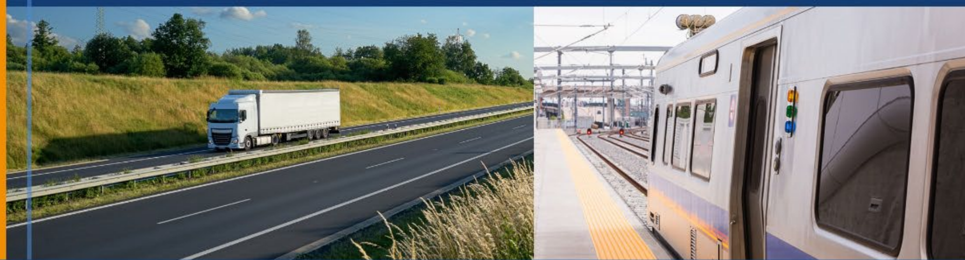


CHAPTER 7: Capital Investment Scenarios

Capital Investment Scenarios – Highways

This section presents a set of future highway investment scenarios covering the 20-year period ending in 2036. Later in this chapter, transit investment scenarios are explored. **All of these scenarios are illustrative, and none is endorsed as a target level of funding.**

Each scenario includes projections for system conditions and performance based on simulations using the Highway Economic Requirements System (HERS) and National Bridge Investment Analysis System (NBIAS). Together, the scopes of the two models cover spending on highway expansion and pavement improvements on Federal-aid highways (HERS) and spending on bridge rehabilitation on all roads (NBIAS). Each scenario scales up the total amount of simulated investment to account for other types of capital improvements that are outside the scopes of the two models, and for which limited information is available on the benefits of costs of individual investments. Such "nonmodeled" investments (sometimes called "other" in the exhibits) account for 29.7 percent of the spending in each scenario, consistent with the estimated share of total capital spending directed toward these investments for 2012 through 2016.

The future investment scenarios presented in this chapter build on analyses of alternative levels of future investment in highways and bridges, presented in Chapter 10. Supplemental analyses relating to these scenarios, including comparisons with the investment levels presented for comparable scenarios in previous C&P Reports, are the subject of Chapter 8. A series of sensitivity analyses that explore the implications of alternative technical assumptions for the scenario investment levels is presented in Chapter 9.

KEY TAKEAWAYS

- Three illustrative 20-year scenarios are considered: Sustain Recent Spending, Maintain Conditions and Performance, and Improve Conditions and Performance. Each scenario relates to total highway capital spending by all levels of government combined and the private sector, in constant 2016 dollars.
- Each scenario includes components modeled in HERS and NBIAS (for which a benefit-cost ratio can be computed) and a nonmodeled component (for which insufficient information is available to compute a benefit-cost ratio). The nonmodeled component represents 29.7 percent of the total value of each scenario, consistent with spending in recent years for these types of improvements. The Improve Conditions and Performance scenario assumes funding would be provided for all projects that meet or exceed a benefit-cost ratio of 1.0 (plus a scaling factor to add funding for nonmodeled improvement types). This would require an average annual investment of $165.9 billion.
- Approximately 30.5 percent of the investment required under the Improve Conditions and Performance scenario would go toward addressing an existing backlog of cost-beneficial investments of $1.01 trillion. The rest would address new needs arising from 2017 through 2036.
- Achieving the objectives of the Maintain Conditions and Performance scenario is estimated to cost $98.0 billion per year, 8.3 percent less than the $106.9 billion per year that would be needed to sustain spending at its recent (2012–2016) average level. In other words, sustaining spending at recent levels would be sufficient to lead to improvements in average pavement ride quality and reductions in the percentage of bridges in poor condition.

Scenarios Selected for Analysis

This section examines three spending scenarios based on capital investment by all levels of government combined. **The question of what portion should be funded by the Federal government, State governments, local governments, or the private sector is beyond the scope of this report.** Analyses were conducted for the entire public road network (titled "Systemwide" in the exhibits). Additional details on the impacts of alternative investment levels on system subsets, including Federal-aid highways, the National Highway System (NHS), and the Interstate System, are presented in Chapter 10.

Changes in Scenario Definitions Relative to the 23rd C&P Report

Recent editions of this report have included scenarios projecting the impact of sustaining investment at base-year levels in constant-dollar terms. For example, the 23rd C&P Report included a Sustain 2014 Spending scenario. One issue with this approach was that spending levels in a single base year could be influenced by one-time events, and might not be representative of typical annual spending. This edition replaces those scenarios with a Sustain Recent Spending scenario, based on average annual spending over 5 years (2012–2016) converted to base-year (2016) constant dollars. This approach is expected to smooth out annual variations and make the scenarios more consistent between editions of this report.

The remaining scenarios presented in this edition are consistent with those presented in the 23rd edition.

As discussed in the Introduction to Part II, combined highway capital spending by all levels of government for 2012 through 2016 averaged $106.9 billion per year, in constant 2016 dollars. The objective of the Sustain Recent Spending scenario is to predict the impact on highway conditions and performance after 20 years, if highway capital spending remains constant (adjusted for inflation) at this level over that period.

The Maintain Conditions and Performance scenario seeks to identify the level of investment needed to keep overall system conditions and performance unchanged after 20 years. The Improve Conditions and Performance scenario seeks to identify the level of investment needed to address all potential investments estimated to be cost-beneficial. *Exhibit 7-1* describes the derivation of each of these scenarios in greater detail.

Exhibit 7-1 ■ Capital Investment Scenarios for Highways and Bridges and Derivation of Components

Scenario Component	Sustain Recent Spending Scenario	Maintain Conditions and Performance Scenario	Improve Conditions and Performance Scenario	State of Good Repair Benchmark
HERS-Derived	Sustain spending on types of capital improvements modeled in HERS at the average level over the last 5 years in constant dollar terms over the next 20 years.	Set spending at the lowest level at which (1) projected average IRI in 2036 matches (or is better than) the value in 2016 and (2) projected average delay per VMT in 2036 matches (or is better than) the value in 2016.	Set spending at the level sufficient to fund all cost-beneficial potential projects (i.e., those with a benefit-cost ratio greater than or equal to 1.0).	Subset of Improve Conditions and Performance scenario; includes spending on system rehabilitation; excludes spending on system capacity.
NBIAS-Derived	Sustain spending on types of capital improvements modeled in NBIAS at the average level over the last 5 years in constant dollar terms over the next 20 years.	Set spending at the level at which the projected percentage of deck area on bridges in poor condition in 2036 matches that in 2016.	Set spending at the level sufficient to fund all cost-beneficial potential projects.	Includes all NBIAS-derived spending included in the Improve Conditions and Performance scenario.
Other (Nonmodeled)	Sustain spending on types of capital improvements not modeled in HERS or NBIAS at the average level over the last 5 years in constant dollar terms over the next 20 years.	Set spending at the level necessary so that the nonmodeled share of total highway and bridge investment over the next 20 years will remain the same as over the last 5 years in constant dollar terms.	Set spending at the level necessary so that the nonmodeled share of total highway and bridge investment over the next 20 years will remain the same as over the last 5 years in constant dollar terms.	Subset of Improve Conditions and Performance scenario; includes spending on system rehabilitation; excludes spending on system capacity and system enhancement.

Note: NBIAS is National Bridge Investment Analysis System; IRI is International Roughness Index; VMT is vehicle miles traveled.

Exhibit 7-1 also references a critical subset of the Improve Conditions and Performance scenario: the State of Good Repair benchmark. This benchmark represents the level of investment necessary to address all cost-beneficial investments to improve the physical conditions of existing highway infrastructure assets without improvements to system capacity or system enhancements.

The projections for conditions and performance in each scenario are estimates of what could be achieved with a given level of investment assuming an economically driven approach to project selection. (The project selection method is explained in Chapter 10.) The projections do not necessarily represent what would be achieved given current decision-making practices, which may include non-economic criteria such as geographic equity considerations, the readiness of projects to proceed to construction, the inclusion of projects on existing long-term improvement plans, and State or local policies that preclude some types of projects from being built in certain locations. Consequently, comparing the relative conditions and performance outcomes across the different scenarios might be more illuminating than focusing on specific projections for each scenario individually.

Scenario Spending Levels and Sources

Exhibit 7-2 summarizes capital investment levels associated with each 20-year scenario and benchmark, stated in constant 2016 dollars. The Sustain Recent Spending scenario fixes average annual investment at its 5-year (2012 to 2016) average level of $106.9 billion, resulting in total investment of greater than $2.1 trillion over 20 years.

Exhibit 7-2 ■ Highway Capital Investment Levels, by Scenario

Scenario and Comparison Parameter	Capital Investment for 2017 through 2036 (Billions of $2016)		Percent Difference Relative to Recent Spending	Investment Pattern
	20-year Total	Average Annual		
Sustain Recent Spending Scenario	$2,138.9	**$106.9**	0.0%	Flat
Maintain Conditions and Performance Scenario	$1,960.7	**$98.0**	-8.3%	Flat
Improve Conditions and Performance Scenario	$3,318.5	**$165.9**	55.2%	Variable
State of Good Repair Benchmark*	$2,093.3	**$104.7**		

*The estimated spending under this benchmark is a subset of the estimated spending under the Improve Conditions and Performance Scenario.

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

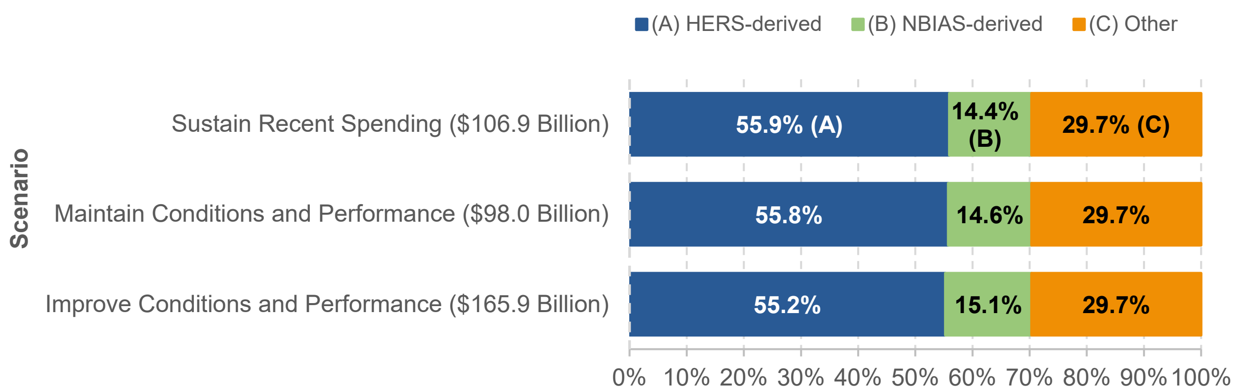
The estimated level of annual investment needed to achieve the objectives of the Maintain Conditions and Performance scenario is $98.0 billion, 8.3 percent less than the Sustain Recent Spending scenario level. This suggests that recent levels of investment would be sufficient to keep overall conditions and performance from worsening over time. However, some individual measures of conditions and performance (aside from those specifically targeted by the scenario definition) would likely improve over 20 years, whereas others would likely see some deterioration. Also, because this scenario is focused on maintaining the average state of the overall system, it may result in a combination of improvements and deterioration of subsets of the overall network.

Achieving the objectives of the Improve Conditions and Performance scenario would require an estimated average annual spending level of $165.9 billion, which exceeds the Sustain Recent Spending scenario level by 55.2 percent. Because there is an existing backlog of cost-beneficial investments that have not previously been addressed, the Improve Conditions and Performance scenario results in higher levels of investment in the early years of the analysis and lower levels in the later years. This frontloaded investment pattern is discussed in greater detail in Chapter 10. The total needed to address both the existing backlog and additional cost-beneficial investments required over the next 20 years is estimated to be approximately $3.3 trillion; the backlog is quantified later in this section.

The average annual investment level associated with the State of Good Repair benchmark is $104.7 billion, which is the total amount of investment in pavement and bridge rehabilitation that is projected to be cost-beneficial. This benchmark is the rehabilitation portion of the investment in the Improve Conditions and Performance scenario. In determining the level of investment under this benchmark, HERS and NBIAS screen out, through benefit-cost analysis, any assets that might have outlived their original purpose, rather than automatically reinvesting in all assets in perpetuity. With national consensus lacking on exactly what constitutes a "state of good repair" for highway assets, alternative benchmarks with different objectives could be equally valid from a technical perspective.

The sources of the estimates of average annual investment levels are presented in *Exhibit 7-3*. The HERS-derived component is fairly consistent at 55 percent to 56 percent of each scenario. It accounts for most of the total investment in each scenario and represents spending on pavement rehabilitation and capacity expansion on Federal-aid highways.

Exhibit 7-3 ■ Source of Estimates for Highway Capital Investment Scenarios, by Model



Note: NBIAS is National Bridge Investment Analysis System; HERS is Highway Economic Requirements System.
Sources: Highway Economic Requirements System and National Bridge Investment Analysis System.

Key Limitations of the HERS Model

The HERS model relies on various assumptions about travel behavior and associated travel costs as well as the benefits and costs of infrastructure improvements. Research is conducted on an ongoing basis to assess the accuracy of these assumptions, and when possible the HERS model assumptions are adjusted to more accurately reflect real-world dynamics. Substantial changes in the HERS model assumptions from those used in the 23rd C&P Report are described in Appendix A.

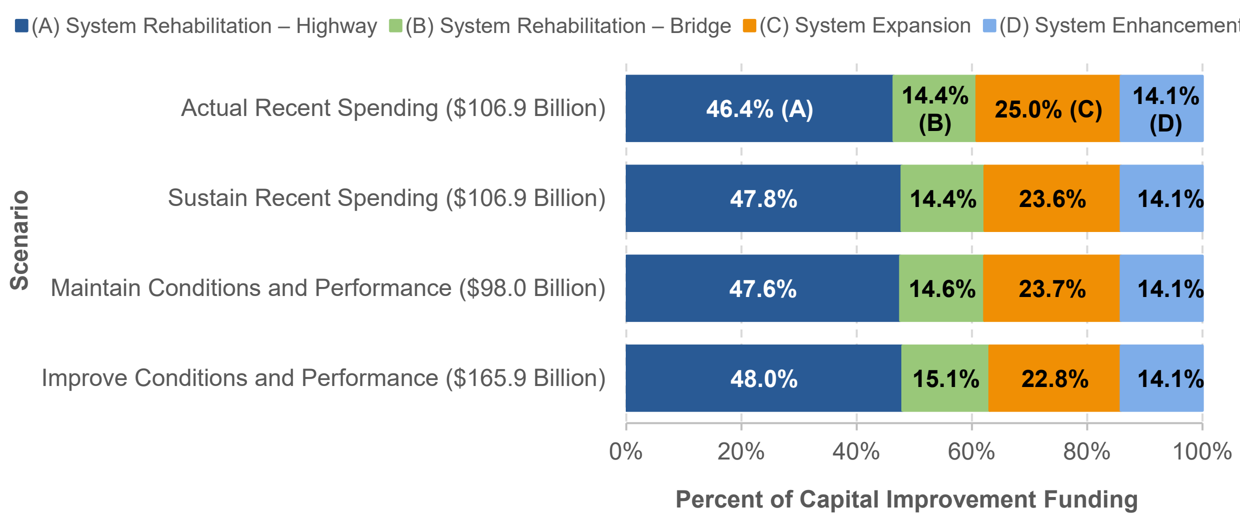
The NBIAS-derived component represents rehabilitation spending on all bridges, including those not on Federal-aid highways. Other (nonmodeled) spending, which accounted for 29.7 percent of total investment in 2016, is assumed to comprise the same share in all systemwide scenarios. The nonmodeled share includes most expenditures on roads not classified as Federal-aid highways (the HERS analysis is limited to Federal-aid highways only) and expenditures on all roads classified in Chapter 2 as system enhancements (safety enhancements, traffic operation improvements, and environmental enhancements). As discussed in the Introduction to Part II, the nonmodeled share is much lower for major system subsets, such as Federal-aid highways, the NHS, and Interstate highways.

Systemwide Scenario Spending Patterns and Conditions and Performance Projections

Exhibit 7-4 compares the distributions from each scenario for investment spending by improvement type with the actual recent spending distribution from 2012 to 2016. Comparing the Sustain Recent Spending scenario to the actual recent spending distribution, HERS modeling results support less spending on system expansion and more spending on highway rehabilitation in the future than currently occurs. At the higher levels of spending attempted in the Improve Conditions and Performance scenario, the modeling results suggest devoting a greater share of investment to both highway and bridge system rehabilitation relative to highway system expansion.

In the Improve Conditions and Performance scenario, annual spending on highway and bridge rehabilitation averages $104.7 billion, considerably more than the $65.1 billion of such annual spending from 2012 to 2016. This result suggests that achieving a state of good repair on the Nation's highways by implementing cost-beneficial system rehabilitation improvements would require either a significant increase in overall highway and bridge investment or a significant redirection of investment from other types of improvements toward system rehabilitation (the latter of which could involve prioritizing rehabilitation improvements over more cost-beneficial expansion investments).

Exhibit 7-4 ■ Systemwide Highway Capital Investment Scenarios, 2017–2036: Distribution by Capital Improvement Type Compared with Actual Recent Spending

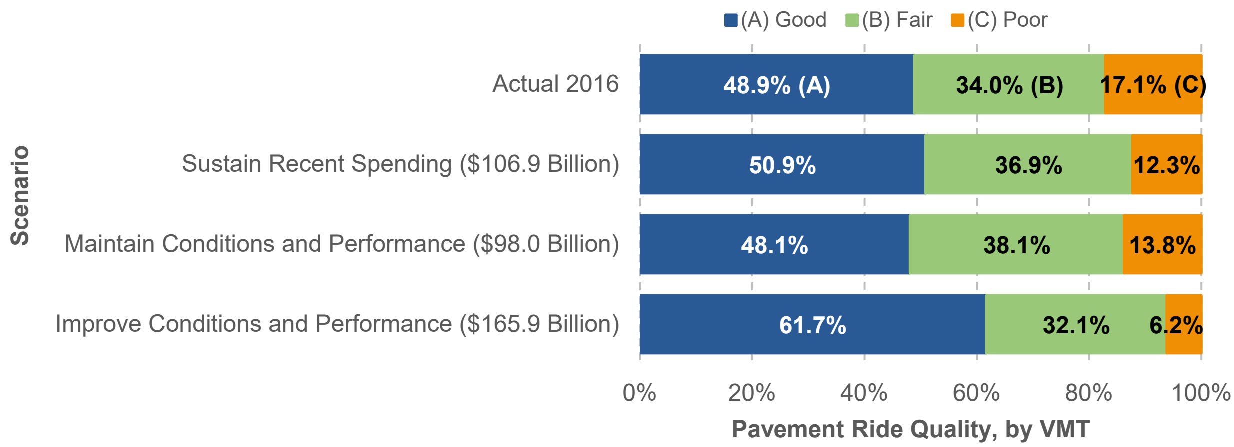


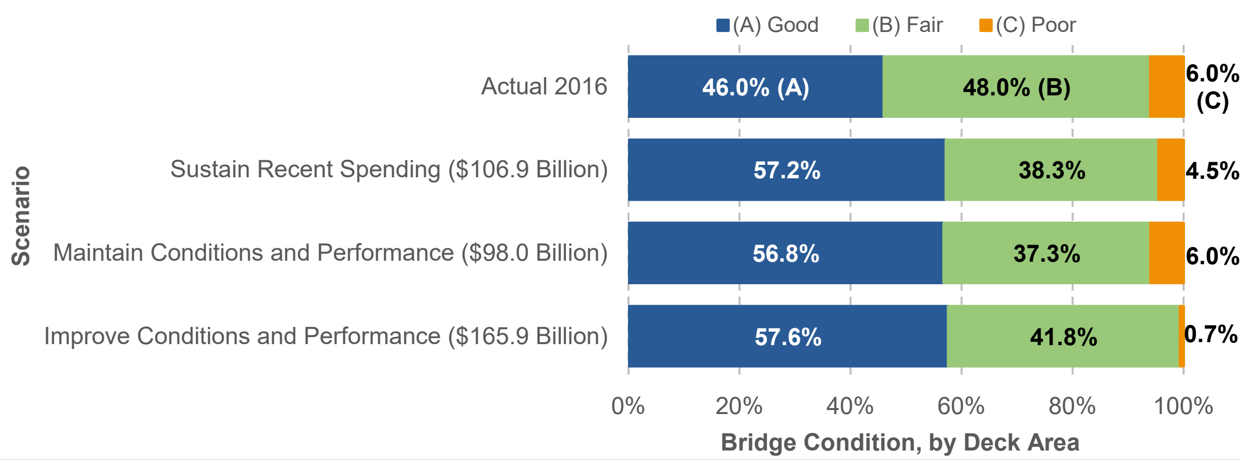
Average Annual Distribution by Capital Improvement Type (Billions of 2016 Dollars)				
Capital Improvement Type	**Actual Recent Spending Distribution**	**Sustain Recent Spending Scenario**	**Maintain Conditions & Performance Scenario**	**Improve Conditions & Performance Scenario**
System Rehabilitation – Highway	$49.7	$51.1	$46.6	$79.6
System Rehabilitation – Bridge	$15.4	$15.4	$14.3	$25.1
System Rehabilitation – Total	**$65.1**	**$66.5**	**$60.9**	**$104.7**
System Expansion	$26.8	$25.3	$23.2	$37.8
System Enhancement	$15.1	$15.1	$13.9	$23.5
Total, All Improvement Types	**$106.9**	**$106.9**	**$98.0**	**$165.9**

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

Exhibit 7-5 presents conditions and performance indicators for all systemwide scenarios. This information can also be found in various tables in Chapter 10, along with additional indicators for a wider range of alternative funding levels. Because HERS considers only Federal-aid highways, the indicators for the Federal-aid highway scenarios are presented in place of indicators for all roads in *Exhibit 7-5*. In contrast, NBIAS considers bridges on all roads.

Exhibit 7-5 ■ Systemwide Highway Capital Investment Scenarios, 2017–2036: Projected Impacts on Selected Highway Performance Measures





Highway Performance Measure	Actual 2016 Values	Sustain Recent Spending Scenario	Maintain Conditions & Performance Scenario	Improve Conditions & Performance Scenario
Pavement Ride Quality and Bridge Conditions (Good/Fair/Poor)				
Percent of VMT on pavements with good ride quality[1]	48.9%	50.9%	48.1%	61.7%
Percent of VMT on pavements with fair ride quality[1]	34.0%	36.9%	38.1%	32.1%
Percent of VMT on pavements with poor ride quality[1]	17.1%	12.3%	13.8%	6.2%
Percent of bridges rated as good condition, by deck area	46.0%	57.2%	56.8%	57.6%
Percent of bridges rated as fair condition, by deck area	48.0%	38.3%	37.3%	41.8%
Percent of bridges rated as poor condition, by deck area	**6.0%**	4.5%	**6.0%**	0.7%
Projected Changes by 2036 Relative to 2016 for Selected Indicators				
Percent change in average IRI (VMT-weighted)[1]	0.0%	-3.2%	**0.0%**	-16.4%
Percent change in average delay per VMT[1]	0.0%	-25.7%	-24.8%	-28.8%

Note: HPMS is Highway Performance Monitoring System; VMT is vehicle miles traveled; IRI is International Roughness Index.

[1] The HERS indicators shown apply only to Federal-aid highways as HPMS sample data are not available for rural minor collectors, rural local, or urban local roads.

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

VMT-Weighting vs. Deck Area-Weighting

The performance indicators presented in Exhibit 7-5 were drawn from the more detailed analysis of the impacts of alternative investment levels presented in Chapter 10. The pavement and delay statistics presented in terms of VMT were derived from HERS; the bridge condition statistics weighted by deck area were derived from NBIAS. Although weighting by use is more relevant from an economic perspective, FHWA has traditionally reported bridge performance statistics on a deck area-weighted basis rather than weighting by average daily traffic. Under the PM-2 rule referenced in the Introduction to Part I and Chapter 6, States set performance targets for pavements on a lane mile-weighted basis and performance targets for bridges on a deck area-weighted basis. For consistency purposes, future C&P reports will place a greater emphasis on lane-mile weighted measures for pavements.

Under the Sustain Recent Spending scenario, the share of vehicle miles traveled (VMT) on Federal-aid highways with poor ride quality would be reduced from 17.1 percent in 2016 to 12.3 percent in 2036, whereas the share on pavements with good ride quality would rise slightly from 48.9 percent to 50.9 percent. The average International Roughness Index (IRI) value would decrease (improve) by 3.2 percent in 2036 relative to 2016, whereas average delay per VMT would decrease (improve) by 25.7 percent. The share of bridges (weighted by deck area) that are rated as poor would drop from 6.0 percent in 2016 percent to 4.5 percent in 2036, while the share rated as good would rise from 46.0 percent to 57.2 percent.

The cells shaded in *Exhibit 7-5* are the values relevant to the definition of the Maintain Conditions and Performance scenario. The cell showing 6.0 percent of bridges (as measured by deck area) rated in poor condition in 2036 is highlighted, as it matches the actual value for that metric in 2016. The cell showing that the average change in VMT-weighted IRI is 0.0 percent is highlighted, showing that this metric is unchanged relative to the actual 2016 value.

Under the Improve Conditions and Performance scenario, the share of VMT on Federal-aid highways with poor ride quality would be reduced to 6.2 percent in 2036, whereas the share on pavements with good ride quality would rise to 61.7 percent. Average IRI would decrease (improve) by 16.4 percent over the 20-year period, whereas the average delay per VMT would decrease (improve) by 28.8 percent. The share of bridges (weighted by deck area) that are rated in poor condition is projected to drop to 0.7 percent in 2036, whereas the share rated as good would rise to 57.6 percent.

Improve Conditions and Performance Scenario

The manner in which the Improve Conditions and Performance scenario is constructed makes it easier to drill down further into the results than is the case for the Maintain Conditions and Performance scenario. For example, looking at the Maintain Conditions and Performance scenario output on a functional class basis could be misleading, as conditions and performance could improve on some functional classes while declining on others. Thus, the investment levels identified for each functional class on a systemwide analysis would differ from those obtained by separately analyzing each functional class. This limitation does not apply to the Improve Conditions and Performance scenario: since the objective of the scenario is to make all cost-beneficial investments, one would obtain the same result for each functional class whether analyzed separately or as part of a systemwide run.

Spending by System and by Capital Improvement Type

Exhibit 7-6 compares the distribution of spending for the Improve Conditions and Performance scenario by system and by capital improvement type against the actual recent spending distribution. As noted in Chapter 1, the Interstate Highway System is a subset of the NHS, which is a subset of Federal-aid highways, which is a subset of the overall highway network (all roads).

A total of 50.4 percent of the Improve Conditions and Performance scenario spending goes for improvements to the NHS, while 25.2 percent goes for improvements to Interstate highways.

The Improve Conditions and Performance scenario would increase spending for all systems and capital improvement types shown in *Exhibit 7-6* relative to the actual recent (2012 to 2016) spending amounts. Overall spending on all capital improvement types for Interstate highways under the Improve Conditions and Performance scenario is 76.7 percent higher than actual recent spending; overall spending on the NHS is 48.8 percent higher under this scenario than actual recent spending.

For each system identified in *Exhibit 7-6*, the largest gap between average annual spending under the Improve Conditions and Performance scenario and the Sustain Recent Spending scenario is for bridge system rehabilitation. The $9.5 billion in average annual bridge system rehabilitation needs identified under the Improve Conditions and Performance scenario for Interstate highways is 174.1 percent higher than actual spending in this category from 2012 to 2016.

Exhibit 7-6 ■ Improve Conditions and Performance Scenario, 2017–2036: Distribution by System and Capital Improvement Type Compared with Recent Spending

System Component	System Rehabilitation			System Expansion	System Enhancement	Total	Percent of Total
	Highway	Bridge	Total				
Average Annual Investment in Billions of 2016 Dollars							
Interstate Highway System	$16.8	$9.5	$26.3	$12.4	$3.0	$41.7	25.2%
National Highway System	$37.1	$14.9	$51.9	$23.7	$8.0	$83.6	50.4%
Federal-aid Highways	$60.2	$20.7	$80.8	$31.5	$14.3	$126.7	76.3%
All Roads	$79.6	$25.1	$104.7	$37.8	$23.5	$165.9	100.0%
Percentage that the Improve Conditions and Performance Scenario is Above (positive %) or Below (negative %) Average Recent Annual Investment							
Interstate Highway System	36.2%	174.1%	66.3%	103.7%	76.7%	76.7%	
National Highway System	43.6%	93.5%	55.0%	36.7%	48.8%	48.8%	
Federal-aid Highways	62.0%	83.3%	67.0%	38.8%	58.0%	58.0%	
All Roads	60.3%	62.7%	60.9%	41.2%	55.2%	55.2%	

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

Spending by Improvement Type and Highway Functional Class

Exhibit 7-7 presents the distribution by improvement type and highway functional class for the Improve Conditions and Performance scenario compared with the Sustain Recent Spending scenario for Federal-aid highways.

Moving to a finer level of detail in the analysis tends to reduce the reliability of simulation results from HERS and NBIAS, so the results presented in this exhibit should be viewed with caution. Nevertheless, the patterns suggest certain directions in which spending patterns would need to change for scenario goals to be achieved. The scenarios can feature shifts in spending across highway functional classes, and in highway spending between rehabilitation and expansion, because the modeling frameworks determine allocations through benefit-cost optimization.

The Improve Conditions and Performance scenario suggests that the largest funding gaps (in percentage terms) relative to actual recent (2012 to 2016) spending are for bridge rehabilitation on the rural portion of the Interstate System (475.6 percent), highway system rehabilitation on urban other freeway and expressways (168.2 percent), and system expansion for urban other freeways and expressways (155.0 percent).

Exhibit 7-7 ■ Improve Conditions and Performance Scenario for Federal-aid Highways: Distribution of Average Annual Investment, 2017–2036, Compared with Actual Recent Spending by Functional Class and Improvement Type

Functional Class	System Rehabilitation			System Expansion	System Enhancement	Total
	Highway	Bridge	Total			
Rural Arterials and Major Collectors						
Interstate	$5.3	$2.7	$8.0	$1.4	$1.0	$10.4
Other Principal Arterial	$5.1	$1.4	$6.5	$1.1	$1.2	$8.8
Minor Arterial	$3.5	$1.1	$4.5	$0.4	$1.0	$6.0
Major Collector	$3.7	$2.1	$5.8	$0.3	$1.1	$7.2
Subtotal	**$17.5**	**$7.4**	**$24.9**	**$3.2**	**$4.3**	**$32.3**
Urban Arterials and Collectors						
Interstate	$11.6	$6.7	$18.3	$11.0	$1.7	$31.0
Other Freeway and Expressway	$5.0	$1.6	$6.6	$5.4	$1.2	$13.2
Other Principal Arterial	$10.8	$2.4	$13.2	$5.1	$3.0	$21.3
Minor Arterial	$10.0	$1.8	$11.7	$4.6	$2.3	$18.7
Collector	$5.3	$0.8	$6.1	$2.2	$1.8	$10.1
Subtotal	**$42.6**	**$13.3**	**$55.9**	**$28.3**	**$10.1**	**$94.3**
Total, Federal-aid highways[1]	**$60.2**	**$20.7**	**$80.8**	**$31.5**	**$14.3**	**$126.7**

Percent Above Actual Recent Capital Spending on Federal-aid Highways by All Levels of Government Combined

Functional Class	System Rehabilitation			System Expansion	System Enhancement	Total
	Highway	Bridge	Total			
Rural Arterials and Major Collectors						
Interstate	20.3%	475.6%	64.9%	-9.7%	58.0%	47.9%
Other Principal Arterial	6.6%	121.0%	20.4%	-69.2%	58.0%	-9.3%
Minor Arterial	17.4%	28.9%	19.9%	-68.4%	58.0%	3.9%
Major Collector	8.3%	101.4%	29.9%	-61.1%	58.0%	21.7%
Subtotal	**12.9%**	**144.6%**	**34.3%**	**-55.3%**	**58.0%**	**14.0%**
Urban Arterials and Collectors						
Interstate	44.9%	126.0%	66.9%	142.4%	58.0%	87.0%
Other Freeway and Expressway	168.2%	119.8%	154.6%	155.0%	58.0%	141.4%
Other Principal Arterial	103.3%	-5.3%	68.5%	-1.7%	58.0%	42.7%
Minor Arterial	162.6%	37.8%	131.1%	92.8%	58.0%	108.7%
Collector	100.4%	7.5%	79.4%	65.6%	58.0%	72.1%
Subtotal	**97.4%**	**61.0%**	**87.3%**	**81.8%**	**58.0%**	**82.1%**
Total, Federal-aid highways[1]	**62.0%**	**83.3%**	**67.0%**	**38.8%**	**58.0%**	**58.0%**

[1] 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.

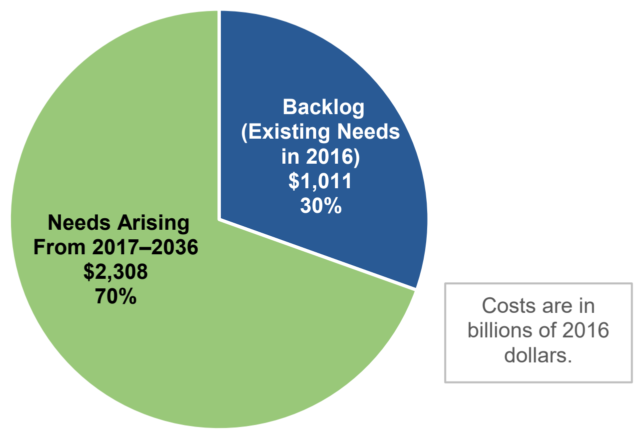
Sources: Highway Economic Requirements System and National Bridge Investment Analysis System.

Looking more broadly at the rural and urban portions of Federal-aid highways, the Improve Conditions and Performance scenario suggests that increasing investment for system rehabilitation on rural bridges by 144.6 percent (to $7.4 billion) could be cost beneficial. The Improve Conditions and Performance scenario also suggests that increasing investment for system rehabilitation on urban highways by 97.4 percent (to $42.6 billion) and increasing system expansion on urban highways and bridges by 81.8 percent (to $28.3 billion) could be economically justified.

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). Unlike NBIAS, HERS does not routinely produce rolling backlog figures over time as an output, but is equipped to do special analyses to identify the base-year backlog. Under this analysis, any potential improvement that would correct an existing pavement or capacity deficiency and that has a benefit-cost ratio greater than or equal to 1.0 is considered part of the current highway and bridge investment backlog.

Exhibit 7-8 ■ Composition of 20-year Improve Conditions and Performance Scenario, Backlog vs. Emerging Needs



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

Conceptually, the backlog represents a subset of the investment levels reflected in the Improve Conditions and Performance scenario. *Exhibit 7-2* identified an average annual investment level of $165.9 billion for this scenario, for a 20-year total of over $3.3 trillion. Of this total, just over $1.0 trillion (30.5 percent) is attributable to the existing backlog as of 2016, while the remainder is attributable to additional projected pavement, bridge, and capacity needs that might arise over the next 20 years (see *Exhibit 7-8*).

It should be noted that the procedures for estimating the backlog continue to be refined between C&P Report editions, so increases or decreases in the size of the estimated base-year backlog should not be interpreted as an indicator of changes in overall system conditions and performance.

Exhibit 7-9 presents an estimated distribution of the $1.0 trillion backlog estimated for 2016, by type of capital improvements. Similar to the process used to derive the capital investment scenario estimates, an adjustment factor was applied to the backlog values computed by HERS and NBIAS to account for nonmodeled capital improvement types. The values shown in blue italics are nonmodeled; NBIAS was used to compute the values in the System Rehabilitation – Bridge column and all other values in the table were derived from HERS.

Of the estimated more than $1.0 trillion total backlog, approximately $150.2 billion (14.9 percent) is for the Interstate System, $426.5 billion (42.2 percent) is for the NHS, and $773.9 billion (76.6 percent) is for Federal-aid highways.

The share of the total backlog attributable to system rehabilitation for the Interstate System is 60.6 percent, for the NHS is 65.4 percent, and for Federal-aid highways is 70.6 percent. For all roadways, approximately 68.0 percent ($687.4 billion) of the total backlog is attributable to system rehabilitation needs, 17.9 percent ($180.5 billion) is for system expansion, and 14.1 percent ($142.9 billion) for system enhancement.

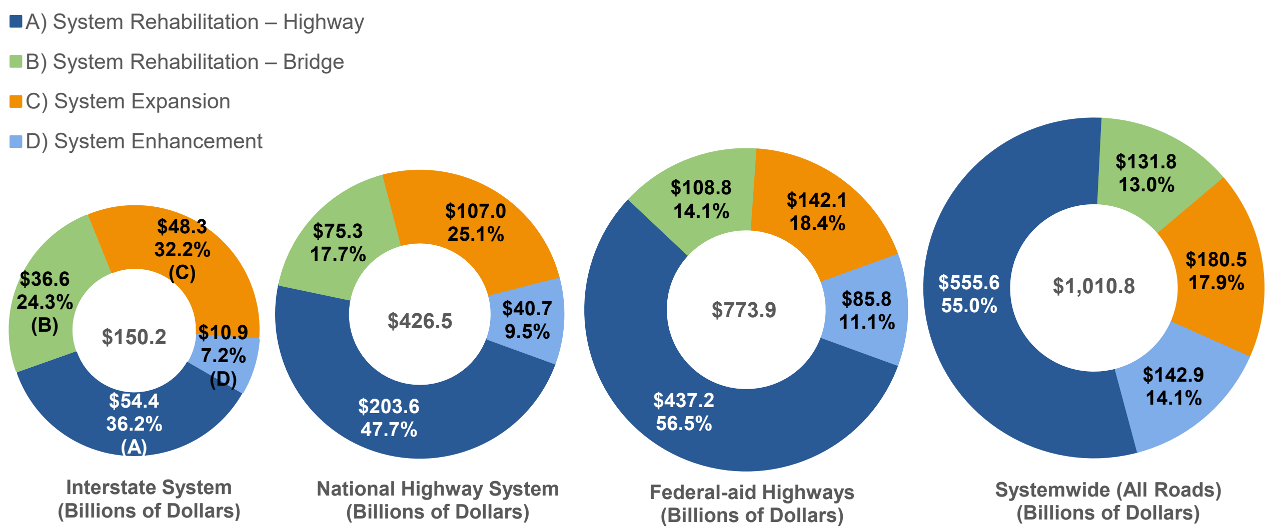
Why Does the Bridge Backlog Presented in Exhibit 7-9 Differ from Bridge Backlog Figures Estimated by Some Other Organizations?

One major reason for such differences is that the $131.8 billion backlog estimated by NBIAS is not intended to constitute an estimate of the complete bridge investment backlog. The NBIAS estimates relate only to investment needs associated with the condition of existing structures, and thus exclude capacity expansion needs. The backlog HERS estimates includes estimates of capacity-related needs for highways and bridges combined.

Some estimates of bridge backlog produced by other organizations do attempt to combine estimates of needs relating to bridge capacity with those relating to existing structures.

The over $1.0 trillion estimated backlog is weighted toward urban areas; approximately 58.8 percent of this total is attributable to Federal-aid highways in urban areas. As noted in Chapter 6, average pavement ride quality on Federal-aid highways is worse in urban areas than in rural areas; urban areas also face relatively greater problems with congestion than do rural areas. Very little of the backlog spending (just 1.1 percent) is targeted toward system expansion on rural Federal-aid highways.

Exhibit 7-9 ■ Estimated Highway and Bridge Investment Backlog, by System and Improvement Type, as of 2016



System Component	Billions of 2016 Dollars[1]						Percent of Total
	System Rehabilitation			System Expansion	System Enhancement	Total	
	Highway	Bridge	Total				
Federal-aid Highways – Rural	$108.4	$34.7	$143.1	$11.0	*$25.6*	$179.6	17.8%
Federal-aid Highways – Urban	$328.8	$74.2	$403.0	$131.1	*$60.3*	$594.3	58.8%
Federal-aid Highways – Total	**$437.2**	**$108.8**	**$546.0**	**$142.1**	***$85.8***	**$773.9**	**76.6%**
Non-Federal-aid Highways	*$118.4*	$22.9	$141.4	*$38.4*	*$57.1*	$236.8	23.4%
All Roads	**$555.6**	**$131.8**	**$687.4**	**$180.5**	**$142.9**	**$1,010.8**	**100.0%**
Interstate System	$54.4	$36.6	$91.0	$48.3	*$10.9*	$150.2	14.9%
National Highway System	$203.6	$75.3	$278.9	$107.0	*$40.7*	$426.5	42.2%

Note: NBIAS is National Bridge Investment Analysis System; HERS is Highway Economic Requirements System.

[1] Italicized values are estimates for those system components and capital improvement types not modeled in HERS or NBIAS, such as system enhancements and 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.

Capital Investment Scenarios – Transit

KEY TAKEAWAYS

The SGR backlog is expected to decrease marginally from an estimated $105.1 billion in 2016 to $102.2 billion in 2036, a 3.7 percent decrease. This is the first time FTA has estimated that the backlog is not growing at current investment levels ($11.6 billion average annual investment in preservation). An estimated $18.1 billion in annual reinvestment would be required to fully eliminate the SGR backlog by 2036.

In addition, the following investment levels in expansion would be required for the Low-Growth and High-Growth scenarios:

- Low-Growth scenario: This scenario forecasts $6.3 billion per year investment in new assets to accommodate an estimated annual ridership increase of 1.3 percent (20 percent below historical growth).
- High-Growth scenario: In this scenario, investments of $7.6 billion are needed to support a ridership increase of 1.8 percent per year (20 percent higher than historical growth).

Chapter 7 considers the impacts of varying levels of capital investment on transit conditions and performance. This chapter provides in-depth analysis of three specific investment scenarios: Sustain Recent Spending, Low Ridership Growth, and High Ridership Growth, along with the State of Good Repair benchmark for comparison, as outlined in *Exhibit 7-10*.

The State of Good Repair (SGR) benchmark considers the level of investment required to eliminate the existing capital investment backlog and the impact on condition from doing so. In contrast to the three investment scenarios considered here, the SGR benchmark considers only the preservation needs of existing transit assets; it does not consider expansion requirements. Moreover, the SGR benchmark does not require investments to pass TERM's benefit-cost test. Hence, it brings all assets to SGR regardless of TERM's assessment of whether reinvestment is warranted, and should thus be considered illustrative rather than as a subset of the primary investment scenarios.

The Sustain Recent Spending scenario assesses the expected impact on asset conditions and system performance if annual reinvestment expenditures are sustained at their recent 5-year average (2012–2016) over the next 20 years.[24] For this report, recent expenditure levels are roughly in line with the level of investment required to maintain asset conditions and performance at current levels. Both the Low-Growth and High-Growth scenarios assess the required levels of reinvestment to (1) preserve existing transit assets at a condition rating of 2.5 or higher and (2) expand transit service capacity to support differing levels of ridership growth while passing the Transit Economic Requirements Model's (TERM's) benefit-cost test.

The State of Good Repair (SGR) benchmark considers the level of investment required to eliminate the existing capital investment backlog and the condition of doing so. In contrast to the three investment scenarios considered here, the SGR benchmark considers only the preservation needs of existing transit assets (it does not consider expansion requirements). Moreover, the SGR benchmark does not require investments to pass TERM's benefit-cost test. Hence, it brings all assets to SGR regardless of TERM's assessment of whether reinvestment is warranted.

TERM's estimates for capital expansion needs in the scenarios are driven by the projected growth in passenger miles traveled (PMT), calculated as the compound average annual PMT growth by FTA region, urbanized area (UZA) stratum, and mode over the most recent 15-year period. For example, all bus operators located in the same FTA region in UZAs of the same population stratum are assigned

[24] In prior reports, this scenario tied preservation and expansion spending to the most recent reporting year (in this case, 2016). For this report, the Sustain Recent Spending scenario has been modified to tie to inflation-adjusted annual average preservation and expansion spending for the most recent 5-year period reported to the National Transit Database (NTD; 2012–2016). This 5-year annual average helps smooth year-to-year variations in spending while limiting the analysis to more recent program funding levels.

the same growth rate. Use of the 10 FTA regions captures regional differences in PMT growth, whereas use of population strata (greater than 1 million; 1 million to 500,000; 500,000 to 250,000; and less than 250,000) captures differences in urban area size. Perhaps more importantly, the approach also recognizes differences in PMT growth trends by transit mode. Over the past decade, the rate of PMT growth has differed markedly across transit modes: highest for heavy rail, vanpool, and demand-response, and low to flat for motor bus. These differences are accounted for in the expansion need projections for the Low-Growth and High-Growth scenarios.

Exhibit 7-10 ■ SGR Benchmark and Transit Investment Scenarios

Scenario Aspect	SGR	Sustain Recent Spending	Low Growth	High Growth
Description	Level of investment to attain and maintain SGR over the next 20 years (no assessment of expansion needs)	Sustain preservation and expansion spending at recent levels (average from 2012–2016) over the next 20 years	Preserve existing assets and expand the asset base to support historical average annual rate of annual ridership growth less 0.3%, which equals 1.2%	Preserve existing assets and expand the asset base to support historical average annual rate of ridership growth plus 0.3%, which equals 1.8%
Objective	Requirements to attain SGR (as defined by assets in condition 2.5 or better)	Assess impact of constrained funding on condition, SGR backlog, and ridership capacity	Assess unconstrained preservation and capacity expansion needs assuming low ridership growth	Assess unconstrained preservation and capacity expansion needs assuming high ridership growth
Apply Benefit-cost Test?	No	Yes[1]	Yes	Yes
Preservation?	Yes[2]	Yes[2]	Yes[2]	Yes[2]
Expansion?	No	Yes	Yes	Yes

[1] To prioritize investments under constrained funding.

[2] Replace at condition 2.5.

Source: Transit Economic Requirements Model (TERM).

Exhibit 7-11 summarizes the analysis results for each scenario and benchmark. Note that all three scenarios and the SGR benchmark impose the same asset condition replacement threshold (i.e., assets are replaced at condition rating of 2.5 when budget is sufficient) when assessing transit reinvestment needs. Hence, the differences in the total preservation expenditure amounts across each scenario primarily reflect the impact of either (1) an imposed budget constraint (Sustain Recent Spending scenario) or (2) application of TERM's benefit-cost test. (The SGR benchmark does not apply the benefit-cost test.) A brief review of the national-level needs analysis in *Exhibit 7-11* reveals the following:

- **SGR benchmark:** The level of expenditures required to immediately attain and then to maintain SGR over the upcoming 20 years, which would cover preservation needs but excludes expansion investments, is roughly 50 percent higher than that currently expended on asset preservation. The SGR benchmark is valuable in evaluating the gap between existing funding capacity and the level of investment required to quickly attain and maintain an optimal SGR (i.e., condition 2.5).
- **Sustain Recent Spending scenario:** Total preservation spending under this scenario is well below that of the SGR benchmark and the other scenarios, indicating that sustaining recent spending levels is insufficient to attain the backlog elimination of the SGR benchmark and ridership growth objectives of the Low-Growth scenario, or the High-Growth scenario. In this report, FTA estimates that recent capital reinvestment levels are roughly sufficient to maintain the current size of the SGR backlog, whereas the recent level of expansion investments is marginally below that required to support expected ridership growth.
- **Low-Growth and High-Growth scenarios:** The level of investment to address expected preservation and expansion needs is estimated to be roughly 23 to 30 percent higher than that currently expended by the Nation's transit operators. Preservation and expansion needs are

highest for UZAs exceeding 1 million in population. (These UZAs are listed in Chapter 1, *Exhibit 1-16*.)

The following subsections present greater detail on the assessments for each scenario.

Exhibit 7-11 ■ Annual Average Cost by Investment Scenario, 2016–2036

Mode, Purpose, and Asset Type	SGR Benchmark	Sustain Recent Spending	Low Growth	High Growth
Urbanized Areas Over 1 Million in Population[1]				
Nonrail[2]				
Preservation	$5.2	$3.6	$4.4	$4.4
Expansion	NA	$0.4	$0.3	$0.7
Subtotal Nonrail[3]	$5.2	$4.0	$4.7	$5.1
Rail				
Preservation	$11.2	$6.6	$11.1	$11.1
Expansion	NA	$6.4	$5.5	$6.4
Subtotal Rail[3]	$11.2	$13.0	$16.6	$17.5
Total, Over 1 Million in Population[3]	**$16.4**	**$17.0**	**$21.3**	**$22.6**
Urbanized Areas Under 1 Million in Population and Rural				
Nonrail[2]				
Preservation	$1.6	$1.3	$1.5	$1.5
Expansion	NA	$0.4	$0.4	$0.5
Subtotal Nonrail[3]	$1.6	$1.8	$1.9	$2.0
Rail				
Preservation	$0.1	$0.0	$0.0	$0.0
Expansion	NA	$0.0	$0.0	$0.0
Subtotal Rail[3]	$0.1	$0.0	$0.0	$0.0
Total, Under 1 Million and Rural[3]	**$1.7**	**$1.8**	**$1.9**	**$2.1**
Total Preservation	**$18.1**	**$11.6**	**$17.0**	**$17.1**
Total Expansion	**NA**	**$7.2**	**$6.3**	**$7.6**
Total[3]	**$18.1**	**$18.8**	**$23.2**	**$24.7**

[1] Includes 37 urbanized areas.

[2] Buses, vans, and other (including ferryboats).

[3] Dollar amounts are in billions. Note that totals may not sum due to rounding.

Source: Transit Economic Requirements Model.

Sustain Recent Spending Scenario

From 2012 to 2016, as reported to the NTD by transit agencies, transit operators spent an average of $18.8 billion annually on capital projects (see Chapter 10, Impact of Preservation Investments on Transit Backlog and Conditions section and the corresponding discussion). Of this amount, $11.6 billion was dedicated to preserving existing assets, whereas the remaining $7.2 billion was dedicated to investment in asset expansion—both to support ongoing ridership growth and to improve service performance. The Sustain Recent Spending scenario considers the expected impact on the long-term physical condition and service performance of the Nation's transit infrastructure if these average expenditure levels were to be sustained in constant-dollar terms through 2036.

TERM's funding allocation: The following analysis of the Sustain Recent Spending scenario relies on TERM's allocation of the recent preservation and expansion expenditures to the Nation's existing transit operators, their modes, and their assets over the upcoming 20 years, as depicted in *Exhibit*

7-12. As with other TERM analyses involving the allocation of constrained transit funds, TERM allocates limited funds based on the results of the model's benefit-cost analysis, which ranks potential investments based on their assessed benefit-cost ratios (with the highest-ranked investments funded first).

Exhibit 7-12 ■ Sustain Recent Spending Scenario: Average Annual Investment by Asset Type, 2016–2036

Asset Type	Average Annual Investment (Billions of 2016 Dollars)		
	Preservation	Expansion	Total
Rail			
Guideway Elements	$2.0	$1.4	$3.4
Facilities	$0.0	$0.2	$0.3
Systems	$2.4	$0.4	$2.8
Stations	$0.5	$1.0	$1.5
Vehicles	$1.8	$1.6	$3.5
Other Project Costs	$0.0	$1.7	$1.7
Subtotal Rail[1]	**$6.7**	**$6.4**	**$13.1**
Subtotal UZAs Over 1 Million[1]	**$6.6**	**$6.4**	**$13.0**
Subtotal UZAs Under 1 Million and Rural[1]	**$0.0**	**$0.0**	**$0.0**
Nonrail			
Guideway Elements	$0.0	$0.0	$0.0
Facilities	$0.0	$0.2	$0.2
Systems	$0.2	$0.0	$0.2
Stations	$0.0	$0.0	$0.1
Vehicles	$4.7	$0.7	$5.3
Other Project Costs	$0.0	$0.0	$0.0
Subtotal Nonrail[1]	**$4.9**	**$0.8**	**$5.8**
Subtotal UZAs Over 1 Million[1]	**$3.6**	**$0.4**	**$4.0**
Subtotal UZAs Under 1 Million and Rural[1]	**$1.3**	**$0.4**	**$1.8**
Total	**$11.6**	**$7.2**	**$18.8**
Total UZAs Over 1 Million	**$10.2**	**$6.8**	**$17.0**
Total UZAs Under 1 Million and Rural	**$1.4**	**$0.4**	**$1.8**

[1] Totals may not sum due to rounding.

Note: All investment values are in billions of 2016 dollars.

Source: Transit Economic Requirements Model and FTA staff estimates.

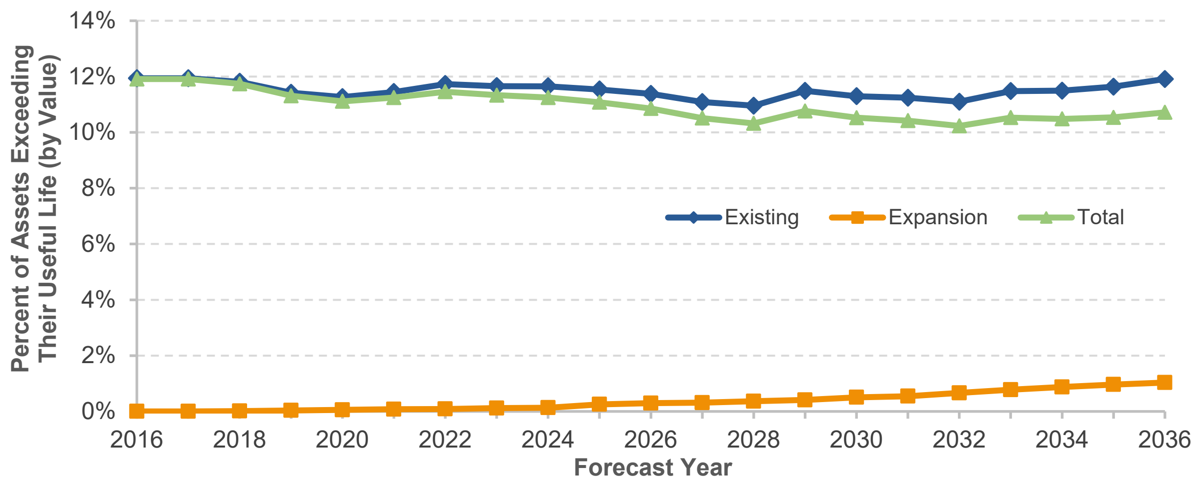
Preservation Investments

As noted earlier in this section, from 2012 to 2016 transit operators spent an estimated $11.6 billion annually rehabilitating and replacing existing transit infrastructure. Based on current TERM analyses, this level of reinvestment is less than that required to address the anticipated reinvestment needs of the Nation's existing transit assets. If sustained over the forecasted 20 years, this level would result in an overall decline in the condition of existing transit assets while roughly maintaining the size of the investment backlog. Similarly, *Exhibit 7-13* presents the proportion of transit assets (by value) that are estimated to exceed their useful life. Under the Sustain Recent Spending scenario, this amount is between roughly 11 to 12 percent for existing assets over the period 2016 through 2036. However, when the impact of new assets related to expansion is added in, the percentage of assets that exceed their useful life is projected to decline to roughly 10.7 percent by 2036.

Finally, *Exhibit 7-14* presents the projected change in the size of the investment backlog if reinvestment levels are sustained at the recent level of $11.6 billion, in constant-dollar terms. As described in Chapter 10, the investment backlog represents the level of investment required to replace all assets that exceed their useful life and to address all rehabilitation activities that are currently past due. Rural and smaller urban needs are estimated using NTD records for vehicle ages and types, and from records generated for rural and smaller urban agency facilities based on counts from NTD. Under the current rate of capital reinvestment, the size of that backlog would be projected to decrease marginally from the currently estimated level of $105.1 billion to roughly $102.3 billion by 2036.

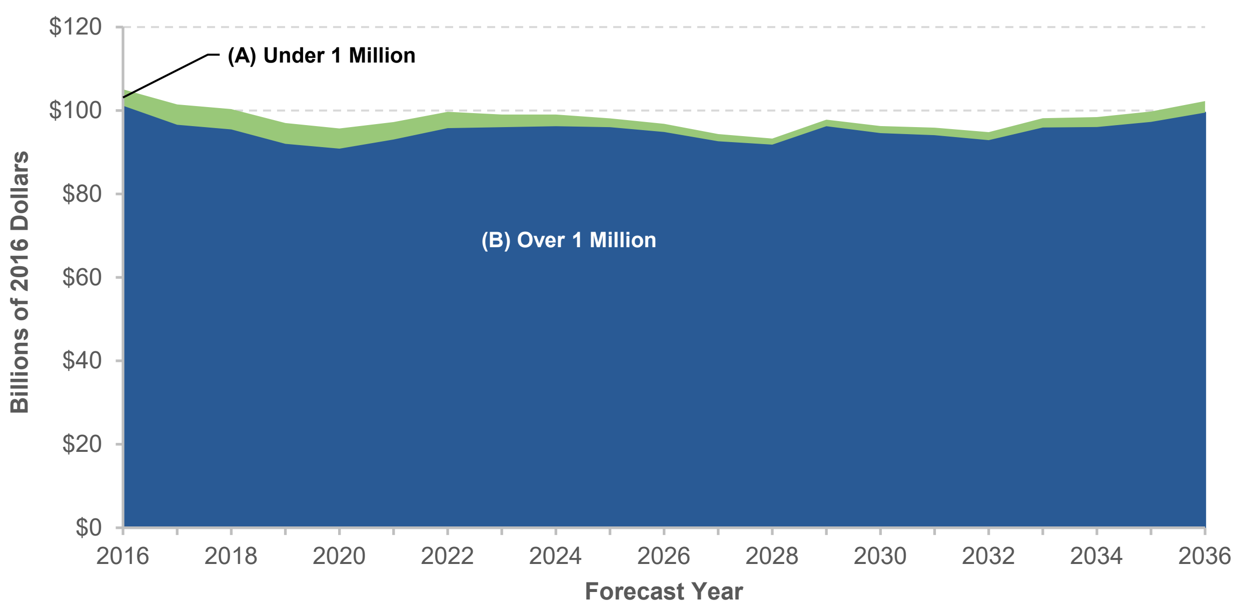
The chart in *Exhibit 7-14* also divides the backlog amount according to size of transit service area, with the lower portion showing the backlog for UZAs having populations greater than 1 million and the upper portion showing the backlog for all other UZAs and rural areas combined. This segmentation highlights the significantly higher existing backlog for those UZAs serving the largest number of transit riders.

Exhibit 7-13 ■ Sustain Recent Spending Scenario: Percentage of Assets Exceeding Useful Life, 2016–2036



Note: The proportion of assets exceeding their useful life is measured based on asset replacement value, not asset quantities.
Source: Transit Economic Requirements Model.

Exhibit 7-14 ■ Projected Backlog Under the Sustain Recent Spending Scenario, 2016–2036



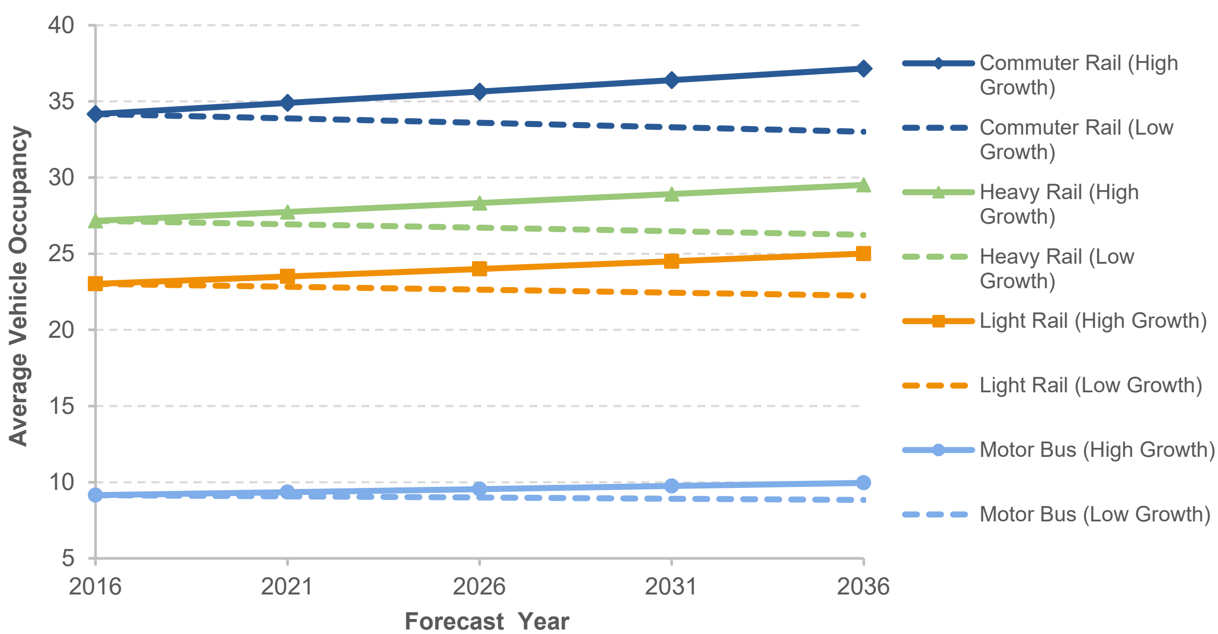
Source: Transit Economic Requirements Model.

Expansion Investments

In addition to the average $11.6 billion spent on preserving transit assets in recent years, transit agencies spent an average of $7.2 billion on expansion investments to support ridership growth and improve transit performance. This section considers the impact of sustaining the recent level of expansion investment on future ridership capacity and vehicle utilization rates under the assumptions of both lower and higher growth rates in ridership (i.e., the Low-Growth and High-Growth scenarios).

As considered in Chapter 10, the recent rate of investment in transit expansion is not sufficient to expand transit capacity at a rate equal to the rate of growth in travel demand, as projected by the historical trend rate of increase. Under these circumstances, transit capacity utilization (the average number of riders per transit vehicle) should be expected to increase, with the level of increase determined by actual growth in demand. Although the impact of this change could be minimal for systems that currently have lower capacity utilization, service performance on some higher-utilization systems likely would decline as riders experience increased vehicle crowding and service delays. *Exhibit 7-15* illustrates this potential impact. It presents the projected change in vehicle occupancy rates by mode from 2016 through 2036 (reflecting the impacts of spending from 2016 through 2036) under both the Low-Growth and High-Growth scenarios in transit ridership, assuming that transit agencies continue to invest an average of $7.2 billion per year on transit expansion. Under the Low-Growth scenario, capacity utilization is relatively flat or increases slightly across each of the four modes depicted, indicating that investment is sufficient or slightly lower than needed to maintain current occupancy levels. For the High-Growth scenario, however, the average number of riders per transit vehicle rises steadily across each mode. Chapter 10 provides greater detail on the methodology for both the Low-Growth and High-Growth scenarios.

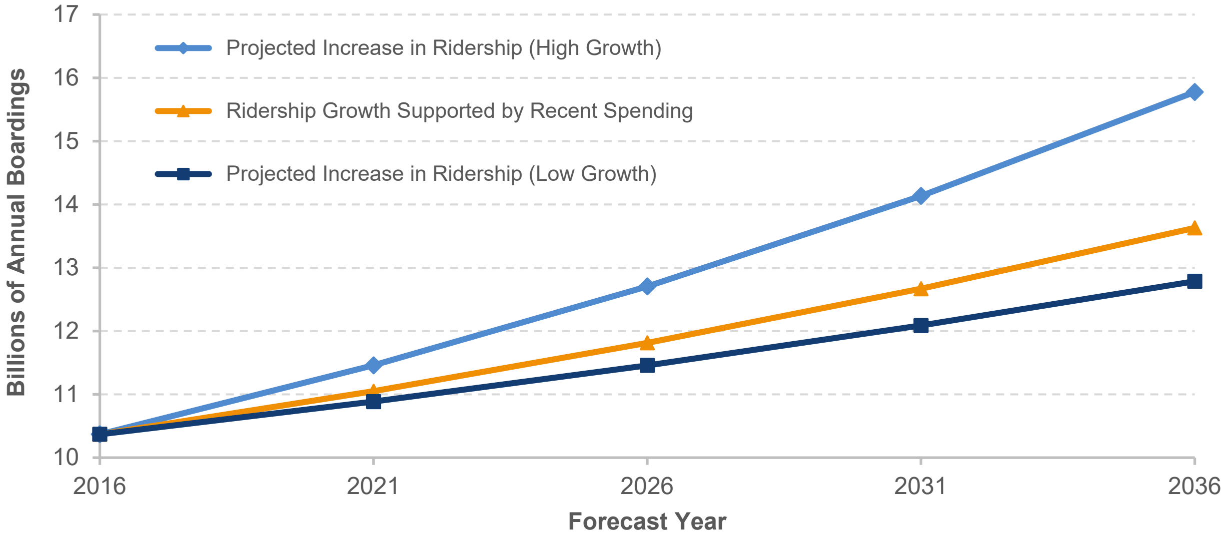
Exhibit 7-15 ■ Sustain Recent Spending Scenario: Capacity Utilization by Mode Forecast, 2016–2036



Source: Transit Economic Requirements Model.

Exhibit 7-16 presents the projected growth in transit riders that the recent level of investment (keeping vehicle occupancy rates constant) can accommodate compared with the potential growth in total ridership under both the Low-Growth and High-Growth scenarios. Without affecting service performance, the $7.2 billion level of investment for expansion is insufficient to support ridership growth that is similar to the ridership increases projected in the High-Growth scenario.

Exhibit 7-16 ■ Projected vs. Currently Supported Ridership Growth



Source: Transit Economic Requirements Model.

State of Good Repair Benchmark

This section focuses on the level of investment required to eliminate the investment backlog over the next 20 years and to provide for sustainable rehabilitation and replacement needs once the backlog has been addressed. Specifically, the SGR benchmark estimates the level of annual investment required to replace assets that currently exceed their useful lives, to address all deferred rehabilitation activities (yielding an SGR where the asset has a condition rating of 2.5 or higher), and to address all future rehabilitation and replacement activities as they come due. The SGR benchmark considered here uses the same methodology as that described in FTA's *National State of Good Repair Assessment*, released June 2012.

In contrast to the other scenarios described in this chapter, the SGR benchmark does not (1) assess expansion needs or (2) apply TERM's benefit-cost test to investments proposed in TERM. These benchmark characteristics are inconsistent with the SGR concept. First, analyses of expansion investments ultimately focus on capacity improvements and not on the needs of deteriorated assets. Second, this is a purely engineering-based performance benchmark that assesses reinvestment levels for all transit assets currently in service, regardless of whether keeping these assets in service would be cost-beneficial.

What Is the Definition of State of Good Repair?

The definition of "state of good repair" used for the SGR benchmark relies on TERM's assessment of transit asset conditions. Specifically, for this benchmark, TERM considers assets to be in a state of good repair if they are rated at a condition of 2.5 or higher and if all required rehabilitation activities have been addressed.

SGR Investment Levels

Annual reinvestment levels under the SGR benchmark are presented in *Exhibit 7-17*. Under this benchmark, an estimated $18.1 billion in annual expenditures would be required over the next 20 years to bring the condition of all existing transit assets to an SGR. Of this amount, roughly $11.3 billion (62 percent) is required to bring rail assets to SGR. Note that a large proportion of rail reinvestment spending would be associated with guideway elements (primarily aging elevated and tunnel structures) and rail systems (including train control, traction power, and communications systems) that are past their useful lives and may be technologically obsolete. Bus-related reinvestment spending under this benchmark is primarily associated with aging vehicle fleets.

Exhibit 7-17 also provides a breakdown of capital reinvestment by type of UZA under this benchmark. This breakdown emphasizes the fact that capital reinvestment levels to achieve SGR are most heavily concentrated in the Nation's larger UZAs. Together, these urban areas account for approximately 90 percent of total reinvestment under the benchmark (across all mode and asset types), with the rail reinvestment in these urban areas accounting for more than two-thirds of the total reinvestment required to bring all assets to an SGR. This high proportion of total needs reflects the high level of investment in older assets found in these urban areas.

Exhibit 7-17 ■ SGR Benchmark: Average Annual Investment by Asset Type, 2016–2036

Asset Type	Average Annual Investment (Billions of 2016 Dollars)		
	Urban Area Type		
	Over 1 Million Population	Under 1 Million Population	Total
Rail			
Guideway Elements	$3.2	$0.0	$3.2
Facilities	$0.8	$0.0	$0.8
Systems	$2.8	$0.0	$2.8
Stations	$2.2	$0.0	$2.2
Vehicles	$2.3	$0.1	$2.3
Subtotal Rail[1]	**$11.2**	**$0.1**	**$11.3**
Nonrail			
Guideway Elements	$0.1	$0.0	$0.1
Facilities	$0.9	$0.1	$1.0
Systems	$0.3	$0.0	$0.3
Stations	$0.1	$0.0	$0.1
Vehicles	$3.8	$1.5	$5.3
Subtotal Nonrail[1]	**$5.2**	**$1.6**	**$6.8**
Total	**$16.4**	**$1.7**	**$18.1**

[1] Totals may not sum due to rounding.

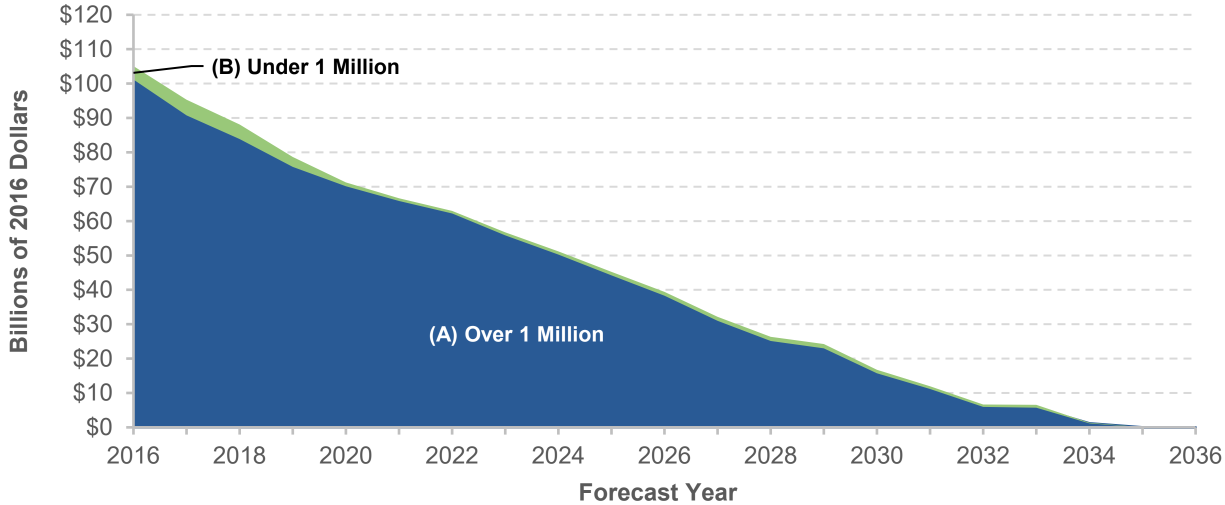
Note: All investment values in billions of 2016 dollars.

Source: Transit Economic Requirements Model.

Impact on the Investment Backlog

Exhibit 7-18 shows the estimated impact of $18.1 billion in annual expenditures on the existing investment backlog over the 20-year forecast period (compare these data with *Exhibit 7-14*). Given this level of expenditures, the backlog would be projected to be eliminated by 2036.

Exhibit 7-18 ■ Investment Backlog: SGR Benchmark ($18.1 Billion Annually)

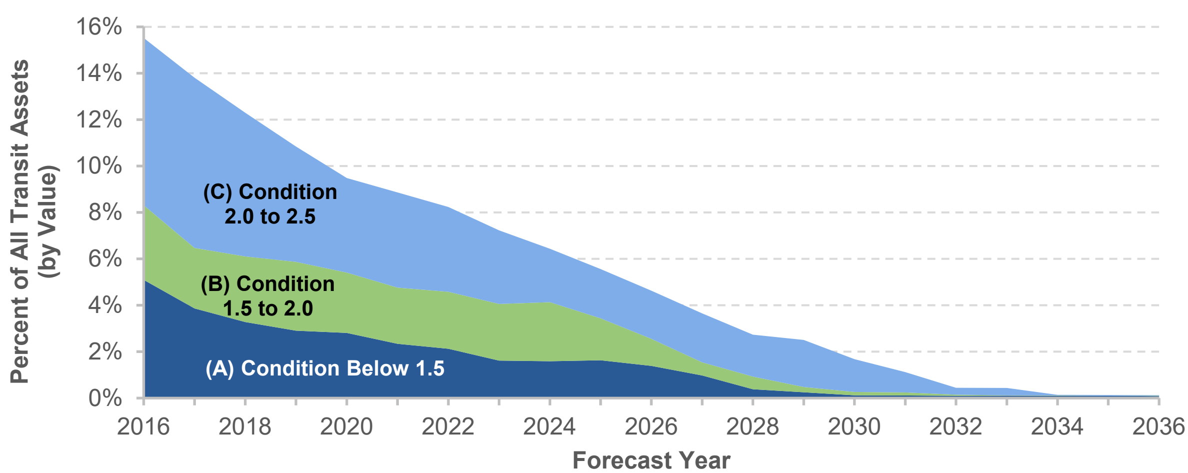


Source: Transit Economic Requirements Model.

Impact on Conditions

In drawing down the investment backlog, annual capital expenditures of $18.1 billion also would lead to the replacement of assets with an estimated condition rating of 2.5 or less. These assets include those in marginal condition having ratings between 2.0 and 2.5 and all assets in poor condition. *Exhibit 7-19* shows the current distribution of asset conditions for assets estimated to be in a rating condition of 2.5 or less (with assets in poor condition divided into two subgroups). Note that this graphic excludes both tunnel structures and subway stations in tunnel structures: these are considered assets that require ongoing capital rehabilitation expenditures but are never actually replaced. As with the investment backlog, the proportion of assets at condition rating 2.5 or lower is projected to decrease under the SGR benchmark from roughly 16 percent of assets in 2016 to less than 1 percent by 2036. Once again, this replacement activity would remove from service those assets with higher occurrences of service failures, technological obsolescence, and lower overall service quality. Importantly, the assets with a condition rating of less than 2.5 presented in *Exhibit 7-19* capture only a subset of assets in the SGR backlog as depicted in *Exhibit 7-18*. Specifically, the total SGR backlog (*Exhibit 7-18*) includes not just those assets in need of replacement (i.e., those at less than condition 2.5), but also those assets in need of rehabilitation or other form of capital reinvestment.

Exhibit 7-19 ■ Proportion of Transit Assets Not in SGR (Excluding Nonreplaceable Assets)



Source: Transit Economic Requirements Model.

Low-Growth and High-Growth Scenarios

The Low-Growth scenario and High-Growth scenarios are required to assess when assets should be rehabilitated or replaced that were applied in the SGR benchmark (e.g., with assets being replaced at condition 2.5), but also require that these preservation and expansion investments pass TERM's benefit-cost test. In general, some reinvestment activities do not pass this test (i.e., have a benefit-cost ratio less than 1), which can result from low ridership benefits, higher capital or operating costs, or a mix of these factors. Excluding investments that do not pass the benefit-cost test has the effect of reducing total estimated needs.

In addition, the Low-Growth and High-Growth scenarios assess transit expansion needs given ridership growth based on the average annual compound rate experienced over the past 15 years, minus 0.3 percent (Low-Growth) or plus 0.3 percent (High-Growth). For the expansion component of this scenario, TERM assesses the level of investment required to maintain current vehicle occupancy rates (at the agency-mode level) subject to the rate of projected growth in transit demand in that UZA and subject to the proposed expansion investment passing TERM's benefit-cost test.

Low-Growth and High-Growth Assumptions

The Low-Growth scenario is intended to represent a lower level of investment required to maintain current service performance (as measured by transit vehicle capacity utilization) as determined by a relatively lower rate of growth in travel demand. In contrast, the High-Growth scenario estimates the higher level of investment required to maintain current service performance as determined by a relatively higher rate of growth in travel demand. The methodology for the Low-Growth and High-Growth scenarios uses a common, consistent approach that reflects differences in PMT growth by mode. Specifically, these scenarios are based on the 15-year trend rate of growth in PMT, which is used to project future growth. When calculated across all transit operators and modes, this historical trend rate of growth converts to a national average compound annual growth rate of approximately 1.5 percent during the 20-year period.

Within this new framework, the Low-Growth scenario is defined as the trend rate of growth (by FTA region, population stratum, and mode) minus 0.3 percent, whereas the High-Growth scenario is defined as the trend rate of growth plus 0.3 percent. Hence, the Low-growth (1.2%) and High-Growth (1.8%) scenarios differ by a full 0.6 percent in annual growth.[25]

Low-Growth and High-Growth Scenario Investment Levels

Exhibit 7-20 presents TERM's projected capital investment levels on an annual average basis under the Low-Growth and High-Growth scenarios, including those for both asset preservation and asset expansion.

[25] Transit ridership has declined significantly in recent years. The impact of this trend on TERM's ridership forecast is small for two reasons: (1) TERM relies on a 15-year historical timeframe to project future ridership, and the decline started only in the last 3 years (2013–2016), and (2) TERM sets to 0 any decreasing trend at the UZA/Agency/Mode level. The overall effect is still an increasing trend, but at a lower rate than in previous forecasts.

Exhibit 7-20 ■ Low-Growth and High-Growth Scenarios: Average Annual Investment by Asset Type, 2016–2036

Asset Type	Average Annual Investment (Billions of 2016 Dollars)					
	Low-Growth			High-Growth		
	Preservation	Expansion	Total	Preservation	Expansion	Total
Rail						
Guideway Elements	$3.1	$1.2	$4.3	$3.1	$1.3	$4.5
Facilities	$0.8	$0.2	$1.0	$0.8	$0.3	$1.1
Systems	$2.8	$0.3	$3.1	$2.8	$0.3	$3.2
Stations	$2.2	$0.9	$3.1	$2.2	$1.0	$3.2
Vehicles	$2.3	$1.4	$3.6	$2.3	$1.8	$4.0
Other Project Costs	$0.0	$1.5	$1.5	$0.0	$1.7	$1.7
Subtotal Rail[1]	**$11.1**	**$5.5**	**$16.7**	**$11.2**	**$6.4**	**$17.6**
Subtotal UZAs Over 1 Million[1]	**$11.1**	**$5.5**	**$16.6**	**$11.1**	**$6.4**	**$17.5**
Subtotal UZAs Under 1 Million and Rural[1]	**$0.0**	**$0.0**	**$0.0**	**$0.0**	**$0.0**	**$0.0**
Nonrail						
Guideway Elements	$0.1	$0.0	$0.1	$0.1	$0.0	$0.1
Facilities	$0.7	$0.1	$0.8	$0.7	$0.2	$0.9
Systems	$0.1	$0.0	$0.1	$0.1	$0.0	$0.1
Stations	$0.1	$0.0	$0.1	$0.1	$0.0	$0.2
Vehicles	$4.8	$0.6	$5.4	$4.8	$0.9	$5.8
Other Project Costs	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Subtotal Nonrail[1]	**$5.9**	**$0.7**	**$6.6**	**$5.9**	**$1.2**	**$7.1**
Subtotal UZAs Over 1 Million[1]	**$4.4**	**$0.3**	**$4.7**	**$4.4**	**$0.7**	**$5.1**
Subtotal UZAs Under 1 Million and Rural[1]	**$1.5**	**$0.4**	**$1.9**	**$1.5**	**$0.5**	**$2.0**
Total Investment[1]	**$17.0**	**$6.3**	**$23.2**	**$17.1**	**$7.6**	**$24.7**
Total UZAs Over 1 Million[1]	**$15.4**	**$5.9**	**$21.3**	**$15.5**	**$7.1**	**$22.6**
Total UZAs Under 1 Million and Rural[1]	**$1.5**	**$0.4**	**$1.9**	**$1.6**	**$0.5**	**$2.1**

[1] Totals may not sum due to rounding.

Note: All investment values are in billions of 2016 dollars.

Source: Transit Economic Requirements Model.

Low-Growth Investment Levels

Assuming the relatively low ridership growth in the Low-Growth scenario, investment needs for system preservation and expansion are estimated to average roughly $23.2 billion each year for the next two decades. Roughly 73% of this amount, or $17 billion, is for preserving existing assets with approximately $11.1 billion associated with preserving existing rail infrastructure alone. Note that the approximate $1 billion difference between the $18.1 billion in annual preservation spending under the SGR benchmark and the $17.0 billion in preservation spending under the Low-Growth scenario is due entirely to the application of TERM's benefit-cost test under the Low-Growth scenario. Finally, expansion needs in this scenario totals $6.3 billion annually, with 89 percent of that amount associated with rail expansion costs.

High-Growth Investment Levels

In contrast, total investment needs under the High-Growth scenario are estimated to be $24.7 billion annually, 6 percent higher than the total investment needs under the Low-Growth scenario. The High-Growth scenario total includes $17.1 billion for system preservation and an additional $7.6 billion for system expansion. Note that system preservation costs are higher under the High-Growth scenario because the higher growth rate leads to a larger expansion of the asset base compared with that under the Low-Growth scenario, and this larger asset base will also need to be preserved. Under this scenario, investment in expansion of rail assets is still larger than that for nonrail expansion (84 percent for rail and 16 percent for nonrail). Under the High-Growth scenario, however, rail consumes 84 percent of total expansion investment funding vs. 89 percent of expansion needs under the Low-Growth scenario. Finally, note that the annual expansion spending under the High-Growth scenario ($7.6 billion) exceeds recent spending ($7.2 billion) levels by roughly $400 million annually.

Impact on Conditions and Performance

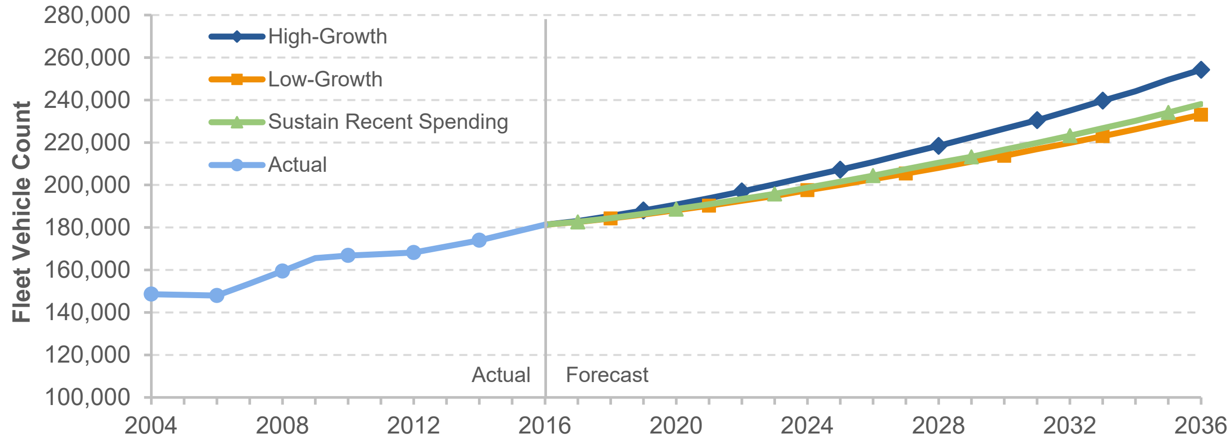
The impact of the Low-Growth and High-Growth rate preservation investments on transit conditions is essentially the same as that already presented for the SGR benchmark in *Exhibits 7-18* and *7-19*. As noted earlier, the Low and High-Growth scenarios use the same rules to assess when assets should be rehabilitated or replaced as were applied in the SGR benchmark (e.g., with assets being replaced at condition rating 2.5). In terms of asset conditions, the primary difference between the SGR benchmark and the Low-Growth and High-Growth scenarios relates to (1) TERM's benefit-cost test not applying to the SGR benchmark (leading to higher SGR preservation needs overall) and (2) the Low-Growth and High-Growth scenarios having some additional spending for replacing expansion assets with short service lives. Together, these impacts tend to work in opposite directions. The result is that the rate of drawdown in the investment backlog and the elimination of assets exceeding their useful lives are roughly comparable between the SGR benchmark and these scenarios and between the two scenarios.

Forecasted Expansion Investment

This section compares key characteristics of the national transit system in 2016 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 forecasts.

TERM's projections of fleet size are presented in *Exhibit 7-21*. The projections for the Low-Growth and High-Growth scenarios create upper and lower targets around the projected Sustain Recent Spending scenario 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.

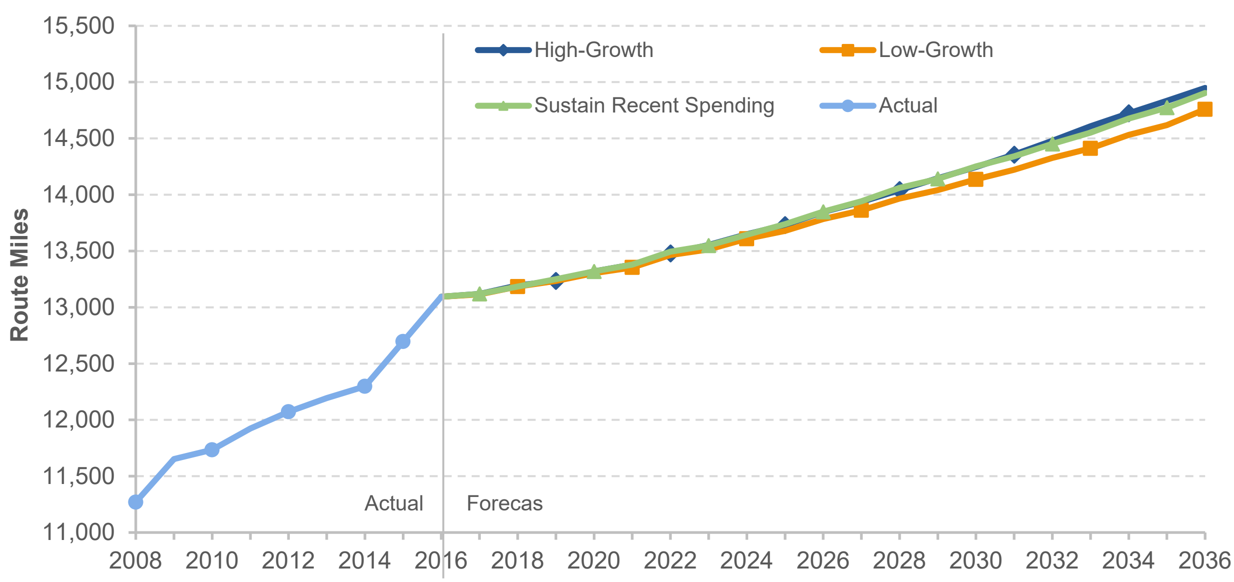
Exhibit 7-21 ■ Projection of Fleet Size by Scenario



Note: Data through 2016 are actual; data after 2016 are estimated based on trends.
Source: Transit Economic Requirements Model.

The projected guideway route miles for the Sustain Recent Spending scenario are less than those for the projected High-Growth scenario, as shown in *Exhibit 7-22*. Note that commuter rail accounts for close to three-quarters of all rail route miles, with the remainder consisting primarily of heavy rail (20 percent) and light rail (7 percent). The average commuter rail system is on the order of two to six times the length of typical heavy and light rail systems; given this split, the projection presented in *Exhibit 7-22* is dominated by route miles for commuter rail.

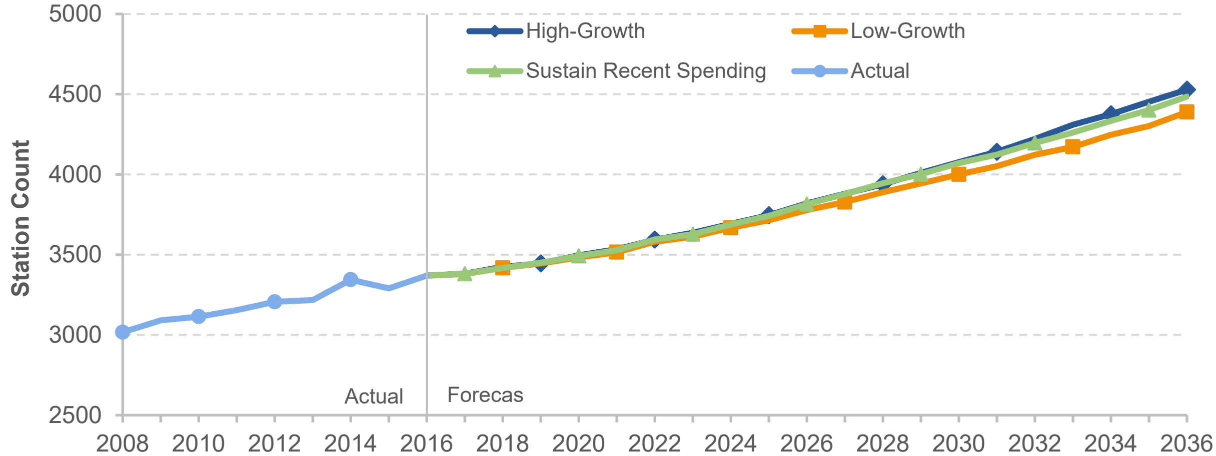
Exhibit 7-22 ■ Projection of Guideway Route Miles by Scenario



Note: Data through 2016 are actual; data after 2016 are estimated based on trends.
Source: Transit Economic Requirements Model.

TERM's projections of the number of stations required to expand transit service capacity to support differing levels of ridership growth (while passing TERM's benefit-cost test), are presented in *Exhibit 7-23*. Unlike *Exhibit 7-22*, which is dominated by commuter rail assets, the station investments presented here are more evenly distributed across rail modes, with commuter rail accounting for 40 percent of new stations, heavy rail 33 percent, and light rail 27 percent. This mix is driven in part by differences in the distance between stations for these three modes (ranging from over four miles between stations for commuter rail to roughly a half-mile between light rail stations).

Exhibit 7-23 ■ Projection of Rail Stations by Scenario

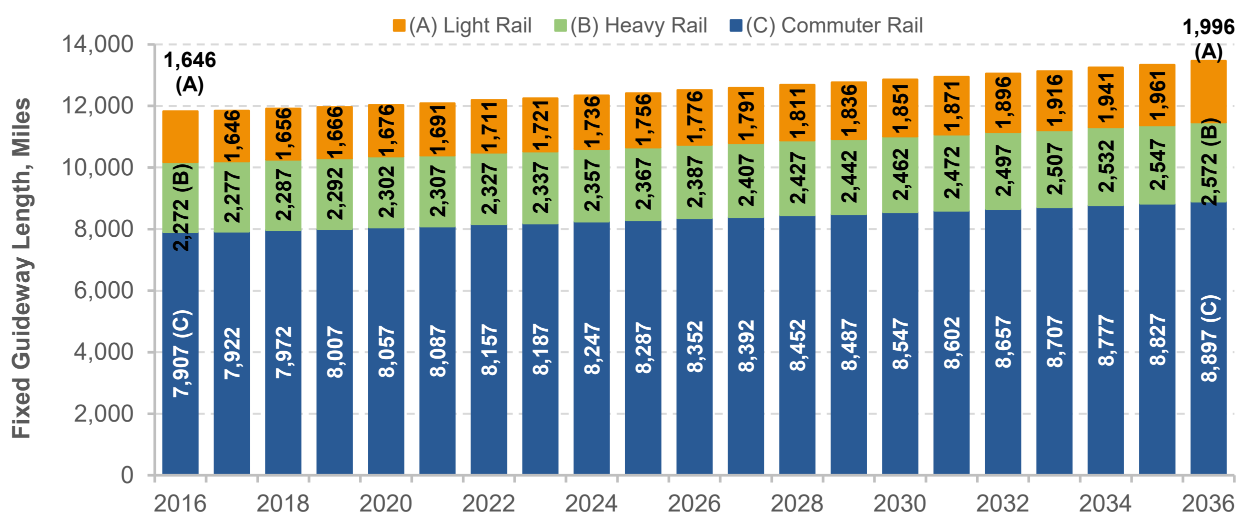


Note: Data through 2016 are actual; data after 2016 are estimated based on trends.

Source: Transit Economic Requirements Model.

For each scenario, TERM estimates future investment in fleet size, guideway route miles, and stations for each of the next 20 years. *Exhibit 7-24* presents TERM's projection for total fixed guideway route miles under the Low-Growth scenario by rail mode. TERM projects different investment needs for each year, which are added to the 2016 actual total stock. Heavy rail's share of the projected annual fixed guideway route miles remains relatively constant over the 20-year period, whereas total fixed guideway route miles increase slightly for light and commuter rail.

Exhibit 7-24 ■ Stock of Fixed Guideway Miles by Year under Low-Growth Scenario, 2016–2036



Source: Transit Economic Requirements Model.

Scenario Impacts Comparison

Finally, this subsection summarizes and compares many of the investment impacts associated with each of the three analysis scenarios and the SGR benchmark considered earlier. Although much of this comparison is based on measures already introduced earlier in this section, this discussion also considers a few additional investment impact measures. These comparisons are presented in *Exhibit 7-25.* The first column of data in *Exhibit 7-25* presents the current values for each of these measures (as of 2016). The subsequent columns present the estimated future values in 2036, assuming the levels, allocations, and timing of expenditures associated with each of the three investment scenarios and the SGR benchmark.

Exhibit 7-25 includes the following measures:

- **Average annual expenditures (billions of dollars):** This amount is broken down into preservation and expansion expenditures.
- **Condition of existing assets:** This analysis considers only the impact of investment funds on the condition of those assets currently in service.
  - Average physical condition rating: The weighted average condition of all existing assets on TERM's condition scale of 5 (excellent) through 1 (poor).
  - Investment backlog: The value of all deferred capital investment, including assets exceeding their useful lives and rehabilitation activities that are past due. (This value can approach but never reach zero due to assets continually aging, with some exceeding their useful lives.) The backlog is presented here both as a total dollar amount and as a percentage of the total replacement value of all U.S. transit assets.
  - Backlog ratio: The ratio of the current investment backlog to the annual level of investment required to maintain normal annual capital needs once the backlog is eliminated.
- **Performance measures:** The impact of investments on U.S. transit ridership capacity and system reliability.
  - New boardings supported by expansion investments: The number of additional riders that transit systems can carry without a loss in performance (given the projected ridership assumptions for each scenario).
  - Revenue service disruptions per PMT: Number of disruptions to revenue service per million passenger miles.
  - Fleet maintenance cost per vehicle revenue mile: Fleet maintenance costs tend to increase with fleet age (or reduced asset condition). This measure estimates the change in fleet maintenance costs expressed in a per-revenue-vehicle-mile basis.

Exhibit 7-25 ■ Scenario Investment Benefits Scorecard

Measure	Baseline 2016: Actual Recent Spending, Conditions, and Performance	Projected Spending, Conditions, and Performance Values in 2036			
		SGR	Sustain Recent Spending	Low Growth	High Growth
Average Annual Expenditures (Billions of 2016 Dollars)					
Preservation	$12.7	$18.1	$11.6	$17.0	$17.1
Expansion	$6.7	NA	$7.2	$6.3	$7.6
Total	**$19.4**	**$18.1**	**$18.9**	**$23.2**	**$24.7**
Conditions (Existing Assets)					
Average Physical Condition Rating	3.0	2.9	2.7	3.1	3.2
Investment Backlog (Billions of Dollars)	$105.1	$0.0	$102.3	$0.0	$0.0
Investment Backlog (% of Replacement Costs)	11%	0%	10%	0%	0%
Backlog Ratio[1]	8.2	0.0	9.0	0.0	0.0
Ridership Impacts of Expansion Investments (2016)					
New Boardings Supported by Expansion (Billions)	NA	NA	4.1	3.0	4.5
Total Projected Boardings in 2036 (Billions)	NA	NA	12.7	12.2	13.5
Fleet Performance					
Revenue Service Disruptions per Thousand PMT	9.2	8.3	8.1	8.3	8.3
Fleet Maintenance Cost per Revenue Vehicle Mile	$1.80	$1.69	$1.69	$1.67	$1.69

[1] The backlog ratio is the ratio of the current investment backlog to the annual level of investment to maintain SGR once the backlog is eliminated.

Source: Transit Economic Requirements Model.

Scorecard Comparisons

Exhibit 7-25 summarizes a review of the scorecard results for each of the three investment scenarios and the SGR benchmark, revealing the impacts discussed in this subsection.

Preservation Impacts

Continued reinvestment at recent annual spending levels is likely to yield a decline in overall asset conditions (from 3.0 in 2016 to 2.7 in 2036) and roughly maintain the size of the investment backlog (from $105.1 billion in 2016 to $102.3 billion in 2036). Continued reinvestment at the recent annual spending level, however, likely will cause a reduction in service disruptions per thousand passenger miles and a decrease in maintenance costs per vehicle revenue mile. Improvements in fleet performance also occur under the SGR benchmark, Low-Growth, and High-Growth scenarios. Note that the overall condition rating measures of 2.9, 3.1, and 3.2 under the SGR benchmark, the Low-Growth scenario, and the High-Growth scenario, respectively, represent sustainable condition levels for the Nation's existing transit assets over the long term. This is in contrast to the current measure of roughly 3.0, which would be difficult to maintain over the long term without replacing many asset types prior to the conclusion of their expected useful lives.

For this and the previous C&P Report, expansion assets are included in the overall condition rating measures. This approach is a departure from that used in earlier reports, in which the goal was to be cognizant of what happens to the SGR of existing assets under alternative scenarios.

Expansion Impacts

Although continued expansion investment at the recent annual spending level appears sufficient to support a low rate of increase in transit ridership to about 2.9 billion new boardings in 2036, higher rates of growth to nearly 4.5 billion new boardings in 2036 suggest that a higher rate of expansion investment (nearly $0.4 billion more annually in expansion investment) would be required to avoid a decline in overall transit performance (e.g., in the form of increased crowding on high-utilization systems) if future transit ridership growth were to exceed historical levels.