CHAPTER 8: Supplemental Analysis

Supplemental Analysis – 50th Anniversary

On the occasion of the 50th anniversary of the C&P Report series, this section takes a look back to the initial report published in 1968 and compares its projections with actual performance over the past 50 years.

FHWA published the first edition of the C&P Report series in 1968, titled "*1968 National Highway Needs Report*, in response to Section 3 of the U.S. Senate Joint Resolution 81, approved in 1965, which directed the U.S. Department of Transportation to produce a biennial report on the highway needs of the Nation.

The initial C&P Report was prepared prior to the opening of the last section of the Interstate System, which links the country's major cities and agricultural and industrial regions with modern freeways. The report was oriented to reexamine the Federal-aid highway program and assist Congress in shaping the direction of future highway programs to meet transportation needs in the last quarter of the 20th century.

The 1968 C&P Report presented the condition of highways in 1965, the role of highways in freight movement, highway finance, and estimated future highway demand for the next two decades. Main topics related to highway development in the 1968 report are summarized in this section, followed by an examination of improvements in the C&P Report series since 1968.

KEY TAKEAWAYS

- Based on State forecasts, the 1968 C&P Report estimated VMT would be 1.5 trillion miles in 1985; actual VMT that year was 1.8 trillion miles.
- The 1968 C&P Report underestimated the wide adoption of vehicle ownership in the next two decades, as national motor vehicle registrations reached 172 million in 1985, higher than the forecast of 144 million.
- Actual growth of vehicle registration slowed in the following three decades. When the same trend of 1968–1985 was extended to 2016, projected vehicle registration would reach 294 million, higher than actual vehicle registration of 264 million in 2016.
- A similar pattern is observed for travel demand. In 1966–1985, VMT was projected to increase by 2.7 percent per year. In reality, VMT grew by 3.5 percent in 1966–1985 and slowed to 1.9 percent in 1986–2016.
- Total freight by all modes rose from 1.7 to 5.2 trillion ton-miles in 1965–2015, with the share of highway trucks growing from 23 to 40 percent.
- The 1968 C&P Report estimated average annual highway capital investment needs at $86.1 billion (2016 constant dollars) for 1965–1972, similar to actual spending of $83.3 billion per year.
- The 1968 C&P Report estimated average annual highway capital investment needs at $110.4 billion (2016 constant dollars) for 1973–1985, almost double the actual spending level of $ 56.9 billion.
- The 1968 C&P Report discussed topics on rural highways, urban mobility, highway finance, and toll facilities.
- Including the initial 1968 C&P Report, a total of 24 reports have been produced with continuous improvement in data and analytical approaches.

Forecast of VMT and Registration

Similar to recent editions of C&P Reports, the 1968 C&P Report provided past trends (1935–1965) and 20-year forecasts (1965–1985) of travel conditions. It included a limited number of indicators: motor vehicle registration, vehicle miles traveled (VMT), and gross national product (GNP). Unlike modern editions of the C&P Report, the 1968 report did not include detailed discussions on highway safety. A separate report on highway safety needs was prepared by the National Highway Safety Bureau and submitted to Congress in parallel with the 1968 C&P Report.

The VMT projections were derived by aggregating VMT forecasts developed by each State highway department in cooperation with the Bureau of Public Roads (the predecessor of Federal Highway Administration). Each State was directed to forecast VMT based on a systematic consideration of travel trends, population growth, and motor vehicle ownership and use trends, whereas the Bureau of Public Roads provided regional and national guides on related criteria.

Recognizing that VMT could have a range of possible growth rates due to uncertainty in future GNP, population, and vehicle ownership, the 1968 C&P Report included a brief sensitivity analysis for highway travel between 1965 and 1985. The minimum VMT growth analyzed was 60 percent over its 1965 level (0.89 trillion miles), growing at 2.4 percent annually. The maximum VMT growth analyzed was 100 percent over its 1965 level, growing at 3.6 percent annually. The 1968 Report estimated that within a range of 60 to 100 percent growth, the most likely VMT projection would be 71 percent over its 1965 level, an average annual growth rate of 2.7 percent.

Assuming a growth rate of 2.7 percent per year, the 1968 C&P Report forecast national travel at 1.516 trillion vehicle miles in 1985 (*Exhibit 8-1*). Actual VMT in 1985 was 1.775 trillion, well above the 1968 C&P Report forecast level. This implies a 3.5 percent annual growth rate, which is close to the maximum growth of 3.6 percent.

Exhibit 8-1 ■ VMT, GNP, and Motor Vehicle Registrations, 1936–2016

Category	VMT (trillion)		GNP (trillion 2009 $)		Registration (million)	
	Actual	Forecast/ Extrapolation	Actual	Forecast/ Extrapolation	Actual	Forecast/ Extrapolation
1936	0.252		1.1		29	
1950	0.458		2.2		49	
1965	0.888		4.0		90	
1985	1.775	1.516	7.6	8.1	172	144
2005	2.989	*2.589*	14.3	*16.5*	247	*228*
2016	3.174	*3.476*	16.9	*24.4*	264	*294*
Annual Growth Rate						
1965–1985	3.5%	2.7%	3.3%	3.6%	3.3%	2.3%
1986–2016	1.9%	*2.7%*	2.6%	*3.6%*	1.4%	*2.3%*
1965–2016	2.5%	*2.7%*	2.9%	*3.6%*	2.1%	*2.3%*

Note: Extrapolated values for 1986–2016 shown in italics were computed by applying the 1965–1985 forecast growth rate and applying it to subsequent years.

Sources: Forecast from 1968 National Highway Needs Report Figure 3; actual GNP from Federal Reserve Bank of St. Louis; population from U.S. Census Bureau; VMT and registration 1935–1992 from Highway Statistics Summary to 1995; VMT and registration 1993–2016 from Highway Statistics.

The GNP forecast was based on forecasts in *Resources in America's Future*.[26] GNP was predicted to more than double in 20 years by 1985, expanding from $4.0 trillion in 1965 to $8.1 trillion in 1985 (in 2009 constant dollars). Actual GNP in 1985 was lower than forecast at $7.6 trillion, reflecting an average annual growth of 3.3 percent per year. The forecast growth rate of 3.6 percent turned out to be more optimistic than actual growth from 1965 to 1985.

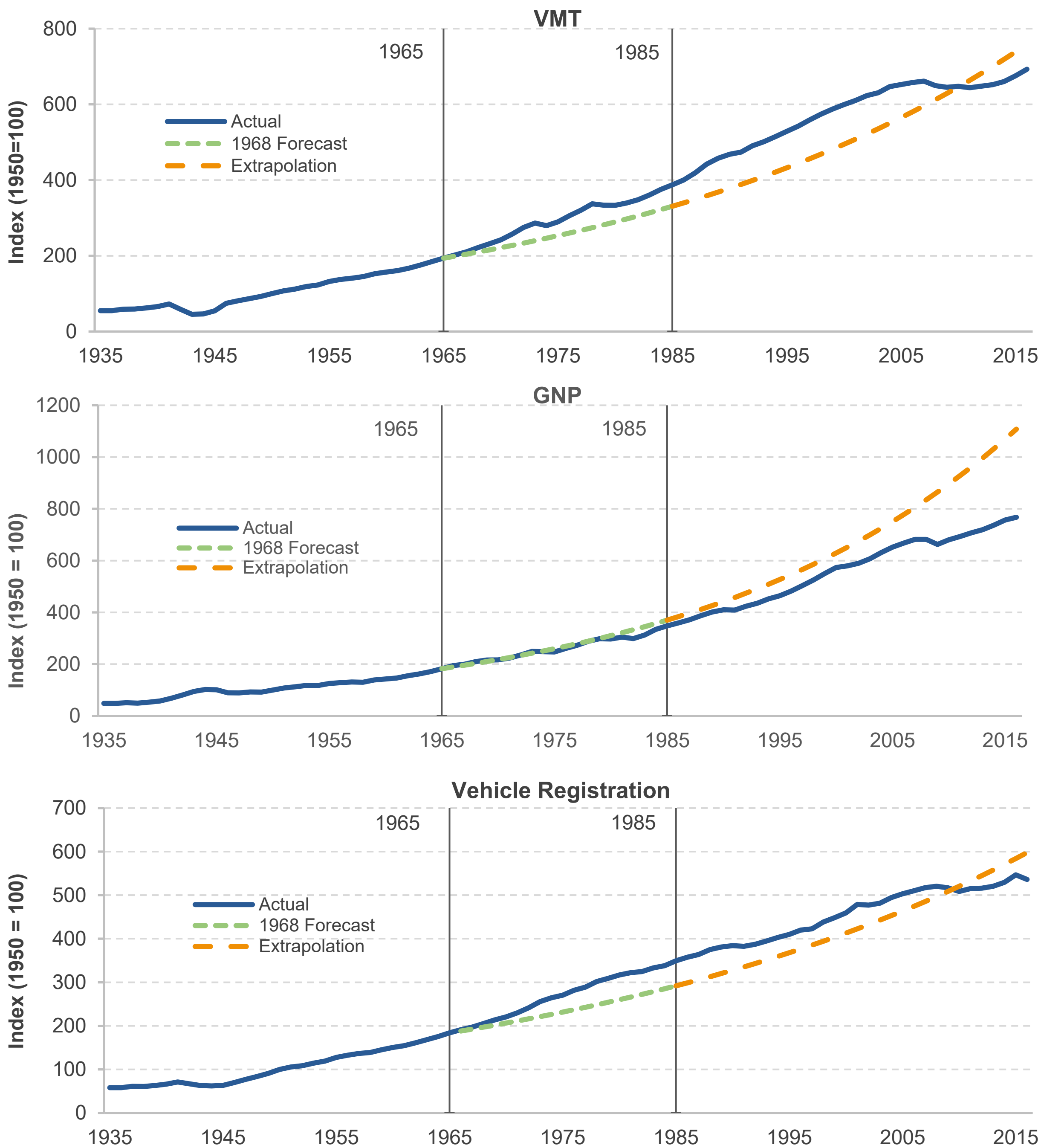
Forecasts of national motor vehicle registrations were summarized from projections by the States, based on assumptions of population and vehicle registration trends. The population projection was from the Bureau of the Census. The 1968 C&P Report underestimated the wide adoption of vehicle ownership that would occur in the 1970s and 1980s. The report projected that the total motor vehicle fleet would grow to 144 million by 1985, far below the actual 172 million registrations in that year. The forecast growth rate was 2.3 percent for 1965–1985, 1 percentage point lower than the actual growth rate.

[26] Landsberg, Hans H., Leonard L. Fischman, and Joseph L. Fisher. 1963. *Resources in America's Future: Patterns of Requirements and Availabilities, 1960–2000*. Published for Resources for the Future by Johns Hopkins Press, Baltimore, MD.

Extrapolations through 2016

Exhibit 8-2 illustrates the trends of VMT, GNP, and vehicle registration that result from extending the 1965–1985 compound growth rate projection through 2016. The solid lines represent actual values of GNP, VMT, and vehicle registration; the dashed lines represent the 1968 forecast and further extrapolation. Both projected and actual values of GNP, VMT, and vehicle registration follow an upward trend, showing positive growth over the past five decades.

Exhibit 8-2 ■ Trends of VMT, GNP, and Motor Vehicle Registrations, 1936–2016



Note: Values are normalized to 100 in 1950.

Sources: Forecast from 1968 National Highway Needs Report Figure 3; actual GNP from Federal Reserve Bank of St. Louis; population from U.S. Census Bureau; VMT and registration 1935–1992 from Highway Statistics Summary to 1995; VMT and registration 1993–2016 from Highway Statistics.

The trend line for actual VMT was above that of the VMT forecast until the late 2000s. VMT declined around the time of the December 2007–June 2009 recession and did not recover to its previous level until 2015. Compared with its robust 3.5 percent average annual growth rate from 1965–1985, the VMT growth rate declined to an average of 1.9 percent per year from 1986–2016. Actual VMT was 3.174 trillion miles in 2016, far below the extrapolation of 3.476 trillion miles shown in *Exhibit 8-1*.

Unlike the strong growth of 3.6 percent per year forecast to occur between 1965 and 1985 and extrapolated to continue to 2016, actual economic expansion slowed substantially from 1986 to 2016, with GNP growing by only 2.6 percent annually. This is shown in the large gap between the solid and dotted lines depicting GNP in *Exhibit 8-2*.

The 1968 C&P Report used the ratio of VMT to GNP to measure economic output relative to highway transportation. The U.S. economy expanded at roughly the same pace as highway travel until the 2000s, and the ratio of VMT to GNP remained relatively steady until the turn of the century: VMT for every $1 GNP (in 2009 constant dollars) was 0.22 in 1965, 0.24 in 1975, 0.23 in 1985, 0.24 in 1995, and 0.22 in 2000. However, VMT growth started to slow in 2006, despite robust economic expansion (except for a brief dip in GNP during the December 2007 to June 2009 recession). As a result, the ratio of VMT to GNP has dropped gradually to 0.19 in recent years, suggesting a weakening in the traditional relationship between VMT and GNP.

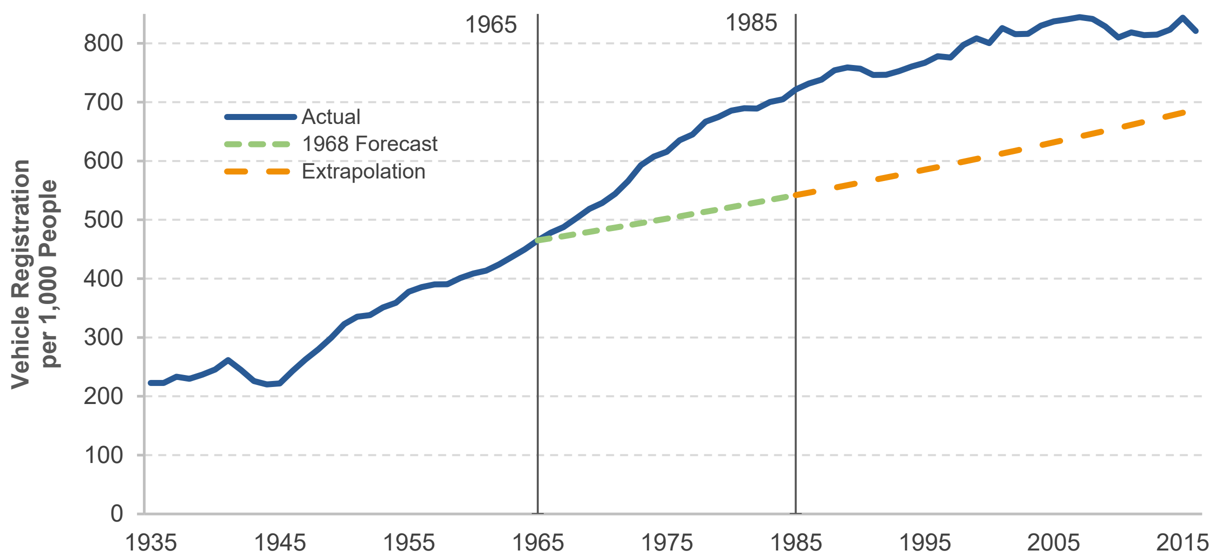
Vehicle registration followed a similar trend as VMT and its growth slowed in the mid-2000s. Registered vehicles increased at a much slower pace (1.4 percent per year) from 1986 to 2016, less than half of the growth rate from 1965–1985 (3.3 percent). Thus, extrapolating the projected annual growth rate of registrations in the 1968 C&P Report (2.3 percent annually) over an additional 31 years would result in a projected value of 294 million registrations in 2016—much higher than the actual registrations of 264 million (*Exhibit 8-1*).

In summary, although State highway departments might have assumed "modest" growth rates of VMT and registration for the period of 1965–1985, by historical standards this was a period of rapid expansion in travel demand associated with high economic and population growth. When these high growth projections derived from the expansion period are applied over a long time horizon, including periods of slow growth, it is very likely that future travel demand will be overestimated. This retrospective exercise shows that transportation planning needs to be constantly adjusted according to social and economic conditions to avoid misalignment of transportation facilities with ever-changing travel demand.

Registrations per Person, VMT per Vehicle, and VMT per Person

The implications of the travel forecast in the 1968 C&P Report are shown in *Exhibits 8-3*, *8-4*, and *8-5*. The ratio of motor vehicles per 1,000 people was 465 in 1965, and was projected to reach 542 vehicles per 1,000 people by 1985 (*Exhibit 8-3*). The projection underestimated vehicle ownership by about one-third, as statistics indicate there were 722 vehicles registered per 1,000 people in 1985. Despite a slowdown in growth since 1985, registrations remained higher than would be suggested by a straight-line extrapolation from the 1968 C&P Report.

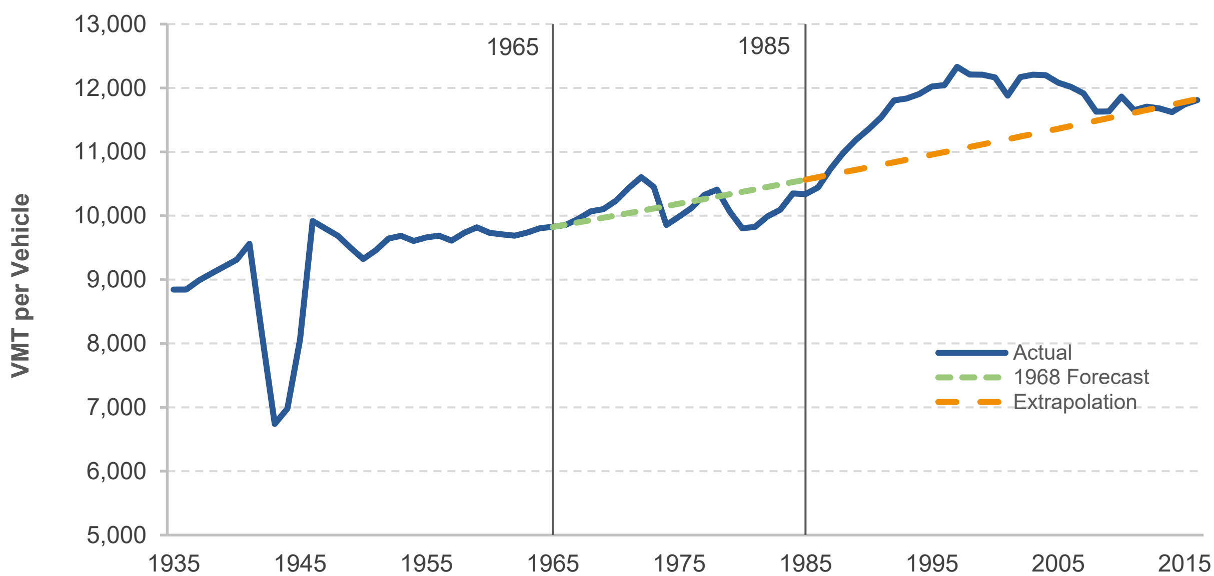
Exhibit 8-3 ■ Vehicle Registration per 1,000 People, 1936–2016



Sources: Forecast from 1968 National Highway Needs Report, Figure 4; actual population from U.S. Census Bureau; registration 1935–1992 from Highway Statistics Summary to 1995; registration 1993–2016 from Highway Statistics.

Although annual travel per motor vehicle showed a relatively smooth and flat pattern after World War II (*Exhibit 8-4*), this was no longer the case after 1965 as people traveled more frequently and farther. Annual VMT per vehicle was 9,823 miles in 1965 and rose to 10,337 miles in 1985, close to the 10,564 miles forecast for that year in the 1968 C&P Report. However, instead of following the same steady slow growth from the end of World War II to 1965, actual average distance traveled per vehicle fluctuated between 1965 and 1985. After 1985, annual VMT travel per vehicle peaked in the late 1990s, then declined continuously and did not pick up again until 2016. *Exhibit 8-4* shows that the actual VMT per vehicle was higher than the dotted extrapolation line from the 1968 forecast, with the exception of 2013–2015.

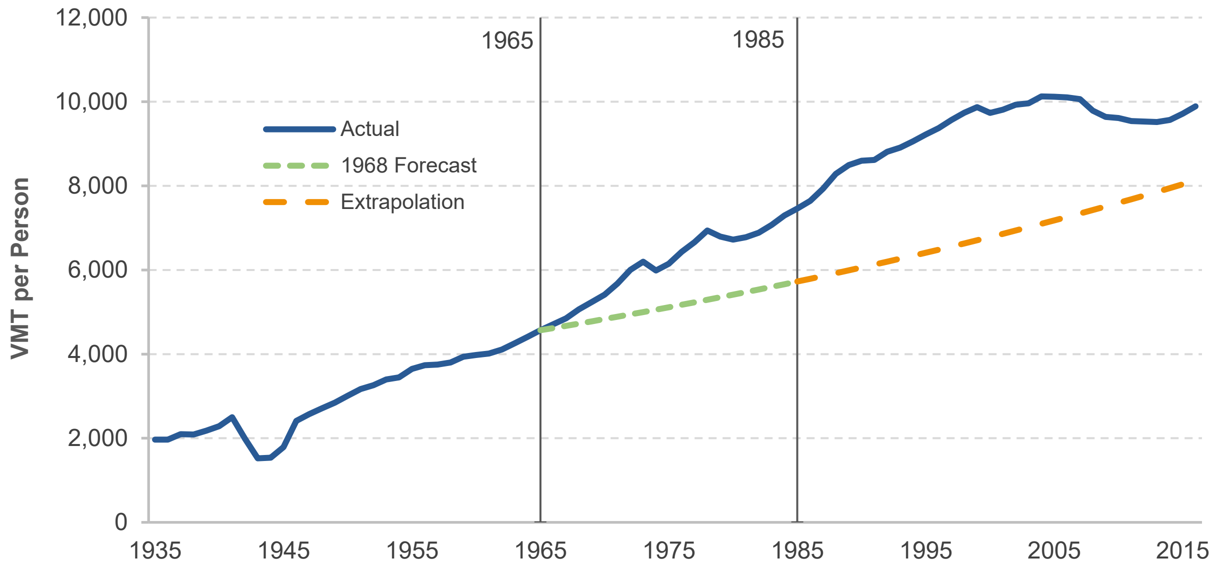
Exhibit 8-4 ■ Annual VMT per Vehicle, 1936–2016



Sources: Forecast from 1968 National Highway Needs Report, Figure 4; actual VMT and registration 1935–1992 from Highway Statistics Summary to 1995; VMT and registration 1993–2016 from Highway Statistics.

Total annual highway travel was about 4,600 miles for every man, woman, and child in 1965, but VMT per person expanded at a much faster pace than was projected in the 1968 report. *Exhibit 8-5* shows that actual values of annual VMT per person have been consistently above the forecast VMT since 1965. Average VMT per person was forecast to be 5,726 miles in 1985, whereas actual travel was much higher at 7,460 miles per person. Average VMT per person continued to rise at a rate above the 1968 forecast, reached its highest level at 10,125 miles per person in 2004, slowly dropped to 9,517 in 2013, and then resumed an upward swing. However, the average VMT per person of 9,888 in 2016 had not recovered to its 2004 pre-recession level.

Exhibit 8-5 ■ Annual VMT per Person, 1936–2016



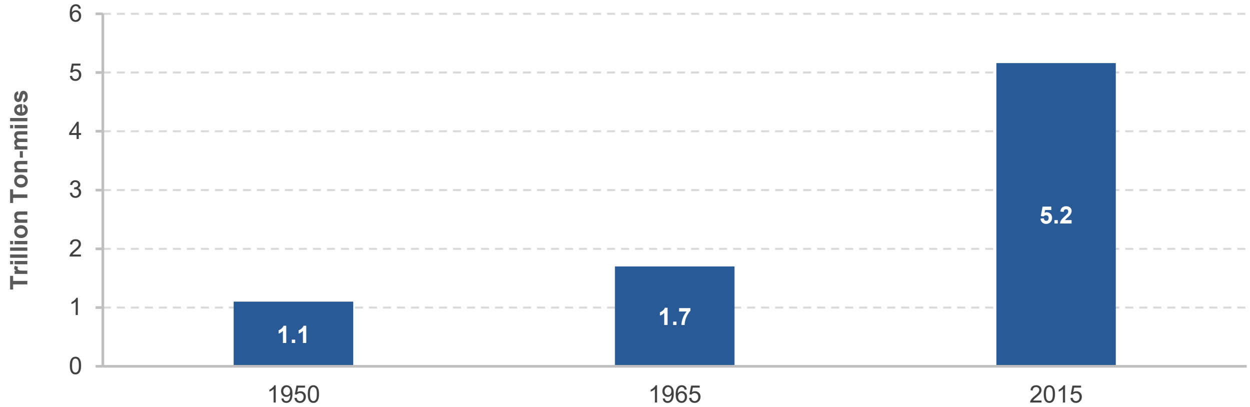
Sources: Forecast from 1968 National Highway Needs Report, Figure 4; actual population from U.S. Census Bureau; VMT 1935–1992 from Highway Statistics Summary to 1995; VMT 1993–2016 from Highway Statistics.

Modal Distribution of Freight

The 1968 edition first discussed the performance of the Nation's transportation system in terms of freight volume and mode from 1950 to 1965. It reported that total freight movement increased from 1.1 to 1.7 trillion ton-miles over this period, averaging 2.9 percent growth per year. Between 1965 and 2015, total actual freight expanded by 2.2 percent per year to 5.2 trillion ton-miles (*Exhibit 8-6*).

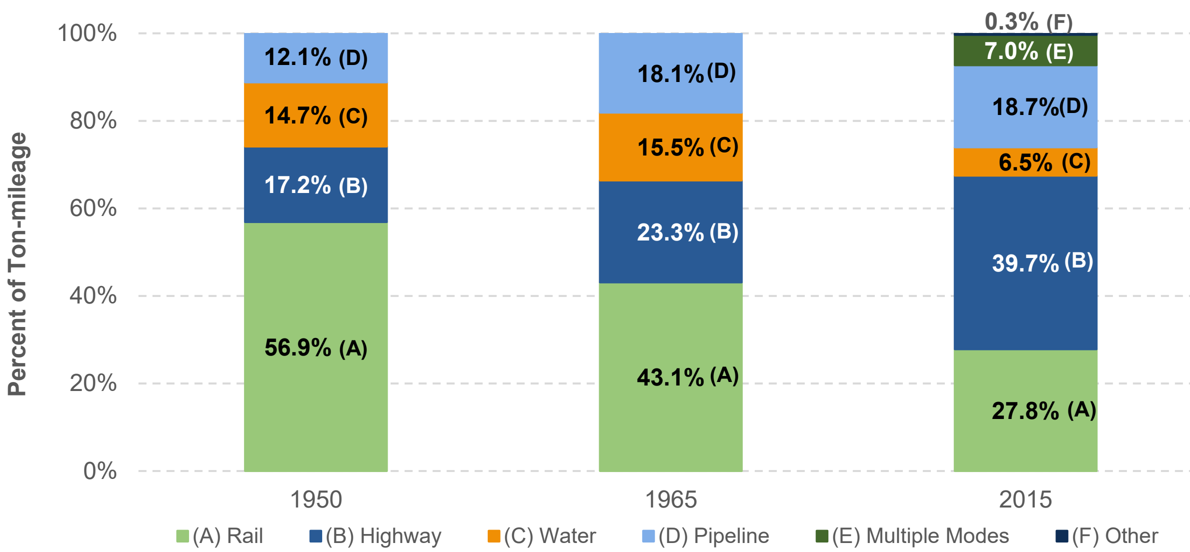
The composition of freight transportation also changed substantially over the past half century. The share of railroads by ton-miles decreased from 56.9 percent in 1950 to 43.1 percent in 1965, and dropped further to 27.8 percent in 2015 (*Exhibit 8-7*). Trucks on highways almost completely took over the lost share of railroads, as freight transported by highways rose steadily: the share of highway freight transport was 17.2 percent in 1950, 23.3 percent in 1965, and 39.7 percent in 2015. Water transportation played a declining role in freight movement: its share was 6.5 percent in 2015, less than half of its share of 15.5 percent in 1965. Pipelines, which are used to transport goods and materials, remain an important mode of transportation, with the share of freight by pipeline holding steady around 18–19 percent. Many goods are now shipped via more than one transportation mode, with multimodal freight shipment accounting for 7.0 percent of total freight ton-miles in 2015.

Exhibit 8-6 ■ Total Freight Transport, 1950–2015



Sources: Freight transport in 1950 and 1965 from the 1968 National Highway Needs Report; in 1997–2015 from the Freight Analysis Framework (FAF4) at https://faf.ornl.gov/fafweb/Extraction1.aspx.

Exhibit 8-7 ■ Freight Transport by Mode, 1950–2015



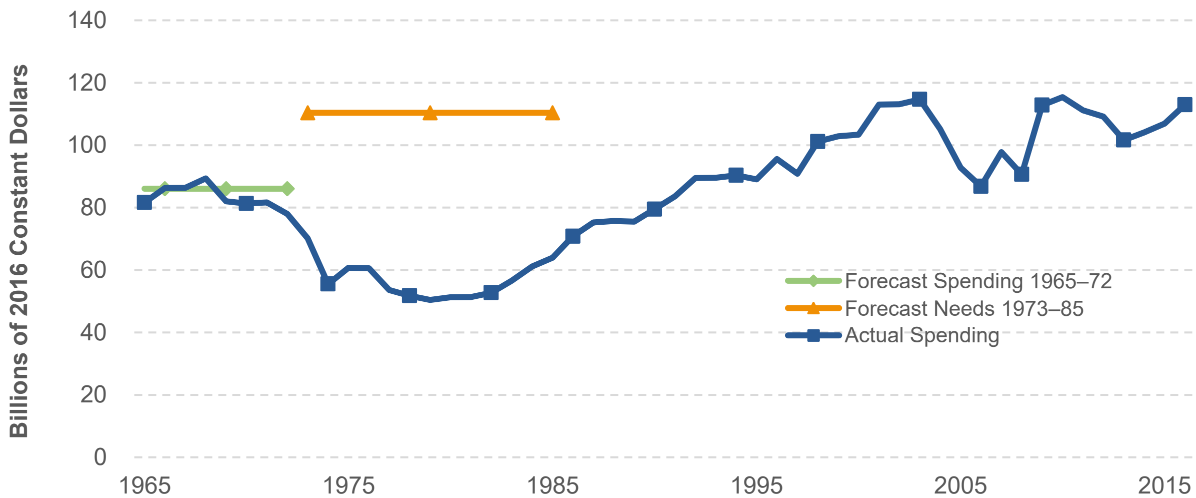
Sources: Freight transport in 1950 and 1965 from the 1968 National Highway Needs Report, Figure 2; in 1997–2015 from the Freight Analysis Framework (FAF4) at https://faf.ornl.gov/fafweb/Extraction1.aspx.

Estimates of Future Investment Needs

The 1968 C&P Report provided an estimate of capital investment needed to raise the highway system to a predetermined design standard. Highway needs refer to the estimated investments (costs of major repair, reconstruction, and new construction) required to maintain or improve systems of streets and highways to established engineering standards (such as lane width and number, maximum grades, minimum curvature) and to a capacity adequate to accommodate traffic forecast for 20 years ahead. The 1968 C&P Report separated the 20-year forecast period into the Interstate program period of 1965–1972 and post-Interstate period of 1973–1985, although the Interstate program was later extended beyond 1972.

Exhibit 8-8 summarizes the average annual investment needs for all roads and streets, as estimated by the States. Highway capital investment for the period of 1965–1972 was estimated based on the level of expected expenditures on Federal-aid highways, State highways, and other local roads and streets. The 1968 report estimated that the average annual expected highway capital investment for 1965–1972 was $8.5 billion (base year 1963). After adjusting inflation to the 2016 level, the average annual estimated capital investment needs to improve highways would be $86.1 billion, presented in constant 2016 dollars. Actual annual spending was $83.3 billion for the period of 1965–1972, aligned with the needs estimates in the 1968 C&P Report (lower panel of *Exhibit 8-8*).

Exhibit 8-8 ■ Highway Investment Needs Estimates from 1968 C&P Report Compared with Actual Highway Capital Spending



Category	1965–1972 (in 1963 dollars)	1973–1985 (in 1972 dollars)	1965–1972 (in 2016 dollars)	1973–1985 (in 2016 dollars)
Annual (billion)				
Estimated Needs	$8.5	$17.4	$86.1	$110.4
Actual Spending	$8.2	$9.0	$83.3	$56.9

Sources: Forecast from 1968 National Highway Needs Report, Table 2; investment levels adjusted by FHWA staff for inflation using the FHWA Construction BPI and National Highway Construction Cost Index 2.0; actual capital spending from FHWA Bulletin: Highway Funding 2013–2016, Table HF-10B and Highway Statistics, various years, Table HF-10A.

For the period of 1973–1985, the estimated capital investment needs to meet engineering standards was $17.4 billion (in 1972 constant dollars) per year, or $110.4 billion in constant 2016 dollars. However, actual capital investment quickly fell from the level in the preceding period of 1965–1972 in constant-dollar terms, averaged only $56.9 billion (in 2016 dollars), about half of the capital investment needs estimated in the 1968 report. Capital allocation for the period of 1973–1985 never reached the high level of needs identified in the 1968 C&P Report, which could be attributable to factors such as a shift in highway program priority, transportation resource constraints, and rising construction costs. The needs assessment in the 1968 C&P Report has similarities to the process used in current C&P Reports, but differs in several aspects. Some points of interest include:

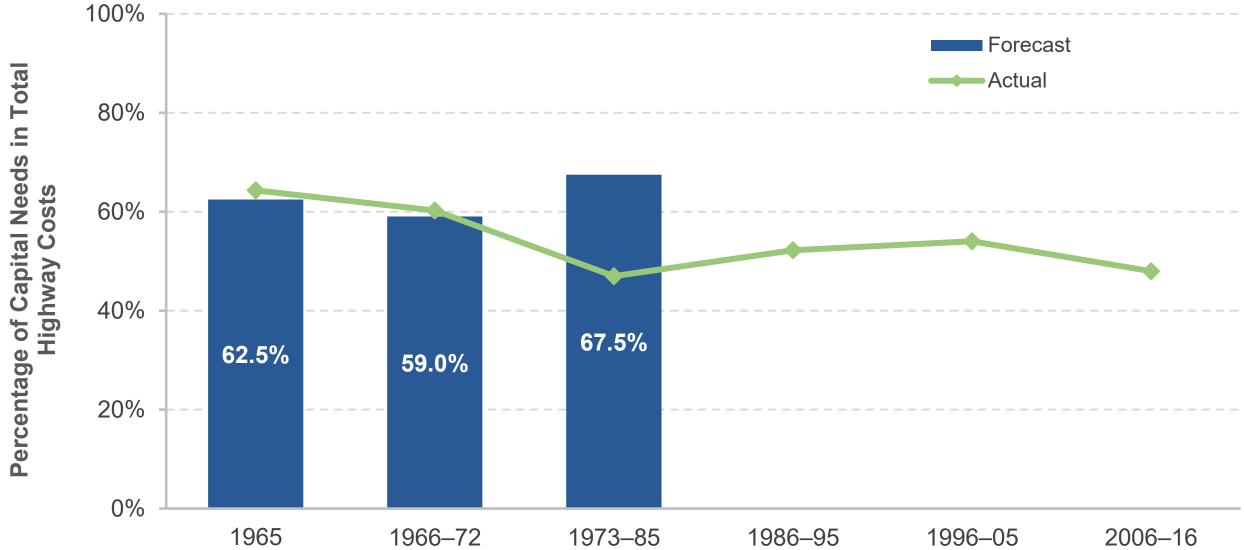
- While the needs estimates presented were not based on benefit-cost analysis, the report referenced its importance in actual project selection. The needs assessment in the 1968 C&P Report was an aggregate of the State highway departments' estimates of future highway needs for the period of 1965–1985, in contrast to the current approach of applying analytical models to State-supplied data using benefit-cost analysis. The 1968 report gave the States only a few months to prepare their needs estimates, and the estimates did not provide any measure of monetized benefits derived from reduction in accidents, gains in travel time and pavement quality, or vehicle operation savings. The needs study in this case was more an inventory, providing the level of investment required to ensure all roads of the system meet or exceed a predetermined level of traffic efficiency and safety in engineering design standards. The report describes a needs estimate as "a preliminary to actual benefit-cost study," indicating that in making actual project selections, "highway departments evaluate the relative benefit from competing projects, and programing decisions usually give heavy weight to this factor."

- The 1968 C&P Report referenced components of needs beyond its scope. The estimated highway needs prepared by the States provided a national summary of the costs that would be required to improve deficient sections of all highways in the Nation to an engineering standard considered appropriate for each class of roadway. However, the report notes that it does not include all costs that would be required for an extensive program of traffic engineering improvements in urban areas, or for other possible improvements such as parking facilities and special features on urban streets and highways to expedite bus movements.
- Analyses were presented in constant dollars, and the potential effect of inflation was discussed in the 1968 C&P Report. The price index for highway construction rose at an annual rate of 3 percent between 1960 and 1966. The 1968 report estimated that if the rising price trend was extended to the 1965–1972 period to consider the uncertainty associated with construction prices, the adjusted average annual capital outlays for 1965–1972 would need to be elevated from $8.5 billion (in 1963 dollars) to $10 billion. Even without any further construction price increase after 1972, the annual capital needs estimate for 1973–1985 would have to increase from $17.4 billion (in 1972 dollars) to $22.6 billion to make the same improvements after accounting for earlier construction price increases.
- Unlike current reports, which focus solely on highway capital investment, the 1968 C&P Report also provided projections of highway noncapital expenditures, including maintenance costs and administrative needs. Maintenance costs included costs of physical work to preserve highways in good functional condition, and costs of traffic control and services, including winter maintenance (snow and ice control), summer maintenance (mowing, weed control, etc.), and traffic operations. Maintenance costs were estimated based on the record of expenditures by State and local governments and probable future unit-cost increases. Administrative and miscellaneous costs included costs related to highway activities, such as office and administrative operations, planning and research, highway safety programs (including highway patrol, vehicle inspection, driver training programs), and interest and amortization costs of highway bonds.

Exhibit 8-9 compares the 1965–1985 forecast with actual expenditures in 1965–2016 to examine the share of capital needs in total highway costs (including capital cost, maintenance cost, and administrative and miscellaneous cost). In the period of 1965–1985, the Interstate was under construction, many Federal-aid highways were planned to be upgraded, and capital needs were projected to account for the majority of total highway costs: 59.0 percent in 1966–1972 and 67.5 percent in 1973–1985.

The share of actual capital outlay of total disbursement was slightly above the 1968 C&P Report forecast, by 1–2 percentage points, from 1965 to 1972. However, as actual capital spending was far below the forecast during 1973–1985 (*Exhibit 8-8*), the share of capital in total spending fell to 47 percent, much lower than the projected share of 67.5 percent. As the highway system matures, more resources are being allocated to noncapital spending, which is reflected in a smaller capital share that has stabilized at below 50 percent in recent years.

Exhibit 8-9 ■ Share of Capital Needs in Total Highway Costs from the 1968 C&P Report, 1965–2016



Sources: Capital needs estimate from 1968 National Highway Needs Report, Table 2; maintenance and administration and other from 1968 National Highway Needs Report, Table 4; actual capital spending from FHWA Bulletin: Highway Funding 2013–2016, Table HF-10B and Highway Statistics, various years, Table HF-10A.

Topics Covered

In addition to highway conditions and future investment needs, the 1968 C&P Report discussed the following topics with respect to transportation agencies of all levels: rural highways, urban mobility, highway finance, and toll facilities.

- Rural highways. The 1968 C&P Report acknowledged the crucial role of highways for economic development in underdeveloped regions of the United States that were characterized by high unemployment rates, such as the Appalachian region. The report recommended using the Federal-aid highway program to supplement and reinforce development programs. The report recognized the intercity impact on rural highways, as intercity travel accounted for a large portion of total VMT on rural highways, and future rural road construction would be focused on highway improvement to meet higher standards and reconstruction of pavements worn out in service. The report identified the climbing demand to meet recreational needs of the American people, and suggested that more attention be paid to scenic roads, parkways, and highway beautification to protect and enhance the physical beauty of the country's natural environment.
- Urban mobility. Urban development has shaped the U.S. landscape. The rapid growth of urban areas and the heavy travel demands of dispersed land development have led to a phenomenal rise in urban travel. In 1967, 50.5 percent of motor vehicle travel took place in urban areas; about half of the projected future vehicle travel increase could be accounted for by population increase, and the other half from changing travel habits attributable to the dispersal of homes and rising incomes. Although urban mobility had improved tremendously for most Americans, the 1968 C&P Report recognized that some segments of the population—particularly the poor and disadvantaged living in central cities—still lacked personal mobility, restricting them from jobs and services, as income was revealed as a main determinant of car ownership and highway travel.
- Highway funding. Two marked trends in highway funding had developed from 1915 to 1965: a shift from local to the State and Federal governments, and a shift away from the generation of funds through property and other general fund taxes toward taxes on highway users. The 1968 C&P Report outlined potential resources for future capital improvements as revenue available for

highways minus requirements for highway maintenance and administration. A few Federal-aid program options were presented based on different financing mechanisms to illustrate how the Federal-aid highway program could significantly influence the future of highways by directing outlays to priority areas (Interstate vs. metropolitan system, for instance).

- Toll facilities. The 1968 C&P Report discussed Federal policies on toll facilities and suggested an in-depth study on the interrelationships between toll and free highway facilities, Federal involvement in regulating toll facilities, and reimbursement for the States.
- Recommendations. To provide information for Congress to shape the broad outlines of future highway programs, the 1968 C&P Report recommended some options to address transportation issues through large future investment in highways and mass transit, including completing the Interstate program; undertaking a systematic nationwide functional highway classification study; dedicating more resources to improve urban transportation, including development of mass transit and rail rapid transit and efficient use of bus transit; broadening Federal-aid funds to include parking elements; improving traffic engineering; establishing mechanisms for long-range advance acquisition of highway rights-of-way; and joint development of highway corridors in urban areas through coordination with the Department of Housing and Urban Development.

Evolution of the C&P Report

Since the first C&P Report in 1968, a total of 24 C&P Reports have been produced to provide Congress and other decision makers with an objective appraisal of the physical conditions and operational performance on the Nation's highway, bridge, and public transit systems, as well as financing mechanisms.

The 1968 C&P Report provided a rough approximation of costs needed to raise the highway system to a predetermined engineering design standard. A more thorough study of highway classification of all segments of the network was described in the 1970 C&P Report, and more analytical estimates of improvement needs were undertaken in the 1972 C&P Report.

Recognizing its lack of rigorous economic analysis, the 1968 C&P Report included a recommendation to build models that considered costs and benefits for various components of the Nation's highway and transit systems. Subsequently, several benefit-cost analysis models were developed and applied in C&P analyses: the Highway Economic Requirements System (HERS), the Transit Economic Requirements Model (TERM), and National Bridge Investment Analysis System (NBIAS).

Exhibit 8-10 highlights five key milestones achieved over the course of the C&P Report series that remain directly relevant today. The 1980 edition (sixth in the series) was the first to report data collected through the Highway Performance Monitoring System (HPMS), which marked a transition from relying on special studies to a routine annual reporting system. The 1993 edition (twelfth in the series) was the first to report information on the Nation's transit systems, folding in information previously provided to Congress via a separate transit-only report series. The HERS model for highways was first introduced in the 1995 edition (thirteenth in the series), the TERM for transit was introduced in the 1997 edition (fourteenth in the series), and the NBIAS for bridges was introduced in the 2002 edition (sixteenth in the series). These models are economic analyses based on a comprehensive study of highway and transit investment needs to help guide the formulation of future highway programs to achieve an efficient allocation of resources. All three models remain in use today, although each has been significantly enhanced over the years.

Exhibit 8-10 ■ List of C&P Reports

Edition	Transmittal Date	Title	Milestone
1968	January 1968	1968 National Highway Needs Report	
1970	January 1970	1970 National Highway Needs Report	
1972	May 1972	1972 National Highway Needs Report	
1974	January 1975	The 1974 National Highway Needs Report	
1977	September 1977	The Status of the Nation's Highways: Conditions and Performance Report	
1980	January 1981	The Status of the Nation's Highways: Conditions and Performance Report	HPMS introduced
1983	July 1983	The Status of the Nation's Highways: Conditions and Performance Report	
1985	May 1985	The Status of the Nation's Highways: Conditions and Performance Report	
1987	June 1987	The Status of the Nation's Highways: Conditions and Performance Report	
1989	June 1989	The Status of the Nation's Highways and Bridges: Conditions and Performance AND Highway Bridge Replacement Program – 1989 Report	
1991	July 1991	The Status of the Nation's Highways and Bridges: Conditions and Performance Report	
1993	January 1993	The Status of the Nation's Highways, Bridges, and Transit: Conditions and Performance Report	Transit added
1995	October 1995	1995 Status of the Nation's Surface Transportation System: Condition & Performance Report	HERS introduced
1997	March 1998	1997 Status of the Nation's Surface Transportation System: Condition and Performance Report	TERM introduced
1999	May 2000	1999 Status of the Nation's Highways, Bridges, and Transit: Conditions & Performance Report	
2002	January 2003	2002 Status of the Nation's Highways, Bridges, and Transit: Conditions & Performance Report	NBIAS introduced
2004	February 2006	2004 Status of the Nation's Highways, Bridges, and Transit: Conditions & Performance Report	
2006	February 2007	2006 Status of the Nation's Highways, Bridges, and Transit: Conditions & Performance Report	
2008	January 2010	2008 Status of the Nation's Highways, Bridges, and Transit: Conditions & Performance Report	
2010	March 2012	2010 Status of the Nation's Highways, Bridges, and Transit: Conditions & Performance Report	
2013	January 2014	2013 Status of the Nation's Highways, Bridges, and Transit: Conditions & Performance Report	
2015	December 2016	2015 Status of the Nation's Highways, Bridges, and Transit: Conditions & Performance Report	
23rd	November 2019	Status of the Nation's Highways, Bridges, and Transit: Conditions & Performance Report – 23rd Edition	
24th	2021	Status of the Nation's Highways, Bridges, and Transit: Conditions & Performance Report – 24th Edition	

Source: FHWA staff compilation.

Supplemental Analysis – Highway

This section explores the implications of the highway investment scenarios considered in Chapter 7, starting with a comparison of the scenario investment levels with those presented in previous C&P Reports. The section next reviews alternative assumptions about the allocation of capital investment between system expansion and system rehabilitation, and compares the resulting highway and bridge performance after 20 years.

This section also examines the timing of investment over the 20-year analysis period, and assesses the implications of concentrating all available funding to specific functional classes. A subsequent section of this chapter provides supplementary analysis regarding the transit investment scenarios.

KEY TAKEAWAYS

- The gap between the average annual investment level under the Improve Conditions and Performance scenario and base-year spending level has increased between the 23rd and 24th editions. Much of this increase is attributable to changes in the HPMS data between 2014 and 2016, which appear to relate to gradual improvements in the quality of the data reporting since new data items and procedures were adopted in 2009. The gap remains smaller than that estimated in the 2010 edition.
- The gap between the average annual investment level under the Maintain Conditions and Performance scenario and base-year spending has been negative since the 2013 edition (i.e., base-year spending is bigger).
- As should be expected, altering the Sustain Recent Spending scenario to favor system expansion over system rehabilitation projects results in better operational performance (in terms of reduced traveler delay) and worse physical conditions (in terms of increases in pavements and bridges in poor condition). However, the share of travel on pavements with good ride quality would be higher because of the addition of new lanes.
- As should also be expected, altering the Sustain Recent Spending scenario to favor system rehabilitation over system expansion projects would lead to better overall physical conditions and worse operational performance. However, for Interstate highways and urban other freeways and expressways, the share of travel on pavements with poor ride quality would rise slightly, as some pavement improvement projects would not be cost-beneficial unless the facility was widened concurrently.
- The timing of investment is not very significant in terms of conditions and performance results after 20 years; the advantage of front-loading highway investment comes mainly from allowing users to enjoy the benefits from improved system conditions and performance earlier.

Comparison with the 23rd C&P Report

Although the general concepts behind the Maintain Conditions and Performance scenario and the Improve Conditions and Performance scenario remain the same between the scenarios presented in this 24th edition of the C&P Report and the 23rd edition, the time periods analyzed differ. This 24th edition covers a 20-year period of 2017 through 2036; the 23rd C&P Report covered 2015 through 2034.

The Maintain Conditions and Performance scenario identifies a level of investment associated with keeping overall conditions and performance at their base-year levels in 20 years. As discussed in Chapter 7, the investment level is set to stay at a fixed level in constant-dollar terms over the analysis period.

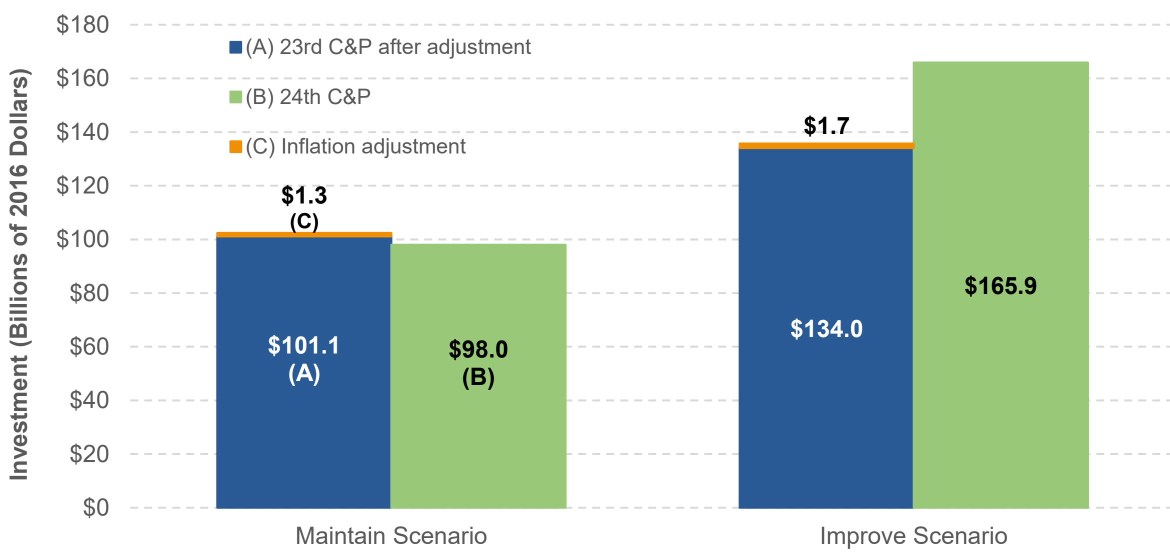
In the Maintain scenario, the targets of components derived from the Highway Economic Requirements System (HERS) were set as spending at the lowest level at which (1) the projected average International Roughness Index (IRI) in 2036 matches (or is better than) the value in 2016 and (2) the projected average delay per vehicle miles traveled (VMT) in 2036 matches (or is better than) the value in 2016. The target of components derived from the National Bridge Investment Analysis System (NBIAS) was set as maintaining the share of total deck area on bridges in poor condition in the current 24th edition.

The Improve Conditions and Performance scenario sets a level of spending sufficient to fund all potential highway and bridge projects that are cost-beneficial over 20 years. The scenario used in both the 23rd and this 24th edition assumes that cost-beneficial investments will be addressed immediately as they are identified.

As discussed in Chapter 2, highway construction costs were converted to constant dollars using the Federal Highway Administration's (FHWA's) National Highway Construction Cost Index (NHCCI) 2.0, which decreased by 1.3 percent between 2014 and 2016. Consequently, the observed and projected highway construction costs would decrease by 1.3 percent after adjusting the need figures in the 23rd C&P Report's scenario from 2014 constant dollars to 2016 dollars. *Exhibit 8-11* shows that the 23rd C&P Report estimated the average annual investment level in the current Maintain Conditions and Performance scenario at $102.4 billion in 2014 dollars; this figure shifts down to $101.1 billion in 2016 dollars after adjusting for inflation using NHCCI 2.0 (taking away $1.3 billion). The comparable amount for the Maintain Conditions and Performance scenario presented in Chapter 7 of this edition is $98.0 billion in 2016 dollars, approximately 3.0 percent lower than the adjusted 23rd C&P Report estimate.

Similarly, the average annual investment level in the 23rd C&P Report for the Improve Conditions and Performance scenario was estimated to be $135.7 billion in 2014 dollars, the equivalent of $134.0 billion in 2016 dollars after adjusting for inflation. The comparable amount for the Improve Conditions and Performance scenario presented in Chapter 7 of this edition is $165.9 billion, 23.8 percent higher than the adjusted annual investment level based on the 23rd C&P Report.

Exhibit 8-11 ■ Selected Highway Investment Scenario Projections from the 24th C&P Report Compared with Projections from the 23rd C&P Report



Note: Inflation adjustment refers to the investment levels for the highway and bridge scenarios adjusted for inflation using the FHWA National Highway Construction Cost Index 2.0.

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

Sources of Investment Needs Change from the 23rd and 24th C&P Report

Exhibit 8-11 illustrates that under the Improve Conditions and Performance scenario, total estimated average annual investment needs increased by $30.2 billion, from the $135.7 billion in the 23rd C&P Report to $165.9 billion in the 24th C&P Report. As discussed in Chapter 7, this scenario is built from three components: one derived from the HERS model, one derived from the NBIAS model, and one covering nonmodeled investment types that are assumed to grow proportionally to the HERS and NBIAS analysis results.

The NBIAS-derived portion of the Improve scenario rose by 10.2 percent. As the same version of NBIAS was used in the development of both reports, this difference is attributable solely to changes in the National Bridge Inventory and parameters for user costs and improvement costs assumed in the model for 2016 vs. 2014. The HERS-derived component of the Improve Conditions and Performance scenario is the major driver of the total increase, rising 25.2 percent from $73.2 billion per year in the 23rd C&P Report (in 2014 constant dollars) to $91.7 billion annually in the 24th C&P Report (in 2016 constant dollars). Multiple factors contributed to this large increase, including the versions of HERS used, differences in input parameters, differences in the Highway Performance Monitoring System (HPMS) data reported by States for the two years, and changes in procedures for adjusting data outliers and populating blank HPMS data cells.

Exhibit 8-12 shows the results of a series of incremental HERS runs conducted to isolate the sources of the $18.5 billion difference between the HERS results used in the development of the Improve Conditions and Performance scenarios in the 23rd C&P report and 24th C&P report. Substituting revised procedures for addressing outliers and gaps in the HPMS data increased the annual investment level by $4.1 billion. Changes in the HPMS data between 2014 and 2016 are the major source of increase in the scenario investment level, accounting for $16.9 billion per year. (The quality of HPMS data reporting appears to be gradually improving since new data items and procedures were adopted in 2009.) Updates to various model parameters (including construction costs per mile and safety costs, as well as updating values from 2014 dollars to 2016 dollars), increased the annual investment level by $1.4 billion. Changes in the assumptions regarding exogenous price changes, in particular the elimination of an assumed annual increase in the average value of time per hour, reduced the annual investment levels by $2.6 billion. Refinements to HERS modelling procedures (see *Appendix A*) further dampened annual investment needs by $6.1 billion. Changes in the assumed annual rate of future VMT growth (1.07 percent in the 23rd C&P Report vs. 1.20 percent in the 24th Report) increased the HERS-derived highway investment projection by $4.5 billion. While sequencing these incremental HERS runs differently would have an effect on the level of investment attributed to specific sources, the general implication is that the increase in the average annual investment levels for this scenario between the two C&P editions is attributable to the HPMS data, rather than to the changes in the HERS model itself.

Exhibit 8-12 ■ Comparison of HERS-Derived Highway Investment Projections under the Improve Conditions and Performance Scenario in the 23rd and 24th C&P Report

Source of Difference	Changes in Annual Investment
Data preprocessor	$4.1
HPMS Data	$16.9
HERS Parameters	$1.7
Exogenous Price Change Assumptions	-$2.6
HERS Upgrades	-$6.1
VMT Growth Assumption	$4.5
Net Change	**$18.5**

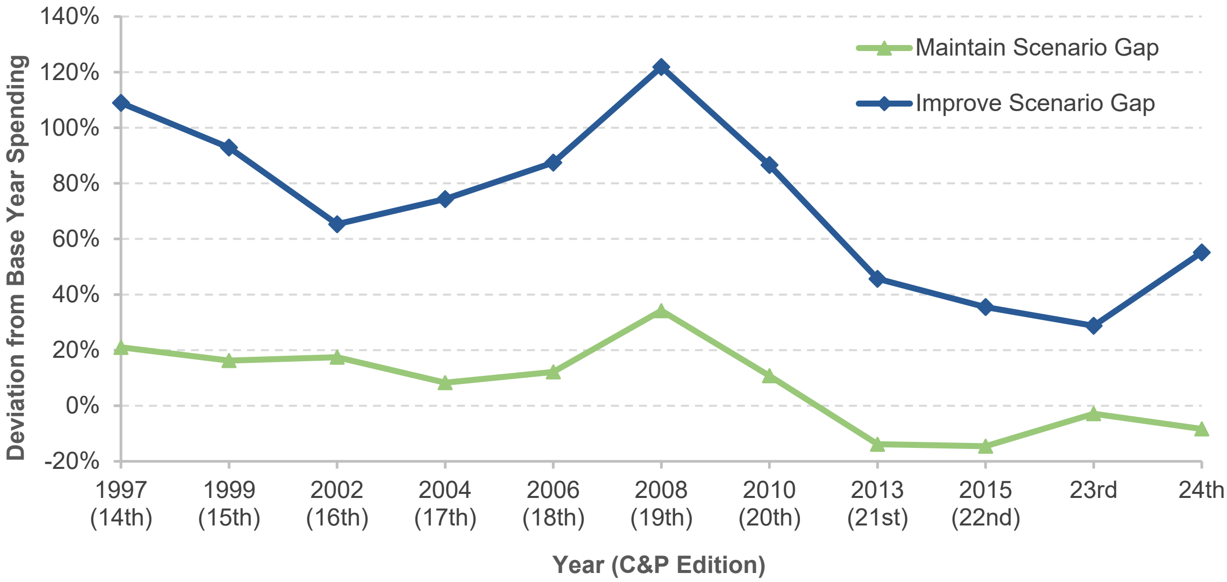
Sources: Highway Economic Requirements System.

Comparisons of Implied Funding Gaps

Each edition of this report presents projections of travel growth, pavement conditions, and bridge conditions under different performance scenarios. The projections cover 20-year periods, beginning the first year after the data were presented on current conditions and performance. Although the scenario names and criteria have varied over time, the C&P Report traditionally has included highway investment scenarios corresponding in concept to the Maintain Conditions and Performance scenario (i.e., a "Maintain" scenario) and the Improve Conditions and Performance scenario (i.e., an "Improve" scenario) presented in Chapter 7.

Exhibit 8-13 compares the funding gaps implied by the analysis in the current report with those implied by previous C&P Report analyses. The funding gap is measured as the percentage by which the estimated average annual investment needs for a specific scenario exceed the base-year level of investment. The scenarios examined are each edition's primary "Maintain" scenario and primary "Improve" scenario.

Exhibit 8-13 ■ Comparison of Average Annual Highway and Bridge Investment Scenario Estimates with Base-period Spending, 1997 Edition to 24th C&P Edition



Note: 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 among reports. Negative numbers signify that the investment scenario estimate was lower than base-period spending. The base-period for the 24th edition is the average from 2012 to 2016, expressed in 2016 Dollars. The base period for previous editions was a single year; the base years for the 2013, 2015, and 23rd editions were 2010, 2012, and 2014, respectively. The base years for the 1997 to 2010 editions were each two years prior to the cover dates (i.e., the base year for the 1997 edition was 1995; the base year for the 2010 edition was 2008).

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

Prior to the 2013 C&P Report, each C&P Report edition showed that actual annual spending in the base year for that report had been below the estimated average investment level required to maintain conditions and performance at base-year levels over 20 years. Beginning with the 2013 C&P Report, the trend was reversed and gaps between actual and required amounts for the primary "Maintain" scenario became negative. This result differed remarkably from the positive numbers estimated in pre-2013 C&P Reports, indicating that base-year spending reported in recent C&P Reports was higher than the average annual spending levels identified for the "Maintain" scenario.

The "Improve" scenario gap follows a similar trend, which dropped steadily from its peak in the 2008 C&P Report through the 23rd Report, rising again in the 24th Report. The positive values associated with the primary "Improve" scenario gap suggest that actual spending in the base year has been consistently below the estimated required investment level to fund all cost-beneficial potential projects.

Changes in 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" and "Improve" scenarios presented in the 2008 C&P Report coincided with a large increase in construction costs experienced between 2004 and 2006 (the base year for the 2008 C&P Report). The decreases in the gaps presented in recent editions coincided with subsequent declines in construction costs.

The differences among C&P Report editions in the implied gaps reported in *Exhibit 8-13* are not a reliable indicator of change over time in how effectively highway investment needs are addressed. FHWA continues to enhance the methodology used to determine scenario estimates for each edition of the C&P Report to provide a more comprehensive and accurate assessment. In some cases, these refinements have increased the level of investment in one or both scenarios (the Maintain or Improve scenarios, or their equivalents); other refinements have reduced this level. For example, this current 24th C&P edition updated the cost matrix to incorporate new technologies employed in the construction and maintenance of highways and bridges, which tend to lower the required cost of improvements. Hence, more projects are deemed cost-beneficial with a benefit-cost ratio greater than or equal to 1.0, leading to a larger set of projects eligible for inclusion in the "Improve" scenario and pushing up total needs estimate.

Improvements in data quality can also have an impact on the ability of the analytical models to identify potential future investments. Since new data items and procedures were adopted in 2009, the quality and completeness of the HPMS data reporting have gradually improved, making the analytical models less reliant on default values. In comparing the gap between the "Improve" scenario and base-period spending, the decrease between the 2010 edition (based on 2008 data) and the 24th edition may better represent the long-term trend than the increase between the 23rd edition and the 24th edition.

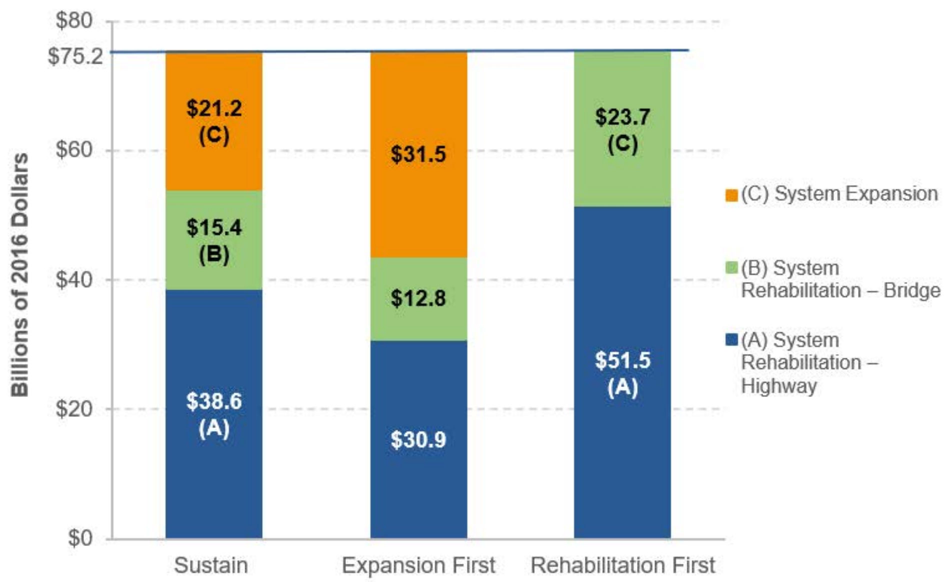
Allocation of Investment

Currently, projects in HERS and NBIAS are treated equally in a pool of candidates for capital improvement. The models use the benefit-cost ratio (BCR) to rank and implement projects, regardless of which spending category or functional class they happen to fall into. For funding-constrained analyses, the project with the highest BCR is selected first, followed by the project with the second-highest BCR, and so on until all available funding is expended. This project selection process splits spending between capital expansion projects and system rehabilitation projects based solely on BCR, rather than through a predetermined allocation.

Exhibit 8-14 describes an alternative approach to allocating capital investment, in which the HERS and NBIAS settings were altered, and the results of separate model runs were combined to project the impacts of altering the proportion of investment directed to capacity expansion vs. system rehabilitation. The benchmark investment strategy, labeled "Sustain," maintains a constant investment level as presented in the Sustain Recent Spending scenario in Chapter 7. In one alternative allocation, named "Expansion First," funds were first distributed to all cost-beneficial capital expansion projects with the remainder of available funds directed to system rehabilitation projects. In the other fund allocation, named "Rehabilitation First," the HERS model was prevented from adding lanes to existing facilities and all investment was directed toward system rehabilitation projects.

For the Sustain case, total capital spending was capped at the same level as that of the Sustain Recent Spending scenario in Chapter 7, excluding nonmodeled components of capital investment, a total of $75.2 billion in 2016 dollars. Under this scenario, $38.6 billion went toward highway rehabilitation, $15.4 billion for bridge rehabilitation, and $21.2 billion for system expansion for highways and bridges. (Bridge capacity expansion is modeled in HERS, so there is no separate capacity expansion category for bridges.)

Exhibit 8-14 ■ Capital Investment under Alternative Allocations



Source: FHWA staff analysis.

For the Expansion First case, the average annual investment level of system expansion was set at $31.5 billion, which covered all cost-beneficial highway and bridge projects defined as the capital requirement under the Improve Conditions and Performance scenario in Chapter 7. The remaining $43.7 billion went to system rehabilitation for highways and bridges, based on actual rehabilitation spending split between highway and bridge projects: $30.9 billion for highways and $12.8 billion for bridges.

For the Rehabilitation First case, the cap of $75.2 billion was below the estimated capital needs of $85.2 billion for system rehabilitation under the Improve Conditions and Performance scenario in Chapter 7. Hence, all capital investment in the rehabilitation allocation was completely assigned to system rehabilitation, with the spending shares of highways and bridges the same as in the Improve Conditions and Performance scenario: $51.5 billion for highways and $23.7 billion for bridges.

Alternative Allocation of Investment in HERS

Exhibit 8-15 compares the annual spending level under the Sustain Recent Spending scenario with the hypothetical spending levels under the Expansion First and Rehabilitation First strategies. Among the three spending strategies, the Expansion First strategy allocates more resources to the expansion of highways and bridges. Under the Rehabilitation First strategy, the entirety of capital spending goes to system rehabilitation, leaving nothing for capacity expansion.

For instance, under the Sustain Recent Spending scenario for rural Interstates, HERS directed $0.9 billion for system expansion and $3.2 billion for system rehabilitation, totaling $4.1 billion. Under the Expansion First strategy, HERS directed a similar amount ($4.0 billion) to rural Interstates, but with a different composition of expansion and rehabilitation. Under this strategy, rural Interstate spending on system expansion increased to $1.4 billion but spending on system rehabilitation decreased to $2.6 billion. Under the Rehabilitation First strategy, HERS directed $4.3 billion annually to system rehabilitation on rural Interstates. (See Chapter 1 for additional discussion of functional classification.)

Exhibit 8-15 ■ Comparison of Annual HERS Spending by Functional Class under Alternative Strategies

Billion of 2016 Dollars	System Expansion Spending			System Rehabilitation Spending		
	Sustain Recent Spending Scenario	Expansion First Strategy	Rehabilitation First Strategy	Sustain Recent Spending Scenario	Expansion First Strategy	Rehabilitation First Strategy
Rural Arterials and Major Collectors						
Interstate	$0.9	$1.4	$0.0	$3.2	$2.6	$4.6
Other principal arterial	$0.7	$1.1	$0.0	$3.3	$2.6	$5.2
Minor arterial	$0.3	$0.4	$0.0	$2.4	$1.8	$3.7
Major collector	$0.1	$0.3	$0.0	$2.6	$2.0	$4.0
Rural total	$2.0	$3.2	$0.0	$11.4	$9.1	$17.5
Urban Arterials and Collectors						
Interstate	$8.2	$11.0	$0.0	$7.3	$6.3	$6.6
Other freeway and expressway	$3.7	$5.4	$0.0	$3.1	$2.6	$3.1
Other principal arterial	$3.0	$5.1	$0.0	$6.9	$5.4	$9.8
Minor arterial	$3.0	$4.6	$0.0	$6.4	$5.0	$9.3
Collector	$1.3	$2.2	$0.0	$3.3	$2.6	$5.1
Urban total	$19.2	$28.3	$0.0	$27.2	$21.9	$34.0
Total	**$21.2**	**$31.5**	**$0.0**	**$38.6**	**$30.9**	**$51.5**

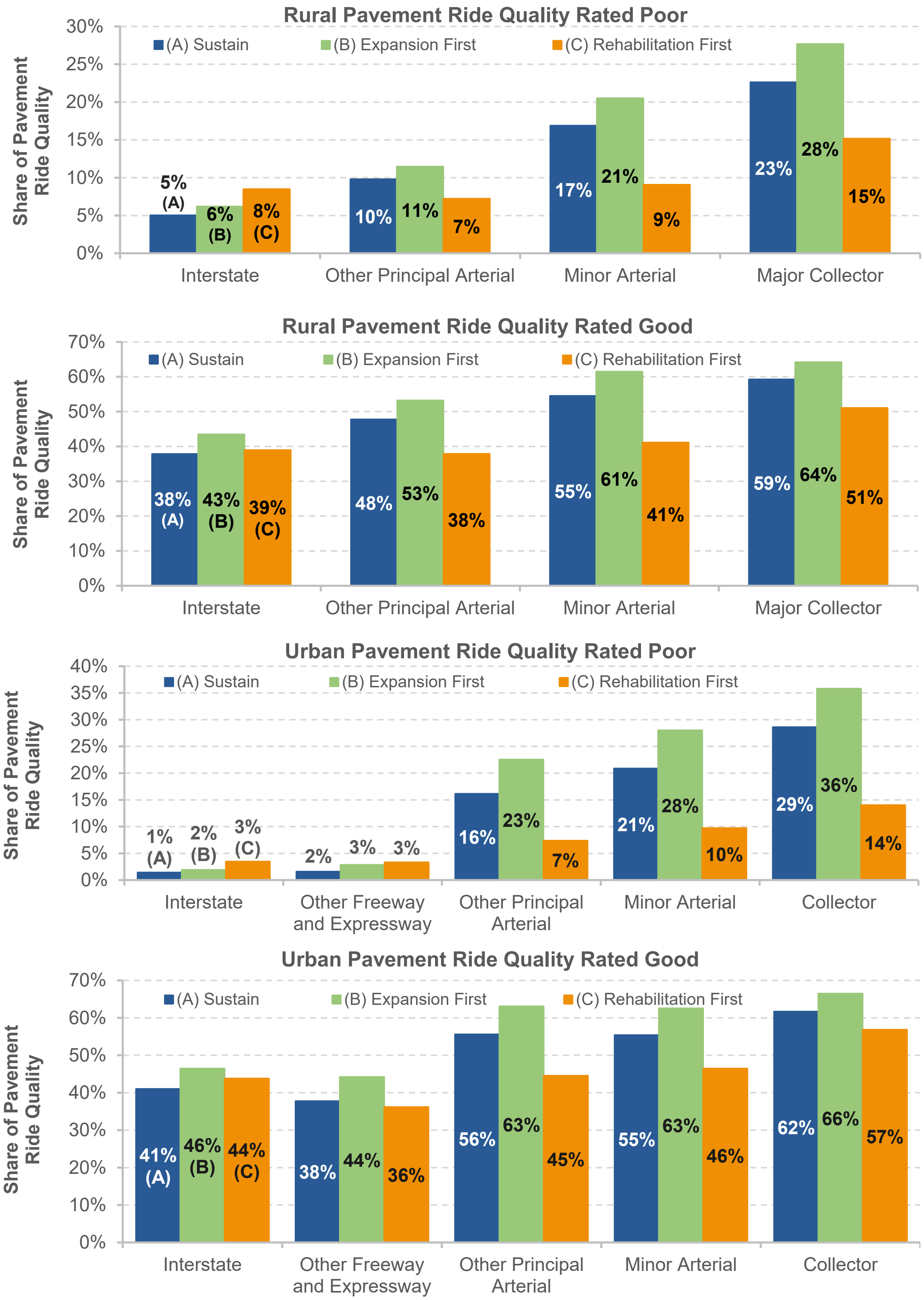
Source: Highway Economic Requirements System.

Exhibit 8-16 illustrates the impacts on pavement ride quality in 2036 from three different capital distribution strategies, based on HERS simulation results. The charts compare the share of VMT on pavement with ride quality rated as poor and good on rural and urban highways in HERS, respectively.

Compared with the Sustain Recent Spending scenario, the share of travel on pavements rated as poor and the share rated as good would both be higher for every functional class in 2036 under the Expansion First scenario. (The share of pavement rated as fair—which is not shown in the exhibits—would decrease.) For example, for rural Interstates under the Expansion First scenario, the projected shares of travel on pavements with ride quality rated as good, fair, and poor were 43 percent, 50 percent, and 6 percent, respectively, whereas the comparable shares under the Sustain Recent Spending scenario were 38 percent, 57 percent, and 5 percent, respectively. The cause of the higher shares rated as poor is obvious in this case: redirecting funds away from system rehabilitation projects would cause more needs to go unmet. The higher share of VMT on pavements rated as good can be attributed to the fact that all newly added lanes under this strategy will start with good ride quality.

Prioritizing preservation over capacity expansion (as was done in the Rehabilitation First strategy) would produce more variation in results by functional class. For roads functionally classified as urban other freeways and expressways, other principal arterial, minor arterial, or collector, the shares of VMT on pavements with good ride quality or poor ride quality would decline relative to the Sustain Recent Spending scenario (which is the opposite of the results noted earlier for the Expansion First strategy). However, on rural Interstates and urban Interstates the share of VMT on pavements with either poor or good ride quality would increase. On urban other freeways and expressways, the share of VMT on pavement with good ride quality would decrease but the share of VMT with poor ride quality would increase.

Exhibit 8-16 ■ Comparison of 2036 Highway Pavement Ride Quality by Functional Class under Alternative Strategies

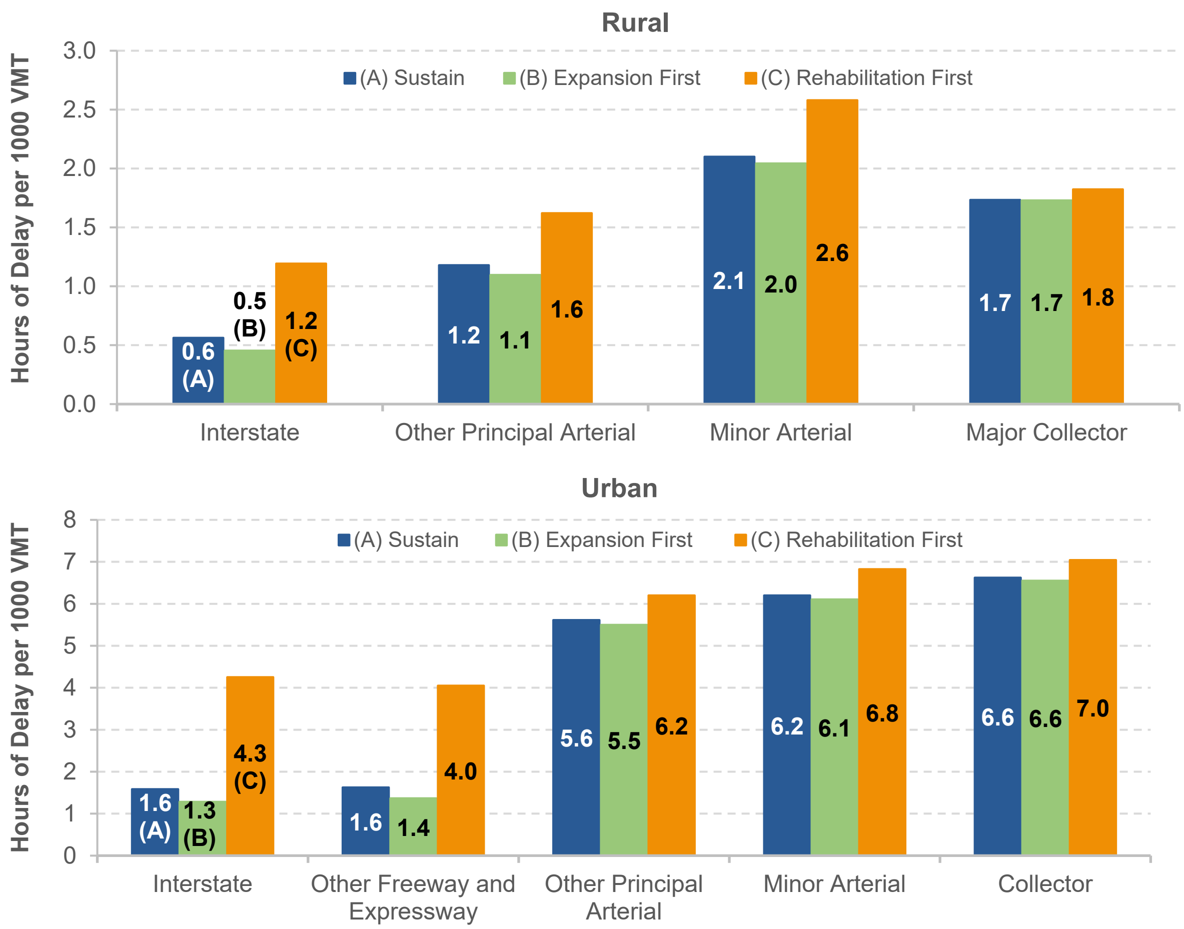


Source: Highway Economic Requirements System.

For example, the proportion of urban Interstate VMT on pavement with poor ride quality would rise from 1 percent under the Sustain Recent Spending scenario to 3 percent under the Rehabilitation First strategy, whereas the share of good pavement would rise from 41 percent to 44 percent. The implication of the elevated share of poor pavement on Interstate is that without a widening component, some Interstate projects would no longer be cost-beneficial and would be dropped from HERS simulation, resulting more roadways in poor riding condition.

HERS also simulates traffic delay in 2036, which varies by alternative spending distributions (see *Exhibit 8-17*). The Expansion First strategy, a spending pattern that favoring capacity expansion first, delivers better travel conditions, as measured in highway delay per 1,000 VMT in both rural and urban areas. The Interstate delay in 2036 is projected to be 0.6 and 1.6 hours per 1,000 VMT in rural and urban areas, respectively, under the Sustain Recent Spending scenario, but would be 0.1 and 0.3 hours lower under the Expansion First strategy.

Exhibit 8-17 ■ Comparison of Highway Delay by Functional Class under Alternative Strategies



Source: Highway Economic Requirements System.

On the other hand, the simulation also suggests that delays under the Rehabilitation First strategy would be longer than under the Sustain Recent Spending scenario, especially on urban limited-access roads where heavy traffic is concentrated. When compared with the Sustain Recent Spending strategy, *Exhibit 8-17* illustrates that travel delay would be prolonged by 0.6 hours per 1,000 VMT on rural Interstates and 2.7 hours on urban Interstates if capacity expansion investment were to be sharply curtailed to prioritize system rehabilitation.

Alternative Allocation of Investment in NBIAS

Exhibit 8-18 presents the average annual spending on bridge rehabilitation under three defined spending strategies. Bridge capital expansion is modeled in HERS; NBIAS captures only system preservation and rehabilitation. Hence, no system expansion spending for NBIAS is reported here. Annual spending for system rehabilitation is $15.4 billion under the Sustain Recent Spending scenario and $12.8 billion under the Expansion First strategy. The Rehabilitation First strategy requires the highest amount of capital investment for system rehabilitation ($23.7 billion).

Exhibit 8-18 ■ Comparison of Annual NBIAS Spending by Functional Class under Alternative Strategies

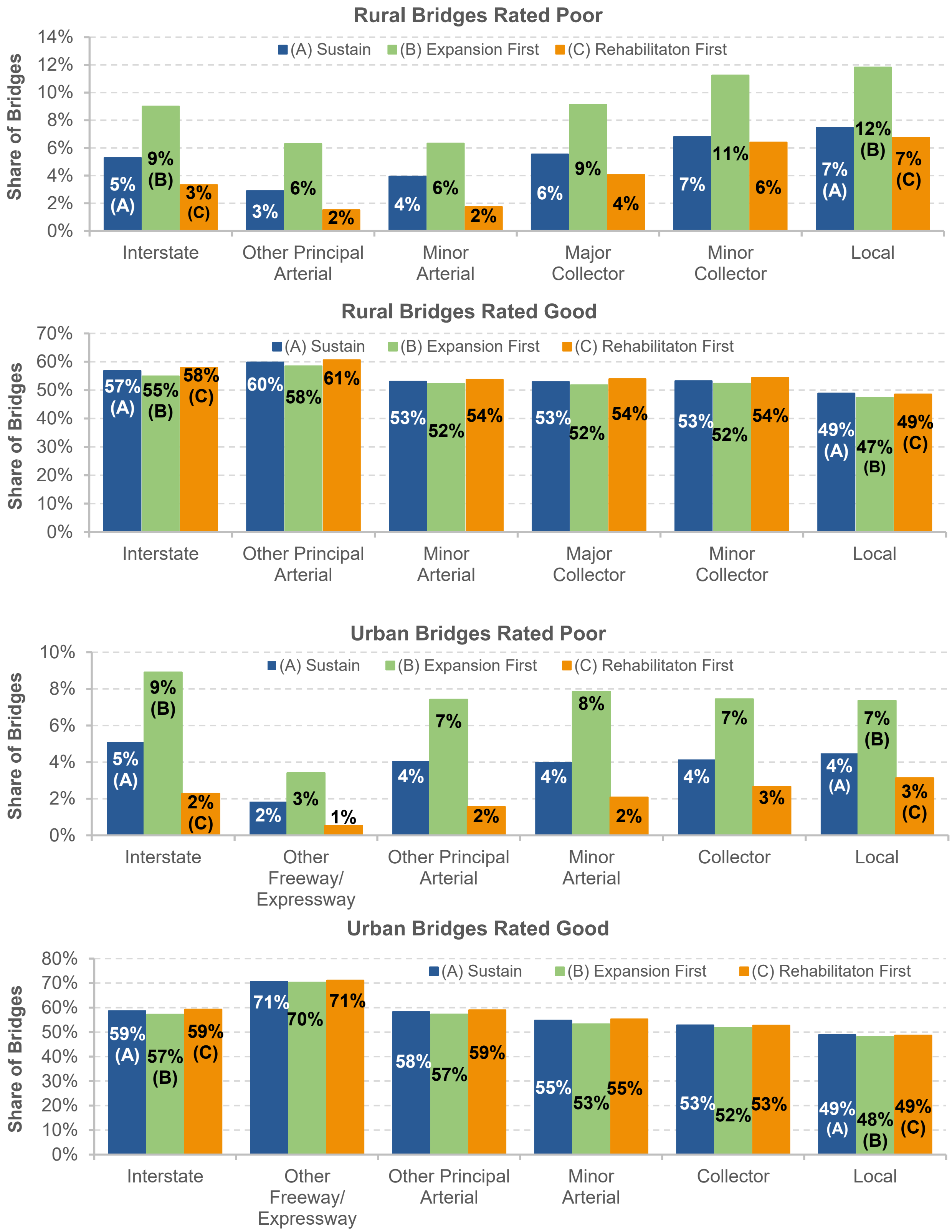
	System Rehabilitation Spending		
Billion of 2016 Constant Dollars	**Sustain Recent Spending Scenario**	**Expansion First Strategy**	**Rehabilitation First Strategy**
Rural			
Interstate	$1.3	$1.0	$2.5
Other principal arterial	$1.0	$0.9	$1.4
Minor arterial	$0.8	$0.7	$1.0
Major collector	$1.3	$1.1	$2.0
Minor collector	$0.6	$0.5	$0.9
Local	$1.6	$1.3	$2.4
Rural total	**$6.6**	**$5.5**	**$10.3**
Urban			
Interstate	$3.6	$2.9	$6.4
Other freeway and expressway	$1.3	$1.1	$1.6
Other principal arterial	$1.7	$1.4	$2.3
Minor arterial	$1.2	$1.0	$1.7
Collector	$0.5	$0.4	$0.8
Local	$0.5	$0.4	$0.7
Urban total	**$8.8**	**$7.3**	**$13.4**
Total	**$15.4**	**$12.8**	**$23.7**

Note: NBIAS is National Bridge Investment Analysis System.
Source: National Bridge Investment Analysis System.

Although NBIAS was given a total budget with which to work, the distribution of investment by functional class reflects the model's assessment of the most cost-beneficial projects among those analyzed. For example, of total NBIAS investment under the Sustain Recent Spending scenario, $1.3 billion went for improvements to rural Interstate bridges. The level of rural Interstate bridge spending for the Expansion First strategy was lower at $1.0 billion, but at a much higher level of $2.5 billion under the Rehabilitation First strategy.

Exhibit 8-19 illustrates the projected impacts of the two alternative investment strategies relative to the Sustain Recent Spending scenario. The charts compare the share of bridges (weighted by deck area) rated as poor and good in 2036 by functional class in rural and urban areas. For example, the share of rural Interstate bridges rated as poor in 2036 would be lower under the Rehabilitation First strategy (3 percent) than under the Sustain Recent Spending scenario (5 percent). Conversely, under the Expansion First strategy, the share of rural Interstate bridges rated as poor would be 9 percent. A similar pattern can be observed for each of the other rural and urban functional classes.

Exhibit 8-19 ■ Comparison of 2036 Bridge Condition by Functional Class under Alternative Strategies



Note: Shares are weighted by bridge deck area.

Source: National Bridge Investment Analysis System.

The Expansion First strategy consistently results in a lower share of bridges rated as good and a higher share of bridges rated as poor in 2036 than does the Sustain Recent Spending scenario across all functional classes. However, the results for this performance indicator are not as consistent for the Rehabilitation First strategy: although the share of bridges rated good is higher for this strategy relative to the Sustain Recent Spending scenario for most functional classes, this is not true for rural local, urban collector, or urban local. For these three functional classes, the projected shares of bridges rated good under the Rehabilitation First strategy (48.6 percent, 52.7 percent, and 48.6 percent, respectively) were actually slightly lower than under the Sustain Recent Spending scenario (48.8 percent, 52.8 percent, and 48.8 percent, respectively). This anomaly can be attributed to investment timing: the higher budget for bridge investment under the Rehabilitation First strategy allows more work to be done on these bridges toward the beginning of the 20-year period, but these bridges are less likely to be improved in later years as it becomes more challenging to address rising bridge needs with a fixed annual budget. (Investment timing implications are discussed in greater detail later in this section.)

Implications of Alternative Investment Strategies

The results from NBIAS and HERS simulations have broader implications in terms of assessing the information presented in this report. They show that the Expansion First strategy has some advantages when compared with the Sustain Recent Spending scenario, such as reduced delay in the long run. The share of good pavement conditions would increase from newly added lanes. However, this strategy has disadvantages as it could lead to an increase in the share of pavements and bridges in poor condition.

Compared with the baseline of Sustain Spending, the Rehabilitation First strategy would improve bridge conditions slightly, but it would also considerably increase delays on urban limited access roads. In the HERS simulation, the Rehabilitation First strategy marginally increases the share of good-pavement Interstate projects but considerably reduces the share of good-pavement projects on lower functional class roads. Although focusing on rehabilitation projects first could be an effective way to improve highway and bridge condition, this approach fails to consider needs from future demand growth, and hence could possibly lead to insufficient capacity and delayed system upgrades to higher design standards in the long run.

As discussed in Chapter 7, the Sustain Recent Spending scenario itself seeks to implement projects within the available budget based on the HERS and NBIAS models' assessments of their relative BCRs, without regard to the resulting mix of investment between system expansion and system rehabilitation.

There are several caveats to note in this study of alternative investment strategies, because some of the results appear to be artifacts of the manner in which the alternative investment strategies were modeled. For example, capital investment is split between broad categories such as System Rehabilitation and System Expansion for convenience, but these are not actually clear-cut distinctions. When widening a facility, system owners typically resurface or reconstruct the existing lanes as well, resulting in improvements in both delay and in the share of VMT on pavements with good ride quality. In the absence of a widening component, some potential projects would likely be deferred until pavement conditions further deteriorate.

System rehabilitation projects can influence delay in some cases, if pavement conditions have deteriorated to the point that they are affecting vehicle speed. Additionally, capital improvements of any kind involve work zones which lead to temporary increases in delay. System conditions and performance indicators can also be influenced by the timing of investment, as discussed in the next subsection.

Timing of Investment

The investment-performance analyses presented in this report focus mainly on how alternative average annual investment levels over 20 years might affect system performance at the end of this period. Within this period, the timing of investment can significantly influence system performance.

The following discussion explores the effects of three alternative assumptions about the timing of future investment—ramped spending, flat spending, or spending driven by BCR—on system performance within the 20-year period analyzed. These patterns can be related to the capital investment scenarios described in Chapter 7, in which the spending levels are set as flat in the Sustain Recent Spending scenario and the Maintain Conditions and Performance scenario and set as BCR-driven in the Improve Conditions and Performance scenario. For purposes of this analysis, the total amount of spending over 20 years was set at identical levels for all three spending patterns: $1.702 trillion for HERS and $382 billion for NBIAS. Translated into annual average spending, this equates to $85.1 billion per year for HERS and $19.1 billion per year for NBIAS.

The flat spending assumption is that combined investment would immediately jump to the average annual level being analyzed, then remain fixed at that level for 20 years. Because spending would stay at the same level in each of the 20 years, the distribution of spending within each 5-year period comprises one-quarter of the total. The Sustain Recent Spending scenario and the Maintain Conditions and Performance scenario both assume flat spending. Chapter 7 specifies the spending level under the Sustain Recent Spending scenario as the average level over the 5-year period 2012–2016 in constant-dollar terms. Annual spending under the Maintain Conditions and Performance scenario was set at the level at which selected measures of conditions and performance in 2036 would match, or be better than, their average values in 2016.

The ramped spending assumption is that any change from the combined investment level by all levels of government would occur gradually over time and at a constant growth rate. The constant growth rate of the ramped spending analysis measures future investment in real terms; thus, the distribution of spending among funding periods is driven by the annual growth of spending. Under the constraint of total amount of spending, the growth rate is determined by the initial level of investment in the first 5-year period. For example, to ensure higher overall growth rates for a given amount of total investment, a smaller portion of the 20-year total investment would have to occur in the earlier years than in the later years. Some previous reports used a ramped spending assumption, the most recent being the 2015 edition.

The Improve Conditions and Performance scenario presented in Chapter 7 was tied directly to a BCR cutoff of 1.0, rather than to a particular level of investment in any given year. This BCR-driven approach resulted in significant front-loading of capital investment in the early years of the analysis, as the existing backlog of potential cost-beneficial investments was first addressed, followed by a sharp decline in later years when there are fewer projects that are cost-beneficial.

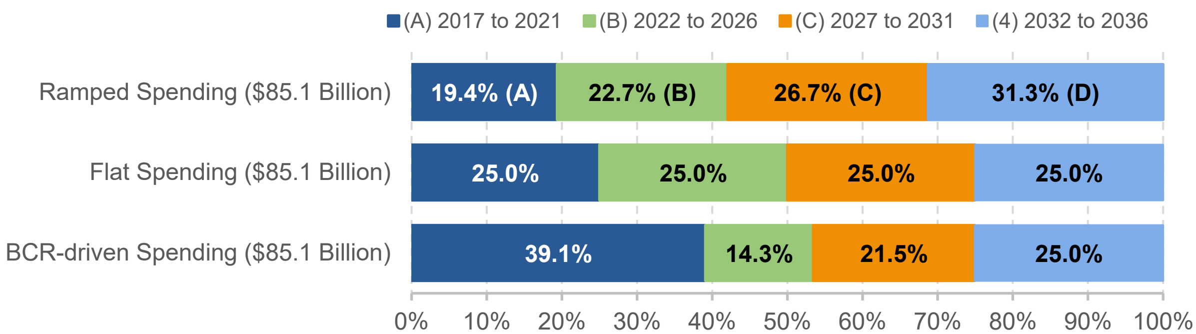
Alternative Timing of Investment in HERS

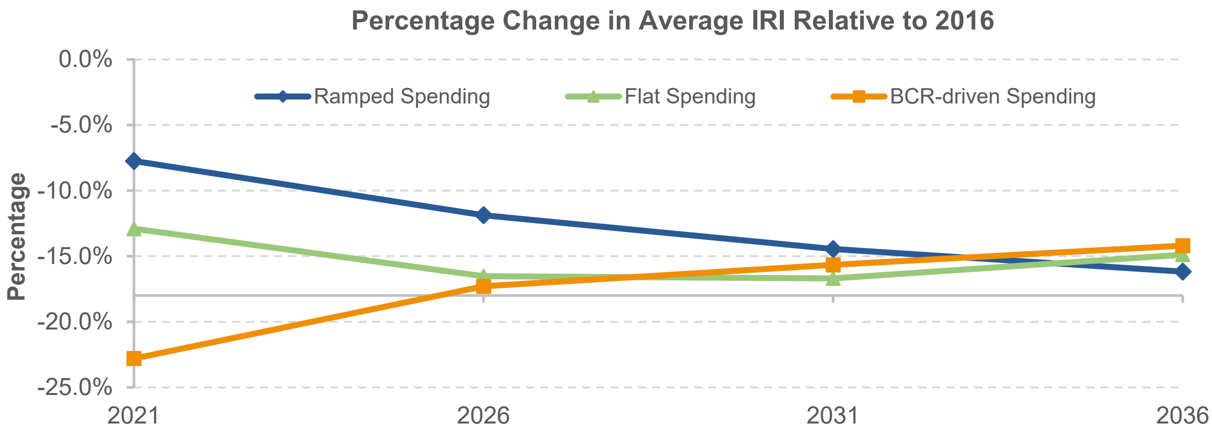
Exhibit 8-20 presents information regarding how the timing of investment would affect the distribution of spending among the four 5-year funding periods considered in HERS and how these spending patterns could affect performance in pavement condition (measured using the IRI) and delay per VMT. Three investment patterns—flat spending, ramped spending, and BCR-driven spending—were compared based on a uniform total budget constraint of $1.702 trillion over 20 years in constant 2016 dollars.

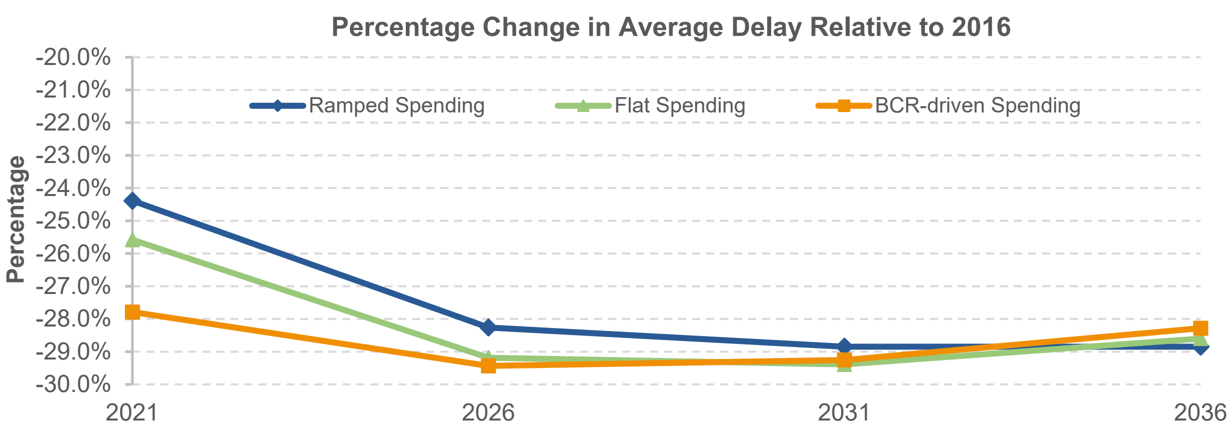
As shown in the top panel of *Exhibit 8-20*, investment under the flat spending alternative is equally distributed over time so that each 5-year period accounts for exactly one-quarter of the total 20-year investment.

In the ramped spending case, the level of investment grows over time assuming a constant growth of real investment. Under this assumption, annual investment would grow by 3.25 percent per year to reach the total budget constraint of $1.702 trillion over 20 years. Only 19.4 percent of the total 20-year investment occurs in the first 5-year period, 2017 to 2021, whereas 31.3 percent of total investment occurs in the last 5-year period, 2032 to 2036.

Exhibit 8-20 ■ Impact of Investment Timing on HERS Results for a Selected Investment Level – Effects on Pavement Roughness and Delay per VMT







Note: HERS is Highway Economic Requirements System; VMT is vehicle miles traveled; IRI is International Roughness Index; BCR is benefit-cost ratio.

Source: Highway Economic Requirements System.

For the BCR-driven spending alternative, a minimum BCR cutoff of 1.029 was applied, which resulted in a total 20-year investment of $1.702 trillion. A high proportion of total spending, 39.1 percent of total investment, would occur in the first 5-year period to partially address the large backlog of cost-beneficial investment the system is facing now (see the backlog discussion in Chapter 7). Under this alternative, investment needs in the second 5-year period would drop significantly to 14.3 percent of the total 20-year investment. Investment needs would increase in the last two 5-year periods because many roadways that were rehabilitated in the first 5-year period would need to be resurfaced or reconstructed again.

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 2021.

The middle panel of *Exhibit 8-20* presents the percentage change of average pavement roughness, as measured by IRI, compared with the 2016 level under the three investment cases. A reduction in average IRI represents improvement in pavement conditions. The graph shows that the BCR-driven spending case yields the greatest improvement in pavement conditions in the first 5-year period, represented by a large drop in average IRI by 22.8 percent from its 2016 level. The improvement under the BCR-driven spending alternative shrinks gradually to 14.2 percent by the last 5-year period. Slower but steady pavement improvement over time is achieved under the ramped spending assumption. Average IRI decreases by 7.7 percent by 2021, and the decrease accelerates in the next three 5-year periods, reaching 16.2 percent by 2036. The investment pattern does not significantly affect the pavement condition by the end of the 20-year period, as average IRI in 2036 falls within a range of 14–16 percent from baseline under all three alternatives of investment timing.

The bottom panel of *Exhibit 8-20* illustrates the progress in average delay reduction across three investment cases. The percentage change of average delay per VMT, relative to its 2016 level, remains negative over the entire study period of 20 years, indicating travel time savings from a decrease in average delay of travelers. In the first 5 years, the BCR-driven spending approach results in the largest reduction in average delay per VMT, 27.8 percent, and the ramped spending the smallest reduction, 24.4 percent. Capital investment in expanding capacity can result in sustained benefits, as the percentages of delay reduction continue to grow in the next 5-year period in all three cases. By 2036, the reductions in average delay converge to 28–29 percent under all three alternative spending assumptions.

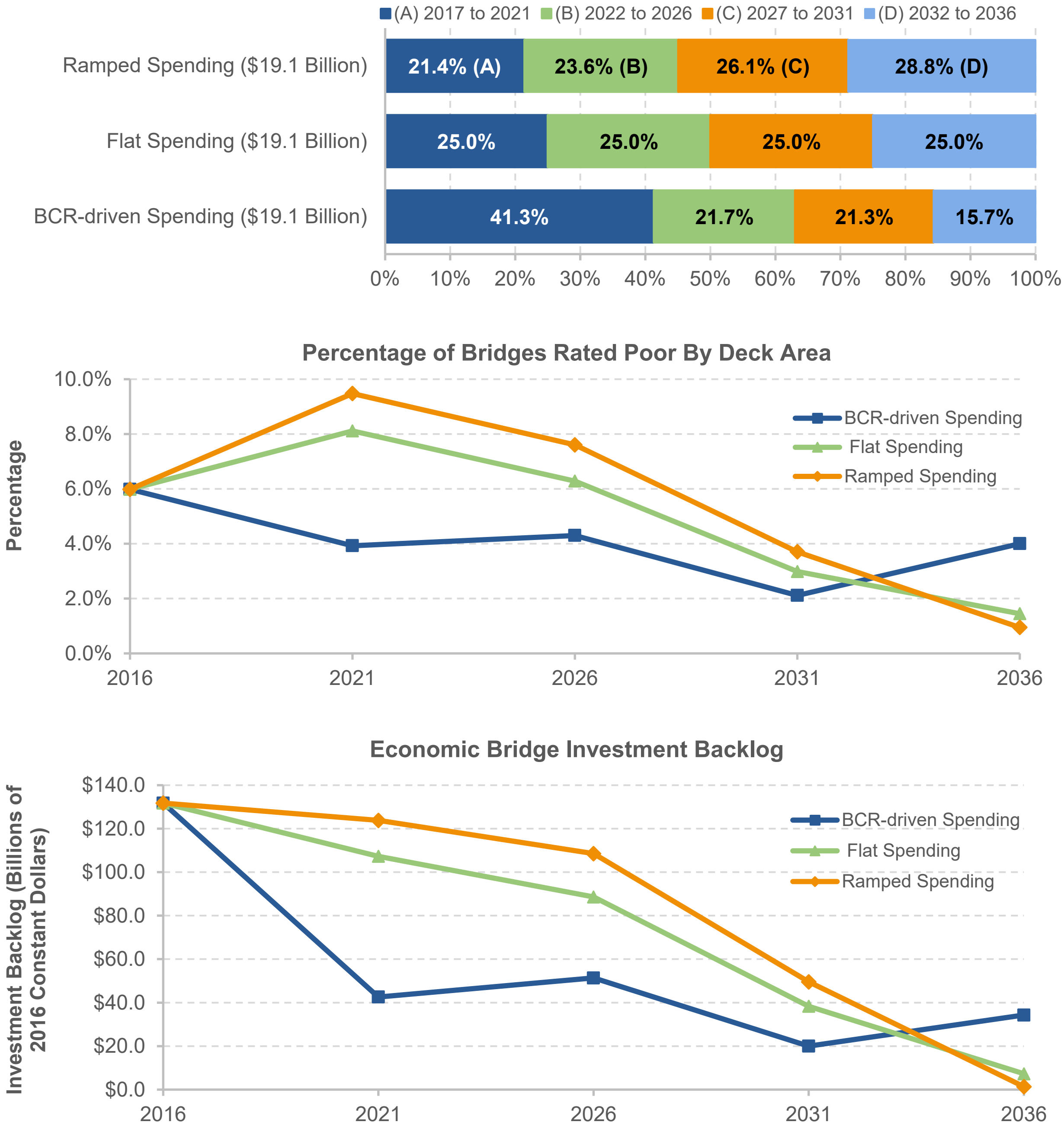
These results show that the BCR-driven approach achieves the highest IRI and delay reductions in the medium run (the first 5-year period) because existing backlog is addressed first. The ramped spending approach results in the smallest pavement and delay improvement over the same period. System performance, however, does not differ substantially across investment timing in the long run of 20 years. Based on this analysis, the key advantage to front-loading highway investment is not in reducing 20-year total investment needs; instead, the strength of BCR-driven spending lies in the years of extra benefits that highway users would enjoy sooner if system conditions and performance were improved earlier in the 20-year analysis period.

Alternative Timing of Investment in NBIAS

Exhibit 8-21 identifies the impacts of alternative investment timing on the share of bridges that are classified as poor by deck area using the three investment assumptions described earlier: ramped spending, flat spending, and BCR-driven spending. Total 20-year investment of $382 billion in constant 2016 dollars was assumed for each alternative analyzed.

Similar to the results from pavement investment in HERS presented earlier, investment timing has an impact on the share of bridges classified as poor. The ramped case for the NBIAS assumes constant annual spending growth of 2.0 percent, resulting in a total 20-year investment of $382 billion in constant 2016 dollars. The top panel of *Exhibit 8-21* indicates that more investment occurs in the later years under the ramped case of gradual and constant growth—from 21.4 percent in the initial 5-year period to 28.8 percent in the last 5-year period. The BCR-driven spending case applies a minimum BCR cutoff of 1.13. It is front-loaded, which requires a large portion of the total 20-year investment in the first 5-year period (41.3 percent) and declines sharply to 15.7 percent in the last 5-year period. Spending levels remain constant at $19.1 billion per year in the flat spending case.

Exhibit 8-21 ■ Impact of Investment Timing on NBIAS Results for a Selected Investment Level – Effects on Bridges Rated as Poor and Economic Bridge Investment Backlog



Note: NBIAS is National Bridge Investment Analysis System; BCR is benefit-cost ratio.
Source: National Bridge Investment Analysis System.

A different investment pattern produces substantially different outcomes. The middle panel of *Exhibit 8-21* shows that the greatest bridge improvement in the first 5-year period occurs under the BCR-driven spending assumption, as the share of bridges classified poor by deck area drops from 6.0 percent in 2016 to 3.9 percent in 2021. During the same period, the share of bridges classified as poor increases to 8.1 percent under the flat spending assumption and 9.5 percent under the ramped spending assumption. In the next 15 years, however, this pattern is reversed. At an average annual investment level of $19.1 billion, NBIAS projects it would achieve the lowest share of bridges classified as poor in 2036 under the ramped spending approach, with only 0.9 percent of bridges rated as poor, compared with 1.4 percent assuming flat spending and 4.0 percent for the BCR-driven spending alternative.

The economic bridge investment backlog also exhibits different trends under the alternative investment timing strategies. The lower panel of *Exhibit 8-21* indicates that from 2016 to 2021, the average backlog declines sharply under the BCR-driven alternative, with slower declines under the flat spending alternative and ramped spending. The investment timing determines the rate of decline. High bridge investment in later years under ramped spending leads to a small economic backlog of $1.4 billion by 2036 (in 2016 constant dollars), whereas the projected backlog would be higher at $7.3 billion in 2036 under the flat spending assumption. If future spending follows the BCR-driven spending assumption, economic bridge investment backlog would surge to $34.3 billion by 2036.

Supplemental Analysis – Transit

This section provides a detailed discussion of the assumptions underlying the scenarios presented in Chapter 7 and of the real-world issues that affect transit operators' ability to address their outstanding capital needs. Specifically, this section addresses the following topics:

- Asset-condition and useful-life-consumed forecasts under three scenarios: (1) Sustain Recent Spending, (2) Low-Growth, and (3) High-Growth, as well as a discussion of the State of Good Repair (SGR) Benchmark;
- An assessment of the impact on the backlog estimate of purchasing hybrid vehicles; and
- The forecast of purchased transit vehicles, route miles, and stations under the Low-Growth and High-Growth scenarios.

KEY TAKEAWAYS

The national condition level of transit assets in 2016 stood at 3.0 (on a scale from 1 to 5), which is in the low range of the adequate condition (3.0–3.9).

Asset Conditions under Investment Scenarios

- Low-Growth and High-Growth Investment scenarios: Under these scenarios, after an initial jump, the average condition in 2036 is projected to be in the 3.1–3.2 range, a slight increase from the 2016 level.
- Maintain Recent Spending: Under this scenario, the average condition is predicted to decrease consistently from the 2016 level (3.0) to 2.7, in the top of the marginal condition range (2.0–2.9). There are two main reasons for this result: (1) assets past their useful life are not initially replaced because investment in replacement is constrained; and (2) many asset types have either very long useful lives (up to 80 years or more) or are nonreplaceable (tunnels and historic buildings), which together can pull down the average condition of even unconstrained scenarios.
- To support a ridership increase in the range of 3.0 to 4.5 billion additional annual boardings by 2036, the following expansion investments would be required:
  - Fleet: 51,800 to 72,900 additional vehicles (29 percent to 40 percent increase from 2016)
  - Rail Guideway: 1,700 to 1,900 additional route miles (12 percent to 14 percent increase)
  - Stations: 2,600 to 4,000 additional stations (76 percent to 120 percent increase)

New Technologies in Bus Fleets

- The projected backlog in 2036 might increase slightly if bus fleets running on standard diesel engines are replaced by alternative compressed natural gas fleets or other alternative technologies for propulsion, as newer technologies are more expensive to acquire and maintain than older ones.

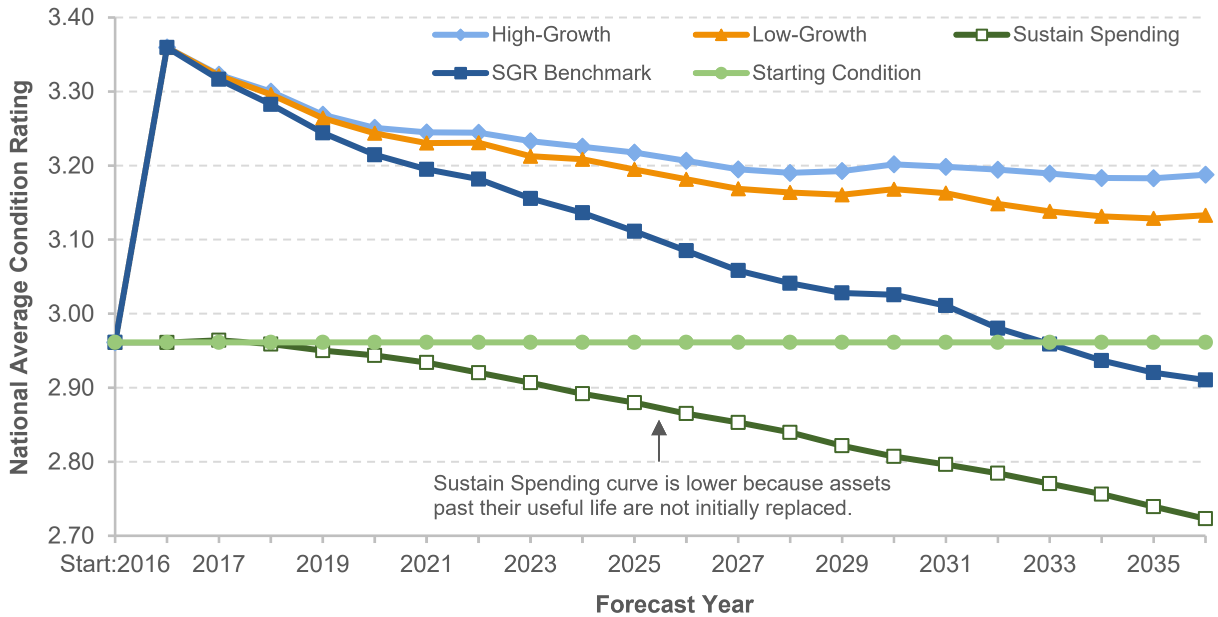
Asset Condition Forecasts and Expected Useful Service Life Consumed

Exhibit 8-22 presents the condition projections for each of the three investment scenarios and the SGR Benchmark. Note that these projections predict the condition of all transit assets in service during each year of the 20-year analysis period, including transit assets that exist today and any investments in additional assets under these scenarios. The projections also include both replaceable and nonreplaceable assets (the latter including assets that undergo decay and require some reinvestment but are ultimately not fully replaced, such as subway tunnels and historic buildings and vehicles). The Sustain Recent Spending, Low-Growth, and High-Growth scenarios each make investments in expansion, which increases the pool of assets, whereas the SGR Benchmark reinvests only in existing assets.

Sustain Recent Spending Scenario

Exhibit 8-22 shows that the estimated current average condition of the Nation's transit assets is 2.96 on the condition scale of 1 to 5 as discussed in Chapter 6. As discussed in Chapter 7, expenditures under the financially constrained Sustain Recent Spending scenario are only sufficient to keep the existing backlog from growing. In addition, the condition of both very long-lived assets and nonreplaceable assets—like tunnels, subway stations, and historic buildings—continue to slowly decline under this scenario. Together, these two factors lead to an ongoing overall decline in average condition of transit assets, as shown for this scenario in *Exhibit 8-22*. It is important to note that while the decline in nonreplaceable asset conditions is known to be occurring, the rate of decline for these asset types is currently subject to some uncertainty.

Exhibit 8-22 ■ Asset Condition Forecast for All Existing and Expansion Transit Assets



Note: SGR is state of good repair.
Source: Transit Economic Requirements Model.

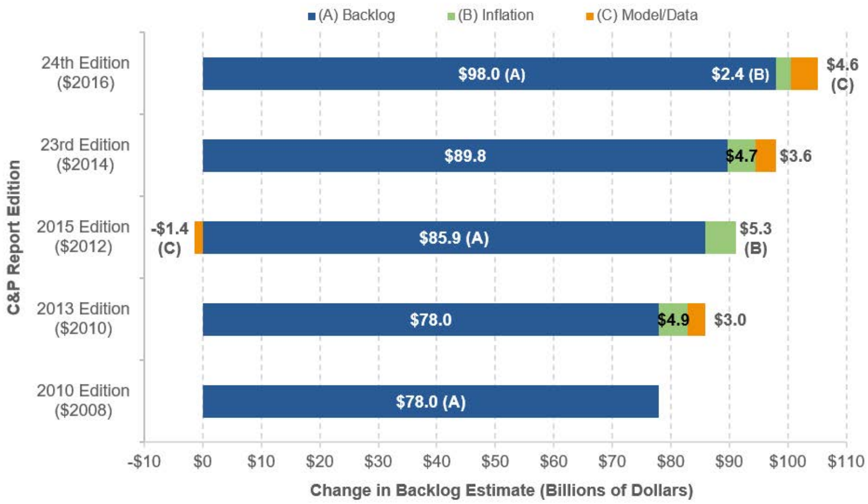
Backlog Estimates Across Recent C&P Reports

The backlog estimate has been increasing steadily since the first estimate was published in the 2010 C&P Report. Changes in the backlog over that period are a function of four causes:

1. Inflation: C&P Report editions are typically published every two years. Therefore, backlog increases should be expected due to inflation alone. Most of the backlog increase between the 2010 and the current reports (64 percent) is caused by inflation, as shown in *Exhibit 8-23*.
2. Additional assets exceeding services lives: Additional assets have reached the end of their useful life (i.e., they have fallen below condition 2.5) since the last period of analysis and have yet to be replaced.
3. Changes to inventory data: Inventory data are updated between C&P Reports based on new NTD fleet data and new data submitted by grantees. Updated inventory submissions can capture recent asset replacements, the acquisition of additional (expansion) assets, changes in unit cost and quantity assumptions, and changes in the level of reported detail (including the addition or deletion of some asset types).
4. Changes to TERM methodology/assumptions: Changes in asset decay curves are the primary source of model-based changes.

Given these sources of change, the current backlog estimate should be viewed as an independent best estimate of the current SGR backlog, as opposed to the most recent data point of a long-term trend.

Exhibit 8-23 ■ Change in Backlog Estimate Since the 2010 Report



Source: Transit Economic Requirements Model.

SGR Benchmark and Growth Scenarios

In contrast to the Sustain Recent Spending scenario, the SGR Benchmark and the Low-Growth and High-Growth scenarios are all financially unconstrained with respect to reinvestment needs. Rather, the SGR Benchmark and the two growth scenarios assess 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). The unconstrained nature of these scenarios accounts for the significant improvement in asset conditions at the end of the first year of analysis, at which time all overage assets have been replaced and the SGR backlog has been entirely eliminated.

From this point, the paths of the SGR Benchmark and the Low-Growth and High-Growth scenarios begin to diverge. Despite adopting the objective of maintaining all assets in SGR throughout the forecast period, average conditions under the SGR Benchmark ultimately decline to levels below the current average condition value of 2.96. Three related factors drive this decline. First, close to 90 percent of transit assets have life spans that exceed the 20-year length of the forecast period (the weighted average life span for transit assets is roughly 65 years). Hence, most of the backlog assets replaced at the start of the forecast period will have significant remaining life by the end of the 20-year forecast period. Second, the transit industry has undergone significant expansion since 1980, particularly in light and heavy rail systems. Given the long lives of many asset types, a significant proportion of these expansion assets will not have reached the end of their useful life even by 2036. Third, roughly one-third of all transit assets (by value) are nonreplaceable—examples include subway tunnels and stations—and thus are effectively considered to never require replacement, regardless of age. Together, these three related factors cause a large proportion of assets to continue to decline in condition throughout the full period of analysis, resulting in the downward pull on average conditions under the SGR Benchmark.

Finally, *Exhibit 8-22* also shows some decline in average conditions over time for both the Low-Growth and High-Growth scenarios, but far less than for the SGR Benchmark. As should be expected, this slower rate of decline results from the ongoing investment in new assets under these two scenarios to accommodate (compounding) growth in transit ridership. This is most notable for the High-Growth scenario, where average transit asset conditions remain effectively flat at roughly 3.2 for the last 10 years of the forecast.

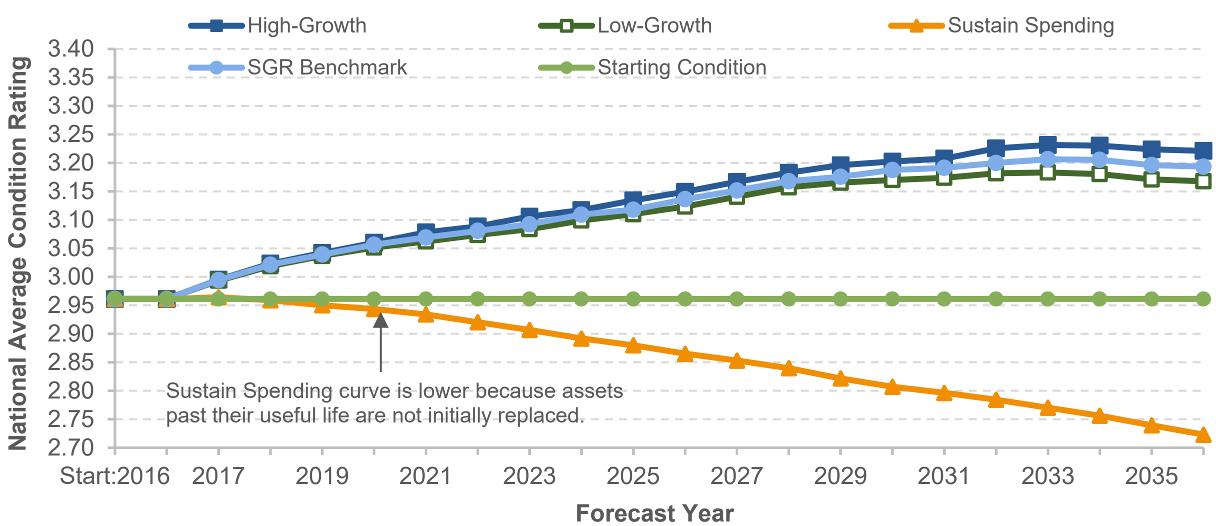
Alternative Methodology

As noted earlier, the level of investment (including funding and physical resources) needed to eliminate the SGR backlog in 1 year is likely infeasible. Hence, the financially unconstrained assumptions in the SGR Benchmark and the Low-Growth and High-Growth scenarios (e.g., spending of unlimited transit investment funds each year) are unrealistic. As indicated in *Exhibit 8-22*, 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 methodology is for all three scenarios to 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. This analysis indicates that investing $18.0 billion annually in preservation would eliminate the backlog in 20 years.

Exhibit 8-24 presents the more realistic condition projections for the two growth scenarios and the benchmark using this alternative methodology. The Low-Growth and High-Growth scenarios and the SGR Benchmark 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. However, the outcome under this modified, more realistic approach is the same for each scenario and for the same reasons: conditions ultimately decline marginally under the SGR Benchmark but improve under the Low-Growth and High-Growth scenarios (being pulled up for the latter two by the impact of increasing annual levels of expansion investment).

Exhibit 8-24 ■ Alternative Asset Condition Forecast for All Existing and Expansion Transit Assets, Using Alternative Methodology



Note: SGR is state of good repair.

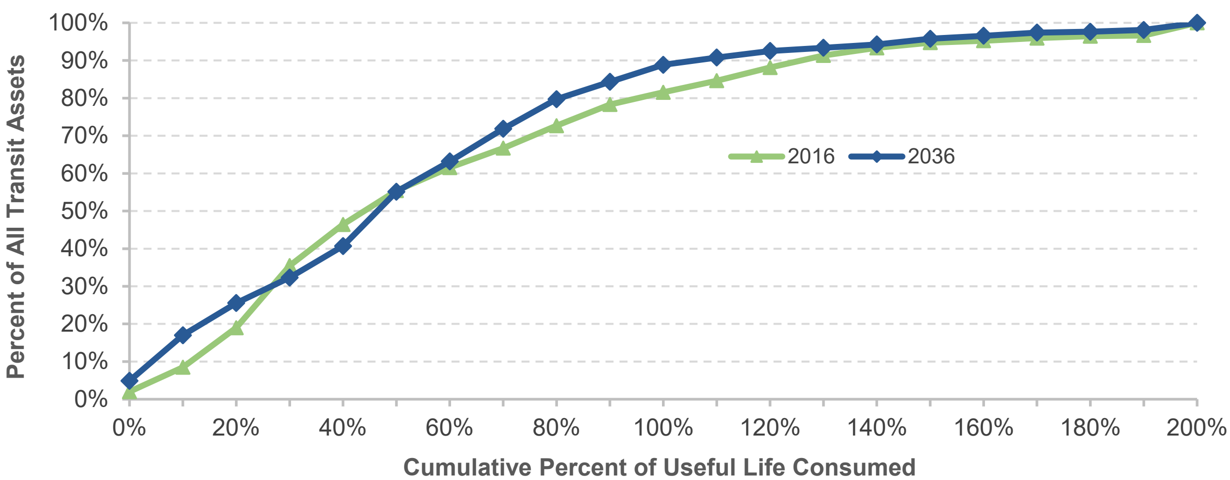
Source: Transit Economic Requirements Model.

Expected Useful Service Life Consumed for Replaceable Assets under Three Growth Scenarios and the SGR Benchmark

The preceding analysis focused on changes in average transit conditions; this section considers changes in the percent of asset life consumed between the start and end years of analysis for each scenario: Sustain Recent Spending, Low-Growth, High-Growth, and the SGR Benchmark. This analysis is valuable in demonstrating how the objectives of each investment scenario drive differences in the long-term distribution of asset ages relative to asset useful life. Given the focus on useful life consumed, this analysis is limited to replaceable assets (those with a defined replacement age), and thus excludes the roughly one-third of transit assets (by value) that are considered nonreplaceable—including tunnels, subway stations, and historic buildings and historic vehicles. Also, the use of "percent of life consumed" provides a means of making life-cycle comparisons across transit assets with a wide range of lifespans (ranging from roughly 5 to 100 years).

The distribution of the percentage of useful life consumed for the start and end years of the Sustain Recent Spending scenario forecast is shown in *Exhibit 8-25*. Specifically, this exhibit shows the share of all replaceable transit assets (equal to approximately $603 billion in 2016) in relation to their expected useful life. Note this is a cumulative distribution. For example, the chart shows that, as of 2016, roughly 73 percent of replaceable assets were at or below 80 percent of life consumed. In contrast, by 2036, the analysis projects that roughly 80 percent of all replaceable assets will be at or below 80 percent of life consumed. In general, *Exhibit 8-25* suggests that the Sustain Recent Spending scenario has tended to result in a mostly improved distribution in percentage of life consumed by the year 2036 (i.e., the 2036 curve mostly lies to the left of the 2016 curve). Most notably, there has been a reduction in the percentage of assets that exceed 100 percent of life consumed. However, it is also important to note that much of the improvement in the life-consumed distribution results not from asset replacement, but rather from investment in new expansion assets (which account for much of the leftward shift by 2036). In addition, the distribution has deteriorated marginally for a short segment of the curve (between 30 and 50 percent of life consumed).

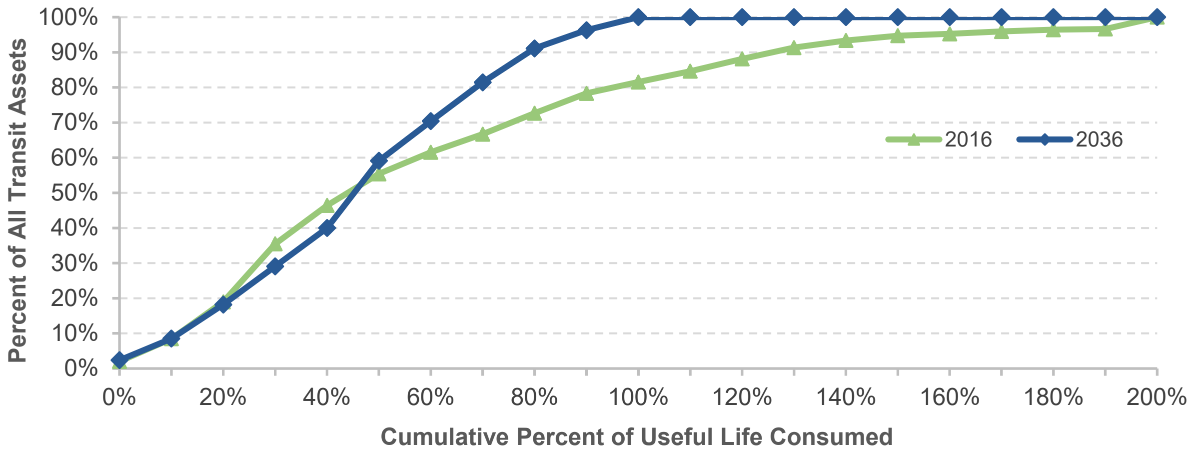
Exhibit 8-25 ■ Sustain Recent Spending Scenario – Cumulative Asset Percent of Useful Life Consumed (Replaceable Assets)



Source: Transit Economic Requirements Model.

Similarly, *Exhibit 8-26* presents the cumulative percentage of useful life consumed under the SGR Benchmark scenario (which is financially unconstrained with respect to reinvestment needs but does not include any expansion investments). Given the nature of this scenario (where all reinvestment needs are addressed as they arise), the percentage of life consumed is significantly reduced for most assets—and no replaceable assets exceed 100 percent of useful life. However, as with the Sustain Recent Spending scenario, the distribution has deteriorated marginally for a short segment of the curve (here between 20 and 50 percent of life consumed). This segment reflects the ongoing deterioration of long-lived assets that continually age, but do not require replacement, over the 20-year period of analysis.

Exhibit 8-26 ■ SGR Baseline Scenario – Cumulative Asset Percent of Useful Life Consumed (Replaceable Assets)

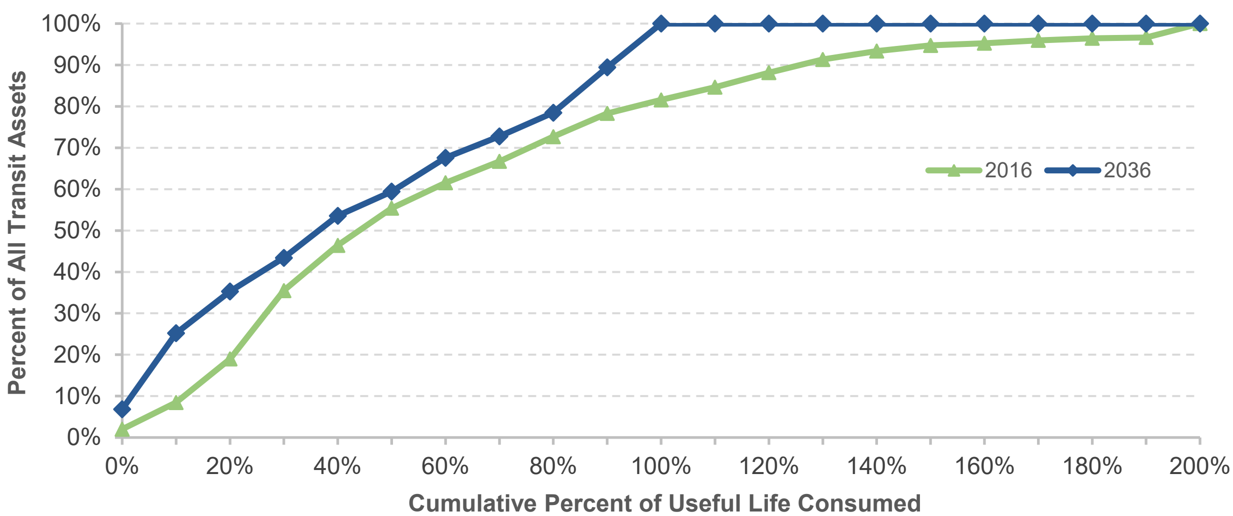


Note: SGR is state of good repair.

Source: Transit Economic Requirements Model.

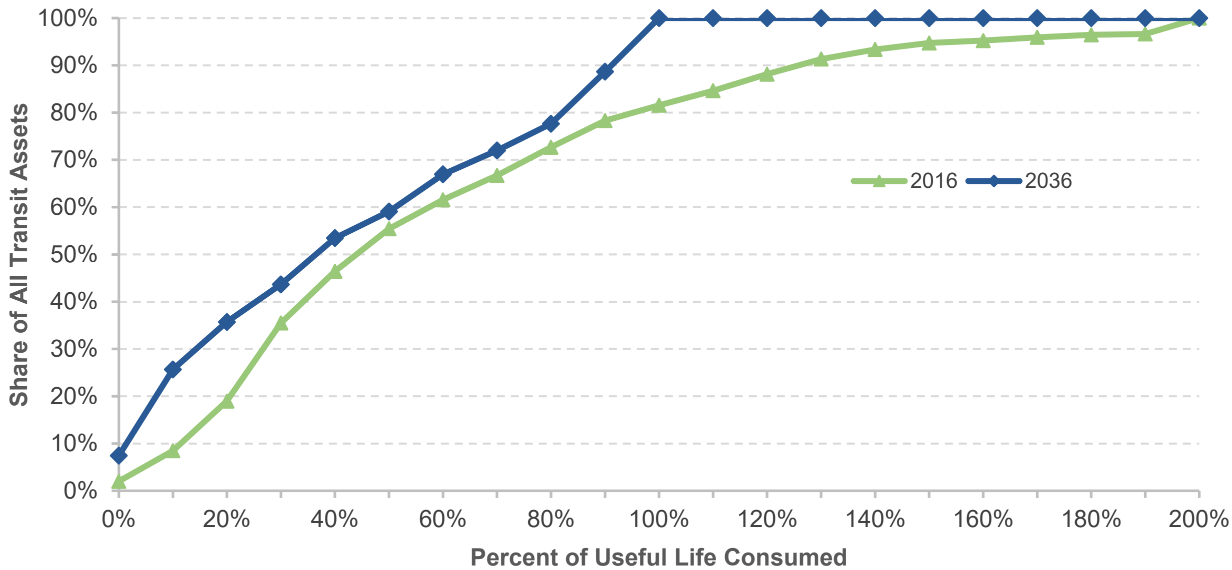
Finally, *Exhibits 8-27* and *8-28* present projections for the percentage of useful life consumed under the Low-Growth and High-Growth scenarios respectively (which are financially unconstrained with respect to reinvestment needs and invest in expansion assets to support low to high rates of ridership growth, when cost-beneficial). As these two scenarios address all SGR and expansion investment needs, the distribution of the percentage of life consumed for these scenarios is somewhat better than that for the SGR Benchmark, particularly below 50 percent of life consumed (primarily driven by investments in new, expansion assets).

Exhibit 8-27 ■ Low-Growth Scenario – Cumulative Asset Percent of Useful Life Consumed (Replaceable Assets)



Source: Transit Economic Requirements Model.

Exhibit 8-28 ■ High-Growth Scenario – Cumulative Asset Percent of Useful Life Consumed (Replaceable Assets)



Source: Transit Economic Requirements Model.

Effect of New Technologies on Transit Investment Scenarios

The investment scenarios presented in Chapter 7 implicitly assume that all replacement and expansion assets will use the same technologies that are currently in use today (i.e., all asset replacement and expansion investments are "in kind"). As with most other industries, however, 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). Although many improvements are standardized and hence embedded in the asset (i.e., the transit operator has little or no control over this change), it is common for transit operators to select technology options that are significantly more costly than preexisting assets of the same type. A key example is the frequent decision to replace diesel motor buses with compressed natural gas or hybrid buses. This increase in the cost of new assets would tend to increase current and long-term reinvestment costs and, in a budget-constrained environment, would increase the expected future size of the investment backlog. This increase might 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 investment scenarios under current methodologies used in this report.

In addition to improvements in preexisting asset types, transit operators periodically expand their existing asset stock to introduce new asset types that take advantage of technological innovations. 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 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 and the expected future size of the SGR backlog.

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