9	$1.4	$16.3
Other Freeway & Expressway	$1.4	$1.1	$2.6	$3.1	$0.6	$6.2
Other Principal Arterial	$4.3	$1.3	$5.6	$5.9	$0.9	$12.4
Minor Arterial	$3.7	$0.6	$4.3	$2.6	$0.7	$7.7
Collector	$2.4	$0.2	$2.7	$1.1	$0.4	$4.1
Subtotal	**$15.2**	**$6.9**	**$22.1**	**$20.6**	**$4.1**	**$46.8**
Subtotal Rural and Urban	**$30.9**	**$9.7**	**$40.6**	**$29.9**	**$6.0**	**$76.5**
Rural and Urban Local	$6.7	$0.9	$7.6	$8.4	$1.5	$17.5
Total	**$37.6**	**$10.6**	**$48.1**	**$38.3**	**$7.5**	**$94.0**

Exhibit 7-13

1998-2017 Cost to Improve Highways and Bridges, Distribution By Improvement Type



Transit Investment Requirements

The Transit Economic Requirements Model (TERM) (see Appendix I for a technical description) generates estimates of future transit investment requirements. TERM uses inputs on the existing transit asset base, transit system operating statistics, and projections of future transit ridership growth to forecast the amount of capital investment which would be required from 1998-2017 in order to meet various asset condition and operational performance goals. These goals are:

- **Maintain Conditions**
  Transit assets are replaced and rehabilitated over the 20-year period such that the average condition of assets present at the beginning of the period remains the same at the end of the period.
- **Maintain Performance**
  New transit vehicles and infrastructure are deployed in order to maintain vehicle utilization rates (one of the system performance measures discussed in Chapter 4) at a constant rate even as transit passenger miles increase over time. Estimates of future growth in transit passenger miles are obtained from forecasts made by Metropolitan Planning Organizations (MPOs).
- **Improve Conditions**
  Transit asset rehabilitation and replacement is accelerated in order to improve the average condition of each asset type in the existing asset base to at least a "good" level (see Chapter 3) by 2017.
- **Improve Performance**
  The performance of the Nation's transit system are improved as additional investments are made in the urbanized areas with the most crowded vehicles and the slowest systems, reducing average vehicle utilization rates and increasing average transit operating speeds. Service would be improved by reducing headways and/or increasing coverage. Vehicle crowding would also be reduced.

Investment Requirements

Exhibit 7-14 shows the necessary levels of annual capital investment that would be necessary to meet the goals described above. The annual cost to **Maintain Conditions and Performance** is $10.8 billion. Improving performance while maintaining current conditions would require an investment of $14.4 billion, while improving conditions at the current level of performance would cost $11.1 billion annually. The cost to **Improve Conditions and Performance** is $16.0 billion each year.

Exhibit 7-14

Summary of Transit Average Annual Investment Requirements 1998-2017 (Billions of Dollars)

Conditions	Performance	Average Annual Cost
Maintain	Maintain	10.8
Maintain	Improve	14.4
Improve	Maintain	11.1
Improve	Improve	16.0

Source: Transit Economic Requirements Model.

Transit investment requirements by type of improvement are displayed in Exhibit 7-15. The replacement and rehabilitation of the existing transit capital stock would cost $7.0 billion annually if conditions are to be maintained, and $8.6 billion if conditions are to be improved. Asset expansion to accommodate transit PMT growth requires $3.7 billion under maintained conditions ($3.8 billion if conditions are also improved). Enhancements to raise the overall performance of the Nation's transit system carries an annual price tag of $3.6 billion when conditions are maintained ($3.7 billion when conditions are improved). The totals in each column in Exhibit 7-15 reflect the total amounts for the Maintain Conditions/Improve Performance and the Improve Conditions/Improve Performance scenarios, respectively.

Exhibit 7-15

Annual Transit Investment Requirements by Type of Improvement (Billions of 1997 Dollars)

Type of Improvement	Maintain Conditions	Improve Conditions
Replacement and Rehabilitation	$7.0	$8.6
Asset Expansion	$3.7	$3.8
Performance Improvements	$3.6	$3.7
Total	**$14.4**	**$16.0**

Source: Transit Economic Requirements Model.

Exhibits 7-16 and 7-17 show the costs to maintain conditions and to make incremental improvements in performance and conditions. The exhibits disaggregate the forecast investments in transit capital by

Exhibit 7-16

Annual Average Cost to Maintain and Improve Transit Conditions and Performance 1998-2017 (Millions of 1997 Dollars)

Mode, Purpose, & Asset Type	Cost to Maintain Conditions	Incremental Cost to Maintain Performance	Incremental Cost to Improve Performance	Total
Areas Over 1 Million in Population				
Bus				
Replacement & Rehabilitation (Vehicles)	966			966
Replacement & Rehabilitation (Non-Vehicles)	350			350
Fleet Expansion (Vehicles)		311		311
Fleet Expansion (Non-Vehicles)		466		466
New Bus (Vehicles & Non-Vehicles)			375	375
Elderly and Disabled (Vehicles & Non-Vehicles)	24			24
Subtotal Bus	**1,339**	**777**	**375**	**2,492**
Rail				
Replacement & Rehabilitation (Vehicles)	1,360			1,360
Replacement & Rehabilitation (Non-Vehicles)	3,549			3,549
Fleet Expansion (Vehicles)		273		273
Fleet Expansion (Non-Vehicles)		2,501		2,501
New Rail (Vehicles & Non-Vehicles)			3,151	3,151
Subtotal Rail	**4,909**	**2,774**	**3,151**	**10,835**
Total Areas Over 1 Million	**6,248**	**3,551**	**3,527**	**13,327**
Areas Under 1 Million in Population				
Bus				
Replacement & Rehabilitation (Vehicles)	352			352
Replacement & Rehabilitation (Non-Vehicles)	164			164
Fleet Expansion (Vehicles)		94		94
Fleet Expansion (Non-Vehicles)		102		102
New Bus (Vehicles & Non-Vehicles)			121	121
Elderly and Disabled (Vehicles & Non-Vehicles)	135			135
Nonurbanized Area (Vehicles & Non-Vehicles)	110			110
Subtotal Bus	**761**	**196**	**121**	**1,078**
Rail				
Replacement & Rehabilitation (Vehicles)	2			2
Replacement & Rehabilitation (Non-Vehicles)	5			5
Fleet Expansion (Vehicles)		0		0
Fleet Expansion (Non-Vehicles)		0		0
Subtotal Rail	**7**	**0**		8
Total Areas Under 1 Million	**769**	**196**	**121**	**1,086**
Total	**7,017**	**3,748**	**3,648**	**14,413**

Source: Transit Economic Requirements Model (TERM).

urbanized area population (over and under 1 million), mode (bus and rail), improvement purpose, and asset type (vehicles and non-vehicles). Investment requirements are greatest in major urbanized areas, reflecting the fact that 90 percent of the Nation's transit passenger miles are on transit systems in these 33 areas. The most expensive investments for replacement, expansion, and performance improvements are in non-vehicle rail infrastructure. Replacement of the bus fleet, with its relatively short useful life (approximately 12 years), is also a major expense.

Exhibit 7-17

Annual Average Cost to Maintain and Improve Transit Conditions and Performance 1998-2017 (Millions of 1997 Dollars)

Mode, Purpose, & Asset Type	Cost to Maintain Conditions	Incremental Cost to Improve Conditions	Incremental Cost to Maintain Performance	Incremental Cost to Improve Performance	Total
Areas Over 1 Million in Population					
Bus					
Replacement & Rehabilitation (Vehicles)	966	1			966
Replacement & Rehabilitation (Non-Vehicles)	350	344			693
Fleet Expansion (Vehicles)			333		333
Fleet Expansion (Non-Vehicles)			466		466
New Bus (Vehicles & Non-Vehicles)				405	405
Elderly and Disabled (Vehicles & Non-	24	21			45
Subtotal Bus	**1,339**	**365**	**799**	**405**	**2,909**
Rail					
Replacement & Rehabilitation (Vehicles)	1,360	301			1,661
Replacement & Rehabilitation (Non-Vehicles)	3,549	419			3,968
Fleet Expansion (Vehicles)			272		272
Fleet Expansion (Non-Vehicles)			2,493		2,493
New Rail (Vehicles & Non-Vehicles)				3,151	3,151
Subtotal Rail	**4,909**	**720**	**2,765**	**3,151**	**11,546**
Total Areas Over 1 Million	**6,248**	**1,085**	**3,564**	**3,556**	**14,454**
Areas Under 1 Million in Population					
Bus					
Replacement & Rehabilitation (Vehicles)	352	0			352
Replacement & Rehabilitation (Non-Vehicles)	164	268			432
Fleet Expansion (Vehicles)			101		101
Fleet Expansion (Non-Vehicles)			102		102
New Bus (Vehicles & Non-Vehicles)				141	141
Elderly and Disabled (Vehicles & Non-	135	118			253
Nonurbanized Area (Vehicles & Non-Vehicles)	110	93			203
Subtotal Bus			**203**	**141**	**1,584**
Rail					
Replacement & Rehabilitation (Vehicles)	2	2			4
Replacement & Rehabilitation (Non-Vehicles)	5	1			7
Fleet Expansion (Vehicles)			0		0
Fleet Expansion (Non-Vehicles)			0		0
Subtotal Rail	**7**	**3**	**0**		10
Total Areas Under 1 Million	**7**	**3**	**203**	**141**	**1,595**
Total	**6,256**	**1,088**	**3,767**	**3,698**	**16,049**

Source: Transit Economic Requirements Model (TERM).

Exhibit 7-18 provides a more detailed description of investment requirements by asset type. Annual costs are shown for each of the five major transit asset categories used in TERM (guideways, facilities, systems, stations, and vehicles), as well as other project costs. The largest expenditures on rehab and replacement are for vehicles, followed by guideway elements (new busways, track, roadbeds, bridges, and tunnels). Guideway elements are the largest expense for system expansion and performance improvements, as fixed-guideway systems (both new and expansions of existing systems) are constructed to accommodate increased passenger growth and to increase operating speeds.

Exhibit 7-18

Average Annual Investment Requirements by Asset Type and Type of Improvement (Billions of 1997 Dollars)

	Maintain Conditions			
Asset Type	Replacement/ Rehabilitation	Asset Expansion	Performance Improvements	Total
Guideway Elements	2,268	1,113	941	**4,323**
Facilities	654	594	259	**1,507**
Systems	958	191	154	**1,304**
Stations	277	393	325	**995**
Vehicles	2,860	678	298	**3,836**
Other Costs	0	777	1,672	**2,448**
Total	**7,017**	**3,748**	**3,648**	**14,413**

	Improve Conditions			
Asset Type	Replacement/ Rehabilitation	Asset Expansion	Performance Improvements	Total
Guideway Elements	2,480	1,109	941	**4,531**
Facilities	1,492	594	259	**2,344**
Systems	1,039	190	154	**1,383**
Stations	257	393	325	**975**
Vehicles	3,317	706	347	**4,370**
Other Costs	0	775	1,672	**2,447**
Total	**8,584**	**3,767**	**3,698**	**16,049**

Source: Transit Economic Requirements Model.

Existing Deficiencies

In addition to projecting annual investment requirements for future years, TERM also calculates the amount of investment that would be required to correct existing deficiencies in the nation's transit system. This is similar to the highway needs backlog calculated by HERS. TERM does this by immediately replacing assets whose condition is below the specified replacement level (see Appendix I). These corrective expenditures in the first year then become part of the 20-year investment totals. Eliminating the 1997 deficiencies under the Maintain Conditions scenario would cost $15.1 billion, while eliminating deficiencies under the Improve Conditions scenario totals $25.1 billion.