Chapter 9

Supplemental Scenario Analysis

Highway Supplemental Scenario Analysis

This section explores the implications of the investment scenarios considered in Chapter 8 and of scenarios with alternative assumptions about investment-related policies. Differences in the level and composition of investment between the Chapter 8 scenarios for the projection period (2009–2028) and patterns in the base year (2008) are compared for potential insights into the recent trends in highway conditions and performance reported in Chapters 3 and 4. The scenario projections for investment are also compared with those presented in previous editions and converted from real to nominal dollars, taking account of inflation. This section includes a comparison of the long-term projections from two previous editions, the 1989 C&P Report and the 1999 C&P Report, with actual changes to the condition and performance of the highway system over time.

This section also explores alternative assumptions concerning the timing of investment over the 20-year projection period and identifies the initial backlog of cost-beneficial highway and bridge investments as of the 2008 base year. In addition, this section examines the potential impact on future vehicle miles traveled (VMT), capital investment needs, and overall system performance of several variations to the policy assumptions underlying the scenarios in Chapter 8, including:

- Setting the target of the **Maintain Conditions and Performance scenario** on individual components of the highways system rather than the system as a whole.
- Financing the increase in scenario projections for spending relative to base year spending through increases in user charges, including flat rate surcharges assessed on a per-mile or per-gallon basis, and peak-period congestion charges.
- Accelerating the deployment of intelligent transportation systems (ITSs) and operations strategies
- Implementing alternative bridge management strategies.

Comparison of Scenarios With Previous Reports

The **Maintain Conditions and Performance scenario** presented in this report is generally comparable to the fixed-rate financing version of the **Sustain Conditions and Performance scenario** presented in the 2008 C&P Report. The two key differences are in the portion of the scenario derived from the Highway Economic Requirements System (HERS) model. First, the revised scenario targets average speed rather than adjusted average user costs. Second, the revised scenario makes no assumption about how the increased investment needed to support the scenario would be generated, whereas the scenario in the 2008 C&P Report assumed that this funding gap would be covered by a flat-rate surcharge per VMT. The **Improve Conditions and Performance scenario** presented in this edition of the C&P report is generally comparable to the MinBCR=1.0 scenario with fixed-rate user financing that was presented in the 2008 edition, except that the revised scenario in this edition makes no assumption about financing mechanisms. The potential impacts of alternative financing mechanisms are explored later in this chapter. It should also be noted that the values reported in the 2008 C&P Report were stated in constant 2006 dollars and that the scenarios covered the period from 2007 to 2026; in contrast, the scenarios presented in this report are stated in constant 2008 dollars and cover the period from 2009 to 2028.

As discussed in Chapter 6, highway construction costs as measured by the Federal Highway Administration's (FHWA's) new National Highway Construction Cost Index decreased by 3.4 percent between 2006 and 2008. Consequently, adjusting the 2008 C&P Report's scenario figures from 2006 dollars to 2008 dollars causes them to appear smaller. As shown in *Exhibit 9-1,* the 2008 C&P Report estimated the average annual investment level in the scenario comparable to the current **Maintain Conditions and Performance scenario** at $105.6 billion; adjusting for inflation (actually deflation) decreases this amount to $102.0 billion in 2008 dollars. The comparable amount for the **Maintain Conditions and Performance scenario** presented in Chapter 8 of this edition is $101.0 billion, approximately 1.0 percent lower.

Exhibit 9-1

Selected Highway Investment Scenario Projections Compared With Comparable Data From the 2008 C&P Report (Billions of Dollars)

	2007–2026 Projection (Based on 2006 Data)		2009–2028 Projection (Based on 2008 Data)
Highway and Bridge Scenarios—All Roads	**2008 C&P Report (Billions of 2006 Dollars)**	**Adjusted for Inflation [1] (Billions of 2008 Dollars)**	**(Billions of 2008 Dollars)**
Maintain Conditions and Performance scenario [2]	$105.6	$102.0	$101.0
Improve Conditions and Peformance scenario [3]	$174.6	$168.6	$170.1

[1] The investment levels for the highway and bridge scenarios were adjusted for inflation using the FHWA National Highway Construction Cost Index (NHCCI).

[2] The $105.6 billion figure from the 2008 C&P Report is from the "Sustain Conditions and Performance Scenario Assuming Fixed Rate User Financing." The HERS component of that scenario focused on maintaining adjusted average user costs, rather than maintaining average speed.

[3] The $174.6 billion figure from the 2008 C&P Report is from the "MinBCR=1.0 Scenario Assuming Fixed Rate User Financing."

Sources: Highway Economic Requirements System and National Bridge Investment Analysis System.

Q&A

How did the change in the scenario target measure for the Maintain Conditions and Performance scenario affect its average annual investment level?

As referenced in Chapter 8, the **Maintain Conditions and Performance scenario** in this report targeted maintaining average speed in 2028 at base year 2008 levels. The comparable scenario from the 2008 C&P Report had instead targeted maintaining adjusted average user costs in 2026 at base year 2006 levels in constant dollar terms.

Based on information presented in Chapter 7 (see *Exhibit 7-10*) and the scenario computation methods described in Chapter 8 (see *Exhibit 8-8*), the average annual investment level for the **Maintain Conditions and Performance scenario** would have been approximately $1.0 billion lower ($100.0 billion rather than $101.0 billion, stated in constant 2008 dollars) if adjusted average user costs had been used as the target measure in this report rather than average speed. As shown in *Exhibit 9-1*, the comparable figure presented in the 2008 C&P Report was $105.8 billion (stated in constant 2006 dollars).

The average annual investment level in the 2008 C&P Report scenario comparable to the current **Improve Conditions and Performance scenario** was $174.6 billion; adjusting for inflation decreases this amount to $168.6 billion in 2008 dollars. The comparable amount for the current **Improve Conditions and Performance scenario** presented in Chapter 8 of this edition is $170.1 billion, approximately 0.8 percent higher.

The relatively small changes between the scenario findings in this report relative to the 2008 C&P Report are attributable both to changes in the underlying characteristics, conditions and performance of the highway system reported in Chapters 2, 3, and 4, and to changes in the methodology and models used to generate the estimates. The changes in the scenario definitions noted above had a small impact; the changes in the HERS and National Bridge Investment Analysis System (NBIAS) models were relatively minor for this edition compared with previous editions. Appendices A and B include additional information on these two models.

Comparisons of Implied Funding Gaps

Exhibit 9-2 compares the estimated percentage differences of current spending and the average annual investment scenario estimates for the **Maintain Conditions and Performance scenario** and the **Improve Conditions and Performance scenario** with the comparable estimated percentage differences identified in previous C&P reports. For each of the reports identified, actual spending in the base year for that report has been below the estimate of the average annual investment level required to maintain conditions and performance at base-year levels over 20 years. In the current report, the gap between these amounts, 10.8 percent, is smaller than in the 2008 C&P Report, which stems partly from the decrease in highway construction costs since 2006 discussed above, and from the increase in spending by all levels of government combined between 2006 and 2008 (as identified in Chapter 6). A 10.8 percent gap is more consistent with the corresponding estimate in the 2004 and 2006 editions of the C&P report. The same is true for the 86.6-percent gap between 2008 spending and the average annual investment level in the **Improve Conditions and Performance scenario** in the present edition.

Exhibit 9-2

Average Annual Highway and Bridge Investment Scenario Estimates Versus Current Spending, 1997 to 2010 C&P Reports

Report Year	Relevant Comparison	Percent Above Current Spending: Primary "Maintain" Scenario*	Percent Above Current Spending: Primary "Improve" Scenario*
1997	Average annual investment scenario estimates for 1996–2015 compared with 1995 spending	21.0%	108.9%
1999	Average annual investment scenario estimates for 1998–2017 compared with 1997 spending	16.3%	92.9%
2002	Average annual investment scenario estimates for 2001–2020 compared with 2000 spending	17.5%	65.3%
2004	Average annual investment scenario estimates for 2003–2022 compared with 2002 spending	8.3%	74.3%
2006	Average annual investment scenario estimates for 2005–2024 compared with 2004 spending	12.2%	87.4%
2008	Average annual investment scenario estimates for 2007–2026 compared with 2006 spending	34.2%	121.9%
2010	Average annual investment scenario estimates for 2009–2028 compared with 2008 spending	10.8%	86.6%

** Amounts shown correspond to the primary investment scenario associated with maintaining or improving the overall highway system in each C&P report; the definitions of these scenarios are not fully consistent between reports. The values shown for this report reflect the Maintain Conditions and Performance and the Improve Conditions and Performance scenarios.*

Sources: Highway Economic Requirements System and National Bridge Investment Analysis System.

Changes in the actual capital spending by all levels of government combined can substantially alter these spending "gaps," as can sudden, large swings in construction costs such as the large increase experienced between 2004 and 2006. However, **the differences among C&P report editions in the implied gaps**

reported in *Exhibit 9-2* are not a consistent indicator of changes over time in how effectively highway investment needs are being addressed. The FHWA continues to enhance the methodology used to determine scenario estimates for each edition of the C&P report in order to provide a more comprehensive and accurate assessment. In some cases, these refinements have increased the level of investment in one or both of the scenarios (the "Maintain" or "Improve" scenarios, or their equivalents); other refinements have reduced this level.

Comparison of 1989 C&P Report Scenario Projections for 2005 With Actual Condition and Performance in 2005

The highway component of the C&P report is part of a series dating back to the 1968 *National Highway Needs* report to Congress. It is challenging to directly compare the results of different editions over time for many reasons, including differences in base year conditions and analysis periods, changes in analytical models, and changes in scenario definitions. However, comparing the long-term scenario projections from previous editions with what actually occurred in terms of system conditions and performance is a useful exercise that can be of assistance in putting the scenario findings from this edition into the proper perspective. The 1989 *Status of the Nation's Highways and Bridges: Condition and Performance and Highway Bridge Replacement and Rehabilitation Program* report to Congress (1989 C&P Report) is the most recent edition for which the period of the long-term capital investment scenarios has ended, and thus represents a useful document for comparative analysis.

Differences in 1989 C&P Report Scenario Design and Construction

In order to evaluate the 1989 C&P Report's scenarios, it is important to note certain critical differences from those presented in the current edition. The current edition relies primarily on 2008 data, includes 20-year capital investment scenarios covering investment for the period 2009 through 2028, and includes "Maintain" scenarios that estimate the costs of maintaining conditions and performance at base year 2008 levels through 2028. In contrast, although the 1989 C&P Report relied primarily on 1987 data, its "Maintain" scenarios focused on maintaining conditions and performance at 1985 levels through 2005. Further, the 1989 C&P Report's capital investment scenarios included spending for the period 1987 through 2005 (a 19-year period which included the 1987 base year, a year that had already passed).

Another key difference between the current edition and the 1987 C&P Report is in the coverage of the capital investment scenarios. The current edition includes rough estimates for functional classes for which data are not available in the Highway Performance Monitoring System (HPMS), so that the systemwide versions of the scenarios include needs associated with all roads and bridges. In contrast, the 1987 C&P Report's highway investment scenarios explicitly excluded roads functionally classified as rural local or urban local (though bridges on these functional systems were included).

The HERS model was first utilized in the 1995 C&P Report and the NBIAS model made its debut in the 2002 C&P Report; the scenarios presented in the 1989 C&P Report were based on older tools that placed more emphasis on engineering criteria and less on economic considerations.

1989 C&P Report Scenario Definitions

The 1989 C&P Report presented three primary scenarios (identified as "investment strategies" in the document) for highways and bridges.

The **Constrained Full Needs** scenario estimated the investment levels required to address all existing and projected future highway and bridge deficiencies through the year 2005. Deficiencies were identified by comparing simulated conditions and performance against an established set of minimum conditions standards. The 1989 C&P Report noted that these standards were set well below full design standards for new roads, so that the resulting system would not be in perfect condition. The word "constrained" in the scenario title related to the treatment of capacity improvements. If the data reported in the HPMS for a particular highway segment indicated that there was no room within the existing right of way for additional through lanes, no expansion options were considered, regardless of how congested the facility might become. The document specifically noted that overall operational performance was expected to get worse in urban areas under this scenario.

The **Maintain Overall 1985 Conditions scenario** estimated the cost to maintain the highway system at 1985 levels through 2005, based on a composite rating taking into account service, safety, and condition measures. In general, the scenario provided for some improvement in highway physical conditions while resulting in some deterioration in operational performance. Specifically, the document notes that operational performance would decline on both the rural and urban components of the Interstate System. (The bridge investment requirements included in this scenario were identical to those included in the **Constrained Full Needs scenario** because a new bridge model had just been adopted that was not yet considered sufficiently robust to support a separate "Maintain" analysis.)

The Maintain System Performance scenario focused on identifying the predominant purpose that individual functional systems serve and estimating the cost of sustaining effective delivery of that function through the year 2005. For instance, on the higher functional systems, maintaining service and safety was considered to be the priority; the level of service, a measure of peak-period congestion, was used to simulate the service characteristics on the higher-level systems. For other roads, the composite index of maintaining safety, condition, and performance was utilized. The document notes that, despite the increased emphasis on operational performance under this scenario, congestion was still projected to get worse, as no widening options were considered outside of the existing right of way. (The bridge investment requirements included in this scenario were identical to those included in the **Constrained Full Needs scenario**.) Although the **Maintain System Performance scenario** was presented as a theoretical refinement to the approach taken in the **Maintain Overall 1985 Conditions scenario** (which was more consistent with previous editions), the average annual investment levels associated with the two scenarios were very close because neither included potential higher-cost capacity expansion options such as building parallel routes, double-decking, tunneling, or investing in alternative transportation modes.

The composite average annual VMT growth rate derived from the HPMS forecasts of future VMT through 2005 was 2.34 percent per year. For the highway components of each scenario, two alternative versions were developed, one assuming an average annual VMT growth rate of 2.0 percent and one assuming 3.0 percent annual VMT growth. The actual VMT growth rate for the period 1987 through 2005 was 2.52 percent, which is conveniently near the midpoint of these two alternative scenario assumptions. For the bridge components of each scenario, the average annual growth rate of 2.34 percent taken from HPMS was utilized.

Comparison of 1989 C&P Report Scenarios With Actual Spending

Exhibit 9-3 shows the estimated average annual and cumulative 19-year highway and bridge needs associated with each of the scenarios presented in the 1989 C&P Report. The cumulative values are also adjusted for inflation to 2008 dollars using the FHWA Composite Bid Price Index (BPI) through the year 2006 and the new FHWA National Highway Construction Cost Index (NHCCI) for subsequent years.

Exhibit 9-3

Primary 1989 C&P Report Investment Scenario Estimates Versus Cumulative Spending, 1987 Through 2005

	1987–1995 Projection From 1989 C&P Report		Adjusted for Inflation
	Average Annual (Billions of 1987 Dollars)	Cumulative 19 Years (Billions of 1987 Dollars)	Cumulative 19 Years (Billions of 2008 Dollars)
Scenarios Assuming 3.0 Percent Annual VMT Growth			
Cost to Maintain 1985 Overall Conditions	$28.8	$546.8	**$1,169.3**
Cost to Maintain 1985 System Peformance	$28.7	$545.6	$1,166.7
Constrained Full Needs	$39.4	$748.5	**$1,600.6**
Scenarios Assuming 2.0 Percent Annual VMT Growth			
Cost to Maintain 1985 Overall Conditions	$25.1	$476.0	**$1,017.9**
Cost to Maintain 1985 System Peformance	$25.1	$476.0	$1,017.9
Constrained Full Needs	$34.7	$658.4	**$1,407.9**
Actual Highway Capital Outlay, Adjusted to 2008 Dollars [1]			
Cumulative Capital Outlay, 1987 through 2005 [2]			$1,562.8
Estimated Capital Outlay on Comparable Facilities [3]			**$1,257.2**

[1] *VMT grew at an average annual rate of 2.52 percent between 1987 and 2005.*

[2] *Highway capital outlay by all levels of government combined totaled $1,210.5 billion in nominal dollar terms over the 19-year period from 1987 through 2005. This equates to $730.8 billion in constant 1987 dollars or $1,562.8 billion in constant 2008 dollars.*

[3] *An estimated 80.4 percent of highway capital spending from 1997 through 2005 was directed toward arterials and collectors covered by the 1989 C&P Report investment scenarios. This equates to $587.9 billlion in constant 1987 dollars or $1,257.2 billion in constant 2008 dollars.*

Sources: 1989 Status of the Nation's Highways and Bridges: Conditions and Performance Report to Congress, page 112; Highway Statistics, various years, Tables HF-10A, HF-10, PT-1, and SF-12A; and unpublished FHWA data.

The average annual highway capital investment needs reported for the **Maintain 1985 Overall Conditions scenario** ranged from $25.1 billion to $28.8 billion in constant 1987 dollars, depending on whether future average annual VMT growth was assumed to be 2.0 percent or 3.0 percent. Cumulative 19-year needs for the period from 1987 through 2005 were identified as $476.0 billion to $546.8 billion in constant 1987 dollars; this equates to $1.0179 trillion to $1.1667 trillion in constant 2008 dollars. The investment needs associated with the **Maintain System Performance scenario** were very similar because the limitations on capacity expansion assumed in both scenarios tended to overwhelm the differences in their theoretical approaches.

The average annual highway capital investment needs reported for the **Constrained Full Needs scenario** ranged from $34.7 billion to $39.4 billion in constant 1987 dollars, depending on whether future average annual VMT growth was assumed to be 2.0 percent or 3.0 percent. Cumulative 19-year needs for the period from 1987 through 2005 were identified as $658.4 billion to $748.5 billion in constant 1987 dollars; this equates to $1.4079 trillion to $1.6006 trillion in constant 2008 dollars.

Actual highway capital spending by all levels of government from 1987 through 2005 totaled $1.2105 trillion in nominal dollar terms; this equates to $1.5628 trillion in constant 2008 dollars. Of this total, approximately 80.4 percent, or $1.2572 trillion in constant 2008 dollars was directed towards the types of facilities (arterials and collectors) reflected in the 1989 C&P Report scenarios; the remaining 19.6 percent was directed to roads functionally classified as rural local or urban local.

In constant dollar terms, actual highway capital spending for the 19-year period from 1987 through 2005 was 7.5 percent higher than the version of the **Maintain 1985 Overall Conditions scenario** assuming 3.0 percent annual VMT growth and 23.5 percent higher than the version assuming 2.0 percent annual VMT growth. In contrast, cumulative 19-year spending was 10.7 percent below the version of the **Constrained Full Needs scenario** assuming 2.0 percent annual VMT growth and 21.5 percent lower than the version assuming 3.0 percent annual VMT growth. To the extent that the 1989 C&P Report scenario projections were accurate, this would suggest that the outcomes in terms of system conditions and performance in 2005 should have been better than what was projected for the **Maintain 1985 Overall Conditions scenario**, but worse than what was projected for the **Constrained Full Needs scenario**.

Comparison of 1989 C&P Report Projections With Actual Outcomes

The pavement condition data shown in the 1989 C&P Report was based on the Present Serviceability Rating (PSR) data reported by the States. As discussed in Chapter 3, the PSR is a subjective measure of overall pavement quality. FHWA has subsequently adopted the International Roughness Index (IRI), a mechanically measured indicator of pavement ride quality, as its primary performance measure. States are still permitted to provide PSR data for some functional classes; in such cases, the PSR values are converted to IRI equivalents for reporting purposes in Chapter 3. The information presented in *Exhibit 9-4* was developed in a similar manner, with PSR values from 1985 converted to their IRI equivalents and reported using terminology consistent with Chapter 3.

Actual capital spending in constant dollars over the 19-year period from 1987 through 2005 was higher than the investment levels associated with the **Maintain 1985 Overall Conditions scenario**, which suggests that some improvements to pavement conditions should have been achieved. As shown in *Exhibit 9-4*, pavement conditions have generally improved over this period. The percentage of arterial and collector pavements with "acceptable" ride quality increased from 88.6 percent in 1985 to 94.0 percent in 2005, while the percentage of pavements with "good" ride quality increased from 39.7 percent to 43.2 percent. (It should be noted that this overall improvement was driven primarily to improvements in the quality of rural pavements because the percentage of urban pavements in both the "good" and "acceptable" categories declined from 1985 to 2005.)

Exhibit 9-4

Percent of Mileage With Good and Acceptable Ride Quality, by Functional System, for 1985 and 2005

	Percent Good	
Functional System	**1985**	**2005**
Rural Interstate	59.6%	75.1%
Rural Principal Arterial	49.1%	63.7%
Rural Minor Arterial	42.6%	52.5%
Rural Major Collector	30.3%	35.2%
Subtotal Rural	**39.7%**	**44.9%**
Urban Interstate	55.8%	57.8%
Urban Other Freeway & Expressway	51.0%	47.2%
Urban Other Principal Arterial	44.3%	25.2%
Urban Minor Arterial	39.5%	31.8%
Urban Collector	32.5%	30.9%
Subtotal Urban	**39.7%**	**32.1%**
Total Good *	**39.7%**	**43.2%**

	Percent Acceptable	
Functional System	**1985**	**2005**
Rural Interstate	93.0%	98.3%
Rural Principal Arterial	92.6%	99.1%
Rural Minor Arterial	90.9%	97.1%
Rural Major Collector	75.0%	93.5%
Subtotal Rural	**88.4%**	**95.2%**
Urban Interstate	93.4%	93.8%
Urban Other Freeway & Expressway	95.4%	96.2%
Urban Other Principal Arterial	91.9%	81.4%
Urban Minor Arterial	88.9%	87.6%
Urban Collector	85.1%	83.2%
Subtotal Urban	**89.4%**	**85.4%**
Total Acceptable *	**88.6%**	**94.0%**

** 1985 values primarily reflect PSR data; 2005 values reflect a mix of PSR and IRI data.*

Source: Highway Statistics 1985 and Highway Statistics 1995, Tables HM-63 and HM-64.

Due to the timing of data availability, the bridge data in the C&P report has typically run a year ahead of the pavement data. *Exhibit 9-5* compares the percent of deficient bridges in 1986 with that in 2006. During this period, the percentage of bridges classified as functionally deficient declined from 22.9 percent to 12.6 percent, and the percentage of bridges classified as functionally obsolete declined from 19.5 percent to 15.0 percent (Chapter 3 includes definitions of these terms). These reductions in bridge deficiencies represent a significant improvement to the state of the Nation's bridges; this is consistent with actual capital spending in constant dollars over the 19-year period from 1987 through 2005 having been higher than the investment levels associated with the **Maintain 1985 Overall Conditions scenario**.

Exhibit 9-5

Systemwide Bridge Deficiencies, 1986 and 2006

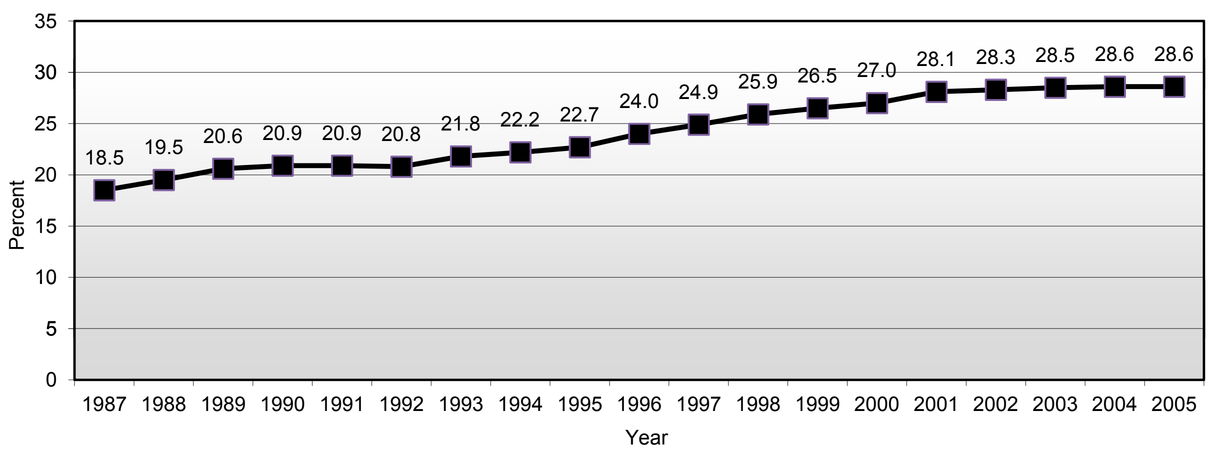
	1986	2006
Structurally Deficient	22.9%	12.6%
Functionally Obsolete	19.5%	15.0%
Total Deficient	**42.3%**	**27.6%**

Source: National Bridge Inventory.

The 1989 C&P Report discussed operational performance using measures such as volume/capacity ratios. Such measures are not directly consistent over time because the theoretical capacity of different roadway types has been updated periodically to reflect changes in driver behavior and other factors. Although the statistics presented in Chapter 4 based on analysis by the Texas Transportation Institute (TTI) had not yet been developed at that time, TTI has computed data on a consistent basis back to 1987 to facilitate comparisons over time. *Exhibit 9-6* shows that the percentage of travel occurring under congested conditions rose from 18.5 percent in 1987 to 28.6 percent in 2008. This increase is very significant and has resulted in a significant increase in the costs experienced by travelers in the form of wasted fuel and time. The 1989 C&P Report was very explicit about expected increases in highway congestion and delay even if investment had reached the level of the **Constrained Full Needs scenario**. Because actual capital spending in constant dollars over the 19-year period from 1987 through 2005 fell well below the level of this scenario, it is not surprising that congestion increased significantly over this period.

Exhibit 9-6

Average Daily Percentage of VMT Under Congested Conditions for All Urbanized Areas, 1987–2005



Source: Texas Transportation Institute.

Comparison of 1999 C&P Report Scenario Projections for 2017 With Actual Condition and Performance Through 2008

The scenario projections from the 1999 C&P Report extended from a base year of 1997 through the year 2017. While it is too early to make a definitive assessment of these 20-year forecasts, it is possible to draw some initial conclusions based on changes in conditions and performance that have occurred through 2008, the 11th year of this forecast period.

Unlike the 1989 C&P Report, the general approach for developing the investment scenarios for the 1999 C&P Report was similar to the approach in the current report. The 1999 C&P Report relied on 1997 base year data, and its 20-year scenarios projected the impact of investment for 1998 through 2017; the "Maintain" scenarios presented in the 1999 C&P Report focused on maintaining measures of conditions and performance at base year 1997 levels through 2017.

The coverage of the 1999 C&P investment scenarios also is similar to the current edition in that they include estimates for types of highway capital improvements that were not captured through the analytical models. Consequently, when comparing actual highway capital spending with the investment scenarios, it is not necessary to deduct a percentage of spending to align with the scope of the scenarios, as was the case in the discussion of the 1989 C&P Report presented earlier.

The investment requirements associated with the primary scenarios are broken down into three major categories—System Preservation, System Expansion, and System Enhancements—that roughly correspond to the categories presented in the current edition. The HERS model was used in the development of the highway components of the 1999 C&P Report, although the bridge analysis relied on an older model that did not incorporate the economic considerations built into the NBIAS model used in the current report.

1999 C&P Report Scenario Definitions

The 1999 C&P Report presented two main scenarios for highways and bridges, supplemented by two "benchmarks" defined around their highway components.

The **Cost to Improve Highways and Bridges** combined the investment levels associated with a **Maximum Economic Investment scenario** for highways with an **Eliminate Deficiencies scenario** for bridges. This costs associated with the highway component of this scenario were estimated to be sufficient to implement all potential highway improvements identified by HERS with a benefit-cost ratio (BCR) greater than or equal to 1.0. The costs associated with the bridge component of this scenario were estimated to be sufficient to fully address the existing backlog of bridge investments, and to correct other bridge deficiencies projected to develop over the next 20 years. (This scenario is very similar in definition to the **Improve Conditions and Performance scenario** in the current edition, except that the bridge analysis did not apply benefit-cost criteria in computing the backlog of bridge investments.) At this level of investment, key performance indicators such as pavement condition, travel time, and total highway user costs were all projected to improve.

The **Cost to Maintain Highways and Bridges** combined the investment levels associated with a **Maintain Conditions scenario** for highways with a **Maintain Backlog scenario** for bridges. The costs associated with the highway component of this scenario were estimated to be sufficient to implement all potential highway improvements identified by HERS with a BCR greater than or equal to 2.33, which were projected to result in average pavement conditions in 2017 that matched those in the 1997 base year. The costs associated with the bridge component of this scenario were estimated to be sufficient to keep the overall backlog of bridge investments in 2017 from growing larger than the amount computed for the 1997 base year. At this level of investment, travel time and total highway user costs were projected to rise, reflecting a deterioration in systemwide operational performance.

Similar to the **Maintain Condition scenario** for highways, the **Maintain User Cost benchmark** and **Maintain Travel Time benchmark** were developed by progressively increasing the minimum BCR cutoff point above 1.0 so that fewer potential highway investments would be undertaken until the point where the particular indicator targeted would be maintained at the 1997 level on average over the 20-year period through 2017. The costs associated with the **Maintain User Cost benchmark** were estimated to be sufficient to implement all potential highway improvements identified by HERS with a BCR greater than or equal to 2.15; at this level of investment, average user costs were projected to remain steady over 20 years while average pavement conditions improved and average operational performance declined. The costs associated with the **Maintain Travel Time benchmark** were estimated to be sufficient to implement all potential highway improvements identified by HERS with a BCR greater than or equal to 1.50; at this level of investment, average travel time costs were projected to remain steady over 20 years while average pavement conditions improved and average highway user costs were reduced. Although these two benchmarks did not formally include a bridge component, investment levels for bridges were interpolated between those computed for the two main scenarios in order to produce combined highway and bridge needs estimates that could be more readily compared to combined highway and bridge capital spending figures.

Comparison of 1999 C&P Report Scenarios With Actual Spending

Exhibit 9-7 shows the estimated average annual highway and bridge needs associated with the scenarios and benchmarks presented in the 1999 C&P Report for the 20-year period ending in 2017, stated in constant 1997 dollars; these average annual values are converted to cumulative 11-year values in 1997 dollars for the period ending in 2008. The cumulative 11-year values are also adjusted for inflation to 2008 dollars, using the FHWA BPI through the year 2006, and the new FHWA NHCCI for subsequent years.

The average annual **Cost to Maintain Highways and Bridges** was identified as $56.6 billion in constant 1997 dollars in the 1999 C&P Report; over 11 years, this equates to $623.0 billion in constant 1997 dollars or $1.0201 trillion in constant 2008 dollars. Actual highway capital spending by all levels of government

Exhibit 9-7

1999 C&P Report Investment Scenario Estimates Versus Cumulative Spending, 1998 Through 2008

	1998–2017 Projection From 1999 C&P Report		Adjusted for Inflation
	Average Annual Over 20 Years (Billions of 1997 Dollars)	Cumulative for First 11 Years Through 2008 (Billions of 1997 Dollars)	Cumulative for First 11 Years Through 2008 (Billions of 2008 Dollars)
Cost to Maintain Highways and Bridges	$56.6	$623.0	**$1,020.1**
Maintain User Costs Benchmark [1]	$60.1	$661.5	$1,083.2
Maintain Travel Time Benchmark [1]	$76.3	$838.9	$1,373.6
Cost to Improve Highways and Bridges	$94.0	$1,033.6	**$1,692.4**
Actual Highway Capital Outlay, Adjusted to 2008 Dollars [2]			**$1,029.2**

[1] The 1999 C&P Report defined these benchmarks in terms of highway performance only, but interpolated a separate bridge component to facilitate comparisons with combined highway and bridge spending.

[2] Highway capital outlay by all levels of government combined totaled $782.4 billion in nominal dollar terms over the 11-year period from 1998 through 2008. This equates to $628.5 billion in constant 1987 dollars or $1,029.2 billion in constant 2008 dollars.

Sources: 1999 Status of the Nation's Highways, Bridges and Transit: Conditions and Performance report to Congress, Exhibit 9-4, Highway Statistics, various years, Tables HF-10A, HF-10, PT-1, and SF-12A; and unpublished FHWA data.

combined from 1998 through 2008 totaled $782.4 billion in nominal dollar terms; this equates to $1.0292 trillion in constant 2008 dollars, which is 0.9 percent higher than the **Cost to Maintain Highways and Bridges** level.

The average annual cost associated with the **Maintain User Costs benchmark** (including an interpolated bridge figure) was identified as $60.1 billion in constant 1997 dollars in the 1999 C&P Report; over 11 years, this equates to $661.6 billion in constant 1997 dollars or $1.0832 trillion in constant 2008 dollars. Actual highway capital outlay from 1998 through 2008 ($1.0292 trillion in constant 2008 dollars) would have had to have been 5.0 percent higher in constant dollar terms in order to have reached the level for this benchmark.

The average annual cost associated with the **Maintain Travel Time benchmark** (including an interpolated bridge figure) was identified as $76.3 billion in constant 1997 dollars in the 1999 C&P Report; over 11 years, this equates to $838.9 billion in constant 1997 dollars or $1.3736 trillion in constant 2008 dollars. Actual highway capital outlay from 1998 through 2008 ($1.0292 trillion in constant 2008 dollars) would have had to have been 25.1 percent higher in constant dollar terms in order to have reached the level for this benchmark.

The average annual **Cost to Improve Highways and Bridges** was identified as $94.0 billion in constant 1997 dollars in the 1999 C&P Report; over 11 years, this equates to $1.0336 trillion in constant 1997 dollars or $1.6924 trillion in constant 2008 dollars. Actual highway capital outlay from 1998 through 2008 ($1.0292 trillion in constant 2008 dollars) would have had to have been 39.2 percent higher in constant dollar terms in order to have reached the **Cost to Improve Highways and Bridges** level.

Comparison of 1999 C&P Report Projections With Actual Outcomes

Actual capital spending in constant dollars over the 11-year period from 1998 through 2008 was 0.9 percent higher than the investment levels associated with the **Cost to Maintain Highways and Bridges,** suggesting that some small improvements to pavement and bridge conditions should have been achieved. Actual constant dollar spending was significantly lower than the investment levels associated with the **Maintain Travel Time benchmark** over this period, suggesting that operational performance should have gotten worse.

Based on the HPMS sample sections evaluated by HERS, average IRI improved slightly from 1997 to 2008, from a value of 115.0 to 114.4 (the former value was not identified in the 1999 C&P Report itself, but was used in the computation of projected changes in average IRI that were reported). As illustrated in *Exhibit 9-8*, changes in pavement ride quality varied by functional class. Although the percentage of travel

Exhibit 9-8

Percent of VMT on Pavements With Good and Acceptable Ride Quality, by Functional System, 1997 and 2008

	Percent Good	
Functional System	**1997**	**2008**
Rural Interstate	56.5%	79.0%
Rural Principal Arterial	47.0%	68.4%
Rural Minor Arterial	43.8%	56.2%
Rural Major Collector	41.9%	39.0%
Subtotal Rural	**47.9%**	**62.5%**
Urban Interstate	36.3%	55.7%
Urban Other Freeway & Expressway	28.0%	44.4%
Urban Other Principal Arterial	27.1%	26.9%
Urban Minor Arterial	41.1%	32.5%
Urban Collector	39.3%	31.5%
Subtotal Urban	**34.1%**	**38.9%**
Total Good *	**39.4%**	**46.4%**

	Percent Acceptable	
Functional System	**1997**	**2008**
Rural Interstate	95.7%	97.3%
Rural Principal Arterial	93.8%	97.6%
Rural Minor Arterial	92.1%	94.5%
Rural Major Collector	87.3%	88.3%
Subtotal Rural	**92.5%**	**94.8%**
Urban Interstate	88.5%	91.9%
Urban Other Freeway & Expressway	87.2%	91.4%
Urban Other Principal Arterial	74.4%	72.4%
Urban Minor Arterial	83.4%	75.5%
Urban Collector	83.6%	72.0%
Subtotal Urban	**82.7%**	**81.0%**
Total Acceptable *	**86.4%**	**85.4%**

** Totals shown reflect Federal-aid highways only and exclude roads classified as rural minor collector, rural local, or urban local, for which pavement data are not reported in HPMS.*

Source: Highway Performance Monitoring System as of December 2009.

on pavements with good ride quality increased from 39.4 percent in 1997 to 46.4 percent in 2008, the portion of travel meeting this criteria declined for rural major collectors, urban other principal arterials, and urban collectors. In contrast, the percentage of travel on pavements with acceptable ride quality declined from 86.4 percent in 1997 to 85.4 percent in 2008; declines on urban other principal arterials, urban minor arterials, and urban collectors over this period outweighed improvements on other functional systems. Given how close actual spending from 1997 to 2008 was to the **Cost to Maintain Highways and Bridges** level in constant dollar terms, these types of mixed results are not surprising.

The bridge investment backlog figures presented in the 1999 C&P Report were computed differently than those in the current edition, and thus are not directly comparable. However, the definition of structurally deficient and functionally obsolete bridges has remained consistent. *Exhibit 9-9* compares the percentage of deficient bridges for 1998 presented in the 1999 C&P Report with those for 2009 presented in the current edition. The overall percentage of bridges classified as structurally deficient or functionally obsolete declined from 29.6 percent in 1998 to 26.5 percent in 2009. The percentage of bridges classified as structurally deficient declined over this period from 28.8 percent to 24.3 percent, and the percentage of bridges classified as functionally obsolete increased from 13.6 percent to 14.5 percent. The percentage of structurally deficient and functionally obsolete bridges declined in both rural and urban areas between 1998 and 2009. However, while the percentage of rural functionally obsolete bridges declined from 11.4 percent to 11.0 percent during this period, the percentage of urban functionally obsolete bridges rose from 21.5 percent to 24.5 percent. This finding has significant implications in terms of the bridge investment backlog because the cost of addressing functional obsolescence can be particularly expensive in urban areas due to potentially high construction costs and right of way limitations.

Exhibit 9-9

Bridge Deficiencies by Functional System, 1998 and 2009

	Structurally Deficient	
	1998	**2009**
Rural	17.4%	13.3%
Urban	11.0%	8.4%
Rural and Urban	**16.0%**	**12.0%**
	Functionally Obsolete	
	1998	**2009**
Rural	11.4%	11.0%
Urban	21.5%	24.5%
Rural and Urban	**13.6%**	**14.5%**
	Total Deficient	
	1998	**2009**
Rural	28.8%	24.3%
Urban	32.5%	32.9%
Rural and Urban	**29.6%**	**26.5%**

Source: National Bridge Inventory.

The operational performance metrics presented in the 1999 C&P Report are not fully comparable to those presented in the current edition. However, as shown in *Exhibit 9-10*, applying a consistent methodology over time the TTI has estimated that the average daily percentage of travel in urbanized areas occurring under congested conditions has risen from 24.9 percent in 1997 to 26.3 percent in 2008. Although operational performance declined over this period, the magnitude of that decline appears smaller than what might have been expected given the large gap between the **Maintain Travel Time benchmark** and actual spending from 1998 through 2008 in constant dollar terms. This apparent discrepancy can be explained in part by the 1999 C&P Report's estimates of future travel volumes. The 1999 C&P Report projected that, based on State travel forecasts provided via HPMS and assuming a spending increase to the level of

Exhibit 9-10

Average Daily Percentage of VMT Under Congested Conditions for All Urbanized Areas, 1997–2008

Year	Average	Year	Average
1997	24.9%	2003	28.5%
1998	25.9%	2004	28.6%
1999	26.5%	2005	28.6%
2000	27.0%	2006	28.4%
2001	28.1%	2007	27.8%
2002	28.3%	2008	26.3%

Source: Texas Transportation Institute.

the **Cost to Maintain Highways and Bridges**, total VMT would rise to 3.4 trillion by 2008. However, actual VMT in 2008 was only 3.0 trillion. Because VMT has grown more slowly than had been projected, congestion has also worsened more slowly. Chapter 2 includes a discussion of VMT growth rates over time and of the decline in VMT associated with the recent recession.

Linkage Between Recent Conditions and Performance Spending Trends and Selected Capital Investment Scenarios

The inferences that can be drawn from comparing this report's prospective capital investment scenarios with its retrospective analyses of conditions, performance, and system finance are limited. As a result of the aging of existing highway and bridge infrastructure and growth in travel volumes, an amount of funding that achieved a certain level of system performance in the past might be inadequate to sustain that same level of performance in the future. In addition, while this report's consideration of past levels of investment focuses on the base year of 2008, system conditions and performance in that and previous years will depend on the amounts invested over a long period. That said, while the real level of highway investment fluctuated substantially within 2000–2008—the historical period with which this section compares 2009–2028— it was fairly stable for this period as a whole, increasing at an average annual rate of only 0.1 percent according to the estimates in Chapter 6.

Recognizing these potential limitations, simple comparisons between the retrospective and prospective analyses can still yield suggestive findings that help draw out the implications of the capital investment scenarios. *Exhibit 9-11* compares selected observations based on the investment/performance relationships identified in Chapter 7 with retrospective performance observations drawn from Chapters 3 and 4; these observations are discussed in more detail below.

Pavement Conditions

As shown in Chapter 6, all levels of government spent a combined $15.0 billion on highway system (pavement) rehabilitation in 2008 (see *Exhibit 6-15*) on the NHS. This is well above the $10.8-billion figure estimated as the average annual investment level (in constant 2008 dollars) needed to sustain average IRI in 2028 at base year 2008 levels (see *Exhibit 7-12*). HERS projects that if this $15.0 billion spending level were sustained in constant dollar terms over 20 years, pavement conditions would increase significantly. This projection is generally consistent with recent trends identified in Chapter 3—the percentage of VMT on the National Highway System (NHS) on pavements with good ride quality increased from 48 percent in 2000 to 57 percent in 2008.

In contrast, for Federal-aid highways, HERS projects that maintaining average pavement condition would require annual spending on pavement rehabilitation to average more than the 2008 level. From 2009 through 2028, investment in pavement improvements on Federal-aid highways would need to average an estimated $29.0 billion per year to sustain average IRI at the 2008 level (see *Exhibit 7-5*), whereas actual investment in pavement improvements on Federal-aid highways in 2008 was only $26.4 billion. Alternatively, continuing to invest in pavement improvements on Federal-aid highways at a level of $26.4 billion annually (constant dollars) is projected to produce mixed pavement results by 2028. Relative to 2008, a higher percentage of VMT on the Federal-aid highways would occur on pavements with good ride quality and a lower percentage on pavements with acceptable ride quality.

Exhibit 9-11

Comparison of Capital Investment Scenarios With Recent System Performance for Selected Indicators

Future Investment Scenario Observation	Historic Performance Observation
System Rehabilitation—Pavements	
Base year 2008 levels of capital spending on NHS pavements are projected to be adequate to support improvements to pavement ride quality through 2028. [Exhibit 7-12]	From 2000 to 2008, the share of NHS VMT on pavements with good ride quality and acceptable ride quality both increased. [Exhibit 3-2]
Base year 2008 levels of capital spending on all Federal-aid highway pavements (including the NHS) are projected to be inadequate to support improvements to average pavement ride quality through 2028. [Exhibit 7-5]	From 2000 to 2008, the percent of VMT on pavements with good ride quality declined for rural major collectors, urban minor arterials, and urban collectors. The percent of total Federal-aid highway VMT on pavements with acceptable ride quality declined slightly over this period. [Exhibit 3-4]
System Rehabilitation—Bridges	
Base year 2008 levels of capital spending on NHS bridges are projected to be adequate to support a reduction to the existing backlog of potential cost-beneficial bridge improvements through 2028. [Exhibit 7-19]	From 2001 to 2009, the share of NHS briges classified as structurally deficient has been reduced. [Exhibit 3-14]
Base year 2008 levels of capital spending on all bridges (including NHS bridges) are projected to be adequate to support a reduction to the existing backlog of potential cost-beneficial bridge improvements through 2028. [Exhibit 7-17]	From 2001 to 2009, the share of all briges classified as structurally deficient has been reduced. [Exhibit 3-15]
System Expansion	
Base year 2008 levels of capital spending on capacity expansion for all Federal-aid highways are projected to be inadequate to support improvements to operational performance (in terms of average delay) through 2028. [Exhibit 7-7]	From 2000 to 2008, the average percentage of VMT under congested conditions rose in urbanized areas less than 1 million in population. For larger urbanized areas, this percentage rose from 2000 to 2006 before dropping off by 2008. (This improvement is primarily attributable to the decline in VMT between 2006 and 2008; VMT has subsequently begun to rise again.) [Exhibit 4-3]

Sources: Highway Performance Monitoring System, Highway Economic Requirements System, National Bridge Inventory, and National Bridge Investment Analysis System.

As indicated in Chapter 3, the percent of VMT on Federal-aid highway pavements with good ride quality rose from 42.8 percent in 2000 to 46.4 percent in 2008, while the comparable percentage in the category for acceptable quality decreased slightly (see *Exhibit 3-4*). Although this historic performance observation appears more positive than the HERS projection for the next 20 years, it should be noted that recent pavement performance results have been mixed. The percent of VMT on pavements with good ride quality fell between 2006 and 2008 for Federal-aid highways overall, and declined over the longer eight-year period from 2000 to 2008 for rural major collectors, urban minor arterials, and urban collectors.

Bridge Conditions

NBIAS projects that if NHS bridge replacement and rehabilitation investment were sustained in constant dollar terms at the 2008 level of $5.4 billion, this would be adequate to slightly reduce the economic bridge investment backlog below its 2008 level by 2028 (see *Exhibit 7-19*). This finding appears generally consistent with recent trends identified in Chapter 3, as the percent of deficient NHS bridges fell from 23.3 percent in 2001to 21.9 percent in 2009 (see *Exhibit 3-14*).

Looking more broadly at all bridges, NBIAS projects that sustaining the 2008 level of bridge rehabilitation and replacement investment of $12.8 billion in constant dollar terms over 20 years could reduce the economic bridge investment backlog by 11.2 percent by 2028 (see *Exhibit 7-17*), reflecting an overall improvement in bridge conditions. The percent of deficient bridges fell from 30.1 percent in 2001 to 26.5 percent in 2009 (see *Exhibit 3-15*), suggesting an improvement in bridge conditions.

It should be noted that the bridge statistics presented in Chapter 3 are affected by the addition of new bridges, as well as changes in the conditions of existing bridges; for some subsets of the Nation's bridge inventory, the deck area of deficient bridges actually rose from 2001 to 2009, but at a slower rate than the deck area of new bridges.

Operational Performance

As referenced in Chapter 6, all levels of government spent a combined $28.3 billion for system expansion on Federal-aid highways in 2008 (see *Exhibit 6-14*). This falls well below the $36.6 billion average annual level of system expansion spending identified in Chapter 7 as being needed to maintain average delay in 2028 at 2008 base-year levels (see *Exhibit 7-7*). The existence of a funding gap of this nature appeared consistent with the general worsening of congestion observed in previous editions of the C&P report, but congestion appears to have stabilized based on statistics computed using the methodology from the Texas Transportation Institute's 2009 Urban Mobility Study. As indicated in Chapter 4, the percent of VMT under congested conditions in 2008 was lower than in 2000 for urbanized areas overall. However, this decrease was driven by urbanized areas of more than 1,000,000 in population; smaller urbanized areas experienced an increase in congestion over this period.

Part of the recent improvement in certain measures of congestion is attributable to the decline in overall VMT that occurred between 2006 and 2008. However, VMT has subsequently started to grow and States are projecting larger annual increases for the 20-year period through 2028. In light of this presumed increase in future VMT, HERS projecting a worsening of congestion (unless annual investment in system expansion increases) does not constitute a direct contradiction of recent observed trends in congestion. If VMT were to grow more slowly than projected, this would reduce the level of investment needed to maintain average delay so that the current level of investment in system expansion could be adequate to avoid increases in congestion. Chapter 10 includes an analysis of alternative assumptions about future VMT growth on the investment requirement projections. An analysis of the potential impacts of congestion pricing on reducing peak-period VMT and future investment needs is presented later in this chapter.

Accounting for Inflation

The analysis of potential future investment/performance relationships in the C&P report traditionally stated future investment levels in constant dollars, with the base year set according to the year of the conditions and performance data supporting the analysis. Throughout Chapters 7 and 8, this edition of the C&P report has stated all investment levels in constant 2008 dollars. For some purposes, however, such as comparing investment spending in a particular scenario with nominal dollar revenue projections, one would want to adjust for inflation. Given an assumption about future inflation, one could either convert the C&P report's constant-dollar numbers to nominal dollars or convert the nominal projected revenues to constant 2008 dollars.

Exhibit 9-12 illustrates how the constant dollar figures associated with three of the four systemwide scenarios for highways and bridges presented in Chapter 8 could be converted to nominal dollars, based on two alternative inflation rates. The 3.5 percent inflation rate represents the average annual increase in highway construction costs over the last 20 years (from 1988 to 2008). The 2.0 percent inflation rate corresponds

Exhibit 9-12

Illustration of Potential Impact of Alternative Inflation Rates on Selected Systemwide Investment Scenarios

	Highway Capital Investment (Billions of Dollars)								
	Constant 2008 Dollars*			Nominal Dollars (Assuming 2.0 Percent Annual Inflation)			Nominal Dollars (Assuming 3.5 Percent Annual Inflation)		
Year	Sustain Current Spending Scenario	Maintain Conditions & Performance Scenario	Improve Conditions & Performance Scenario	Sustain Current Spending Scenario	Maintain Conditions & Performance Scenario	Improve Conditions & Performance Scenario	Sustain Current Spending Scenario	Maintain Conditions & Performance Scenario	Improve Conditions & Performance Scenario
2008	$91.1	$91.1	$91.1	$91.1	$91.1	$91.1	$91.1	$91.1	$91.1
2009	$91.1	$92.0	$96.3	$93.0	$93.9	$98.2	$94.3	$95.2	$99.6
2010	$91.1	$92.9	$101.7	$94.8	$96.7	$105.8	$97.6	$99.5	$108.9
2011	$91.1	$93.8	$107.4	$96.7	$99.6	$114.0	$101.1	$104.0	$119.1
2012	$91.1	$94.7	$113.4	$98.7	$102.5	$122.8	$104.6	$108.7	$130.2
2013	$91.1	$95.6	$119.8	$100.6	$105.6	$132.3	$108.3	$113.6	$142.3
2014	$91.1	$96.6	$126.6	$102.6	$108.7	$142.5	$112.0	$118.7	$155.6
2015	$91.1	$97.5	$133.7	$104.7	$112.0	$153.5	$116.0	$124.0	$170.1
2016	$91.1	$98.4	$141.2	$106.8	$115.3	$165.4	$120.0	$129.6	$185.9
2017	$91.1	$99.4	$149.1	$108.9	$118.8	$178.2	$124.2	$135.5	$203.2
2018	$91.1	$100.3	$157.5	$111.1	$122.3	$192.0	$128.6	$141.5	$222.2
2019	$91.1	$101.3	$166.4	$113.3	$126.0	$206.9	$133.1	$147.9	$242.9
2020	$91.1	$102.3	$175.7	$115.6	$129.7	$222.9	$137.7	$154.6	$265.5
2021	$91.1	$103.3	$185.6	$117.9	$133.6	$240.1	$142.5	$161.5	$290.3
2022	$91.1	$104.3	$196.0	$120.3	$137.6	$258.7	$147.5	$168.8	$317.3
2023	$91.1	$105.3	$207.1	$122.7	$141.7	$278.7	$152.7	$176.4	$346.9
2024	$91.1	$106.3	$218.7	$125.1	$145.9	$300.2	$158.0	$184.3	$379.2
2025	$91.1	$107.3	$231.0	$127.6	$150.3	$323.5	$163.6	$192.6	$414.6
2026	$91.1	$108.4	$244.0	$130.2	$154.8	$348.5	$169.3	$201.3	$453.2
2027	$91.1	$109.4	$257.7	$132.8	$159.4	$375.4	$175.2	$210.4	$495.4
2028	$91.1	$110.5	$272.2	$135.4	$164.2	$404.5	$181.4	$219.8	$541.6
Total	**$1,822.9**	**$2,019.7**	**$3,401.0**	**$2,258.9**	**$2,518.5**	**$4,363.9**	**$2,667.7**	**$2,988.0**	**$5,284.0**
	0.00%	**0.97%**	**5.62%**	**Constant Dollar Growth Rate**					
	$91.1	**$101.0**	**$170.1**	**Average Annual Investment Level in Constant 2008 Dollars**					

* *Based on average annual investment levels and annual constant dollar growth rates identified in Exhibit 8-8.*

Source: FHWA Staff Analysis.

to the average annual increase in highway construction costs from 1980 to 2000; this is the 20-year period with the lowest construction cost inflation since the creation of the Federal Highway Trust Fund in 1956. (Historic inflation rates were determined using the FHWA Composite Bid Price Index through 2006, and the new FHWA National Highway Construction Cost Index from 2006 to 2008; these indices are discussed in Chapter 6.)

The systemwide **Sustain Current Spending scenario** presented in Chapter 8 assumes that combined capital spending for highway and bridge improvements would be sustained at its 2008 level in constant dollar terms for 20 years. Hence, *Exhibit 9-12* shows $91.1 billion of spending in constant 2008 dollars for each year from 2009 through 2028, for a 20-year total of $1.8 trillion. Assuming annual inflation in construction costs of 2.0 percent, or alternatively 3.5 percent, would imply a 20-year total in nominal dollars of $2.3 trillion or $2.7 trillion for this scenario.

Why are the investment analyses presented in this report expressed in constant base-year dollars?

Q&A

The investment/performance models discussed in this report estimate the future benefits and costs of transportation investments in constant-dollar terms. This is standard practice for this type of economic analysis. To convert the model outputs from constant dollars to nominal dollars, it would be necessary to externally adjust them to account for projected future inflation.

Traditionally, this type of adjustment has not been made in the C&P report. Because inflation prediction is an inexact science, adjusting the constant-dollar figures to nominal dollars would tend to add to the uncertainty of the overall results and make the report more difficult to use if the inflation assumptions were later proved to be incorrect. Allowing readers to make their own inflation adjustments based on actual trends observed subsequent to the publication of the C&P report and/or the most recent projections from other sources is expected to yield a better overall result, particularly in light of the sharp swings in highway construction materials costs over the last several years.

The use of constant dollar figures is also intended to provide readers with a reasonable frame of reference in terms of an overall cost level that they have recently experienced. When inflation rates are compounded for 20 years, even relatively small growth rates can produce nominal dollar values that appear very large when viewed from the perspective of today's typical costs.

The primary drawback to using constant base-year dollar figures in the C&P report is that they are sometimes misapplied by readers and treated as if they were expressed in current-year dollars. However, because the C&P report is produced every 2 years, the base-year costs reflected in the most recent edition are generally close enough to current costs to provide a useful perspective.

Inflation is just one of two separate and distinct factors that account for why the value of a dollar, as seen from the present, diminishes over time. The second factor is the time value of resources, which reflects that there is a cost associated with diverting the resources needed for an investment from other productive uses. The investment/performance models described in this report take the time value of resources into account via a separate mechanism called the discount rate, which is discussed in Chapter 10.

Chapter 8 indicates that achieving the objectives of the systemwide **Maintain Conditions and Performance scenario** would require investment averaging $101.0 billion per year in constant 2008 dollars (see *Exhibit 8-8*), and, to attain this average, a 0.97-percent annual growth in constant-dollar spending (see *Exhibit 8-9*). *Exhibit 9-12* illustrates the application of this real growth rate, demonstrating how annual capital investment would increase from $91.1 billion in 2008 to $110.5 billion in 2028, resulting in a 20-year (2009 to 2028) total of $2.0 trillion in constant 2008 dollars. A 2.0-percent inflation rate applied to these constant-dollar estimates would produce a 20-year cost of $2.5 trillion, and a 3.5-percent inflation rate a 20-year cost of $3.0 trillion, both measured in nominal dollars.

The compounding impacts of inflation are even more evident in the figures for the systemwide **Improve Conditions and Performance scenario** presented in *Exhibit 9-12*. As described in Chapter 8, this scenario assumes 5.62 percent growth in constant dollar highway capital spending per year in order to address all potentially cost-beneficial highway and bridge improvements by 2028. The $170.1 billion average annual investment level associated with this scenario equates to a 20-year investment level of $3.4 billion in constant 2008 dollars. Adjusting this figure to account for inflation of 2.0 percent or 3.5 percent would translate into 20-year nominal dollar costs of $4.4 trillion or $5.3 trillion, respectively.

Costs of Maintaining Individual System Components Versus Maintaining the Overall System

The goal of the **Maintain Conditions and Performance scenario** presented in Chapter 8 is to invest at a level sufficient so that two measures of conditions and performance (average speed and the economic backlog of bridge investments) can be maintained through 2028 at their 2008 levels. The HERS and NBIAS analyses on which the scenario is based attempt to achieve this objective for the lowest cost possible. The conditions and performance of individual functional systems are allowed to vary under this scenario; they tend to improve for higher-ordered functional systems with high traffic volumes (as improvements in these systems tend to have higher BCRs), and deteriorate for lower-ordered systems.

What if one were to add to this scenario further requirements for maintaining certain measures of conditions and performance? Even before rerunning the simulations, one could predict with confidence that the estimate of the total investment requirement would increase. A general rule in mathematical optimization is that when seeking to find the lowest cost solution that meets a set of objectives, adding constraints to the system of equations increase the cost of the solution. For example, in the context of this scenario, adding a constraint that system performance must be maintained individually for each county in the Nation may involve selecting potential improvements with lower BCRs in some counties than in others; when these separate analyses are added together, their cost would tend to be higher than a nationwide approach that applies the same minimum BCR across all counties.

Exhibit 9-13 further illustrates this concept by presenting the level of investment needed to maintain average IRI (a targeted measure of pavement condition), average delay per VMT (a targeted measure of operational performance), and the economic bridge investment backlog (a targeted measure of bridge condition) for individual functional systems (to the extent that it would be cost-beneficial to do so). Logically, applying the constraint that indicators should be maintained for individual functional systems and applying more specific indicators (IRI and average delay rather than average speed) will tend to increase the cost of achieving the general objective of the scenario. As shown in *Exhibit 9-13*, the combined cost of maintaining these modified indicators on individual functional systems is estimated to be $88.8 billion per year over 20 years in constant 2008 dollars; this is 10.9 percent higher than the $80.1-billion average annual investment level identified for the **Maintain Conditions and Performance scenario** for Federal-aid highways, identified in Chapter 8 (see *Exhibit 8-5*).

The negative percentages identified in the comparison at the bottom of *Exhibit 9-13* reflect cases in which maintaining a particular performance indicator on a particular functional class would cost less than the amount in the comparable component of the **Maintain Conditions and Performance scenario** for Federal-aid highways (the implication is that performance actually improved for these system components under that scenario). The positive percentages indicate system components for which conditions or performance deteriorated under that scenario (so that additional resources would be needed to maintain these components at 2008 levels through 2028).

While broad national targets, such as those of the Chapter 8 **Maintain Conditions and Performance scenario**, are consistent with this report's focus on overall conditions and performance, targets specific to functional classes, such as those of the supplemental analysis presented in *Exhibit 9-13* would be more suitable for certain analytical objectives. For example, in projecting the costs associated with maintaining

Exhibit 9-13

Cost of Maintaining System Components Compared With the Cost to Maintain Scenario for Federal-Aid Highways for 2009 to 2028

Average Annual National Investment to Maintain Average IRI, Bridge Investment Backlog, and Average Delay on Individual Functional Classes (Billions of 2008 Dollars) [1]

	System Rehabilitation			System	System	
Functional Class	**Highway**	**Bridge**	**Total**	**Expansion**	**Enhancement**	**Total**
Rural Arterials and Major Collectors						
Interstate	$1.0	$0.7	$1.7	$2.0	$0.5	$4.2
Other Principal Arterial	$1.4	$0.6	$2.0	$1.3	$0.9	$4.2
Minor Arterial	$3.4	$0.5	$3.9	$0.5	$0.6	$5.0
Major Collector	$5.4	$0.9	$6.3	$0.6	$0.8	$7.7
Subtotal	**$11.3**	**$2.6**	**$13.9**	**$4.4**	**$2.8**	**$21.1**
Urban Arterials and Collectors						
Interstate	$4.9	$2.5	$7.4	$10.1	$1.3	$18.7
Other Freeway and Expressway	$2.2	$1.0	$3.2	$3.9	$0.8	$7.9
Other Principal Arterial	$4.7	$1.6	$6.3	$9.0	$1.5	$16.8
Minor Arterial	$6.3	$1.5	$7.8	$6.5	$1.2	$15.4
Collector	$4.3	$0.7	$5.0	$3.2	$0.6	$8.9
Subtotal	**$22.5**	**$7.2**	**$29.8**	**$32.5**	**$5.3**	**$67.7**
Total, Federal-Aid Highways [2]	**$33.8**	**$9.9**	**$43.7**	**$36.9**	**$8.2**	**$88.8**

Percent Above the Cost to Maintain Scenario for Federal-Aid Highways for 2009 to 2028

	System Rehabilitation			System	System	
Functional Class	**Highway**	**Bridge**	**Total**	**Expansion**	**Enhancement**	**Total**
Rural Arterials and Major Collectors						
Interstate	-41.8%	2.6%	-29.7%	24.6%	10.9%	-6.3%
Other Principal Arterial	-19.3%	0.2%	-14.7%	55.2%	10.9%	5.1%
Minor Arterial	74.0%	0.7%	59.0%	38.3%	10.9%	48.9%
Major Collector	111.4%	6.4%	86.3%	129.0%	10.9%	75.7%
Subtotal	**39.7%**	**2.9%**	**30.9%**	**43.4%**	**10.9%**	**30.1%**
Urban Arterials and Collectors						
Interstate	-24.1%	-8.8%	-19.6%	-23.5%	10.9%	-20.3%
Other Freeway and Expressway	-27.4%	-6.1%	-22.0%	-27.2%	10.9%	-22.5%
Other Principal Arterial	-16.2%	-7.0%	-14.1%	123.8%	10.9%	32.1%
Minor Arterial	-6.6%	12.9%	-3.3%	97.8%	10.9%	24.5%
Collector	62.1%	38.8%	58.5%	133.6%	10.9%	73.3%
Subtotal	**-8.5%**	**-0.8%**	**-6.8%**	**20.1%**	**10.9%**	**6.0%**
Total, Federal-Aid Highways [2]	**3.3%**	**0.2%**	**2.6%**	**22.5%**	**10.9%**	**10.9%**

[1] Amounts shown reflect the cost of maintaining average ride quality (system rehabilitation—highway), the bridge investment backlog (system rehabilitation—bridge) and average delay (system expansion) at base year 2008 levels for individual functional classes. In those cases where maintaining an indicator at base year levels would not be cost-beneficial, the comparable value from the Cost to Improve Highways and Bridges scenario was utilized.

[2] The term "Federal-aid highways" refers to those portions of the road network that are generally eligible for Federal funding. Roads functionally classified as rural minor collectors, rural local, and urban local are excluded, although some types of Federal program funds can be used on such facilities.

Sources: Highway Economic Requirements System and National Bridge Investment Analysis System.

average pavement conditions specifically on urban arterials and collectors, the $22.5 billion identified in *Exhibit 9-13* constitutes a better estimate than the $24.7 billion highway system rehabilitation component of the **Maintain Conditions and Performance scenario** for Federal-aid highways presented in Chapter 8 (as urban pavement conditions actually improve somewhat under that scenario, offset by declines in condition and performance elsewhere on the system).

As noted above, the investment levels presented in *Exhibit 9-13* only seek to maintain individual measures of conditions and performance on individual functional classes where such investment is projected to be cost-beneficial. The average annual investment level for each system component was capped at the corresponding amount identified as part of the **Improve Conditions and Performance scenario** for Federal-aid highways.

Highway and Bridge Investment Backlog

The investment backlog represents all highway and bridge improvements that could be economically justified for immediate implementation, based solely on the current conditions and operational performance of the highway system (without regard to potential future increases in VMT or potential future physical deterioration of infrastructure assets). Conceptually, the backlog represents a subset of the investment levels reflected in the **Improve Conditions and Performance scenario** presented in Chapter 8; that scenario addresses the existing backlog as well as additional projected pavement, bridge, and capacity needs that may arise over the next 20 years.

Exhibit 9-14 presents an estimate of the backlog in 2008 for those types of capital improvements that are modeled in HERS and NBIAS. The shaded cells in the table represent types of improvements that are not currently modeled, including improvements to non-Federal-aid highways pavements and system enhancements; the data are presented in this manner to emphasize that the estimated backlog of $648.2 billion is incomplete. (In contrast, the scenarios presented in Chapter 8 include an adjustment factor for non-modeled capital improvement types.)

Exhibit 9-14

Estimated Highway and Bridge Investment Backlog as of 2008

	(Billions of 2008 Dollars)						
	System Rehabilitation						
System Component	Highway	Bridge	Total	System Expansion	System Enhancement*	Total	Percent of Total
Federal-Aid Highways—Rural	$58.2	$28.1	$86.3	$11.0		$97.3	15.0%
Federal-Aid Highways—Urban	$243.3	$74.0	$317.3	$214.5		$531.8	82.0%
Federal-Aid Highways—Total	$301.6	$102.1	$403.6	$225.5		$629.1	97.1%
Non-Federal-Aid Highways*		$19.1	$19.1			$19.1	2.9%
All Roads*	**$301.6**	**$121.2**	**$422.8**	**$225.5**		**$648.2**	**100.0%**
Interstate Highway System	$68.7	$38.1	$106.8	$102.7		$209.5	32.3%
National Highway System	$139.5	$60.4	$199.9	$157.1		$356.9	55.1%

** Estimated backlog includes only those system components and capital improvement types modeled in HERS or NBIAS. System enhancements are excluded, as well as pavement and expansion improvements to roads functionally classified as rural minor collector, rural local, or urban local, for which HPMS data are not available to support a HERS analysis.*

Sources: Highway Economic Requirements System and National Bridge Investment Analysis System.

The portion of the backlog derived from NBIAS accounts for $121.2 billion of the total backlog presented in *Exhibit 9-14*; Chapters 7 and 8 also reference this figure since targets for the economic backlog of bridge investment are used as a performance metric in defining the **Maintain Conditions and Performance scenario** and the **Improve Conditions and Performance scenario**. The remaining $527.0 billion included in the total backlog is derived from the HERS model; this represents the pool of potentially cost-beneficial capital investment for system expansion or pavement improvements based solely on the conditions and performance of the system in 2008.

Of the $648.2 estimated backlog figure presented in *Exhibit 9-14*, approximately $209.5 billion (32.3 percent) is on the Interstate highway system and $356.9 billion (55.1 percent) is on the NHS (which includes the Interstate highway system). Approximately 65.2 percent ($422.8 billion) of the total backlog is attributable to system rehabilitation needs, while the remainder is associated with system expansion improvements to address existing capacity deficiencies. The share of the total backlog attributable to system rehabilitation is progressively lower for Federal-aid highways (64.2 percent), the NHS (56.0 percent), and the Interstate highway system (51.0 percent), but still represents a majority of the total backlog in each case.

The $648.2 billion estimated backlog is heavily weighted towards urban areas; approximately 82.0 percent of this total is attributable to Federal-aid highways in urban areas. As noted in Chapter 3, pavement ride quality in 2008 was better on average for rural Federal-aid highways than those in urban areas; urban areas also face relatively greater problems with congestion and functionally obsolete bridges than do rural areas.

Timing of Investment

The investment/performance analyses presented in this report focus mainly on how alternative average annual investment levels over 20 years might impact system performance at the end of this period. Within this period, system performance can be significantly influenced by the timing of investment. Consistent with the approach in the 2008 edition of the C&P report, and as discussed in Chapter 7, the analyses in the present edition assumed that any change from the 2008 level of combined investment per year by all levels of government would occur gradually, at a constant percent rate. However, some previous editions used different approaches. The HERS 2006 C&P Report assumed that combined investment would immediately jump to the average annual level being analyzed, then remain fixed at that level for 20 years. The HERS analyses presented in the 2004 C&P Report were tied directly to alternative BCR cutoffs rather than to particular levels of investment in any given year. At higher spending levels, this approach resulted in a significant front-loading of capital investment in the early years of the analysis as the existing backlog of potential cost-beneficial investments (discussed above) was addressed, followed by a sharp decline in later years.

The discussion below explores the impact of the choice among these three assumptions about the timing of future investment—ramped spending, flat spending, or BCR-driven spending—on system performance within the 20-year period analyzed. The average annual investment levels analyzed each correspond to the baseline HERS analyses for Federal-aid Highways, and the baseline NBIAS analyzes for all bridges presented in Chapter 7.

Alternative Timing of Investment in HERS

Exhibit 9-15 indicates how alternative assumptions regarding the timing of investment would impact the distribution of spending among the four 5-year funding periods considered in HERS, and how these spending patterns could potentially impact average speeds. The eight investment levels shown correspond to the baseline ("ramped") HERS analyses for Federal-aid highways presented in Chapter 7. For the baseline

Exhibit 9-15

Distribution of Spending Among 5-Year HERS Analysis Periods and Projected Impacts on Average Speeds, for Alternative Approaches to Investment Timing

Average Annual HERS-Modeled Capital Investment (Billions of 2008 Dollars) [1]	Percentage of HERS-Modeled Spending Occurring in Each 5-Year Period											
	Baseline				Alternatives							
	Ramped Spending				Flat Spending				BCR-Driven Spending [2]			
	2009 to 2013	2014 to 2018	2019 to 2023	2024 to 2028	2009 to 2013	2014 to 2018	2019 to 2023	2024 to 2028	2009 to 2013	2014 to 2018	2019 to 2023	2024 to 2028
$105.4	15.5%	20.6%	27.4%	36.5%	25.0%	25.0%	25.0%	25.0%	*37.9%*	*19.5%*	*19.9%*	*22.8%*
$93.4	16.9%	21.4%	27.2%	34.5%	25.0%	25.0%	25.0%	25.0%	37.0%	20.2%	20.6%	22.2%
$80.1	18.9%	22.5%	26.8%	31.8%	25.0%	25.0%	25.0%	25.0%	34.1%	22.8%	20.8%	22.3%
$74.7	20.0%	23.0%	26.5%	30.5%	25.0%	25.0%	25.0%	25.0%	32.6%	23.6%	21.6%	22.2%
$62.9	22.6%	24.1%	25.8%	27.5%	25.0%	25.0%	25.0%	25.0%	30.4%	25.9%	21.8%	21.9%
$58.0	24.0%	24.6%	25.3%	26.1%	25.0%	25.0%	25.0%	25.0%	29.2%	26.7%	22.5%	21.5%
$54.7	**25.0%**	**25.0%**	**25.0%**	**25.0%**	**25.0%**	**25.0%**	**25.0%**	**25.0%**	27.8%	27.7%	22.3%	22.3%
$49.3	26.9%	25.6%	24.3%	23.1%	25.0%	25.0%	25.0%	25.0%	26.3%	28.9%	23.0%	21.8%

Average Annual HERS-Modeled Capital Investment (Billions of 2008 Dollars) [1]	Change in Average Speeds Relative to 2008 on Roads Modeled In HERS [3]											
	Baseline				Alternatives							
	Ramped Spending, Percent Change as of:				Flat Spending, Percent Change as of:				BCR-Driven Spending [2] Percent Change as of:			
	2013	2018	2023	2028	2013	2018	2023	2028	2013	2018	2023	2028
$105.4	2.0%	1.8%	2.1%	2.6%	2.9%	2.9%	2.8%	2.5%	*3.7%*	*3.3%*	*2.8%*	*2.4%*
$93.4	1.9%	1.6%	1.7%	2.0%	2.6%	2.5%	2.3%	1.9%	3.5%	3.0%	2.5%	1.9%
$80.1	1.8%	1.3%	1.1%	1.2%	2.4%	2.0%	1.6%	1.2%	2.9%	2.4%	1.8%	1.2%
$74.7	1.8%	1.2%	0.9%	0.9%	2.2%	1.8%	1.3%	0.8%	2.7%	2.2%	1.5%	0.8%
$62.9	1.7%	0.9%	0.4%	**0.0%**	1.9%	1.2%	0.5%	0.0%	2.2%	1.6%	0.7%	-0.1%
$58.0	1.7%	0.7%	0.1%	-0.4%	1.7%	0.9%	0.2%	-0.4%	2.0%	1.3%	0.4%	-0.5%
$54.7	1.6%	0.6%	-0.1%	-0.7%	1.6%	0.6%	-0.1%	-0.7%	1.8%	1.0%	0.1%	-0.7%
$49.3	1.6%	0.4%	-0.5%	-1.3%	1.5%	0.2%	-0.6%	-1.3%	1.5%	0.6%	-0.4%	-1.3%

[1] The eight alternative investment levels shown correspond to the levels identified in Chapter 7 (Exhibit 7-3) as being associated with the investment needed to achieve certain specific targets (expressed in terms of minimum BCR cutoffs, maintaining specific performance indicators, or growing at a specific rate in constant dollar terms). Of the $91.1 billion of total capital expenditures in 2008, $54.7 billion was used for the types of capital improvements modeled in HERS.

[2] Each percentage distribution shown corresponds to a HERS analysis assuming investment up to a minimum benefit-cost ratio cutoff point (not shown). For each row, this cutoff was set at a level such that total spending would be consistent with the average annual spending level shown. The italicized values identified for the row labeled $105.4 billion are actually based on a lower average annual investment level of $104.0 billion, as HERS projects this to be the highest level of investment that would be cost-beneficial (given a front-loaded, BCR-driven spending strategy).

[3] The performance impacts identified in this table are driven by spending modeled in HERS and do not reflect rural minor collectors, rural local, or urban local roads, because these functional systems are not included in the HPMS sample data.

Source: Highway Economic Requirements System.

analyses, the distribution of spending among funding periods is driven by the annual constant dollar spending growth rate assumed; for higher growth rates, a smaller percentage of a total 20-year investment would occur in the first 5 years.

The “flat spending” alternative is linked directly to the average annual investment levels associated with each of the baseline analyses; as spending would remain the same in each of the 20 years, the distribution of spending within each 5-year period makes up exactly one-quarter of the total. When HERS-modeled capital investment spending is sustained at the base-year level of $54.7 billion, the results of the ramped spending and flat spending alternatives are identical. (Spending is flat when its growth rate is zero.)

The "BCR-driven" spending percentages identified in *Exhibit 9-15* represent the distribution of spending that would occur if a uniform minimum BCR were applied in HERS across all four 5-year funding periods. The benefit-cost cutoff points were selected to coordinate with the total 20-year spending for each of the baseline analyses. At higher spending levels, the existence of the backlog of cost-beneficial investments would cause a higher percentage of spending to occur in the first 5-year period through 2013. This effect is less pronounced at lower levels of investment, as some potential projects included in the estimated backlog would have a BCR below the cutoff point associated with that level of spending, and would thus be deferred for consideration in later funding periods. The portion of total BCR-driven spending occurring in the first 5 years ranged from 26.3 percent for the lowest spending level analyzed to 37.9 percent for the highest level analyzed. (As noted in *Exhibit 9-15,* applying a uniform minimum BCR of 1.0 across all 20 years would result in an average annual investment level of $104.0 billion, slightly below the $105.4 billion level identified for the baseline ramped spending approach.)

The analyses presented in Chapter 7 (see *Exhibit 7-2*) show that increasing HERS-modeled capital spending by 1.31 percent per year over 20 years above the baseline 2008 level of $54.7 billion would result in a 20-year spending figure of $1.257 trillion, translating into an average annual investment level of $62.9 billion. (This is the HERS-modeled component of the **Maintain Conditions and Performance scenario** presented in Chapter 8.) As shown in *Exhibit 9-15*, at this level of investment, the baseline ramped spending approach would direct that approximately 22.6 percent of the total 20-year amount be expended in the first five years, rising to 27.5 percent in the last five years. In contrast, given the same 20-year budget constraint under the BCR-driven alternative, approximately 30.4 percent of total spending would be expended in the first five years, falling to 21.9 percent in the last five years.

The projected average speeds for 2028 shown in *Exhibit 9-15* are similar among the three investment patterns. For example, at an average annual investment level of $62.9 billion, average speed in 2028 would match that in 2008 for both the ramped spending and flat spending alternatives, and would decrease by 0.1 percent under the BCR-driven spending approach. This suggests that the amount of cumulative 20-year constant-dollar investment is more critical to final-year system performance than the distribution of that investment within the 20-year period.

The potential benefits of front-loading capital spending toward the early part of the analysis period become more apparent when examining projected average speeds for the intermediate years of 2013, 2018, and 2023. At an average annual investment level of $62.9 billion, average speeds are projected to increase by 1.7 percent by 2013 for the baseline ramped spending approach, compared to a 1.9 percent increase for the flat spending approach and a 2.2 percent increase for the BCR-driven spending approach. These speed reductions in the early years, along with corresponding reductions in delay and pavement roughness and improvements in other system performance indicators, would translate into significant user cost savings during these years.

Alternative Timing of Investment in NBIAS

Exhibit 9-16 identifies the impacts of alternative investment timing on the backlog of potentially cost-beneficial bridge investments. As discussed in Chapter 7, changes in the economic bridge investment backlog can be viewed as a proxy for changes in overall bridge conditions.

Exhibit 9-16

Distribution of Spending Among 5-Year Periods in NBIAS and Projected Impacts on the Bridge Investment Backlog, for Alternative Approaches to Investment Timing

Average Annual NBIAS-Modeled Capital Investment (Billions of 2008 Dollars) [1]	Percentage of NBIAS-Modeled Spending Occurring in Each 5-Year Period											
	Baseline				Alternatives							
	Ramped Spending				Flat Spending				BCR-Driven Spending [2]			
	2009 to 2013	2014 to 2018	2019 to 2023	2024 to 2028	2009 to 2013	2014 to 2018	2019 to 2023	2024 to 2028	2009 to 2013	2014 to 2018	2019 to 2023	2024 to 2028
$20.5	17.7%	21.9%	27.0%	33.4%	25.0%	25.0%	25.0%	25.0%	35.5%	21.9%	20.7%	21.8%
$18.7	18.9%	22.5%	26.8%	31.8%	25.0%	25.0%	25.0%	25.0%	35.1%	21.5%	21.2%	22.2%
$17.5	20.0%	23.0%	26.5%	30.5%	25.0%	25.0%	25.0%	25.0%	34.6%	21.3%	21.4%	22.8%
$14.7	22.6%	24.1%	25.8%	27.5%	25.0%	25.0%	25.0%	25.0%	32.6%	20.3%	22.4%	24.7%
$13.6	24.0%	24.6%	25.3%	26.1%	25.0%	25.0%	25.0%	25.0%	31.7%	20.3%	22.4%	25.6%
$12.8	**25.0%**	**25.0%**	**25.0%**	**25.0%**	**25.0%**	**25.0%**	**25.0%**	**25.0%**	31.0%	20.5%	22.4%	26.2%
$11.9	26.3%	25.4%	24.5%	23.7%	25.0%	25.0%	25.0%	25.0%	29.8%	20.3%	23.1%	26.9%
$11.5	26.9%	25.6%	24.3%	23.1%	25.0%	25.0%	25.0%	25.0%	29.3%	19.8%	23.3%	27.5%

Average Annual NBIAS-Modeled Capital Investment (Billions of 2008 Dollars) [1]	Change in Bridge Investment Backlog Relative to 2008 [3]											
	Baseline				Alternatives							
	Ramped Spending, Percent Change as of:				Flat Spending, Percent Change as of:				BCR-Driven Spending [2] Percent Change as of:			
	2013	2018	2023	2028	2013	2018	2023	2028	2013	2018	2023	2028
$20.5	-37.2%	-51.5%	-73.4%	**-100%**	-57.7%	-74.6%	-84.4%	-83.4%	-75.1%	-79.2%	-80.9%	-78.0%
$18.7	-36.0%	-46.5%	-62.9%	-79.1%	-51.7%	-65.3%	-73.0%	-71.4%	-68.4%	-69.9%	-72.4%	-69.5%
$17.5	-35.0%	-43.0%	-55.4%	-65.3%	-47.3%	-57.8%	-63.9%	-61.5%	-62.6%	-62.6%	-64.1%	-60.5%
$14.7	-32.6%	-33.7%	-37.3%	-34.7%	-37.6%	-40.8%	-41.8%	-35.1%	-48.8%	-43.5%	-42.1%	-35.9%
$13.6	-31.5%	-29.6%	-29.0%	-20.9%	-33.5%	-32.5%	-31.4%	-21.7%	-43.0%	-35.7%	-31.8%	-24.2%
$12.8	-30.7%	-26.8%	-22.9%	-11.2%	-30.7%	-26.8%	-22.9%	-11.2%	-38.7%	-29.6%	-24.0%	-15.1%
$11.9	-29.7%	-23.1%	-15.7%	**0.0%**	-27.4%	-20.0%	-13.0%	1.5%	-33.2%	-21.3%	-14.5%	-3.2%
$11.5	-29.3%	-21.8%	-12.9%	4.9%	-26.1%	-17.4%	-9.1%	6.7%	-31.2%	-17.2%	-9.6%	1.7%

[1] The eight alternative investment levels shown correspond to the levels analyzed in Chapter 7 (Exhibit 7-17) for all bridges; these levels were linked to annual rates of growth in spending relative to the baseline 2008 level. Of the $91.1 billion of total capital expenditures in 2008, $12.8 billion was used for the types of capital improvements modeled in NBIAS.

[2] Each percentage distribution shown corresponds to an NBIAS analysis assuming investment up to a minimum BCR cutoff point (not shown). For each row, this cutoff was set at a level such that total spending would be consistent with the average annual spending level shown.

[3] As discussed in Chapter 7, the economic investment backlog for bridges represents the total level of investment that would be required to address existing bridge deficiencies where it is cost-beneficial to do so. Reductions in this backlog would be consistent with an overall improvement in bridge conditions. The amounts shown do not reflect system expansion needs; the bridge component of such needs are addressed as part of the HERS model analysis.

Source: National Bridge Investment Analysis System.

The relative impacts of the alternative bridge investment approaches identified in *Exhibit 9-16* vary by funding level. At the three highest average annual NBIAS-modeled investment levels analyzed for the 2009 to 2028 period ($17.5 billion or higher), the ramped spending approach assumed in the baseline analyses from Chapter 7 would result in a lower economic backlog in 2028 than the flat-spending or BCR-driven spending alternatives. At the five lowest investment levels analyzed (average annual NBIAS-related spending of $14.7 billion or lower), the "BCR-driven" spending approach would result in a lower economic backlog in 2028 than the other two alternatives.

The poorer relative performance of the flat spending approach may be related to "lumpiness" in the future bridge investment needs identified by NBIAS. As discussed in Chapter 3, the rate of construction of new bridges has not been uniform over time, so that the age distribution of the bridge inventory includes some peaks. Consequently, the need for certain types of bridge repair and rehabilitation actions is clustered in time to some extent. Holding spending constant at the same level across all years is not consistent with this pattern.

The BCR-driven spending approach is intended to link annual spending to annual needs; as noted above, for the lowest five levels of investment analyzed, this approach results in a lower projected bridge investment backlog in 2028 than the baseline ramped spending approach. However, at the three highest levels of investment analyzed, the BCR-driven spending approach is even more front-loaded, concentrating a significant amount of spending into a relatively short period of time; although this approach has benefits in reducing ongoing maintenance costs, it also tends to exacerbate the concentration of future bridge needs by putting a larger number of bridges onto the same repair and rehabilitation cycle. The imposition of an annual spending constraint in the baseline ramped spending analyses tends to stretch out bridge work across a longer period, so that subsequent repair and rehabilitation cycles would be more spread out.

Road Pricing and Financing Mechanisms

As referenced in the Introduction to Part II, the HERS model can be run with a "balanced budget" constraint, which forces changes to highway capital spending from the base-year level to be budget-neutral. Neutrality is achieved through adjustments to highway user taxes—specifically, to flat rate user charges such as a systemwide VMT charge or fuel tax. By altering the demand for highway travel, these adjustments would also affect system operational performance and investment needs. An increase in the flat-rate charges would reduce the effective VMT growth rate, which would in turn improve system performance. For congestion pricing, which HERS can also simulate, the linkage to highway operational performance is stronger, since the charges vary by the time and location of travel according to level of congestion. Moreover, with operational performance improved, the amount of highway investment needed to achieve a given performance target is reduced. These concepts and related analytical procedures are discussed in more detail in Appendix A.

The primary investment scenarios presented in the 2006 C&P Report assumed that any increase in highway and bridge capital investment above 2004 baseline levels would be funded by a flat rate per-gallon surcharge; this had the effect of reducing the average annual investment levels for these scenarios by 2 to 4 percent and resulted in small improvements in projected performance.

The 2008 C&P Report presented two versions of each of the primary investment scenarios, one of which was similar to the approach used in the 2006 C&P Report, except that the flat rate surcharge was imposed on a per-VMT basis rather than a per-gallon basis and was computed relative to a baseline year of 2006 rather than 2004. The second set of scenarios presented in the 2008 C&P Report assumed the immediate imposition of peak-period congestion charges on all congested highway sections, with rates set for individual locations based on the estimated marginal cost that each user of a congested facility imposes on all other users of that facility. To the extent that these congestion charges did not cover the full additional capital investment costs associated with a particular scenario, an additional flat rate surcharge was imposed; to the extent that the congestion charges would more than cover these costs, a reduction in existing user charges was assumed. The results indicated that by reducing growth in VMT, the mechanisms for funding additional highway investment would improve future system performance and reduce future system investment needs, but these effects would be much greater with widespread congestion pricing in place (second set of scenarios) than with the flat rate surcharge as the only mechanism (first set of scenarios). The indications were that congestion pricing could substantially reduce the amount of investment that would be needed to achieve different system performance objectives.

The primary investment scenarios presented in Chapter 8 of this report make no assumptions about funding sources for future highway investment and assume congestion pricing to be absent. The discussion below compares the impacts of six alternative sets of assumptions regarding future revenue mechanisms and congestion pricing mechanisms:

- No future congestion pricing assumed; additional revenue needed to cover scenario funding levels not taken into consideration (baseline assumptions from Chapter 8)
- No future congestion pricing; additional revenue needed to cover scenario funding levels would come from a VMT-based surcharge (comparable to 2008 C&P Report "fixed-rate" scenarios)
- No future congestion pricing; additional revenue needed to cover scenario funding levels would come from a per-gallon surcharge (comparable to 2006 C&P Report baseline scenarios)
- Peak-period congestion charges imposed; additional revenue needed to cover scenario funding levels not taken into consideration
- Peak-period congestion charges imposed; additional revenue needed to cover scenario funding levels would come from a VMT-based surcharge (comparable to 2008 C&P Report "variable-rate" scenarios)
- Peak-period congestion charges imposed; additional revenue needed to cover scenario funding levels would come from a per-gallon surcharge.

Exhibit 9-17 shows how these alternative analytical assumptions affect the overall level of investment identified by HERS as cost-beneficial and the projected impacts of this investment on future VMT, average pavement roughness, and average delay per VMT. The baseline values shown correspond to the HERS-modeled portion of the **Improve Conditions and Performance scenario** presented in Chapter 8.

Exhibit 9-18 shows how these alternative analytical assumptions would affect projected future system performance given a fixed level of future investment. The particular level chosen corresponds to the HERS-modeled portion of the **Maintain Conditions and Performance scenario** presented in Chapter 8.

Impacts Assuming All Cost-Beneficial Improvements Implemented

Exhibit 9-17 shows how incorporation of the balanced budget constraint and/or congestion charges affects key results from HERS investment scenarios targeted at implementing all potentially cost-beneficial investments. Without a "balanced budget" constraint or congestion charge, the amount of such investment within the scope of HERS was estimated to average $105.4 billion per year over the 2009–2028 projection period.

If a balanced budget constraint were assumed so that any increase in spending above 2008 levels would be funded by a VMT-based or per-gallon surcharge, this would reduce the estimate of average annual cost-beneficial investment because the increased costs experienced by highway users would tend to reduce future VMT. It is important to note that while the investment amounts shown in *Exhibit 9-17* include only spending within the scope of HERS, the balanced budget constraint is applied to total highway capital spending. As described in Appendix A, the difference between the HERS-modeled capital investment presented in *Exhibit 9-17* and the $54.7 billion actually spent on the types of capital improvements modeled in HERS (representing 60.0 percent of total capital spending by all levels of government in 2008) is scaled upward to account for the types of capital improvements not modeled in HERS.

Exhibit 9-17

Impact of Alternative Revenue Mechanisms and Congestion Pricing Assumptions on the Level of Potentially Cost-Beneficial HERS-Modeled Investment and on Selected Performance Indicators

Analytical Assumptions		Assumptions Reflected in Highways Scenarios in Prior C&P Reports [3]	Average Annual HERS-Modeled Capital Investment (Billions of 2008 Dollars) [4]	Projected VMT on Federal-Aid Highways in 2028 (Trillions)	Percent Change, 2028 Compared With 2008		Minimum BCR Cutoff
Scenario Financing Mech-anism [1]	Congestion Pricing [2]				Average Pavement Roughness (IRI)	Average Delay per VMT	
None	None	**2010 C&P Baseline**	**$105.4**	3.724	-24.3%	-7.7%	1.00
Per VMT	None	2008 C&P Fixed Rate	$101.4	3.652	-23.8%	-8.3%	1.00
Per Gallon	None	2006 C&P Baseline	$103.2	3.684	-24.0%	-7.7%	1.00
None	Peak Period		$73.8	3.583	-20.0%	-10.8%	1.00
Per VMT	Peak Period	2008 C&P Variable Rate	$73.6	3.584	-20.2%	-10.1%	1.00
Per Gallon	Peak Period		$73.5	3.581	-20.1%	-10.1%	1.00

[1] The analyses presented in this table each assumes that either (1) there is no linkage between the investment scenario and funding mechanisms ("None") or (2) the difference between the scenario investment level and current 2008 capital outlay by all levels of government combined would be financed by a user fee imposed on either a gallonage ("Per Gallon") or a distance traveled ("Per VMT") basis. For those analyses which also include congestion pricing, the resulting revenues are assumed to be available to cover part of the cost of the scenario.

[2] The analyses presented in this table assume that congestion pricing, if implemented, would commence mid-2011.

[3] The baseline scenarios presented in Chapters 7 and 8 of this report assume no linkage between scenario investment levels and financing mechanisms, returning to the approach utilized in the 2004 C&P Report and prior editions. The 2008 C&P Report included two versions of each scenario: a fixed-rate user financing version assuming user charges imposed on a per VMT basis, and a variable-rate user financing version assuming both peak-only congestion pricing beginning in the base year and fixed-rate VMT-based user charges. The 2006 C&P Report baseline scenarios assumed fixed-rate user charges imposed on a per gallon basis.

[4] Of the $91.1 billion of total capital expenditures for highways and bridges in 2008, $54.7 billion was used for types of capital improvements modeled in HERS.

Source: Highway Economic Requirements System.

HERS projects that the average annual level of cost-beneficial investment assuming a VMT-based surcharge would be $101.4 billion; assuming a per-gallon surcharge, HERS projects an investment level of $103.2 billion. The magnitude of the reductions in travel demand reflect that the surcharges are relatively small, adding about 2.5 cents per mile to the user cost of travel compared to an average user cost of $1.07 per mile in the 2008 base year. The estimated impacts of adding a balanced funding constraint on average pavement roughness and average delay are likewise shown by *Exhibit 9-17* to be marginal.

In contrast, the impacts of imposing congestion pricing (with or without a balanced budget constraint) substantially reduce the estimate of potentially cost-beneficial investment. Assuming congestion pricing without a balanced budget constraint, the estimated amount of such investment averages $73.8 billion per year, or 30.0 percent less than the baseline estimate of $105.4 billion per year. The difference reflects that VMT is lower with congestion pricing in place—for example, 3.8 percent lower in the final year of the analysis period (2028)—and that the reduction is concentrated on the heavily congested sections of highway that generate much of the need for investments in system capacity.

Despite the amount of investment being lower, the summary measure of congestion—average delay per VMT—shows improvement with congestion pricing, reflecting the role of pricing in managing demand. From 2008 to 2028, average delay per VMT is projected to decline by 10.1 percent, compared to only 7.7 percent for the baseline assumptions of no pricing or balanced budget requirement. For average

How high are the congestion charges being imposed by HERS, and what would be the associated revenues?

Q&A

Taking, as an example from *Exhibit 9-17,* the application of congestion pricing without a balanced budget constraint (but with all cost-beneficial improvements assumed implemented over the entire 20-year analysis period), the peak-period tolls average 33.8 cents per VMT across all sections where the tolls are assumed to apply.

These sections are projected to carry 4.4 percent of all VMT on Federal-aid highways during the final 5-year funding period modeled (2024–2028) and a slightly lower percentage during the earlier years of the analysis. (For technical reasons, the imposition of the congestion charges is assumed to kick in at the middle of the first 5-year funding period, in mid-2011, rather than immediately at the beginning of that period in 2009.)

Projected gross revenue from the congestion charge averages $37.6 billion per year over the entire analysis period (2009–2028), stated in constant 2008 dollars. The costs of implementing and operating the congestion pricing system—including, for example, the costs of billing systems and, assuming a Global Positioning System (GPS)-based system, on-board vehicle computers, and GPS transponders—have not been estimated for this report, and could make net revenue significantly lower than gross revenue.

At the lower level of capital spending presented in *Exhibit 9-18*, peak-period tolls would average 34.6 cents per VMT across all sections where the tolls are assumed to apply, and would generate an average of $39.6 billion per year over the 20-year period. If spending were sustained at 2008 base year levels, HERS estimates that peak-period tolls would average 35.2 cents per VMT and generate an average of $41.3 billion per year. The projected average rates and revenues are higher at lower levels of investment because the overall level of congestion would be higher (because less investment would be made in adding capacity to the system), and the rates for the congestion charge for each location are set based on the level of congestion on that facility.

pavement roughness, however, the pattern is reversed: the projected change over the analysis period is a decline of 20.1 percent with congestion pricing versus a somewhat greater decline of 24.3 percent under the baseline assumptions. This pattern is explained by differences in the projected level of investment. Relative to the baseline assumptions, the projections predicated on pricing indicate about 70 percent as much investment in pavement preservation and approximately half as much investment in system expansion. The lower level of investment in pavement preservation is one reason why the pavements are typically rougher with pricing in place. The other reason is that with investment in system expansion also lower, fewer miles of new, smooth lanes are added to the existing system, thereby reducing average ride quality.

Exhibit 9-17 also reveals that adding a balanced funding constraint to the congestion pricing analysis has only minor effects on the estimate of potentially cost-beneficial investment and the conditions and performance indicators.

Impacts Assuming Fixed Total Spending Level

Exhibit 9-18 shows key results from HERS simulations that assume 1.31 percent annual growth over the projection period in real highway capital spending, which corresponds to average annual spending of $62.9 billion in 2008 dollars. For the baseline assumptions without congestion pricing or a balanced budget constraint, HERS projects that average speed in 2028, the final year of the projection period, would be the same as in the base year, 2008.

Adding peak congestion pricing to the picture increases the average speed projected for 2028 by 2.3 percent, and turns the projected 2008–2028 change in average delay per VMT from a deterioration of 3.8 percent to an improvement of 8.7 percent. *Exhibit 9-18* also shows a projected 2008-2028 improvement in average pavement roughness of 14.6 percent assuming congestion pricing, compared to a 3.8 percent improvement for the baseline assumptions. Contributing to this favorable outcome for pavements is the effect of congestion pricing on the HERS allocation of capital spending between pavement preservation and system

Exhibit 9-18

Impact of Alternative Revenue Mechanisms and Congestion Pricing Assumptions on Selected Performance Indicators, Assuming a Uniform Level of Capital Spending

Analytical Assumptions		Assumptions Reflected in Highways Scenarios in Prior C&P Reports [3]	Average Annual HERS-Modeled Capital Investment (Billions of 2008 Dollars)[4]	Percent Change, 2028 Compared With 2008			Minimum BCR Cutoff
Scenario Financing Mech-anism [1]	**Congestion Pricing [2]**			**Average Speed**	**Average Pavement Roughness (IRI)**	**Average Delay per VMT**	
None	None	**2010 C&P Baseline**	$62.9	**0.0%**	-3.8%	3.8%	2.02
Per VMT	None	2008 C&P Fixed Rate	$62.9	**0.0%**	-3.9%	4.0%	2.01
Per Gallon	None	2006 C&P Baseline	$62.9	**0.0%**	-3.8%	4.1%	2.01
None	Peak Period		$62.9	2.3%	-14.6%	-8.7%	1.24
Per VMT	Peak Period	2008 C&P Variable Rate	$62.9	2.1%	-14.7%	-7.6%	1.24
Per Gallon	Peak Period		$62.9	2.1%	-14.8%	-7.9%	1.23

[1] The analyses presented in this table each assumes that either (1) there is no linkage between the investment scenario and funding mechanisms ("None") or (2) the difference between the scenario investment level and current 2008 capital outlay by all levels of government combined would be financed by a user fee imposed on either a gallonage ("Per Gallon") or a distance traveled ("Per VMT") basis. For those analyses which also include congestion pricing, the resulting revenues are assumed to be available to cover part of the cost of the scenario.

[2] The analyses presented in this table each assume congestion pricing, if implemented, would commence in mid-2011.

[3] The baseline scenarios presented in Chapters 7 and 8 of this report assume no linkage between scenario investment levels and financing mechanisms, returning to the approach utilized in the 2004 C&P Report and prior editions. The 2008 C&P Report included two versions of each scenario: a fixed-rate user financing version assuming user charges imposed on a per VMT basis, and a variable-rate user financing version assuming both peak-only congestion pricing beginning in the base year and fixed-rate VMT-based user charges. The 2006 C&P Report baseline scenarios assumed fixed-rate user charges imposed on a per gallon basis.

[4] Of the $91.1 billion of total capital expenditures for highways and bridges in 2008, $54.7 billion was used for types of capital improvements modeled in HERS. The $62.9 billion average annual investment level assumed for each analysis represents the HERS-derived portion of the baseline Cost to Maintain Highways and Bridges scenario presented in Chapter 8.

Source: Highway Economic Requirements System.

expansion. Although average annual capital spending is fixed at $62.9 billion, incorporating congestion pricing increases the portion that HERS allocates to pavement rehabilitation from $32.7 billion to $40.5 billion. This reallocation arises because the needs for system expansion are more sensitive to changes in traffic volume than are the needs for pavement preservation, which, especially with weather-related effects, stem partly from time- rather than traffic-related deterioration.

As in the results presented in *Exhibit 9-17*, the results shown in *Exhibit 9-18* are relatively insensitive to the inclusion or omission of a balanced funding constraint. Adding this constraint to the base case leaves the projections for the conditions and performance indicators essentially unchanged. Adding it to the congestion pricing regime also does little to the results; the largest impact is on the projected 2009–2028 change in average delay per VMT, which is a decline of 8.7 percent with only congestion pricing assumed versus 7.6 percent when pricing is combined with a balanced budget constraint. This difference occurs because the gross congestion pricing revenues would exceed the amount needed to support the level of funding assumed for this analysis; as a result, the balanced budget constraint would force a reduction to existing user charges, which would encourage additional VMT outside the peak period. This aspect of the balanced budget procedure is discussed in more detail in Appendix A.

Accelerating Operations/ITS Deployments

As described in Chapter 7, the HERS model considers the impacts on highway conditions and performance of various types of ITS and other operational enhancements to highways. Appendix A describes the types of strategies considered (including arterial management, freeway management, incident management, and traveler information systems) and three scenarios for future deployment. The baseline assumptions used in Chapters 7 and 8 of this report are consistent with the "Continuation of Existing Deployment Trends" scenario. One of the alternative sets of assumptions used in this section is consistent with the "Aggressive Deployment" scenario, which assumes an accelerated pace of deployment above existing trends along with more advanced forms of operations strategies than are considered in the baseline. The other set of alternative assumptions is consistent with the "Full Deployment" scenario, which differs from the "Aggressive Deployment" scenario in assuming that all deployments will occur immediately rather than being phased in over 20 years.

The analyses presented in Chapter 7 (see *Exhibit 7-2*) show that increasing HERS-modeled capital spending by 5.90 percent per year over 20 years above the baseline 2008 level of $54.7 billion would result in a 20-year spending figure of $2.108 trillion, translating into an average annual investment level of $105.4 billion. This level of investment was estimated to be sufficient to finance all potential capital improvements up to a BCR cutoff of 1.00. (This is the HERS-modeled component of the **Improve Conditions and Performance scenario** presented in Chapter 8.) As shown in the top half of *Exhibit 9-19*, under the Aggressive Deployment alternative, HERS identifies even more potentially cost-beneficial investments, which average $109.5 billion annually. This finding suggests that the types of operations strategies and ITS deployments considered as part of this scenario are complementary to widening options in some circumstances; in some cases, expanding a facility while simultaneously deploying advanced operations technology can yield more benefits than could be achieved by either action alone. At this level of investment, system performance measured by average speed, average pavement roughness, and average delay would be better in 2028 assuming aggressive deployment patterns than would be the case under the baseline assumption. Under the Full Immediate Deployment alternative, the average annual investment level associated with a BCR of 1.00 would be $115.1 billion; this alternative would result in even better performance than the Aggressive Deployments alternative.

While HERS does not perform benefit-cost analysis of spending on operational deployments versus lane additions in a particular location, it can help to elucidate the tradeoffs between these spending alternatives at a systemwide basis. The bottom of *Exhibit 9-19* shows the impacts on HERS projections of deploying operational improvements more aggressively without changing the total amount invested in highways. This analysis assumes that any extra spending on deployment of operational improvements will be funded by reducing the HERS-modeled investment in system expansion and rehabilitation. The initial amounts of this investment before any reduction is applied are, alternatively, the amount actually spent in 2008 ($54.7 billion from the **Sustain Current Spending scenario**) plus the amounts estimated to be sufficient to maintain current average speed ($62.9 billion) or fund all cost-beneficial improvements ($105.4 billion) under the baseline projections.

At each of these initial levels, funding the more aggressive operational improvement spending by curtailing system expansion and rehabilitation investment worsens projected average pavement roughness in 2028. This is to be expected because operational improvements have no direct impacts on pavement condition and could indirectly worsen pavement condition by inducing additional travel; thus, they produce no benefits in pavement condition to offset the deterioration associated with the curtailment of spending on system expansion and rehabilitation. At an initial level of $105.4 billion in HERS-modeled investment in system expansion and rehabilitation, average pavement roughness is projected to decrease over the analysis period

Exhibit 9-19

Impact of Alternative Operations Strategies Deployment Rate Assumptions on the Level of Potentially Cost-Beneficial HERS-Modeled Investment and on Selected Performance Indicators

Operations/ITS Deployments Assumption [1]	Average Annual HERS-Modeled Capital Investment (Billions of 2008 Dollars) [2]	Percent Change, 2028 Compared With 2008 [3]			Minimum BCR Cutoff [4]
		Average Speed	Average Pavement Roughness (IRI)	Average Delay per VMT	
Make All Cost-Beneficial Investments					
2010 C&P Baseline (existing trends)	**$105.4**	2.6%	-24.3%	-7.7%	**1.00**
Aggressive deployments alternative	$109.5	2.8%	-24.4%	-8.9%	1.00
Full immediate deployments alternative	$115.1	3.2%	-24.7%	-11.1%	1.00
Average Annual Spending $105.4 Billion					
2010 C&P Baseline (existing trends)	$105.4	2.6%	-24.3%	-7.7%	1.00
Aggressive deployments alternative	$105.4	2.6%	-22.9%	-8.2%	1.06
Full immediate deployments alternative	$105.4	2.7%	-20.9%	-9.0%	1.16
Average Annual Spending $62.9 Billion					
2010 C&P Baseline (existing trends)	$62.9	0.0%	-3.8%	3.8%	2.02
Aggressive deployments alternative	$62.9	-0.1%	-0.3%	3.9%	2.21
Full immediate deployments alternative	$62.9	-0.4%	4.5%	4.0%	2.48
Sustain Current Highway Spending	**$188.7**	**-0.5%**	**0.5%**	**11.6%**	**6.71**
2010 C&P Baseline (existing trends)	$54.7	-0.7%	2.8%	6.7%	2.42
Aggressive deployments alternative	$54.7	-1.0%	6.9%	7.1%	2.67
Full immediate deployments alternative	$54.7	-1.4%	12.3%	7.7%	2.99

[1] The analyses presented in this table assume one of the following: (1) existing trends in ITS deployments will continue for 20 years; (2) an aggressive pattern of deployment will occur over the next 20 years; or (3) all of the aggressive deployments would occur immediately, rather than being spread out over 20 years. The costs associated with the more aggressive deployments were deducted from the budget available in HERS for pavement and widening investments.

[2] Of the $91.1 billion of total capital expenditures for highways and bridges in 2008, $54.7 billion was used for types of capital improvements modeled in HERS.

[3] Increases in average speed reflect an improvement to system performance, as do decreases in average pavement roughness (IRI) and average delay per VMT.

[4] The minimum BCR represents the lowest benefit-cost ratio for any project implemented by HERS during the 20-year analysis period at the level of funding cutoff shown.

Source: Highway Economic Requirements System.

from 2008 to 2028 by 24.3 percent in the existing trends scenario for operational improvements versus 20.9 percent in the full immediate deployment scenario. In the aggressive deployment scenario, which is intermediate between the existing trends and full deployment scenarios, the corresponding estimate is a reduction of 22.9 percent. At lower initial levels of HERS-modeled investment in system expansion and rehabilitation, reallocating funding to operational improvements is projected to result in even more significant effects on pavement roughness. At the lowest level considered, sustaining spending at the $54.7 billion level of 2008, projections in all the operational improvement scenarios are for pavements to be rougher on average in 2028 than 2008; however, the deterioration goes from 2.8 percent in the baseline existing trend scenario to 12.3 percent in the most aggressive "full immediate deployments" scenario.

Reallocating funding to operational improvements produces a more marked sacrifice of pavement quality at lower levels of initial investment in HERS-modeled highway system expansion and rehabilitation, which is consistent with the prioritization of investments in HERS according to BCR. As discussed in relation to *Exhibit II-1* in the Introduction to Part II of this report, the marginal BCR rises as the level of HERS-modeled investment in system expansion and rehabilitation declines. The marginal BCR (in *Exhibit 9-19*, the "minimum BCR cutoff") represents the benefit foregone per marginal dollar of investment reduction below the initial level, and reduced pavement quality constitutes part of this loss. Thus, curtailing investment in system expansion and rehabilitation by a given amount will tend to produce larger reduction in pavement quality at lower levels of overall investment.

Unlike pavement quality, travel time directly benefits from the operational improvements represented in HERS so that increased spending on these improvements can potentially affect speed and delay favorably, even when the increase is funded by spending cutbacks on system expansion and rehabilitation. In *Exhibit 9-19*, when the initial level of investment in HERS-modeled system expansion and rehabilitation averages $105.4 billion per year, or about the maximum that HERS can justify on benefit-cost grounds, these overall beneficial impacts would be realized under both of the more aggressive operational deployment strategies considered. However, when this investment is at one of the lower levels shown, *Exhibit 9-19* indicates that pursuing the more aggressive operational deployment alternatives would have adverse overall impacts on both average speed and average delay. At these initial levels of investment, which average $62.9 billion and $54.7 billion annually, the beneficial impacts on these performance measures from the earlier and more widespread deployment of operational improvements are outweighed by the adverse impacts stemming from the offsetting cutbacks in spending on system expansion and rehabilitation. That the overall adverse impacts are more pronounced at lower initial spending levels is again reflective of the pattern of diminishing marginal returns depicted in *Exhibit II-1* (the marginal BCR declines as the level of investment increases). When annual investment is assumed to remain at the 2008 level of $54.7 billion, the average delay per VMT is projected to increase between 2008 and 2028 by 7.1 percent under the "aggressive deployment alternative," which compares with a 6.7 percent assuming continuation of existing deployment trends. When the full immediate deployment of operational improvements is assumed, this projected change in average delay becomes still larger at 7.7 percent.

Alternative Bridge Management Strategies

The NBIAS model includes a capability to analyze the impact of alternative strategies regarding bridge replacements; this section explores how such strategies would impact the backlog of investments needed to address bridge deficiencies. As noted in Chapter 7, the NBIAS model considers bridge deficiencies at the level of individual bridge elements based on engineering criteria and computes an initial value for the cost of a set of corrective actions that would address all such deficiencies. NBIAS tracks this backlog of potential bridge improvements over time, recomputing it to account for corrective actions taken and for the ongoing deterioration of bridge elements. A portion of this engineering-based backlog represents potential corrective actions that would not pass a benefit-cost test and hence would not be implemented by the model even if available funding were unlimited. The remaining portion of the backlog that would be cost-beneficial to address is identified as the economic bridge investment backlog.

The analyses presented in Chapter 7 focused on the economic bridge investment backlog, which NBIAS estimates to have been $121.2 billion in 2008. The analyses presented in Chapter 7 (see *Exhibit 7-2*) show that real growth in NBIAS-modeled spending over 20 years of 4.31 percent annually would make average annual spending $20.5 billion, which would just suffice to eliminate the economic backlog by 2028. From *Exhibit 9-20*, however, it would not suffice to eliminate the engineering backlog, of which $6.4 billion would remain, which is 5.0 percent of the engineering backlog estimated to have existed in 2008. This represents the portion of the engineering backlog that NBIAS did not find cost-beneficial to address. The analysis in this chapter focuses more on the engineering backlog, partly to facilitate comparisons among alternative bridge management strategies.

Exhibit 9-20

Impact of Alternative Bridge Management Strategies on the Projected System Rehabilitation Investment Backlog for All Bridges

Alternative Bridge Management Strategies [1]	Average Annual NBIAS-Modeled Capital Investment (Billions of 2008 Dollars) [2]	Bridge Investment Backlog for System Rehabilitation [3]			
		2008 Economic Backlog	2008 Engineering Backlog	2028 Engineering Backlog	Percent Change 2028 vs. 2008
Maximum (Ramped) Spending Level [4]					
2010 C&P Baseline	$20.5	$121.2	$127.6	$6.4	-95.0%
Replace Bridges over 50 years old	$33.3		$183.9	$289.3	57.3%
Replace Bridges over 75 years old	$22.5		$136.3	$51.0	-62.6%
Replace Bridges with Health Index <85	$42.6		$212.6	$115.4	-45.7%
Replace Bridges with Health Index <80	$36.5		$184.4	$37.2	-79.8%
Replace Bridges with Health Index <75	$30.2		$163.3	$20.9	-87.2%
Sustain Current Spending Level					
2010 C&P Baseline	$12.8	$121.2	$127.6	$114.0	-10.6%
Replace Bridges over 50 years old	$12.8		$183.9	$386.7	110.3%
Replace Bridges over 75 years old	$12.8		$136.3	$158.4	16.2%
Replace Bridges with Health Index <85	$12.8		$212.6	$565.1	165.7%
Replace Bridges with Health Index <80	$12.8		$184.4	$446.3	142.0%
Replace Bridges with Health Index <75	$12.8		$163.3	$331.0	102.7%

[1] The alternative bridge strategies presented would each apply an additional bridge replacement criteria on top of the decision making criteria implicit in the baseline analyses presented in Chapter 7. Applying these criteria would increase the 2008 engineering backlog and alter the mix of bridge investments over the 20-year period analyzed.

[2] Of the $91.1 billion of total capital expenditures for highways and bridges in 2008, $12.8 billion (14.0 percent) was used for types of capital improvements modeled in NBIAS.

[3] Reductions in the economic investment backlog for bridges would be consistent with an overall improvement in bridge conditions. The amounts shown do not reflect system expansion needs; the bridge component of such needs are addressed as part of the HERS model analysis.

[4] The investment levels identified for each alternative represent the average annual level of investment over 20 years consistent with the highest constant annual rate of spending growth above the 2008 baseline level for which NBIAS would spend the full amount of funds available in each of the 20 years.

Source: National Bridge Investment Analysis System.

Of the five alternative management strategies discussed in this section, two relate to the age of bridges and three relate to the average health index rating for bridges as described below. These strategies are intended to be illustrative. Other strategies based on different targets could be used and be equally valid from a technical perspective.

Age-Based Replacement Rules

The number of new bridges constructed per year has varied over time. Many existing bridges were built decades ago during the peak era of Interstate Highways construction. Based on estimates of a 50-year design life of a bridge structure, this has raised concerns that such bridges will soon reach their service life limit.

The assumption of a maximum design life of 50 years may be conservative when timely maintenance and rehabilitation has kept a structure in good repair, thus potentially extending its service life. Conversely, less than aggressive maintenance and factors such as loading a bridge in excess of its anticipated, as-built limit can make a structure deteriorate more quickly or require more extensive rehabilitation.

Exhibit 9-20 shows the impacts on NBIAS projections of mandating replacement of bridges older than 50 years or, alternatively, 75 years. In the model runs that include them, these rules are additional to the other NBIAS criteria for project selection. In one set of these runs, NBIAS implements over the 20-year analysis period all improvements meeting these criteria or required by the replacement rules without any funding constraints assumed. In the other set of runs, annual investment in constant dollars is fixed over the 20 years at the 2008 level of $12.8 billion.

Requiring the replacement of bridges older than 50 years would sharply increase the NBIAS estimate of the engineering backlog that existed in 2008, from the baseline estimate of $127.6 billion to $183.9 billion. This increase is attributable to bridges that are currently over 50 years old that NBIAS does not find to be in need of immediate replacement based on other criteria. In the model runs that maintain spending at $12.8 billion per year (in constant-dollar terms), the engineering backlog soars by 110.3 percent to $386.7 billion by 2028. In the runs where funding is unlimited, spending on the types of bridge improvements modeled in NBIAS increases by 8.42 percent annually over the 20 years, making for an average annual investment of $33.3 billion. Even so, the engineering backlog continues to grow (to $289.3 billion in 2028) as large numbers of bridges cross the 50-year threshold.

A less aggressive replacement rule applied to bridges older than 75 years would increase the estimated engineering backlog for bridges to $136.3 billion in 2008; this is lower than the estimated backlog referenced above for an age-50 replacement rule because there are far fewer bridges that are currently over age 75 than are currently over age 50. When the funding assumption is that annual spending on the types of bridge improvements modeled in NBIAS stays at the 2008 level of $12.8 billion, the engineering backlog is projected to rise by 16.2 percent by 2028. When no funding constraint is assumed, the investment that the model can justify over the 20 years averages $22.5 billion per year, and would be sufficient to cut the $136.3-billion backlog by 62.6 percent to $51.0 billion by 2028.

Health Index-Based Replacement Rules

The health index is a measure of the structural integrity of an element of the bridge. Each element is evaluated individually and these values are then compiled into a total bridge score. The health index ranges from a high of 100 to a low of 0; a lower the health index number indicates a higher priority for structure rehabilitation or maintenance. In *Exhibit 9-20,* the results of analyses based on three alternative replacement thresholds are presented, corresponding to health indices of 85, 80, and 75. With a higher threshold, more bridges would qualify for replacement. A threshold of 85 would be associated with a larger backlog and higher investment needs to address that backlog. As is the case for the age-based alternatives discussed above, these analyses assume that any bridge crossing the health index threshold will be replaced, in addition to other bridge actions selected based on the normal NBIAS criteria.

Among these three alternatives, the estimated engineering bridge backlog for 2008 ranges from $163.3 billion to $212.6 billion, which is considerably higher than the comparable figure of $127.6 billion computed using the baseline assumptions. Assuming investment is sustained at the 2008 level, this backlog projected for 2028 varies from $331.0 billion to $565.1 billion, depending on the health index threshold assumed. As noted at the beginning of this section, the particular health index threshold selected for analysis is intended to illustrate the implications of setting these types of criteria, rather than to suggest that any of these alternatives would form the basis for a comprehensive bridge management strategy.

Transit Supplemental Scenario Analysis

This section is intended to provide the reader with a deeper understanding of the assumptions behind the scenarios presented in Chapters 7 and 8 and also of the real world issues that impact transit operators' ability to address their outstanding capital needs. Specifically, this section includes discussion of the following topics:

- A comparison of the **State of Good Repair (SGR) benchmark** with the maintain conditions and improve conditions scenarios from prior years' C&P reports
- A comparison of recent historic passenger miles traveled (PMT) growth rates with the growth projections of the Nation's metropolitan planning organizations (MPOs) (used for the **Low** and **High Growth scenarios**)
- The gap between cost and revenue growth for transit operations
- The accuracy of TERM in predicting transit capital needs.

TERM Scenarios: SGR Versus Maintain or Improve Conditions

Prior editions of the C&P report included scenarios that considered the level of investment required either to (1) *maintain* the condition of the Nation's existing transit assets at current levels or to (2) *improve* the condition of those assets to an overall condition of "good" (i.e., 4.0 on the Transit Economics Requirements Model's [TERM's] asset condition rating scale). For this edition, these "maintain" and "improve" conditions scenarios have been replaced by the **SGR benchmark**, which estimates the level of investment required to *attain* and then *maintain* an overall state of good repair for the Nation's existing transit assets. This section considers the reasoning and implications of this change.

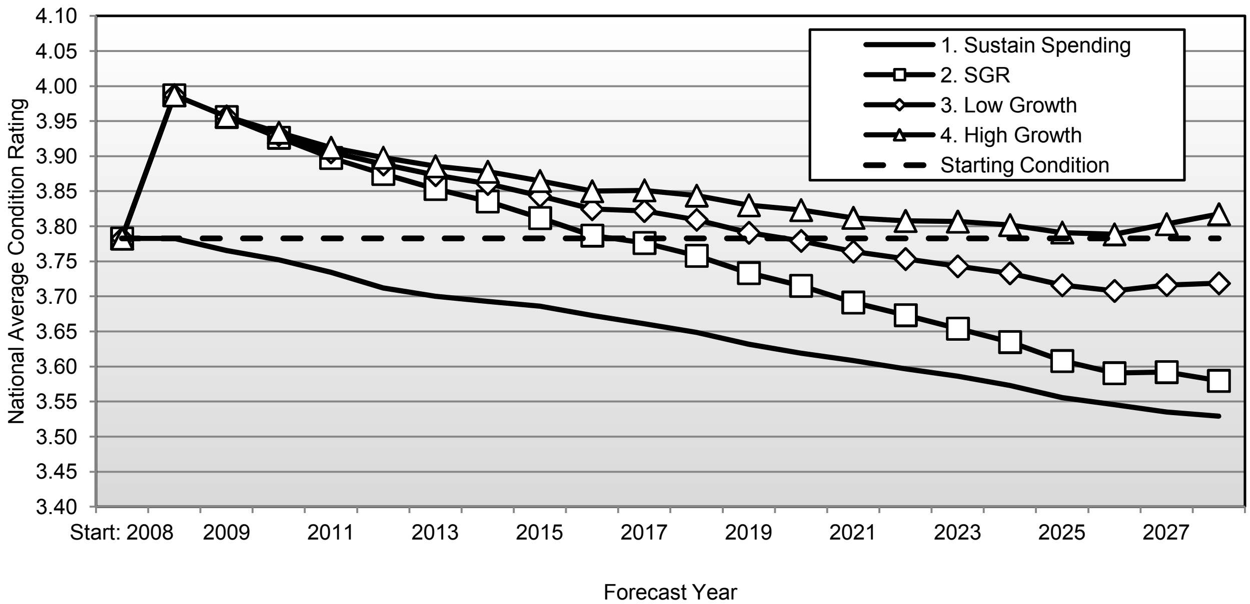
Challenges With the Maintain and Improve Conditions Scenarios

While easy to comprehend and explain conceptually, the maintain and improve conditions scenarios presented in prior editions also suffered from a number of key limitations. First, while each of these scenarios provides a helpful investment reference point, it is not clear that either the maintain or improve conditions outcome is desirable or even sensible. For example, are current asset conditions at an acceptable level or are they too low (or too high) for individual asset types? Is maintaining current conditions financially sensible in the long term and does this objective represent sound asset management practice? Similar questions may be asked of improving conditions to an overall condition of "good." Would this result in replacing assets before the end of their useful lives? Are average conditions truly significant, or is it more critical to improve those assets with the worst conditions?

To help answer these questions, consider *Exhibit 9-21*, which presents the condition projections for each of the four scenarios considered in this report. Note that these projections predict the condition of all transit assets in service at any one time, including transit assets that exist today and any investments in expansion

Exhibit 9-21

Asset Condition Forecast for All Transit Assets: Includes Both Existing and Expansion Assets



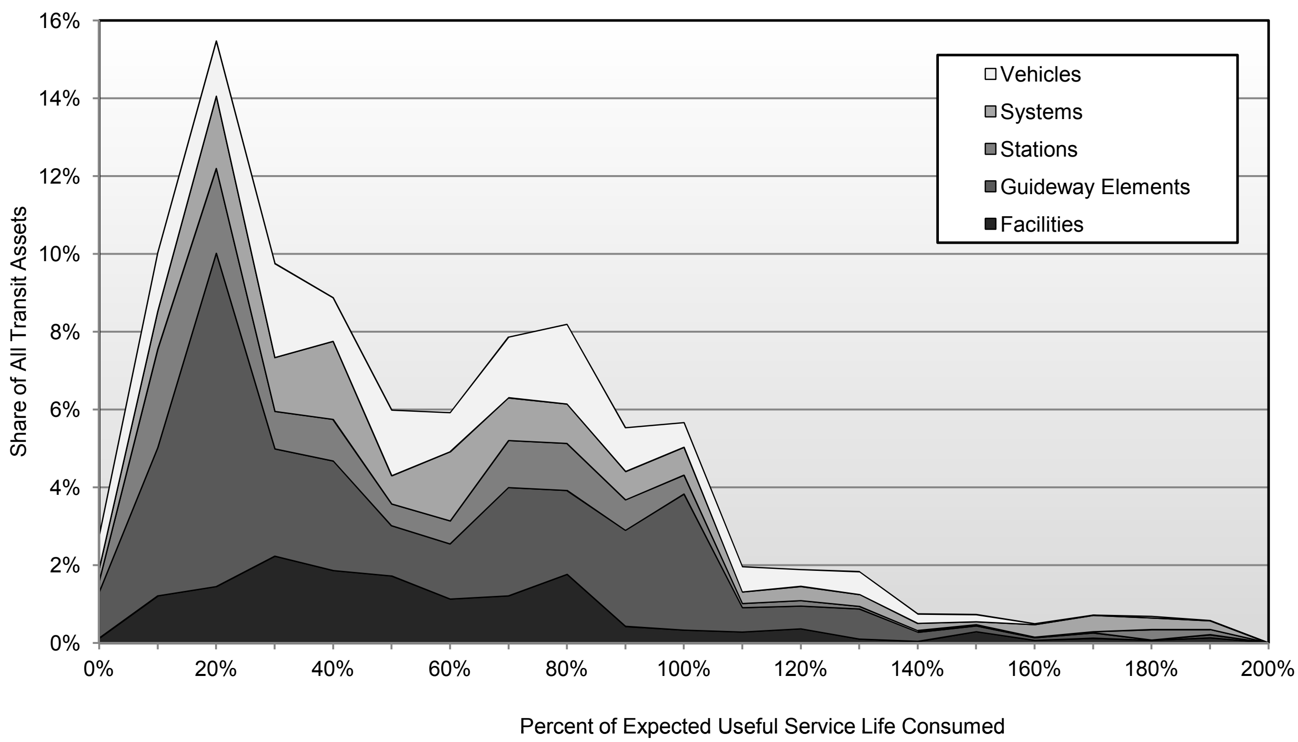
Source: Transit Economic Requirements Model.

assets by these scenarios (the **Sustain Current Spending**, **Low Growth**, and **High Growth scenarios** each have investment in expansion assets and the **SGR benchmark** only reinvests in existing assets). Note also that the estimated current average condition of the Nation's transit assets is 3.78. As discussed in Chapter 8, expenditures under the financially constrained **Sustain Current Spending scenario** are not sufficient to address replacement needs as they arise, leading to a predicted increase in the investment backlog. This increasing backlog is a key driver in the decline in average transit asset conditions as shown for this scenario in *Exhibit 9-21*.

In contrast, the **SGR benchmark** is financially unconstrained and considers the level of investment required both to eliminate the current investment backlog and to address all ongoing reinvestment needs as they arise such that all assets remain in a SGR (i.e., a condition of 2.50 or higher). In *Exhibit 9-21*, elimination of the investment backlog yields the sharp improvement in asset conditions as shown in the early years of the projection (e.g., as all over age assets are replaced). Nonetheless, despite adopting the objective of maintaining all assets in SGR throughout the forecast period, average conditions under the **SGR benchmark** also ultimately decline to levels well below the current average condition value of 3.78. While this result may appear counterintuitive it is explained by a high proportion of long-lived assets (e.g., guideway structures, facilities, and stations) that currently have fairly high average condition ratings and a significant amount of useful life remaining, as shown in *Exhibit 9-22*. The spike in *Exhibit 9-22* at the point where only 20 percent of useful life has been consumed is driven in part by ongoing expansion investments. Hence, while elimination of the current SGR backlog removes a significant number of over age assets from service (resulting in an initial jump in asset conditions), the ongoing aging of the longer-lived assets will ultimately draw the average asset conditions down to a long-term condition level that is consistent with the objective of SGR (and hence sustainable) but ultimately measurably below current average aggregate conditions.

Exhibit 9-22

Comparison of Expected Useful Service Life Consumed for All Transit Assets, by Component



Source: Transit Economic Requirements Model.

Now consider the implications of this finding for the maintain conditions scenario presented in prior reports. If the **SGR benchmark** represents a reasonable long-term investment strategy—namely replacing assets within a short time of attaining their expected useful life—that nonetheless yields a long-term decline in average conditions, then investing to maintain current conditions necessarily implies an investment strategy of replacing assets at earlier ages, in better conditions, and potentially before the end of their useful life. In short, under current asset conditions, the maintain conditions scenario does not align with a reasonable reinvestment policy and, for the same reasons, neither does the improve conditions scenario. In practice, the maintain conditions scenario and the improve conditions scenario from prior editions of the C&P report never did attain the stated maintain and improve conditions investment objectives precisely because these scenarios would have required that some assets be replaced at unreasonably early ages and TERM does not permit early asset replacement. In this context, the **SGR benchmark** provides results that are more realistic and that reflect a sounder reinvestment strategy.

Finally, to underscore these findings, note that the **Low Growth scenario** and the **High Growth scenario** include investments in both asset replacements and asset expansions. Hence, not only are older assets replaced as needed without financial constraint, but new expansion assets are also continually added to support ongoing growth in travel demand. While initially insufficient to fully arrest the decline in average conditions, the impact of these expansion investments ultimately would reverse the downward decline in average asset conditions in the final years of the 20-year projections. As should be expected, the **High Growth scenario** adds newer expansion assets at a higher rate than does the **Low Growth scenario**, ultimately yielding higher average condition values for that scenario (and average condition values that exceed the current average of 3.78 throughout the entire forecast period).

Historic Versus Projected Transit Travel Growth

The **Low** and **High Growth scenarios** presented in Chapter 8 assessed transit expansion investment needs assuming two differing rates of growth in transit PMT. Specifically, the **Low Growth scenario** assumed urbanized-area (UZA)–specific rates of PMT growth as projected by the Nation's MPOs, while the **High Growth scenario** assumed the UZA-specific average annual compound rates experienced over the most recent 10-year period. The objective of this discussion is to help place these two differing growth rates into better perspective.

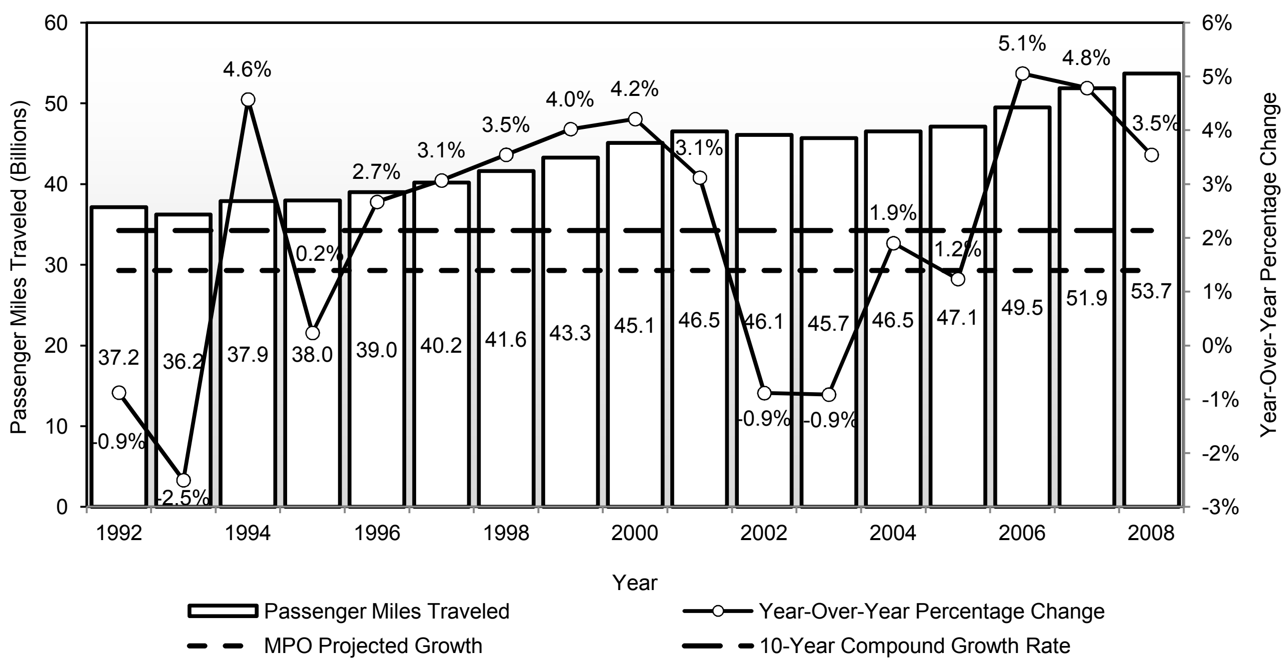
In general, the MPO projections are believed to provide a lower range for PMT growth because these projections are financially constrained (i.e., the assumed rate of transit and highway network expansion is constrained to what is feasible given expected future funding capacity and long-term expansion plans). Hence, while the **Low Growth scenario** is intended to represent unconstrained transit investment needs given a projected rate of increase in PMT, the MPO PMT growth rates underlying this scenario are financially constrained, thus imposing an implicit financial constraint on this scenario. The UZA PMT projections used for the **Low Growth scenario** were provided by a sample of MPOs; this sample was dominated by the Nation's largest UZAs but also included a mix of small- and medium-sized metropolitan areas from around the Nation. When weighted to account for differences in current annual PMT, this sample yields a weighted national average PMT growth rate of 1.3 percent.

MPO Versus Historical Growth for All Urbanized and Rural Areas

As shown in *Exhibit 9-23*, the historical rates of PMT growth experienced over the past 20 years have typically been in excess of the MPO-projected growth rates. During the period from 1992 through 2008 as presented here, the compound annual growth rate averaged roughly 2.1 percent as compared with the 1.3-percent growth rate projected by MPOs for the upcoming 20- to 30-year period (note that this analysis period differs from the 1999 to 2008 period used to assess average growth for the **High Growth scenario.**

Exhibit 9-23

Passenger Miles Traveled, All Urbanized and Rural Areas



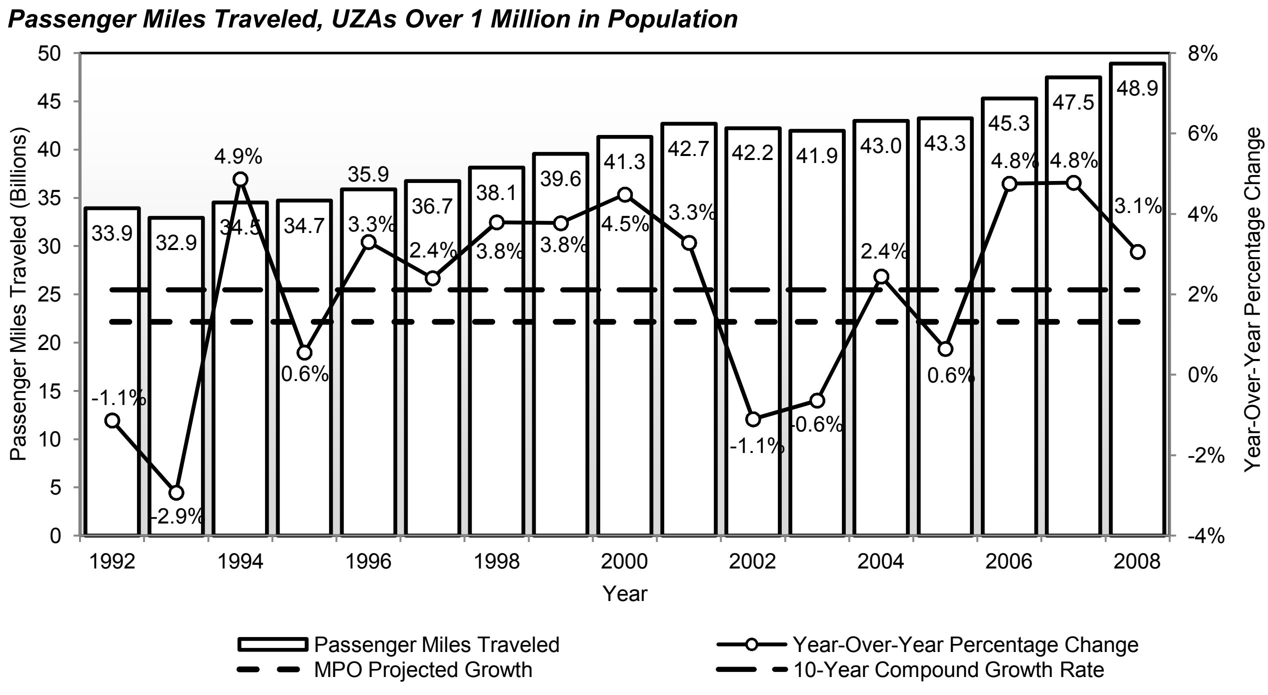
Source: National Transit Database and metropolitan planning organization estimates.

The objective here is to contrast MPO forecasts with long-term PMT growth trends. In contrast, the growth rate identified for the **High Growth scenario** was intended to be more representative of recent higher PMT growth). Given the significant difference in these two rates (and the relatively high rate of historic PMT growth as compared to other additional measures, such as urban area population growth), the historical rate of PMT was identified as a reasonable input value for the **High** (or higher) **Growth Scenario**.

UZAs Over 1 Million in Population

As shown in *Exhibit 9-24*, the difference between the MPO-projected growth rate and the recent historical PMT growth rate remains unchanged when limited to UZAs with populations greater than 1 million. For these larger UZAs, the compound average annual growth rate again averaged roughly 2.1 percent during the period from 1992 through 2008 as compared with the 1.3-percent growth rate projected by MPOs for the up-coming 20- to 30-year period. Note that the larger UZAs carry the vast majority of PMT each year.

Exhibit 9-24



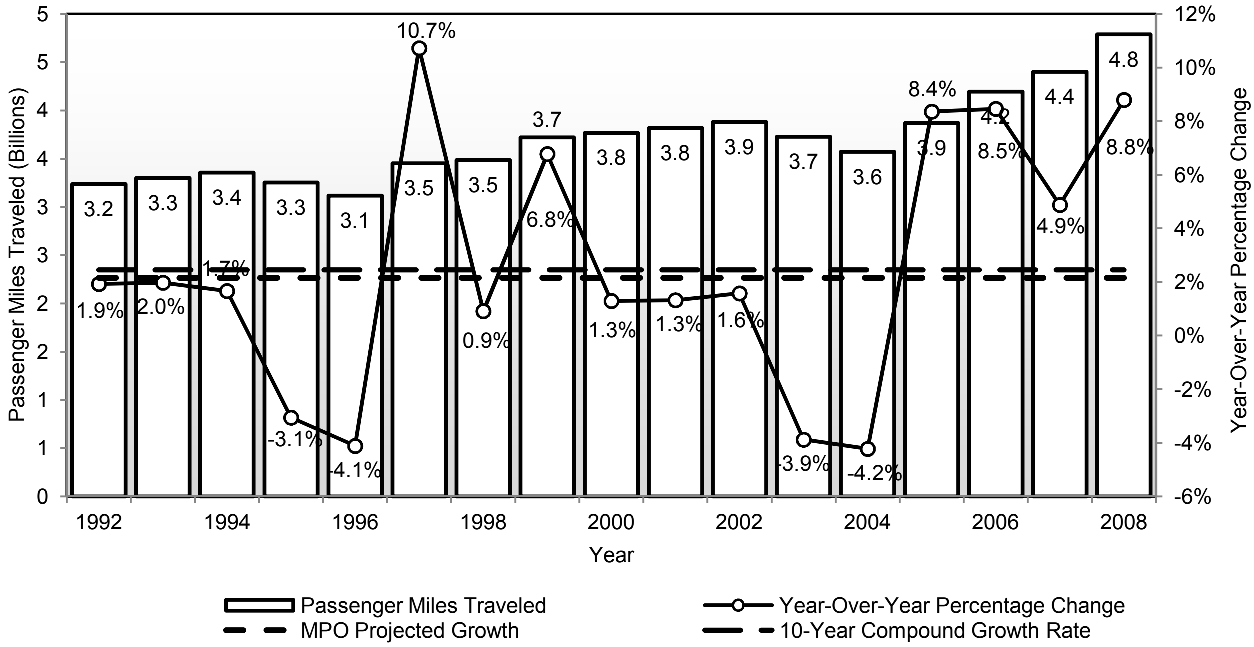
Source: National Transit Database and metropolitan planning organization estimates.

Other Urbanized and Rural Areas

Finally, as shown in *Exhibit 9-25* there is significantly less difference between the MPO-projected and recent annual average historical PMT growth rates when the analysis is limited to urbanized areas with populations less than 1 million and rural areas (i.e., when the larger UZAs are excluded). For this group, the compound average annual growth rate averaged roughly 2.4 percent over the period from 1992 through 2008, which is close to the 2.2-percent growth rate projected by MPOs for this group. There are two significant differences to note here with the findings for the larger UZAs. First, the MPO-projected rate of increase for these smaller UZAs is roughly 64 percent higher than for the largest UZAs. This difference is partly accounted for by (1) the higher rates of population growth in many of these smaller UZAs (particularly in the south and in the west) and (2) proposed light and commuter rail investments in some UZAs in this group. Second, the year-to-year variance in the actual growth rates for this group roughly double that experienced by the largest UZAs.

Exhibit 9-25

Passenger Miles Traveled, UZAs Under 1 Million in Population



Source: National Transit Database and metropolitan planning organization estimates.

Assessing the Accuracy of TERM

The Federal Transit Administration's (FTA's) TERM is an analysis tool designed to estimate transit capital investment needs. It has been used since 1995 to support preparation of the U.S. Department of Transportation's (U.S. DOT's) biennial C&P report. Since TERM has been predicting transit capital investment needs for many years, it is worth considering how accurate TERM has been in estimating how resource levels will impact outcomes.

This section compares TERM's 2004 C&P Report predictions (based on 2002 data) with 2009 data and draws the following conclusions:

- Actual reinvestment expenditures were somewhat lower than TERM's predictions of reinvestment need (less was spent on SGR than was needed to maintain conditions).
- Actual asset conditions in 2009 were lower than TERM predictions in the 2004 C&P Report, which should be expected since transit operators did not reinvest at a rate sufficient to maintain conditions (the objective of the TERM scenario used for comparison).
- Actual capital expansion expenditures for the 2003 to 2009 period were generally lower than TERM estimated would be required to maintain vehicle capacity utilization at 2002 levels. As would then be expected, vehicle capacity utilization increased over the 2003 to 2009 period.
- In general, TERM provided reasonable predictions of transit investment requirements (as determined by actual investment rates) while the differences between TERM's predictions of transit asset conditions and vehicle capacity utilization and the actual, realized values of these measures were consistent with expectations.

Assessment Approach

This section assesses the accuracy of TERM in predicting the following measures: (1) transit reinvestment and expansion needs, (2) future asset conditions, (3) asset expansion, and (4) actual ridership growth. Additional information about TERM is provided in Appendix C. This accuracy evaluation test is based on a comparison of 2004 C&P Report projections of conditions, ridership, and system capacity with actual measures from 2009 data. The 2004 C&P Report that used the 2002 version of TERM with 2002 National Transit Database (NTD) data was selected as the basis of comparison. The 2002 version of TERM was selected because the quality of the asset inventory data that year was much improved relative to submissions in earlier years used to support prior C&P reports. Note that inventory data for TERM must be requested from a sample of agencies. At present (1) there is no Federal asset inventory reporting requirement, and (2) there are no standards for maintaining and reporting such data—hence, there is a broad range of data quality and limited consistency in the asset data obtained for TERM analysis. This situation will change with the introduction of asset reporting through NTD within the next few years. The 2002 version of TERM, which uses 2002 NTD data as reflected in the 2004 C&P Report, also reflects the earliest time period for which reliable reporting of transit capital expenditures segmented between reinvestment and expansion is available.

Investment Needs—Reinvestment

Exhibit 9-26 compares the 2004 C&P Report capital reinvestment needs projections (maintain conditions) with the actual average annual amounts for the 2003 through 2009 period with all amounts expressed in 2008 dollars. Review of this exhibit shows that, over the period from 2003 through 2009, the Nation's transit operators expended an estimated $1.6 billion less on annual capital reinvestment than the amount required to maintain assets at the condition levels prevailing in 2002 (as estimated by TERM). This spending "deficit" was spread across all asset types with the exception of guideway and stations, where actual expenditures reported exceeded TERM's needs estimates.

The largest gap between needs and actual expenditures occurred for bus vehicles (where the gap was on the order of $2.4 billion). Note that, in TERM's estimates, bus life-cycle costs have been reduced since the 2004

Exhibit 9-26

Predicted Versus Actual Capital Reinvestment

Asset Category	TERM Predicted Needs: 2004 C&P—Maintain Conditions (Millions of 2008 Dollars)	Actual Expenditures: NTD Average for 2003 Through 2009 (Millions of 2008 Dollars)[1]	Predicted Minus Actual	Percent Difference
Guideway (track and structures)	$1,678	$2,283	-$605	-36%
Facilities (including admin buildings)	$1,721	$1,427	$295	17%
Systems (including fare collection)	$1,242	$997	$245	20%
Stations	$1,560	$1,800	-$240	-15%
Vehicles[2]	$5,917	$3,477	$2,440	41%
– Rail	$1,731	$1,594	$137	8%
– Bus/Other	$4,186	$1,810	$2,376	57%
Other	$0	$493	-$493	100%
Total	**$12,119**	**$10,477**	**$1,642**	**14%**

[1] TERM, being unconstrained, replaces all assets on a shorter cycle than financially constrained local operators.

[2] Bus life-cycle costs have been reduced since the 2004 C&P Report to reflect the fact that only the Nation's largest bus operators perform capital budget funded mid-life overhauls.

Source: National Transit Database and 2004 Conditions and Performance Report.

C&P Report to reduce the cost of mid-life rehabilitations. Specifically, while major bus operators invest heavily in mid-life bus rehabilitations, mid- to small-size bus operators do not. At the time the 2004 C&P Report was produced, TERM assumed that all bus operators performed extensive mid-life overhauls. Based on the revised needs calculations, the gap between estimated and actual bus reinvestment needs would be reduced by roughly $1.0 billion annually, thus reducing the overall investment gap to roughly $600 million.

Enhancement Versus Rehabilitation and Replacement Spending: It should also be noted that the annual capital expenditures reported to NTD for asset reinvestment include investments in asset "enhancements" (e.g., technology and materials upgrades and minor capacity improvements) to existing assets in addition to in-kind rehabilitation and replacement activities. Given that TERM is primarily focused on in-kind asset rehabilitation and replacement (i.e., does not estimate all enhancement needs), the actual gap between the level of investment in rehabilitation and replacement to maintain current conditions and actual rehabilitation and replacement spending for 2003 through 2009 is larger than that reported in *Exhibit 9-26*.

Asset Conditions

Given the shortfall between actual spending and that required to maintain conditions (roughly 15 percent annually), asset conditions should be expected to decline over the 2003 through 2009 period. Subject to an important caveat, this expectation is generally supported by the analysis in *Exhibit 9-27*. Specifically, *Exhibit 9-27* compares the 2004 C&P Report estimated asset conditions by asset category as of 2009 with the "actual" conditions based on the 2009 asset inventory data set (and estimated using TERM's decay curves). With the exception of passenger stations (where expenditures were higher than those required to maintain conditions), this comparison shows a decline in condition for all asset types. A significant outlier is guideway elements where asset conditions actually declined even though reported actual reinvestment expenditures were higher than the estimated amount required to maintain conditions (hence, the actual change in asset conditions is at odds with the expected change given the level of reinvestment). This is likely more the result of changes in consistency in reporting asset inventory data both between operations and from one period to the next than an actual change in condition.

Exhibit 9-27

Predicted Versus "Actual" Asset Conditions as of 2009

Asset Category	TERM Predicted Condition: 2004 C&P Report	2009 "Actual" Condition[1]	Predicted Minus Actual[2]
Guideway Elements (track and structures)	4.28	3.79	0.49
Maintain and Admin Facilities	3.52	3.35	0.17
Systems (including fare collection)	3.68	3.31	0.37
Stations	3.26	3.32	-0.06
Vehicles[3]	3.4	3.32	0.08
– Rail	3.47	3.4	0.07
– Bus/Other	3.24	3.16	0.08
All	**3.74**	**3.49**	**0.25**

[1] "Actual" 2009 conditions estimated based on 2008 data set and TERM decay curves. Agencies with significant New Starts investments over the 2003 to 2009 period have been removed from this analysis.

[2] Change in conditions between 2004 and 2005 partially driven by changes in data quality since 2002.

[3] Vehicle conditions for 2009 modified to exclude expansion vehicle purchases between 2003 and 2009.

Source: National Transit Database, TERM, and 2004 Conditions and Performance Report.

Finally, *Exhibit 9-28* summarizes the comparative results between *Exhibits 9-26* and *9-27*. Specifically, *Exhibit 9-28* shows whether TERM correctly "predicted" improvements or declines in asset conditions between 2002 (2004 C&P Report) and 2009 based on whether actual levels of reinvestment were above or below TERM's estimate of the amount required to maintain current conditions. Excluding guideway, *Exhibit 9-28* shows that TERM correctly predicted asset conditions.

Exhibit 9-28

Summary of TERM Prediction Tests: Capital Reinvestment

Asset Category	Actual Expenditures Above or Below Maintain Condition Level?	Expected Change in Condition	Actual Change in Condition	Change in Condition Predicted Correctly?
Guideway (track and structures)	⇧	⇧	⇩	No
Maintenance and Admin Facilities	⇩	⇩	⇩	Yes
Systems (including fare collection)	⇩	⇩	⇩	Yes
Stations	⇧	⇧	⇧	Yes
Vehicles	⇩	⇩	⇩	Yes
– Rail	⇩	⇩	⇩	Yes
– Bus/Other	⇩	⇩	⇩	Yes

Caveat on Changes in Asset Data Quality: While the improvement in station conditions might be expected (as spending was slightly higher than that predicted to maintain conditions—see *Exhibit 9-26*), by the same logic, some improvement in the condition of guideway elements (track and structures) also might be expected; but in fact, there is an estimated decline. Why? The answer lies in the quality of the asset data reported. Given that, as noted above, there is no Federal asset inventory reporting requirement and that there are currently no standards for maintaining and reporting such data, the TERM analysis is subject to inconsistency in data reporting both between operations and from one period to the next. Moreover, from 2003 through 2009, a number of the Nation's larger transit operators exerted considerable effort to improve the quality of the asset inventory data that they maintain for their own analysis purposes. While this improved data quality has greatly benefited the accuracy of TERM's needs and condition analysis, it has also resulted in significant changes to TERM's estimates of current asset conditions—most notably for rail track and structures. This issue of changes in the underlying data used to generate TERM's needs and condition analysis will be eliminated as required asset inventory reporting through NTD is implemented within the next few years. For the purposes of this analysis, it should be noted that the differences in 2009 asset condition estimates reported in *Exhibit 9-27* are the product of both (1) changes in condition resulting from reinvestment levels that are higher/lower than those required to maintain asset conditions and (2) changes in the quality of the reported data.

Investment Needs—Expansion

Exhibit 9-29 compares the 2004 C&P Report capital expansion investment needs projections ("maintain performance") with the actual average annual amounts of investments for the 2003 through 2009 period, with all amounts expressed in 2008 dollars. Note that expansion needs are presented both by asset category (top of exhibit) as well as for the four primary transit modes (commuter rail, heavy rail, light rail, and bus—bottom of exhibit). Note also that the maintain performance level of expansion investment is that level of

Exhibit 9-29

Predicted Versus Actual Capital Expansion Investment

Asset Category	TERM Predicted Needs: 2004 C&P—Maintain Performance (Millions of 2008 Dollars)	Actual Expenditures: NTD Average for 2003 Through 2009 (Millions of 2008 Dollars)	Predicted Minus Actual	Percent Difference
General Assets				
Guideway (track and structures)	$1,474	$2,638	-$1,164	-79%
Maintenance and Admin Facilities	$508	$251	$257	51%
Systems (includes fare collection)	$336	$121	$215	64%
Stations	$723	$427	$296	41%
Vehicles	$2,472	$497	$1,975	80%
– Rail	$1,084	$344	$740	68%
– Bus/Other	$1,388	$150	$1,238	89%
Other Projects	$1,165	$140	$1,025	88%
Total	**$6,678**	**$4,074**	**$2,604**	**39%**
For Primary Transit Modes				
Commuter Rail	$1,192	$526	$666	56%
Heavy Rail	$2,605	$586	$2,019	78%
Light Rail	$705	$2,451	-$1,746	-248%
All Rail	**$4,502**	**$3,563**	**$939**	**21%**
Bus	**$1,359**	**$422**	**$937**	**69%**

Source: National Transit Database, metropolitan planning organization estimates, and 2004 Conditions and Performance Report.

investment required to maintain current vehicle utilization rates (i.e., the number of riders per passenger vehicle) given the projected growth in transit ridership (based on a sample of the ridership projections of those MPOs representing the Nation's 30 largest UZAs as well as a sample of MPO projections representing the Nation's smaller UZAs). Similar to the reinvestment needs comparison (*Exhibit 9-26*), actual investment in asset expansion was less than that required to maintain current transit performance by roughly $2.6 billion annually. On an asset category basis, actual annual expenditures lagged the maintain performance levels for all asset categories except guideway elements.

On the basis of major transit mode, *Exhibit 9-29* suggests that, with the exceptions of light rail, expansion investments were insufficient to address the projected increase in transit ridership for this period. This hypothesis is tested below based on changes in vehicle capacity utilization and the actual expansion in the number of track miles, stations, and fleet vehicles in transit service over the 2003 to 2009 period. Before proceeding to that analysis, note that the large actual expansion investment in light rail relative to the maintain performance needs level should not come as a surprise given that the vast majority of expenditures funded by FTA New Starts over the 2003 to 2009 period was invested in light rail projects.

Changes in Vehicle Occupancy

Given that expenditures on bus and rail expansion were less than that required to maintain performance (*Exhibit 9-29*), it may be expected that vehicle occupancy levels increased for both bus and all rail modes in total. Within the rail modes, *Exhibit 9-29* suggests that vehicle utilization rates should have increased for commuter rail and heavy rail (where actual investment was less than the estimated amount to maintain the number of riders per passenger vehicle) and decreased for light rail. With one exception, *Exhibit 9-30*, which presents the change in actual vehicle utilization rates from 2002 to 2009 by mode, confirms all of these expectations. The exception is commuter rail where actual utilization rates declined despite levels of actual expansion investment that were well below those required to maintain the current utilization rate.

Exhibit 9-30

Vehicle Capacity Utilization Rates for Rail and Bus (From NTD)

Asset Category	2002	2009	Difference	Percent Difference
Commuter Rail	36.7	35.7	-1	-2.70%
Heavy Rail	22.6	25.7	3.1	13.70%
Light Rail	26.1	24.1	-2	-7.70%
Rail (weighted avg.)	**24.4**	**26.6**	**2.2**	**8.80%**
Bus	**10.5**	**10.8**	**0.3**	**2.90%**

Source: National Transit Database.

To better understand the rail expansion investment and vehicle capacity utilization results in *Exhibit 9-30*, it is helpful to review *Exhibit 9-31,* which compares TERM's 2002 (2004 C&P Report) estimates of the increase in the number of track miles, stations, and revenue vehicles by major mode (for the 2003 through 2009 period) with the actual increase in these asset counts as reported to NTD over this same time period. Note that the actual expansion in commuter rail and light rail assets was greater overall than the estimated amount required to maintain performance (particularly for vehicles), thus helping explain the reduction in vehicle occupancy rates as reported in *Exhibit 9-30* for these two modes. In contrast, the actual expansion in heavy rail and bus fleets was less than the estimated amount required to maintain performance, thus helping explain the increase in vehicle occupancy rates as reported in *Exhibit 9-30* for the heavy rail and bus modes.

Exhibit 9-31

Predicted Versus Actual Capital Expansion

Asset Category	TERM Predicted Needs: 2004 C&P—Maintain Performance (Millions of 2008 Dollars)	Actual Counts: Increase Reported to NTD 2003–2009	Predicted Minus Actual	Percent Difference
		Track Miles		
Commuter Rail	380	386.7	-7	-1.80%
Heavy Rail	67	93.1	-27	-40.00%
Light Rail	98	172.6	-75	-76.10%
Rail Total	**545**	**652**	**-107**	**-19.70%**
		Stations		
Commuter Rail	152	71	81	53.30%
Heavy Rail	67	47	20	29.30%
Light Rail	118	196	-78	-66.70%
Rail Total	**337**	**314**	**23**	**6.80%**
		Revenue Vehicles—Rail		
Commuter Rail	551	1,053	-502	-91.10%
Heavy Rail	910	464	446	49.00%
Light Rail	245	543	-298	-121.30%
Rail Total	**1,706**	**2,060**	**-354**	**-20.80%**
		Revenue Vehicles—Bus		
Bus	**9,121**	**5,249**	**3872**	**42.40%**

Source: National Transit Database, TERM estimates, and 2004 Conditions and Performance Report.

Exhibit 9-32 summarizes the comparison of TERM's ability to correctly predict actual changes in vehicle utilization rates by mode based on whether the rate of actual expansion investments for 2003 to 2009 was above or below the estimated amount to maintain current utilization rates. *Exhibit 9-32* shows that TERM correctly predicted the change in utilization for all vehicles except commuter rail.

Exhibit 9-32

Summary of TERM Prediction Tests: Expansion Investments

Asset Category	Actual Investment Above or Below Maintain Performance Level?	Expected Change in Utilization (Riders per Vehicle)	Actual Change in Utilization (Riders per Vehicle)	Change in Utilization Predicted Correctly?
Commuter Rail	⇩	⇧	⇩	No
Heavy Rail	⇩	⇧	⇧	Yes
Light Rail	⇧	⇩	⇩	Yes
All Rail	⇩	⇧	⇧	Yes
Bus	⇩	⇧	⇧	Yes
All Modes	⇩	⇧	⇧	Yes

Assessment Results

This section assessed the accuracy of TERM's projections prepared for the 2004 C&P Report in predicting (1) transit investment needs (as compared with actual expenditures); (2) future asset conditions; (3) asset expansion requirements; and (4) actual ridership growth for the 2003 through 2009 period. First, in the 2004 C&P Report, TERM's predictions of reinvestment needs were comparable to, but generally higher than, actual reinvestment expenditures for the 2003 through 2009 period. This result should be expected given that TERM is predicting reinvestment needs (to maintain asset conditions), not actual spending, and that TERM's needs estimates are financially unconstrained (in direct contrast to local agency investment levels). Second, in the 2004 C&P Report, TERM tended to overpredict actual asset conditions as of 2009, which again should be expected if transit operators are not reinvesting at a rate sufficient to maintain conditions (the objective of the TERM scenario used for comparison). Last, as with reinvestment expenditures, TERM's predictions of capital expansion needs in the 2004 C&P Report were generally higher than actual capital expansion expenditures for the 2003 to 2009 period. Again, this outcome is not unexpected given that TERM's needs estimates are financially unconstrained. Moreover, given that the actual expansion investments were less than what TERM estimated as required to maintain vehicle capacity utilization at 2002 levels, it should be expected that vehicle capacity utilization increased, which indeed was the case over the 2003 to 2009 period. In general, TERM provided reasonable predictions of transit investment requirements (as compared with actual, constrained investment rates) while the differences between TERM's predictions of transit asset conditions and vehicle capacity utilization and the actual, realized values of these measures were consistent with prior expectations (i.e., given the differences in predicted needs and actual expenditures).

This analysis raised a number of issues and questions to be addressed through further research and related improvements to future TERM and C&P analysis:

- Constructability Constraints: TERM's underestimation of rail expansion for light rail, commuter rail, and track miles is likely driven in part by constructability constraints designed to ensure that the model "builds" only a limited number of additional track miles in any given year (constrained on a UZA basis). These constraints may be set too low and hence should be reviewed and potentially revised (i.e., loosened).
- Differential Growth Rates by Mode: TERM is designed to establish the rate of ridership growth at the UZA level, and hence the ridership growth rate is fixed across all mode types within the same UZA. Revising the tool to allow for differential ridership growth by mode may help reduce the imbalance between individual rail modes (i.e., across commuter, heavy, and light rail) as well as between rail and bus.
- Revised Expansion Assumptions for Commuter Rail: TERM's per-mile costs for commuter rail expansion are likely too high (TERM may be investing in too many assets—including number of stations per mile—and the unit costs of those assets are also likely too high). These assumptions should be reviewed and modified based on actual per-mile costs for recent New Starts commuter rail projects.