CHAPTER 9

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Highway Supplemental Scenario Analysis

This section explores the implications of the highway investment scenarios considered in Chapter 8, starting with a comparison of the scenario investment levels relative to those presented in previous C&P reports. For a longer-term perspective, this section also looks back to the 20-year projections presented in the 1989 C&P Report relative to actual outcomes in terms of system conditions and performance.

This section also includes an illustration of the impact of alternative rates of future inflation on the constant dollar scenario investment levels presented in Chapter 8, and explores alternative assumptions concerning the timing of investment over the 20-year analysis period. A subsequent section within this chapter provides supplementary analysis regarding the transit investment scenarios.

Comparison of Scenarios With Previous Reports

Each edition of this report presents various projections of travel growth, pavement conditions, and bridge conditions under different scenarios. The projections cover 20 year periods, beginning the first year after the data presented on current conditions and performance. While the scenario names and criteria have varied over time, the C&P Report has traditionally included highway investment scenarios corresponding in concept to **Maintain Conditions and Performance** scenario and **Improve Conditions and Performance** scenario presented in Chapter 8.

Comparison With 2010 C&P Report

As discussed in Chapter 8, the measures targeted by the **Maintain Conditions and Performance** scenario have been changed; the 2010 C&P Report version of this scenario attempted to maintain average speed and the bridge investment backlog, but the current version targets average pavement roughness, average delay and the average bridge sufficiency rating. However, the fundamental purpose of the scenario is to identify a level of investment associated with keeping overall conditions and performance in 20 years at roughly base-year levels. The criteria used to define the **Improve Conditions and Performance** scenario remains unchanged from the 2010 C&P Report; the only difference is that the 2010 C&P Report projected the impact of investment for 2009 through 2028, rather than the 2011 through 2030 period covered in the current edition.

As discussed in Chapter 6, highway construction costs as measured by the Federal Highway Administration's (FHWA's) National Highway Construction Cost Index decreased by 18.0 percent between 2008 and 2010. Consequently, adjusting the 2010 C&P Report's scenario figures from 2008 dollars to 2010 dollars causes them to appear smaller. As shown in *Exhibit 9-1,* the 2010 C&P Report estimated the average annual investment level in the scenario comparable to the current **Maintain Conditions and Performance** scenario at $101.0 billion; adjusting for inflation (or, in this discussion, deflation) decreases this amount to $82.8 billion in 2010 dollars. The comparable amount for the **Maintain Conditions and Performance** scenario presented in Chapter 8 of this edition is $86.3 billion, approximately **4.2 percent higher**.

The average annual investment level in the 2010 C&P Report scenario comparable to the current **Improve Conditions and Performance** scenario was $170.1 billion; adjusting for inflation decreases this amount to $139.4 billion in 2010 dollars. The comparable amount for the current **Improve Conditions and Performance** scenario presented in Chapter 8 of this edition is $145.9 billion, approximately **4.7 percent higher**.

Exhibit 9-1 Selected Highway Investment Scenario Projections Compared With Comparable Data From the 2010 C&P Report (Billions of Dollars)

Highway and Bridge Scenarios—All Roads	2009–2028 Projection (Based on 2008 Data)		2011–2030 Projection
	2010 C&P Report (Billions of 2008 Dollars)	Adjusted for Inflation[1] (Billions of 2010 Dollars)	(Billions of 2010 Dollars)
Maintain Conditions and Performance scenario[2]	**$101.0**	**$82.8**	**$86.3**
Improve Conditions and Performance scenario	**$170.1**	**$139.4**	**$145.9**

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

2 In the 2010 C&P report, the HERS component of this scenario focused on maintaining average speed, rather than representing the average of the cost associated with maintaining average delay and the cost associated with maintaining average pavement condition; the NBIAS component of the scenario focused on maintaining the bridge investment backlog, rather than maintaining the average sufficiency rating for bridges.

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

The changes in the scenario findings in this report relative to the 2010 C&P Report are also partially attributable to changes in the underlying characteristics, conditions, and performance of the bridge system reported in Chapters 2 and 3, as well as to changes in the analytical methodology in the National Bridge Investment Analysis System (NBIAS) model. As noted in Chapter 7, the version of the Highway Economic Requirements System (HERS) used for this report was not significantly different from that used in the 2010 C&P Report, and the same underlying Highway Performance Monitoring System (HPMS) dataset was used. The main differences within the HERS analysis related to updated model parameter values.

Comparisons of Implied Funding Gaps

Exhibit 9-2 compares the funding gaps implied by the analysis in the present report with those implied by previous C&P report analyses. Each such gap is measured as the percentage by which the average annual investment estimated for a specific scenario exceeds the base-year level of investment. The scenarios examined are this report's **Maintain Conditions and Performance** and **Improve Conditions and Performance** scenarios, and their counterparts 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, negative 13.9 percent, is dramatically different than in the 2010 C&P Report when it was positive 10.8 percent. This indicates that 2010 spending was greater than the level of spending identified for the **Maintain Conditions and Performance** scenario. This is partly due to the increase in funding under the American Recovery and Reinvestment Act, but largely due to the fact that construction costs have declined, making it cheaper to meet the scenario's objectives.

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. The large increase in the gap between base-year spending and the primary "Maintain" scenario presented in the 2008 C&P Report coincided with a large increase of construction costs experienced between 2004 and the 2006 base year for that report. The decreases in the gaps presented in the 2010 and 2012 editions coincided with declines in construction costs since their 2006 peak.

The differences among C&P report editions in the implied gaps reported in *Exhibit 9-2* do not constitute a consistent indicator of change over time in how effectively highway investment needs are 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.

Exhibit 9-2 Comparison of Average Annual Highway and Bridge Investment Scenario Estimates With Base Year Spending, 1997 to 2013 C&P Reports

Report Year	Relevant Comparison	Percent Above Base-Year Spending	
		Primary "Maintain" Scenario*	Primary "Improve" Scenario*
1997	Average annual investment scenario estimates for 1996 through 2015 compared with 1995 spending	21.0%	108.9%
1999	Average annual investment scenario estimates for 1998 through 2017 compared with 1997 spending	16.3%	92.9%
2002	Average annual investment scenario estimates for 2001 through 2020 compared with 2000 spending	17.5%	65.3%
2004	Average annual investment scenario estimates for 2003 through 2022 compared with 2002 spending	8.3%	74.3%
2006	Average annual investment scenario estimates for 2005 through 2024 compared with 2004 spending	12.2%	87.4%
2008	Average annual investment scenario estimates for 2007 through 2026 compared with 2006 spending	34.2%	121.9%
2010	Average annual investment scenario estimates for 2009 through 2028 compared with 2008 spending	10.8%	86.6%
2013	Average annual investment scenario estimates for 2011 through 2030 compared with 2010 spending	-13.9%	45.7%

** 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. Negative numbers signify that the investment scenario estimate was lower than base year spending.*

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

Comparison of Scenario Projections in 1991 C&P Report to Actual Expenditures, Conditions, and Performance

The highway component of the C&P report is part of a series dating back to the 1968 *National Highway Needs* report to Congress.

The *1991 Status of the Nation's Highways and Bridges: Condition and Performance* report to Congress (1991 C&P Report) is the most recent edition for which the 20-year forecast period has ended. This section explores the predictions made in the 1991 report for the year 2009 relative to what actually occurred in terms of pavement conditions, bridge conditions, and operational performance, taking into account actual investment and travel growth that has occurred.

Comparing such past predictions with actual results can be very informative in placing the projections from the current edition in their proper context. However, direct comparisons of results across different C&P editions pose challenges for multiple reasons, including differences in base-year conditions and analysis periods, changes in analytical models, and changes in scenario definitions.

1991 C&P Report Scenario Definitions

Similar to the current edition, the 1991 C&P Report estimated two scenarios for future investment requirements: **Improve 1989 Conditions and Performance** and **Maintain 1989 Conditions and Performance**. The investment levels presented were stated in constant 1989 dollars.

The 1991 C&P Report develops scenarios based on engineering standards that were applied uniformly nationwide without the consideration of the relative importance of specific facilities, regional variation, or other policy considerations. The scenario predictions were designed to provide general financial and performance benchmarks and were a basis for development and evaluation of policy and program options.

Improve 1989 Conditions and Performance

The **Improve 1989 Conditions and Performance** scenario estimated the costs associated with addressing deficiencies relative to a set of engineering-based minimum standards for physical conditions and performance. The goal of this scenario was to improve conditions and performance across all functional systems on a uniform basis nationwide, for both urban and rural, even as travel demand increased at a rate of 2.5 percent annually for 20 years. However, the 1991 C&P Report indicates that a cap on the width of individual highway sections was imposed, which resulted in a set of unmet capacity needs to the extent to which operational performance in larger urbanized areas could not be maintained. The scenario reflected estimated annual capital savings from an aggressive traffic management program.

Unlike the present edition, which prioritizes investment based on benefit-cost analysis, the 1991 C&P Report acknowledges that the scenarios did not involve priorities regarding cost-effectiveness and was not intended to represent an optimum recommended investment strategy. Instead, the scenario was intended to provide a framework for policy development by establishing a measure of the total capital costs of providing a desirable level of highway and bridge infrastructure on all facilities, assuming a future travel demand growth of 2.5 percent annually.

Maintain 1989 Conditions and Performance

The **Maintain 1989 Conditions and Performance** scenario estimated the cost of maintaining both current overall physical conditions and current levels of performance as traffic increased over a 20-year period. The 1991 C&P Report notes that overall system performance would not be maintained in the largest urbanized areas assuming a 2.5 percent annual growth in vehicle miles traveled (VMT).

Comparison of Scenario Projections in 1991 C&P Report to Actual Spending

Exhibit 9-3 shows the estimated average annual and cumulative 20-year highway and bridge needs associated with the two scenarios presented in the 1991 C&P Report. The cumulative values are also adjusted for

Exhibit 9-3 1991 C&P Report Highway and Bridge Investment Scenario Estimates and Cumulative Spending, 1990 Through 2009

	1990–2009 Projection From 1991 C&P Report		Adjusted for Inflation
	Average Annual (Billions of 1989 Dollars)	Cumulative 20 Years (Billions of 1989 Dollars)	Cumulative 20 Years (Billions of 2010 Dollars)
20-Year Highway Capital Investment Scenarios (Assuming 2.5-Percent Annual VMT Growth from 1989 to 2009)			
Improve Conditions and Performance Scenario	$74.9	$1,498.0	**$2,422.2**
Maintain Conditions and Performance Scenario	$45.7	$914.0	**$1,477.9**
Actual 20-Year Highway Capital Investment (VMT Grew 1.74 Percent per Year from 1989 to 2009)			
Cumulative Capital Outlay, 1990 through 2009*			**$1,418.9**

** Highway capital outlay by all levels of Government combined totaled $1.2111 trillion in nominal dollar terms over the 20-year period from 1990 through 2009. This equates to $1.4189 trillion in constant 2010 dollars.*

Sources: 1991 Status of the Nation's Highways and Bridges: Conditions and Performance Report to Congress; Highway Statistics, various years, Tables HF-10A, HF-10, PT-1, and SF-12A; and unpublished FHWA data.

inflation to 2010 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.

The 1991 C&P Report estimated the average annual cost of the **Improve 1989 Condition and Performance** scenario at $74.9 billion for 1990 through 2009, assuming a 2.5 percent VMT growth rate.

The average annual cost to **Maintain 1989 Condition and Performance** on existing roads and bridges through 2009 was estimated at $45.7 billion, again assuming a 2.5 percent VMT growth rate.

The cumulative 20-year value inflated to 2010 dollars for the **Improve 1989 Condition and Performance** scenario equates to $2.422 trillion. The cumulative value of the **Maintain Conditions and Performance** scenario in 2010 dollars equates to $1.478 trillion, which is within 4 percent of the actual cumulative capital outlay of $1.419 trillion, stated in constant 2010 dollars.

Assumptions about future VMT growth are a critical input to the investment scenario. The actual rate of VMT growth over the 20-year period from 1989 to 2009 was 1.74 percent per year, well below the 2.5 percent annual VMT growth forecast used in the 1991 C&P Report scenarios.

The 1991 C&P Report included sensitivity analysis that assumed a higher average annual VMT growth rate of 3.0 percent for some of the major components of the two investment scenarios, which increased their cost by 13 percent (Improve) to 17 percent (Maintain). However, the 1991 C&P Report did not conduct any tests of VMT growth rates lower than 2.5 percent. As a result, although these analyses demonstrate that the scenarios were significantly affected by the VMT growth rate assumption, it would not be safe to assume that the reductions in scenario costs associated with lower VMT growth rates would be proportional to these increases in scenario costs associated with higher VMT growth forecasts. If the forecasts had been developed assuming a 1.74-percent average annual growth rate, the cost associated with both scenarios would have been lower.

Comparison of Scenario Projections in 1991 C&P Report to Actual Outcomes

The 1991 C&P Report included projections for measures of pavement condition, bridge condition, and operational performance. As was demonstrated in *Exhibit 9-3*, actual capital spending from 1990 through 2009 was slightly lower than the investment levels associated with the **Maintain Conditions and Performance** scenario, which suggests that overall highway and bridge system conditions would have deteriorated slightly relative to 1989. However, because the VMT growth rate assumed in that scenario was significantly higher than what actually occurred from 1989 to 2009, the investment levels associated with that scenario were overstated to some degree. Consequently, improvements to some measures of conditions and performance relative to 1989 could reasonably be expected.

Exhibit 9-4 compares the percentage of pavement in good condition by facility type; bridge deficiencies; and travel under congested condition for 1989, 2008, and 2010. The pavement condition ratings presented in the 1991 C&P Report were based on a subjective evaluation of overall pavement quality which has subsequently been replaced by a more objective measure of pavement ride quality. However, the percentage of pavements in good condition is roughly comparable between the two reports. Since 1989, the percent of good pavement mileage has increased for the rural functional classes shown, except for rural major collectors. In contrast, for urban highways, the percent of good pavement mileage has decreased for all functional classes shown except urban Interstate.

The percentage of bridges classified as structurally deficient or functionally obsolete is still defined in a manner comparable to that in the 1991 C&P Report. There has been improvement since 1989, as the percentage of structurally deficient bridges has been cut sharply and reductions in the percentage of functionally obsolete bridges have been achieved.

Exhibit 9-4 Selected Pavement, Bridge, and Congestion Metrics, 1989, 2008, and 2010

Scenario and Comparison Parameter	1989	2008	2010
Percent of "Good" Pavement Mileage[1]			
Rural Interstate	58.2%	78.2%	73.8%
Rural Other Principal Arterial	51.9%	66.5%	N/A
Rural Minor Arterial	45.5%	53.3%	49.7%
Rural Major Collector	34.2%	34.0%	28.7%
Urban Interstate	57.4%	61.4%	63.2%
Urban Other Freeway & Expressway	52.7%	50.6%	48.0%
Urban Other Principal Arterial	42.7%	27.4%	26.7%
Urban Minor Arterial	40.7%	32.1%	22.2%
Urban Collector	31.3%	28.3%	N/A
Bridge Deficiencies[2]			
Percent Structurally Deficient	23.2%	11.9%	11.5%
Percent Functionally Obsolete	15.9%	13.3%	12.8%
Total Percent Deficient	39.2%	25.2%	24.3%
Operational Performance[3]			
Percent of Travel Under Congested Conditions	20.6%	26.3%	26.2%

[1] The 1991 C&P Report classified pavements as "Good" if they had a Pavement Serviceability Rating (PSR) of 3.5 or higher on a scale of 5.0. The current terminology reflected in Chapter 3 describes pavements as having "Good Ride Quality" if they have a reported IRI of 95 inches per mile or lower (or a PSR of 3.5 or higher if IRI is not available). Subtotals and Totals are not provided because the 1991 C&P Report did not include them. N/A is shown for functional classes that were split starting in 2010.

[2] See Chapter 3 for more information on these measures.

[3] See Chapter 5 for more information on this measure.

Sources: Sources: 1991 C&P Report, Highway Performance Monitoring System, National Bridge Inventory, and Texas Transportation Institute.

The operational performance measures presented in the 1991 C&P Report are not consistent with those in the current edition. However, the Texas Transportation Institute has computed a fully comparable historic time series for a metric presented in Chapter 5: the percent of travel occurring under congested conditions. Based on this measure, congestion has worsened since 1989.

Although these types of rough comparisons of individual conditions and performance measures are not sufficiently robust to make definitive statements of the validity of the analyses presented in the 1991 C&P Report, actual trends over the forecast period do not appear to be wildly inconsistent with the report's findings, taking into account the lower than projected growth in VMT. Because actual capital investment over the 20-year period was relatively close to the **Maintain 1989 Conditions and Performance** scenario, it is not surprising that actual performance outcomes were mixed, with pavement condition improving on some functional classes while worsening on others, with bridge conditions improving, and with operational performance deteriorating relative to 1989.

Accounting for Inflation

The analysis of potential future investment/performance relationships in the C&P report has 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 2010 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 2010 dollars.

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 tends to add to the uncertainty of the overall results and make the report more difficult to use if the inflation assumptions are inaccurate. 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 in recent 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.

Why does this report assume that construction costs measured in constant dollars remain unchanged over the analysis period?

Q&A

Chapter 7 provided the definition of constant dollar measurement that the Office of Management and Budget includes in its guidance on benefit-cost analysis. Under this definition, any price predicted for a future year must be adjusted for the general inflation expected to occur between the base year and the future year, For example, if a future-year price is expected to be $1.10, whereas prices in general are expected to increase 3 percent between the base year and the future year, the price in constant dollars would be calculated as $1.10 divided by 1.03, which is approximately $1.068.

With a few exceptions, this report's analyses of future investments in highways assume that prices entering the HERS model will change by the same percentage as general inflation, as measured by the Consumer Price Index (CPI). Under this assumption, the future price in constant dollars simply equates to the base-year price. As discussed in Chapter 7, the exceptions include the price of motor fuel and the marginal damage cost of CO emissions; as discussed in Chapter 10, the values of travel time savings and of crash reductions are also exceptions.

The costs of highway improvements were not among the exceptions. Typical prices by type of improvement were assumed to increase at the same rate as the CPI, so that base-year prices were applied to future years. One reason for making this simplifying assumption is that, as discussed in Chapter 6, highway construction prices have been volatile in recent years; this suggests that forecasting their future movements relative to the CPI would be challenging. (Motor fuel price have also been volatile, but long-range forecasts are available from the Energy Information Administration.)

Additional challenges to attempting such forecasting include limitations of the historical data on construction prices, as discussed in Appendix D of the 2010 C&P Report. It should be noted that the assumption that construction prices will change at the rate of general inflation may be fairly reasonable on average. As noted in Chapter 6, this report's reading of the historical evidence is that, over the 20-year period from 1990 to 2010, highway construction costs increased 60.5 percent, which is not much different from the 66.8 percent increase in the CPI.

The average annual increase in highway construction costs over the last 20 years (1990 to 2010) was 2.4 percent. Since the creation of the Federal Highway Trust Fund in 1956, the 20-year period with the smallest increase in construction costs was 1980 to 2000, when costs grew by 2.0 percent per year; the largest increase occurred from 1960 to 1980, when costs grew by 7.4 percent per year. From 1986 to 2006, highway construction costs grew by 4.0 percent annually. (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 2010; these indices are discussed in Chapter 6.) *Exhibit 9-5* 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 of 2.0 percent and 4.0 percent.

The systemwide **Sustain 2010 Spending** scenario presented in Chapter 8 assumes that combined capital spending for highway and bridge improvements would be sustained at its 2010 level in constant-dollar terms for 20 years. Hence, *Exhibit 9-5* shows $100.2 billion of spending in constant 2010 dollars for each year from 2011 through 2030, for a 20-year total of $2.0 trillion. Applying annual inflation in construction costs of 2.0 percent or 4.0 percent would imply a 20-year total in nominal dollars of $2.5 trillion or $3.1 trillion, respectively, for this scenario.

Chapter 8 indicates that achieving the objectives of the systemwide **Maintain Conditions and Performance** scenario would require investment averaging $86.3 billion per year in constant 2010 dollars, equivalent to the level of investment achieved with a reduction of 1.44 percent per year in constant-dollar spending. *Exhibit 9-5* illustrates the application of this real reduction rate, demonstrating how annual capital investment would decrease from $100.1 billion in 2010 to $74.9 billion in 2030, resulting in a 20-year

Exhibit 9-5 Illustration of Potential Impact of Alternative Inflation Rates on Selected Systemwide Investment Scenarios

	Highway Capital Investment (Billions of Dollars)								
	Constant 2010 Dollars*			Nominal Dollars (Assuming 2.0 Percent Annual Inflation)			Nominal Dollars (Assuming 4.0 Percent Annual Inflation)		
Year	Sustain 2010 Spending Scenario	Maintain Conditions & Performance Scenario	Improve Conditions & Performance Scenario	Sustain 2010 Spending Scenario	Maintain Conditions & Performance Scenario	Improve Conditions & Performance Scenario	Sustain 2010 Spending Scenario	Maintain Conditions & Performance Scenario	Improve Conditions & Performance Scenario
2010	$100.2	$100.2	$100.2	$100.2	$100.2	$100.2	$100.2	$100.2	$100.2
2011	$100.2	$98.7	$103.6	$102.2	$100.7	$105.7	$104.2	$102.7	$107.8
2012	$100.2	$97.3	$107.2	$104.2	$101.2	$111.6	$108.3	$105.2	$116.0
2013	$100.2	$95.9	$110.9	$106.3	$101.8	$117.7	$112.7	$107.9	$124.8
2014	$100.2	$94.5	$114.8	$108.4	$102.3	$124.2	$117.2	$110.6	$134.3
2015	$100.2	$93.2	$118.7	$110.6	$102.8	$131.1	$121.9	$113.3	$144.5
2016	$100.2	$91.8	$122.8	$112.8	$103.4	$138.3	$126.8	$116.2	$155.4
2017	$100.2	$90.5	$127.1	$115.1	$103.9	$146.0	$131.8	$119.1	$167.3
2018	$100.2	$89.2	$131.5	$117.4	$104.5	$154.1	$137.1	$122.0	$180.0
2019	$100.2	$87.9	$136.0	$119.7	$105.0	$162.6	$142.6	$125.1	$193.6
2020	$100.2	$86.6	$140.7	$122.1	$105.6	$171.6	$148.3	$128.2	$208.3
2021	$100.2	$85.4	$145.6	$124.6	$106.1	$181.1	$154.2	$131.4	$224.2
2022	$100.2	$84.1	$150.7	$127.0	$106.7	$191.1	$160.4	$134.7	$241.2
2023	$100.2	$82.9	$155.9	$129.6	$107.3	$201.6	$166.8	$138.1	$259.5
2024	$100.2	$81.7	$161.3	$132.2	$107.8	$212.8	$173.5	$141.5	$279.2
2025	$100.2	$80.5	$166.8	$134.8	$108.4	$224.5	$180.4	$145.1	$300.5
2026	$100.2	$79.4	$172.6	$137.5	$109.0	$236.9	$187.6	$148.7	$323.3
2027	$100.2	$78.2	$178.6	$140.3	$109.6	$250.0	$195.1	$152.4	$347.8
2028	$100.2	$77.1	$184.7	$143.1	$110.1	$263.9	$202.9	$156.2	$374.3
2029	$100.2	$76.0	$191.1	$145.9	$110.7	$278.5	$211.1	$160.1	$402.7
2030	$100.2	$74.9	$197.8	$148.9	$111.3	$293.8	$219.5	$164.1	$433.3
Total	**$2,003.5**	**$1,725.9**	**$2,918.6**	**$2,482.7**	**$2,118.3**	**$3,697.1**	**$3,102.3**	**$2,622.6**	**$4,717.9**
	0.00%	**-1.44%**	**3.46%**	**Constant Dollar Growth Rate**					
	$100.2	**$86.3**	**$145.9**	**Average Annual Investment Level in Constant 2010 Dollars**					

** Based on average annual investment levels and annual constant dollar growth rates identified in* Exhibit 8-2.

Source: FHWA staff analysis.

(2011 to 2030) total of $1.7 trillion in constant 2010 dollars. A 2.0-percent inflation rate applied to these constant-dollar estimates would produce a 20-year cost of $2.1trillion in nominal dollar terms, while a 4.0-percent inflation rate results in a 20-year nominal dollar cost of $2.6 trillion.

The compounding impacts of inflation are even more evident in the figures for the systemwide **Improve Conditions and Performance** scenario presented in *Exhibit 9-5*. As described in Chapter 8, this scenario assumes 3.46 percent growth in constant-dollar highway capital spending per year in order to address all potentially cost-beneficial highway and bridge improvements by 2030. The $145.9-billion average annual investment level associated with this scenario equates to a 20-year investment level of $2.9 trillion in constant 2010 dollars. Adjusting this figure to account for inflation of 2.0 percent or 4.0 percent would translate into 20-year nominal dollar costs of $3.7 trillion or $4.7 trillion, respectively.

Over any 20 year period, construction costs will increase despite the occasional year-to-year drops sometimes experienced. Using a low inflation rate of 2.0 percent adds between 23 and 27 percent to the constant dollar estimates for the 20-year period for the three scenarios. Using a higher inflation rate of 4.0 percent requires between 52 and 62 percent of additional funding to meet the needs identified under the three scenarios.

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 C&P Report, and as discussed in Chapter 7, the analyses in the present edition assume that any change from the 2008 level of combined investment per year by all levels of government would occur gradually and 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 benefit-cost ratio (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 analysis did not assume any increase in material and labor costs in response to the sharp increase in the number of highway construction projects.

The discussion below explores the impact of each of 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. Each of the average annual investment levels analyzed correspond to the baseline HERS analyses for Federal-aid Highways, and the baseline NBIAS analyses for all bridges presented in Chapter 7.

Alternative Timing of Investment in HERS

This section presents information regarding how 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 pavement conditions (measured using International Roughness Index [IRI]) and delay per VMT. Because the timing of investment is varied for any given capital investment level, the pavement condition and delay per VMT will change.

Alternative Investment Patterns

Exhibit 9-6 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 pavement condition and delay per VMT. The six investment levels were selected from the baseline ("ramped") HERS analyses for Federal-aid highways presented in Chapter 7. Each investment level is compared across the three investment patterns: baseline (ramped) spending, flat spending, and BCR-driven spending.

Exhibit 9-6 Distribution of Spending Among 5-Year HERS Analysis Periods and Projected Impacts on Average IRI and Average Delay, for Alternative Approaches to Investment Timing

Average Annual HERS-Modeled Capital Investment (Billions of 2010 Dollars)	Percentage of HERS-Modeled Spending Occurring in Each 5-Year Period											
	Baseline				Alternatives							
	Ramped Spending				Flat Spending [1]				BCR-Driven Spending [2]			
	2011 to 2015	2016 to 2020	2021 to 2025	2026 to 2030	2011 to 2015	2016 to 2020	2021 to 2025	2026 to 2030	2011 to 2015	2016 to 2020	2021 to 2025	2026 to 2030
$86.9	18.3%	22.2%	26.9%	32.7%	25.1%	25.1%	25.1%	24.7%	41.2%	18.7%	18.2%	21.9%
$67.8	21.9%	23.9%	26.0%	28.3%	25.0%	25.0%	25.0%	25.0%	37.5%	21.4%	18.9%	22.1%
$60.9	23.7%	24.5%	25.4%	26.4%	25.0%	25.0%	25.0%	25.0%	35.8%	23.3%	19.7%	21.3%
$56.4	**25.0%**	**25.0%**	**25.0%**	**25.0%**	25.0%	25.0%	25.0%	25.0%	34.2%	24.0%	20.4%	21.4%
$51.1	26.8%	25.6%	24.4%	23.2%	25.0%	25.0%	25.0%	25.0%	32.7%	25.4%	21.0%	20.8%
$43.2	30.2%	26.4%	23.1%	20.3%	25.0%	25.0%	25.0%	25.0%	29.5%	26.9%	22.2%	21.4%

Average Annual HERS-Modeled Capital Investment (Billions of 2010 Dollars)	Change in Average IRI Relative to Base Year on Federal-aid Highways											
	Baseline				Alternatives							
	Ramped Spending, Percent Change as of:				Flat Spending, Percent Change as of:				BCR-Driven Spending, Percent Change as of:			
	2015	2020	2025	2030	2015	2020	2025	2030	2015	2020	2025	2030
$86.9	-9.6%	-18.2%	-23.3%	-26.7%	-17.7%	-25.0%	-26.5%	-25.5%	-31.0%	-30.2%	-26.7%	-24.5%
$67.8	-8.1%	-13.7%	-17.1%	-18.0%	-11.4%	-17.0%	-18.5%	-17.7%	-21.9%	-22.6%	-19.8%	-17.6%
$60.9	-7.6%	-11.8%	-14.4%	-14.3%	-8.7%	-13.2%	-14.9%	-14.2%	-17.9%	-19.1%	-16.8%	-14.1%
$56.4	-7.2%	-10.5%	-12.2%	-11.5%	-7.2%	-10.5%	-12.2%	-11.5%	-15.0%	-16.2%	-14.0%	-11.5%
$51.1	-6.5%	-8.7%	-9.2%	-7.6%	-4.8%	-6.9%	-8.0%	-7.5%	-11.4%	-12.5%	-10.4%	-7.9%
$43.2	-5.2%	-5.5%	-4.0%	**0.0%**	-1.1%	-0.8%	-1.2%	0.4%	-4.9%	-5.4%	-3.4%	0.0%

Average Annual HERS-Modeled Capital Investment (Billions of 2010 Dollars)	Change in Average Delay Per VMT Relative to Base Year on Federal-aid Highways											
	Baseline				Alternatives							
	Ramped Spending, Percent Change as of:				Flat Spending, Percent Change as of:				BCR-Driven Spending, Percent Change as of:			
	2015	2020	2025	2030	2015	2020	2025	2030	2015	2020	2025	2030
$86.9	-9.2%	-8.3%	-7.8%	-8.0%	-11.9%	-11.5%	-9.6%	-7.4%	-16.9%	-14.0%	-10.3%	-7.1%
$67.8	-8.6%	-6.5%	-4.4%	-2.4%	-9.7%	-7.9%	-5.4%	-2.2%	-13.3%	-10.4%	-5.8%	-1.7%
$60.9	-8.3%	-5.8%	-2.7%	**0.0%**	-8.8%	-6.3%	-3.0%	0.1%	-11.8%	-8.9%	-4.0%	0.4%
$56.4	-8.0%	-5.2%	-1.5%	1.9%	-8.0%	-5.2%	-1.5%	1.9%	-10.6%	-7.4%	-2.5%	2.3%
$51.1	-7.8%	-4.5%	-0.3%	4.3%	-7.3%	-3.8%	0.0%	4.2%	-9.5%	-6.0%	-0.9%	4.7%
$43.2	-7.5%	-3.2%	2.0%	7.6%	-6.1%	-1.6%	3.0%	7.4%	-7.2%	-3.1%	2.3%	7.6%

[1] The shaded values identified for the row labeled $86.9 billion actually reflect a lower average annual investment level of $86.5 billion, as HERS did not find a sufficient pool of cost-beneficial potential investments to spend the full amount in the last funding period.

[2] Each percentage distribution shown corresponds to a HERS analysis assuming investment up to a minimum benefit-cost ratio cutoff point (not shown) which was set at a level such that 20-year spending would be consistent with the average annual spending level shown. The shaded values for the row labeled $86.9 billion are actually based on a lower average annual investment level of $86.5 billion, as spending more than that amount would have required investing in improvements with a BCR lower than 1.0 (which HERS won't do).

Source: Highway Economic Requirements System.

For the baseline (ramped) 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 shown in the top section of *Exhibit 9-6*, because 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. For example, when HERS-modeled capital investment spending is sustained at the base-year level of $56.4 billion, the results of the ramped spending and flat spending alternatives are identical. (Spending is flat when its growth rate is zero.) As noted in *Exhibit 9-6*, although HERS finds an average annual investment level of $86.9 billion to be cost-beneficial assuming ramped spending, the model identifies only $86.5 billion of cost-beneficial investment assuming flat spending.

The BCR-driven spending percentages identified in *Exhibit 9-6* 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 2015. This effect is less pronounced at lower levels of investment because 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 percentage of total HERS-modeled, BCR-driven spending occurring in the first 5 years ranged from 29.5 percent for the lowest spending level analyzed to 41.2 percent for the highest level analyzed.

Impacts of Alternative Investment Patterns

An obvious difference among the three alternative investment patterns is that the higher the level of investment within the first 5-year analysis period, the better the level of performance achieved by 2015. At levels of HERS-modeled investment above $56.4 billion per year, the flat spending approach invests more in the first 5 years, resulting in lower IRI and average delay in 2015 than under the ramped spending approach; the reverse is true at funding levels less than $56.4 billion. The BCR-driven approach invests more in the first 5 years for all but the lowest average annual investment level presented of $43.2 billion per year; thus, at the higher investment levels, the BCR-driven approach achieves more IRI and delay reduction by 2015.

The more significant results pertain to system performance in 2030. In terms of average IRI, the flat spending approach and the BCR-driven approach yield results that are equal to or slightly inferior to those assuming ramped spending. For example, at an average annual investment level of $43.2 billion, average IRI would remain unchanged under the ramped spending approach or the BCR-driven approach in 2030 relative to 2010, but would increase by 0.4 percent under the flat spending approach.

The flat spending alternative achieves the largest reduction in average delay per VMT in 2030 relative to the baseline ramped spending approach only for HERS investment levels below the base-year level of $56.4 billion; the BCR-driven alternative produces average delay results equal or slightly inferior to the other two approaches at all levels of investment. For example, at an average annual investment level of $60.9 billion, average delay would remain unchanged under the ramped spending approach, but would increase by 0.1 percent under the flat funding alternative and by 0.4 percent under the BCR-driven funding alternative.

The significance of these 2030 results is that, although the ramped funding approach is often marginally superior to the two alternatives presented, it is ultimately the amount of funding invested over 20 years that has the most impact on system performance rather than the timing of that investment. Based on this analysis, the main advantage to front-loading highway investment is not in reducing 20-year investment needs; instead, the advantage is the years of additional benefits that highway users would accrue over time if system conditions and performance were improved earlier in the 20-year period.

Alternative Timing of Investment in NBIAS

Exhibit 9-7 identifies the impacts of alternative investment timing on the average bridge sufficiency rating using four investment levels selected from those presented in Chapter 7. (See Chapter 7 for additional discussion of the sufficiency rating.) One of these investment levels matches the 2010 spending level of $17.1 billion on types of investments modeled in NBIAS, one corresponds to a higher level of investment of $20.2 billion annually (representing the NBIAS-derived component of the **Improve Conditions and Performance** scenario presented in Chapter 8), and two lower investment average annual levels of $14.3 billion and $12.2 billion (representing the NBIAS-derived component of the **Maintain Conditions and Performance** scenario presented in Chapter 8).

Exhibit 9-7 Distribution of Spending Among 5-Year Periods in NBIAS and Projected Impacts on the Average Bridge Sufficiency Rating, for Alternative Approaches to Investment Timing

Average Annual NBIAS-Modeled Capital Investment (Billions of 2010 Dollars)	Percentage of NBIAS-Modeled Spending Occurring in Each 5-Year Period											
	Baseline				Alternatives							
	Ramped Spending				Flat Spending				BCR-Driven Spending*			
	2011 to 2015	2016 to 2020	2021 to 2025	2026 to 2030	2011 to 2015	2016 to 2020	2021 to 2025	2026 to 2030	2011 to 2015	2016 to 2020	2021 to 2025	2026 to 2030
$20.2	22.2%	24.0%	25.9%	28.0%	25.0%	25.0%	25.0%	25.0%	38.9%	21.4%	20.7%	19.0%
$17.1	**25.0%**	**25.0%**	**25.0%**	**25.0%**	**25.0%**	**25.0%**	**25.0%**	**25.0%**	37.3%	22.8%	20.9%	19.1%
$14.3	28.3%	26.0%	23.8%	21.9%	25.0%	25.0%	25.0%	25.0%	34.5%	24.4%	21.3%	19.7%
$12.2	31.7%	26.7%	22.6%	19.0%	25.0%	25.0%	25.0%	25.0%	31.6%	23.5%	24.6%	20.3%

Average Annual NBIAS-Modeled Capital Investment (Billions of 2010 Dollars)	Projected Average Bridge Sufficiency Rating											
	Baseline				Alternatives							
	Ramped Spending, Percent Change as of:				Flat Spending, Percent Change as of:				BCR-Driven Spending* Percent Change as of:			
	2015	2020	2025	2030	2015	2020	2025	2030	2015	2020	2025	2030
$20.2	82.8	83.9	84.6	84.6	83.4	84.4	84.5	84.3	85.3	84.6	84.1	83.9
$17.1	82.5	83.2	83.9	84.1	82.5	83.2	83.9	84.1	84.3	83.9	83.6	83.4
$14.3	82.3	82.5	82.9	83.2	81.5	81.8	82.7	83.5	83.2	82.9	82.8	82.9
$12.2	82.0	81.8	81.7	**81.7**	80.6	80.3	80.9	82.2	82.1	81.5	81.8	82.1

** Each percentage distribution shown corresponds to a NBIAS analysis assuming investment up to a minimum benefit-cost ratio cutoff point (not shown) which was set at a level such that 20-year spending would be consistent with the average annual spending level shown.*

Source: National Bridge Investment Analysis System.

Similar to the HERS results presented earlier, the projected average bridge sufficiency rating in 2015 is driven by the amount of NBIAS investment during the first 5-year period. Unlike the HERS results presented earlier, NBIAS does not find the maximum level of cost-beneficial investment to be lower under the two alternatives than under the baseline ramped spending approach; in all three cases, NBIAS identified 20 years of cost-beneficial investment corresponding to an average annual investment level of $20.2 billion.

At an average annual investment level of $20.2 billion, NBIAS projects that the highest average bridge sufficiency rating in 2030 would be achieved under the baseline ramped spending approach at 84.6 (on a scale of 0 to 100), compared to 84.3 assuming ramped spending and 83.9 for the BCR-driven spending alternative. However, at an average annual investment level of $12.2 billion, NBIAS projects that the average bridge sufficiency rating in 2030 would match the 2010 level of 81.7 assuming the baseline ramped funding approach, which is lower than the 82.2 and 82.1 average sufficiency ratings projected for the flat spending and BCR-driven spending alternatives, respectively.

The BCR-driven spending approach is intended to better align annual capital spending to annual needs. This approach has a benefit in terms of reducing ongoing maintenance costs; however, front-loading capital investment in this manner tends to exacerbate the concentration of future bridge needs by putting a larger number of bridges on 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.

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:

- Asset condition forecasts under four scenarios: (1) Sustain 2010 Spending, (2) State of Good Repair (SGR) benchmark, (3) Low Growth, and (4) High Growth
- A comparison of 2010 to 2013 TERM results
- A comparison of recent historic passenger miles traveled (PMT) growth rates with the growth projections of the Nation's Metropolitan Planning Organizations (MPOs)
- An assessment of the impact of purchasing hybrid vehicles to the backlog estimate
- The forecast of purchased transit vehicles, route miles, and stations under the **High Growth** and **Low Growth** scenarios.

Asset Conditions Forecasts and Expected Useful Service Life Consumed for All Transit Assets Under Four Scenarios

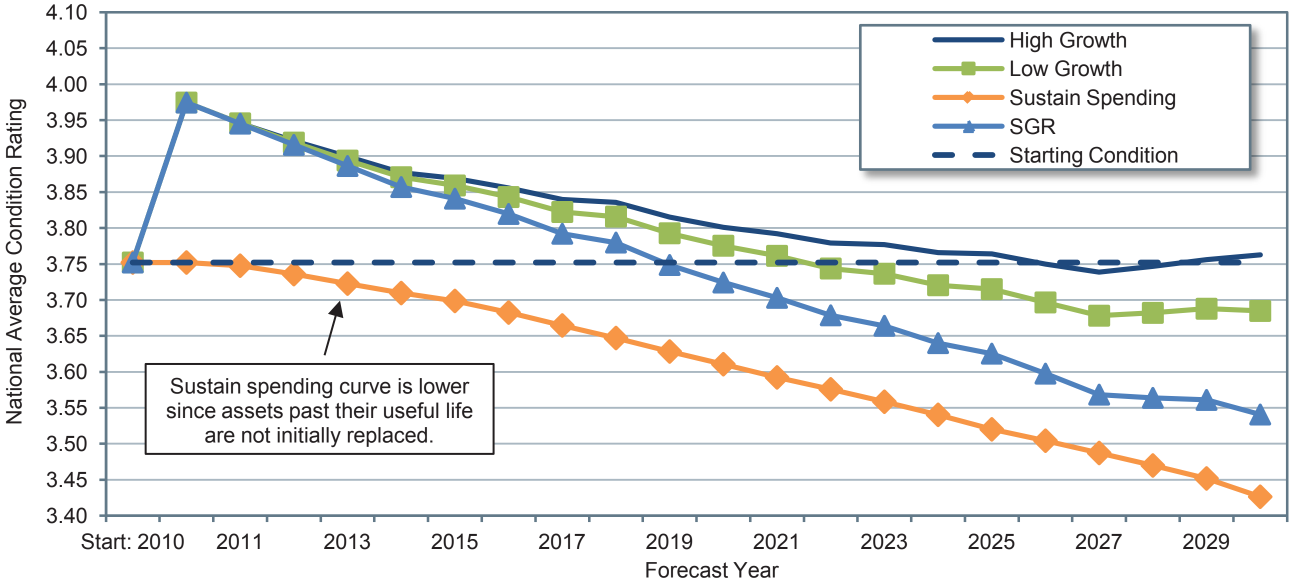
As in the 2010 edition, this edition of the C&P report uses four condition projection scenarios (i.e., **SGR benchmark**, **Sustain 2010 Spending**, **Low Growth**, and **High Growth** scenarios) to better understand which conditions outcome is desirable or even sensible. For example, are current asset conditions at an acceptable level or are they too low (or too high) for individual asset types?

To help answer this question, consider *Exhibit 9-8*, which presents the condition projections for each of the four scenarios. Note that these projections predict the condition of all transit assets in service each year of the 20-year analysis period, including transit assets that exist today and any investments in expansion assets by these scenarios. The **Sustain 2010 Spending**, **Low Growth**, and **High Growth** scenarios each make investments in expansion assets while the **SGR benchmark** scenario only reinvests in existing assets. Note that the estimated current average condition of the Nation's transit assets is 3.75. As discussed in Chapter 8, expenditures under the financially constrained **Sustain 2010 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 9-8*.

In contrast to the **Sustain 2010 Spending** scenario, the **SGR benchmark** scenario is financially unconstrained and considers the level of investment required to both eliminate the current investment backlog and to address all ongoing reinvestment needs as they arise such that all assets remain in an SGR (i.e., a condition of 2.5 or higher). Despite adopting the objective of maintaining all assets in an SGR throughout the forecast period, average conditions under the **SGR benchmark** scenario ultimately decline to levels well below the current average condition value of 3.75.

This result, although counterintuitive, 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 9-9.* The exhibit shows the share of all transit assets (equal to approximately $658 billion in 2010) as a function of their useful life consumed. The spike in

Exhibit 9-8 Asset Condition Forecast for All Existing and Expansion Transit Assets

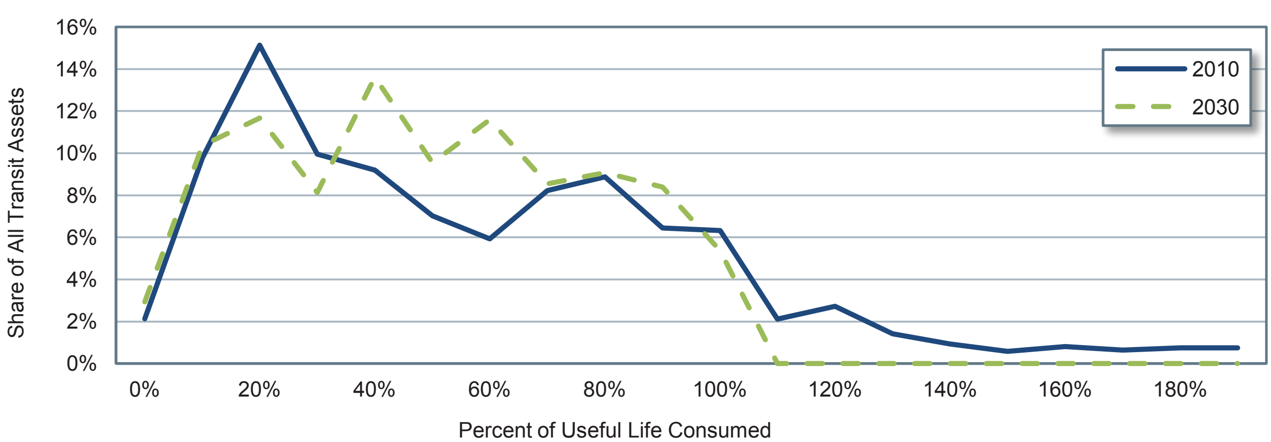


Source: Transit Economic Requirements Model.

Exhibit 9-9 at the point where only 20 percent of useful life has been consumed is driven in part by ongoing expansion investments. Elimination of the current SGR backlog removes a significant number of over-age assets from service (resulting in an initial jump in asset conditions), but 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.

If the **SGR benchmark** scenario represents a reasonable long-term investment strategy (i.e., replacing assets close to the end of their useful life which results in a long-term decline in average conditions), then investing under the **Sustain 2010 Spending** scenario implies an investment strategy of replacing assets at later ages, in worse conditions, and potentially after the end of their useful life, as shown in *Exhibit 9-10*. Expenditures on asset reinvestment for the **Sustain 2010 Spending** scenario are insufficient to address ongoing reinvestment needs, leading to an increase in the size of the backlog. Note that the forecast for 2030 for the **Sustain 2010**

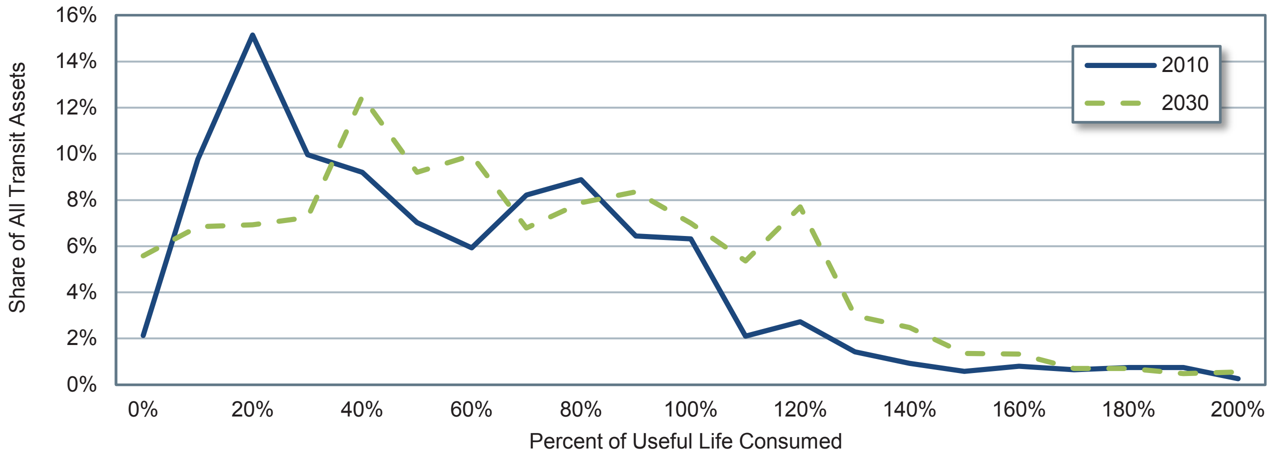
Exhibit 9-9 SGR Baseline Scenario: Asset Percent of Useful Life Consumed



Source: Transit Economic Requirements Model.

Spending scenario in *Exhibit 9-10* indicates that assets under this scenario will be closer to or beyond the end of their useful life when compared with the other scenarios; this difference reflects a larger portion of the national transit assets still in use after the end of their useful lives.

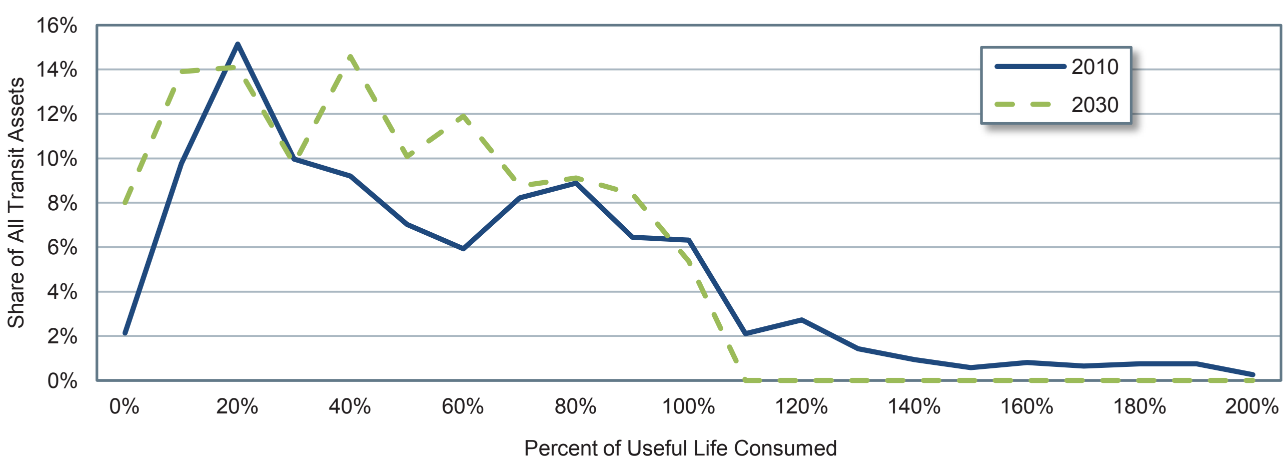
Exhibit 9-10 Sustain 2010 Spending Scenario: Asset Percent of Useful Life Consumed



Source: Transit Economic Requirements Model.

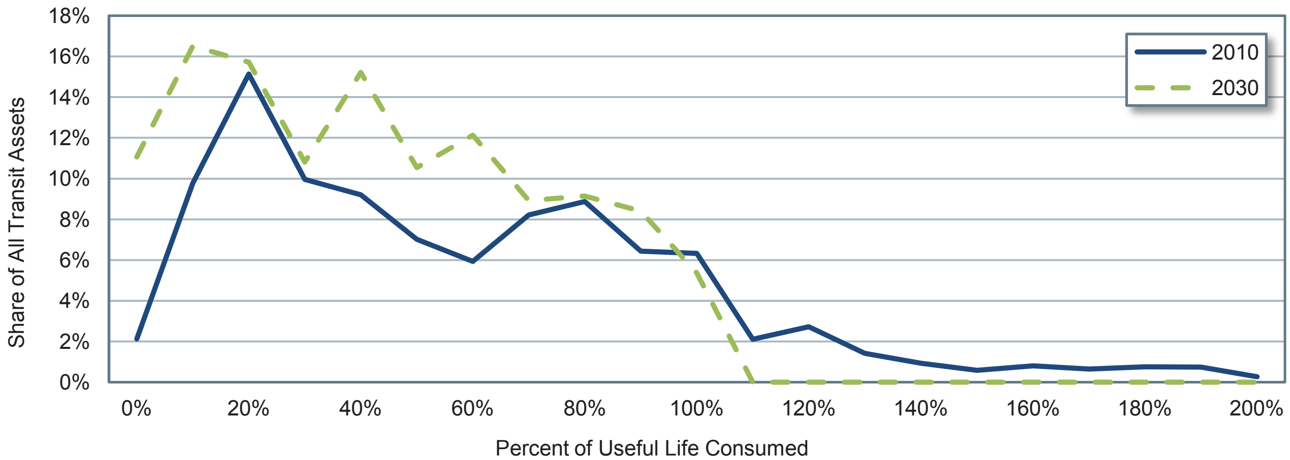
To underscore these findings, note that the **Low Growth** scenario and the **High Growth** scenario include unconstrained investments in both asset replacements and asset expansions. Hence, not only are older assets replaced as needed with an aggressive reinvestment rate, but new expansion assets are 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 would ultimately reverse the downward decline in average asset conditions in the final years of the 20-year projections. This would also result in a higher proportion of long-lived assets with a larger amount of useful life remaining in 2030 than in 2010 as illustrated in *Exhibit 9-11* and *Exhibit 9-12,* respectively. Furthermore, the **High Growth** scenario (*Exhibit 9-12*) adds newer expansion assets at a higher rate than does the **Low Growth** scenario (*Exhibit 9-11*), ultimately yielding higher average condition values for that scenario (and average condition values that exceed the current average of 3.75 throughout the entire forecast period).

Exhibit 9-11 Low Growth Scenario: Asset Percent of Useful Life Consumed



Source: Transit Economic Requirements Model.

Exhibit 9-12 High Growth Scenario: Asset Percent of Useful Life Consumed



Source: Transit Economic Requirements Model.

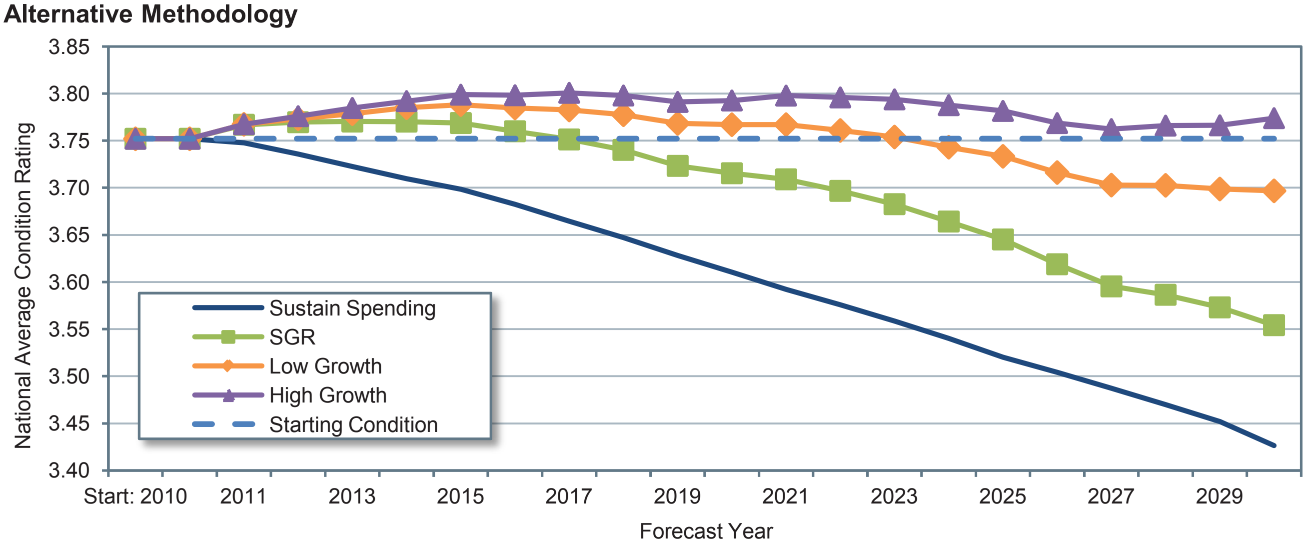
Alternative Methodology

When we consider current transit investment practices, the level of investment needed to eliminate the SGR backlog in 1 year is unfeasible. So the **SGR benchmark**, **Low Growth**, and **High Growth** scenarios' financially unconstrained assumptions (e.g., spending of unlimited transit investment funds each year) is unrealistic. As indicated in *Exhibit 9-8*, the elimination of the backlog in the first year and the resulting jump in asset conditions in year 1 can be attributed to this unconstrained assumption.

An alternative, more feasible methodology is to have the **SGR benchmark**, **Low Growth**, and **High Growth** scenarios use a financially constrained reinvestment rate to eliminate the SGR backlog by year 20 while maintaining the collective national transit assets at a condition rating of 2.5 or higher. Analysis has determined that investing $17.5 billion annually would achieve this objective of eliminating the backlog in 20 years.

Exhibit 9-13 presents the condition projections for each of the four scenarios using this alternative methodology. However, the **SGR benchmark**, **Low Growth**, and **High Growth** scenarios are financially constrained so the investment strategies result in replacing assets at later ages, in worse conditions, and potentially after the end of their useful lives.

Exhibit 9-13 Asset Condition Forecast for All Existing and Expansion Transit Assets Under Alternative Methodology



Source: Transit Economic Requirements Model.

Comparison of 2010 to 2013 TERM Results

The backlog and investment needs estimated by TERM differ between the 2010 and 2013 C&P Reports. This section compares the TERM results between these two reports and explains why they differ.

The estimated backlog in the 2013 C&P Report increased from $77.7 billion (as reported in the 2010 C&P Report) to $85.9 billion, representing an increase of more than 10 percent. There are three primary reasons for the increase in the backlog:

- **Additional needs:** The value of the backlog is strongly correlated to the age of the inventory of assets. Certain assets that were nearing the condition threshold of 2.5 in 2008 continued to age and degrade until 2010. As the predicted condition of these assets moved from better than 2.5 to worse than 2.5 during this period, the cost of replacing them was added to the backlog calculation. The backlog increased by $9 billion for this reason between the 2010 and the 2013 C&P Report.
- **Inflation:** Using published construction inflation factors, the backlog was escalated from 2008 to 2010 dollars. The impact of inflation on the backlog between the 2010 and 2013 C&P Reports is $3.6 billion.
- **Changed Asset Inventory:** The asset inventory used in the TERM simulation consists of nearly 84,000 asset records for almost 2,400 transit agencies. For each edition of the C&P report, the Federal Transit Administration (FTA) collects new asset data from select agencies. In general, agencies continue to improve the defensibility and accuracy of their inventory data. As a result, FTA expects some change to reflect the improved data. For the 2013 C&P Report, the impact of improved data resulted in a net decrease of approximately $4.4 billion.

Exhibit 9-14 Causes of the Increase in the Backlog between the 2010 C&P Report and the 2013 C&P Report

	Billion $
SGR Backlog as reported in the 2010 C&P report	**$77.7**
Impact of two additional years of needs	**+9.0**
Impact of inflation	**+3.6**
Impact from the change in the asset inventory	**-4.4**
SGR Backlog as reported in the 2013 C&P report	**$85.9**

Source: Transit Economic Requirements Model.

Exhibit 9-14 provides a summary of these three adjustments. Note that the SGR backlog of $77.7 billion dollars comes from *Exhibit 8-30* in the 2008 C&P Report.

Nonrail investment projections decreased in this 2013 C&P Report relative to the 2010 C&P Report for all scenarios, as presented in *Exhibit 9-15*, while rail investments decreased in this report relative to the previous report only for the **High Growth** scenario. This is because the high growth rate in this 2013 C&P Report is lower than the high growth rate in the 2010 C&P Report.

The high growth rate is projected using 10- or 15-year historical ridership growth trends. The 2010 C&P Report used a 10-year trend (1999 to 2008), which gave a high growth rate of 2.8 percent. The 10-year trend for the 2013 C&P Report (2001 to 2010) included the effects of the recession and, thus, was not

Exhibit 9-15 Comparison of Projected Investment Needs for 2010 and 2013 C&P Report Investment Scenarios

	Investment Projection (Billions of 2010 Dollars)					
	Nonrail		Rail		Total	
Scenario	2010 C&P Report	2013 C&P Report	2010 C&P Report	2013 C&P Report	2010 C&P Report	2013 C&P Report
Sustain 2010 Spending	$6.4	$5.8	$10.7	$10.7	**$17.1**	**$16.5**
SGR Benchmark	$7.5	$6.7	$11.6	$11.7	**$19.1**	**$18.5**
Low Growth	$8.4	$7.8	$13.6	$14.2	**$22.1**	**$22.0**
High Growth	$10.0	$9.2	$16.0	$15.3	**$26.0**	**$24.5**

Source: Transit Economic Requirements Model.

much higher than the low growth rate of 1.4 percent. Accordingly, a 15-year historical time horizon was used to calculate the high growth rate for the 2013 C&P Report, which resulted in a growth rate of 2.2 percent. The low growth rate is the MPO-projected ridership growth rate and is roughly the same for both reports.

Comparison of Passenger Miles Traveled (PMT) Growth Rates

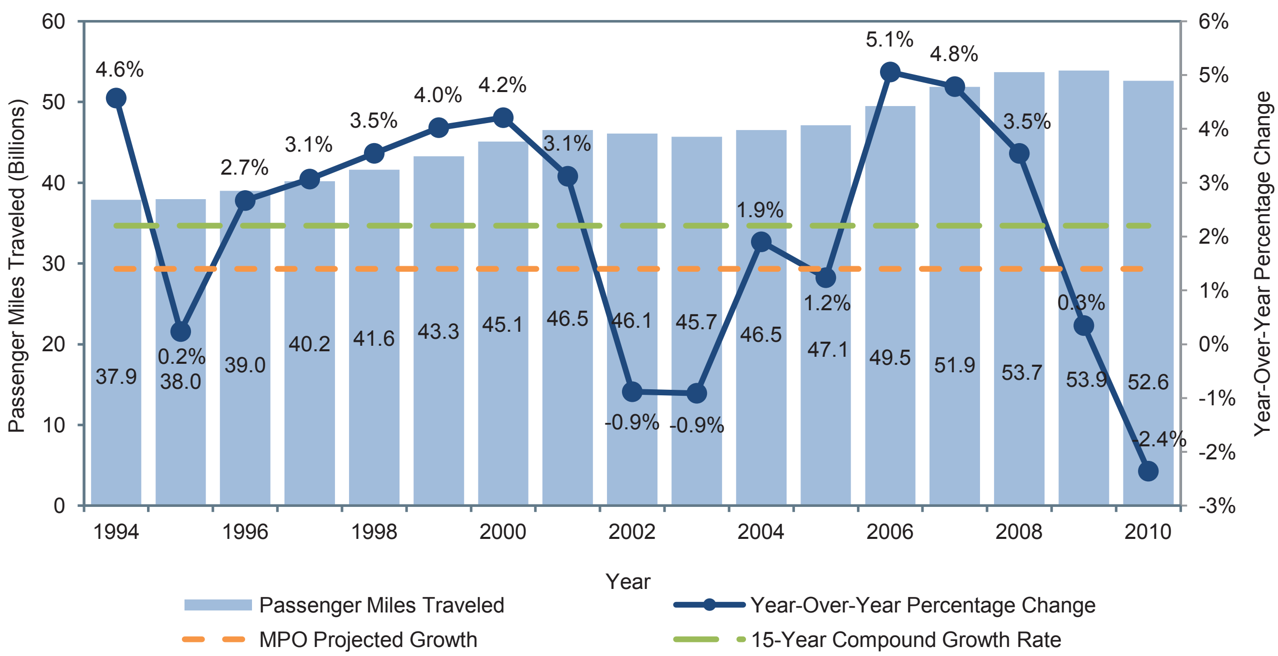
The **Low Growth** and **High Growth** scenarios presented in Chapter 8 assessed transit expansion investment needs assuming two differing rates of growth in transit PMT. Specifically, the **Low Growth** scenario assumed urbanized-area (UZA)–specific rates of PMT growth as projected by the Nation's MPOs. The **High Growth** scenario assumed the UZA-specific average annual compound rates experienced over the most recent 15-year period. The objective of this discussion is to put into perspective these two differing growth rates.

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 Growth Compared to Historical Growth for All Urbanized and Rural Areas

As shown in *Exhibit 9-16*, the historical rates of PMT growth experienced over the past 16 years have typically been in excess of the MPO-projected growth rates. During the period from 1994 through 2010

Exhibit 9-16 Passenger Miles Traveled, All Urbanized and Rural Areas



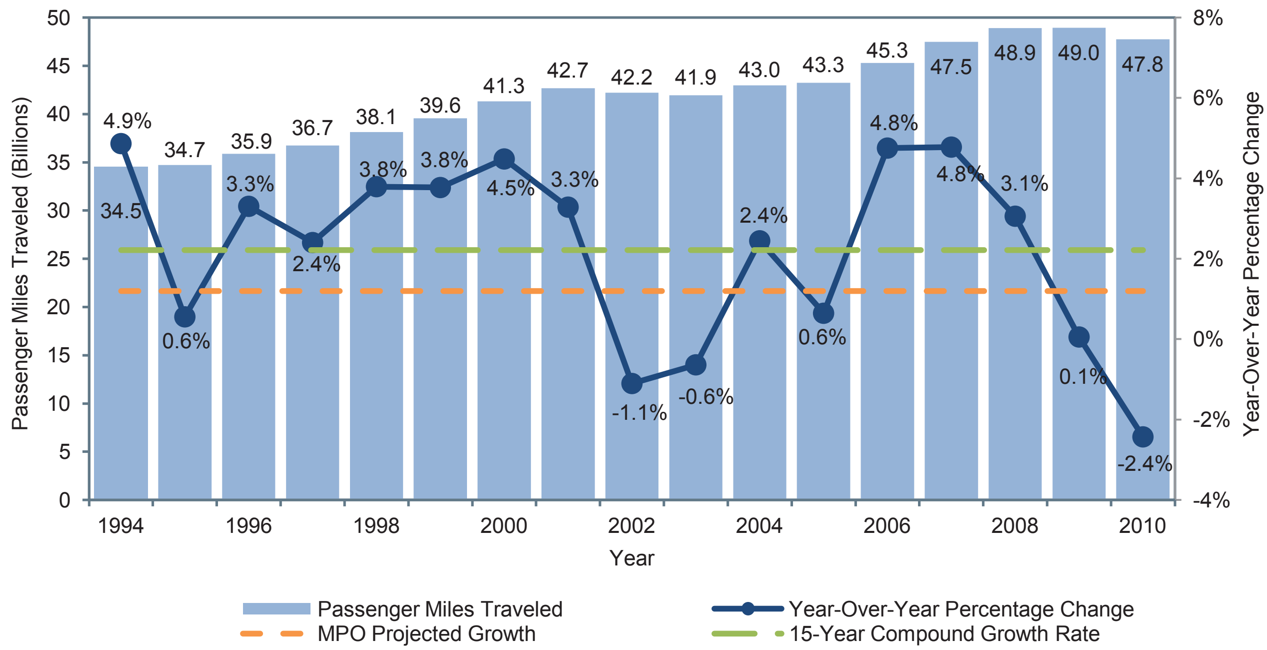
Source: NTD and MPO estimates.

presented in *Exhibit 9-16*, the compound annual growth rate averaged roughly 2.1 percent rather than the 1.3-percent growth rate projected by MPOs for the upcoming 20- to 30-year period. The average compound annual growth rate of 2.1 percent closely resembles the 2.0 percent high growth rate. 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 Growth** (or higher-growth) scenario. There is a significant drop in year-over-year percentage change in 2009 and 2010 PMT that is mostly due to the decrease in PMT for UZAs over 1 million in population.

UZAs Over 1 Million in Population

As shown in *Exhibit 9-17*, 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 2.2 percent during the period from 1994 through 2010 as compared with the 1.2-percent growth rate projected by MPOs for the up-coming 20- to 30-year period.

Exhibit 9-17 Passenger Miles Traveled, UZAs over 1 Million in Population

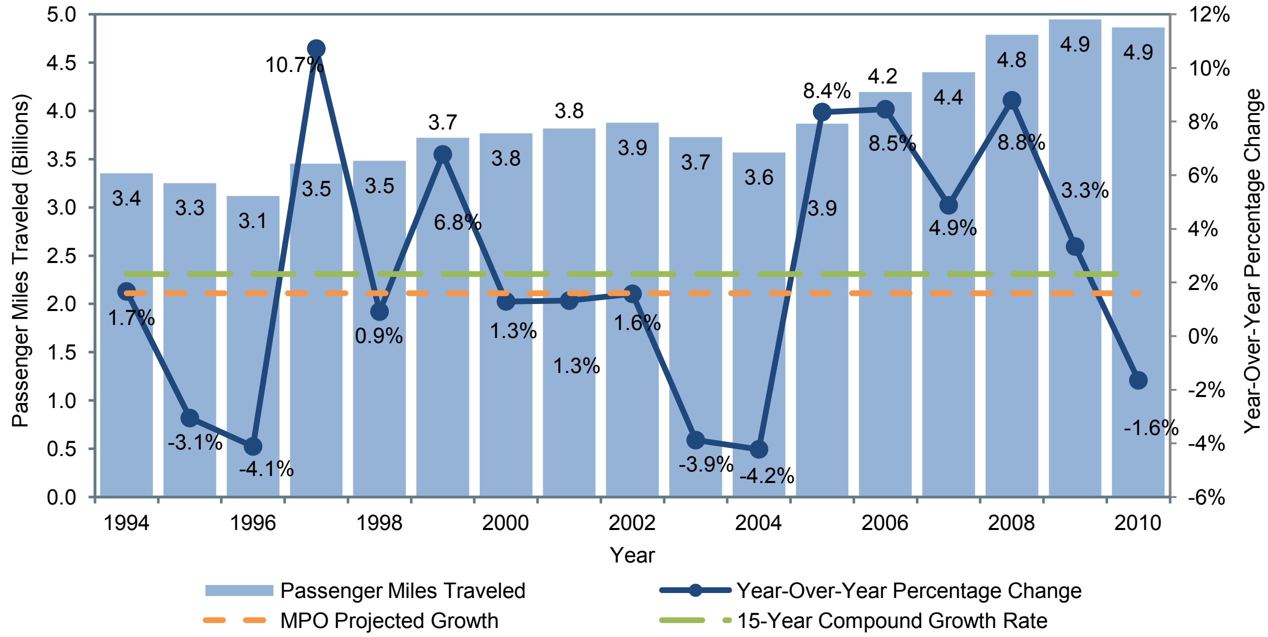


Source: NTD and MPO estimates.

UZAs Under 1 Million in Population and Rural Areas

Finally, as shown in *Exhibit 9-18*, 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. For UZAs under 1 million in population, the compound average annual growth rate averaged roughly 2.3 percent during the period from 1994 through 2010, 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 UZAs under 1 million in population is roughly 64 percent higher than for UZAs over 1 million in population. 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 is roughly double that

Exhibit 9-18 **Passenger Miles Traveled, UZAs Under 1 Million in Population**



Source: NTD and MPO estimates.

experienced by UZAs over 1 million in populations. The percent change in annual passenger miles traveled varies with a low of -4.2 percent to a high of 10.7 percent over the 17-year period. Given this variability in growth rates, it is important to have alternative growth rates (i.e., **Low Growth** and **High Growth** scenarios) for projection purposes.

Impact of New Technologies on Transit Investment Needs

The investment needs scenarios presented in Chapter 8 implicitly assume that all replacement and expansion assets will utilize the same technologies as are currently in use today (i.e., all asset replacement and expansion investments are "in kind'). However, as with most other industries, the existing stock of assets used to support transit service is subject to ongoing technological change and improvement and this change tends to result in increased investment costs (including future replacement needs). While many of these improvements are standardized and hence embedded in the asset (i.e., the transit operator has little or no control over this change), there are numerous instances where transit operators have intentionally selected technology options that can be significantly more costly than pre-existing assets of the same type. A key example here is the frequent decision to replace diesel motor buses with compressed natural gas (CNG) or hybrid buses. While these options offer clear environmental benefits (and CNG may also result in decreases in operating costs), acquisition costs for these vehicle types are 20 to 60 percent higher than diesel. This increase in costs generally increases current and long-term reinvestment needs and, in a budget-constrained environment, increases the expected future size of the investment backlog. This increase may be offset by lower operating costs from more reliable operation, longer useful lives, and improved fuel efficiency, but this possible offset is not captured in this assessment of capital needs. Again, the impact of these technology-driven increases in needs is not included in the needs estimates presented in Chapters 7 and 8 of this report.

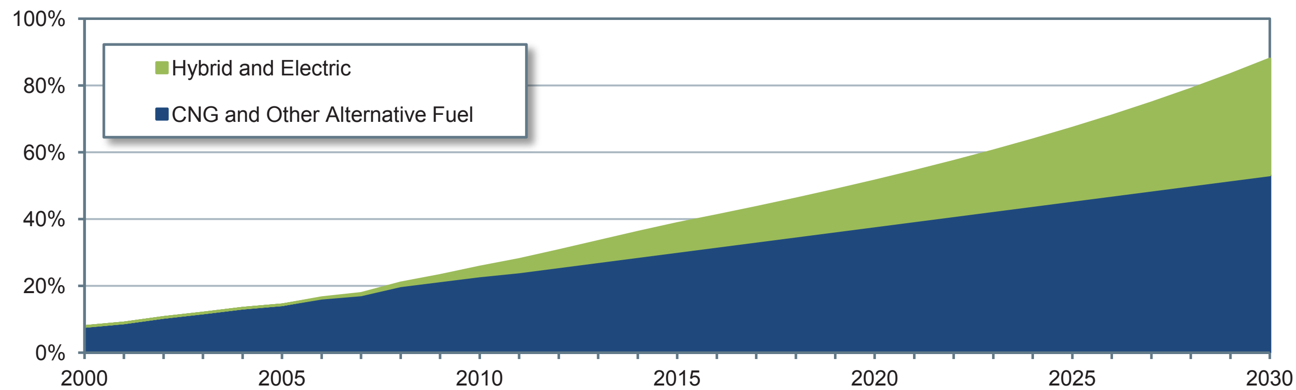
In addition to improvements in pre-existing asset types, transit operators periodically expand their existing asset stock to introduce new asset types that take advantage of technological innovations. Good examples include investments in intelligent transportation system technologies such as real-time passenger information systems and automated dispatch systems, assets and technologies that are common today but that were not available 15 to 20 years ago. These improvements typically yield improvements in service quality and efficiency, but they also tend to yield increases in asset acquisition, maintenance, and replacement costs, resulting in an overall increase in reinvestment costs as well as the expected future size of the SGR backlog.

Impact of Compressed Natural Gas and Hybrid Buses on Future Needs

To provide a better sense of the impact of new technology adoption on long-term needs, the analysis below presents estimates of the long-term cost of the shift from diesel to compressed natural gas (CNG) and hybrid buses. It is important to emphasize that this analysis is only intended to provide a sense of the significance of this impact on long-term capital needs (including the possible consequences of not capturing this impact in TERM's needs estimates). This is not an assessment of the full range of operational, environmental, or other potential costs and benefits arising from this shift and, hence, is not an evaluation of the decision to invest in any specific technology.

Exhibit 9-19 below presents historical (2000 to 2010) and forecast (2011 to 2030) estimates of the share of transit buses that rely on CNG and other alternative fuels vehicles and on hybrid power sources. The forecast estimates assume the current trend rate of increase in alternative and hybrid vehicle shares as observed over the period 2005 to 2010. Based on this projection, the share of vehicles powered by alternative fuels is estimated to increase from 23 percent in 2010 to 53 percent in 2030. During the same period, the share of hybrid buses is estimated to increase from 3 percent to 35 percent. This results in diesel shares declining from roughly 74 percent today to roughly 12 percent by 2030.

Exhibit 9-19 Hybrid and Alternative Fuel Vehicles: Share of Total Bus Fleet, 2000–2030



Source: Transit Economic Requirements Model.

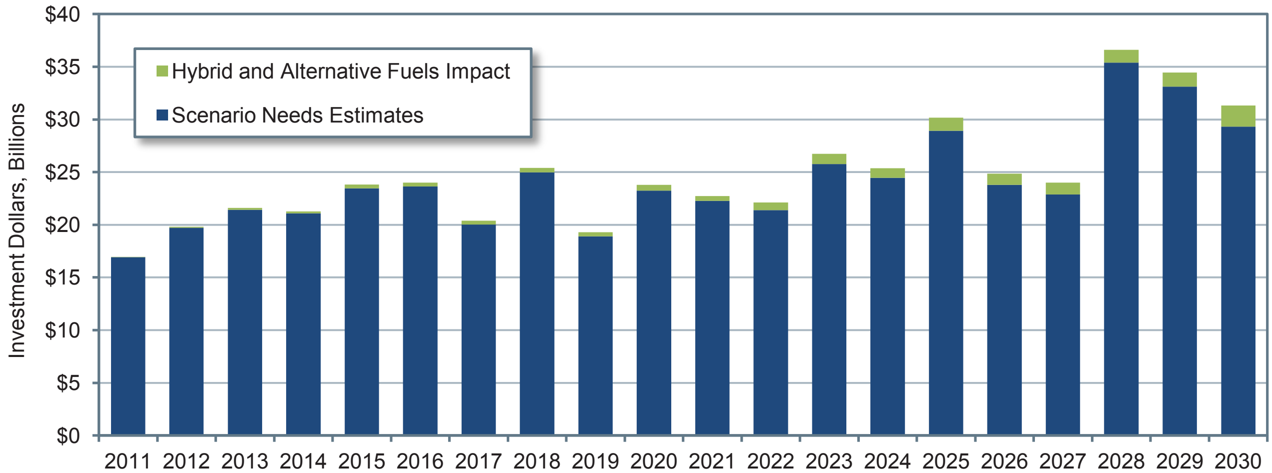
Impact on Costs

Based on FTA analysis, the average unit cost of an alternative fuels bus is 15.5 percent higher than that of a standard diesel bus of the same size. Similarly, hybrid buses cost roughly 65.9 percent more than standard diesel buses of the same size. When combined with the current and projected mix of bus vehicle types presented above in *Exhibit 9-19*, these cost assumptions yield an estimated increase in average bus vehicle capital costs of 25.7 percent over the period 2010 to 2030 (using the mix of bus types from 2010 as the base of comparison). (It is important to note here that this cost increase represents a shift in the mix of bus types purchased and not the impact of underlying inflation, which will impact all vehicle types, including diesel, alternative fuels, and hybrid.) Reductions in operating costs due to the new technology are not shown in this analysis of capital needs but are presumably part of the motivation for agencies that purchase these vehicles.

Impact on Needs

What, then, is the impact of this cost increase on long-term transit capital needs? *Exhibit 9-20* presents the impact of this potential cost increase on annual transit needs as estimated for the **Low Growth** scenario

Exhibit 9-20 Impact of Shift to Vehicles Using Hybrid and Alternative Fuels on Investment Needs: Low Growth Scenario



Source: Transit Economic Requirements Model.

presented in Chapter 8. For this scenario, the cost impact is negligible in the early years of the projection period but grows over time as the proportion of buses using alternative fuel and hybrid power increases (note that the investment backlog is not included in this depiction). The impact on total investment needs for all Chapter 9 investment scenarios (**SGR baseline**, **Low Growth**, and **High Growth**) is presented in dollar and percentage terms in *Exhibit 9-21*. Note that the shift to alternative fuels and hybrid buses is estimated to increase average annual replacement needs by $0.5 to $0.8 billion, yielding a 2.5- to 3.5-percent increase in investment needs. To help place these estimated amounts in perspective, it is helpful to note that (1) the shift from diesel to alternative fuels and hybrid buses is only one of a number of technology changes that may impact long-term transit reinvestment needs, but (2) reinvestment in transit buses likely represents the largest share of transit needs subject to this type of significant technological change. Hence, the impact of all new technology adoptions (not accounted for in the Chapter 8 scenarios and including but not limited to new bus propulsion systems) may add on the order of 5 to 10 percent to long-term transit capital needs.

Exhibit 9-21 Impact of Shift from Diesel to Alternative Fuels and Hybrid Vehicles on Annual Investment Needs

Measure	SGR Baseline	Low Growth	High Growth
Average Annual Needs	$0.47B	$0.67B	$0.83B
Percent Increase	2.50%	3.00%	3.50%

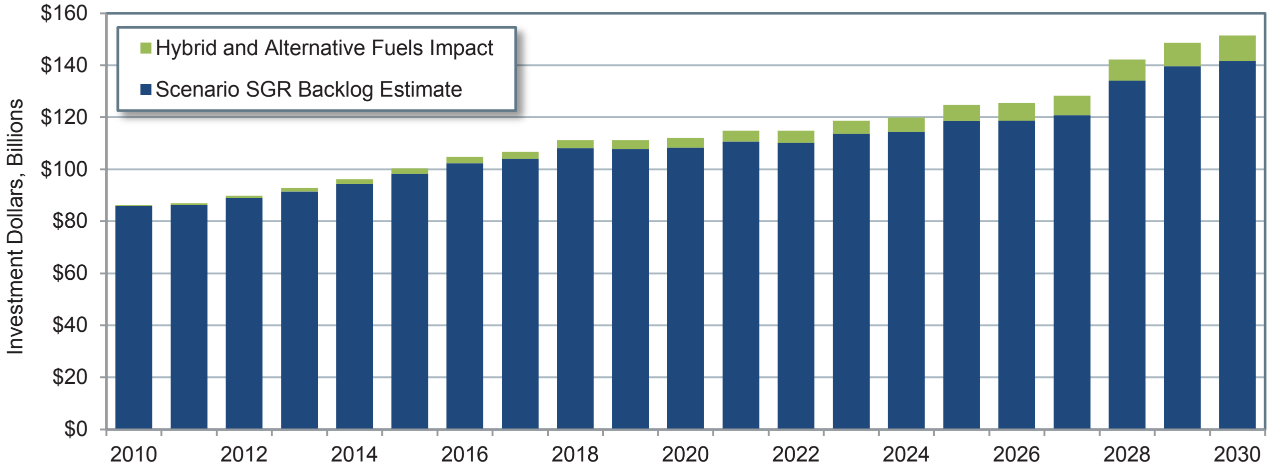
Source: Transit Economic Requirements Model.

Impact on Backlog

Finally, in addition to impacting unconstrained capital needs, the shift from diesel to hybrid and alternative-fuel vehicles can also have an impact on the size of the future backlog. For example, *Exhibit 9-22* shows the estimated impact of this shift on the SGR backlog as was estimated for the **Sustain 2010 Spending** scenario from Chapter 8. Under this scenario, long-term spending is capped at current levels such that any increase in costs over the analysis period must necessarily be added to the backlog. Moreover, given that buses' useful lives as estimated by TERM range from roughly 7 to 14 years, all existing and many expansion vehicles will need to be replaced over the 20-year analysis period, meaning that any increase in costs for this asset type will be added to the backlog over this period of analysis.

As with the analysis above, *Exhibit 9-22* suggests that the initial impact of the shift to hybrid and alternative-fuel vehicles is small but increases over time as these vehicle types make up an increasing share of the Nation's bus fleet. By 2030, this shift is estimated to increase the size of the backlog from $141.7 billion to $151.4 billion, an increase of $9.8 billion or 6.9 percent.

Exhibit 9-22 Impact of Shift to Vehicles Using Hybrid and Alternative Fuels on Backlog Estimate: Sustain 2010 Spending Scenario



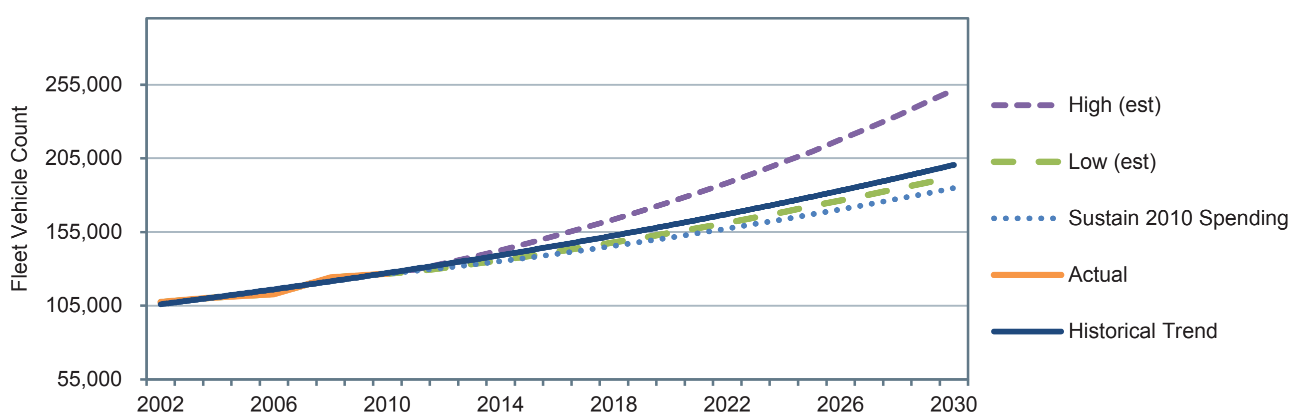
Source: Transit Economic Requirements Model.

Forecasted Expansion Investment

This section compares key characteristics of the national transit system in 2010 to their forecasted TERM results over the next 20 years for different scenarios. It also includes expansion projections of fleet size, guideway route miles, and stations broken down by scenario to better understand the expansion investments that TERM is making.

TERM's projections of fleet size are presented in *Exhibit 9-23*. The projections for the **Low Growth** and **High Growth** scenarios are higher than the projected **Sustain 2010 Spending** scenario in order to preserve existing transit assets at a condition rating of 2.5 or higher and expand transit service capacity to support differing levels of ridership growth while passing TERM's benefit-cost test. An exponential trend line based on historical data from 2002 to 2010 is extrapolated 20 years into the future also is shown in *Exhibit 9-23*. This extrapolated historical trend line falls between the low and high growth projections indicating that the **Low Growth** and **High Growth** scenario investments potentially could maintain current conditions.

Exhibit 9-23 Projection of Fleet Size by Scenario

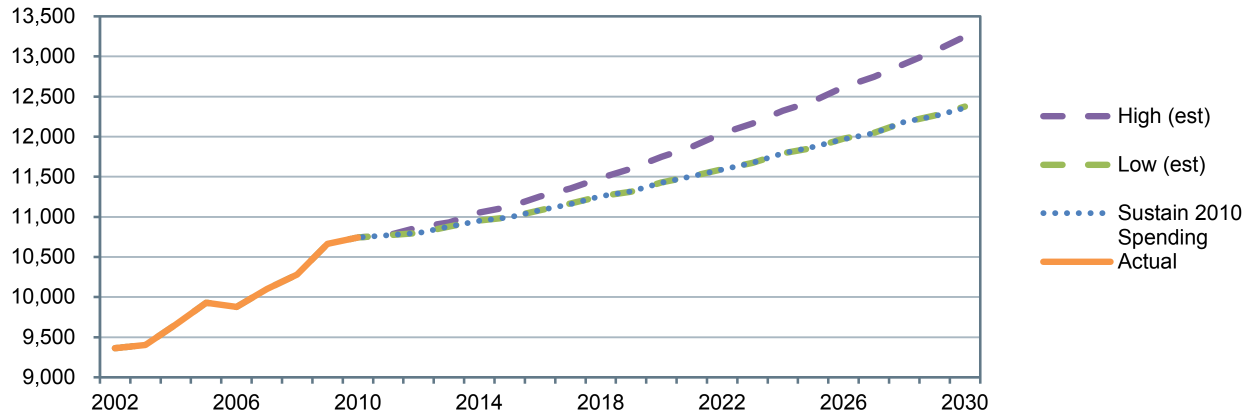


Note: Data through 2010 are actual; data after 2010 are estimated based on trends.

Source: Transit Economic Requirements Model.

In contrast, the projected guideway route miles for the **Sustain 2010 Spending**, **Low Growth**, and **High Growth** scenarios are less than the projected historical trend scenario as shown in *Exhibit 9-24*. (Note that TERM's projections of guideway route miles for the **Sustain 2010 Spending** and **Low Growth** scenarios are nearly identical.) Commuter rail has substantially more guideway route miles than heavy and light rail, making it very hard to accurately project total guideway route miles for all rail modes; therefore, the historical trend line is not provided.

Exhibit 9-24 Projection of Guideway Route Miles by Scenario

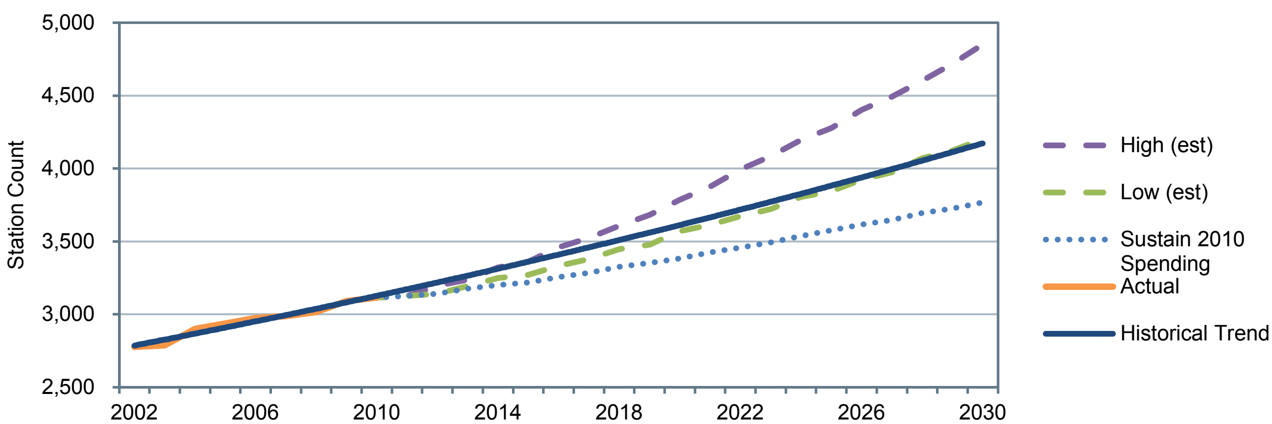


Note: Data through 2010 are actual; data after 2010 are estimated based on trends.

Source: Transit Economic Requirements Model.

TERM's expansion projections of stations by scenario needed to preserve existing transit assets at a condition rating of 2.5 or higher and expand transit service capacity to support differing levels of ridership growth (while passing TERM's benefit-cost test) are presented *Exhibit 9-25*, along with the historical trend. TERM's **Low Growth** estimates generally are in line with the historical trend, indicating that expansion projects of stations under the **Low Growth** scenario could maintain current transit conditions.

Exhibit 9-25 Projection of Stations by Scenario

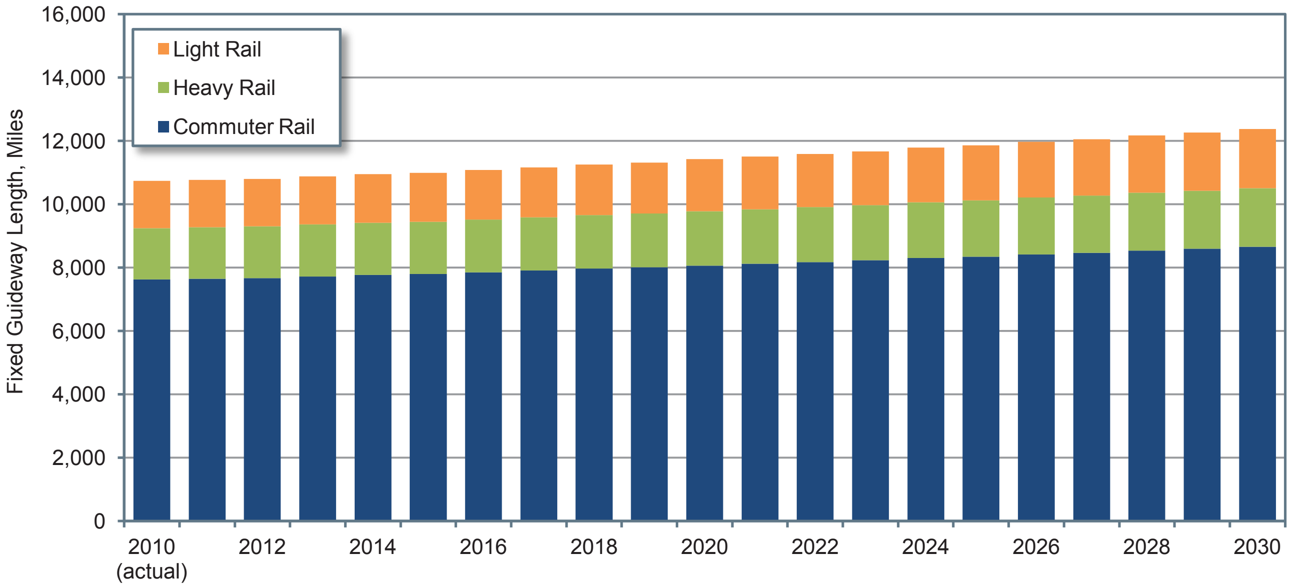


Note: Data through 2010 are actual; data after 2010 are estimated based on trends.

Source: Transit Economic Requirements Model.

For each of the various scenarios, TERM estimates future investment in fleet size, guideway route miles, and stations for each of the next 20 years. *Exhibit 9-26* presents TERM's projection for total fixed guideway route miles under a **Low Growth** scenario by rail mode. TERM projects different investment needs for each year that is added to the year 2010 actual total stock. Heavy rail's share of the projected annual fixed guideway route miles remains relatively constant over the 20-year period, while the amount of fixed guideway route miles increases slightly for light and commuter rail.

Exhibit 9-26 Stock of Fixed Guideway Miles by Year Under Low Growth Scenario, 2010–2030



Source: Transit Economic Requirements Model.