Status of the Nation's Highways, Bridges, and Transit

Conditions and Performance

23rd Edition

U.S. Department of Transportation

Federal Highway Administration

Federal Transit Administration

REPORT TO CONGRESS

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Abbreviations

AADT	Annual average daily traffic
AADTT	Annual average daily truck traffic
AASHTO	American Association of State Highway and Transportation Officials
ACS	American Community Survey
ADA	Americans with Disabilities Act of 1990
ADT	Average daily traffic
AIM	Asset inventory module
ATRI	American Transportation Research Institute
BCA	Benefit-cost analysis
BCR	Benefit-cost ratio
BPI	Bid price index
BTS	Bureau of Transportation Statistics
C&P	Conditions and performance
CES	Consumer Expenditure Surveys
CFR	Code of Federal Regulations
CIG	Capital Investment Grants
CMAQ	Congestion Mitigation and Air Quality
CNG	Compressed natural gas
COG	Council of Governments
CPI	Consumer Price Index
CRFC	Critical Rural Freight Corridors
CUFC	Critical Urban Freight Corridors
DOT	Department of Transportation
DRM	Directional route miles
EDC	Every Day Counts
FAF	Freight Analysis Framework
FARS	Fatality Analysis Reporting System
FAST	Fixing America's Surface Transportation
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FPM	Freight Performance Measurement
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
GARVEE	Grant Anticipation Revenue Vehicle
GDP	Gross domestic product
GPS	Global positioning system
GTFS	General Transit Feed Specification
HERS	Highway Economic Requirements System
HOT	High occupancy toll
HOV	High occupancy vehicle
HPMS	Highway Performance Monitoring System
HPTE	High Performance Transportation Enterprise
HSIP	Highway Safety Improvement Program

HSM	Highway Safety Manual
HTF	Highway Trust Fund
IRI	International Roughness Index
ITS	Intelligent Transportation Systems
JARC	Jobs Access and Reverse Commute
MCDM	Multi-criteria decision method
MIRE	Model Inventory of Roadway Elements
MOVES	Motor Vehicle Emission Simulator
MPO	Metropolitan planning organization
MR&R	Maintenance, repair, and rehabilitation
NASS	National Automotive Sampling System
NBI	National Bridge Inventory
NBIAS	National Bridge Investment Analysis System
NHCCI	National Highway Construction Cost Index
NHFN	National Highway Freight Network
NHFP	National Highway Freight Program
NHPP	National Highway Performance Program
NHS	National Highway System
NHTS	National Household Travel Survey
NHTSA	National Highway Traffic Safety Administration
NPMRDS	National Performance Management Research Data Set
NPTS	Nationwide Personal Transportation Survey
NSC	National Safety Council
NTD	National Transit Database
O&M	Operations and maintenance
OMB	Office of Management and Budget
PBES	Prefabricated bridge elements
PHED	Peak hour excessive delay
PHFS	Primary Highway Freight System
PM	Performance measures
PMT	Passenger miles traveled
PSR	Present Serviceability Rating
PT	Purchased transportation
PTI	Planning Time Index
RAIRS	Rail Accident/Incident Reporting System
RTZ	Road to Zero
RWIS	Road Weather Information System
SGR	State of good repair
SHSP	Strategic Highway Safety Plan
SIB	State Infrastructure Banks
SNBIBE	Specification for National Bridge Inventory Bridge Elements
SOV	Single occupancy vehicle
SQC	Synthesis, Quantity, and Condition
STAA	Surface Transportation Assistance Act
STIC	Small Transit Intensive Cities
TAM	Transit asset management
TAMP	Transportation Asset Management Plan
TERM	Transit Economic Requirements Model

TIFIA	Transportation Infrastructure Finance and Innovation Act
TOPS	Table of Potential Samples
TPM	Transportation performance management
TREDIS	Transportation Economic Development Impact System
TSI	Transportation Services Index
TTI	Travel Time Index
TVT	Traffic Volume Trends
UHPC	Ultra-High Performance Concrete
UPT	Unlinked passenger trips
USACE	U.S. Army Corps of Engineers
USC	United States Code
UZA	Urbanized areas
VMT	Vehicle mile traveled
VRM	Vehicle revenue mile

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Introduction

This is the 23rd in a series of reports dating back to 1968 that the U.S. Department of Transportation (DOT) has prepared to satisfy requirements for reporting to Congress on system condition, system performance, and future capital investment needs. Beginning in 1993, this report series has covered both highways and transit; previous editions had covered the Nation's highway systems only. A separate series of reports on the Nation's transit systems' performance and conditions was issued from 1984 to 1992.

This report incorporates highway, bridge, and transit information required by 23 United States Code (U.S.C.) §503(b)(8) and transit system information required by 49 U.S.C. §308(e). This edition also includes a report on the conditions and performance of the National Highway Freight Network required by 23 U.S.C. §167(h). The statutory due dates specified in these sections differ; this 23rd edition is intended to address the requirements for reports due:

- July 31, 2017, under 23 U.S.C. §503(b)(8);
- December 4, 2017, under 23 U.S.C. §167(h); and
- March 31, 2018, under 49 U.S.C. §308(e).

This 23rd edition of the Status of the Nation's Highways, Bridges, and Transit: Conditions and Performance Report to Congress (C&P Report) draws primarily on 2014 data. In assessing recent trends, many of the exhibits presented in this report present statistics for the 10 years from 2004 to 2014. Other charts and tables cover different periods, depending on data availability and years of significance for particular data series. The prospective analyses presented in this report generally cover the 20-year period ending in 2034.

Previous editions of the C&P Report have been identified by year, generally linked to the due date in 23 U.S.C. §503(b)(8). This has caused some confusion due to differences among the due dates, the transmittal date to Congress, and the base year of the data. For example, the 2015 C&P Report drew primarily on 2012 data, and was transmitted to Congress in December 2016. For continuity's sake, previous editions will continue to be referenced based on the year on their cover, but this 23rd edition and future editions will be identified based on their numeric sequence in the report series.

Given the data years covered by this edition, the information presented on system conditions and performance do not yet show the impacts of funding authorized by the Fixing America's Surface Transportation (FAST) Act.

Report Purpose

This document is intended to provide decision makers with an objective appraisal of the physical conditions, operational performance, and financing mechanisms of highways, bridges, and transit systems based on both their current state and their projected future state under a set of alternative future investment scenarios. This report offers a comprehensive, data-driven background context to support the development and evaluation of legislative, program, and budget options at all levels of government. It also serves as a primary source of information for national and international news media, transportation associations, and industry.

This C&P Report consolidates conditions, performance, and financial data provided by States, local governments, and public transit operators to present a national-level summary. Some of the underlying data are available through DOT's regular statistical publications. The future investment scenario analyses are developed specifically for this report and provide projections at the national level only.

Report Organization

This report begins with a Highlights section that summarizes key findings of the overall report, which is followed by an Executive Summary that summarizes the key findings in each individual chapter. The main body of the report is organized into four major sections.

The six chapters in Part I, *Moving a Nation*, contain the core retrospective analyses of the report. Most of these chapters include separate highway and transit sections discussing each mode in depth. This structure is intended to accommodate report users who might be interested primarily in only one of the two modes.

- The Introduction to Part I provides background information issues pertaining to transportation performance management, which relates closely to the material presented in Part I.
- Chapter 1 quantifies the Nation's highways, bridges, and transit infrastructure assets.
- Chapter 2 describes highway and transit revenue sources and expenditure patterns for all levels of government.
- Chapter 3 discusses selected topics relating to personal travel.
- Chapter 4 describes trends pertaining to mobility and access.
- Chapter 5 discusses issues relating to the safety of highways and transit.
- Chapter 6 identifies the current physical conditions of the Nation's highways, bridges, and transit assets.

The four chapters in Part II, *Investing for the Future*, contain the core prospective analyses of the report, including 20-year future capital investment scenarios. The Introduction to Part II provides critical background information and caveats that should be considered while interpreting the findings presented in Chapters 7 through 10.

- Chapter 7 presents a set of selected capital investment scenarios, and relates these scenarios to the current levels of capital investment for highways, bridges, and transit.
- Chapter 8 provides supplemental analysis relating to the primary investment scenarios, comparing the findings of the future investment scenarios to findings in previous reports and discussing scenario implications.
- Chapter 9 discusses how changing some of the underlying technical assumptions would affect the future highway and transit investment scenarios.
- Chapter 10 projects the potential impacts of additional alternative levels of future highway, bridge, and transit capital investment on the future performance of various components of the system.

Part III, *Highway Freight Transportation Conditions and Performance*, explores issues pertaining specifically to freight movement.

- Chapter 11 discusses freight transportation in general, focusing on the National Highway System (NHS).
- Chapter 12 examines the conditions and performance of the National Highway Freight Network.

Part IV, *Recommendations for HPMS Changes*, provides information on the status and planned direction of the Highway Performance Monitoring System (HPMS).

The C&P Report also contains three technical appendices that describe the investment/performance methodologies used in the report for highways, for bridges, and for transit. A fourth appendix describes an ongoing research effort for *Reimagining the C&P Report in a Performance Management-Based World*.

Highway Data Sources

Highway characteristics and conditions data are derived from HPMS (https://www.fhwa.dot.gov/policyinformation/hpms.cfm), a cooperative data/analytical effort dating from the late 1970s that involves the Federal Highway Administration (FHWA) and State and local governments. HPMS includes a random sample of roughly 120,000 sections of Federal-aid highways selected by each State using instructions provided by DPT. HPMS data include current physical and operating characteristics and projections of future travel growth on a highway section-by-section basis. All HPMS data are provided to FHWA through State departments of transportation from existing State or local government databases or transportation plans and programs, including those of metropolitan planning organizations (MPOs).

FHWA annually collects bridge inventory and inspection data from the States, Federal agencies, and Tribal governments and incorporates the data into the National Bridge Inventory (NBI) (https://www.fhwa.dot.gov/bridge/nbi.cfm). NBI contains information from all bridges covered by the National Bridge Inspection Standards (Title 23, Code of Federal Regulations, Part 650, Subpart C) located on public roads throughout the United States and Puerto Rico. Inventory information for each bridge includes descriptive identification data, functional characteristics, structural design types and materials, location, age and service, geometric characteristics, navigation data, and functional classifications; condition information includes inspectors' evaluations of the primary components of a bridge, such as the deck, superstructure, and substructure.

State and local finance data are derived from the financial reports States provide to FHWA in accordance with *A Guide to Reporting Highway Statistics* (https://www.fhwa.dot.gov/policyinformation/hss/guide/). These data are the same as those used in compiling FHWA's annual Highway Statistics report. Highway safety performance data are drawn from the Fatality Analysis Reporting System (https://www.nhtsa.gov/research-data/fatality-analysis-reporting-system-fars).

Highway operational performance data are drawn primarily from the National Performance Management Research Data Set (NPMRDS) (https://ops.fhwa.dot.gov/perf_measurement/). This database compiles observed average travel times, date and time, and direction and location for freight, passenger, and other traffic. The data cover the period after the Moving Ahead for Progress in the 21st Century Act (MAP-21) for the NHS plus arterials at border crossings. The dataset is made available to States and MPOs monthly to assist them in performance monitoring and target setting. Because NPMRDS data are available only for 2012 onward, historical time series data are drawn from the Texas Transportation Institute's Urban Mobility Scorecard (https://mobility.tamu.edu/ums/).

Under MAP-21, FHWA was charged with establishing a national tunnel inspection program. In 2015, development began on the National Tunnel Inventory database system (https://www.fhwa.dot.gov/bridge/inspection/tunnel/inventory.cfm), and inventory data were collected for all highway tunnels reported. Concurrently, FHWA implemented an extensive program to train inspectors nationwide on tunnel inspection and condition evaluation. The annual collection of complete inventory and condition data for all tunnels began in 2018; these data will be available for use in future C&P Reports.

Transit Data Sources

Transit data are derived from the National Transit Database (NTD) (https://www.transit.dot.gov/ntd) and transit agency asset inventories. NTD comprises comprehensive data on the revenue sources, capital and operating expenses, basic asset holdings, service levels, annual passenger boardings, and safety data for more than 800 urban and 1,300 rural transit agencies. NTD also provides data on the composition and age of transit fleets.

NTD does not currently provide data required to assess the physical condition of the Nation's transit infrastructure. To meet this need, the Federal Transit Administration (FTA) collects transit asset inventory data from a sample of the Nation's largest rail transit operators. In direct contrast to the data in NTD and HPMS—which local and State funding grantees must report to FTA and FHWA, respectively, and which are subject to standardized reporting procedures—the transit asset inventory data used to assess current transit conditions are provided to FTA in response to direct requests submitted to grantees and are subject to no reporting requirements.

In recent practice, data requests primarily have been made to the Nation's 20 to 30 largest transit agencies because they account for roughly 85 percent of the Nation's total transit infrastructure by value. Considering the slow rate of change in asset holdings of transit agencies over time (excluding fleet vehicles and major expansion projects), FTA has requested these data from any given agency only every 3 to 5 years. The asset inventory data collected through these requests document the age, quantity, and replacement costs of the grantees' asset holdings by asset type. The nonvehicle asset holdings of smaller operators have been estimated using a combination of the (1) fleet-size and facility-count data reported to NTD and (2) actual asset age data of a sample of smaller agencies that responded to previous asset inventory requests.

Based on changes to Federal transit law made by MAP-21, FTA is currently in the process of significantly expanding the asset inventory and condition information collected through the NTD. The expanded Asset Inventory Module of the NTD opened for voluntary reporting in 2017, and then became part of the mandatory NTD reporting requirements in 2018. As with the longstanding revenue vehicle inventory data collection in the NTD, the reporting burden on the transit industry will be minimized by carrying over asset inventories from one year to the next in the NTD for reporting transit agencies. The expanded asset inventory module will directly collect condition ratings for all passenger stations and maintenance facilities in the NTD. In addition, age and performance data will be collected for both guideway infrastructure and track. This influx of additional asset inventory and condition data in the NTD should significantly improve the transit estimates in future editions of the C&P Report.

Multimodal Data Sources

Freight data are derived primarily from the Freight Analysis Framework version 4.3 (https://ops.fhwa.dot.gov/freight/freight_analysis/faf/), which includes all freight flows to, from, and within the United States. The framework is built from a variety of datasets, such as the Census Bureau's Commodity Flow survey (https://www.census.gov/programs-surveys/cfs.html) and HPMS.

Personal travel data are derived primarily from the National Household Travel Survey (https://www.fhwa.dot.gov/policyinformation/nhts.cfm), which collects detailed information on travel by all modes for all purposes for each household member in the sample. The survey has collected data intermittently since 1969 using a national sample of households in the civilian noninstitutionalized population, and includes demographic characteristics of households and people and information about all vehicles in the household. These data are supplemented by information collected through the annual American Community Surveys and the Consumer Expenditure Surveys.

Investment/Performance Analytical Procedures

Executive Order 12893, Principles for Federal Infrastructure Investments, dated January 1994, directs each executive department and agency with infrastructure responsibilities to base investments on "systematic analysis of expected benefits and costs, including both quantitative and qualitative measures." Consistent with this directive, the tools used to analyze future investment and performance in this report include an economic component, which takes into account the impacts of transportation investments on the costs incurred by users of the transportation system, in addition to engineering considerations (the earliest versions of the reports in this combined series relied exclusively on engineering-based estimates and considered only the costs incurred by transportation agencies). This approach failed to adequately consider a critical dimension of transportation programs.

The highway investment scenarios presented in this report are developed in part from the Highway Economic Requirements System (HERS), which models highway investment using benefit-cost analysis. The HERS model quantifies user, agency, and societal costs for various types and combinations of capital improvements. HERS considers costs associated with travel time, vehicle operation, safety, routine maintenance, and emissions. Bridge investment scenario estimates are developed from the National Bridge Investment Analysis System (NBIAS) model, which also incorporates benefit-cost analysis principles.

The transit investment analysis is based on the Transit Economic Requirements Model (TERM). TERM consolidates older engineering-based evaluation tools and uses benefit-cost analysis to ensure that investment benefits exceed investment costs. TERM identifies the investments needed to replace and rehabilitate existing assets, improve operating performance, and expand transit systems to address the growth in travel demand.

HERS, NBIAS, and TERM are not able to be used for direct multimodal analysis. Although the three models use benefit-cost analysis, their methods for implementing this analysis are very different. Each model is based on a separate, distinct database, and uses data applicable to its specific part of the transportation system and addresses issues unique to each mode. For example, HERS assumes that adding lanes to a highway causes highway user costs to decline, which results in additional highway travel. Under this assumption, some of this increased traffic would be newly generated travel and some could be the result of travel shifting from transit to highways. HERS, however, does not distinguish between different sources of additional highway travel. Similarly, TERM's benefit-cost analysis assumes that some travel shifts from automobile to transit because of transit investments, but the model cannot project the effect of such investments on highways.

In interpreting the findings of this report, it is essential to recognize the limitations of these analytical tools and the potential impacts of different assumptions made for the analyses. The technical appendices and the Introduction to Part II contain information critical to contextualizing the future investment scenarios.

Changes to C&P Report Scenarios from the 2015 Edition

The highway scenarios presented in the 2015 C&P Report were "ramped" to assume that spending would increase at a constant annual rate for 20 years beginning in the base year (2012). Most of the highway investment analyses presented in this 23rd edition are instead "flat," assuming investment at a fixed level in constant-dollar terms each year for 20 years. This edition also includes a scenario in which funding is assumed to vary by year depending on the level of investment estimated to be cost-beneficial.

The Maintain Conditions and Performance scenario for highways and bridges presented in the 2015 C&P Report used average pavement roughness, average delay per vehicle mile traveled (VMT), and the percentage of deck area on bridges classified as deficient as primary indicators. This edition substitutes the percentage of deck area on bridges rated as poor for the percentage classified as deficient in defining this scenario.

The 2015 C&P Report presented Sustain 2012 Spending scenarios for both highways and transit, which projected the impacts of sustaining spending at base year 2012 levels in constant-dollar terms over 20 years. Because the base year for the current report is 2014, the scenarios have been renamed Sustain 2014 Spending.

Key Information for Properly Interpreting This Report

To interpret the analyses presented in this report correctly, it is critical both to understand the framework in which they were developed and to recognize their limitations. This document is not a statement of Administration policy, and the future investment scenarios presented are intended to be illustrative only. **The report does not endorse any particular level of future highway, bridge, or transit investment**. It neither addresses how future Federal programs for surface transportation should look, nor identifies the level of future funding for surface transportation that could or should be provided by the Federal, State, or local governments; the private sector; or system users. Making recommendations on such policy issues is beyond the legislative mandate for this report and would be inconsistent with its objective intent. Analysts outside FHWA and FTA can and do use the statistics presented in the C&P Report to draw their own conclusions, but any analysis attempting to use the information presented in this report to determine a target Federal program size would require a series of additional policy and technical assumptions that are well beyond what is reflected here.

The analytical models assume that projects are prioritized based on their benefit-cost ratios, an assumption that deviates from actual patterns of project selection and funding distribution in the real world. Therefore, the level of investment identified as the amount required for achieving a certain performance level should be viewed as illustrative only—not as a projection or prediction of an actual condition and performance outcome likely to result from a given level of national spending.

Some of the highway and transit scenarios are defined to include all potential investments for which estimated future benefits would exceed their costs. These scenarios can best be viewed as “investment ceilings” above which it would not be cost-beneficial to invest, even if unlimited funding were available. The main value in applying a benefit-cost screen to infrastructure investment analysis is that it avoids relying purely on engineering standards that could significantly overestimate future investment needs.

As in any modeling process, simplifying assumptions have been made to make the analysis practical and to report within the limitations of available data. Because asset owners at the State and local levels primarily make the ultimate decisions concerning highways, bridges, and transit systems, they have a much more direct need to collect and retain detailed data on individual system components. The Federal government collects selected data from States and transit operators to support this report and several other Federal activities, but these data are not sufficiently robust to make definitive recommendations concerning specific transportation investments in specific locations.

Future travel projections are central to evaluating capital investment on transportation infrastructure. Forecasting future travel, however, is extremely difficult because of the many uncertainties related to traveler behavior. Even where the underlying relationships may be correctly modeled, the evolution of key variables (such as expected regional economic growth) could differ significantly from the assumptions made in the travel forecast. Future transit ridership projections have significant implications for estimated system expansion needs, but there is uncertainty regarding long-term growth rates, particularly in light of recent declines in transit ridership. Neither the transit nor highway travel forecasts reflect the potential impacts of emerging transportation technology options such as car share, scooters, and autonomous vehicles.

The Department remains committed to an ongoing program of research to identify approaches for refining, supplementing, and potentially replacing the analytical tools used in developing the C&P Report. Future editions will reflect refined data and modeling.

Highlights

This edition of the C&P Report is based primarily on data through 2014. In assessing recent trends, this report generally focuses on the 10-year period from 2004 to 2014. The prospective analyses generally cover the 20-year period ending in 2034; the investment levels associated with these scenarios are stated in constant 2014 dollars. This section presents key findings for the overall report; key findings for individual chapters are presented in the Executive Summary.

Highlights: Highways and Bridges

Extent of the System

- The Nation's road network included 4,177,074 miles of public roadways and 610,749 bridges in 2014. This network carried more than 3.040 trillion vehicle miles traveled (VMT) and almost 5.205 trillion person miles traveled, up from 2.982 trillion VMT and up from 4.876 trillion person miles traveled in 2004.
- The 1,016,963 miles of Federal-aid highways (24 percent of total mileage) carried 2.572 trillion VMT (85 percent of total travel) in 2014.
- Although the 226,767 miles on the National Highway System (NHS) comprise only 5 percent of total mileage, the NHS carried 1.661 trillion VMT in 2014, approximately 55 percent of total travel.

Highway System Terminology

"Federal-aid highways" are roads that generally are eligible for Federal funding assistance under current law. (Note that certain Federal programs do allow the use of Federal funds on other roadways.)

The "National Highway System" (NHS) includes those roads that are most important to interstate travel, economic expansion, and national defense. It includes the entire Interstate System. The NHS was expanded under MAP-21.

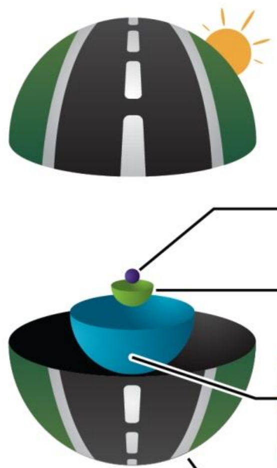
- The 47,944 miles on the Interstate System carried 0.751 trillion VMT in 2014, slightly over 1 percent of total mileage and just under 25 percent of total VMT. The Interstate System has grown since 2004, when it consisted of 46,836 miles carrying 0.727 trillion VMT.

Spending on the System

- All levels of government spent a combined $222.6 billion for highway-related purposes in 2014. About 47.4 percent of total highway spending ($105.4 billion) was for capital improvements to highways and bridges; the remainder included expenditures for physical maintenance, highway and traffic services, administration, highway safety, and debt service.
- Of the $105.4 billion spent on highway capital improvements in 2014, $25.3 billion (24 percent) was spent on the Interstate System, $56.3 billion (53 percent) was spent on the NHS, and $79.3 billion (75 percent) was spent on Federal-aid highways (including the NHS).
- In nominal dollar terms, highway spending increased by 50.9 percent (4.2 percent per year) from 2004 to 2014; after adjusting for inflation, this equates to a 9.5-percent increase (0.9 percent per year).
- Highway capital expenditures rose from $70.3 billion in 2004 to $105.4 billion in 2014, a 50.0-percent (4.1 percent per year) increase in nominal dollar terms; after adjusting for inflation, this equates to a

1.0-percent (0.1 percent per year) decrease, meaning that capital spending did not keep pace with increases in construction costs.

2014 Extent of the Highway System



United States Road System	EXTENT (Miles per System)	VMT (Vehicle Miles Traveled)	CAPITAL SPENDING ($ Billions)
Interstate System	1% 47,944 miles	25% 0.751 trillion VMT	24% $25.3 billion
National Highway System	5% 226,767 miles	55% 1.661 trillion VMT	53% $56.3 billion
Federal-aid Highways	24% 1,016,963 miles	85% 2.572 trillion VMT	75% $79.3 billion
Systemwide (All Roads)	100% 4,177,074 miles	100% 3.040 trillion VMT	100% $105.4 billion

You drive 85% of your VMT on Federal-aid Highways.

- The portion of total highway capital spending funded by the Federal government decreased from 43.8 percent in 2004 to 42.5 percent in 2014. Federally funded highway capital outlay grew by 3.8 percent per year over this period, compared with a 4.4-percent annual increase in capital spending funded by State and local governments.
- The composition of highway capital spending shifted from 2004 to 2014. The percentage of highway capital spending directed toward system rehabilitation rose from 51.7 percent in 2004 to 62.0 percent in 2014. Over the same period, the percentage of spending directed toward system enhancement rose from 11.2 percent to 13.5 percent, while the percentage of spending directed toward system expansion fell from 37.1 percent to 24.5 percent.

Constant-Dollar Conversions for Highway Expenditures

This report uses the Federal Highway Administration's National Highway Construction Cost Index (NHCCI) 2.0 for inflation adjustments to highway capital expenditures and the Consumer Price Index (CPI) for adjustments to other types of highway expenditures. From 2004 to 2014 the NHCCI 2.0 increased by 51.5 percent (4.2 percent per year), while the CPI increased by only 25.3 percent (2.3 percent per year). Previous editions of the C&P Report reflected an earlier version of the NHCCI, which showed smaller increases than the CPI in recent years.

Highway Capital Spending Terminology

This report splits highway capital spending into three broad categories. "System rehabilitation" includes resurfacing, rehabilitation, or reconstruction of existing highway lanes and bridges. "System expansion" includes the construction of new highways and bridges and the addition of lanes to existing highways. "System enhancement" includes safety enhancements, traffic control facilities, and environmental enhancements.

Conditions and Performance of the System

Highway vehicle miles traveled increased by 2.0 percent (0.2 percent per year) from 2004 to 2014, while highway capital spending declined by 1.0 percent in constant-dollar terms (and overall highway spending increased). These trends were present while indicators of the performance and condition of the overall system had mixed results.

Pavement Condition Trends Have Been Mixed

- In general, pavement condition trends over the past decade have been better on the NHS (the 5 percent of total system mileage that carries 55 percent of total system VMT) than on Federal-aid highways (the 24 percent of system mileage that carries 85 percent of total system VMT, including the NHS).
- The share of Federal-aid highway VMT on pavements with "good" ride quality rose from 44.2 percent in 2004 to 47.0 percent in 2014. The share of mileage with good ride quality declined from 43.1 percent to 38.4 percent over this same period, however, indicating that conditions have worsened on roads with lower travel volumes.

Pavement Condition Terminology

This report uses the International Roughness Index (IRI) as a proxy for overall pavement condition. Pavements with an IRI value of less than 95 inches per mile are considered to have "good" ride quality. Pavements with an IRI value greater than 170 inches per mile are considered to have "poor" ride quality. Pavements that fall between these two ranges are considered "fair."

- The share of Federal-aid highway pavements with "poor" ride quality rose from 2004 to 2014, as measured on both a VMT-weighted basis (rising from 15.1 percent to 17.3 percent) and a mileage basis (rising from 13.4 percent to 22.2 percent). Although this trend is exaggerated due to changes in data reporting instructions beginning in 2010, the data clearly show that more of the Nation's pavements have deteriorated to the point that they are adding to vehicle operating costs and reducing driver comfort.
- The share of VMT on NHS pavements with good ride quality rose from 52 percent in 2004 to 59 percent in 2014. This gain is especially impressive considering MAP-21 expanded the NHS by 62,292 miles (37 percent), as pavement conditions on the additions to the NHS were not as good as those on the pre-expansion NHS. The share rose from 52 percent in 2004 to 60 percent in 2010 based on the pre-expansion NHS and from an estimated 54.7 percent in 2010 to 58.7 percent in 2014 based on the post-expansion NHS, which translates into an average increase of more than 1 percentage point per year.
- The share of VMT on NHS pavements with poor ride quality declined from 9 percent to 7 percent from 2004 to 2010; since the expansion of the NHS under MAP-21, this share has remained relatively constant at approximately 11 percent.

Bridge Condition Trends Have Been Mixed

- Based directly on bridge counts, the share of bridges classified as poor has improved, dropping from 11.0 percent in 2004 to 8.7 percent in 2014 (and to 8.3 percent in 2015). The share of NHS bridges classified as poor also improved over this period, dropping from 5.6 percent to 4.1 percent (and to 3.7 percent in 2015).
- Weighted by deck area, the share of bridges classified as poor improved, declining from 9.4 percent in 2004 to 6.7 percent in 2014 (and to 6.4 percent in 2015). The deck area-weighted share of poor NHS bridges dropped from 8.7 percent to 5.8 percent over this period (and to 5.5 percent in 2015).
- Weighted by deck area, the share of bridges classified as structurally deficient improved, declining from 10.1 percent in 2004 to 7.1 percent in 2014. The deck area-weighted share of structurally deficient NHS bridges dropped from 8.9 percent to 6.0 percent over this period.
- While the percentage of poor bridges has declined over the last decade, the share of bridges classified as good has also gone down. Weighted by deck area, the share of bridges classified as good worsened, declining from 46.1 percent in 2004 to 44.7 percent in 2014 (before rebounding to 45.5 percent in 2015). The deck area-weighted share of good NHS bridges dropped from 43.8 percent to 42.2 percent over this period (rising to 43.0 percent in 2015).

FHWA Bridge Classifications

FHWA is currently transitioning to a new set of bridge condition descriptors. Bridges are given an overall rating of "poor" if the deck, substructure, or superstructure is found to be in poor condition due to deterioration or damage. The legacy term "structurally deficient" includes "poor" bridges as well as those failing other criteria, such as adequacy of the waterway opening under the bridge. The classification of a bridge as poor or structurally deficient does not mean it is unsafe.

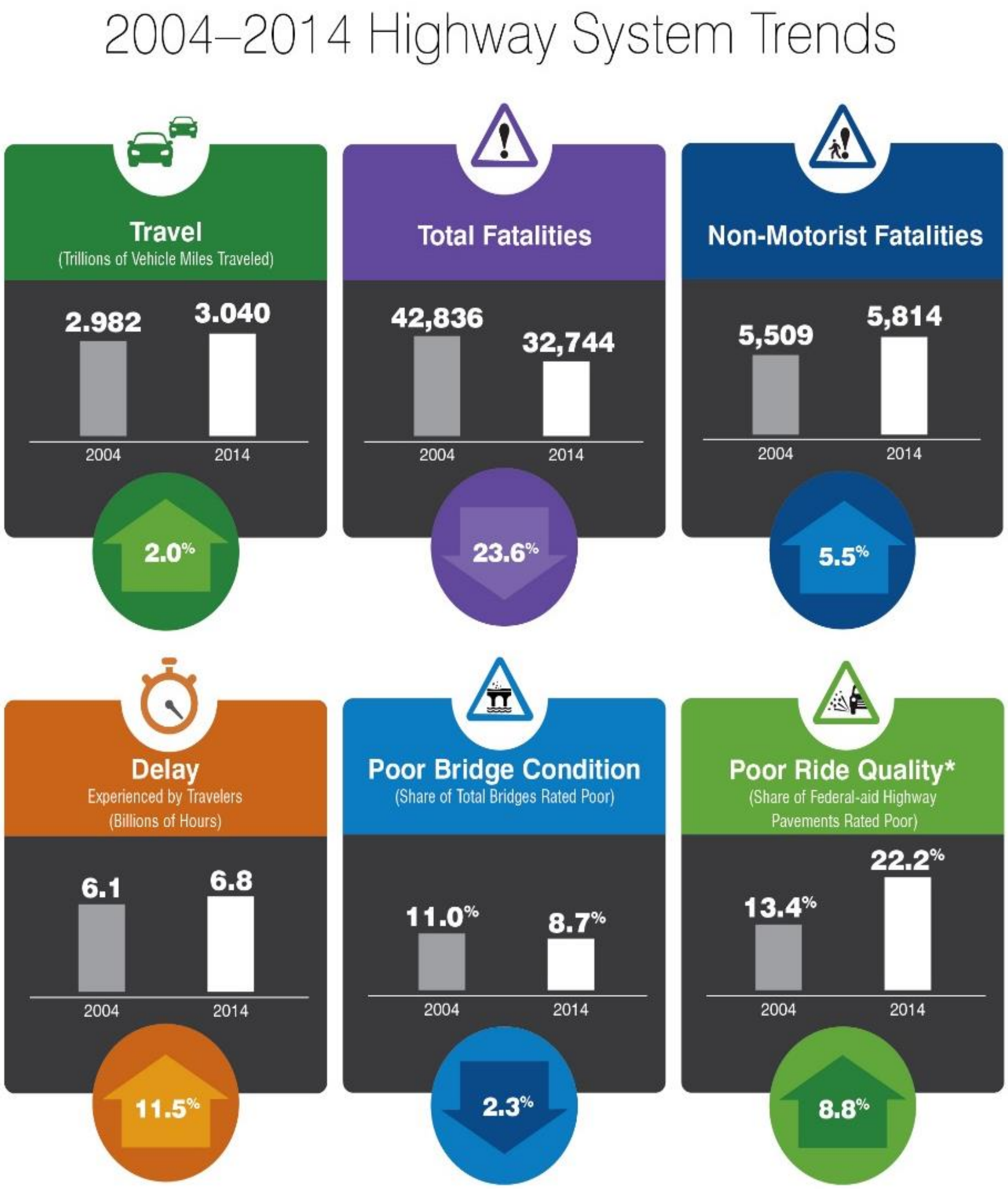
These classifications are often weighted by bridge deck area, recognizing that bridges are not all the same size and, in general, larger bridges are more costly to rehabilitate or replace to address deficiencies. The classifications are also sometimes weighted by annual daily traffic, recognizing that more heavily traveled bridges have a greater impact on total highway user costs.

Another legacy term is "functionally obsolete," which relates to the geometric characteristics of a bridge (e.g., bridge width, load-carrying capacity, clearances, approach roadway alignment) in relation to current design standards. The magnitude of such deficiencies determines whether a bridge is classified as "functionally obsolete." This metric is a legacy classification that was used to implement the Highway Bridge Program, which was discontinued as a separate program with the enactment of MAP-21. In the absence of a programmatic reason to collect the data necessary to support this classification, some of the data necessary to compute it are being removed from the National Bridge Inventory. Future editions of the C&P Report will not contain this information. This edition presents "functionally obsolete" as a measure of operational performance, rather than a measure of physical conditions.

Operational Performance in Urbanized Areas Has Slowly Worsened

- The Texas Transportation Institute 2015 Urban Mobility Scorecard estimates that the average commuter in 471 urbanized areas experienced a total of 42 hours of delay resulting from congestion in 2014, up from 41 hours in 2004. Congestion delay was worse in the largest metro areas, for example averaging 82 hours in Washington D.C., 80 hours in Los Angeles/Long Beach, 78 hours in San Francisco/Oakland, and 74 hours in New York/Newark. Total delay experienced by all urbanized area travelers combined rose by 11.5 percent from 6.1 billion hours in 2004 to 6.8 billion hours in 2014, an all-time high.

- The combined cost of wasted time and wasted fuel caused by congestion in urbanized areas rose from an estimated $136 billion in 2004 to $160 billion in 2014. Although these costs had declined during the most recent recession, they now exceed their pre-recession peak.
- One indicator with more positive trends relates to bridge geometrics, which can influence operational performance. Based directly on bridge counts, the share of bridges classified as functionally obsolete declined from 15.2 percent in 2004 to 13.8 percent in 2014 (unchanged at 13.8 percent in 2015). Weighted by deck area, the share of bridges classified as functionally obsolete improved slightly, dropping from 20.5 percent in 2004 to 20.3 percent in 2014 (before rebounding to 20.5 percent in 2015). Functional obsolescence tends to be a more significant problem on larger bridges carrying more traffic.



*Poor ride quality data are affected by changes in reporting instructions beginning in 2010. The share rated poor rose from 15.8 percent in 2008 to 20.0 percent in 2010.

Highway Safety Improved Overall, but Nonmotorist Fatalities Rose

- The annual number of highway fatalities was reduced by 23.6 percent from 2004 to 2014, dropping from 42,836 to 32,744 (before rising to 35,485 in 2015 and 37,806 in 2016, then declining to 37,133 in 2017).
- From 2004 to 2014, the number of nonmotorists (pedestrians, bicyclists, etc.) killed by motor vehicles increased by 5.5 percent, from 5,509 to 5,814 (17.8 percent of all fatalities). From 2006 to 2009, nonmotorist fatalities showed a steady decline of 15.0 percent, but beginning in 2009 that trend began to shift and resulted in a 19.6-percent increase through 2014. (Nonmotorist fatalities rose to 6,556 in 2015 and 7,193 in 2016 before declining to 6,988 in 2017).
- Fatalities related to roadway departure decreased by 24.8 percent from 2004 to 2014, but roadway departure remains a factor in over half (54.4 percent) of all highway fatalities. Intersection-related fatalities decreased by 17.0 percent from 2004 to 2014, but over one-fourth (26.5 percent) of highway fatalities in 2014 occurred at intersections.
- The fatality rate per 100 million VMT declined from 1.45 in 2004 to an all-time low of 1.08 in 2014 (before rising to 1.15 in 2015 and 1.19 in 2016, then declining to 1.16 in 2017).
- The number of traffic-related injuries decreased by 18.8 percent, from 2.7 million in 2004 to 2.2 million in 2014. The injury rate per 100 million VMT declined from 90 in 200 to 71 in 2014.

Future Capital Investment Scenarios

The scenarios that follow pertain to spending by all levels of government combined for the 20-year period from 2014 to 2034 (reflecting the impacts of spending from 2015 through 2034); the funding levels associated with all of these analyses are stated in constant 2014 dollars. The results below apply to the overall road system; separate analyses for the Interstate System, the NHS, and Federal-aid highways are presented in the body of this report.

Modeled vs. Nonmodeled Investment

Each highway investment scenario includes projections for system conditions and performance based on simulations using the Highway Economic Requirements System (HERS) and National Bridge Investment Analysis System (NBIAS). Each scenario scales up the total amount of simulated investment to account for capital improvements that are outside the scopes of the models, or for which no data are available to analyze. In 2014, 13.5 percent of highway capital spending was used for system enhancements (safety enhancements, traffic control facilities, and environmental enhancements) that neither model analyzes directly. An additional 15.8 percent was used in 2014 for pavement and capacity improvements on non-Federal-aid highways; FHWA does not collect the detailed information for such roadways that would be necessary to support analysis using HERS. (FHWA does collect sufficient data for all of the nation's bridges to support analysis using NBIAS.)

Combining these two percentages yields a total of 29.3 percent; each scenario for the overall road system was scaled up so that nonmodeled investment would comprise this share of its total investment level.

Highway Investment / Performance Analyses

To provide an estimate of the costs that might be required to maintain or improve system performance, this report includes a series of investment/performance analyses that examine the potential impacts of alternative levels of future combined investment by all levels of government on highways and bridges for different subsets of the overall system.

Drawing on these investment/performance analyses, a series of illustrative scenarios was selected for more detailed exploration and presentation.

The Sustain 2014 Spending scenario and the Maintain Conditions and Performance scenario each assume a fixed level of highway capital spending in each year in constant-dollar terms (i.e., spending keeps pace with inflation each year).

Spending under the Improve Conditions and Performance scenario varies by year depending on the set of potential cost-beneficial investments available at that time. Because there is an existing backlog of cost-beneficial investments that have not previously been addressed, investment under this scenario is frontloaded, with higher levels of investment in the early years of the analysis and lower levels in the latter years.

Sustain 2014 Spending Scenario

- The Sustain 2014 Spending scenario assumes that capital spending by all levels of government is sustained in constant-dollar terms at the 2014 level ($105.4 billion systemwide) through 2034. It also assumes that spending would be directed toward projects with the largest benefit-cost ratios. At this level of capital investment, average pavement roughness on Federal-aid highways would be projected to improve by 0.3 percent, while the share of bridges classified as poor would be projected to improve, declining from 6.8 percent in 2014 to 4.7 percent in 2034. Average delay per VMT would be projected to improve by 18.5 percent, as travel growth gradually slows over time and various highway management and operational strategies are adopted more broadly.

Maintain Conditions and Performance Scenario

- The Maintain Conditions and Performance scenario seeks to identify a level of capital investment at which selected measures of future conditions and performance in 2034 are maintained at 2014 levels. It also assumes that spending would be directed toward projects with the largest benefit-cost ratios. The average annual level of investment associated with this scenario is $102.4 billion, 2.9 percent less than actual highway capital spending by all levels of government in 2014.
- Under this scenario, $66.5 billion per year would be directed to system rehabilitation, $22.1 billion to system expansion, and 13.8 billion to system enhancement. Average pavement roughness on Federal-aid highways and the share of bridges classified as poor in 2034 would match their 2014 levels. Average delay per VMT would be projected to improve by 18.4 percent, as travel growth gradually slows over time and various highway management and operational strategies are adopted more broadly.

2014–2034 Future Highway Capital Investment Scenarios

	AVERAGE ANNUAL INVESTMENT*	AVERAGE DELAY PER VMT	AVERAGE PAVEMENT ROUGHNESS	SHARE OF DECK AREA ON POOR BRIDGES
Maintain Conditions and Performance at 2014 Levels	$102.4	REDUCE BY 18.4%	NO CHANGE 0.0%	NO CHANGE 6.8%
Sustain Spending at 2014 Level, Adjusted for Inflation	$105.4	REDUCE BY 18.5%	REDUCE BY 0.3%	REDUCE TO 4.7%
Improve Conditions and Performance (BCR 1.0 or Higher)	$135.7	REDUCE BY 19.3%	REDUCE BY 5.6%	REDUCE TO 0.6%

*Billions of 2014 dollars. Includes all public and private investment.

29.3 percent of each scenario (including $39.8 percent of the Improve scenario) is derived from non-modelled estimates for which the BCR is not known.

Improve Conditions and Performance Scenario

- The Improve Conditions and Performance scenario seeks to identify the level of capital investment needed to address all potential investments estimated to be cost-beneficial. The average annual level of systemwide capital investment associated with this scenario is $135.7 billion, 28.8 percent higher than actual 2014 capital spending.
- Approximately 29 percent of the investment under the Improve Conditions and Performance scenario would go toward addressing an existing backlog of cost-beneficial investments of $786.4 billion. The rest would address new needs arising from 2015 through 2034.
- The State of Good Repair benchmark represents the subset of the Improve Conditions and Performance scenario spending level that is directed toward addressing deficiencies in the physical condition of existing highway and bridge assets. The average annual investment level associated with this benchmark is $88.4 billion, 65.1 percent of the $135.7 billion cost of the overall scenario. The scenario also includes average annual spending of $29.1 billion (21.4 percent) directed toward system expansion, and $18.3 billion (13.5 percent) directed toward system enhancement.
- An estimated $39.8 billion of the spending in this scenario is not constrained by benefit-cost analysis because it is outside the scope of the models. The amount of such “nonmodeled” spending included in this scenario’s estimate is equal to the share of capital spending in 2014 that was outside the scope of the

models. Such spending is for system enhancement projects on all public roads, and pavement rehabilitation and capacity expansion projects on non-Federal aid highways.

- Under the Improve Conditions and Performance scenario, average pavement roughness on Federal-aid highways would be projected to improve by 5.6 percent, while the share of bridges classified as poor would be projected to improve, declining from 6.8 percent in 2014 to 0.6 percent in 2034. This scenario would not eliminate all poor pavements and bridges because, while in some cases it is cost-beneficial to proactively improve assets before they become poor, in other cases it only becomes cost-beneficial to improve assets after they have declined into poor condition. Therefore, at the end of any given year, some portion of the pavement and bridge population would remain deficient.

Highlights: Transit

Extent of the System

- Of the transit agencies that submitted data to the National Transit Database (NTD) in 2014, 849 provided service primarily to urbanized areas and 1,684 provided service to rural areas. Urban and rural agencies operated 1,267 bus systems, 1,858 demand-response systems, 15 heavy rail systems, 29 commuter rail systems, 33 light rail and streetcar systems, 25 streetcar systems, and 5 hybrid rail systems. There were also 98 transit vanpool systems, 29 ferryboat systems, 5 trolleybus systems, 6 monorail and automated guideway systems, 3 inclined plane systems, 1 cable car system, 2 tramway systems, and 1 público. (Público is a mode that exists only in Puerto Rico but has the same operating characteristics as Jitney. These modes operate on fixed routes but with no fixed schedules.)
- Transit operators reported 10.6 billion unlinked passenger trips on 4.6 billion vehicle revenue miles in 2014.

Bus, Rail, and Demand Response: Transit Modes

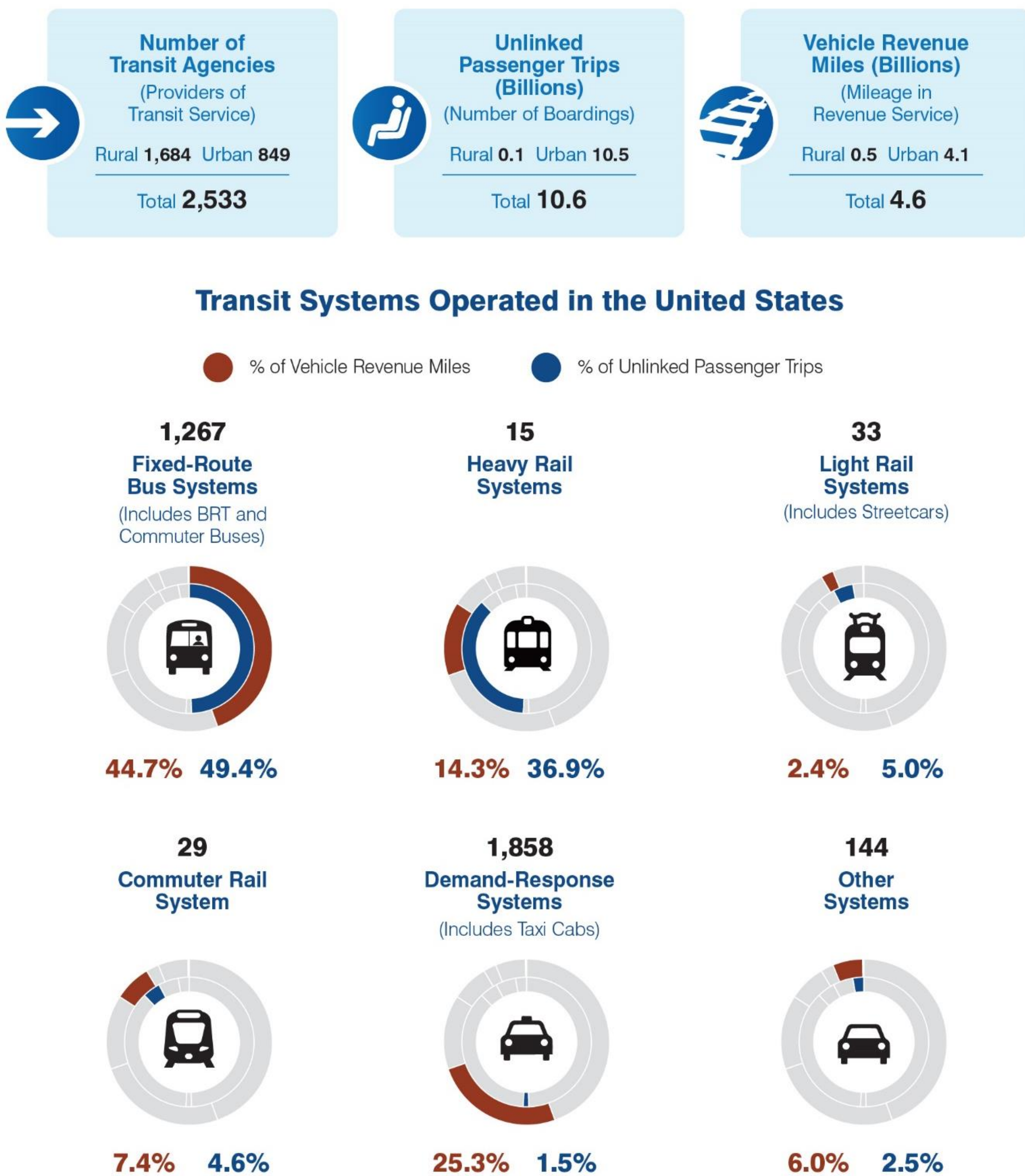
Public transportation is provided by several different types of vehicles that are used in different operational *modes*. The most common is *fixed-route bus* service, which uses different sizes of rubber-tired buses that run on scheduled routes. *Commuter bus* service is similar, but uses over-the-road buses and runs longer distances between stops. *Bus rapid transit* is high-frequency bus service that emulates light rail service. *Públicos and jitneys* are small owner-operated buses or vans that operate on less-formal schedules along regular routes.

Larger urban areas are often served by one or more varieties of *fixed-guideway* (rail) service. These include *heavy rail* (often running in subway tunnels), which is primarily characterized by third-rail electric power and exclusive dedicated guideway. Extended urban areas may have *commuter rail*, which often shares track with freight trains and often uses overhead electric power (but may also use diesel power or third rail). *Light rail* systems are common in large-and medium-sized urban areas; they feature overhead electric power and run on track that is entirely or in part on city streets that are shared with pedestrian and automobile traffic. *Streetcars* are small light rail systems, usually with only one or two cars per train that often run in mixed traffic. *Hybrid Rail,* previously reported as light rail or commuter rail, is a mode with shared characteristics of these two modes. It has higher average station density (stations per track mileage) than commuter rail and lower than light rail; it has a smaller peak-to-base ratio than that of commuter rail. *Cable cars*, *trolley buses*, *monorail*, and *automated guideway* systems are less-common fixed-guideway systems.

Demand-response transit service is usually provided by vans, taxicabs, or small buses that are dispatched to pick up passengers upon request. This mode is mostly used to provide paratransit service as required by the Americans with Disabilities Act. These vehicles do not follow a fixed schedule or route.

- Bus and heavy rail modes continue to be the largest segments of the industry, serving 48 percent and 37 percent of all transit trips, respectively. Commuter rail supports a relatively high share of passenger miles (20.5 percent). Light rail is the fastest-growing rail mode (with passenger miles growing at 4.7 percent per year between 2004 and 2014), but it still provides only 4.4 percent of transit passenger miles. Vanpool growth during that period was 11.1 percent per year, but with vanpools still accounting for only 2.3 percent of all transit passenger miles.

2014 Extent of the Transit System



Spending on the System

- All levels of government spent a combined $65.2 billion to provide public transportation and maintain transit infrastructure. Of this total, 29 percent was system-generated revenue, of which most came from passenger fares. Eighteen percent of revenues came from the Federal government while the remaining funds came from State and local sources.
- Of the combined $65.2 billion spent on public transportation, public transit agencies spent $17.7 billion on capital investments in 2014. Regularly authorized and appropriated Federal funding made up 39.5 percent of these capital expenditures. Funds from the Federal American Recovery and Reinvestment Act provided another 2.5 percent.
- Federal funding is targeted primarily for capital assistance, although Federal funding for operating expenses at public transportation agencies increased from 30 percent of all Federal funding in 2004 to 36 percent in 2014. Virtually all of the increase is due to increased use of “preventive maintenance” eligible for reimbursement from 5307 grant funds.
- From 2004 to 2014, the urban systems’ total fares per revenue mile increased by 1.6 percent and operating costs per mile increased by 32 percent over the same period in 2014 constant dollars. The average fare box recovery ratio decreased from 36.2 percent to 35 percent. For the Nation’s 10 largest transit agencies, which account for majority of the transit ridership, average fares per mile increased by 18 percent in constant-dollar terms from 2004 to 2014, while average constant-dollar operating costs per mile increased by 23.3 percent. This resulted in a decline in the average fare recovery ratio (the percentage of operating costs covered by passenger fares) from 45 percent in 2004 to 43 percent in 2014.

Federal Transit Funding Urban and Rural

Federal Transit Administration (FTA) Urbanized Area Formula Funds are apportioned to *urbanized areas* (UZAs), as defined by the Census Bureau. UZAs in this report were defined by the 2010 census. Each UZA has a designated recipient, usually a metropolitan planning organization (MPO) or large transit agency, which then sub-allocates FTA funds in its area according to local policy. The designated recipient may then allow these organizations to apply directly for a grant with FTA as a designated recipient. In small urban and rural areas, FTA apportions funds to the State, which allocates them according to State policy. Indian tribes are apportioned their formula funds directly. Once obligated in a grant, all funds then become available, on a reimbursement basis.

Conditions and Performance of the System

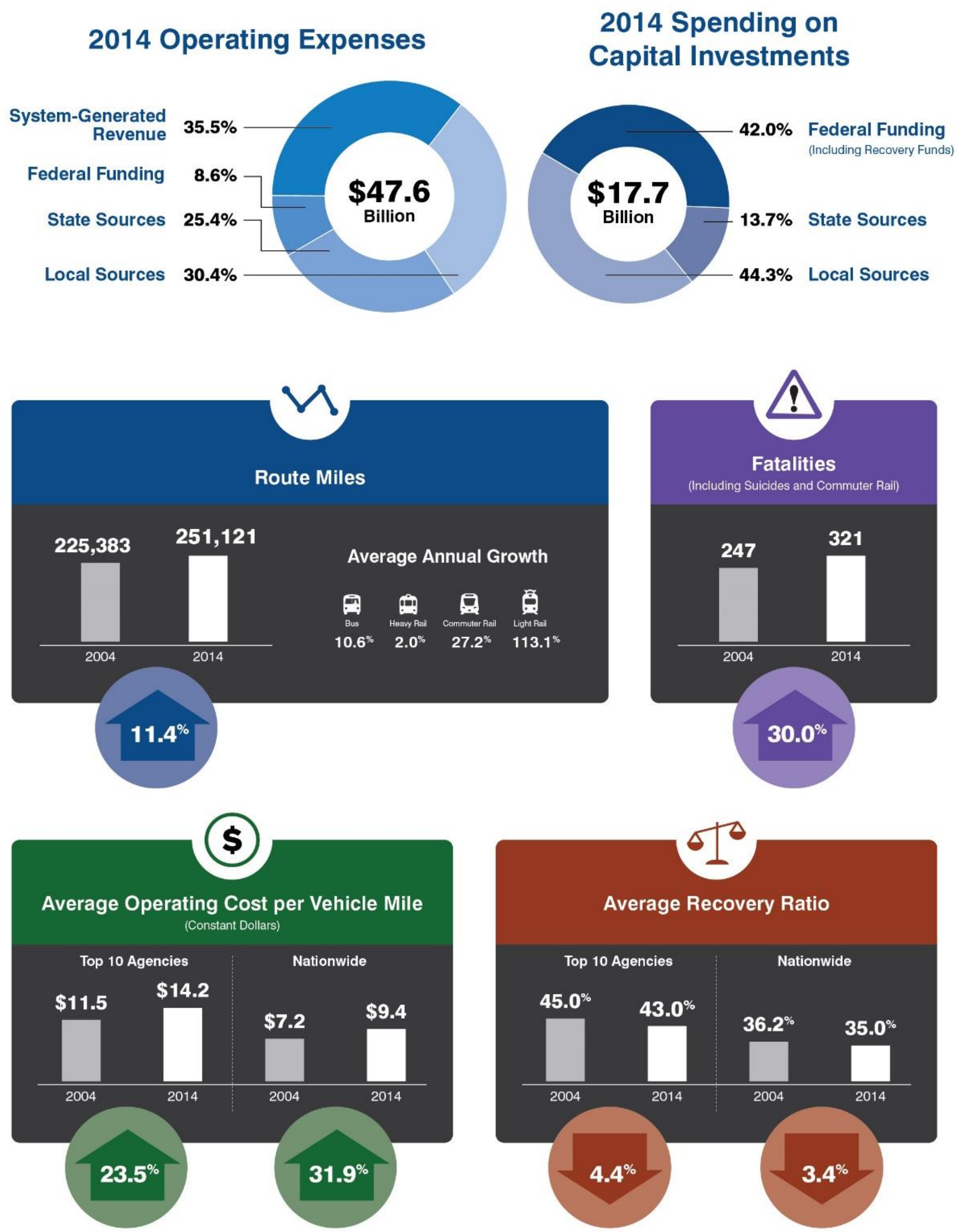
Some Aspects of System Performance Have Improved

- Between 2004 and 2014, the service offered by transit agencies grew substantially. The annual rate of growth in route miles ranged from 0.2 percent per year for heavy rail to 7.9 percent per year for light rail. This has resulted in 42 percent more route miles available to the public.
- Between 2004 and 2014, the number of annual service miles per vehicle (vehicle productivity) remained unchanged and the average number of miles between breakdowns (mean distance between failures) decreased by 9 percent.
- Growth in service offered was nearly in accordance with growth in service consumed. Despite steady growth in route miles and revenue miles, average vehicle occupancy levels did not decrease. Passenger miles traveled grew at a 2.0 percent annual pace while the number of trips grew by 1.6 percent annually. This is significantly faster than the annual growth rate in the U.S. population during this period (0.93 percent), suggesting that transit has been able to attract riders who previously used other modes of travel. Increased availability of transit service has likely been a factor in this success.

Fatalities Increased Due to an Increase in Suicides

- The number of fatalities on transit systems in the United States increased steadily between 2004 and 2011, from 250 fatalities in 2004 to 300 fatalities in 2011. This number increased to around 350 per year in 2012 and 2013, declining to 321 in 2014. In 2014, one in four transit-related fatalities was classified as a suicide (excluding commuter rail). In 2004, the rate was just one in 10. The rate of suicides in transit facilities has gone up every year since 2005.

2004–2014 Transit Trends



Unlinked Passenger Trips, Passenger Miles, Route Miles, and Revenue Miles

Unlinked passenger trips (UPT), also called boardings, count every time a person gets on an in-service transit vehicle. Each transfer to a new vehicle or route is considered another unlinked trip, so a person's commute to work may count as more than one trip if that person transferred between routes.

Passenger miles traveled (PMT) simply count how many miles people travel on transit. UPT and PMT are both commonly used measures of transit *service consumed*.

Directional route miles (DRM) measure the number of miles of transit route available to customers. They are directional because each direction counts separately; thus, a one-mile-out and one-mile-back bus route would be two DRM. *Vehicle Revenue Miles* (VRM) count the miles of revenue service provided by transit operators over their networks.

Future Capital Investment Scenarios – Systemwide

As in the highway discussion, the transit investment scenarios that follow pertain to spending by all levels of government combined for the 20-year period from 2014 to 2034 (reflecting the impacts of spending from 2015 through 2035); the funding levels associated with all of these analyses are stated in constant 2014 dollars. These transit scenarios also assume an immediate jump to a higher (or lower) investment level that is maintained in constant-dollar terms throughout the analysis period.

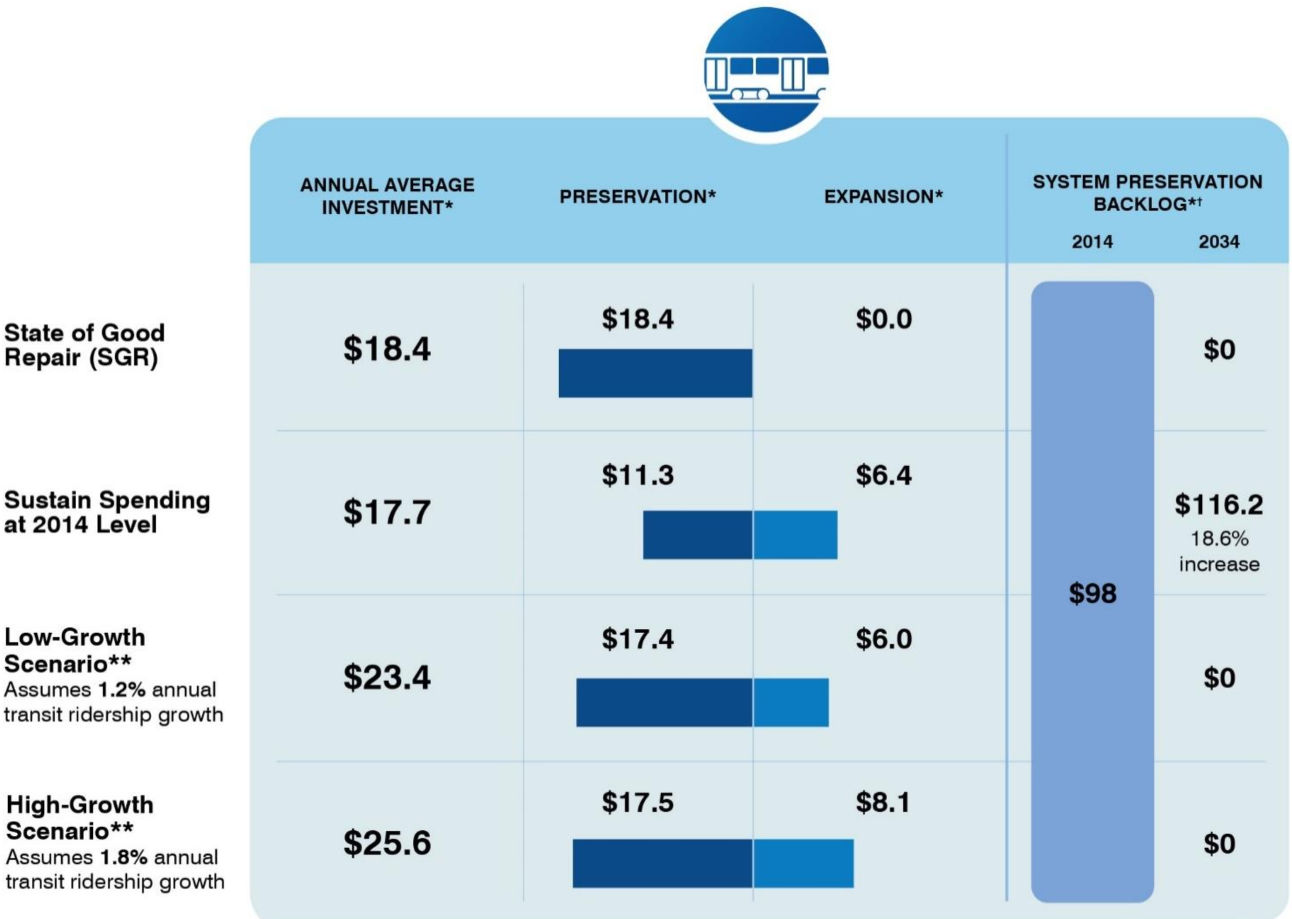
Included in this section for comparison purposes is an assessment of the investment level needed to replace all assets that are currently past their useful life or that will reach that state over the forecast period. This level of investment would be necessary to achieve and maintain a state of good repair (SGR), but would not address any increases in demand during that period. Although not a realistic scenario, it provides a benchmark for infrastructure preservation investment requirements. All capital investment scenarios are subjected to cost-benefit constraints.

State of Good Repair – Expansion vs. Preservation

State of Good Repair (SGR) is defined in this report as all transit capital assets being within their useful service life. This is a general construct that allows FTA to estimate *system preservation* needs. The analysis looks at the age of all transit assets and adds the value of those that are past the age at which that type of asset is usually replaced to a total reinvestment needs estimate. Some assets may continue to provide reliable service well past the average replacement age and others will not; over the large number of assets nationally, the differences are assumed to average out. Some assets will need to be replaced, some will just get refurbished. Both types of cost are included in the reinvestment total. SGR is a measure of system preservation needs, and failure to meet these needs results in increased operating costs and poor service.

Expansion needs are treated separately in this analysis. They result from the need to add vehicles and route miles to accommodate more riders. Failure to meet this type of need results in crowded vehicles and represents a lost opportunity to provide the benefits of transit to a wider customer base.

2014–2034 Future Transit Capital Investment Scenarios



*Billions of 2014 dollars

**The Low-Growth and High-Growth scenarios in this report are based on 15-year ridership trends as of 2014, the cut-off year for this report. The Department does note that transit ridership has, in fact, not increased since 2014 through the early months of 2019. The causes of the decreased transit ridership since 2014 will be analyzed in the next edition of this report. The ridership trends since that time will also be incorporated into the capital investment needs forecasts presented in future editions of this report.

†Spending level of $18.4 billion under the SGR scenario can clear the backlog by 2034, but the Sustain Spending scenario at current funding level of $17.7 billion will add significantly to the backlog. This is due to the fact that under the Sustain Spending scenario, investments are made for expansion as well as preservation.

Sustain 2014 Spending Scenario

- The **Sustain 2014 Spending scenario** assumes that capital spending by all levels of government is sustained in constant-dollar terms at the 2014 level ($17.7 billion systemwide), including Recovery Act funds, through 2034. Assuming that the current split between expansion and preservation investments is maintained, this will allow for enough expansion to meet the national trend growth for the period 2004–2014 at 1.5 percent annual average increase, but will fall short of meeting system preservation needs. By 2034, this scenario will result in roughly $116.2 billion in deferred system preservation projects. If Recovery Act funds are not included in the baseline spending, the baseline spending would fall to $17.3 billion annually, with the deferred system preservation needs at approximately $117.2 billion.

Low-Growth Scenario

- The **Low-Growth scenario** assumes that transit ridership will grow at an average annual rate of 1.2 percent between 2014 and 2034. During that period, it also eliminates the current $98.0 billion system preservation backlog. The annualized cost of this scenario is $23.4 billion.

High-Growth Scenario

- The **High-Growth scenario** assumes that transit ridership will grow at an annual rate of 1.8 percent between 2014 and 2034. It also eliminates the current $98.0 billion system preservation backlog. The annualized cost of this scenario is $25.6 billion.

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Executive Summary

Part I: Moving a Nation

Part I includes six chapters, each of which describes the current system from a different perspective:

- Chapter 1, Assets, describes the existing extent of the highways, bridges, and transit systems. Highway and bridge data are presented for system subsets based on functional classification and Federal system designation, while transit data are presented for different types of modes and assets.
- Chapter 2, Funding, provides detailed data on the revenue collected and expended by different levels of governments to fund transportation construction and operations. The chapter also explores alternative financing and delivery of transportation projects.
- Chapter 3, Travel, discusses vehicle miles traveled and passenger miles traveled on highways and transit, drivers' licensing levels, and commute times. The chapter also analyzes the impact of income levels on travel.
- Chapter 4, Mobility and Access, covers highway congestion and reliability in the Nation's urban areas, and the economic costs of congestion. The transit section explores ridership, average speed, vehicle utilization, and maintenance reliability. The chapter also looks at accessibility to transit for persons with disabilities and the elderly, as well as transit accessibility more generally.
- Chapter 5, Safety, presents statistics on highway safety performance, focusing on the most common roadway factors that contribute to roadway fatalities and injuries. The transit section summarizes safety and security data by mode and type of transit service.

Chapter 6, Infrastructure Conditions, presents data on the current physical conditions of the Nation's highways, bridges, and transit assets.

Transportation Performance Management

A key change under the Moving Ahead for Progress in the 21 Century Act (MAP-21), and the Fixing America's Surface Transportation (FAST) Act, is the transition to a performance- and outcome-based program. Performance measures will be established through rulemakings; grant recipients will set performance targets based on these measures, and will periodically report on their progress toward meeting these targets. FHWA has finalized six related rulemakings to implement the transportation performance management (TPM) framework established by MAP-21 and the FAST Act:

- Statewide and Metropolitan/Nonmetropolitan Planning Rule (defines coordination in the selection of targets, linking planning and programming to performance targets).
- Safety Performance Measures Rule (PM-1) (establishes performance measures to assess fatalities and serious injuries).
- Highway Safety Improvement Program (HSIP) Rule (integrates performance measures, targets, and reporting requirements into the HSIP).
- Pavement and Bridge Performance Measures Rule (PM-2) (defines pavement and bridge condition performance measures, along with minimum condition standards).
- Asset Management Plan Rule (defines the contents and development process for an asset management plan).
- System Performance Measures Rule (PM-3) (includes measures for performance, freight movement, and the Congestion Mitigation and Air Quality program).

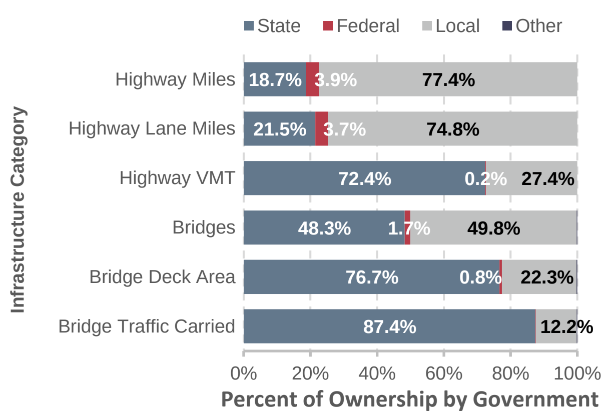
Executive Summary

CHAPTER 1: System Assets – Highways

In 2014, local governments owned 77.4 percent of the Nation's 4,177,074 miles and 74.8 percent of its 8,766,049 lane miles. However, State-owned roads carried a disproportionate share of the Nation's travel, accounting for 72.4 percent of the 3.040 trillion vehicle miles traveled (VMT) in 2014.

Ownership of bridges is more evenly split, as local governments owned slightly more (49.8 percent) of the Nation's 610,749 bridges in 2015 than did State governments (48.3 percent). Although the Federal government provides significant financial support for the Nation's highways and bridges, it owns relatively few of these facilities.

Highway (2014) and Bridge (2015) Ownership by Level of Government



Sources: HPMS and NBI.

Roadways are categorized by functional classifications based on the degree to which they provide access relative to the degree to which they provide mobility. Arterials serve the longest distances with the fewest access points; roads classified as local (which are not all owned by local governments) are greatest in number and provide the most access to the system, while collectors funnel traffic from local roads to arterials.

Nearly half the Nation's road mileage was classified as rural local in 2014, part of the 71.2 percent of mileage located in rural areas. Although only 28.8 percent of the road mileage is located in urban areas, these roads carry 69.7 percent of VMT.

Highway Extent and Travel By Functional System, 2014

Functional System	Highway Miles	Highway VMT
Rural Areas (4,999 or less in population)		
Interstate	0.7%	7.6%
Other Freeway and Expressway	0.1%	0.9%
Other Principal Arterial	2.2%	6.2%
Minor Arterial	3.2%	4.6%
Major Collector	9.8%	5.2%
Minor Collector	6.2%	1.6%
Local	49.1%	4.1%
Subtotal Rural Areas	**71.2%**	**30.3%**
Urban Areas (5,000 or more in population)		
Interstate	0.4%	17.3%
Other Freeway and Expressway	0.3%	7.5%
Other Principal Arterial	1.6%	15.5%
Minor Arterial	2.7%	12.9%
Major Collector	3.1%	6.4%
Minor Collector	0.3%	0.4%
Local	20.4%	9.7%
Subtotal Urban Areas	**28.8%**	**69.7%**
Total	**100.0%**	**100.0%**

Sources: HPMS and NBI.

In general, public roads that are functionally classified as arterials, urban collectors, or rural major collectors are eligible for Federal-aid highway funding (and are described as "Federal-aid highways"). MAP-21 expanded the National Highway System (NHS) to include almost all principal arterials; the NHS also includes collector and local mileage that connect principal arterials to other transportation modes and defense installations.

Executive Summary

CHAPTER 1: System Assets – Transit

Most transit systems in the United States report to the National Transit Database (NTD). In 2014, 849 systems served 497 urbanized areas, which have populations greater than 50,000. In rural areas, 1,684 systems were operating. Thus, the total number of transit systems reporting to NTD in 2014 was 2,533.

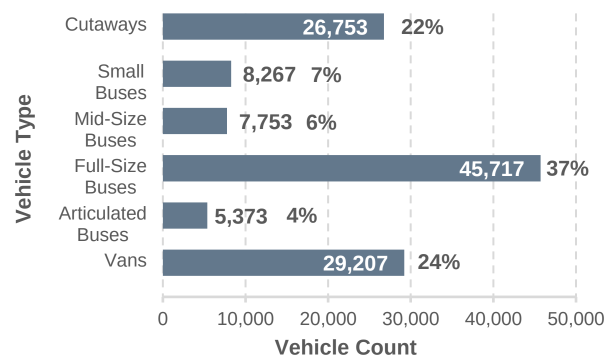
Modes. Transit is provided through nine distinct modes in two major categories: rail and nonrail. Rail modes include heavy rail, light rail, streetcar, commuter rail, and other less common modes that run on fixed tracks, such as hybrid rail, inclined plane, monorail, and cable car. Nonrail modes include bus, commuter bus, bus rapid transit, demand response, vanpools, other less common rubber-tire modes, ferryboats, and aerial tramways. This edition of the C&P Report includes one new mode: aerial tramway.

Organization Structure of Urban and Rural Agencies. Nearly 50 percent of transit agencies in the United States are transportation units or departments of cities, counties, and local government units. Independent public authorities or agencies account for 24 percent. Eighteen percent are private operators, and the remaining 13 percent are other organizational structures such as state governments, area agencies on aging, MPOs, planning agencies, tribes, and universities.

National Transit Assets

- Of the 849 urban reporters, 428 were cities, counties, and local government transportation units.
- Of the 169,197 transit vehicles in urban and rural areas, most are nonrail vehicles (buses, demand response, and vanpool), while most rail vehicles are either heavy, commuter, or light rail passenger cars.
- Rail systems operate on 12,793 miles of track, of which 7,760 miles are for commuter rail. Bus systems operate over 237,654 directional route miles.
- Urban and rural areas have 5,264 stations, of which 1,245 are for commuter rail, and 2,451 maintenance facilities.
- Full-size 40-foot buses (seating 45 people) are the most common road vehicle in transit, accounting for 37 percent of the national road fleet. Full- and mid-size buses are used primarily as fixed-route bus service. Small buses (seating 25 people) and cutaways (seating 15 people) are split between low-demand fixed-route systems and demand response. Vans are used mostly as vanpools and demand response.

Composition of Transit Road Vehicle Fleet, 2014



Note: There is not a one-to-one map between modes and vehicle types. For instance, cutaways are used for both fixed-route bus and demand response.

Source: Transit Economic Requirements Model (TERM) and National Transit Database.

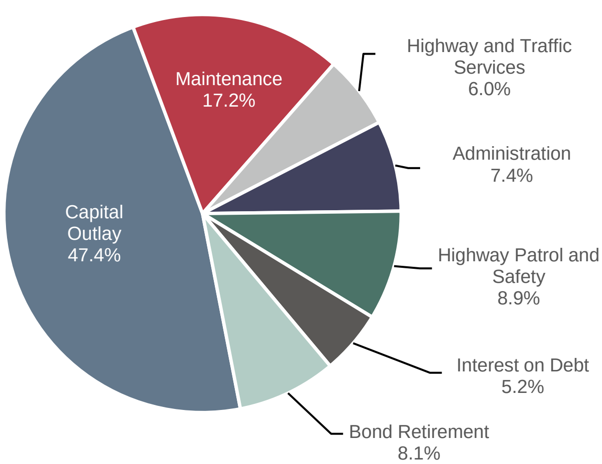
ADA Compliance. The Americans with Disabilities Act of 1990 (ADA) prohibits discrimination and ensures equal opportunity and access for persons with disabilities. ADA requires transit agencies to ensure that vehicles and facilities are accessible to and usable by persons with disabilities, including wheelchair users. The level of accessibility is high for the national fleet, but lower for older heavy-rail systems built before the enactment of ADA.

CHAPTER 2: Funding – Highways

Combined expenditures for highways by all levels of government totaled $222.6 billion in 2014, with the Federal government funding $47.3 billion, States $111.2 billion, and local governments $64.1 billion. Most of the Federal funding was in the form of grants to State and local governments; direct Federal expenditures for federally owned roads, highway research, and program administration totaled $3.2 billion.

Highway capital spending totaled $105.4 billion, or 47.4 percent of total highway spending in 2014. Spending on maintenance totaled $38.2 billion, $13.2 billion was for highway and traffic services, $16.4 billion was for administrative costs (including planning and research), $19.8 billion was spent on highway patrol and safety, $11.5 billion was for interest on debt, and $17.9 billion was used to retire debt.

Highway Expenditure by Type, 2014

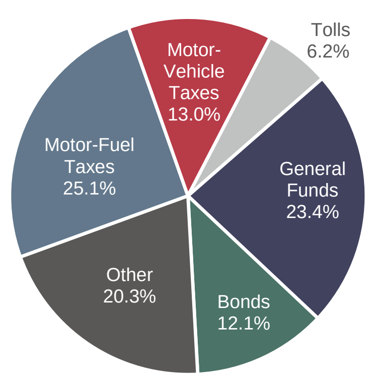


Sources: Highway Statistics 2015, Table HF-10A (preliminary), and unpublished FHWA data.

Total highway spending increased by 50.9 percent from 2004 to 2014, averaging 4.2 percent per year. (In inflation-adjusted constant-dollar terms, highway spending grew by 0.9 percent per year.) Expenditures funded by local governments grew by 4.4 percent per year, outpacing annual increases at the State and Federal levels of 4.3 percent and 3.6 percent, respectively. Over this period, the share of total highway expenditures funded by the Federal government dropped from 22.4 percent to 21.2 percent, while the federally funded share of highway capital spending declined from 43.8 percent to 42.5 percent.

Combined revenues generated for use on highways by all levels of government totaled $241.1 billion in 2014 (the $18.6 billion difference between expenditures and receipts is the amount placed in reserves for future use). In 2014, $106.4 billion (44.1 percent) of total highway revenues came from highway user charges, including motor-fuel taxes, motor-vehicle fees, and tolls. Other major sources for highways included general fund appropriations of $56.5 billion (23.4 percent) and bond proceeds of $29.2 billion (12.1 percent). All other sources, such as property taxes, other taxes and fees, investment income, and other receipts, totaled $49.0 billion (20.3 percent).

Revenue Sources for Highways, 2014



Sources: Highway Statistics 2015, Table HF-10A (preliminary), and unpublished FHWA data.

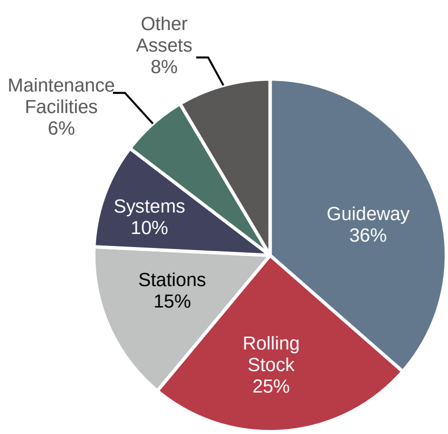
CHAPTER 2: Funding – Transit

In 2014, $65.2 billion was generated from all sources to fund urban and rural transit. Transit funding comes from public funds that Federal, State, and local governments allocate, and from system-generated revenues that transit agencies earn from the provision of transit services. Of the funds generated in 2014, **71 percent came from public sources and 29 percent came from system-generated funds** (passenger fares and other system-generated revenue sources). The Federal share was $11.6 billion (25 percent of total public funding and 17.7 percent of all funding).

In 2014, operating expenses consumed $47.5 billion (73 percent) of all funding devoted to transit ($65.2 billion).

Guideway assets use the largest share of capital—36 percent ($6.4 billion)—for expansion and rehabilitation projects.

Urban Capital Expenditure by Asset Category, 2014

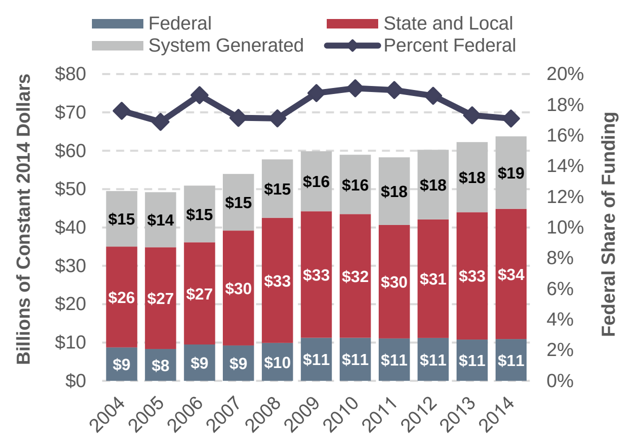


Source: National Transit Database.

Between 2004 and 2014, all sources of public funding for transit increased by over 2.5 percent per year.

The Federal share remained relatively stable, varying in the range of 16–20 percent.

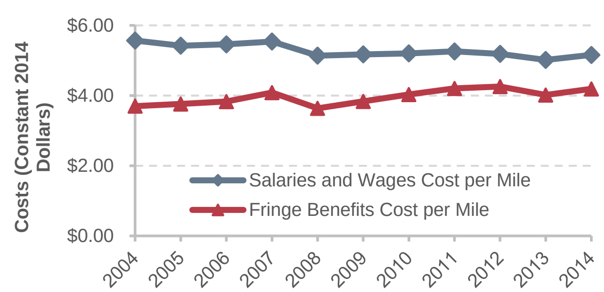
Funding for Urban Transit by Government Jurisdiction, 2004–2014



Source: National Transit Database.

From 2004 to 2014, for the top 10 transit agencies, fringe benefits increased at the highest rate of any operating cost category on a per-mile basis. Over this period, fringe benefits increased at an annual compound average rate of 1.3 percent. Meanwhile, salaries and wages decreased by nearly 1 percent.

Salaries and Wages and Fringe Benefits, Average Cost per Mile—Top 10 Transit Agencies, 2004–2014



Source: National Transit Database.

CHAPTER 3: Travel – National and Household Trends

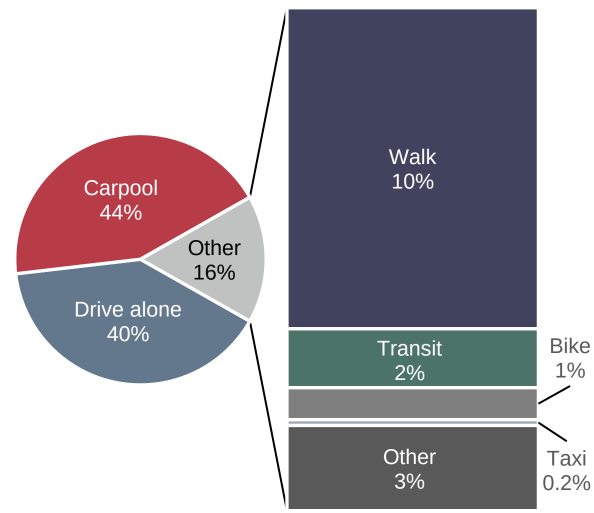
Total VMT on the Nation's roads has rebounded from declines during and following the 2008–2009 recession, rising back above previous levels. Total VMT in 2014 was 3.03 trillion miles, dominated by passenger vehicles (81.4 percent) and personal purposes (81.7 percent). Approximately 90 percent of 2014 VMT was in light-duty vehicles (passenger cars, light trucks, vans, and sport utility vehicles).

Nationally, transit passenger miles traveled (PMT) reached 55.7 billion in 2014, as unlinked passenger trips (each journey on one transit vehicle) totaled 10.5 billion. Average passenger trip length increased from 4.8 miles in 1991 to 5.4 miles in 2014, as growth in PMT (2.1 percent annually) outpaced growth in unlinked passenger trips (1.7 percent).

The share of licensed drivers in the total population grew steadily from 1960 to 1990, and subsequently stabilized at about 70 percent. In 1960, drivers had very limited options in terms of which household vehicle to drive, because there were fewer automobiles than licensed drivers (the vehicle-to-driver ratio was below 1.0). The situation has reversed since 1980, with the average ratio of vehicles per licensed driver remaining close to 1.2, indicating on average more than one vehicle available per licensed driver.

Choice of travel modes is critical in understanding household travel behavior, which has great implications for transportation policy design. The 2009 National Household Travel Survey showed Americans took 191 billion person trips for all purposes. Driving was the dominant mode of household travel. Multi-occupant vehicles (carpools) accounted for 44 percent of all person trips, followed by single-occupant vehicles (40 percent), walking (10 percent), transit (2 percent) and bicycling (1 percent).

Person Trips By Transportation Modes, 2009



Source: National Household Travel Survey 2009.

Commuting was responsible for 28 percent of total personal VMT in 2009. The 2009 American Community Survey showed that approximately 86 percent of commuting trips were made in private vehicles for commuting (76 percent driving alone, 10 percent carpool). About 5 percent of workers traveled to work using transit, 2.9 percent walked, and 4.3 percent of workers teleworked from home.

Examined over a longer period, the share of workers driving alone was relatively constant at 76 to 77 percent from 2005 to 2014, while carpooling became less popular as its share slipped from 10.7 percent to 9.2 percent. The proportion of teleworkers expanded from 3.6 percent to 4.5 percent over the same period. The share of workers using transit rose from 4.7 percent to 5.2 percent from 2005 to 2014 (subsequently declining to 5.0 percent in 2017). Workers who commute by walking or biking are still a small part of the entire commuting labor force, and their mode shares barely changed.

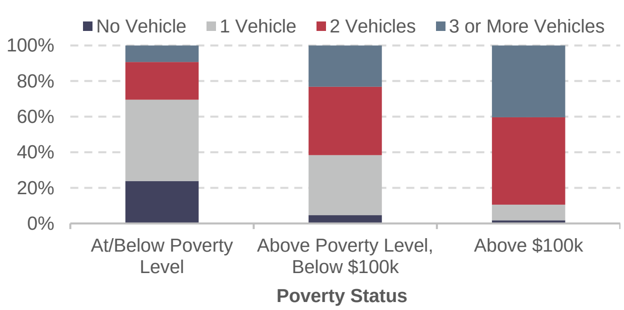
CHAPTER 3: Travel – Impact of Income Distribution

Household income is a crucial factor in determining travel behavior. Only 74 percent of low-income households used a private vehicle in 2009, compared with 86 percent of households with incomes above poverty level. Walking accounted for a higher share of total personal trips among low-income households.

The average number of vehicles that households could access increased marginally from 1.66 in 2000 to 1.68 in 2014, while the total number of vehicles in the country went up from 174 million to 197 million.

Around 24 percent of households at or below poverty level in 2009 had no vehicle. The share of households without a vehicle was below 5 percent for households whose annual income was above poverty level but below $100,000, and less than 2 percent for households with annual income above $100,000.

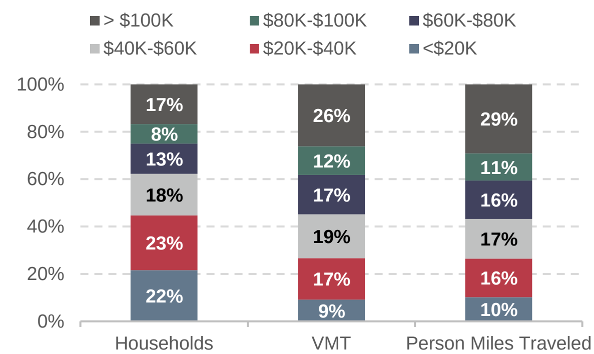
Household Vehicle Access by Poverty Status, 2009



Source: National Household Travel Survey 2009.

Higher-income households benefited more from highway access compared with their lower-income counterparts. The 17 percent of households with an income above $100,000 owned more vehicles, drove further, and represented a larger proportion of national vehicle miles and person miles of travel than any other income class.

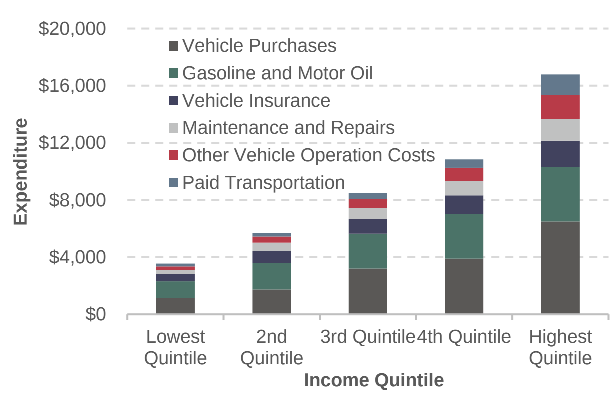
Distribution of Households, VMT, and Person Miles Traveled by Income, 2009



Source: National Household Travel Survey 2009.

The average American household spent $9,073 on transportation in 2014, about 17 percent of total household expenditures. The average annual transportation expenditure for households with the highest 20 percent of income was $16,788 in 2014, 4.7 times the amount spent by households with the lowest 20 percent of income ($3,555). High-income households tended to spend a higher proportion on paid transportation such as intercity travel than did low-income households.

Average Transportation Expenditure by Income Quintile, 2014



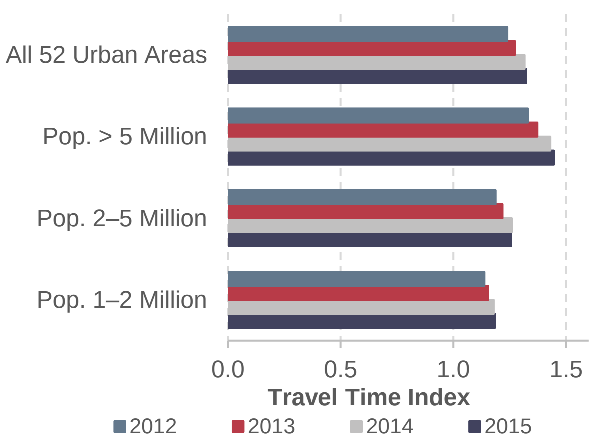
Source: Consumer Expenditure Survey 2014.

CHAPTER 4: Mobility and Access – Highways

Based on the National Performance Management Research Data Set (NPMRDS), the Travel Time Index (TTI) was 1.32 in 2015 for Interstate highways in the 52 largest metropolitan areas, meaning that the average peak-period trip took 32 percent longer than the same trip under free-flow traffic conditions. The TTI value for 2012 (the first year data are available) was only 1.24, indicating that travel time delays increased from 2012 to 2015.

Among these 52 areas, larger areas experienced more severe congestion during this period. The 2015 TTI values were 1.45, 1.26, and 1.18 for areas with population greater than 5 million, between 2 to 5 million, and between 1 and 2 million, respectively.

Travel Time Index for Interstate Highways in the 52 Largest Metropolitan Areas, 2012–2015



Source: FHWA staff calculation from the NPMRDS.

The average number of hours per weekday that Interstate highways are congested also varies by size of area among these 52 metropolitan areas. Congested hours per weekday totaled 7.3, 4.3, and 3.3 for areas with population greater than 5 million, between 2 to 5 million, and between 1 and 2 million, respectively.

The Planning Time Index (PTI) is a measure of travel time reliability, capturing the amount of time drivers would need to plan for to ensure on-time arrival 95 percent of the time. In 2015, the average PTI of Interstate highways in the 52 largest metropolitan areas was 2.52, meaning that drivers making a trip would need to leave early enough each day to account for it taking 2.52 times longer than it would under free-flow traffic conditions, if they wanted to get to their destination on time 19 days out of 20. For example, if an Interstate trip takes 30 minutes on average, a traveler would need to plan for it by taking 75 minutes each time in order to arrive on time 19 out of 20 trips.

Travel delays and reliability for these 52 areas vary over the course of a year. For each year from 2012 to 2015, the TTI on Interstate highways dropped to a lower level in July then quickly rose to the highest monthly value in October, then dropped again in the last two months of the year. The PTI reached its lowest point in July or August, then moved up. Interstate highways usually experienced longer periods of congestion in winter and shorter periods in warmer months.

The NPMRDS also captures data on other freeways and expressways not on the Interstate System, dating back to 2013. Among the 52 largest metropolitan areas, average congestion and reliability for these routes appear worse than on Interstate highways, resulting in higher TTI and PTI values. The TTI for other freeways and expressways was 1.37 in 2015, while the PTI was 2.98.

The Texas Transportation Institute's 2015 Urban Mobility Scorecard indicates that congestion in the Nation's 471 urbanized areas added 6.8 billion hours to travelers' time in 2014, and the total cost of this congestion was $160 billion. The annual average delay per commuter in these areas was 42 hours in 2014, up from 41 hours in 2004.

CHAPTER 4: Mobility and Access – Transit

Transit data from the end of the past decade show steady increases in service provided and consumed, commensurate with the growth of the urbanized population.

Between 2004 and 2014, the geographic coverage of transit increased significantly. New and extended commuter modes, such as vanpools and commuter rail, reached areas with significant transit demand that were previously accessible only by automobile. Revenue service hours and unlinked passenger trips increased by 12 and 19 percent respectively, and passenger miles by 22 percent. The higher increase in ridership compared with service hours is indicative of the better service effectiveness of these modes, and the larger increase in passenger miles compared with unlinked trips is indicative of a growing demand for commuter trips to outlying suburbs and neighboring cities.

The vehicle utilization of commuter rail also increased, indicating higher passenger loads.

Vehicle Service Utilization: Average Annual Vehicle Revenue Miles per Active Vehicle by Mode, 2004–2014

Mode	Vehicle Revenue Miles per Vehicle (Thousands of Miles) 2004	2014	% Change
Rail			
Heavy Rail	57.0	56.5	-0.7%
Commuter Rail	41.1	46.3	12.9%
Light Rail[1]	39.9	45.6	14.4%
Nonrail			
Fixed-Route Bus[2]	29.8	28.4	-4.7%
Vanpool	14.1	15.2	7.5%
Demand-Response[3]	19.8	20.4	3.3%

¹ Includes light rail, hybrid rail, and streetcar rail.

² Includes bus, bus rapid transit, and commuter bus.

³ Includes demand-response and demand-response taxi.

Note: Rail category does not include Alaska railroad, cable car, inclined plane, or monorail/automated guideway. Nonrail category does not include aerial tramway or público.

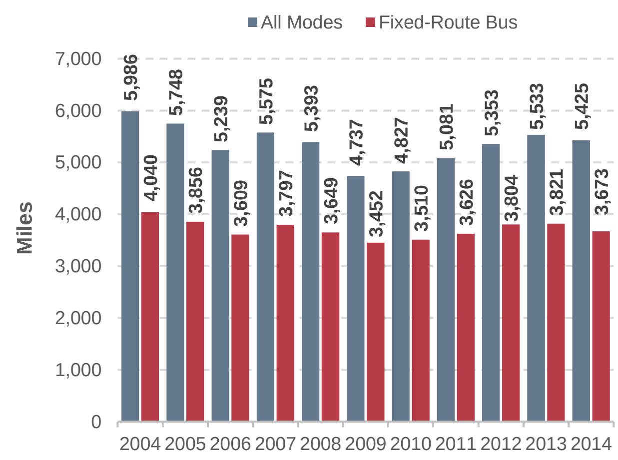
Source: National Transit Database.

Vanpool vehicle utilization also increased, but at a smaller rate because vanpool expansion requires relatively more vehicles than in any other mode.

Light rail (including standard light rail, streetcars and hybrid rail) also expanded service significantly, both geographically and/or in terms of service intensity, and vehicle utilization increased by 14 percent. Fixed-route bus had a significant decrease in service utilization, and heavy rail decreased slightly.

Vehicle reliability is an important performance measure for analysis of replacement and rehabilitation needs of the national transit fleet. In 2004–2014, vehicle reliability fluctuated (based on vehicle revenue miles between mechanical failures). Over these 10 years, the average number of miles between failures decreased by nearly 1 percent, annually. Bus interruptions account on average for 65–70 percent of all interruptions.

Mean Distance Between Urban Vehicle Failures, 2004–2014



Note: Only directly operated vehicle data were used to calculate mean distance between failures.

Note: The data for all years do not include agencies that qualified and opted to use the small systems waiver of the National Transit Database in 2014.

Source: National Transit Database.

Executive Summary

CHAPTER 5: Safety – Highways

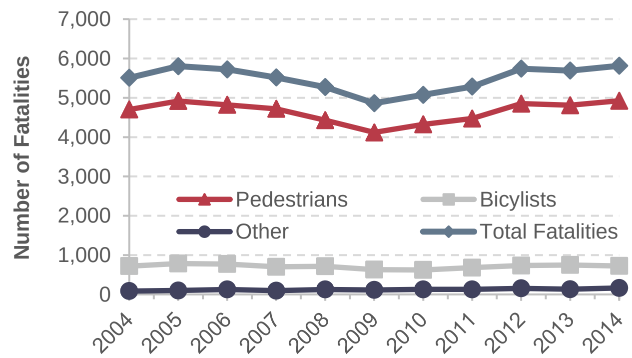
DOT's top priority is to make the U.S. transportation system the safest in the world. Three operating administrations within the DOT (FHWA, NHTSA, and FMCSA) have specific responsibilities for addressing highway safety. This balance of coordinated efforts, coupled with a comprehensive focus on shared, reliable safety data, enables these DOT administrations to concentrate on their areas of expertise while working toward the Nation's safety goal.

Overall Fatalities and Injuries

There has been great progress in reducing overall roadway-related fatalities and injuries during the past two decades, despite increases in population and travel. Consistent with other data in this report, the focus here is on trends that occurred from 2004 to 2014.

- From 2004 to 2014, traffic fatalities decreased by nearly 24 percent despite an almost 9-percent increase in population and a 2-percent increase in travel.
- During the same period, pedestrian and bicyclists fatalities increased by 5.5 percent.
  - From 2004 until 2009, pedestrian and bicyclist fatalities experienced a decreasing trend, declining by 11.8 percent. The trend shifted direction dramatically from 2009 to 2014, increasing by 19.6 percent over that time.
  - In 2004, pedestrian and bicycle fatalities accounted for 12.9 percent of total roadway-related fatalities; this share rose to 17.8 percent in 2014.
- In 2014, rural roads accounted for 30.4 percent of travel and 51.3 percent of roadway fatalities, whereas urban roads accounted for 69.6 percent of travel and 48.6 percent of roadway fatalities.
  - From 2004 to 2014, fatalities on rural roadways decreased by 33.3 percent and fatalities on urban roadways decreased by 9.5 percent.

Pedestrian, Bicyclist, and Other Nonmotorist Traffic Fatalities, 2004–2014



Source: Fatality Analysis Reporting System/National Center for Statistics and Analysis, NHTSA.

Focused Approach to Safety

The Focused Approach to Safety addresses the most critical safety challenges surrounding roadway departure, intersection, and pedestrian/bicyclist-involved crashes. These three areas account for nearly 90 percent of traffic fatalities and represent an opportunity to significantly reduce the number of fatalities and serious injuries.

- In 2014, roadway departure, intersection, and pedestrian/bicyclist-involved crashes accounted for 54.4 percent, 26.5 percent, and 17.8 percent, respectively, of the 32,744 total roadway-related fatalities.
- From 2004 to 2014, fatalities involving roadway departures and intersections decreased by 24.8 percent and 17.0 percent, but fatalities involving pedestrians and bicyclists increased by 5.5 percent.

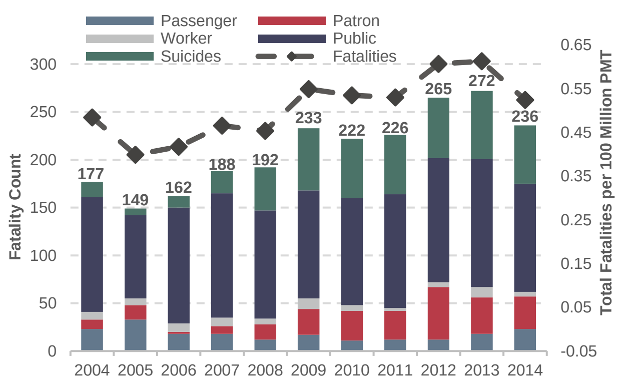
Executive Summary

CHAPTER 5: Safety – Transit

Rates of injuries and fatalities on public transportation generally are lower than for other modes of surface transportation. Nonetheless, serious incidents do occur, and the potential for catastrophic events remains.

Most victims of injuries and fatalities in rail transit are not passengers or patrons. They are pedestrians, automobile drivers, bicyclists, or trespassers. Patrons are individuals in stations who are waiting to board or just got off transit vehicles. In 2014, of the 236 fatalities, only 10 percent were passengers.

Annual Transit Fatalities, Including Suicides, 2004–2014[1]



[1] Per 100 million PMT Including suicides.

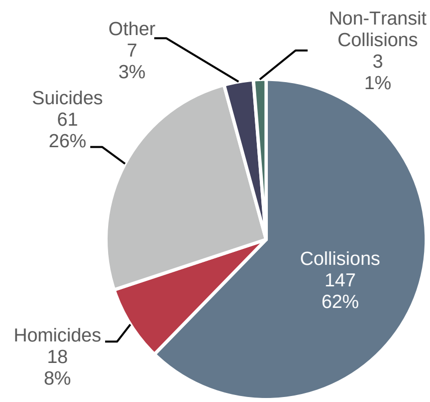
Note: Fatality totals include both directly operated (DO) and purchased transportation (PT) service types.

Source: National Transit Database, Transit Safety and Security Statistics and Analysis Reporting.

Collisions are the most common type of fatal incident in rail transit. In 2014, 147 persons, or 62 percent of all fatalities (excluding commuter rail), died in collision incidents. Suicides were the second most common type, with 61 fatalities in 2014.

Commuter rail fatalities accounted on average for 38 percent of all rail fatalities during the period 2004–2014.

Transit Fatality Event Types, 2014[1]

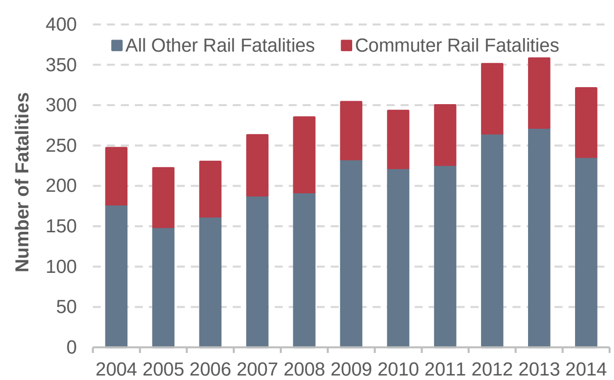


[1] Exhibit includes data for all transit modes, excluding commuter rail.

Note: Other Event Type includes fatalities due to smoke inhalation, slips & falls, electric shock events, and trespassers with an unknown cause of death.

Source: National Transit Database.

Annual Fatalities, Including Suicides and Commuter Rail, 2004–2014



Note: Fatality totals include both directly operated (DO) and purchased transportation (PT) service types.

Note: Data on commuter rail fatalities are not available by victim type and type of incident.

Note: Other fatalities include all other modes.

Sources: Federal Railroad Administration, Railroad Right-of-Way Incident Analysis Research (for commuter rail fatalities) and National Transit Database, Transit Safety and Security Statistics and Analysis Reporting (for all other rail fatalities).

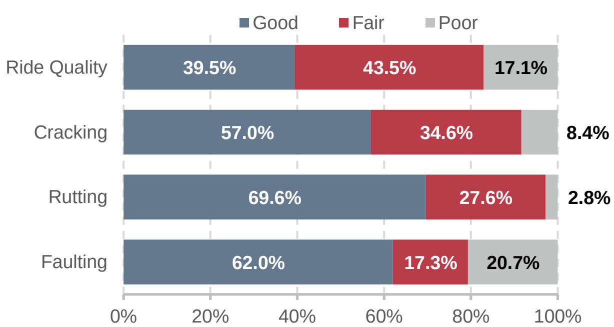
Executive Summary

CHAPTER 6: Infrastructure Conditions – Highways

FHWA is transitioning to a new set of condition measures based on categorical ratings of good, fair, and poor for pavements and bridges. HPMS contains data on multiple types of pavement distresses. Data on pavement roughness are used to assess the quality of the ride that highway users experience. Other measures of pavement distress include pavement cracking, pavement rutting (surface depressions in the vehicle wheel path, generally relevant only to asphalt pavements), and pavement faulting (the vertical displacement between adjacent jointed sections on concrete pavements).

Weighted by lane miles, 17.1 percent of pavements on Federal-aid highways for which data were available had poor ride quality in 2014; the comparable shares for cracking, rutting, and faulting were 8.4 percent, 2.8 percent, and 20.7 percent, respectively.

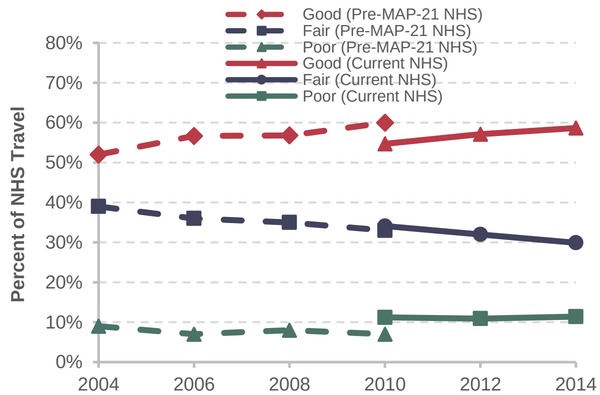
Federal-aid Highway Pavement Conditions, 2014



Source: Highway Performance Monitoring System.

FHWA currently uses the share of VMT on NHS pavements with good ride quality as a metric for performance planning purposes; this rose from 52 percent in 2004 to 58.7 percent in 2014. This gain came despite the significant expansion of the NHS under MAP-21, as pavement conditions on the additions to the NHS were not as good as those on the pre-expansion NHS.

NHS Pavement Ride Quality, Weighted by VMT, 2004–2014



Source: Highway Performance Monitoring System.

NBI contains data on bridge decks, superstructures, substructures, and culverts that can be combined to form an overall bridge condition rating. While the share of bridges rated good has gone down since 2004, the share rated as poor has been reduced even faster. It should be noted that a poor condition rating does not mean that a bridge is unsafe.

Systemwide Bridge Conditions, 2004–2015

	2004	2014	*2015*
Percent Good			
By Bridge Count	48.2%	47.1%	*47.3%*
Weighted by Deck Area	46.1%	44.7%	*45.5%*
Weighted by Traffic	46.4%	44.5%	*45.8%*
Percent Fair			
By Bridge Count	40.6%	44.2%	*44.4%*
Weighted by Deck Area	44.3%	48.3%	*48.2%*
Weighted by Traffic	46.1%	50.6%	*49.8%*
Percent Poor			
By Bridge Count	11.0%	8.7%	*8.3%*
Weighted by Deck Area	9.4%	6.7%	*6.4%*
Weighted by Traffic	7.3%	4.7%	*4.4%*

Source: National Bridge Inventory.

CHAPTER 6: Infrastructure Conditions – Transit

Transit asset infrastructure in the C&P Report includes five major asset groups.

Major Asset Categories

Asset Category	Components
Guideway Elements	Tracks, ties, switches, ballasts, tunnels, elevated structures, bus guideways
Maintenance Facilities	Bus and rail maintenance buildings, bus and rail maintenance equipment, storage yards
Stations	Rail and bus stations, platforms, walkaways, shelters
Systems	Train control, electrification, communications, revenue collection, utilities, signals and train stops, centralized vehicle/train control, substations
Vehicles	Large buses, heavy rail, light rail, commuter rail passenger cars, nonrevenue vehicles, vehicle replacement parts

Source: Transit Economic Requirements Model.

Condition Rating. FTA uses a capital investment needs tool, TERM, to measure the condition of transit assets. The model uses a numeric scale that ranges from 1 to 5. When an asset crosses the middle of the scale (condition 2.5), which is based on age, it is assigned by TERM for replacement or rehabilitation.

Definition of Transit Asset Conditions

Rating	Condition	Description
Excellent	4.8–5.0	No visible defects, near-new condition
Good	4.0–4.7	Some slightly defective or deteriorated components
Adequate	3.0–3.9	Moderately defective or deteriorated components
Marginal	2.0–2.9	Defective or deteriorated components in need of replacement
Poor	1.0–1.9	Seriously damaged components in need of immediate repair

Source: Transit Economic Requirements Model.

The replacement value of the Nation's transit assets was $894.8 billion in 2014, 43 percent of which was guideway elements. Rail modes account for 88 percent of the guideway element amount.

The relatively large proportion of facilities elements and systems assets that are in poor condition (rated 2.0 or below) and the magnitude of the $174-billion investment required to replace them, represent major challenges to the rail transit industry.

Asset Categories in Poor Condition (Rated 2.0 or Below), 2014

Asset Category	Percentage in Poor Condition
Guideway Elements	6.4
Systems	21.4
Facilities	36.4
Vehicles	18.5
Stations	5.3

Source: Transit Economic Requirements Model.

State of Good Repair (SGR). An asset is deemed in a state of good repair if its condition rating is 2.5 or higher. An agency mode is in SGR if all its assets are rated 2.5 or higher.

Trends in Urban Bus and Rail Transit Fleet not in SGR. The average condition rating for bus and rail fleets did not change much between 2004 and 2014, ranging between 3.0 and 3.3 for buses and remaining relatively constant for rail, ranging between 3.5 and 3.6. The percentage of the bus fleet not in SGR also did not change much, ranging between 15 and 18.8 percent. For rail, the percentage not in SGR decreased during the 2004–2014 timeframe overall, although it increased slightly between 2012 and 2014.

Executive Summary

Part II: Investing for the Future

The four chapters in Part II of this report present and analyze general scenarios for future capital investment in highways, bridges, and transit. Each scenario is geared toward maintaining some indicator of physical condition or operational performance at its 2014 level, or achieving some objective linked to benefits versus costs. The average annual investment level over the 20 years from 2015 through 2034 is presented for each scenario, stated in constant 2014 dollars.

This report does not attempt to address issues of cost responsibility. The scenarios do not address how much different levels of government might contribute to funding the investment, nor do they directly address the potential contributions of different public or private revenue sources.

Chapter 7, Selected Capital Investment Scenarios, defines the core scenarios and examines the associated projections for condition and performance. **The scenarios are intended to be illustrative and do not represent comprehensive alternative transportation policies; the U.S. Department of Transportation does not endorse any scenario as a target level of investment.**

Chapter 8, Supplemental Scenario Analysis, explores some implications of the scenarios presented in Chapter 7 and contains some additional policy-oriented analyses. As part of this analysis, highway projections from previous editions of the C&P Report are compared with actual outcomes to illuminate the value and limitations of the projections presented in this edition. Chapter 9, Sensitivity Analysis, explores the impacts on scenario projections of changes to several key assumptions. Lastly, Chapter 10, Impacts of Investment, explains the derivation of the scenario projections from results obtained with the models that have been developed over the years to support the C&P Report.

A comprehensive benefit-cost analysis of a transportation investment considers all impacts of potential significance for society and values them in monetary terms, to the extent feasible. For some types of impacts, monetary valuation is facilitated by the existence of observable market prices. Such prices are generally available for inputs to the provision of transportation infrastructure, such as concrete for building highways or buses purchased for a transit system. The same is true for some types of benefits from transportation investments, such as savings in business travel time, which are conventionally valued at a measure of average hourly labor cost of the travelers.

For some other types of impacts for which market prices are not directly observable, monetary values can be reasonably inferred from behavior or expressed preferences. In this category are savings in personal travel time and reductions in the risk of crash-related fatality or other injury.

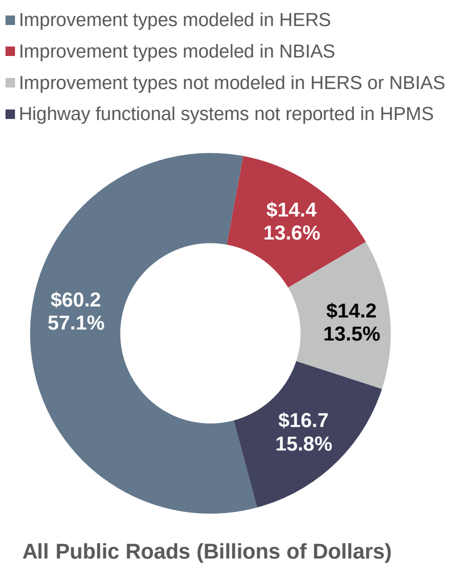
For other impacts, monetary valuation may not be possible because of problems with reliably estimating the magnitude of the improvement, placing a monetary value on the improvement, or both. Even when possible, reliable monetary valuation may require time and effort that would be out of proportion to the likely importance of the impact concerned.

Each of the models used in this report—the Highway Economic Requirements System (HERS), the National Bridge Investment Analysis System (NBIAS), and the Transit Economic Requirements Model (TERM)—omits various types of investment impacts from its benefit-cost analyses. To some extent, this omission reflects the national coverage of the models' primary databases. Such broad geographic coverage requires some sacrifice of detail to stay within feasible budgets for data collection.

Types of Capital Spending Projected by HERS and NBIAS

NBIAS relies on the NBI, which covers bridges on all highway functional classes and evaluates improvements that generally fall within the system rehabilitation category defined in Chapter 2. HERS evaluates pavement improvements and highway widening; the types of improvements included in these categories roughly correspond to system rehabilitation and system expansion categories. Coverage of the HERS analysis is limited to Federal-aid highways, as the HPMS sample does not include data for rural minor collectors, rural local roads, or urban local roads. The term “nonmodeled spending” refers in this report to spending on highway and bridge capital improvements that are not evaluated in HERS or NBIAS. This includes capital improvements on highway classes omitted from the HPMS sample and expenditures classified in Chapter 2 as system enhancements.

Distribution of 2014 Capital Expenditures by Investment Type



Source: Highway Statistics 2014 (Table SF-12A) and unpublished FHWA data.

In 2014, highway capital spending was $105.4 billion. Of that spending, $60.2 billion was for the types of improvement that HERS models and $14.4 billion was for the types of improvement NBIAS models. The other $30.9 billion was for nonmodeled improvement types.

Types of Capital Spending Projected by TERM

TERM is designed to forecast the following types of investment needs:

- Preservation: The level of investment in the rehabilitation and replacement of existing transit capital assets required to attain specific investment goals (e.g., to attain a state of good repair [SGR]) subject to potentially limited capital funding.
- Expansion: The level of investment in the expansion of transit fleets, facilities, and rail networks required to support projected growth in transit demand (i.e., to maintain performance at current levels as demand for service increases).

As reported to NTD, the level of transit capital expenditures peaked in 2009 at $16.8 billion, experienced a slight decrease in 2011 to $15.6 billion, and increased again in 2014 to $17.7 billion. Although the annual transit capital expenditures averaged $15.2 billion from 2004 to 2014, expenditures averaged $16.8 billion in the most recent 5 years of NTD reporting (2010–2014).

Annual Transit Capital Expenditures, 2004–2014

Year	(Billions of Current-Year Dollars)			(Billions of Constant 2014 Dollars)
	Preservation	Expansion	Total	Total
2004	$9.4	$3.2	$12.6	$15.8
2005	$9.0	$2.9	$11.8	$14.3
2006	$9.2	$3.5	$12.7	$14.9
2007	$9.6	$4.0	$13.6	$15.5
2008	$11.0	$5.1	$16.0	$17.6
2009	$11.3	$5.5	$16.8	$18.6
2010	$10.3	$6.2	$16.6	$18.0
2011	$9.9	$5.7	$15.6	$16.5
2012	$9.7	$7.1	$16.8	$17.4
2013	$10.8	$6.4	$17.1	$17.4
2014	$11.0	$6.4	$17.4	$17.4
Average	$10.1	$5.1	$15.2	$16.7

Source: National Transit Database.

Executive Summary

CHAPTER 7: Capital Investment Scenarios – Highways

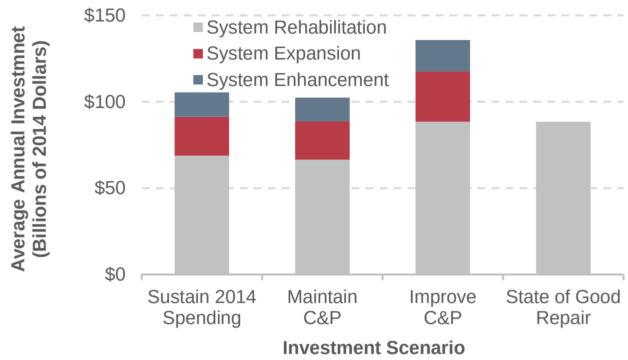
This report presents a set of illustrative 20-year capital investment scenarios based on simulations developed using HERS and NBIAS, with scaling factors applied to account for types of capital spending that are not currently modeled.

The Sustain 2014 Spending scenario assumes that annual capital spending is sustained in constant-dollar terms at the 2014 level of $105.4 billion from 2015 through 2034. (In other words, spending would rise by exactly the rate of inflation during that period.) The model results suggest that it would be economically advantageous to slightly increase the share of total capital spending directed to system rehabilitation (improvements to the physical condition of existing infrastructure assets) from the 62.0 percent observed in 2014 to 64.9 percent ($68.8 billion per year) under this scenario.

The Maintain Conditions and Performance scenario seeks to identify the level of investment needed to keep selected measures of overall system conditions and performance unchanged after 20 years. The average annual investment level associated with this scenario is $102.4 billion; this suggests that sustaining spending at the 2014 level of $105.4 billion should result in improved overall conditions and performance in 2034 relative to 2014.

The Improve Conditions and Performance scenario seeks to identify the level of investment needed to implement all potential investments estimated to be cost-beneficial. This scenario can be viewed as an “investment ceiling,” above which it would not be cost-beneficial to invest. Of the $135.7 billion average annual investment level under the Improve Conditions and Performance scenario, $88.4 billion would be directed toward system rehabilitation; this portion is identified as the State of Good Repair benchmark. This scenario also includes $29.1 billion directed toward system expansion and $18.3 billion for system enhancement.

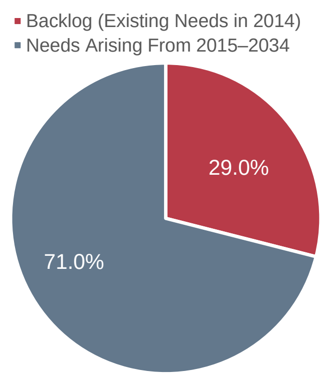
Highway Capital Investment Scenarios



Sources: HERS and NBIAS.

Cumulative 20-year investment under the Improve Conditions and Performance scenario would total $2.7 trillion. This includes an estimated $786.4 billion (29.0 percent) needed to address an existing backlog of cost-beneficial highway and bridge investments as of 2014. The remainder would address future highway and bridge needs as they arise over 20 years.

Composition of 20-Year Improve Conditions and Performance Scenario, Backlog vs. Emerging Needs



Source: HERS and NBIAS.

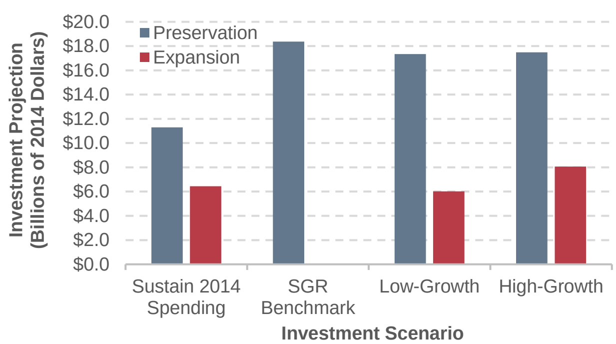
CHAPTER 7: Capital Investment Scenarios – Transit

Chapter 7 presents three transit investment scenarios covering all capital spending, and one benchmark covering only preservation spending.

Sustain 2014 Spending: Under this scenario, 2014 spending on transit asset preservation and expansion ($11.3 billion and $6.4 billion respectively) is sustained for the next 20 years.

- Backlog: $11.3 billion in annual investment is insufficient to cover the cost of new preservation needs as they arise, resulting in a projected increase in the backlog from $98.2 billion to $116.2 billion by 2034 (an increase of $18.0 billion or 19 percent).
- Asset Conditions: The backlog increase and the ongoing aging of rail systems results in an overall decline in asset conditions (from 3.1 to 2.8 by 2034).
- Ridership: The $6.4 billion annual rate of investment is estimated to support a 1.3 percent annual increase in ridership, or 0.2 percent below the 1.5 percent rate of growth experienced since 2000—potentially resulting in increased vehicle crowding if such ridership growth were to continue in the future.

Scenarios Expenditures



Source: Transit Economic Requirements Model.

SGR Benchmark: The level of preservation expenditures required to eliminate the state of good repair (SGR) backlog over 20 years (by 2034).

- Expenditures: An estimated $18.4 billion in annual reinvestment is required to fully eliminate the SGR backlog by 2034. This is 63 percent higher than actual 2014 reinvestment.
- Asset Conditions: Despite elimination of the backlog, average asset conditions are projected to remain near the lower bound of the adequate range (3.0–3.9).

Low- and High-Growth Scenarios[1]: The level of investment required both to eliminate the backlog by 2034 and to support ridership growth within ±0.3 percent of the 1.5 percent average annual rate experienced since 2000.

- Ridership: The estimated annual rate of expansion investment ranges from $6.0 billion to $8.1 billion under the Low- and High-Growth scenarios respectively. This range encompasses the $6.4 billion expended on expansion in 2014. These investments support an additional 3.0 to 4.6 billion annual boardings by 2034.

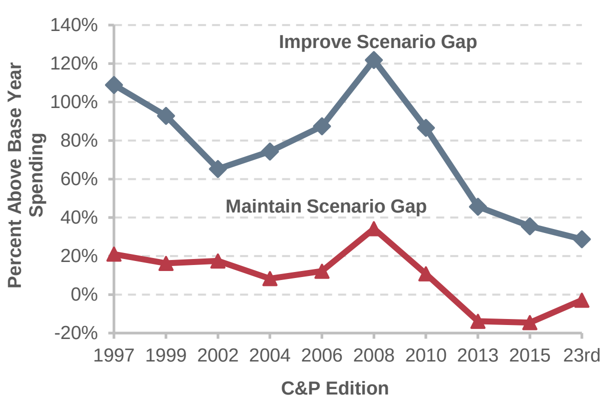
[1]The Low-Growth and High-Growth scenarios in this report are based on 15-year ridership trends as of 2014, the cut-off year for this report. The Department does note that transit ridership has, in fact, not increased since 2014 through the early months of 2019. The causes of the decreased transit ridership since 2014 will be analyzed in the next edition of this report. The ridership trends since that time will also be incorporated into the capital investment needs forecasts presented in future editions of this report.

CHAPTER 8: Supplemental Analysis – Highways

The 2015 C&P Report estimated the average annual investment level for the Maintain Conditions and Performance scenario as $89.9 billion in 2012 dollars, or $94.4 billion in 2014 dollars after adjusting for inflation. The comparable amount in this 23rd edition is $102.4 billion in 2014 dollars, approximately 8.5 percent higher than the adjusted 2015 C&P Report estimate. The average annual investment level under the Improve Conditions and Performance scenario in this edition was 9.3 percent lower than the adjusted annual investment level based on the 2015 C&P Report.

Since the 1997 C&P Report, the "gap" between base-year spending and the average annual investment level for the primary "Maintain" and "Improve" scenarios has varied, reaching the highest level in the 2008 C&P Report. The gap under the Maintain Conditions and Performance scenario shrank in the 23rd edition, but remains negative (i.e., base-year spending is higher). The gap under the Improve Conditions and Performance scenario and base-year spending has declined continually since the 2008 C&P Report.

Comparison of Average Annual Highway and Bridge Investment Scenario Estimates with Base-Year Spending, 1997 to 23rd C&P Editions



Sources: HERS and NBIAS.

The pattern of investment assumed for the scenarios in this edition differed from that in the 2015 C&P Report, which assumed "ramped" highway capital investment, increasing at a constant annual rate starting with the base year. For this edition, the "Maintain" scenario assumes spending will remain constant at $102.4 billion in each year, while the "Improve" scenario assumes all cost-beneficial investments will occur in the year in which they are identified. This benefit-cost ratio-driven approach resulted in a significant frontloading of investment in the early years of the analysis, due to the existence of a large existing backlog of potential cost-beneficial investments. Supplemental analyses of alternative investment timing patterns did not show significant variation in terms of system conditions and performance results after 20 years.

This edition includes a look back to the projections from the 1995 C&P Report, and compares them with actual performance over 20 years. The investment scenarios presented in the 1995 C&P Report assumed VMT would grow by 2.15 percent per year from 1993 to 2013, significantly higher than the actual annual VMT growth over that period of 1.33 percent. However, the predicted urban VMT growth was relatively close to actual VMT; most of the difference was due to a significant overprediction of rural VMT. Adjusted for inflation, actual highway capital spending for 1994 through 2013 was 15 percent below the level estimated for the Maintain Conditions and Performance scenario in the 1995 C&P Report, suggesting that conditions and performance would have been expected to decline. This proved to be true in terms of operational performance in urban areas from 2003 to 2013, as various congestion measures got worse. However, key measures of physical conditions and safety showed improvements over this 20-year period.

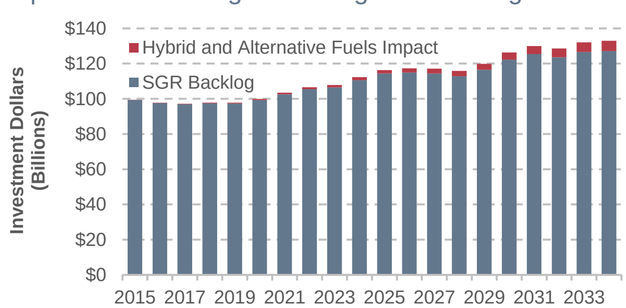
CHAPTER 8: Supplemental Analysis – Transit

Chapter 8 covers analyses designed to help better understand the assumptions and outcomes underlying the scenarios presented in Chapter 9.

Impact of the Sustain 2014 Spending scenario on asset conditions. Continued reinvestment in preservation at the 2014 annual spending level yields a decline in overall asset conditions (from 3.1 in 2014 to 2.8 in 2034) and an increase in the backlog (from $98.8 billion in 2014 to $102.5 billion in 2018). This decline is due in part to deferred investments in rehabilitation and replacement, and in part on the aging of assets that will reach the end of their useful lives after 2034. The share of assets beyond their useful life would increase from 14 percent in 2014 to 19 percent in 2034 if the spending level is kept constant over the 20-year project horizon.

New technologies impact transit investment needs. New technologies often increase the cost of replacement assets and, in the absence of additional funding, the size of the state of good repair (SGR) backlog. As an example, alternative fuel buses add an additional cost as depicted in the figure below.

Impact of Technological Change on Backlog



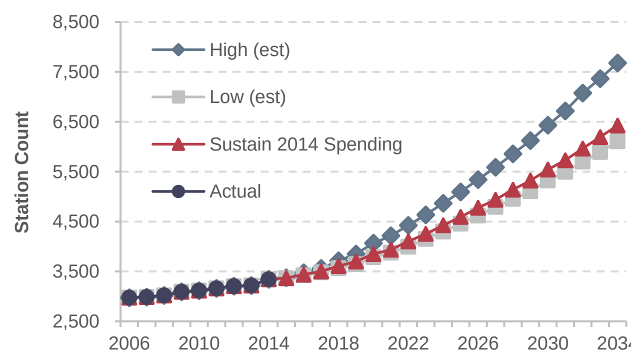
Source: Transit Economic Requirements Model.

As the chart shows, the cost impact on the backlog is negligible in the early years of the projection period but grows over time as the proportion of buses using alternative fuel and hybrid power increases. By 2034, the size of the backlog would increase to $123.5 billion, an increase of $7.3 billion above the original $116.2 billion under the Sustain 2014 Spending scenario.

Investment in expansion assets.[2] Chapter 8 assesses the increase in transit assets required to support the additional 3.0 to 4.6 billion annual boardings by 2034, as projected by the Low- and High-Growth scenarios. This increase includes:

- Fleet: 60,400 to 85,900 additional vehicles (a 35-percent to 49-percent increase from 2014)
- Rail Guideway: 2,300 to 2,800 additional route miles (an 18-percent to 23-percent increase)
- Stations: 2,800 to 4,300 additional stations (an 83-percent to 130-percent increase)

Growth Scenario Investment in Stations



Note: Data through 2014 are actual; data after 2014 are estimated based on trends.

Source: Transit Economic Requirements Model.

[2] The Low-Growth and High-Growth scenarios in this report are based on 15-year ridership trends as of 2014, the cut-off year for this report. The Department does note that transit ridership has, in fact, not increased since 2014 through the early months of 2019. The causes of the decreased transit ridership since 2014 will be analyzed in the next edition of this report. The ridership trends since that time will also be incorporated into the capital investment needs forecasts presented in future editions of this report.

Executive Summary

CHAPTER 9: Sensitivity Analysis – Highways

Sound practice in modeling includes analyzing the sensitivity of key results to changes in assumptions. Chapter 9 analyzes how the baseline scenarios presented in Chapter 7 would be affected by changing some HERS and NBIAS parameters.

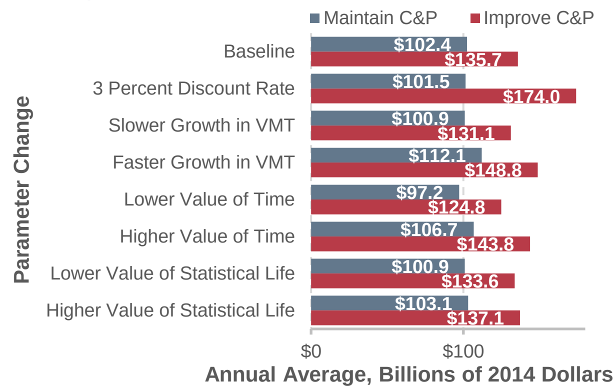
Among the parameters analyzed, the Improve Conditions and Performance scenario is most sensitive to changes in the discount rate, a value used in benefit-cost analyses to scale down benefits and costs arising later in the future relative to those arising sooner. Changing the discount rate from the 7 percent assumed in the baseline analysis to 3 percent would increase the average annual investment level under this scenario from $135.7 billion to $174.0 billion.

For purposes of computing the baseline scenarios, future travel forecasts for individual highway sections and bridges reported by States in the HPMS and NBI were each proportionally reduced so that the national average annual growth over 20 years would match the 1.07 percent figure from the May 2017 release of the FHWA National Vehicle Miles Traveled projection. Had the 0.92 percent annual growth figure from the May 2016 release been used instead, the average annual investment level under the Improve Conditions and Performance scenario would have decreased to $131.1 billion annually. Eliminating this proportional adjustment and directly applying the annual growth forecasts from the HPMS (1.40 percent on average) and the NBI (1.45 percent) increases the annual cost of this scenario to $148.8 billion.

The valuation of travel time savings assumed in the baseline scenarios is linked to average hourly income; personal travel is valued at 50 percent of income, while business travel is valued at 100 percent. Alternative tests were run reducing these shares to 35 percent and 80 percent, respectively, and increasing them to 60 percent and 120 percent. Applying a lower value of time reduces the benefits associated with travel time savings and reduces the average annual investment level under the Improve Conditions and Performance scenario to $124.8 billion. Assuming a higher value of time increases the annual cost of this scenario to $143.8 billion.

The baseline scenarios assume the value of a statistical life is $9.4 million when computing safety-related benefits, consistent with DOT guidance. Reducing this value to $5.2 million would reduce the annual cost of the Improve Conditions and Performance scenario to $133.6 billion; increasing the value to $13.0 million would increase the annual cost to $137.1 billion.

Sensitivity of Highway Scenarios to Alternative Assumptions



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

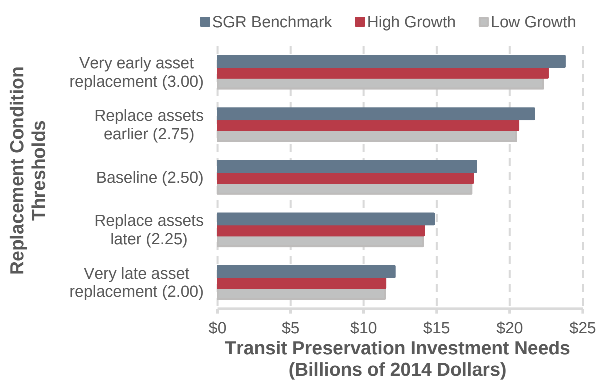
The impacts of alternative assumptions on the Maintain Conditions and Performance scenario are generally smaller and are linked to the models' distribution of spending among different capital improvement types. Among the parameters analyzed, this scenario was most sensitive to higher assumptions about future VMT.

CHAPTER 9: Sensitivity Analysis – Transit

The Transit Economics Requirements Model (TERM) relies on several key input parameters, variations of which can significantly influence the model's needs and backlog estimates.

Impact of alternative replacement thresholds on transit preservation needs. TERM uses a "replacement threshold" to specify the condition at which aging assets are replaced. The benchmark threshold value is 2.5. A 0.5-point change in the thresholds yields a roughly ±30-percent change in replacement needs.

Sensitivity to Replacement Threshold

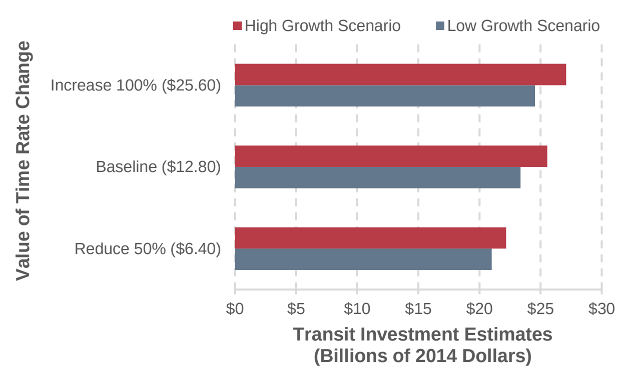


Source: Transit Economic Requirements Model.

Impact of increases in capital costs on transit preservation needs. The sensitivity of scenario needs estimates to changes in capital costs is dependent on whether TERM's benefit-cost test is applied for that scenario. Under the Low- and High Growth scenarios, which both apply the test, a 25-percent increase in asset costs yields 20.3-percent to 18.5-percent increases in needs, as the cost increase forced some reinvestment actions to fail the benefit-cost test.

Impact of changes in the value of time on preservation needs. The per-hour value of travel time for transit riders is a key model input, and a key driver of total investment benefits. Increasing this rate results in greater benefits, allowing more projects to pass the benefit-cost test, leading to higher needs estimates. Decreasing the rate has the opposite effect. Doubling the rate results in increases of 5.0 percent and 6.0 percent in needs for the Low- and High-Growth scenarios, respectively. Reducing the rate by half results in decreases of 10.1 percent and 13.2 percent, respectively.

Sensitivity to Value of Time



Source: Transit Economic Requirements Model.

Impact of discount rate. TERM's benefit-cost test is sensitive to the discount rate used to calculate the present value of investment costs and benefits. TERM's analysis uses a rate of 7.0 percent in accordance with Office of Management and Budget guidance.[3] The analysis using a rate of 3 percent (57 percent smaller) leads to an increase of 4.0 percent in investment needs in the High-Growth scenario, and a 5.6 percent increase in the Low-Growth scenario.

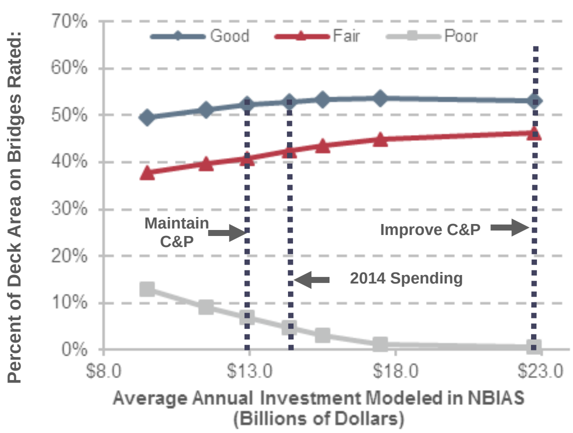
[3] Circular No. A-94 – Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs.

CHAPTER 10: Impacts of Investment – Highways

Of the $135.7 billion average annual investment level for all public roads under the Improve Conditions and Performance scenario presented in Chapter 7, 16.7 percent ($22.7 billion) was derived from NBIAS estimates of rehabilitation and replacement needs for all bridges. HERS evaluates needs on Federal-aid highways associated with pavement resurfacing or reconstruction and widening, including those associated with bridges; 54.0 percent ($73.2 billion) of this scenario was derived from HERS. The remaining 29.3 percent was nonmodeled; this includes estimates for system enhancements on all public roads plus pavement resurfacing or reconstruction and widening not on Federal-aid highways. Nonmodeled spending was scaled so that its share of the total scenario investment level would match its share of actual 2014 spending.

Sustaining NBIAS-modeled investment at $14.4 billion (the portion of 2014 spending directed toward improvement types modeled in NBIAS) in constant-dollar terms over 20 years is projected to result in deck area-weighted bridge conditions of 52.9 percent good, 40.8 percent fair, and 6.3 percent poor. Increasing annual investment to $22.7 billion would increase the deck area-weighted share rated as good to 53.9 percent, and reduce the share rated as poor to 0.5 percent.

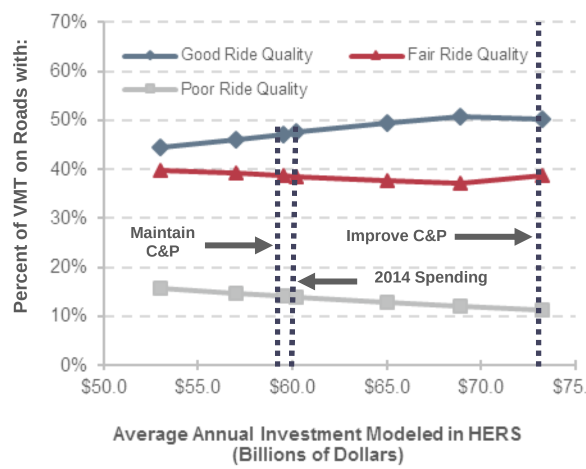
Projected Impact of Alternative Investment Levels on 2034 Bridge Condition Ratings



Source: National Bridge Investment Analysis System.

Sustaining HERS-modeled investment at $60.2 billion (the portion of 2014 spending directed toward improvement types modeled in HERS) in constant-dollar terms over 20 years is projected to result in 47.5 percent of VMT in 2034 occurring on pavements with good ride quality, 38.5 percent on pavements with fair ride quality, and 13.9 percent occurring on pavements with poor ride quality. Increasing annual investment to $73.2 billion would increase the VMT-weighted share rated as good to 50.2 percent and reduce the share rated as poor to 11.2 percent.

Projected Impact of Alternative Funding Levels on 2034 Federal-aid Highway Pavement Ride Quality



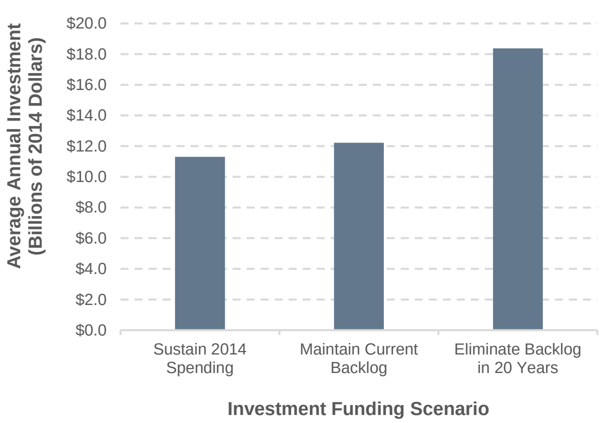
Source: Highway Economic Requirements System.

Other projected impacts of investing at the Improve scenario level include reducing VMT-weighted average pavement roughness by 5.6 percent in 2034 relative to 2014 and reducing average delay per VMT by 19.3 percent.

CHAPTER 10: Impacts of Investment – Transit

The current level of investment in transit asset preservation is insufficient to prevent ongoing growth in the state of good repair (SGR) backlog. Assuming preservation expenditures are sustained at the 2014 level ($11.3 billion annually), the backlog is projected to increase from $98.8 billion to $116.2 billion by 2034. Based on current estimates, $12.2 billion in annual investment is required to prevent further increases in the SGR backlog, while $18.2 billion in annual investment is required to fully eliminate the SGR backlog in 20 years (by 2034).

Investment Funding Scenarios



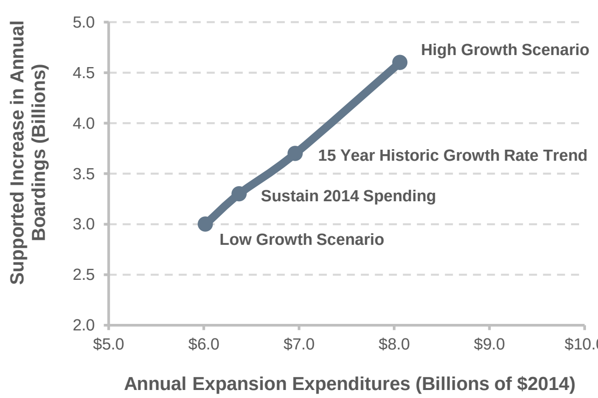
Source: Transit Economic Requirements Model.

A much higher rate of investment is required to maintain the current average condition rating of all transit assets nationwide than is required to maintain the size of the current SGR backlog.

If the current rate of reinvestment is sustained at the 2014 level ($11.3 billion), overall average asset conditions are projected to decline from 3.1 in 2014 to 2.8 by 2034 (near the upper bound of the "marginal" range). In contrast, annual preservation expenditures of $18.2 billion are required to sustain an overall average condition of 3.1, with higher rates of annual investment required to attain significant improvements in overall asset conditions.

The 2014 level of expansion investment supports ridership growth that is marginally below the historical rate.[4] Investment in transit expansion investments was $6.4 billion in 2014. If maintained into the future, this annual investment amount is estimated to support roughly 1.3 percent in annual ridership growth, which is marginally below the 1.5 percent average rate experienced since 2000. Assuming this historical trend continues (it has not since 2014), the limited underinvestment could result in a gradual increase in vehicle occupancy rates through 2034, with increasing incidences of vehicle crowding and longer dwell times during this period.

Growth Scenarios: Expansion Expenditures vs. Increase in Annual Boardings



Source: Transit Economic Requirements Model.

[4] The Low-Growth and High-Growth scenarios in this report are based on 15-year ridership trends as of 2014, the cut-off year for this report. The Department does note that transit ridership has, in fact, not increased since 2014 through the early months of 2019. The causes of the decreased transit ridership since 2014 will be analyzed in the next edition of this report. The ridership trends since that time will also be incorporated into the capital investment needs forecasts presented in future editions of this report.

CHAPTER 11: Freight Transportation

Freight transportation is vital to the U.S. economy and the daily needs of Americans throughout the country. Households and businesses depend on the efficient and reliable delivery of freight to both urban and rural areas. Federal support for freight increased under the Fixing America's Surface Transportation (FAST) Act, as the FAST Act included provisions to define, establish, and provide funding for a national highway freight program. The FAST Act freight provisions were designed to address significant needs in the transportation system to ensure that projected increases in freight volumes can be handled efficiently across all transportation modes.

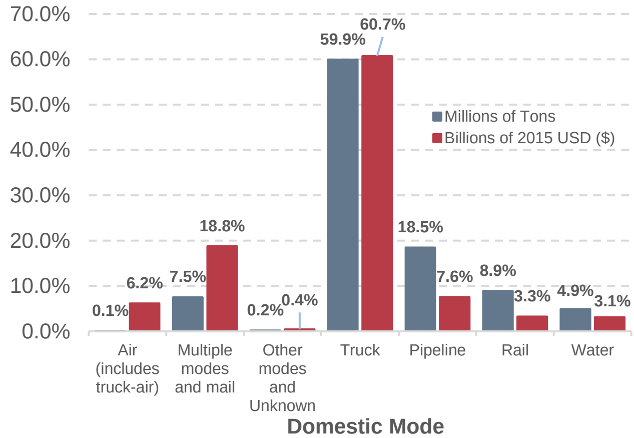
In 2015, the transportation system handled a record amount of freight—including a daily average of approximately 55 million tons of freight, worth approximately $49.5 billion. The freight transportation industry employed 4.6 million workers and contributed 9.5 percent of the Nation's economic activity as measured by gross domestic product (GDP).

Although freight moves on all modes of transportation, trucks are involved in the movement of most goods. The highway system is the most-used mode of transport for freight by tonnage and value of goods moved. Commodities moved by truck have a higher value per weight, which gives trucking a higher share of freight dollar value.

Trucking accounted for nearly 30.5 percent of total transportation and warehousing sector employment. Truck driving is by far the largest freight transportation occupation, with approximately 2.83 million truck drivers. About 57.5 percent of these professional truck drivers operate heavy trucks and 28.2 percent drive light trucks.

As freight movements increase, the number of available safe truck parking spaces diminishes and is a growing concern.

Mode Share by Tonnage and Value, 2015



Note: USD=U.S. dollars

Source: Bureau of Transportation Statistics and FHWA, Freight Analysis Framework, version 4.2, 2016.

Truck Parking

Truck drivers need safe, secure, and accessible truck parking. With the projected growth in truck traffic, demand for truck parking will continue to outpace supply. In 2014, FHWA worked with States and industry partners on the *Jason's Law Truck Parking Survey Results and Comparative Analysis* to assess these needs. The resulting information quantified the commercial motor vehicle parking shortage at public and private facilities along the National Highway System. The survey provided direct insight into parking issues: more than 75 percent of truck drivers surveyed said they regularly experienced problems with finding "safe parking locations when rest was needed."

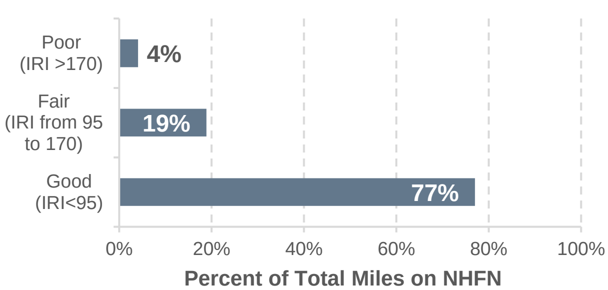
CHAPTER 12: Conditions and Performance of the National Highway Freight Network

The Fixing America's Surface Transportation (FAST) Act designated the National Highway Freight Network (NHFN) and established a national policy of maintaining and improving the conditions and performance of this new network. Furthermore, it required the development of a regular report on the conditions and performance of the NHFN. This chapter serves as the first of these reports.

Conditions

In 2012, the NHFN consisted of 51,029 centerline miles, including 46,947 centerline miles of Interstate and 4,082 centerline miles of non-Interstate roads. Based on 2014 international roughness index (IRI) data from the Highway Performance Monitoring System (HPMS), approximately 77 percent of pavement miles were rated as having good ride quality, 19 percent had fair ride quality, and 4 percent had poor ride quality.

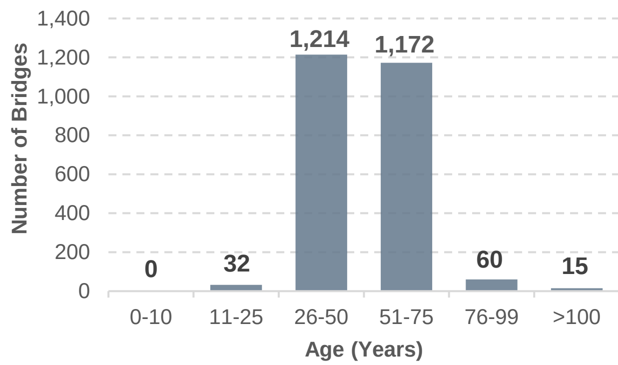
Pavement Ride Quality (IRI) Based on Mileage on NHFN



Source: IRI data in 2014 HPMS files.

The National Bridge Inventory is used to identify current bridge ratings for bridges on the NHFN. This analysis showed there are approximately 57,600 bridges on the NHFN. Around 4.3 percent of those bridges were rated as structurally deficient. Most of these structurally deficient bridges are 25 years and older, and over half are more than 50 years old. These findings have implications for future maintenance and funding needs as well as impacts to operations.

Age of Structurally Deficient Bridges on NHFN, 2014



Source: Bridge condition data contained in 2014 NBI files.

Performance

Travel time, speed, and safety are three measures of performance. Slower speeds and unreliable travel times caused by congestion increase fuel cost and affect operations and productivity, which adds expense to the freight transportation system. In 2014, congestion created stop-and-go conditions on 5,800 miles of the NHFN and caused traffic to travel below posted speed limits on an additional 4,500 miles of the high-volume truck portions of the NHFN. The projected growth in freight and its reliance on trucks will increase congestion and make it more difficult and costly to move freight.

A total of 3,633 fatal crashes occurred on the Interstate portion of the NHFN in 2014, resulting in 4,094 fatalities. In 2015, fatal crashes and fatalities increased by 5.7 percent and 6.1 percent, respectively.

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PART I

Moving a Nation

Introduction

Part I of this 23rd C&P Report includes six chapters, each of which describes the current system from a different perspective:

- Chapter 1, **Assets**, describes the existing extent of the highways, bridges, and transit systems. Highway and bridge data are presented for system subsets based on functional classification and Federal system designation, while transit data are presented for different types of modes and assets.
- Chapter 2, **Funding**, provides detailed data on the revenue collected and expended by different levels of governments to fund transportation construction and operations throughout the United States. The chapter also explores alternative financing and delivery of transportation projects.
- Chapter 3, **Travel**, discusses vehicle miles traveled and passenger miles traveled on highways and transit, drivers' licensing levels, and commute times. The chapter also analyzes the impact of income levels on travel.
- Chapter 4, **Mobility and Access,** covers highway congestion and reliability in the Nation's urban areas, and the economic costs of congestion. The transit section explores ridership, average speed, vehicle utilization, and maintenance reliability. The chapter also looks at accessibility to transit for persons with disabilities and the elderly, as well as transit accessibility more generally.
- Chapter 5, **Safety**, relates directly to DOT's national safety goal. The highway section presents national-level statistics on safety performance, focusing on the most common roadway factors that contribute to roadway fatalities and injuries. The transit section summarizes safety and security data by mode and type of transit service.
- Chapter 6, **Infrastructure Conditions**, presents data on the current physical conditions of the Nation's highways, bridges, and transit assets.

Transportation Performance Management

A recurring theme in Part I of the C&P Report is the impact of changes under the Fixing America's Surface Transportation (FAST) Act pertaining to transportation performance management.

What is Transportation Performance Management?

The Federal Highway Administration (FHWA) defines Transportation Performance Management (TPM) as a strategic approach that uses system information to make investment and policy decisions that contribute toward national performance goals. FHWA works with States and metropolitan planning organizations to transition toward and implement a performance-based approach to carrying out the Federal-aid highway program. This transition supports both FAST Act and Moving Ahead for Progress in the 21st Century (MAP-21) legislation, which integrates performance into many Federal transportation programs.

TPM, systematically applied in a regular ongoing process:

- provides key information to help decision makers, enabling them to understand the consequences of investment decisions across multiple markets;
- improves communications among decision makers, stakeholders, and the traveling public; and
- ensures targets and measures are developed in cooperative partnerships and are based on data and objective information.

National Goals – Federal-aid Program

The FAST Act continues MAP-21's highway program transition to a performance- and outcome-based program. States will invest resources in projects that collectively will make progress toward national goals. FHWA is collaborating with State and local agencies across the country to focus on the national goals established, regardless of resource limitations.

Among the national performance goals specified in 23 United States Code §150(b) for Federal highway programs are:

- **Safety** – To achieve a significant reduction in traffic fatalities and serious injuries on all public roads.
- **Infrastructure Condition** – To maintain the highway infrastructure asset system in a state of good repair.
- **Congestion Reduction** – To achieve a significant reduction in congestion on the National Highway System.
- **System Reliability** – To improve the efficiency of the surface transportation system.
- **Freight Movement and Economic Vitality** – To improve the national freight network, strengthen the ability of rural communities to access national and international trade markets, and support regional economic development.
- **Reduced Project Delivery Delays** – To reduce project costs, promote jobs and the economy, and expedite the movement of people and goods by accelerating project completion through eliminating delays in the project development and delivery process, including reducing regulatory burdens and improving agencies' work practices.

Transportation Performance Management Elements

FHWA has organized the performance-related provisions within MAP-21 into six TPM elements to communicate the efforts for implementing these requirements more effectively. These six TPM elements are listed below.

National Goals	MAP-21 establishment of goals or program purpose to focus the Federal-aid highway program into specific areas of performance.
Measures	The establishment of measures by FHWA to assess performance/condition to carry out performance-based Federal-aid highway programs.
Targets	Establishment of targets by recipients of Federal-aid highway funding for each of the measures to document expectations of future performance.
Plans	Development of strategic or tactical plans, or both, by recipients of Federal funding to identify strategies and investments that will address performance needs.
Reports	Development of reports by recipients of Federal funding that would document progress toward the achievement of targets, including the effectiveness of Federal-aid highway investments.
Accountability and Transparency	Requirements developed by FHWA for recipients of Federal funding to use in achieving or making significant progress toward achieving targets established for performance.

Summary of MAP-21/FAST Act Performance Requirements

The MAP-21 and FAST Act legislation integrate performance into many Federal transportation programs and contain several performance elements. FHWA will help coordinate the alignment of these requirements and provide guidance and resources. Listed below is more information regarding the performance requirements for the National Highway Performance Program, the Highway Safety Improvement Program, the Congestion

Mitigation and Air Quality Improvement Program, and Freight Movement, as established in MAP-21 and the FAST Act.

- National Highway Performance Program (http://www.fhwa.dot.gov/tpm/about/nhpp.cfm)
- Highway Safety Improvement Program (http://www.fhwa.dot.gov/tpm/about/hsip.cfm)
- Congestion Mitigation and Air Quality Improvement Program (http://www.fhwa.dot.gov/tpm/about/cmaq.cfm)
- Freight Movement (http://www.fhwa.dot.gov/tpm/about/freight.cfm)

Implementation of MAP-21/FAST Act Performance Requirements

FHWA has finalized six related rulemakings to implement the TPM framework established by MAP-21 and the FAST Act.

- A Final Rule on **Statewide and Metropolitan/Non-metropolitan Transportation Planning,** published May 27, 2016, implements a performance-based planning process at the State and metropolitan levels. The Final Rule defines coordination in the selection of targets, linking planning and programming to performance targets.
- A Final Rule for **Safety Performance Management Measures (PM-1),** published March 15, 2016, with an effective date of April 14, 2016, establishes five safety performance measures to assess fatalities and serious injuries on all public roads, a process to assess progress toward meeting safety targets, and a national definition for reporting serious injuries.
- A Final Rule for the **Highway Safety Improvement Program (HSIP),** published March 15, 2016, integrates performance measures, targets, and reporting requirements into the HSIP. The Final Rule contains three major policy changes: Strategic Highway Safety Plan Updates, HSIP Report Content and Schedule, and the Subset of the Model Inventory of Roadway Elements.
- A Final Rule for **Pavement and Bridge Performance Measures (PM-2),** published January 18, 2017, with an effective date of May 20, 2017, defines pavement and bridge condition performance measures, along with minimum condition standards, target establishment, progress assessment, and reporting requirements.
- A Final Rule for an **Asset Management Plan,** published October 24, 2016, defines the contents and development process for an asset management plan. The Final Rule also defines minimum standards for pavement and bridge management systems.
- A Final Rule for **System Performance Measures (PM-3),** published January 18, 2017, with an effective date of May 20, 2017, defined performance measures to assess performance of the Interstate System, non-Interstate National Highway System, freight movement on the Interstate System, CMAQ traffic congestion, and on-road mobile emissions.*

*On May 31, 2018, FHWA published a final rule revising the PM-3 to remove the measure for carbon dioxide (CO_2) emissions on the NHS. (83 FR 24920: https://www.federalregister.gov/documents/2018/05/31/2018-11652/national-performance-management-measures-assessing-performance-of-the-national-highway-system)

Summary of MAP-21/FAST Act Performance Measures

Measure Area	Performance Measures
Safety[1]	
National Performance Management Measures to Assess Highway Safety	▪ Number of fatalities ▪ Rate of fatalities per 100 million VMT ▪ Number of serious injuries ▪ Rate of serious injuries per 100 million VMT ▪ Number of nonmotorized fatalities and nonmotorized serious injuries
Pavement and Bridge Condition[2]	
National Performance Management Measures to Assess Pavement Condition	▪ Percentage of pavements of the Interstate System in Good condition ▪ Percentage of pavements of the Interstate System in Poor condition ▪ Percentage of pavements of the non-Interstate NHS in Good condition ▪ Percentage of pavements of the non-Interstate NHS in Poor condition
National Performance Management Measures to Assess Bridge Condition	▪ Percentage of NHS bridges classified as in Good condition ▪ Percentage of NHS bridges classified as in Poor condition
System Performance and Freight[3]	
Performance of the National Highway System	▪ **Interstate Travel Time Reliability Measure**: Percentage of person-miles traveled on the Interstate that are reliable ▪ **Non-Interstate Travel Time Reliability Measure**: Percentage of person-miles traveled on the non-Interstate NHS that are reliable
Freight Movement on the Interstate System	▪ **Freight Reliability Measure:** Truck Travel Time Reliability Index
CMAQ Program[4]	
Measures for Assessing the CMAQ Program – Traffic Congestion	▪ **PHED Measure**: Annual hours of peak hour excessive delay (PHED) per capita ▪ N**on-SOV Travel Measure**: Percentage of non-single occupancy vehicle (SOV) travel
Measures for Assessing the CMAQ Program – On-Road Mobile Source Emissions	▪ **Emissions Measure:** Total emission reductions for carbon monoxide (CO), nitrogen oxides (NOx), volatile organic compounds (VOCs), particulate matter (PM10 and PM2.5) for CMAQ-funded projects in designated nonattainment and maintenance areas

[1] Each performance measure is based on a 5-year rolling average. These measures contribute to assessing the HSIP.

[2] These measures contribute to assessing the National Highway Performance Program (NHPP).

[3] These measures contribute to assessing the NHPP and National Highway Freight Program (NHFP).

[4] These measures contribute to assessing the Congestion Mitigation and Air Quality Improvement (CMAQ) Program.

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CHAPTER 1

System Assets

Highway System Assets

The Nation's extensive network of roadways, bridges, and culverts facilitates movement of people and goods, promotes the growth of the American economy, affords access to national and international markets, and supports national defense by providing the means for rapid deployment of military forces and their support systems.

This chapter explores the characteristics of the Nation's roadways, bridges, and culverts in terms of ownership, purpose, and use. Information is presented for the National Highway System (NHS), including its Interstate Highway System component, and for the overall highway system. Separate statistics are presented for Federal-aid highways, which include roadways, bridges, and culverts that are generally eligible for Federal assistance under current law. Subsequent sections within this chapter explore the characteristics of bridges, culverts, and transit systems.

Road statistics reported in this section draw on data collected from States through the Highway Performance Monitoring System (HPMS). The terms highways, roadways, and roads are generally used interchangeably in this section and elsewhere in the report. Roadways in a community with a population of 5,000 or more are classified as urban; all other roadways are classified as rural.

Bridge and culvert statistics reported in this section draw on data collected from States through the National Bridge Inventory (NBI). This information details physical characteristics, traffic loads, and the evaluation of the condition of each bridge and culvert longer than 20 feet (6.1 meters). As of December 2015, the NBI contained records for 611,845 bridges and culverts. Data for input to NBI are collected regularly as set forth in the National Bridge Inspection Standards.

Key Takeaways

- The number of lane miles on the Nation's roadways increased by 4.7 percent, or almost 393,779 lane miles, between 2004 and 2014.
- The amount of bridge deck area increased by approximately 12.3 percent between 2004 and 2014.
- The National Highway System has 5.4 percent of the Nation's highway mileage, 8.8 percent of the Nation's lane mileage, 23.4 percent of the Nation's bridges, and 57.8 percent of the bridge deck area in the Nation.
- In 2014, approximately 54.6 percent of the Nation's total Vehicle Miles Traveled (VMT) and approximately 82.9 percent of the VMT by combination trucks occurred on the National Highway System.
- Local governmental agencies own 74.8 percent of the Nation's highway lane mileage and 22.3 percent of the bridge deck area in the Nation.
- State agencies own the majority of bridge deck area, 76.7 percent, in the Nation.

The Nation's Roads and Bridges

The Nation's road network is diversely constructed to fit the needs of its surrounding environment. For example, roads in an urban setting will often have multiple lanes on a facility to support high levels of demand, while a rural setting will have fewer lanes supporting lower traffic levels. Highway mileage measures road distances from one point to another while lane mileage accounts for the number of lanes in operation. As shown in *Exhibit 1-1*, highway mileage and its accompanying lane mileage have increased between 2004 and 2014, at an average annual rate of 0.4 percent and 0.5 percent, respectively. With population growth expected throughout the Nation, State and local governments are adding and increasing capacity throughout the road network.

Exhibit 1-1: Highway Extent and Travel, 2004–2014; Bridge Extent and Crossings, 2004–2015

	2004	2006	2008	2010	2012	2014	Annual Rate of Change 2014/2004	2015
Highway Miles	3,997,462	4,032,011	4,059,352	4,083,768	4,109,418	4,177,074	0.4%	
Lane Miles	8,372,270	8,460,352	8,518,776	8,616,206	8,641,051	8,766,049	0.5%	
VMT (trillions)	2.982	3.034	2.993	2.985	2.987	3.040	0.2%	
Person-Miles Traveled (trillions)[1]	4.876	4.961	4.931	5.063	5.050	5.205	0.7%	
Bridges	591,707	597,561	601,506	604,493	607,380	610,749	0.3%	611,845
Bridge Deck Area (millions of square meters)	325.5	333.9	343.5	351.5	358.5	365.5	1.2%	369.1
Annual Daily Traffic over Bridges (billions)[2]	4.119	4.277	4.432	4.439	4.485	4.504	0.9%	4.563

[1] Values for 2004, 2006, and 2008 were based on a vehicle occupancy rate of approximately 1.63 based on data from the 2001 National Household Travel Survey (NHTS). Values for 2010, 2012, and 2014 were based on a vehicle occupancy rate of approximately 1.70 based on data from the 2009 NHTS. Includes estimated values for Puerto Rico PMT.

[2] Average Daily Traffic (ADT) identifies the volume of traffic over all bridges for a one day (24-hour period) during a data reporting year.

Sources: Highway Performance Monitoring System; Highway Statistics, Table VM-1, various years; National Bridge Inventory.

Vehicle miles traveled (VMT) measures the distance each vehicle traverses the Nation's road network in a year. Person-miles traveled weights travel by the number of occupants in a vehicle. As shown in *Exhibit 1-1,* total highway VMT grew at an average annual rate of 0.2 percent between 2004 and 2014. Annual VMT growth fluctuated significantly during this period, and declined relative to the preceding year in 2008, 2009, and 2011. The first two of these three reductions in VMT can be attributed partially to the period of economic contraction in 2008–2009. The largest annual increase over the 10-year period was a 1.2-percent growth in VMT between 2013 and 2014.

Person-miles of travel increased by an average annual rate of 0.7 percent from 2004 to 2014. This is attributable to an increase in VMT and an increase in the average vehicle occupancy as measured in the 2009 National Household Travel Survey (NHTS), used to estimate person-miles of travel for 2014, relative to the 2001 NHTS, which was used to estimate person-miles of travel for 2004.

VMT Trends Since 2014

Based on Highway Statistics Table VM-2, VMT grew by 2.3 percent to 3.110 trillion in 2015, by an additional 2.5 percent to 3.189 trillion in 2016, and by an additional 1.2 percent to 3.227 trillion in 2017.

According to the December 2018 Traffic Volume Trends (TVT) report, the preliminary estimate of VMT growth from 2017 to 2018 is 0.4 percent. The TVT report is a monthly report based on hourly traffic count data. These data, collected at approximately 4,000 continuous traffic-counting locations nationwide, are used to calculate the percentage change in traffic for the current month compared with the same month in the previous year. Because of limited TVT sample sizes, caution should be used with these estimates.

For additional information on ongoing traffic trends, visit (http://www.fhwa.dot.gov/ohim/tvtw/tvtfaq.cfm).

Exhibit 1-1 also shows that the number of bridges cataloged in NBI increased at an annual rate of 0.3 percent between 2004 and 2014, from 591,707 to 610,749, rising further to 611,845 in 2015. Total bridge deck area grew at an average annual rate of 1.2 percent, while bridge crossings (measured as annual daily traffic) increased at an average annual rate of 0.9 percent.

Tunnels

Under MAP-21, FHWA was charged with establishing a national tunnel inspection program. In 2015, development began on the National Tunnel Inventory database system, and inventory data were collected for all highway tunnels reported. Concurrently, FHWA implemented an extensive program to train inspectors nationwide on tunnel inspection and condition evaluation.

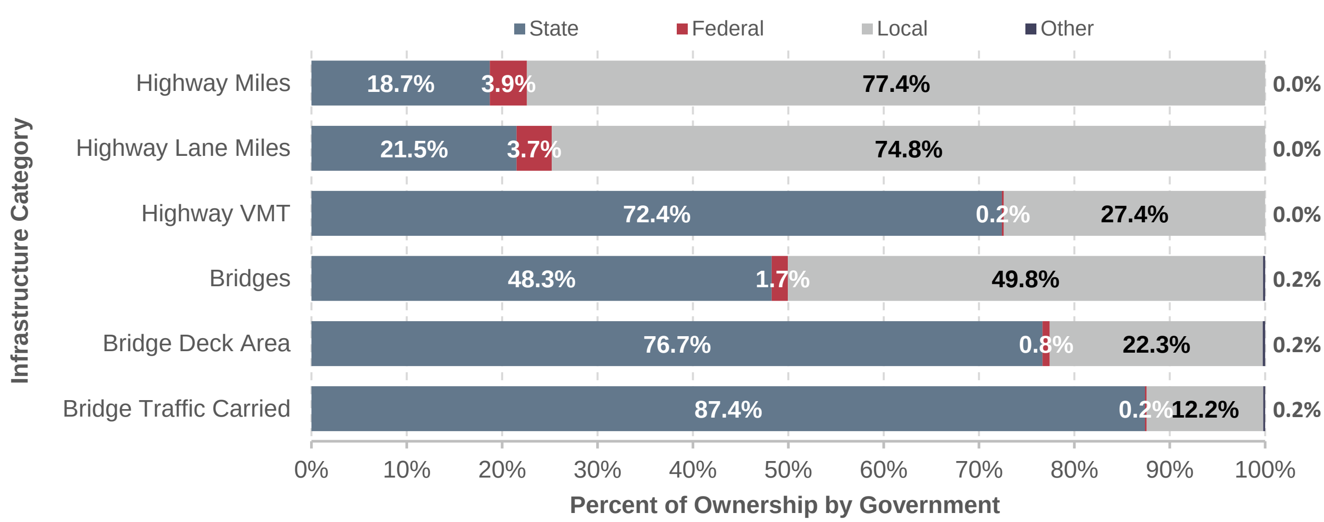
The 2015 preliminary inventory included 473 tunnels. Of these, 271 (57.3 percent) are on the NHS. States own 304 (64.3 percent) of the tunnels, 83 (17.5 percent) are owned by local governments, 77 (16.3 percent) are owned by Federal agencies, and 9 (1.9 percent) are owned by others. Further information can be found at (https://www.fhwa.dot.gov/bridge/inspection/tunnel/).

Complete inventory and condition data for all tunnels will be collected annually, beginning in 2018, and will be available for use in subsequent C&P Reports.

Roads and Bridges by Ownership

State and local governments own the vast majority of public roads and the bridges and culverts located on these roads. As shown in *Exhibit 1-2*, local governments own 77.4 percent of the Nation's public road mileage and 49.8 percent of all bridges. State governments own 18.7 percent of public road mileage and 48.3 percent of the Nation's bridges. Although many roads and bridges are constructed or improved with Federal funding, State and local governments assume ownership responsibilities for maintaining those facilities and keeping them safe for public use. Federally-owned facilities are generally found only on Federal lands, such as national parks and military installations.

Exhibit 1-2: Highway (2014) and Bridge (2015) Ownership by Level of Government



Sources: Highway Performance Monitoring System and National Bridge Investment Analysis System.

Roads and Bridges by Federal System

The mileage eligible for Federal-aid highway assistance is much smaller than the total road mileage throughout the Nation. Federal-aid highway assistance mileage consists of longer routes that may cross multiple States and facilitate higher traffic volumes at increased speeds. Conversely, non-Federal-aid highway mileage generally consists of shorter and smaller roads that eventually feed into the larger facilities that are eligible for Federal assistance.

The NHS is a subset of Federal-aid highways, containing the most critical routes for passenger and goods movement. The Interstate System is a subset of the NHS. The NHS and Interstate System are discussed in more detail below. *Exhibit 1-3* compares the relative magnitudes of these systems to the total extent of the Nation's highways and bridges.

Exhibit 1-3: Interstate, NHS, and Federal-aid Highway Extent, Bridge Count, and Travel, 2014

					Share of Total		
	Interstate	**NHS**	**FAH**	**All**	**Interstate**	**NHS**	**FAH**
Highway Miles	47,944	226,767	1,016,963	4,177,074	1.1%	5.4%	24.3%
Lane Miles	221,229	771,245	2,445,967	8,766,049	2.5%	8.8%	27.9%
VMT (trillions)	0.751	1.661	2.572	3.040	24.7%	54.6%	84.6%
Bridges	56,553	143,165	325,467	610,749	9.3%	23.4%	53.3%

Sources: Highway Performance Monitoring System; National Bridge Inventory.

Ownership of Federal-aid Highway Components

In addition to the Interstate System and NHS, federally assisted highway mileage is found on other routes. Based on mileage, State highway agencies own the vast majority of the Interstate and NHS: State highway agencies own 94.7 percent of the Interstate System and 89.3 percent of the NHS. In contrast, the Federal government owns none of the 47,960 Interstate System mileage and less than 0.2 percent of the 226,767 NHS mileage. Local levels of government own the remaining mileage.

State highway agencies own 55.7 percent of the 1,016,963 miles of Federal-aid highways, while the Federal government owns only 0.8 percent of those miles.

Source: Highway Statistics HM-15 2014

Federal-aid highways constitute just 24.3 percent of the Nation's roadway mileage, but carry 84.6 percent of the Nation's VMT. The NHS includes 5.4 percent of the Nation's roadway mileage, but carries 54.6 percent of highway traffic. The Interstate System makes up only 1.1 percent of the Nation's roads, but carries 24.7 percent of VMT.

The Interstate System and the NHS have more multilane roadways (four lanes or more), and include bridges with greater deck areas. Roadways not on these systems tend to have the vast majority of two-lane roadways and slightly less than 50 percent of bridges. However, a bridge not on either the Interstate System or the remainder of the NHS usually has a much smaller deck area to maintain and is not subject to as much traffic.

Federal-aid Highways

Federal-aid highways comprised approximately 1.02 million miles in 2014 and facilitated more than 2.57 trillion VMT. As shown in *Exhibit 1-4*, highway mileage on the Federal-aid system increased by 49,425 miles between 2004 and 2014, to over 1.02 million miles in 2014. Lane mileage increased by 126,250 miles to almost 2.45 million lane miles in 2014 and VMT increased from 2.53 trillion in 2004 to over 2.57 trillion VMT in 2014, an increase of more than 40 billion VMT.

The number of bridges on Federal-aid highways increased from 307,840 in 2004 to 325,467 in 2014. This is an annual rate of change of approximately 0.5 percent. A net total of 1,279 bridges were added in 2015, bringing the total to 326,746.

Exhibit 1-4: Federal-Aid Highways Extent and Travel, 2004–2014; Bridge Count 2004–2015

	2004	2006	2008	2010	2012	2014	Annual Rate of Change 2014/2004	*2015*
Highway Miles	971,036	984,093	994,358	1,007,777	1,005,378	1,020,461	0.5%	
Lane Miles	2,319,417	2,364,514	2,388,809	2,451,140	2,433,012	2,445,667	0.5%	
VMT (trillions)	2.532	2.574	2.534	2.525	2.527	2.572	0.2%	
Bridges	307,840	312,062	316,012	319,108	321,724	325,467	0.5%	*326,746*

Sources: Highway Performance Monitoring System; National Bridge Inventory.

National Highway System

With the Interstate System largely complete, the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) revised the Federal-aid highway program for the post-Interstate System era. The legislation authorized designation of an NHS that would give priority for Federal resources to roads most important for interstate travel, economic expansion, and national defense; that connect with other modes of transportation; and that are essential to the Nation's role in the international marketplace. The Moving Ahead for Progress in the 21st Century Act of 2012 (MAP-21) modified the scope of the NHS to include some additional principal arterial and related connector mileage not previously designated as part of the NHS. This modification increased the size of the NHS by approximately 37 percent, bringing it from 164,154 miles in 2011 up to an estimated 224,446 miles.[5] The NHS has subsequently grown to 226,767 miles as of 2014.

Exhibit 1-5 compares the NHS in 2004 with the NHS in 2014 after the expansion under MAP-21. As of 2014, the NHS included 39.6 percent more mileage and carried 24.7 percent more travel than in 2004.

Exhibit 1-5: NHS Comparison: 2004 versus 2014

	Year		Percent Increase
	2004	2014	
Miles	162,161	226,767	39.8%
Lane-miles	559,830	771,248	37.8%
VMT (trillions)	1.332	1.661	24.7%
Bridges	115,103	143,165	24.4%
Deck Area (sq. m.)	160,481,200	211,704,373	31.9%

Source: HPMS, NBI.

[5] See https://www.fhwa.dot.gov/planning/national_highway_system/nhs_maps/map21estmileage.cfm. Figures adjusted to include Puerto Rico based on data from Highway Statistics 2011, Tables HM-41 and HM-20.

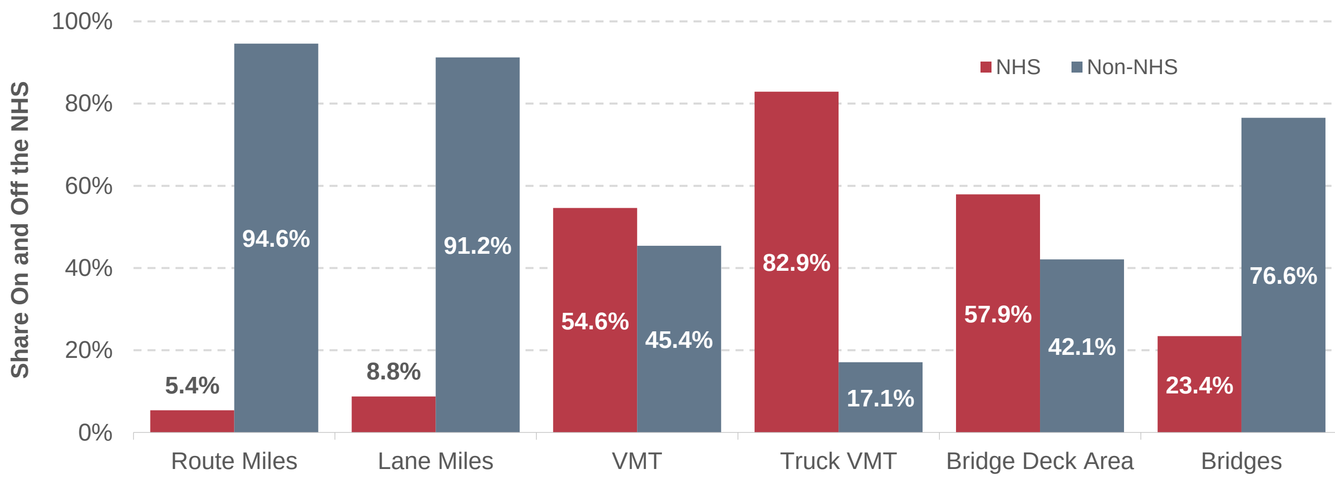
The number of NHS bridges was 24.4 percent higher in 2014 than in 2004, though the 2014 figure may not be exact as final recoding of newly designated NHS bridges in the NBI was still in progress at the time of this report.

The NHS was designed to be a dynamic system capable of changing in response to future travel and trade demands. States must cooperate with local and regional officials in proposing modifications. In metropolitan areas, local and regional officials must act through metropolitan planning organizations and the State transportation department when proposing modifications. Many of these modifications are proposed and approved each year.

The NHS has five components. The first, the Interstate System, is the core of the NHS and includes the most traveled routes. The second component includes other principal arterials deemed most important for commerce and trade. The third is the Strategic Highway Network (STRAHNET), which consists of highways important to military mobilization. The fourth is the system of STRAHNET connectors that provide access between major military installations and routes that are part of STRAHNET. The final component consists of intermodal connectors. These roads provide access between major intermodal passenger and freight facilities and the other four subsystems that comprise the NHS.

As shown in *Exhibit 1-6*, only 5.4 percent of the Nation's highway mileage and 8.8 percent of the Nation's lane mileage were located on the NHS in 2014. Of the total number of the Nation's bridges, 23.4 percent are located on the NHS. However, these bridges account for 57.9 percent of the total bridge deck area in the Nation. Approximately 54.6 percent of the Nation's total VMT occurs on the NHS. The NHS is crucial to truck traffic, which carries cargo long distances, often across multiple State lines. Approximately 82.9 percent of combination truck VMT occurred on the NHS in 2014. Freight transportation is discussed in more detail in Part III of this report.

Exhibit 1-6: Share of Highway Miles, Lane Miles, Vehicle Miles Traveled, Truck Vehicle Miles, Bridge Deck Area, and Number of Bridges On and Off the National Highway System, 2014



Source: Highway Performance Monitoring System, National Bridge Information System.

In view of the importance of the NHS for truck traffic and freight, highways that are part of the NHS are designed to accommodate high amounts of traffic at higher speeds in the safest and most efficient ways possible. Additionally, NHS highways are constructed at higher load carrying capability to withstand the heavier loads conveyed by combination trucks.

Interstate System

The Federal-Aid Highway Act of 1956 declared that the completion of the "National System of Interstate and Defense Highways" was essential to the national interest. The Act committed the Nation to completing the Interstate System within the Federal-State partnership of the Federal-aid highway program, with the States responsible for construction according to approved standards. The Act also resolved the challenging issue of how to pay for construction by establishing the Highway Trust Fund to ensure that revenue from highway user taxes, such as the motor fuels tax, would be dedicated to the Interstate System and other Federal-aid highway and bridge projects.

As shown in *Exhibit 1-7,* there were small increases in the size of the Interstate System from 2004 to 2014. The total number of route miles increased from 46,836 miles in 2004 to 47,960 miles in 2014. Lane miles increased from 212,029 lane miles in 2004 to 222,588 lane miles in 2014. The number of bridges increased as well.

Exhibit 1-7: Interstate Highway Extent and Travel, 2004–2014; Bridge Count, 2004–2015

	2004	2006	2008	2010	2012	2014	Annual Rate of Change 2014/2004	*2015*
Highway Miles	46,836	46,892	47,019	47,182	47,714	47,960	0.2%	
Lane Miles	212,029	213,542	214,880	217,165	220,124	222,588	0.5%	
VMT (trillions)	0.727	0.741	0.725	0.731	0.736	0.751	0.3%	
Bridges	55,315	55,270	55,626	55,339	55,959	56,553	0.2%	*56,883*

Sources: Highway Performance Monitoring System; National Bridge Inventory.

Roads and Bridges by Purpose

The Nation's roadway system is a vast network that connects places and people within and across national borders. The network serves movements from long-distance freight needs to neighborhood travel. Because of the diverse needs for vehicular travel, the network is categorized under the Highway Functional Classification System. Each functional classification defines the role an element of the network plays in serving travel needs.

Exhibit 1-8 presents a formal hierarchy of road functional classifications. *(Highway Functional Classification Concepts, Criteria and Procedures 2013)*. Although the functional classification definitions do not change for each setting, roads are divided into rural and urban classifications.

Arterials serve the longest distances with the fewest access points. Because they have the longest distance between other routes, arterials facilitate the highest speed limits. Several functional classifications are included in the arterial category.

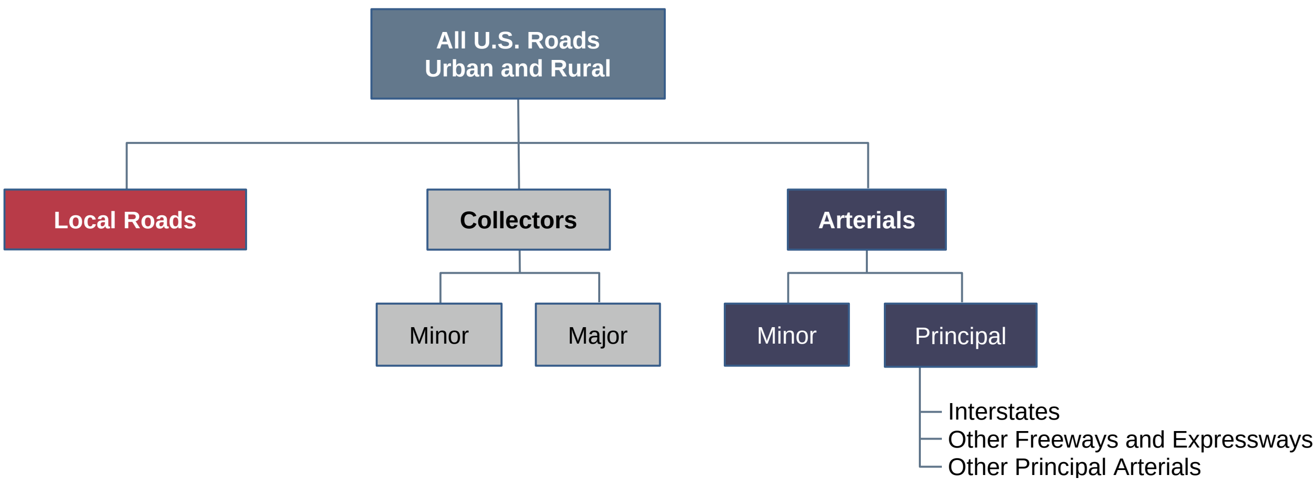
- **Interstates** are the highest classification of arterials, facilitating the highest level of mobility. Interstates are relatively easy to locate due to their official designation by the Secretary of Transportation and distinct signage.
- **Other Freeways and Expressways** are similar to Interstates in that they have directional travel lanes, usually separated by a physical barrier. Access and egress points are limited primarily to on- and off-ramps at grade-separated interchanges.
- **Other Principal Arterials** can serve specific land parcels directly and have at-grade intersections with other roadways that are managed by traffic devices.

- **Minor Arterials**, the lowest of arterial classifications, provide service for trips of moderate length and connectivity between higher arterial classifications and roads with lower functional classifications that provide greater access to businesses and homes.

Collectors serve the critical roles of gathering traffic from local roads and funneling vehicles into the arterial network. Although subtly different, two classifications are included in the collector category.

- **Major Collectors** are longer, have fewer points of access, have higher speed limits, and can have more travel lanes.
- **Minor Collectors** is the classification used for all collectors not classified as major collectors. One distinction between the two classifications is that minor collectors are focused more on access than on mobility.

Exhibit 1-8: Highway Functional Classification System Hierarchy



Source: FHWA Functional Classification Guidelines.

Local Roads are any road not classified as an arterial or collector. They are not intended for use in long-distance travel, except at the origination or termination of a trip. Local roads are often designed to discourage through traffic. (Local functional class should not be confused with local government ownership: the Federal government and State governments own some roadways functionally classified as local.)

Relationship of Federal-aid Highways to Functional Classes

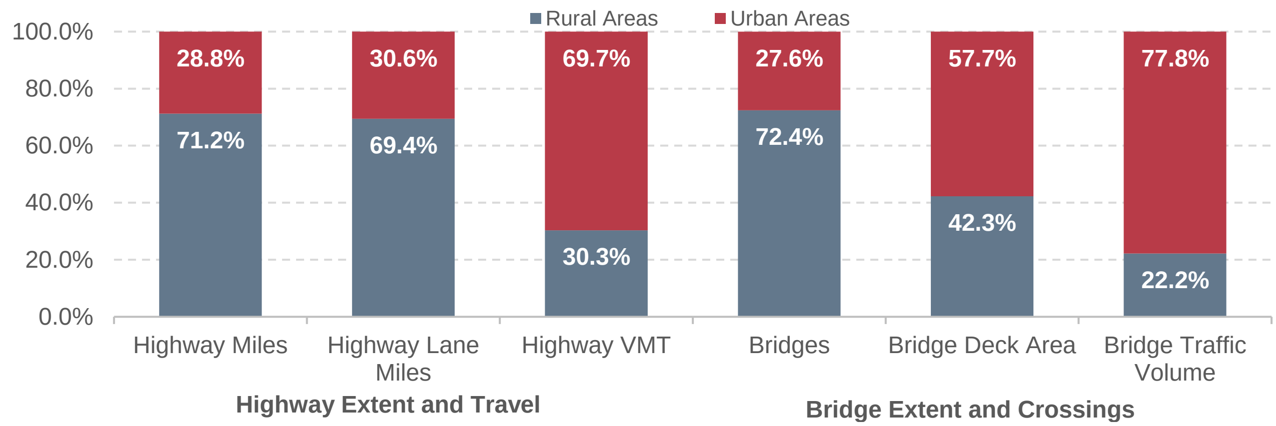
Public roads that are functionally classified higher than rural minor collector, rural local, or urban local are eligible for Federal-aid highway assistance. Although bridges follow the hierarchy scheme, the NBI makes no distinction between urban major and urban minor collectors as HPMS does. Title 23 allows Federal-aid highway funding (specifically Surface Transportation Block Grant Program apportionments) to be used on existing bridges and tunnels that are not on the Federal-aid highways. MAP-21 required each State to obligate at least 15 percent of its 2009 bridge program apportionment for bridges that are not on Federal-aid highways, unless the Secretary determines such expenditures are unjustified.

Extent and Travel by Functional System

As shown in *Exhibit 1-9,* almost half (49.1 percent) of the Nation's highway mileage was classified as rural local in 2014 highway mileage. Urban local roads comprised an additional 20.4 percent of total highway miles.

Exhibit 1-9 also details the breakdown of travel occurring in rural and urban settings. Urban areas have a higher share of VMT and lower highway mileage because urban settings tend to be more consolidated environments. With higher population concentrations, more vehicles use the highway mileage in urban areas. Alternatively, rural areas cover much more land across the country and have a higher share of the highway mileage to provide connectivity and access in areas with lower population density.

Exhibit 1-9: By Functional System and Area: Highway Extent and Travel, 2014; Bridge Extent and Crossings, 2015



Functional System	Highway Miles	Highway Lane Miles	Highway VMT	Bridges	Bridge Deck Area	Bridge Traffic Volume
Rural Areas (less than 5,000 in population)						
Interstate	0.7%	1.4%	7.6%	4.1%	6.8%	8.7%
Other Freeway and Expressway	0.1%	0.2%	0.9%			
Other Principal Arterial	2.2%	2.7%	6.2%			
Other Principal Arterial[1]				6.0%	8.8%	5.7%
Minor Arterial	3.2%	3.1%	4.6%	6.2%	5.8%	2.9%
Major Collector	9.8%	9.4%	5.2%	15.1%	8.9%	2.9%
Minor Collector	6.2%	5.9%	1.6%	7.8%	3.1%	0.7%
Local	49.1%	46.7%	4.1%	33.2%	8.9%	1.3%
Subtotal Rural Areas	**71.2%**	**69.4%**	**30.3%**	**72.4%**	**42.3%**	**22.2%**
Urban Areas (5,000 or more in population)						
Interstate	0.4%	1.2%	17.3%	5.2%	19.5%	36.1%
Other Freeway and Expressway	0.3%	0.6%	7.5%	3.4%	11.0%	16.6%
Other Principal Arterial	1.6%	2.6%	15.5%	4.8%	11.7%	12.3%
Minor Arterial	2.7%	3.3%	12.9%	5.0%	8.1%	7.6%
Collector[1]				3.7%	3.7%	2.8%
Major Collector	3.1%	3.1%	6.4%			
Minor Collector	0.3%	0.3%	0.4%			
Local	20.4%	19.5%	9.7%	5.6%	3.9%	2.3%
Subtotal Urban Areas	**28.8%**	**30.6%**	**69.7%**	**27.6%**	**57.7%**	**77.8%**
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**

[1] Highway data reflect revised HPMS functional classifications. Bridge data still use the previous classifications, so that rural Other Freeway and Expressway is included as part of the rural Other Principal Arterial category, and urban Major Collector and urban Minor Collector are combined into a single urban Collector category.

Sources: Highway Performance Monitoring System; National Bridge Inventory.

Although Interstate highway mileage comprises only 1.1 percent of the Nation's highway mileage, it carries the Nation's highest share of VMT by classification at 24.9 percent. Interstate bridges also receive the highest share of bridge traffic volume by classification with 44.8 percent.

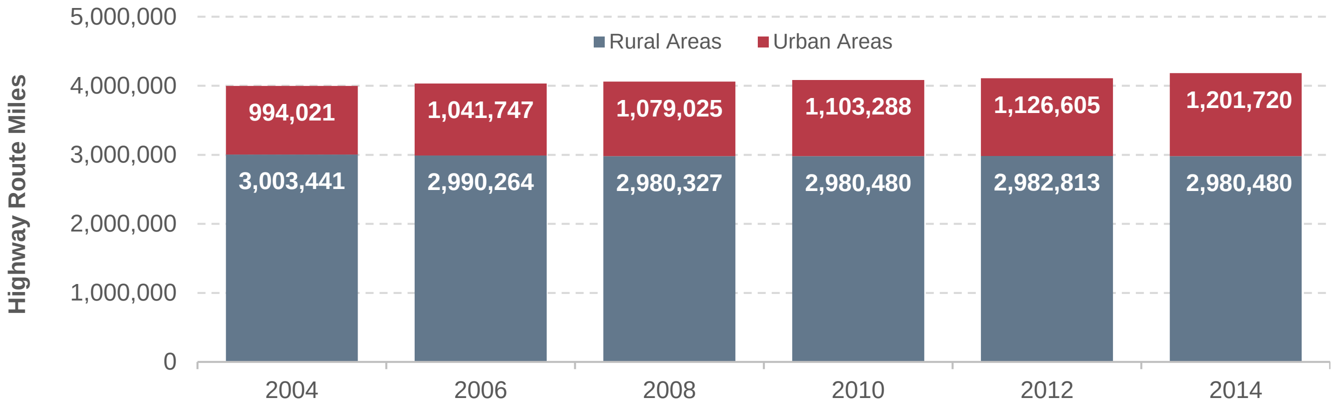
Because 71.2 percent of the Nation's highway mileage is located in rural areas, lane mileage is also higher in rural areas. Local roads in urban and rural settings also continue to have the highest share of the Nation's lane mileage.

The difference seen in *Exhibit 1-9* between the functional classes reported under the highway portion of the exhibit and the bridge portion is due to the fact that the NBI has not been updated to use the new functional classifications used in the HPMS.

Exhibit 1-10 shows the highway route miles in the Nation based on functional system. The Nation's public highways comprised approximately 4.18 million miles in 2014, up from slightly less than 4.0 million miles in 2004. Total mileage in urban areas grew from 994,221 miles in 2004 to 1,201,720 miles in 2014. Highway miles in rural areas, however, decreased from approximately 3.0 million miles in 2004 to slightly more than 2.98 million miles in 2014. The largest decrease in mileage was seen in rural local roadways.

In addition to the construction of new roads, two factors have continued to contribute to the increase in urban highway mileage. First, based on population growth reflected in the decennial census, more people are living in areas that were previously rural, and thus urban boundaries have expanded in some locations. This expansion has resulted in the reclassification of some mileage from rural to urban. States have implemented these boundary changes in their HPMS data reporting gradually. As a result, the impact of the census-based changes on these statistics is not confined to a single year. Second, greater focus has been placed on Federal agencies to provide a more complete reporting of federally-owned mileage.

Exhibit 1-10: Highway Route Miles by Functional System, 2004–2014



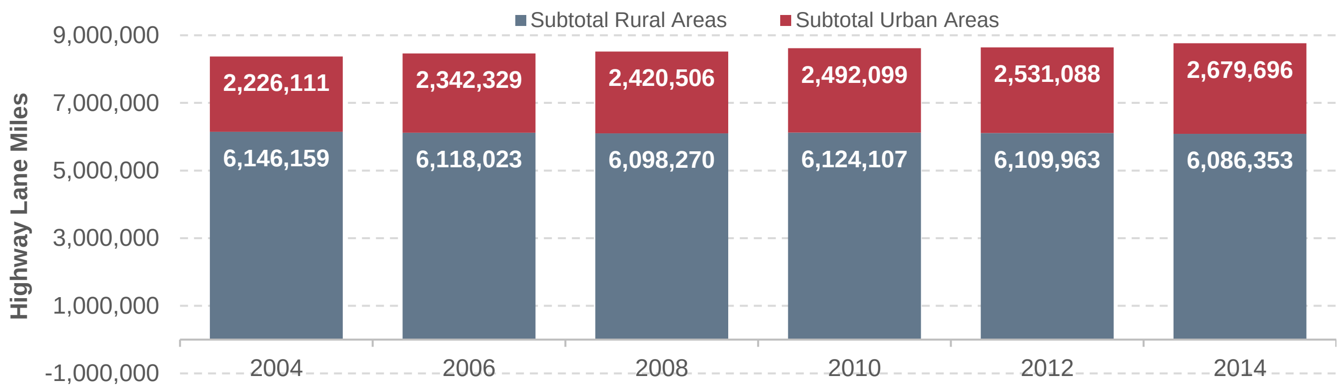
Functional System	2004	2006	2008	2010	2012	2014	Annual Rate of Change 2014/2004
Rural Areas (less than 5,000 in population)							
Interstate	31,477	30,615	30,227	30,260	30,564	29,095	-0.8%
Other Freeway & Expressway[1]				3,299	4,395	3,299	
Other Principal Arterial[1]				92,131	91,462	92,131	
Other Principal Arterial[1]	95,998	95,009	95,002				-0.1%
Minor Arterial	135,683	135,589	135,256	135,681	135,328	132,672	-0.2%
Major Collector	420,293	419,289	418,473	418,848	419,353	418,848	0.0%
Minor Collector	268,088	262,966	262,852	263,271	262,435	263,271	-0.2%
Local	2,051,902	2,046,796	2,038,517	2,036,990	2,039,276	2,036,990	-0.1%
Subtotal Rural Areas	**3,003,441**	**2,990,264**	**2,980,327**	**2,980,480**	**2,982,813**	**2,980,480**	-0.1%
Urban Areas (5,000 or more in population)							
Interstate	15,359	16,277	16,789	16,922	17,150	18,567	1.9%
Other Freeway and Expressway	10,305	10,817	11,401	11,371	11,521	11,784	1.3%
Other Principal Arterial	60,088	63,180	64,948	65,505	65,593	66,761	1.1%
Minor Arterial	98,447	103,678	107,182	108,375	109,337	112,228	1.3%
Collector[1]	103,387	109,639	115,087				3.0%
Major Collector[1]				115,538	116,943	127,809	
Minor Collector[1]				3,303	3,588	11,754	
Local	706,436	738,156	763,618	782,273	802,473	852,755	0.8%
Subtotal Urban Areas	**994,021**	**1,041,747**	**1,079,025**	**1,103,288**	**1,126,605**	**1,201,720**	0.8%
Total Highway Route Miles	**3,997,462**	**4,032,011**	**4,059,352**	**4,083,768**	**4,109,418**	**4,177,074**	**0.2%**

[1] Starting in 2010, the HPMS data reflect revised functional classifications. Rural Other Freeway and Expressway has been split from the rural Other Principal Arterial category, and urban Collector has been split into urban Major Collector and urban Minor Collector. The annual rate of change was computed based on the older combined categories.

Source: Highway Performance Monitoring System.

Exhibit 1-11 shows the change in highway lane miles from 2004 to 2014 by functional class and shows the changes in rural areas versus urban areas of the Nation. Urban areas have seen an increase in lane miles from more than 2.2 million in 2004 to slightly less than 2.7 million in 2014. The largest decrease in lane miles occurred on rural major collectors, a loss of 21,904 lane miles of roadway, while urban local roadways experienced the largest increase in lane miles, at 292,638 lane miles.

Exhibit 1-11: Highway Lane Miles by Functional System, 2004–2014



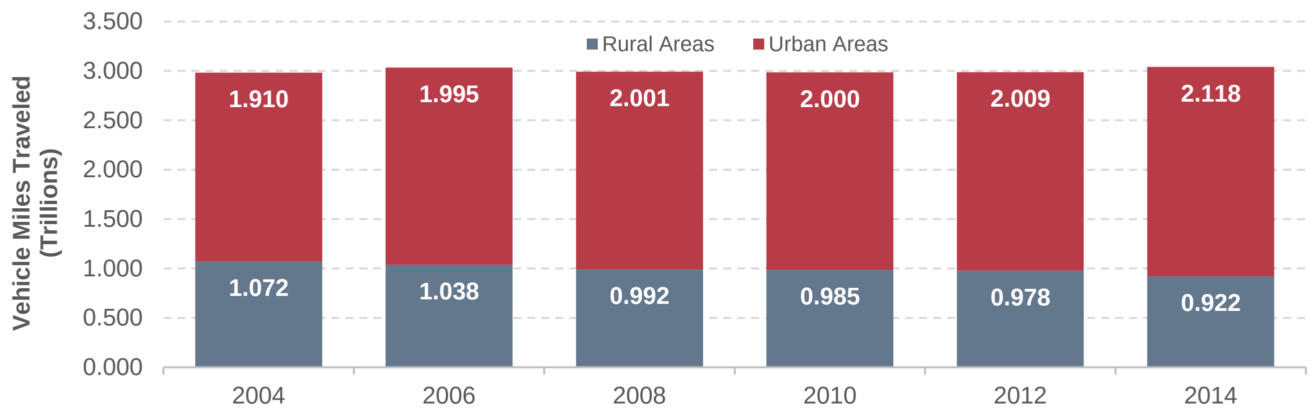
Functional System	Highway Lane Miles						Annual Rate of Change 2014/2004
	2004	2006	2008	2010	2012	2014	
Rural Areas (less than 5,000 in population)							
Interstate	128,012	124,506	122,956	123,762	124,927	118,688	-0.8%
Other Freeway and Expressway[1]				11,907	16,593	20,677	
Other Principal Arterial[1]				243,065	240,639	233,985	
Other Principal Arterial[1]	249,480	248,334	250,153				0.2%
Minor Arterial	283,173	282,397	281,071	287,761	281,660	274,271	-0.3%
Major Collector	845,513	843,262	841,353	857,091	842,722	823,609	-0.3%
Minor Collector	536,177	525,932	525,705	526,540	524,870	517,026	-0.4%
Local	4,103,804	4,093,592	4,077,032	4,073,980	4,078,552	4,098,098	-0.01%
Subtotal Rural Areas	**6,146,159**	**6,118,023**	**6,098,270**	**6,124,107**	**6,109,963**	**6,086,353**	-0.1%
Urban Areas (5,000 or more in population)							
Interstate	84,016	89,036	91,924	93,403	95,197	102,541	2.0%
Other Freeway and Expressway	47,770	50,205	53,073	53,231	54,160	55,385	1.5%
Other Principal Arterial	210,506	221,622	228,792	235,127	234,469	231,099	0.9%
Minor Arterial	250,769	269,912	274,225	285,954	283,608	287,061	1.4%
Collector[1]	220,177	235,240	245,262				3.1%
Major Collector[1]				252,435	250,760	272,931	
Minor Collector[1]				7,404	7,948	25,168	
Local	1,412,872	1,476,314	1,527,230	1,564,546	1,604,946	1,705,510	1.9%
Subtotal Urban Areas	**2,226,111**	**2,342,329**	**2,420,506**	**2,492,099**	**2,531,088**	**2,679,696**	1.9%
Total Highway Lane Miles	**8,372,270**	**8,460,352**	**8,518,776**	**8,616,206**	**8,641,051**	**8,766,049**	**0.5%**

[1] Starting in 2010, the HPMS data reflect revised functional classifications. Rural Other Freeway and Expressway has been split from the rural Other Principal Arterial category, and urban Collector has been split into urban Major Collector and urban Minor Collector. The annual rate of change was computed based on the older combined categories.

Source: Highway Performance Monitoring System.

Exhibit 1-12 shows VMT in trillions of miles by functional class from 2004 to 2014. VMT in rural areas decreased from 1.07 trillion miles in 2004 to 0.92 trillion miles in 2014. Urban VMT increased from 1.91 trillion to slightly less than 2.12 trillion during the same period. *Exhibit 1-12* also shows the largest average annual decrease of 2.3 percent was on rural major collectors and the largest gain was on the combined functional classifications of urban major and minor collectors, an increase of 2.3 percent. Overall, VMT on rural roadways declined by 1.5 percent and VMT on urban roadways increased by 1.0 percent between 2004 and 2014.

Exhibit 1-12: Vehicle Miles Traveled by Functional System and Area, 2004–2014



Functional System	Annual Travel Distance (Trillions of Miles)						Annual Rate of Change 2014/2004
	2004	2006	2008	2010	2012	2014	
Rural Areas (less than 5,000 in population)							
Interstate	0.267	0.258	0.244	0.246	0.246	0.232	-1.4%
Other Freeway & Expressway[1]				0.020	0.020	0.026	
Other Principal Arterial[1]				0.206	0.203	0.188	
Other Principal Arterial[1]	0.241	0.232	0.223				-1.2%
Minor Arterial	0.169	0.163	0.152	0.151	0.149	0.141	-1.8%
Major Collector	0.201	0.193	0.186	0.176	0.176	0.159	-2.3%
Minor Collector	0.060	0.058	0.055	0.053	0.053	0.050	-1.9%
Local	0.132	0.133	0.132	0.133	0.130	0.126	-0.5%
Subtotal Rural Areas	**1.072**	**1.038**	**0.992**	**0.985**	**0.978**	**0.922**	-1.5%
Urban Areas (5,000 or more in population)							
Interstate	0.460	0.483	0.482	0.483	0.490	0.525	1.3%
Other Freeway and Expressway	0.209	0.218	0.224	0.222	0.225	0.228	0.9%
Other Principal Arterial	0.454	0.470	0.466	0.461	0.460	0.471	0.4%
Minor Arterial	0.366	0.380	0.381	0.378	0.375	0.393	0.7%
Collector[1]	0.164	0.176	0.178				2.3%
Major Collector[1]				0.179	0.177	0.195	
Minor Collector[1]				0.004	0.004	0.012	
Local	0.258	0.268	0.271	0.273	0.278	0.295	1.4%
Subtotal Urban Areas	**1.910**	**1.995**	**2.001**	**2.000**	**2.009**	**2.118**	1.0%
Total VMT	**2.982**	**3.034**	**2.993**	**2.985**	**2.987**	**3.040**	**0.2%**

[1] Starting in 2010, the HPMS data reflect revised functional classifications. Rural Other Freeway and Expressway has been split from the rural Other Principal Arterial category, and urban Collector has been split into urban Major Collector and urban Minor Collector. The annual rate of change was computed based on the older combined categories.

Source: Highway Performance Monitoring System.

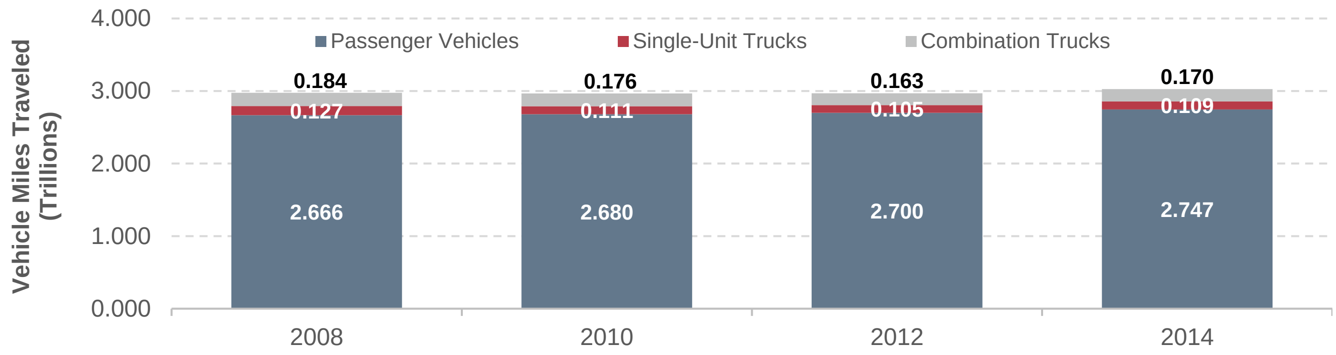
Exhibit 1-13 shows an analysis of the types of vehicles comprising the Nation's VMT between 2008 and 2014. Three groups of vehicles are identified: passenger vehicles, which include motorcycles, buses, and light trucks (two-axle, four-tire models); single-unit trucks having six or more tires; and combination trucks, including those with trailers and semitrailers. Passenger vehicle travel accounted for 90.8 percent of total VMT in 2014; combination trucks accounted for 5.6 percent, and single-unit trucks accounted for 3.6 percent.

Passenger vehicle travel grew at an average annual rate of 0.5 percent from 2008 to 2014. During the same period, combination truck traffic declined at an average annual rate of 1.3 percent and single-unit truck traffic declined at an average annual rate of 2.5 percent. Household travel is discussed in more detail in Chapter 3; highway freight transportation is discussed in Part III.

The change in the number of bridges by functional system from 2004 to 2014 is shown in *Exhibit 1-14.* The number of bridges in the Nation has increased from 594,100 in 2004 to 610,749 in 2014, an annual rate of change of approximately 0.3 percent. From 2014 to 2015 the number of bridges increased to 611,845. Rural Interstate bridges decreased at an annual rate of 1.0 percent from 2004 to 2014, while the number of bridges on urban collectors had the largest average annual increase at 3.5 percent.

The number of bridges on rural local roadways decreased by the largest amount, from 208,641 bridges in 2004 to 203,995 in 2014. During the same period the number of bridges increased by the largest amount—6,286 bridges—on urban collector roadways.

Exhibit 1-13: Highway Travel by Functional System and Vehicle Type, 2008–2014[1,2]



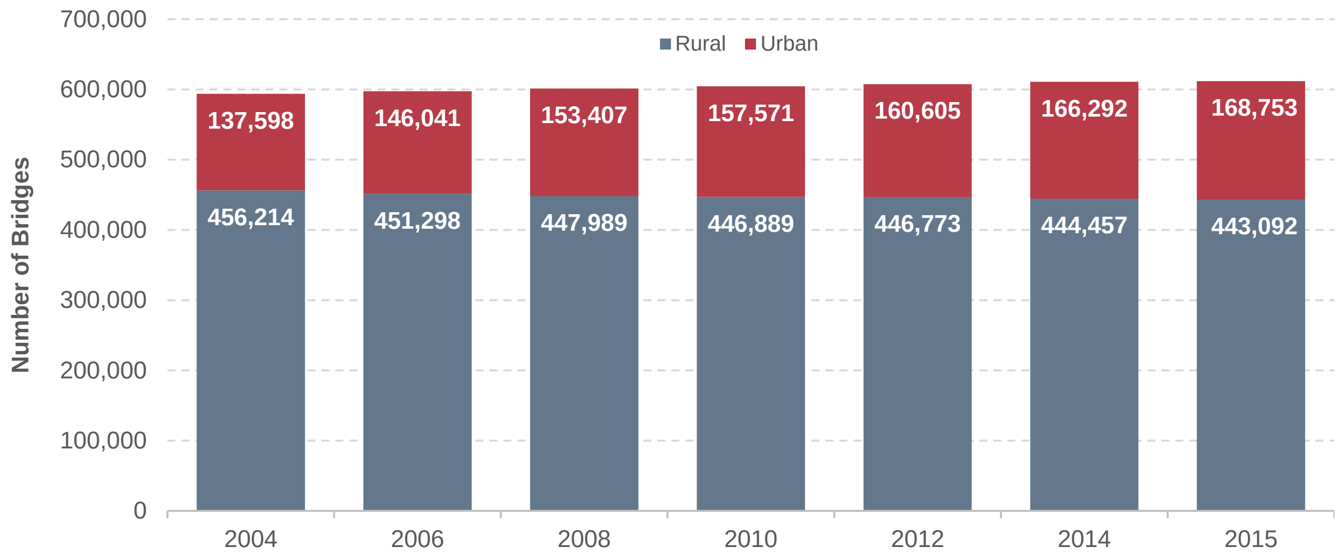
Functional System Vehicle Type	Annual Travel Distance (Trillions of Miles)				Annual Rate of Change 2014/2008
	2008	2010	2012	2014	
Rural					
Interstate					
Passenger Vehicles	0.181	0.185	0.188	0.175	-0.6%
Single-Unit Trucks	0.012	0.011	0.009	0.009	-4.2%
Combination Trucks	0.050	0.049	0.049	0.047	-1.1%
Other Arterial					
Passenger Vehicles	0.322	0.324	0.325	0.309	-0.7%
Single-Unit Trucks	0.020	0.019	0.017	0.016	-3.5%
Combination Trucks	0.032	0.033	0.030	0.029	-1.3%
Other Rural					
Passenger Vehicles	0.335	0.328	0.327	0.304	-1.6%
Single-Unit Trucks	0.019	0.018	0.018	0.017	-2.0%
Combination Trucks	0.016	0.016	0.014	0.013	-3.2%
Total Rural					
Passenger Vehicles	0.839	0.837	0.840	0.789	-1.0%
Single-Unit Trucks	0.051	0.048	0.044	0.043	-3.1%
Combination Trucks	0.098	0.099	0.093	0.089	-1.5%
Urban					
Interstate					
Passenger Vehicles	0.424	0.427	0.434	0.463	1.5%
Single-Unit Trucks	0.017	0.014	0.015	0.016	-0.3%
Combination Trucks	0.036	0.036	0.036	0.041	2.3%
Other Urban					
Passenger Vehicles	1.403	1.415	1.427	1.495	1.1%
Single-Unit Trucks	0.059	0.048	0.046	0.050	-2.6%
Combination Trucks	0.050	0.042	0.035	0.039	-3.9%
Total Urban					
Passenger Vehicles	1.827	1.842	1.861	1.958	1.2%
Single-Unit Trucks	0.075	0.062	0.061	0.067	-2.0%
Combination Trucks	0.086	0.077	0.071	0.080	-1.1%
Total					
Passenger Vehicles	**2.666**	**2.680**	**2.700**	**2.747**	**0.5%**
Single-Unit Trucks	**0.127**	**0.111**	**0.105**	**0.109**	**-2.5%**
Combination Trucks	**0.184**	**0.176**	**0.163**	**0.170**	**-1.3%**

[1] Data do not include Puerto Rico.

[2] The procedures used to develop estimates of travel by vehicle type have been significantly revised; the data available do not support direct comparisons prior to 2007.

Source: Highway Statistics, various years, Table VM-1.

Exhibit 1-14: Number of Bridges by Functional System and Area, 2004–2015



Functional System	2004	2006	2008	2010	2012	2014	Annual Rate of Change 2014/2004	*2015*
Rural								
Interstate	27,648	26,633	25,997	25,223	25,201	25,057	-1.0%	*25,024*
Other Principal Arterial	36,258	35,766	35,594	36,084	36,460	36,711	0.1%	*36,619*
Minor Arterial	40,197	39,521	39,079	39,048	39,123	38,159	-0.5%	*38,084*
Major Collector	94,079	93,609	93,118	93,059	92,875	92,777	-0.1%	*92,547*
Minor Collector	49,391	48,639	48,242	47,866	47,922	47,758	-0.3%	*47,649*
Local	208,641	207,130	205,959	205,609	205,192	203,995	-0.2%	*203,169*
Subtotal Rural	**456,214**	**451,298**	**447,989**	**446,889**	**446,773**	**444,457**	**-0.3%**	***443,092***
Urban								
Interstate	27,667	28,637	29,629	30,116	30,758	31,496	1.3%	*31,859*
Other Freeway and Expressway	17,112	17,988	19,168	19,791	20,139	20,821	2.0%	*20,522*
Other Principal Arterial	24,529	26,051	26,934	27,373	28,141	28,669	1.6%	*29,090*
Minor Arterial	24,802	26,239	27,561	28,103	28,437	29,943	1.9%	*30,646*
Collectors	15,548	17,618	18,932	20,311	20,590	21,834	3.5%	*22,355*
Local	27,940	29,508	31,183	31,877	32,540	33,529	1.8%	*34,281*
Subtotal Urban	**137,598**	**146,041**	**153,407**	**157,571**	**160,605**	**166,292**	**1.9%**	***168,753***
Unclassified	**288**	**222**	**110**	**33**	**2**	**0**	**-100.0%**	***0***
Total	**594,100**	**597,561**	**601,506**	**604,493**	**607,380**	**610,749**	**0.3%**	***611,845***

Source: National Bridge Inventory.

Transit System Assets

System History

The first transit systems in the United States date to the 19th century. These systems were privately owned, for-profit businesses that were instrumental in defining the urban communities of that time. By the postwar period, competition from the private automobile was limiting the ability of transit businesses to operate at a profit. As transit businesses started to fail, local, State, and national government leaders began to realize the importance of sustaining transit services. In 1964, Congress passed the Urban Mass Transportation Act of 1964, established a program to provide Federal funding for transit systems. The Act changed the character of the industry by specifying that Federal funds for transit be given to public agencies rather than private firms; this funding shift accelerated the transition from private to public ownership and operation of transit systems. The Act also required local governments to contribute matching funds as a condition for receiving Federal aid for transit services—setting the stage for the multilevel governmental partnerships that characterize today's transit industry.

State government involvement in the provision of transit services is usually through financial support and performance oversight. Some States, however, have undertaken outright ownership of transit services. Connecticut, Delaware, Georgia, Louisiana, Maryland, Massachusetts, Washington, the U.S. Virgin Islands, and Puerto Rico directly own and operate transit systems. New Jersey and Rhode Island have both set up statewide public transit corporations to operate transit services within their States.

Federal legislation in 1962 instituted the first requirement for transportation planning in urban areas of more than 50,000 population, but did not require the establishment of metropolitan planning organizations (MPOs).

Key Takeaways

Agencies/Reporters

- Most transit systems in the United States report to the National Transit Database (NTD). In 2014, 845 agencies serving almost all 497 urbanized areas and over 1,600 rural agencies reported to the NTD.
- In addition, more than 4,000 nonprofit providers operate in rural and urban areas.

Modal Service

- Transit is provided through 18 distinct modes, which belong to two major categories: rail and nonrail. There were 1,073 regular fixed-route bus systems, 183 commuter bus systems, and 11 bus rapid transit systems in 2014.
- Demand-response service was provided by 724 systems in urban areas, and 1,134 systems in rural areas.
- Open-to-the-public vanpool service was provided by 98 systems.
- Other modes included ferryboat (29 systems), trolleybus (5 systems), and other less common modes.
- Rail modes included heavy rail (15 systems), light rail (22 systems), streetcar (11 systems), hybrid rail (5 systems), commuter rail (29 systems), and other less common rail modes that run on fixed tracks.

Assets

- Agencies reported 204,800 vehicles in urban and rural areas.
- Rail systems were operated on 12,794 miles of track.
- Fixed-route bus, commuter bus, and bus rapid transit systems operated in over 233,000 mixed-traffic route miles.
- Agencies reported 3,281 passenger stations and 1,720 maintenance facilities.

MPOs are composed of State and local officials who work to address transportation planning needs of urbanized areas at a regional level. Twenty-nine years later, the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) made MPO coordination a prerequisite for Federal funding of many transit projects.

In addition, ISTEA made several other changes to transportation law, including changing the name of the Urban Mass Transportation Administration to the Federal Transit Administration (FTA). On the urban side, ISTEA increased transit formula grant funding to all agencies and initiated the use of a formula to allocate capital funds, rather than determine funding allocation on a discretionary project basis. The Act also increased flexibility in using highway trust funds between transit and highway projects.

The Transportation Equity Act for the 21st Century (TEA-21) was passed in 1998 and over the next 6 years increased transit funding by 70 percent. Part of this additional funding was to offset the increased cost of implementing service for persons with disabilities under the Americans with Disabilities Act of 1990 (ADA). The ADA required public transit services to be open to the public without discrimination and to meet all other requirements of the Act. The ADA also further increased flexibility in the use of Federal funds.

The Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) was enacted in 2005. This Act created some new programs—especially for smaller transit providers—and new program definitions. Within the urban formula program, a new formula allocation was added for Small Transit Intensive Cities (STIC). In the Capital Investment Grants (CIG) program, a Small Starts project eligibility was created with streamlined review process for lower-cost alternative approaches to transit projects such as bus rapid transit. In the rural (other than urbanized area) program, funding was increased greatly for rural transit providers, intercity fixed-route bus transportation became eligible for rural funds, and funds were made available for Native American Tribal transit. SAFETEA-LU extension acts were continued until July 2012.The Moving Ahead for Progress in the 21st Century (MAP-21) Act was enacted into law on July 6, 2012. MAP-21 consolidated the Jobs Access and Reverse Commute (JARC) program into the core formula program and added the number of low-income individuals as a new formula factor. Funds for the rural program are to be allocated based on a new service factor—vehicle revenue miles—and a factor for low-income individuals. The Act gave FTA safety oversight authority and directed FTA to issue a new rule requiring transit asset management to promote a state of good repair (SGR). Funds for Tribal transit were increased, and some funds were distributed by a new formula based in part on vehicle revenue miles. Another significant change was the elimination of the Fixed-Guideway Modernization capital program and the creation of the new, formula-based SGR program in its place. The SGR program would dedicate capital funds to the repair, upgrading, and modernization of the Nation's transit fixed-guideway infrastructure. This fixed-guideway infrastructure would include the rail transit systems, high-intensity motor bus systems operating on HOV (high occupancy vehicle) lanes, ferries, and bus rapid transit systems. The Act requires transit agencies to develop a transit asset management plan that inventories their capital assets and evaluates the condition of those assets.

The Fixing America's Surface Transportation (FAST) Act (Pub. L. No. 114-94) was enacted into law on December 4, 2015, covering Fiscal Years 2016 through 2020. The FAST Act retained the basic structure of the urban formula program, but increased the STIC formula funding and allowed certain smaller systems (100 demand response vehicles or fewer) in large urban areas to use some formula funds for operating expense.

System Infrastructure

Urban and Rural Transit Agencies

State and local transit agencies have evolved into several different institutional models. A transit provider can be a unit of a regional transportation agency operated directly by the State, county, or city government, or an independent agency with an elected or appointed board of governors. Transit operators can provide service directly with their own equipment or they can purchase transit services through an agreement with a contractor.

As summarized in *Exhibit 1-15*, in 2014, approximately 845 transit providers in urbanized areas (UZAs) and 1,684 transit providers in rural areas submitted data to the National Transit Database (NTD). *Exhibit 1-16* identifies the population and unlinked transit trips for individual urbanized areas with a population over 1 million, as some exhibits in this report present data on areas over and under 1 million in population.

Of the 845 urban reporters, 281 were independent public authorities or agencies; 428 were city, county, or local government transportation units or departments; 20 were State government unit or Departments of Transportation; and 67 were private operators. The remaining 49 agencies were either private operators or independent agencies, such as MPOs, Councils of Governments (COGs), or other planning agencies, universities, and Indian Tribes.

Exhibit 1-15: Number of Urban and Rural Agencies by Organizational Structure

Organization Structure	City, County, Local Government Transportation Units or Departments	Independent Public Authorities or Agencies	State Government Unit or Departments of Transportation	Private Operators or Independent Agencies[1]	Other[2]	Total
Urban Agencies	428	281	20	67	49	845
Consolidated Urban Reporters					4	4
Net Number of Urban Reporters	428	281	20	67	53	849
Rural Agencies	743	321	4	377	239	1684
Total	**1171**	**602**	**24**	**444**	**292**	**2533**

[1] Private provider reporting on behalf of a public entity, private-for-profit corporation, or private-non-profit corporation.

[2] Other includes "Area Agency on Aging," "MPO or COG or other planning agencies," "Other," "Tribe," and "University."

Source: National Transit Database.

Similarly, of the 1,684 rural reporters, 321 were independent public authorities or agencies; 743 were city, county, or local government transportation units or departments; 4 were State government unit or Departments of Transportation; and 377 were private operators. The remaining 239 agencies were either private operators or independent agencies (e.g., MPOs, COGs, or other planning agencies, universities, and Indian Tribes).

All transit providers that receive either urban formula or rural formula funds from FTA must report to the NTD. In the past, small systems operating fewer than nine vehicles could request a reporting exemption; now all small systems are required to submit a simplified report to the NTD each year, but the report requirements parallel those of rural providers. This small-system reporting waiver was granted to 288 agencies with fewer than 30 vehicles in maximum service and not operating fixed-guideway service.

Some transit providers only receive funds from the Section 5310 program. This program (49 U.S.C. 5310) provides formula funding to States for the purpose of assisting private nonprofit groups in meeting the transportation needs of older adults and people with disabilities when the transportation service provided is unavailable, insufficient, or inappropriate to meeting these needs.

Of the 532 agencies that reported providing service on 1,196 separate modal networks, 409 operated more than one mode. In 2014, an additional 1,342 transit operators were serving rural areas. Some agencies that do not have a reporting requirement to the NTD still choose to submit a report because doing so can help their region receive additional Federal transit funding.

NTD includes urban data reported by mode and type of service (directly operated and purchased transportation). As of December 2010, NTD contained data for 16 modes. Beginning in January 2011, new modes were added to the NTD urban data, including:

- streetcar rail—previously reported as light rail,
- hybrid rail—previously reported as light rail or commuter rail,
- commuter bus—previously reported as motorbus,
- bus rapid transit—previously reported as motorbus, and
- demand-response taxi—previously reported as demand-response.

Data from NTD are presented for each new mode for analyses specific to 2014. For NTD time series analysis, however, streetcar rail and hybrid rail are included as light rail, commuter bus and bus rapid transit as fixed-route bus, and demand response-taxi as demand-response.

Exhibit 1-16: Urbanized Areas (UZA) with Population over 1 Million in Census 2010

UZA Rank	UZA Name	2010 Population (Millions)	2014 Unlinked Transit Trips (in Millions)
1	New York-Newark, NY-NJ-CT	18.4	4,274
2	Los Angeles-Long Beach-Anaheim, CA	12.2	681
3	Chicago, IL-IN	8.6	630
4	Miami, FL	5.5	169
5	Philadelphia, PA-NJ-DE-MD	5.4	392
6	Dallas-Fort Worth-Arlington, TX	5.1	80
7	Houston, TX	4.9	86
8	Washington, DC-VA-MD	4.6	480
9	Atlanta, GA	4.5	137
10	Boston, MA-NH-RI	4.2	419
11	Detroit, MI	3.7	38
12	Phoenix-Mesa, AZ	3.6	75
13	San Francisco-Oakland, CA	3.3	416
14	Seattle, WA	3.1	201
15	San Diego, CA	3.0	109
16	Minneapolis-St. Paul, MN-WI	2.7	98
17	Tampa-St. Petersburg, FL	2.4	31
18	Denver-Aurora, CO	2.4	96
19	Baltimore, MD	2.2	106
20	St. Louis, MO-IL	2.2	51
21	San Juan, PR	2.1	44
22	Riverside-San Bernardino, CA	1.9	21
23	Portland, OR-WA	1.8	112
24	Cleveland, OH	1.8	51
25	San Antonio, TX	1.8	44
26	Pittsburgh, PA	1.7	66
27	Sacramento, CA	1.7	30
28	San Jose, CA	1.7	51

UZA Rank	UZA Name	2010 Population (Millions)	2014 Unlinked Transit Trips (in Millions)
29	Cincinnati, OH-KY-IN	1.6	21
30	Kansas City, MO-KS	1.5	17
31	Orlando, FL	1.5	25
32	Indianapolis, IN	1.5	11
33	Virginia Beach, VA	1.4	18
34	Milwaukee, WI	1.4	43
35	Austin, TX	1.4	34
36	Columbus, OH	1.4	20
37	Austin, TX	1.4	34
38	Charlotte, NC-SC	1.2	30
39	Providence, RI-MA	1.2	22
40	Jacksonville, FL	1.1	13
41	Memphis, TN-MS-AR	1.1	9
42	Salt Lake City-West Valley City, UT	1.0	34
Total		**135.1**	**9,317**

Source: U.S. Department of Commerce, Census Bureau.

The Nation's fixed-route bus and demand-response systems are much more extensive than the rail transit system. Bus fixed-route service includes three distinct modes: regular fixed-route bus, commuter bus, and bus rapid transit.

As summarized in *Exhibit 1-17*, in 2014, 1,267 agencies reported fixed-route bus service, including 1,073 regular bus systems, 183 commuter bus systems, and 11 bus rapid transit systems. Some agencies operate more than one type of fixed-route bus, and so the sum of the three types does not equal the number of agencies operating these systems.

Transit agencies reported 1,858 demand-response systems (including demand-response taxi), 15 heavy rail systems, 29 commuter rail systems, 5 hybrid rail systems, 22 light rail systems, and 11 streetcar systems (some of which are not yet in service). Hybrid rail systems primarily operate routes on the national system of railroads but do not operate with the characteristics of commuter rail. This service typically operates light rail-type vehicles as diesel multiple-unit trains (DMUs).

Exhibit 1-17: Number of Systems by Mode

Mode Type	Urban	Rural	Total
Non-Rail			
Regular Bus	651	422	1,073
Commuter Bus	111	72	183
Bus Rapid Transit (BRT)	10	1	11
Demand-Response/Taxi	724	1,134	1,858
Vanpool	77	21	98
Ferryboat	22	7	29
Trolleybus	5	0	5
Rail			
Heavy Rail	15	0	15
Light Rail	22	0	22
Streetcar[1]	11	0	11
Commuter Rail	24	0	24
Hybrid Rail	5	0	5
Monorail/Automated Guideway	6	0	6
Inclined Plane	3	0	3
Other Rail[2]	4	0	4
Total	**1,686**	**1,657**	**3,343**

[1] Excludes the Galveston, Texas, streetcar, which has been out of service since Hurricane Ike in 2008 but is intended to be restarted. Galveston was designated an urbanized area in the 2000 Census, but did not meet the 50,000-person threshold in the 2010 Census.

[2] Other Rail include Alaska Railroad, Cable Car, and Inclined Plane.

Source: National Transit Database.

In some urban areas one consolidated entity provides paratransit services that are required by Federal law, even though multiple transit agencies serve that region. This is why the number of fixed-route systems is greater than the number of demand response systems.

Although every major urbanized area (population over 1 million) in the United States has fixed-route bus and demand-response systems, 48 urbanized areas were served by at least one of the rail modes, including 20 by commuter rail, 22 by light rail, 12 by heavy rail, 9 by streetcar vehicles, 5 by hybrid rail vehicle, and 11 by the other rail modes. *Exhibit 1-18* depicts the number of passenger car revenue miles for each rail mode by urbanized area.

In addition to fixed-route bus systems, demand-response systems, and rail modes, 84 publicly operated transit vanpool systems, 22 ferryboat systems, 5 trolleybus systems, 7 monorail/automated guideway systems, 3 inclined plane systems, 1 cable car system, 1 aerial tramway system, and 1 público[6] were operating in urbanized areas of the United States and its territories.

Exhibit 1-18: Vehicle Revenue Miles for Rail Modes Serving Urbanized Areas, 2014[1]

UZA Rank	Urbanized Area	Commuter Rail	Heavy Rail	Light Rail	Streetcar	Hybrid Rail	Other[2]	Total Rail
1	New York-Newark, NY-NJ-CT	197,549,135	360,853,386	2,484,796		1,270,176		562,157,493
2	Los Angeles-Long Beach-Anaheim, CA	13,214,358	7,067,079	13,863,381				34,144,818
3	Chicago, IL-IN	46,881,199	70,679,582					117,560,781
4	Miami, FL	3,422,858	7,976,759				1,332,110	12,731,727
5	Philadelphia, PA-NJ-DE-MD	22,734,769	21,112,329		3,449,801			47,296,899
6	Dallas-Fort Worth-Arlington, TX	1,152,028		9,206,750	65,959			10,424,737
7	Houston, TX			1,577,592				1,577,592
8	Washington, DC-VA-MD	2,090,084	74,078,897					76,168,981
9	Atlanta, GA		18,086,375					18,086,375
10	Boston, MA-NH-RI	23,332,209	23,133,946	5,933,203				52,399,358
11	Detroit, MI						544,552	544,552
12	Phoenix-Mesa, AZ			2,467,628				2,467,628
13	San Francisco-Oakland, CA	6,775,525	64,766,101	4,710,732	553,800		291,853	77,098,011
14	Seattle, WA	1,603,802		2,697,552	137,127		222,900	4,661,381
15	San Diego, CA	1,394,955		8,516,212		676,132		10,587,299
16	Minneapolis-St. Paul, MN-WI	528,744		4,005,704				4,534,448
17	Tampa-St. Petersburg, FL				66,590			66,590
18	Denver-Aurora, CO			11,158,766				11,158,766
19	Baltimore, MD	5,863,504	5,072,282	3,102,717				14,038,503
20	St. Louis, MO-IL			6,243,285				6,243,285
21	San Juan, PR		1,910,978					1,910,978
23	Las Vegas-Henderson, NV						2,039,738	2,039,738
24	Portland, OR-WA			7,723,744	350,284	163,404		8,237,432
25	Cleveland, OH		2,432,606	830,016				3,262,622

[6] A privately owned market-driven service using vans and small buses, comprising the largest transit system in Puerto Rico.

UZA Rank	Urbanized Area	Commuter Rail	Heavy Rail	Light Rail	Streetcar	Hybrid Rail	Other[2]	Total Rail
27	Pittsburgh, PA			2,070,100			19,090	2,089,190
28	Sacramento, CA			3,936,754				3,936,754
29	San Jose, CA			3,391,181				3,391,181
32	Orlando, FL	99,456						99,456
34	Virginia Beach, VA			372,914				372,914
37	Austin, TX					279,757		279,757
38	Charlotte, NC-SC			946,240				946,240
40	Jacksonville, FL						172,126	172,126
41	Memphis, TN-MS-AR				209,574			209,574
42	Salt Lake City-West Valley City, UT	5,332,805		6,429,332				11,762,137
44	Nashville-Davidson, TN	199,870						199,870
46	Buffalo, NY			909,413				909,413
47	Hartford, CT	1,870,204						1,870,204
49	New Orleans, LA				1,013,727			1,013,727
56	Albuquerque, NM	1,383,665						1,383,665
88	Little Rock, AR				54,748			54,748
100	Chattanooga, TN-GA						17,347	17,347
102	Stockton, CA	950,383						950,383
104	Denton-Lewisville, TX					624,330		624,330
177	Portland, ME	2,139,537						2,139,537
256	Kenosha, WI-IL				17,247			17,247
393	Morgantown, WV						740,955	740,955
400	Johnstown, PA						3,063	3,063

[1] Based on primary UZA of the transit system. Some smaller urbanized areas are served by rail that is primary to a larger area.

[2] Other rail modes include cable car, inclined plane, and monorail/automated guideway.

Source: National Transit Database.

Transit Fleet and Stations

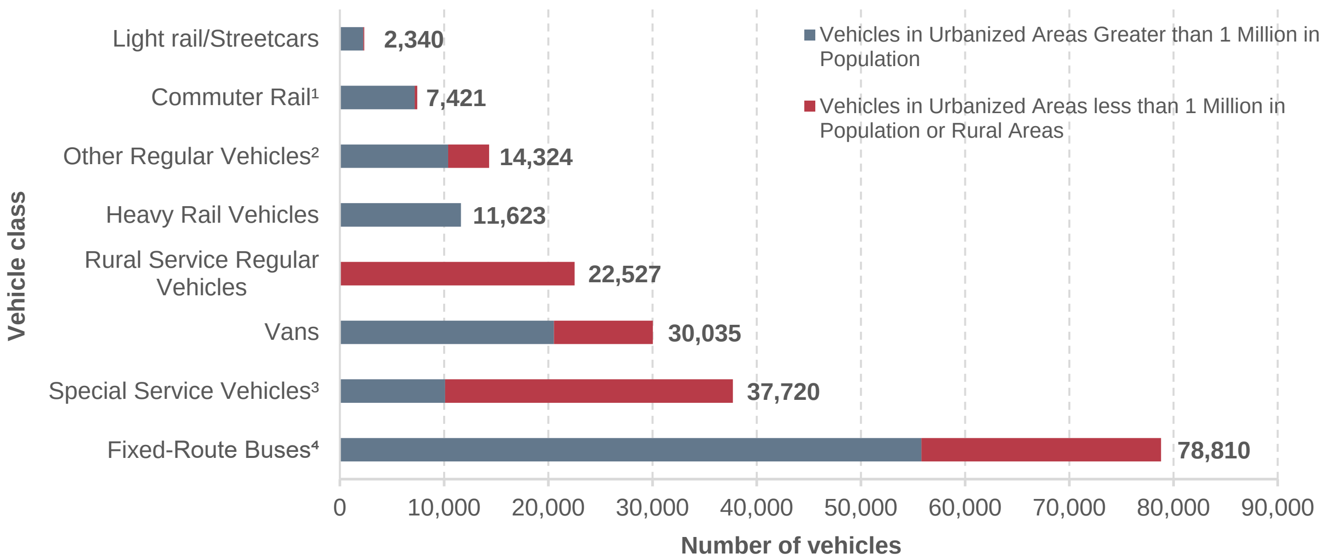
Exhibit 1-19 provides an overview of the Nation's 204,800 transit vehicles in 2014 by type of vehicle and size of urbanized area. Although some types of vehicles are specific to certain modes, many vehicles—particularly small buses and vans—are used by several different transit modes. For example, vans are used to provide vanpool, demand-response, público, or fixed-route bus services.

Exhibit 1-20 shows the composition of the Nation's urban and rural transit road vehicle fleet in 2014. More than one-third of these vehicles, or 37 percent, are full-sized motor buses. Additional information on trends in the number and condition of vehicles over time is included in Chapter 8. Vans, as presented here, are the familiar 10-seat passenger vans. Articulated buses are long vehicles articulated for better maneuverability on city streets. Full-sized buses are standard 40-foot, 40-seat city buses. Mid-sized buses are in the 30-foot, 30-seat range. Small buses, typically built on truck chassis, are shorter and seat around 25 people. Cutaways are typically built on van chassis, and on average have a seating capacity of 15 seats.

Whereas *Exhibit 1-20* depicts fleet by vehicle type, *Exhibit 1-21* depicts fleet by mode. Some modes can be composed of more than one vehicle type. The national fleet includes over 21,000 rail vehicles (passenger cars), and over 146,000 nonrail vehicles, excluding special service vehicles. The bus fleet, which includes bus, commuter bus, and bus rapid transit, accounts for 39 percent of the national fleet, and demand-response for 29 percent of the national fleet.

The size of the ADA fleet and stations are presented in Chapter 4.

Exhibit 1-19: Transit Active Fleet by Vehicle Type, 2014



[1] Includes commuter rail locomotives, commuter rail passenger coaches, and commuter rail self-propelled passenger cars.

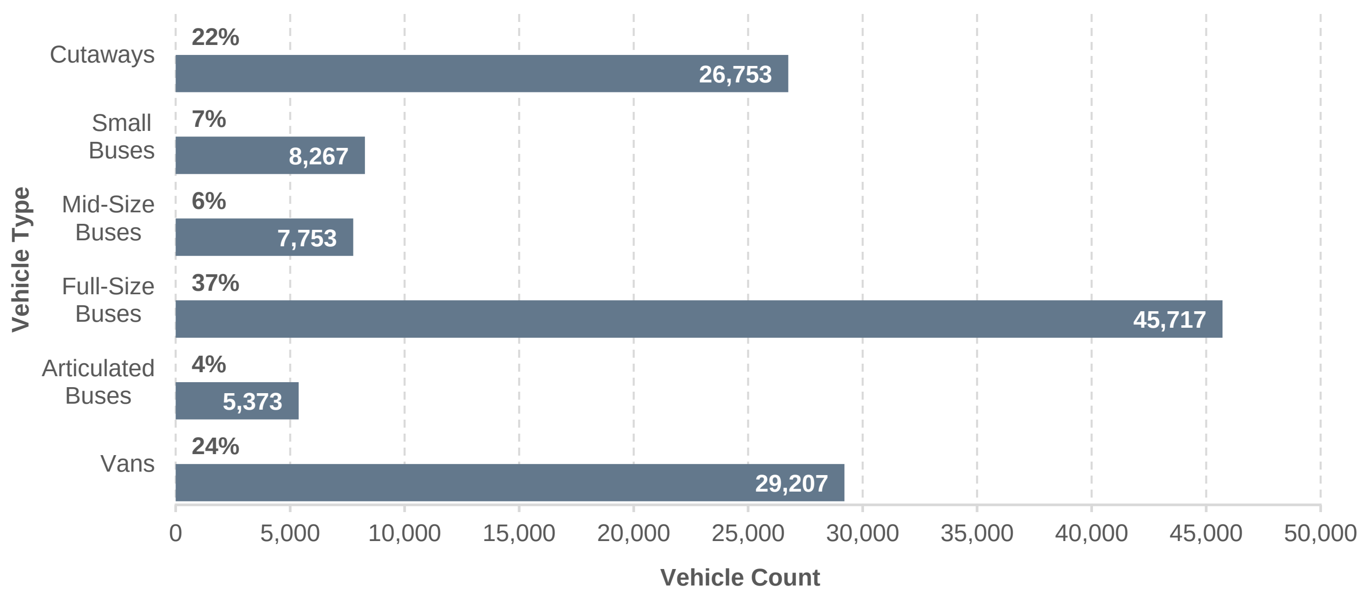
[2] Includes aerial tramway vehicles, automated guideway vehicles, automobiles, cable cars, cutaway, ferryboats, inclined plane vehicles, monorail vehicles, sport utility vehicles, trolleybuses, and vintage trolleys.

[3] Source for "Special Service Vehicles" is the FTA, Fiscal Year Trends Report on the Use of Section 5310 Elderly and Persons with Disabilities Program Funds, 2002.

[4] Includes articulated buses, buses, double decked buses, and over-the-road-buses.

Source: National Transit Database.

Exhibit 1-20: Composition of Transit Road Vehicle Fleet, 2014



Note: There is not a one-to-one map between modes and vehicle types. For instance, cutaways are used for both fixed-route bus and demand response. In addition, TERM uses a different classification for vehicle types than does NTD.

Source: Transit Economic Requirements Model (TERM) and National Transit Database.

Exhibit 1-21: Stations and Fleet by Mode, 2014

Transit Mode	Active Vehicles	Total Stations
Rail		
Heavy Rail	11,623	1,130
Commuter Rail	7,305	1,245
Light Rail	2,071	828
Alaska Railroad	95	11
Monorail/Automated Guideway	159	58
Cable Car	39	0
Inclined Plane	6	6
Hybrid Rail	55	55
Streetcar Rail	86	86
Total Rail	**21,672**	**3,419**
Nonrail		
Bus	65,592	1,476
Demand Response	49,398	0
Vanpool	15,071	0
Ferryboat	166	101
Trolleybus	544	5
Público	2,310	0
Bus Rapid Transit	496	27
Commuter Bus	5,979	234
Demand-Response - Taxi	7,092	0
Aerial Tramway	61	2
Total Nonrail	**146,709**	**1,845**
Total All Modes	**168,381**	**5,264**

Source: National Transit Database.

Track and Maintenance Facilities

Exhibit 1-22 shows maintenance facility counts broken down by mode and by size of urbanized area for directly operated service. Modes such as hybrid rail, demand-response taxi, and público are not included because all such service is purchased. Chapter 6 includes data on the age and condition of these facilities.

A single facility can be used by more than one mode. In these cases, the count of facilities is prorated based on the number of peak vehicles for each mode.

As *Exhibit 1-23* shows, transit rail providers (including other rail and tramway providers) operated 12,794 miles of track in 2014. The Nation's rail system mileage is dominated by the longer distances generally covered by commuter rail. Light and heavy rail typically operate in more densely developed areas and have more stations per track mile.

Exhibit 1-22: Maintenance Facilities, 2014

Maintenance Facility Type[1]	Over 1 Million	Under 1 Million and Rural Areas	Total
Heavy Rail	58	0	58
Commuter Rail	76	8	84
Light Rail	38	1	39
Streetcar Rail	11	4	15
Other Rail[2]	6	5	11
Fixed-Route Bus	449	387	837
Commuter Bus	73	30	103
Bus Rapid Transit	2	1	4
Demand Response	255	266	521
Vanpool	17	7	23
Ferryboat	13	8	21
Trolleybus	4	1	5
Rural Transit[3]	0	729	729
Total Maintenance Facilities	**1,003**	**1,448**	**2,451**

[1] Directly operated service only. Includes owned and leased facilities.

[2] Alaska railroad, automated guideway, cable car, inclined plane, and monorail.

[3] Vehicles owned by operators receiving funding from FTA as directed by 49 USC Section 5311. These funds are for transit services in areas with populations of less than 50,000. (Section 5311 Status of Rural Public Transportation 2000, Community Transportation Association of America, April 2001).

Source: National Transit Database.

Exhibit 1-23: Transit Rail Mileage and Stations, 2014

Urbanized Area Track Mileage	
Heavy Rail	2,274
Commuter Rail	7,760
Light Rail	1,529
Hybrid Rail	202
Streetcar Rail	301
Other Rail and Tramway[1]	729
Total Urbanized Area Track Mileage	**12,794**
Urbanized Area Transit Rail Stations Count	
Heavy Rail	1,130
Commuter Rail	1,245
Light Rail	828
Hybrid Rail	55
Streetcar Rail	86
Other Rail and Tramway[1]	77
Total Urbanized Area Transit Rail Stations	**3,421**

[1] Alaska railroad, automated guideway, cable car, inclined plane, monorail, and aerial tramway.

Source: National Transit Database.

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CHAPTER 2
Funding

Highway Funding

This chapter presents data and analyses on funding trends for highways and transit across all levels of government and sources of funding. The revenue sources for investments in highways and bridges are discussed first, followed by details on total highway expenditures and, more specifically, capital outlays. A separate section presents data on transit system funding, highlighting trends in revenues, capital, and operating expenditures.

The classification of the revenue and expenditure items in this section is based on definitions contained in A Guide to Reporting Highway Statistics (http://www.fhwa.dot.gov/policyinformation/hss/guide/guide.pdf), which is the instructional manual for States providing financial data for the Highway Statistics publication (http://www.fhwa.dot.gov/policyinformation/statistics.cfm).

Revenue Sources for Highways

The revenue collected in 2014 from all levels of government for highways and bridges was $241.1 billion, as illustrated in *Exhibit 2-1*. Of the total revenues generated, the Federal government contributed $54.9 billion; State governments, $121.4 billion; and local governments, $64.8 billion.

These revenues were raised from user charges (motor-fuel taxes, motor-vehicle taxes and fees, and tolls) and several other sources (General Fund appropriations, other taxes, investment income, and debt financing). In 2014, the overall split between user charges and other sources was 44.1 percent versus 55.9 percent. The reliance on different sources, however, differs significantly by level of government.

Key Takeaways

- The revenue collected in 2014 from all levels of government for highways and bridges was $241.1 billion. All levels of government combined spent $222.6 billion for highways in 2014. The difference of $18.6 billion between the total revenues and the total expenditures during the year represents an increase in the Federal, State, and local combined cash balances in 2014.
- In 2014, the overall split between user charges and other sources was 44.1 percent versus 55.9 percent. The reliance on different sources, however, differs significantly by level of government. After 2008, due to flat user revenues and transfers to keep the Highway Trust Fund solvent, the share of user revenues fell below 50 percent.
- Of the $105.4 billion in total highway capital outlay in 2014, an estimated $65.4 billion (62.0 percent) was used for system rehabilitation, $25.9 billion (24.5 percent) was used for system expansion, and $14.2 billion (13.5 percent) was used for system enhancement.
- Total capital outlays on Federal-aid highways were $79.3 billion in 2014. During the same year, capital outlays for the National Highway System and the Interstate System amounted to $56.3 billion and $25.3 billion, respectively.
- From 2004 to 2014, federally funded highway expenditures decreased at an average annual rate of 0.5 percent in constant-dollar terms. The State and local constant-dollar expenditures grew by an average 1.3 percent annually for the same period.
- Many States are increasingly adopting nontraditional financing and delivery methods for transportation projects. They include a variety of public-private partnerships and debt-financing mechanisms.

Exhibit 2-1: Government Revenue Sources for Highways, 2014

Source	Highway Revenue, Billions of Dollars				
	Federal	State	Local	Total	Percent
User Charges[1]					
Motor-Fuel Taxes	$28.0	$31.7	$1.0	$60.6	25.1%
Motor-Vehicle Taxes and Fees	$4.9	$24.5	$2.1	$31.4	13.0%
Tolls	$0.0	$12.3	$2.1	$14.3	5.9%
Subtotal	**$32.8**	**$68.4**	**$5.2**	**$106.4**	**44.1%**
Other					
Property Taxes and Assessments	$0.0	$0.0	$12.8	$12.8	5.3%
General Fund Appropriations[2]	$20.6	$9.6	$26.2	$56.5	23.4%
Other Taxes and Fees	$0.4	$10.3	$6.7	$17.4	7.2%
Investment Income and Other Receipts[3]	$1.0	$10.1	$7.6	$18.7	7.8%
Bond Issue Proceeds	$0.0	$22.9	$6.3	$29.2	12.1%
Subtotal	**$22.1**	**$53.0**	**$59.7**	**$134.7**	**55.9%**
Total Revenues	**$54.9**	**$121.4**	**$64.8**	**$241.1**	**100.0%**
Funds Drawn From (or Placed in) Reserves	($7.6)	($10.2)	($0.8)	($18.6)	-7.7%
Total Expenditures Funded During 2014	**$47.3**	**$111.2**	**$64.1**	**$222.6**	**92.3%**

[1] Amounts shown represent only the portion of user charges that are used to fund highway spending; a portion of the revenue generated by motor-fuel taxes, motor-vehicle taxes and fees, and tolls is used for mass transit and other nonhighway purposes. Gross receipts generated by user charges totaled $136.8 billion in 2014.

[2] The $20.6 billion shown for Federal includes $17.4 billion transferred from the general fund to the Highway Account of the Highway Trust Fund. The remainder supported expenditures by the FHWA and other Federal agencies that were not paid for from the Highway Trust Fund.

[3] The $1.0 billion figure shown for Federal includes $1.0 billion transferred from the balance of the Leaking Underground Storage Tank Fund to the Highway Account of the Highway Trust Fund.

Sources: Highway Statistics 2015, Table HF-10A (preliminary), and unpublished FHWA data.

User charges, in particular motor-fuel taxes, account for most of the Federal revenues raised for highways—60.0 percent in 2014. User charges also account for most of the revenues that State governments raise. In 2014, State governments raised $121.4 billion of highway funding, of which $68.4 billion (56 percent) derived from State-imposed fees on highway users. Funding from other sources ($53.0 billion) included $22.9 billion from bond sale proceeds. In contrast, the revenues that local governments raise for highways derive mainly from sources other than user charges. This difference is partly because many States prohibit local governments from imposing taxes on motor fuel or motor vehicles—and where local taxes are allowed, they are often capped at low rates. The source on which local governments rely most heavily for highways is General Fund appropriations, which in 2014 accounted for 40.0 percent, or $26.2 billion, of the total $64.8 billion in revenue raised. The next largest sources were property taxes and investment income, at $12.8 billion and $7.6 billion. User charges generated only $5.2 billion of revenue.

As shown in *Exhibit 2-1*, all levels of government combined spent $222.6 billion for highways in 2014. The $18.6-billion difference between total revenues and expenditures represents an increase in the Federal, State, and local combined cash balances in 2014.

Disposition of Highway-User Revenue by Level of Government in 2014

The $106.4 billion identified as highway-user charges in *Exhibit 2-1* represents only 77.8 percent of total highway-user revenue, defined as all revenue generated by motor-fuel taxes, motor-vehicle taxes, and tolls. *Exhibit 2-2* shows that combined highway-user revenue collected in 2014 by all levels of government totaled $136.8 billion.

In 2014, $16.2 billion of highway-user revenue was used for transit, and $14.2 billion was used for other purposes, such as ports, schools, collection costs, and general government activities. The $1.7 billion shown as Federal highway-user revenue used for other purposes reflects the difference between total collections in 2014 and the amounts deposited into the Highway Trust Fund during Fiscal Year 2014. Much of this difference is attributable to the proceeds from the deposits of the 0.1-cent-per-gallon portion of the Federal motor-fuel tax into the Leaking Underground Storage Tank Trust Fund.

The $5.9 billion shown as Federal highway-user revenue used for transit includes deposits into the Transit Account of the Highway Trust Fund and deposits into the Highway Account of the Highway Trust Fund that States elected to use for transit purposes.

Exhibit 2-2: Disposition of Highway-User Revenue by Level of Government, 2014

Revenue Use	Revenue, Billions of Dollars			
	Federal	State	Local	Total
Highways	$32.8	$68.4	$5.2	$106.4
Transit	$5.9	$9.2	$1.2	$16.2
Other	$1.7	$12.4	$0.1	$14.2
Total Collected	**$40.4**	**$90.0**	**$6.4**	**$136.8**

Source: Highway Statistics 2015, Table HF-10A (preliminary).

Total proceeds to the Highway Account of the Highway Trust Fund (HTF) have been less than expenditures out of the Highway Account for every year since 2001 except 2005. A total of $53.0 billion was transferred from the Federal General Fund to the Highway Account in 2008, 2009, 2010, 2013, and 2014 to keep the account solvent. In 2014, $17.4 billion was transferred from the Federal General Fund to the HTF Highway Account. In addition, in 2014, $1.0 billion was transferred from the balance of the Leaking Underground Storage Tank Fund to the Highway Account. The 2014 amount is identified as “Investment Income and Other Receipts” in *Exhibit 2-1*, although the original source of these funds was revenues generated in prior years from a 0.1-cent-per-gallon tax on motor fuels.

The Investment Income and Other Receipts category in *Exhibit 2-1* includes development fees and special district assessments and private-sector investment in highways, to the extent that such investment is captured in State and local accounting systems.

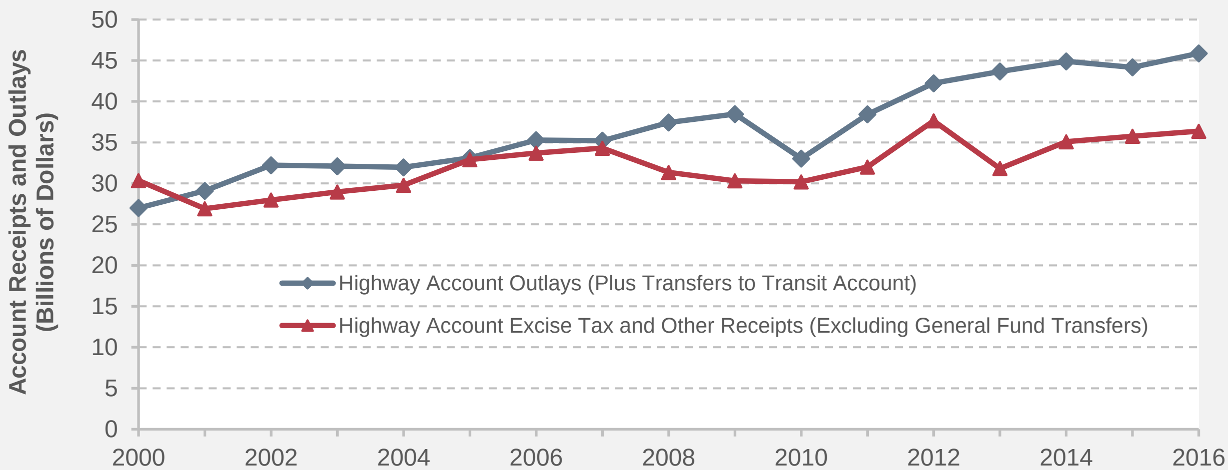
Financing for highways comes from both the public and private sectors. The private sector has increasingly been instrumental in the delivery of highway infrastructure, but the public sector still provides the vast majority of funding. The financial statistics presented in this chapter are drawn predominantly from State reports based on State and local accounting systems. Figures in these systems can include some private-sector investment; where so, these amounts are generally classified as “Other Receipts.” For additional information on public-private partnerships (P3s) in transportation, see (http://www.fhwa.dot.gov/ipd/p3).

HTF Highway Account Excise Tax Receipts and Expenditures

The last time that annual net receipts credited to the Highway Account of the HTF exceeded annual expenditures from the Highway Account was in 2000. As shown in *Exhibit 2-3*, for each year since 2000, total annual receipts to the Highway Account from excise taxes and other income (such as interest income and motor-carrier safety fines and penalties) have been lower than the annual expenditures from the Highway Account (including amounts transferred to the Transit Account).

The HTF Highway Account receipts and outlays shown in *Exhibit 2-3* do not include transfers from the General Fund. To help maintain a positive cash balance in the HTF, transfers from the General Fund to the HTF were legislatively mandated in Fiscal Years 2008, 2009, 2010, 2013, and 2014. In Fiscal Years 2012 and 2014, funds were also transferred from the balance of the Leaking Underground Storage Tank Fund to the HTF; the original source of these funds was revenues generated in previous years from a 0.1-cent-per-gallon portion of the Federal tax on motor fuels.

Exhibit 2-3: Highway Trust Fund Highway Account Receipts and Outlays, Fiscal Years 2000–2016



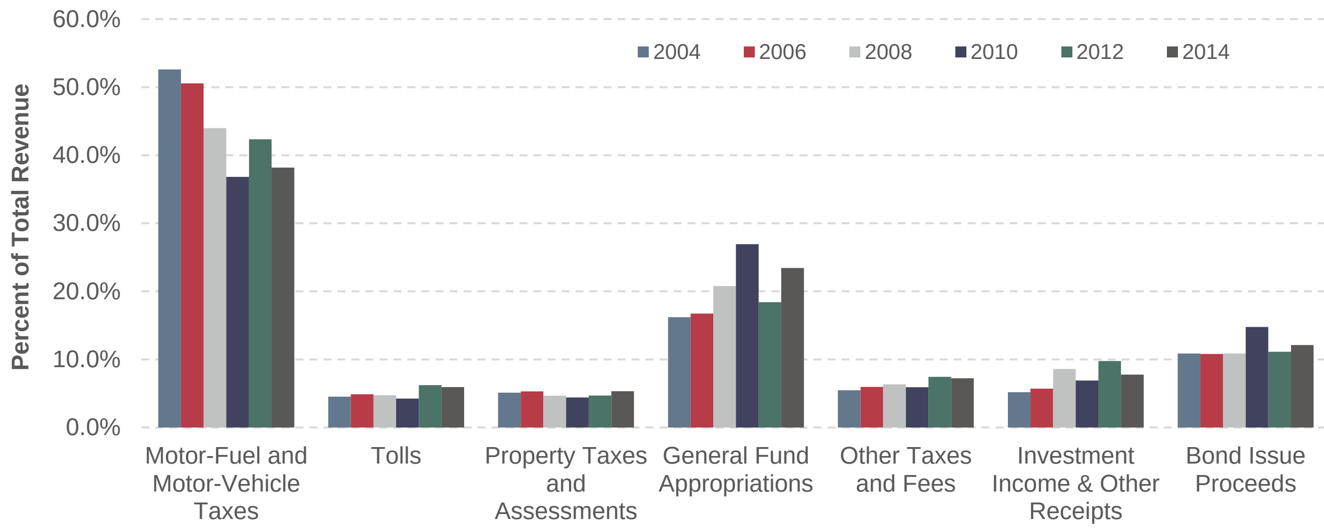
Source: Highway Statistics, various years, Tables FE-210 and FE-10.

Revenue Trends

Following passage of the Federal-aid Highway Act of 1956 and establishment of the HTF, user charges such as motor-fuel taxes, motor-vehicle taxes, and tolls consistently provided most of the combined revenues raised for highway and bridge programs by all levels of government for many years. However, after 2008, due to flat user revenues and transfers to keep the HTF solvent, the share of user revenues fell below 50 percent.

Exhibit 2-4 shows the trends in revenues used for highways by source for all levels of government from 2004 to 2014. From 2012 to 2014, total revenues generated for highways increased from $216.6 billion to $241.1 billion. This increase was driven mainly by a $16.7 billion jump in General Fund appropriations and a $5.2 billion increase in bond issue proceeds. All other sources of revenue also increased between these two years, except for investment income, which fell by $2.4 billion. The combined motor-fuel and motor-vehicle tax revenues rose by $0.6 billion, while toll revenues rose by $0.9 billion. Revenues from property taxes and other taxes went up by $2.7 and $1.3 billion respectively.

Exhibit 2-4: Government Revenue Sources for Highways, 2004–2014



Source	Highway Revenue, Billions of Dollars						Annual Rate of Change 2014/2004
	2004	2006	2008	2010	2012	2014	
Motor-Fuel and Motor-Vehicle Taxes	$76.4	$85.4	$84.7	$84.1	$91.5	$92.1	1.9%
Tolls	$6.6	$8.3	$9.1	$9.7	$13.5	$14.3	8.1%
Property Taxes and Assessments	$7.5	$9.0	$9.0	$10.1	$10.1	$12.8	5.6%
General Fund Appropriations	$23.6	$28.3	$40.0	$61.5	$39.8	$56.5	9.1%
Other Taxes and Fees	$7.9	$10.1	$12.2	$13.5	$16.1	$17.4	8.2%
Investment Income & Other Receipts	$7.6	$9.7	$16.6	$15.8	$21.1	$18.7	9.5%
Bond Issue Proceeds	$15.8	$18.3	$20.9	$33.7	$24.0	$29.2	6.3%
Total Revenues	**$145.3**	**$169.0**	**$192.6**	**$228.3**	**$216.1**	**$241.1**	**5.2%**

Source: Highway Statistics, various years, Tables HF-10A and HF-10.

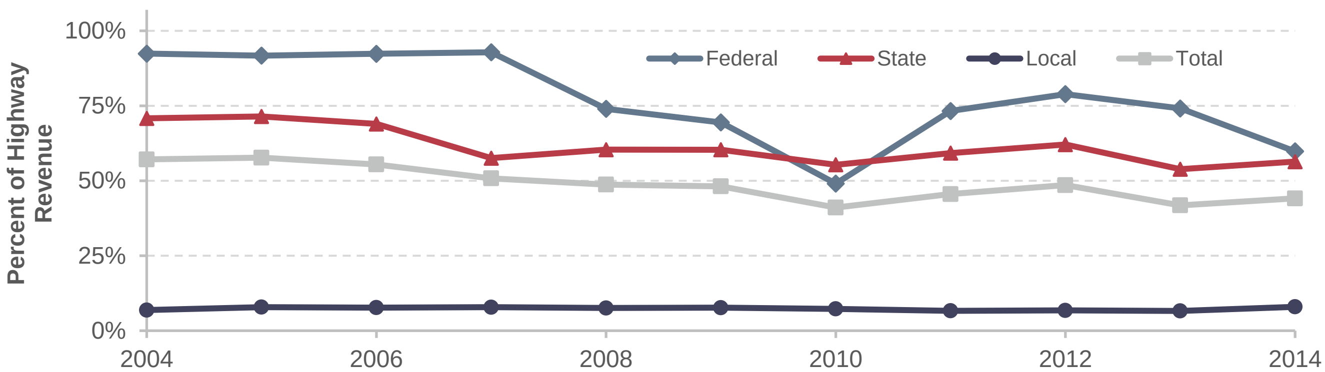
From 2004 to 2014, total revenues for highways increased at an annual rate of 5.2 percent. The increase in motor-fuel and motor-vehicle taxes revenues was 1.9 percent, the lowest among the funding sources. At the opposite end, investment income and other receipts increased at the highest average annual rate, 9.5 percent, over the 10-year period. General Fund appropriations are next with an increase of 9.1 percent per year, despite the recent decline from their peak in 2010. The average annual increases in highway revenues over the same period from other taxes and fees, tolls, and property taxes were 8.2, 8.1, and 5.6 percent respectively.

The graph at the top of *Exhibit 2-4* shows the percentage share of each funding source by year for 2004–2014. After 2006, the share of revenues from user charges, excluding tolls, had declined from more than 50 percent to around 40 percent.

Exhibit 2-5 shows the change in the share of highway revenue derived from user charges by level of government. The share declined at the Federal and State levels while remaining steady at the local level from 2004 to 2014. At the Federal level, the decline from 2007 to 2010 can be attributed in part to General Fund transfers to the HTF and to General Funds provided for highway improvements through the Recovery Act. Between 2010 and 2014, the percentage of Federal highway revenue derived from user charges increased from

49.1 percent to 59.8 percent (though it fell from 2012 to 2014). The State and local governments' user revenue share also increased slightly during this period.

Exhibit 2-5: Percentages of Highway Revenue Derived from User Charges, Each Level of Government, 2004–2014



Source: Highway Statistics, various years, Tables HF-10A and HF-10.

State Revenue Actions

In addition to Federal funding, States use a variety of revenue sources to support their transportation expenditures. These revenue sources include State fuel taxes, vehicle fees, sales taxes, tolls, mode-specific revenues, cigarette taxes, and State lotteries.

According to the 2016 AASHTO report *A 50-State Review of State Legislatures and Departments of Transportation*, State taxes on motor fuels are the largest single source of State revenues for highways, representing more than 30 percent of such revenues nationwide. Over the past decades, fuel tax rates have fallen in real terms because the Federal fuel tax and many State fuel taxes are fixed at static cents-per-gallon rates. In response, many States have structured their fuel tax rates to change over time. Some of these taxes are periodically adjusted based on a measure of inflation, while others are calculated as a percentage of wholesale or retail fuel prices, or by some other criterion. In addition to fuel taxes, some States have structured other taxes and fees so that they keep up with inflation. For example, in Maryland, transit fares are indexed to the Consumer Price Index, as are some toll revenues in Florida. In addition to the impacts of inflation, fuel tax revenues are affected by the increasing fuel efficiency of the vehicle fleet and the use of alternative fuels that may not be taxed or taxed at lower rates.

Tolling is another source of revenue for funding transportation projects. Tolling involves charging fees for the use of a roadway facility. Tolls may be charged as a flat, per-use fee on motorists to use a highway, or they may involve the imposition of fees or tolls that vary by level of vehicle demand on a highway facility (also known as road pricing, congestion pricing, value pricing, or variable pricing). While pricing generates revenue, this strategy also seeks to manage congestion, environmental impacts, and other external costs occasioned by road users.

State and local governments also rely on a variety of nonroad revenue mechanisms to generate revenue that may be tied to specific transportation projects, such as local option taxes, value capture, fares, and other nonpricing revenue sources. Such strategies can be used to help pay for highway improvements by leveraging localized benefits ranging from increased land values to a broader tax base.

Many States have also shown interest in the possibility of charging drivers based on the number of miles they drive, known as "mileage-based user fees." In July 2015, Oregon was the first State to test a mileage-based user fee. Oregon's program is designed to collect 1.5 cents per mile from up to 5,000 cars and light commercial vehicles, and to deposit the revenues to the State's highway fund. In addition, the Federal Fixing America's Surface Transportation (FAST) Act provides $95 million over 5 years in grants for States to "demonstrate user-based alternative revenue mechanisms that utilize a user fee structure to maintain the long-term solvency of the HTF." Additional information on revenue is available at (https://www.fhwa.dot.gov/ipd/revenue/).

Highway Expenditures

Highway expenditures by all levels of government combined totaled $222.6 billion in 2014, as shown in *Exhibit 2-1*. *Exhibit 2-6* breaks down the Federal, State, and local expenditures by type. The rows "Funding Sources for Capital Outlay" and "Funding Sources for Total Expenditures" indicate the level of government that provided the funding for those expenditures. These expenditures represent cash outlays, not authorizations or obligations of funds. (The terms "expenditures," "spending," and "outlays" are used interchangeably in this report.)

Exhibit 2-6: Direct Expenditures for Highways by Expending Agency and Type, 2014

	Highway Expenditures (Billions of Dollars)				
	Federal	State	Local	Total	Percent
Expenditures by Type					
Capital Outlay	**$0.7**	**$80.5**	**$24.2**	**$105.4**	**47.4%**
Noncapital Expenditures					
Maintenance	$0.2	$16.2	$21.8	$38.2	17.2%
Highway and Traffic Services	$0.0	$7.3	$6.0	$13.2	6.0%
Administration	$2.3	$8.4	$5.7	$16.4	7.4%
Highway Patrol and Safety	$0.0	$9.5	$10.3	$19.8	8.9%
Interest on Debt	$0.0	$8.2	$3.3	$11.5	5.2%
Subtotal	**$2.5**	**$49.5**	**$47.2**	**$99.2**	**44.6%**
Total, Current Expenditures	**$3.2**	**$130.0**	**$71.4**	**$204.6**	**91.9%**
Bond Retirement	**$0.0**	**$11.6**	**$6.3**	**$17.9**	**8.1%**
Total, All Expenditures	**$3.2**	**$141.6**	**$77.7**	**$222.6**	**100.0%**
Funding Sources for Capital Outlay[1]					
Funded by Federal Government	*$0.7*	*$43.4*	*$0.7*	*$44.8*	*42.5%*
Funded by State or Local Governments	*$0.0*	*$37.1*	*$23.5*	*$60.6*	*57.5%*
Total	***$0.7***	***$80.5***	***$24.2***	***$105.4***	***100.0%***
Funding Sources for Total Expenditures[1]					
Funded by Federal Government	*$3.2*	*$43.4*	*$0.7*	*$47.3*	*21.2%*
Funded by State Governments	*$0.0*	*$95.1*	*$16.1*	*$111.2*	*50.0%*
Funded by Local Governments	*$0.0*	*$3.2*	*$60.9*	*$64.1*	*28.8%*
Total	***$3.2***	***$141.7***	***$77.7***	***$222.6***	***100.0%***

[1] Amounts shown in italics are provided to link this table back to revenue sources shown in Exhibit 6-1. These are nonadditive to the rest of the table, which classifies spending by expending agency.

Sources: Highway Statistics 2015, Table HF-10A (preliminary), and unpublished FHWA data.

Even though the Federal government funded $47.3 billion of highway expenditures in 2014, direct Federal spending on capital outlay, maintenance, administration, and research was only $3.2 billion (1.4 percent of all highway expenditures). The remaining $44.1 billion was in the form of transfers to State and local governments.

State governments combined $43.4 billion of Federal funds, $95.1 billion of State funds, and $3.2 billion of local funding sources to support direct expenditures of $141.7 billion (63.6 percent of all highway expenditures). Local governments directly spent $0.7 billion of Federal funds, $16.1 billion of State funds, and $60.9 billion of local funds on highways, totaling $77.7 billion (34.9 percent of all highway expenditures).

Types of Highway Expenditures

Definitions for selected expenditure category types referenced in this section are as follows:

- **Capital outlay:** highway improvements such as new construction, reconstruction, resurfacing, rehabilitation, and restoration; and installation of guardrails, fencing, signs, and signals. It also includes the cost of land acquisition and other right-of-way costs and preliminary and construction engineering, in addition to construction costs.
- **Maintenance:** routine and regular expenditures required to keep the highway surface, shoulders, roadsides, structures, and traffic control devices in usable condition. These efforts include spot patching and crack sealing of roadways and bridge decks, and maintaining and repairing highway utilities and safety devices, such as route markers, pavement markings, signs, guardrails, fences, signals, and highway lighting.
- **Highway and traffic services:** activities designed to improve the operation and appearance of the roadway, including items such as the operation of traffic control systems, snow and ice removal, highway beautification, litter pickup, mowing, toll collection, and air quality monitoring.
- **Current expenditures:** all highway expenditures except for bond retirement (principal only).
- **Noncapital expenditures:** all current expenditures except for capital outlay. (Includes interest payments on bonds.)

As shown in *Exhibit 2-6*, $105.4 billion, or 47.4 percent of spending by all levels of government on highways in 2014, was used for capital outlays. Additional information on types of capital outlay and the distribution of capital outlay by type of highway facility is presented later in this chapter. Combined spending on maintenance and traffic services of $51.6 billion represented 23.2 percent of total highway expenditures.

Most Federal funding for highways is for capital outlay rather than noncapital expenditures, which State and local governments primarily fund. The Federal government funded 42.5 percent of capital outlay in 2014, but only 21.2 percent of total highway expenditures.

In terms of direct highway expenditures by expending agency, State expenditures represent a majority of total spending for most expenditure types except for highway patrol and safety, and maintenance. Local governments spent $21.1 billion on maintenance in 2014, which is 56.3 percent of total maintenance spending by all levels of government combined. Local governments also spent $10.3 billion on highway patrol and safety expenditures, representing 52.0 percent of combined spending on these activities by all levels of government.

Historical Expenditure and Funding Trends

Exhibit 2-7 breaks out expenditures since 2004 by type. The largest percentage increases are related to debt service, as bond retirement expenditures grew at an average annual rate of 8.4 percent from 2004 to 2014, while interest on debt grew at an average annual rate of 7.1 percent. Total highway expenditures grew by

4.2 percent per year over this period in nominal dollar terms. Capital outlay rose at an average annual rate of 4.1 percent, thus maintaining its share of total expenditures.

Exhibit 2-7: Expenditures for Highways by Type, All Units of Government, 2004–2014

Expenditure Type	Highway Expenditures, Billions of Dollars						Annual Rate of Change 2014/2004
	2004	2006	2008	2010	2012	2014	
Capital Outlay	$70.3	$80.2	$90.4	$100.0	$105.3	$105.4	4.1%
Maintenance and Traffic Services	$36.3	$40.8	$45.9	$46.3	$48.5	$51.4	3.5%
Administration	$12.7	$13.1	$17.8	$16.5	$16.0	$16.4	2.6%
Highway Patrol and Safety	$14.3	$14.7	$17.3	$16.8	$18.3	$19.8	3.3%
Interest on Debt	$5.8	$6.6	$8.5	$10.1	$11.5	$11.5	7.1%
Total, Current Expenditures	**$139.5**	**$155.5**	**$180.0**	**$189.7**	**$199.5**	**$204.6**	**3.9%**
Bond Retirement	$8.0	$8.1	$8.6	$14.6	$18.9	$17.9	8.4%
Total, All Expenditures	**$147.5**	**$163.5**	**$188.5**	**$204.3**	**$218.4**	**$222.6**	**4.2%**

Source: Highway Statistics, various years, Tables HF-10A and HF-10.

Exhibit 2-8 shows that Federal expenditures for highways increased in nominal terms between 2004 and 2014; however, it declined slightly in real terms using the inflation rate for highway construction (see the Constant-Dollar Expenditures section below). The portion of total highway expenditures funded by the Federal Government declined from 22.4 percent in 2004 to 21.2 percent in 2014. The federally funded share of highway capital outlays exceeded 50 percent each year from 1976 to 1986. Since then, this share has typically varied from 41 to 46 percent. In 1998, 1999, and 2007, however, it fell below 40 percent. From 2005 through 2014, the average of the federally funded share of highway capital outlay was 43.0 percent. The federally funded share of 42.5 percent in 2014 is slightly below the 10-year average.

Exhibit 2-8: Funding for Highways by Level of Government, 2004–2014

	Highway Funding, Billions of Dollars						Annual Rate of Change 2014/2004
	2004	2006	2008	2010	2012	2014	
Capital Outlay							
Funded by Federal Government	$30.8	$34.6	$37.6	$43.3	$45.3	$44.8	3.8%
Funded by State or Local Governments	$39.5	$45.6	$52.8	$56.7	$60.0	$60.6	4.4%
Total	**$70.3**	**$80.2**	**$90.4**	**$100.0**	**$105.3**	**$105.4**	**4.1%**
Federal Share	**43.8%**	**43.1%**	**41.6%**	**43.3%**	**43.0%**	**42.5%**	
Total Expenditures							
Funded by Federal Government	$33.1	$36.3	$39.8	$46.1	$47.3	$47.3	3.6%
Funded by State Governments	$72.8	$77.4	$96.6	$98.7	$105.2	$111.2	4.3%
Funded by Local Governments	$41.6	$49.8	$52.2	$59.5	$65.8	$64.1	4.4%
Total	**$147.5**	**$163.5**	**$188.5**	**$204.3**	**$218.4**	**$222.6**	**4.2%**
Federal Share	**22.4%**	**22.2%**	**21.1%**	**22.6%**	**21.7%**	**21.2%**	

Source: Highway Statistics, various years, Tables HF-10A and HF-10.

The Federal expenditure figures for 2010 include $11.9 billion funded by the Recovery Act. This figure dropped to $3.0 billion by 2012 and $0.2 billion by 2014 as most Recovery Act projects were completed. Federally funded highway expenditures remained at $47.3 billion between 2012 and 2014, while State funding increased from $105.8 billion to $111.2 billion. Local government highway funding declined slightly from $65.8 billion to $64.1 billion over the same period.

Constant-Dollar Expenditures

The types of inputs of materials and labor associated with various types of highway expenditures differ significantly; for example, on a dollar-per-dollar basis, highway maintenance activities are generally more labor-intensive than highway construction activities. This report uses different indices for converting nominal dollar highway spending to constant dollars for capital and noncapital expenditures. For constant-dollar conversions for highway capital expenditures, the Federal Highway Administration (FHWA) National Highway Construction Cost Index (NHCCI) version 2.0 is used. Constant-dollar conversions for other types of highway expenditures are based on the Bureau of Labor Statistics' Consumer Price Index.

Implications of the Revision of the FHWA National Highway Construction Cost Index

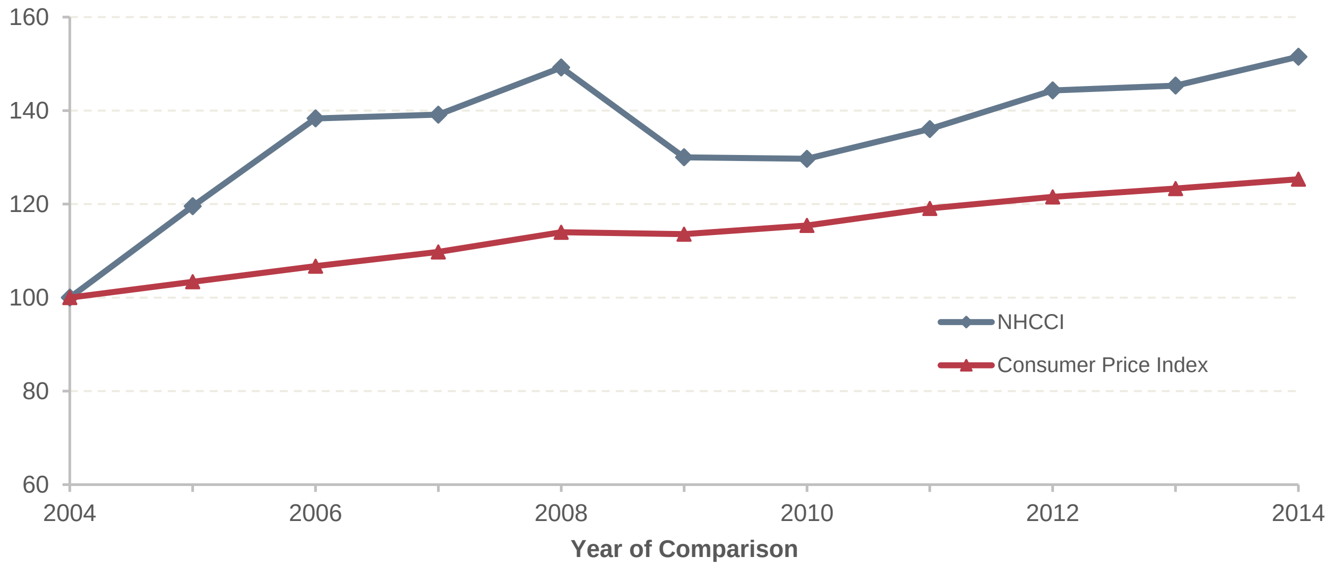
The National Highway Construction Cost Index, first published in 2009, is a price index intended to measure the average changes in the prices of highway construction costs over time and to convert nominal dollar highway construction expenditures to constant-dollar expenditures. FHWA uses data on State website postings of winning bids submitted on highway construction contracts to compile the NHCCI. The index covers the universe of the Nation's highway projects and represents an average cost index for all highway construction.

In recent years, the NHCCI index has exhibited stagnant or declining values. This trend was not consistent with the price changes exhibited by other national level price indicators, such as the Producer Price Index. Thus, FHWA initiated and completed an index review resulting in an updated NHCCI index version 2, published in 2017. The updated NHCCI is consistently higher than the previous index. This results in constant-dollar highway capital expenditures over time being lower than they would otherwise have been using the previous NHCCI.

Exhibit 2-9 illustrates the trends in cost indices used in the report, converted to a common base year of 2004. Over the 10-year period from 2004 to 2014, the Construction Cost Index increase of 51.5 percent (4.2 percent per year) is significantly higher than the increase in the Consumer Price Index of 25.3 percent (2.3 percent per year). In addition, the indices behaved differently.

For example, in the period between 2004 and 2008, sharp increases in the prices of materials such as steel, asphalt, and cement caused NHCCI to increase by 49.2 percent, compared with a 14.0-percent increase in the Consumer Price Index. Highway construction prices as measured by NHCCI subsequently declined but resumed their upward trend after 2010. Despite these fluctuations, this index is consistently higher than the Consumer Price Index from 2004 to 2014. The implication is that the purchasing power of a dollar in highway capital expenditures has declined more than in noncapital expenditures over that period.

Exhibit 2-9: Comparison of Inflation Indices (Converted to a 2004 Base Year), 2004–2014[1]



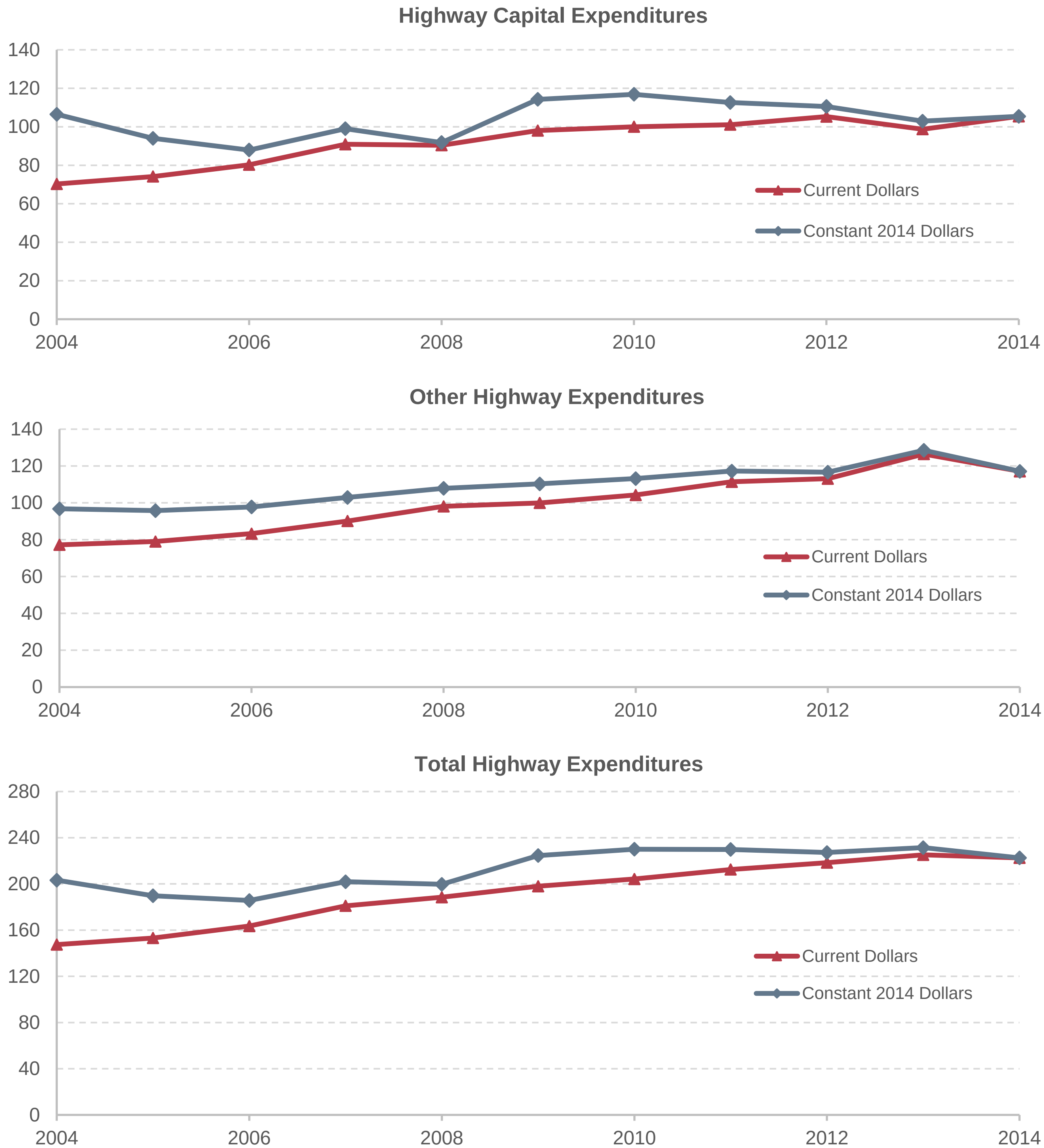
[1] To facilitate comparisons of trends from 2004 to 2014, each index was mathematically converted so that its value for the year 2004 would be equal to 100.

Sources: FHWA Highway Statistics, various years, Table PT-1 (http://www.bls.gov/cpi/).

Exhibits 2-10 and *2-11* display time-series data on highway expenditures in both current (nominal) and constant (real) 2014 dollars. Total highway expenditures in current dollars have generally increased from 2004, reaching 222.6 billion in 2014. However, total highway expenditures expressed in constant dollars have flattened after 2009. Total highway expenditures in current dollars increased by 50.9 percent between 2004 and 2014. Total noncapital (other) expenditures grew similarly in current dollars by 51.7 percent, and capital expenditures grew by 50.0 percent during the same period. When expressed in constant dollars, the growth in total highway expenditures between 2004 and 2014 was 9.5 percent. However, while constant-dollar noncapital expenditures grew by 21.0 percent, constant-dollar capital expenditures declined by 1.0 percent during the same period. The difference is due to the noncapital highway expenditures being converted to constant dollars using the Consumer Price Index, while NHCCI is applied for the capital highway expenditures. From 2004 to 2014, NHCCI increased by 51.5 percent, significantly higher than the increase in the Consumer Price Index of 25.3 percent.

From 2004 to 2014, federally funded highway expenditures decreased at an average annual rate of 0.5 percent in constant-dollar terms. This decrease was more than compensated for by an average 1.3 percent annual growth of State and local constant-dollar expenditures.

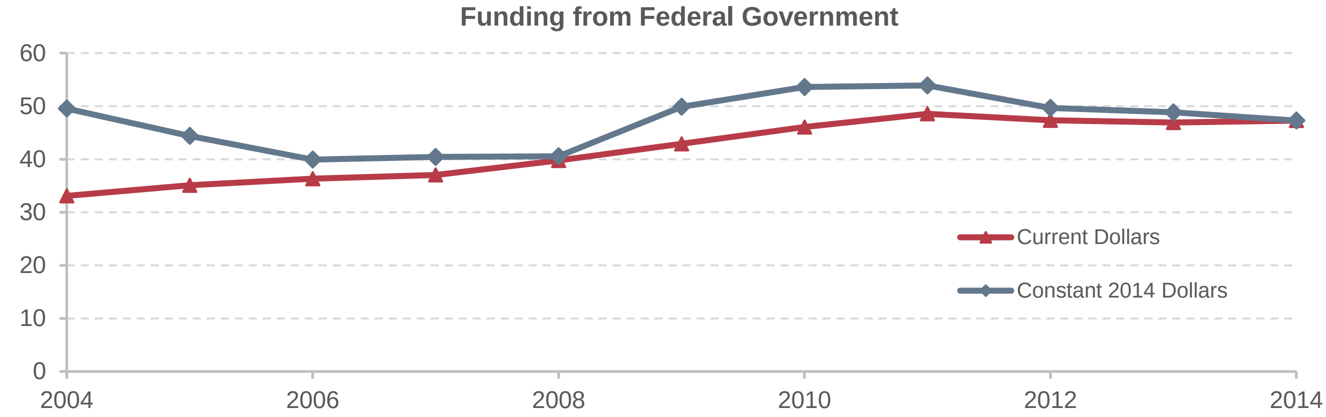
Exhibit 2-10: Highway Capital, Noncapital, and Total Expenditures in Current and Constant 2014 Dollars, All Units of Government, 2004–2014[1]

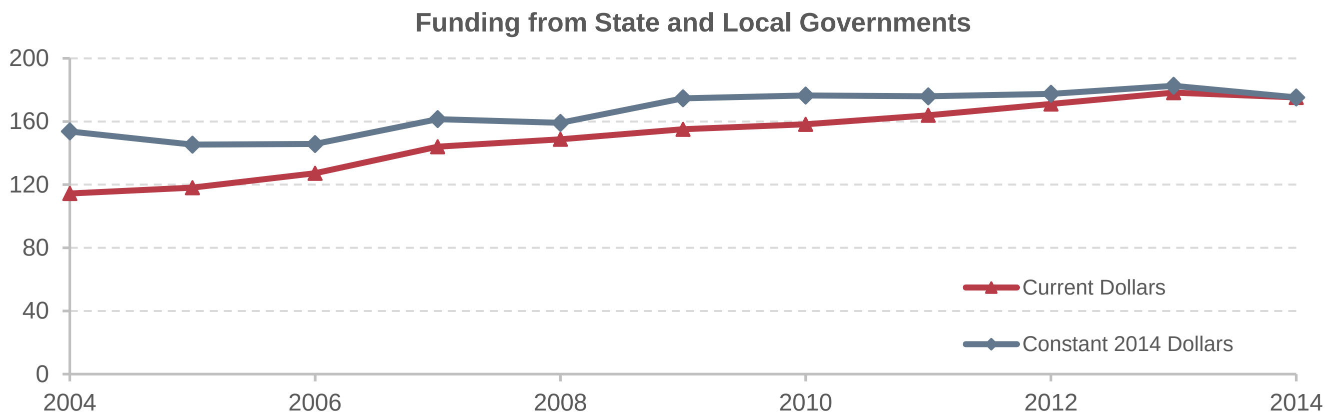


[1] Constant-dollar conversions for highway capital expenditures were made using the FHWA NHCCI. Constant-dollar conversions for other types of highway spending were made using the Bureau of Labor Statistics CPI.

Sources: Highway Statistics, various years, Tables HF-10A, HF-10, PT-1 (http://www.bls.gov/cpi/).

Exhibit 2-11: Highway Expenditures Funded by Federal and Non-Federal Sources in Current and Constant 2014 Dollars, 2004–2014[1]





[1] Constant-dollar conversions for highway capital expenditures were made using the FHWA NHCCI. Constant-dollar conversions for other types of highway spending were made using the Bureau of Labor Statistics CPI.

Sources: Highway Statistics, various years, Tables HF-10A, HF-10, PT-1 (http://www.bls.gov/cpi/).

Highway Capital Outlay

States provide FHWA with detailed data on what they spend on arterials and collectors, classifying capital outlay on each functional system into 17 improvement types. Direct State expenditures on arterials and collectors totaled $68.4 billion in 2014, drawing on a combination of State revenues, transfers from the Federal government, and transfers from local governments. However, comparable data are not available for local government expenditures, direct expenditures by Federal agencies, or State government expenditures on local functional class roads off the National Highway System (NHS). *Exhibit 2-12* presents an estimated distribution by broad categories of improvement types for the total $105.4 billion invested in 2014 on all systems, extrapolating from the available data on the $68.4 billion of State expenditures on arterials and collectors.

Exhibit 2-12 shows how the 17 highway capital improvement types have been allocated among three broad categories: system rehabilitation, system expansion, and system enhancement. These broad categories are also used in Part II of this report to discuss the components of future capital investment scenarios. These categories are defined as follows:

- **System rehabilitation:** capital improvements on existing roads and bridges intended to preserve the existing pavement and bridge infrastructure. These activities include reconstruction, resurfacing, pavement restoration or rehabilitation, widening of narrow lanes or shoulders, bridge replacement, and bridge rehabilitation. Also included is the portion of widening (lane addition) projects estimated for reconstructing or improving existing lanes. System rehabilitation does not include routine maintenance costs.
- **System expansion:** construction of new roads and new bridges and addition of new lanes to existing roads. Expansion includes all new construction, new bridges, and major widening, and most of the costs associated with reconstruction with added capacity, except for the portion of these expenditures estimated for improving existing lanes of a facility.
- **System enhancement:** safety enhancements, traffic operation improvements such as the installation of intelligent transportation systems, and environmental enhancements.

Exhibit 2-12: Highway Capital Outlay by Improvement Type, 2014

Type of Expenditure	Distribution of Capital Outlay, Billions of Dollars				
		System Expansion			
	System Rehabilitation	New Roads and Bridges	Existing Roads	System Enhancements	Total Outlay
Direct State Expenditures on Arterials and Collectors					
Right-of-Way		$1.6	$2.0		**$3.6**
Engineering	$5.5	$0.8	$1.1	$0.9	**$8.3**
New Construction		$4.7			**$4.7**
Relocation			$0.8		**$0.8**
Reconstruction—Added Capacity	$1.8		$4.3		**$6.1**
Reconstruction—No Added Capacity	$4.9				**$4.9**
Major Widening			$2.4		**$2.4**
Minor Widening	$0.8				**$0.8**
Restoration and Rehabilitation	$20.5				**$20.5**
Resurfacing	$0.0				**$0.0**
New Bridge		$1.0			**$1.0**
Bridge Replacement	$5.2				**$5.2**
Major Bridge Rehabilitation	$0.5				**$0.5**
Minor Bridge Work	$3.5				**$3.5**
Safety				$2.5	**$2.5**
Traffic Management/Engineering				$1.1	**$1.1**
Environmental and Other				$2.4	**$2.4**
Total, State Arterials and Collectors	**$42.8**	**$8.1**	**$10.6**	**$6.9**	**$68.4**
Total, Arterials and Collectors, All Jurisdictions (estimated)[1]					
Highways and Other	$39.0	$8.5	$12.5	$8.8	$68.8
Bridges	$11.0	$1.3			$12.3
Total, Arterials and Collectors	**$50.0**	**$9.8**	**$12.5**	**$8.8**	**$81.1**
Total Capital Outlay on All Systems (estimated)[1]					
Highways and Other	$51.0	$11.0	$13.2	$14.2	$89.4
Bridges	$14.4	$1.6			$16.0
Total, All Systems	**$65.4**	**$12.7**	**$13.2**	**$14.2**	**$105.4**
Percent of Total	**62.0%**	**12.0%**	**12.5%**	**13.5%**	**100.0%**

[1] Improvement type distribution was estimated based on State arterial and collector data.

Sources: Highway Statistics 2014, Table SF-12A, and unpublished FHWA data.

Of the $105.4 billion in total highway capital outlay, an estimated $65.4 billion (62.0 percent) was used for system rehabilitation, $25.9 billion (24.5 percent) was used for system expansion, and $14.2 billion (13.5 percent) was used for system enhancement. As shown in *Exhibit 2-12*, most types of highway capital improvement reported by States are assigned to one of these three broad categories; however, engineering is split among the three categories and reconstruction-added capacity is divided between system rehabilitation and system expansion.

Estimation Procedures Used for Exhibit 2-12

Exhibit 2-12 reflects two types of estimates, one for State government capital expenditures off the National highway system and another for direct local government and Federal government capital expenditures.

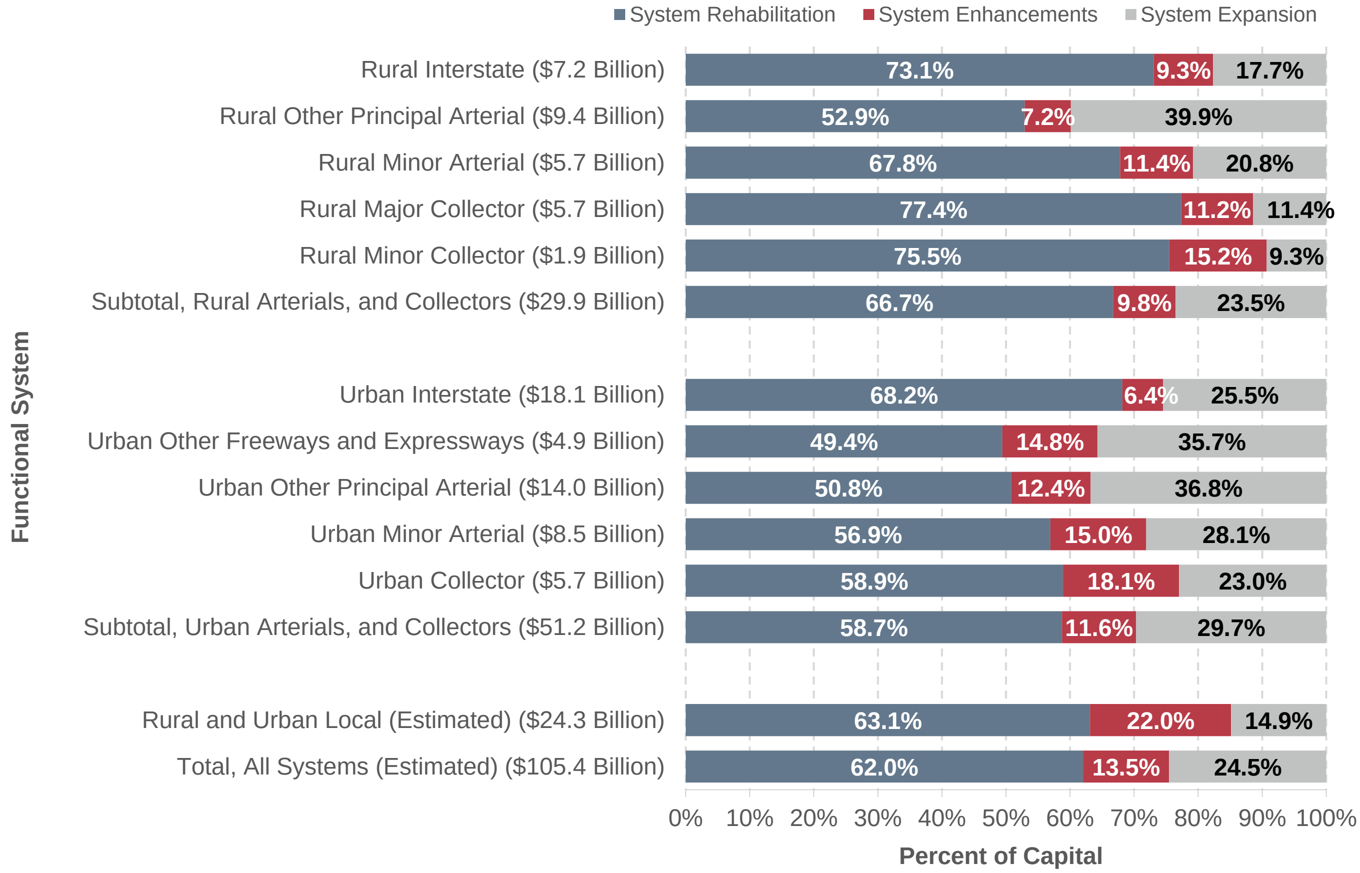
States report total capital expenditures via the FHWA-532 form and report detailed information on capital expenditures by improvement type and functional class on the FHWA-534 report. Reporting is optional for capital expenditures on local functional class roads off the National Highway System, so the differences between the totals reported on these two forms are inferred to represent spending on these roads. States voluntarily reported detailed capital expenditure data for $1.2 billion of their spending on local functional class roads in 2014, constituting 10.1 percent of total spending of $12.1 billion inferred to have occurred in that year. Of the $1.2 billion, States reported spending 64.6 percent for system preservation, 13.3 percent for system expansion, and 22.0 percent for system enhancement.

The percentage splits reported for local functional class roads were then compared with those reported for arterials and collectors, collectors, and rural minor collectors to identify any unexpected outliers. After minor adjustments based on this review, a distribution of 63.1 percent for system preservation, 14.9 percent for system expansion, and 22.0 percent for system enhancement was applied to the $12.1 billion inferred to have occurred on local functional class roads in 2014.

For direct local government expenditures and direct Federal government expenditures, the distribution of capital expenditure by improvement type off the NHS is assumed to be the same as that reported by States for each individual functional class. The share of local and Federal capital expenditures on the NHS and distribution of capital expenditure by improvement type on the NHS is derived based on local government spending data from prior years when such information was routinely collected from the States. The distribution of local and Federal government spending by functional class is based on the estimated distribution of travel, multiplied by weighting factors derived from spending data from prior years.

Exhibit 2-13 shows the distribution of capital expenditures by type and functional system. In 2014, $29.9 billion was invested on rural arterials and collectors, with 66.7 percent directed to system rehabilitation and 23.5 percent to expansion; the remainder was directed to system enhancement. Capital outlays on urban arterials and collectors were $51.2 billion, of which 58.7 percent was for system rehabilitation and 29.7 percent was for system expansion. Among the individual functional systems, rural major collectors had the highest percentage of highway capital outlay directed to system rehabilitation (77.4 percent), while urban other freeways and expressways had the lowest percentage directed for that purpose (49.4 percent).

Exhibit 2-13: Distribution of Capital Outlay by Improvement Type and Functional System, 2014



Sources: Highway Statistics 2014, Table SF-12A, and unpublished FHWA data.

Exhibit 2-14 shows trends in capital outlays by improvement type from 2004 to 2014. Each year, a majority of capital outlay was directed to rehabilitation, reflecting the need to preserve the aging system. The share of total capital spending for system rehabilitation, however, rose dramatically between 2008 and 2010, from 51.1 percent to 60.5 percent. System rehabilitation expenditures increased from $46.2 billion to $60.5 billion, nearly 31 percent over the two years. This dramatic increase was driven partly by the Recovery Act; one of the Recovery Act's stated goals is to support jobs through construction expenditures, an aim best achieved by selecting projects that could be initiated and completed relatively quickly. This strategy led many States to direct a larger portion of their Recovery Act funding toward pavement improvement projects than they usually finance from regular Federal-aid funds in a typical year. However, even after the completion of most Recovery Act-funded projects, the overall share of highway capital spending directed to system preservation rose further to 62.0 percent in 2014. This suggests that the shift toward system preservation beginning in 2008 was likely driven by other factors in addition to the Recovery Act, and thus might represent the start of a long-term trend.

From 2004 to 2014, system rehabilitation expenditures grew at an average annual rate of 6.1 percent. System expansion expenditures decreased slightly at an average annual rate of 0.1 percent. This resulted in a decline in system expansion share of total capital outlays from 37.1 percent in 2004 to 24.5 percent in 2014. System enhancement expenditures grew from 11.2 percent of total capital outlays in 2004 to 13.5 percent in 2014.

Constant-Dollar Expenditures by Capital Improvement Type

Total capital outlay by all capital improvement types declined at an average annual rate of 0.1 percent from 2004 to 2014 in constant-dollar terms. Constant-dollar system rehabilitation expenditures rose by 1.7 percent per year over this period, while system expansion expenditures declined by 4.2 percent annually when adjusted for inflation. Expenditures for system enhancements grew by 1.8 percent per year in constant-dollar terms from 2004 to 2014.

Exhibit 2-14: Capital Outlay on All Roads by Improvement Type, 2004–2014

Improvement Type	Capital Outlay, Billions of Dollars						Annual Rate of Change 2014/2004
	2004	2006	2008	2010	2012	2014	
System Rehabilitation							
Highway	$26.7	$31.0	$33.5	$43.4	$45.8	$51.0	6.7%
Bridge	$9.6	$10.3	$12.7	$17.0	$16.4	$14.4	4.1%
Subtotal	**$36.3**	**$41.3**	**$46.2**	**$60.5**	**$62.2**	**$65.4**	**6.1%**
System Expansion							
Additions to Existing Roadways	$12.1	$14.0	$15.7	$15.0	$14.0	$13.2	0.9%
New Routes	$12.6	$15.2	$16.1	$11.4	$12.1	$11.0	-1.3%
New Bridges	$1.4	$1.2	$1.5	$0.9	$1.1	$1.6	1.2%
Subtotal	**$26.1**	**$30.4**	**$33.3**	**$27.4**	**$27.2**	**$25.9**	**-0.1%**
System Enhancements	**$7.8**	**$8.5**	**$10.9**	**$12.2**	**$15.9**	**$14.2**	**6.1%**
Total	**$70.3**	**$80.2**	**$90.4**	**$100.0**	**$105.3**	**$105.4**	**4.1%**
Percent of Total Capital Outlay							
System Rehabilitation	51.7%	51.5%	51.1%	60.5%	59.0%	62.0%	
System Expansion	37.1%	37.9%	36.9%	27.4%	25.8%	24.5%	
System Enhancements	11.2%	10.6%	12.0%	12.2%	15.1%	13.5%	

Sources: Highway Statistics, various years, Table SF-12A, and unpublished FHWA data.

Capital Outlays on Federal-aid Highways

As discussed in Chapter 1, "Federal-aid highways" includes all roads except those in functional classes that are generally ineligible for Federal funding: rural minor collector, rural local, or urban local. *Exhibit 2-15* shows that total capital outlays on Federal-aid highways increased at an average annual rate of 3.9 percent from 2004 to 2014, rising to $79.3 billion in 2014.

The share of capital outlay on Federal-aid highways directed to system rehabilitation in 2014 was 61.4 percent, below the comparable percentage for all roads of 62.0 percent (see *Exhibit 2-14*). This pattern is consistent with that from 2004 to 2012 as well; in each year, the portion of Federal-aid highway capital outlay directed toward system rehabilitation and system enhancements was lower than the comparable shares for all roads, whereas the portion directed toward system expansion was higher than for all roads.

Exhibit 2-15: Capital Outlay on Federal-aid Highways by Improvement Type, 2004–2014

Improvement Type	Capital Outlay, Billions of Dollars						Annual Rate of Change 2014/2004
	2004	2006	2008	2010	2012	2014	
System Rehabilitation							
Highway	$19.4	$22.9	$26.1	$33.1	$34.5	$38.1	7.0%
Bridge	$7.2	$7.7	$9.3	$12.5	$12.0	$10.5	3.9%
Subtotal	**$26.6**	**$30.6**	**$35.5**	**$45.6**	**$46.5**	**$48.6**	**6.2%**
System Expansion							
Additions to Existing Roadways	$11.6	$12.9	$14.3	$13.8	$12.8	$12.3	0.7%
New Routes	$9.8	$12.0	$12.8	$8.8	$9.3	$8.5	-1.5%
New Bridges	$1.2	$0.9	$1.0	$0.7	$0.8	$1.2	0.7%
Subtotal	**$22.6**	**$25.9**	**$28.1**	**$23.3**	**$22.9**	**$22.1**	**-0.2%**
System Enhancements	**$5.0**	**$5.5**	**$6.4**	**$6.8**	**$9.6**	**$8.6**	**5.4%**
Total	**$54.2**	**$61.9**	**$70.0**	**$75.7**	**$79.0**	**$79.3**	**3.9%**
Percent of Total Capital Outlay							
System Rehabilitation	49.1%	49.3%	50.7%	60.3%	58.9%	61.4%	
System Expansion	41.6%	41.9%	40.1%	30.8%	29.0%	27.8%	
System Enhancements	9.3%	8.8%	9.2%	9.0%	12.1%	10.8%	

Sources: Highway Statistics, various years, Table SF-12A, and unpublished FHWA data.

Capital Outlays on the NHS

The NHS comprises roads essential to the Nation's economy, defense, and mobility, as described in Chapter 1. The NHS was expanded under MAP-21 from 4.0 percent of the Nation's highway mileage to approximately 5.4 percent. *Exhibit 2-16* shows that capital outlays for the NHS amounted to $56.3 billion in 2014. System rehabilitation expenditures of 34.1 billion were the largest amount, followed by system expansion at $17.0 billion and system enhancements at $5.2 billion.

Exhibit 2-16: Capital Outlay on the National Highway System by Improvement Type, 2004–2014[1]

Improvement Type	Capital Outlay, Billions of Dollars						Annual Rate of Change 2014/2004
	2004	2006	2008	2010	2012	2014	
System Rehabilitation							
Highway	$9.5	$12.3	$14.9	$19.9	$19.7	$27.0	11.0%
Bridge	$4.0	$4.3	$5.4	$7.4	$6.7	$7.1	5.9%
Subtotal	**$13.5**	**$16.6**	**$20.4**	**$27.3**	**$26.4**	**$34.1**	**9.7%**
System Expansion							
Additions to Existing Roadways	$7.1	$8.1	$9.2	$8.6	$8.0	$9.2	2.7%
New Routes	$6.8	$8.9	$8.6	$4.7	$5.6	$6.7	-0.2%
New Bridges	$0.9	$0.7	$0.6	$0.3	$0.5	$1.1	1.6%
Subtotal	**$14.8**	**$17.7**	**$18.3**	**$13.7**	**$14.1**	**$17.0**	**1.4%**
System Enhancements	**$2.8**	**$2.8**	**$3.3**	**$3.4**	**$4.0**	**$5.2**	**6.4%**
Total	**$31.1**	**$37.2**	**$42.0**	**$44.4**	**$44.6**	**$56.3**	**6.1%**
Percent of Total Capital Outlay							
System Rehabilitation	43.5%	44.7%	48.5%	61.6%	59.3%	60.6%	
System Expansion	47.6%	47.7%	43.7%	30.8%	31.7%	30.2%	
System Enhancements	8.9%	7.6%	7.8%	7.6%	9.0%	9.2%	

[1] The NHS was expanded under MAP-21 from 4.0 percent of the Nation's highway mileage to approximately 5.4 percent. For 2014, all spending on principal arterials was assumed to have occurred on the NHS.

Sources: Highway Statistics, various years, Table SF-12B, and unpublished FHWA data.

Over the 10-year period beginning in 2004, the share of system rehabilitation on the NHS jumped from 43.5 percent to 60.6 percent while the share of system expansion expenditures declined from 47.6 percent to 30.2 percent of total capital outlays. During the same period, the share of system enhancements on the NHS increased slightly from 8.9 percent to 9.2 percent.

Capital Outlays on the Interstate System

Exhibit 2-17 shows that from 2004 to 2014, capital outlay increased annually on average by 6.3 percent on the Interstate System, to $25.3 billion, well above the 4.1-percent annual increase observed for all roads. This increase is also much higher than the average annual increase in capital outlay for all Federal-aid highways of 3.9 percent observed from 2004 to 2014.

Exhibit 2-17: Capital Outlay on the Interstate System, by Improvement Type, 2004–2014

	Capital Outlay, Billions of Dollars						Annual Rate of Change
Improvement Type	2004	2006	2008	2010	2012	2014	2014/2004
System Rehabilitation							
Highway	$4.7	$5.8	$7.5	$9.4	$8.9	$14.4	11.9%
Bridge	$2.3	$2.5	$3.3	$4.1	$3.8	$3.2	3.4%
Subtotal	**$7.0**	**$8.3**	**$10.8**	**$13.5**	**$12.7**	**$17.6**	**9.7%**
System Expansion							
Additions to Existing Roadways	$2.9	$3.2	$4.5	$3.5	$3.4	$3.8	2.6%
New Routes	$2.5	$3.5	$3.0	$1.7	$2.7	$1.7	-3.9%
New Bridges	$0.2	$0.3	$0.3	$0.1	$0.2	$0.4	8.0%
Subtotal	**$5.6**	**$7.1**	**$7.8**	**$5.3**	**$6.3**	**$5.9**	**0.5%**
System Enhancements	**$1.1**	**$1.2**	**$1.4**	**$1.4**	**$1.5**	**$1.8**	**4.9%**
Total	**$13.7**	**$16.5**	**$20.0**	**$20.2**	**$20.5**	**$25.3**	**6.3%**
Percent of Total Capital Outlay							
System Rehabilitation	50.8%	49.9%	53.9%	66.7%	62.1%	69.6%	
System Expansion	40.9%	42.6%	38.9%	26.3%	30.5%	23.2%	
System Enhancements	8.3%	7.4%	7.1%	6.9%	7.3%	7.2%	

Sources: Highway Statistics, various years, Table SF-12A, and unpublished FHWA data.

The share of Interstate capital outlay directed to system rehabilitation in 2014 was 69.6 percent, higher than the comparable percentages for the NHS, Federal-aid highways, and all roads. This pattern is largely consistent with that from 2004 to 2012; the share of Interstate capital outlay directed to system rehabilitation was higher in each year from 2004 to 2012 than comparable percentages for the NHS or Federal-aid highways, although in some years it was lower than the comparable percentage for all roads. The share of Interstate capital outlay directed toward system enhancements was lower in each year from 2004 to 2014 than comparable percentages for all roads, Federal-aid highways, and the NHS.

Project Finance

Project finance refers to specific techniques and tools that supplement traditional highway funding methods, improving governments' ability to deliver transportation projects. In recent years, State and local transportation agencies have adopted new ways of financing and delivering transportation projects. In the face of stagnating public revenues and demanding fiscal requirements, many jurisdictions are relying on options such as public-private partnerships, Federal credit assistance, and other debt-financing tools. These strategies could enable public agencies to transfer certain project delivery risks and deliver infrastructure projects earlier than would be possible through traditional mechanisms.

Public-Private Partnerships

Public-private partnerships (P3s) are contractual agreements between a public agency and a private entity that allow for greater private-sector participation in the delivery and financing of transportation projects. Typically, this participation involves the private entity's assuming additional project risks, such as design, finance, long-term operation, maintenance, or traffic and revenue. P3 delivery methods can be classified as "design-build," "operate-maintain," "design-build-operate-maintain," "design-build-finance," and "design-build-finance-operate-maintain." The most common type of public-private partnership is the "design-build" agreement, in which a private entity agrees to design and build a highway. Each method can offer advantages or disadvantages, depending on the specific project and parties involved. P3s are undertaken for a variety of purposes, including monetizing the value of existing assets, developing new transportation facilities, or rehabilitating or expanding existing facilities. Although P3s offer certain advantages, such as increased financing capacity and reduced upfront costs, the public sector still must identify a source of revenue for the project to provide a return to the private partner's investment and must ensure that the goals and interests of the public are adequately secured. Due to the inherent complexity of P3 agreements and the scale of the transportation projects involved, many States have adopted specific enabling legislation for these arrangements (a summary report developed by the National Conference of State Legislatures on these statutes is available at (http://www.ncsl.org/Portals/1/Documents/transportation/P3_State_Statutes.pdf)). Additional information on P3s is available at (http://www.fhwa.dot.gov/ipd/p3/index.htm).

Public-Private Partnership Project: U.S. 36 Express Lanes (Phase 2)

U.S. 36 is a four-lane divided highway that connects the City of Boulder to Denver, Colorado, at its intersection with I-25. The U.S. 36 Express Lanes Phase 2 project extends the 10-mile Phase 1 express lane facility five miles further northwest to Boulder and includes one express, high-occupancy toll lane in each direction, replacement of the Coal Creek Bridge, rehabilitation and widening of the South Boulder Creek Bridge, and widening of the McCaslin Boulevard Bridge, bus rapid transit improvements, bikeway along much of the corridor, and intelligent transportation system equipment for tolling, transit information, and incident management. This project is delivered as a design, build, finance, operate, and maintain public-private partnership.

The $208.4-million project is financed by $133.2 million in private funding and $64.4 million in public funding. It includes a mixture of private capital, a Transportation Infrastructure Finance and Innovation Act (TIFIA) loan, private activity bonds, equity, toll revenues, local, State and Federal funding, and sales tax revenue. The concession agreement was finalized in 2012 between the Colorado High Performance Transportation Enterprise (HPTE) and Plenary Roads Finco LP. HPTE awarded the concession in April 2013. The concession also includes the operations and maintenance of the Phase 1 portion of the express lanes. Phase 2 opened to traffic in January 2016 and tolling began in March 2016. The concession period extends for 50 years. The P3 arrangement enabled the project to be completed years sooner than originally planned.

Debt-Financing Tools

Some transportation projects are so large that their cost exceeds available current grant funding and tax receipts or would consume so much of these current funding sources that they would delay many other planned projects. For this reason, State and local governments often seek financing for large projects through borrowing, which provides an immediate influx of cash to fund project construction costs. The borrower then retires the debt by making principal and interest payments over time. Tax-exempt municipal bonds, backed by future government revenues, are the most common method of borrowing by government agencies for transportation projects.

A Grant Anticipation Revenue Vehicle (GARVEE) is a debt-financing instrument that can generate initial capital for major transportation projects. Future Federal-aid funds are used to repay the debt and related financing costs under the provisions of Section 122 of Title 23, U.S. Code. GARVEEs enable a State to accelerate construction timelines and spread the cost of a transportation facility over its useful life rather than just the construction period. As of December 2016, 25 States and three U.S. territories had issued approximately $20.4 billion in GARVEEs.

Private activity bonds (PABs) provide additional borrowing opportunities. PABs are debt instruments issued by State or local governments on behalf of a private entity, allowing a private project sponsor to benefit from the lower financing costs of tax-exempt municipal bonds. In 2005, Federal legislation provided a special authorization for up to $15 billion in PABs for highway and freight transfer projects, with allocations approved by DOT. As of January 2017, nearly $6.6 billion in these PABs had been issued for 17 projects.

Additional information on Federal debt-financing tools is available at (http://www.fhwa.dot.gov/ipd/finance/tools_programs/federal_debt_financing/index.htm).

Debt-Financing Tools: Ohio River Bridges Downtown Crossing—Louisville, Kentucky/Southern Indiana

The Downtown Crossing project includes the new Abraham Lincoln Bridge across the Ohio River and associated roadway and facilities, connecting Louisville, Kentucky, with Clark County, Indiana. The bridge carries six lanes of northbound I-65. The project also includes improved and expanded approaches and the reconstruction of the Kennedy Interchange between I-65, I-64, and I-71 in downtown Louisville.

The Louisville and Southern Indiana Bridges Authority, a bi-State agency, has been responsible for the financing of the $2.8 billion Ohio River Bridges. The Downtown River Bridge is tolled, which will back bonds to partially finance the project.

The project cost of $1,478 million, including financing and interest, is funded by:

- GARVEE bonds - $337 million;
- Project revenue bonds - $272 million;
- TIFIA loan - $452 million;
- Bond Anticipation Notes - $41 million;
- Federal and State funds (Kentucky) - $342 million;
- Federal and State funds (Indiana) - $34 million

These innovative delivery approaches have allowed for significant cost savings. Project construction began in June 2013. The Abraham Lincoln Bridge opened to traffic December 2015.

Federal Credit Assistance

Federal credit assistance for highway improvements can take one of two forms: (1) loans, where project sponsors borrow Federal funds from a State department of transportation or the Federal government; and (2) credit enhancements, where a State department of transportation or the Federal government makes Federal funds available on a contingent (or standby) basis. Loans can provide the capital necessary to proceed with a project and reduce the amount of capital borrowed from other sources. Credit enhancement helps reduce risk to investors and thus allows project sponsors to borrow at lower interest rates. Loans also might serve a credit enhancement function by reducing the risk borne by other investors. Federal tools currently available to project sponsors include the TIFIA Credit Program, State Infrastructure Banks (SIBs) programs, and Section 129 (U.S.C. 129 (A)(7)) loans.

The TIFIA Credit Program provides Federal credit assistance in the form of direct loans, loan guarantees, and standby lines of credit to finance surface transportation projects of national and regional significance. A TIFIA project must pledge repayment in whole or in part with dedicated revenue sources, such as tolls, user fees, special assessments (taxes), or other non-Federal sources.

SIBs enable States to use their Federal apportionments to establish a revolving fund that, much like a bank, can offer low-cost loans and other credit assistance to help finance highway and transit projects. As of September 2016, 33 States and territories had entered into an estimated 834 SIB loan agreements for a total of $5.9 billion.

Section 129 loans allow States to use regular Federal-aid highway apportionments to fund loans to toll and nontoll projects, which can be paid back with dedicated revenue streams. Because loan repayments can be delayed until five years after project completion, this mechanism provides flexibility during the ramp-up period of a new facility.

The DOT Build America Bureau streamlines credit opportunities and grants and provides access to the various credit and grant programs. Additional information on credit assistance tools is available at (https://www.fhwa.dot.gov/innovativeprograms/centers/innovative_finance/).

Transit Funding

Transit funding comes from two major sources: (1) public funds allocated by Federal, State, and local governments, and (2) system-generated revenues earned from providing transit services. As shown in *Exhibit 2-18*, $65.3 billion was available for transit funding in 2014. Federal funding for transit includes fuel taxes dedicated to transit from the Mass Transit Account of the Highway Trust Fund (HTF) and General Fund appropriations. State and local governments also provide funding for transit from their General Fund appropriations and from fuel, income, sales, property, and other taxes, specific percentages of which can be dedicated to transit. These percentages vary considerably among taxing jurisdictions and by type of tax. Other public funds, from toll revenues and other sources, also might be used to fund transit. Passenger fares principally comprise system-generated revenues, although transit systems earn additional revenues from advertising and concessions, park-and-ride lots, investment income, and rental of excess property and equipment.

Key Takeaways

- Capital and operating expenses in 2014 totaled $65.2 billion, including $17.7 billion for capital and $47.5 billion for operating expenses.
- Passenger fares contributed $16.5 billion, or 25%. Other directly generated funds such as parking revenues, concessions, and other sources contributed $2.7 billion, or 4%.
- Public assistance accounted for 71% of all funds, of which Federal funds accounted for 25%, State for 31%, and local by 43%.
- Capital investment grew at an average of 1.0% per year, from $15.8 billion in 2004 to $17.4 billion in 2014.
- Capital investment in rehabilitation of existing assets and expansion in 2014 were $12.8 billion and $4.6 billion, respectively, a 73/27% split ratio. In 2004, the ratio was 70/30%.

Financial Indicators of the Top 10 agencies

- The average recovery ratio (fare revenues per total operating expenses) of the top 10 transit agencies decreased slightly from 33.9% in 2004 to 32.7% in 2014.
- Average fare revenues per mile increased by 19%, from $4.4 per mile in 2004 to $5.2 per mile in 2014 (constant dollars).
- Operating cost per mile increased by 23%, from $12.9 per mile in 2004 to $15.9 per mile in 2014. Average labor costs for the top 10 transit agencies increased by 0.9%, from $9.3 per mile in 2004 to $9.4 per mile in 2014.

Level and Composition of Transit Funding

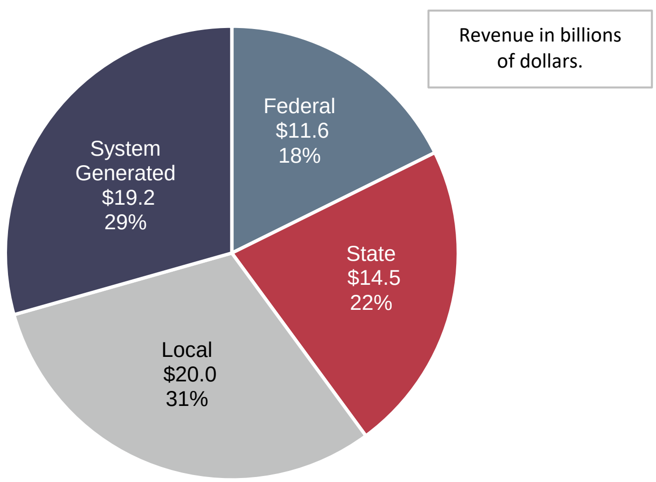
Exhibit 2-19 breaks down the sources of total urban and rural transit funding. In 2014, public funds of $46.1 billion were available for transit, accounting for 73 percent of total transit funding. Of this amount, Federal funding was $11.6 billion or 25 percent of total public funding and 18 percent of all funding from both public and nonpublic sources. State funding was $14.5 billion, accounting for 31 percent of total public funds and 22 percent of all funding. Local jurisdictions provided the bulk of transit funds at $20.0 billion in 2014, or 43 percent of total public funds and 31 percent of all funding. System-generated revenues were $19.2 billion, or 29 percent of all funding.

Exhibit 2-18: Revenue Sources for Transit Funding, 2014

	Revenue Sources (Millions of Dollars)					
	Directly Generated Funds	Federal	State	Local	Total	Percent
Public Funds		**11,557**	**14,505**	**20,047**	**46,109**	**71%**
General Fund		2,311	3,979	4,870	11,160	17%
Fuel Tax		9,245	1,011	193	10,450	16%
Income Tax			459	108	568	1%
Sales Tax			3,914	6,207	10,121	16%
Property Tax			15	518	533	1%
Other Dedicated Taxes			2,644	89	2,733	4%
Other Public Funds			263	1,135	1,398	2%
System-Generated Revenue	**19,185**				**19,185**	**29%**
Passenger Fares	16,469				16,469	25%
Other Revenue	2,716				2,716	4%
Total All Sources					**65,294**	**100%**

Source: National Transit Database.

Exhibit 2-19: Public Transit Revenue Sources, 2014

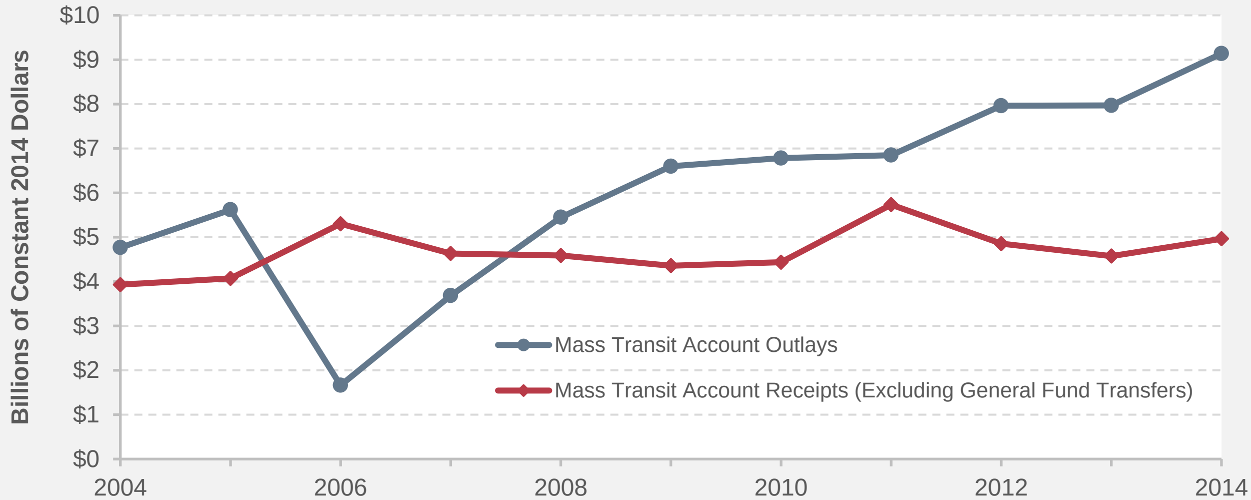


Source: National Transit Database.

How long has it been since excise tax revenue deposited into the Mass Transit Account exceeded expenditures?

The last time annual net receipts credited to the Mass Transit Account of the HTF exceeded annual expenditures from the Mass Transit Account was 2007. As shown in *Exhibit 2-20*, for nine of the 11 years since 2004, total annual receipts to the Mass Transit Account from excise taxes and other income (including amounts transferred from the Highway Account) have been lower than the annual expenditures from the Mass Transit Account. The gap between Mass Transit Account outlays and receipts increased by about 10 percent from both 2012 to 2013 and 2013 to 2014, respectively.

Exhibit 2-20: Mass Transit Account Receipts and Outlays, Fiscal Years 2004–2014[1]



[1] As shown in 2014 constant dollars.

Note: Prior to 2006 Mass Transit Account funds were immediately transferred to the General Fund at the time funds were obligated for expenditures in future years. Starting in 2006, Mass Transit account funds were not transferred until the year in which expenditures by transit agencies were made. This accounting change resulted in a dip in outlays in 2006.

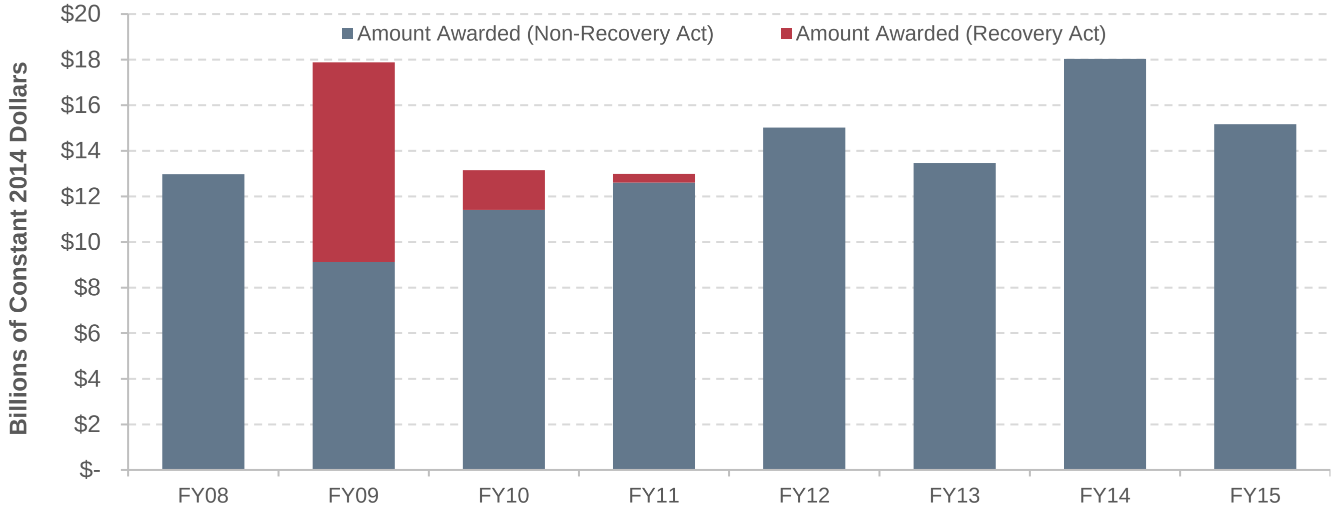
Sources: Highway Statistics, various years, Tables FE-210 (https://www.fhwa.dot.gov/policyinformation/statistics/2014/fe210.cfm) and FE-10 (https://www.fhwa.dot.gov/policyinformation/statistics/2014/fe10.cfm).

Federal Funding

Federal funding for transit comes from two sources: the general revenues of the U.S. government, and revenues generated from fuel taxes credited to the Mass Transit Account of the HTF. The largest part of transit funding from the HTF is distributed by formula, which is legislatively defined. A smaller part is distributed competitively or at agency discretion.

General revenue sources include income taxes, corporate taxes, tariffs, fees, and other government income not required by statute to be accounted for in a separate fund. The Mass Transit Account is generally the largest source of Federal funding for transit, although in 2009 the Mass Transit Account contribution was surpassed by Recovery Act funds from the General Fund. *Exhibit 2-21* shows how Recovery Act funds were awarded in 2009, 2010, and 2011 compared with other Federal funding from the Mass Transit Account and the General Fund. Of the funds authorized for transit grants in the Federal Transit Administration's (FTA) 2012 budget, 81.0 percent were derived from the Mass Transit Account. Funding from the Mass Transit Account in nominal dollars increased from $0.5 billion in 1983 to $12.8 billion in 2012.

Exhibit 2-21: Recovery Act Funding Awards Compared to Other FTA Fund Awards



Source: Federal Transit Administration, Grants Data (https://www.fhwa.dot.gov/policyinformation/statistics/2014/fe210.cfm).

Since 1973, Federal statutes authorizing surface transportation have contained flexible funding provisions that enable transfers from certain highway funds to transit programs and vice versa. Transfers are subject to State and regional/local discretion, and priorities are established through statewide transportation planning processes. All States participate in the flexible funding program, except Arkansas, Delaware, Hawaii, Nebraska, North Dakota, South Dakota, and Wyoming. U.S. territories, including American Samoa, Guam, the Northern Mariana Islands, Puerto Rico, and the Virgin Islands, also do not participate. Flexible funding transferred from highways to transit fluctuates from year to year and is drawn from several different sources.

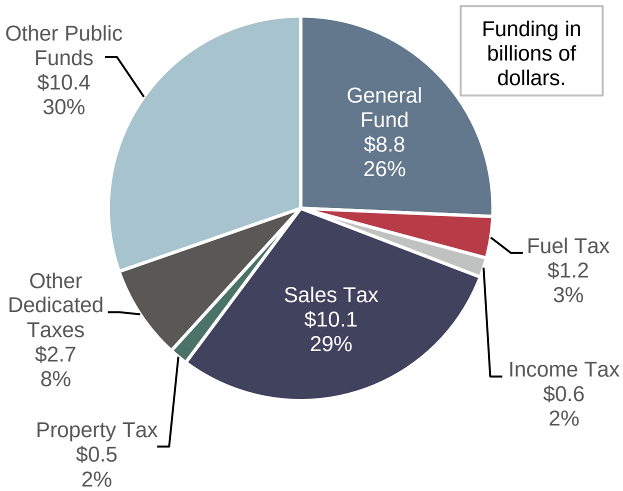
The Surface Transportation Block Grant Program is the primary source of Federal Highway Administration (FHWA) funds that are “flexed” to the FTA to pay for transit projects. Funding is up to 80 percent of the eligible project costs and may be used for all capital and maintenance projects eligible for funds under current FTA programs. These funds may not be used for operating assistance.

FHWA’s Congestion Mitigation and Air Quality (CMAQ) Improvement Program funds are another source of flexed funds used to support transit projects in air quality nonattainment areas. A CMAQ project must contribute to the attainment of the National Ambient Air Quality Standards by reducing air pollutant emissions from transportation sources. Public transportation projects can be funded through CMAQ, which also includes some provision for transit operating assistance.

State and Local Funding

General funds and other dedicated public funds (vehicle licensing and registration fees, communications access fees, surcharges and taxes, lottery and casino receipts, and proceeds from property and asset sales) are important sources of funding for transit at both the State and local levels. State and local funding sources for transit are shown in *Exhibit 2-22*. Taxes, including fuel, sales, income, property, and other dedicated taxes, provide 44.8 percent of public funds for State and local sources. General funds provide 26 percent of transit funding, and other public funds provide the remaining 30 percent.

Exhibit 2-22: State and Local Sources of Urban Transit Funding



Source: National Transit Database.

System-Generated Funds

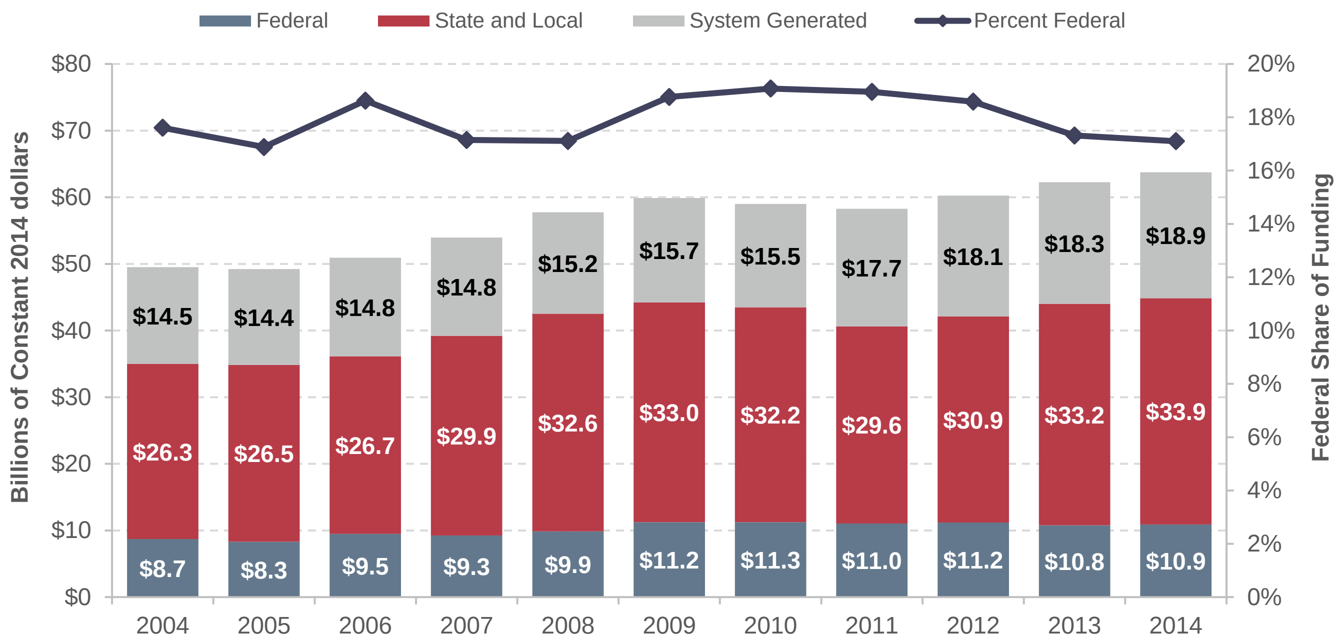
In 2014, system-generated funds were $19.2 billion and provided 29.4 percent of total transit funding. Passenger fares contributed $16.5 billion, accounting for 25.2 percent of total transit funds. These passenger fare figures do not include payments by State entities to transit systems that offset reduced transit fares for certain segments of the population, such as students and the elderly. These payments are included in the "other revenue" category.

Trends in Funding

Between 2004 and 2014, public funding for transit increased at an average annual rate of 2.6 percent, Federal funding increased at an average annual rate of 2.5 percent, and State and local funding increased at an average annual rate of 2.9 percent after adjusting for inflation (constant dollars). These data are presented in *Exhibit 2-23*.

Federal funding for transit, as a percentage of total funding for transit from Federal, State, and local sources combined, reached a peak of 43 percent in the late 1970s, and declined to near its present value by the early 1990s. State and local funding increased during this same period. *Exhibit 2-23* shows that, since 2004, the Federal government has provided between 17 and 19 percent of total funding for transit (including system-generated funds). In 2014, it provided 17 percent.

Exhibit 2-23: Funding for Urban Transit by Government Jurisdiction, 2004–2014



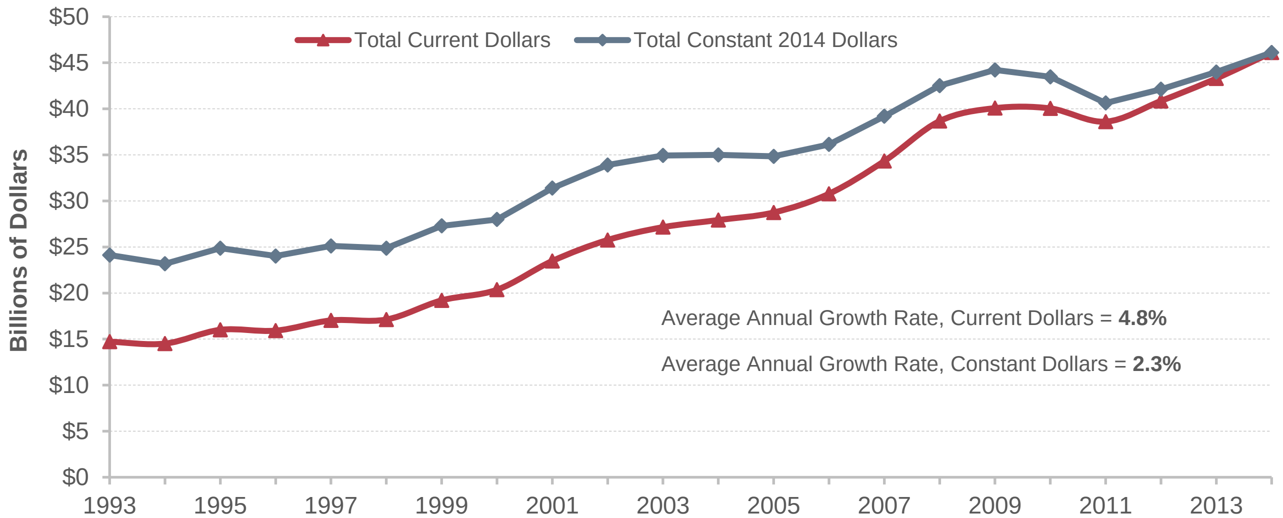
Source: National Transit Database.

Funding in Current and Constant Dollars

Public funding for transit in current dollars and constant (adjusted for inflation) dollars since 1993 is presented in *Exhibit 2-24*. Total public funding for transit was $45.3 billion in 2014. In constant dollar terms, this amount was 4 percent lower than in 2010. Between 2012 and 2014, Federal funding stayed nearly constant at around $10.9 billion in current dollars. In constant dollars, however, this represents a 2.7 percent decrease in funding. From 2012 to 2014, in current dollars, State and local funding increased from $29.9 billion to $34.4 billion (15 percent). In constant dollars, this represents an 11-percent increase in funding.

Federal funds directed to capital expenditures increased by 4.5 percent from 2004 to 2014, while capital funds applied to operating expenditures increased by 8.4 percent during the same period (constant dollars). As indicated in *Exhibit 2-25*, $2.5 billion was applied to operating expenditures and $7.4 billion was applied to capital expenditures in 2014. More than half the operating expenditures were for preventive maintenance, which is reimbursed as a capital expense under FTA's 5307 grant program.

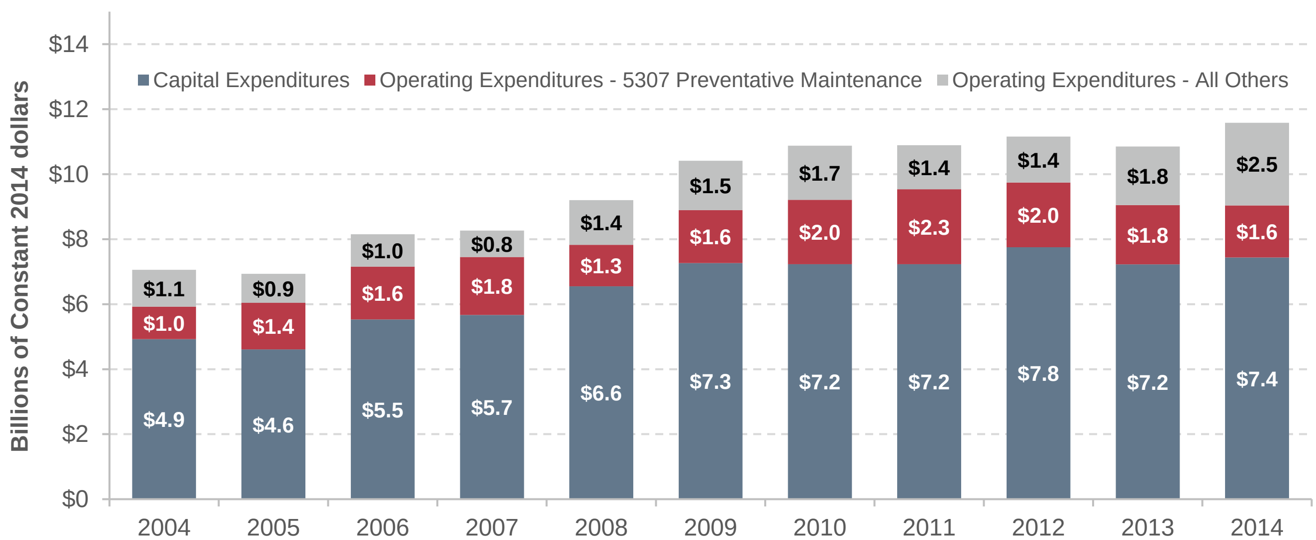
Exhibit 2-24: Current and Constant Dollar Public Funding for Public Transportation (All Sources)



Note: Constant dollars based on Consumer Price Index.

Source: National Transit Database.

Exhibit 2-25: Applications of Federal Funds for Transit Operating and Capital Expenditures, 2004–2014



Source: National Transit Database.

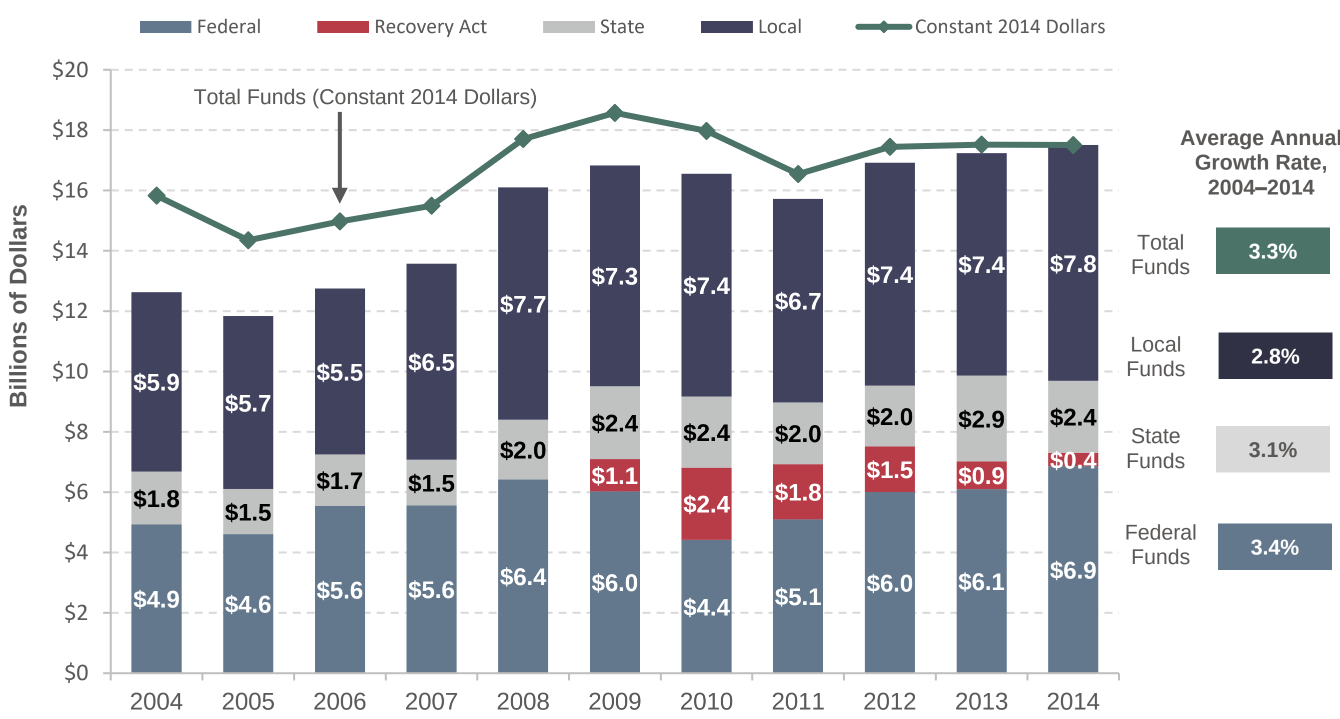
Capital Funding and Expenditures

Funding for capital investments by transit operators in the United States comes primarily from public sources. A relatively small amount of private-sector funding for capital investment in transit projects is generated through innovative finance programs.

Capital investments include the design and construction of new transit systems, extensions of existing systems, and the modernization or replacement of existing assets. Capital investment expenditures can be made for the acquisition, renovation, and repair of vehicles (e.g., buses, railcars, locomotives, and service vehicles) or fixed assets (e.g., guideway elements, track, stations, and maintenance and administrative facilities).

As shown in *Exhibit 2-26*, total public transit agency expenditures for capital investment were $17.7 billion in 2014. This expenditure accounted for 28 percent of total available funds for transit. Federal funds provided $6.9 billion in 2014, accounting for 39.5 percent of total transit agency capital expenditures. State funds provided 13.7 percent and local funds provided 44.3 percent of total transit funding. Recovery Act funds provided the remaining 2.5 percent of revenues for agency capital expenditures in 2014 (constant dollars).

Exhibit 2-26: Sources of Funds for Transit Capital Expenditures, 2004–2014[1]



[1] Data prior to 2007 do not include rural expenditures.

Source: National Transit Database.

From 2009 to 2012, substantial amounts of Recovery Act funds were expended, and non-Recovery Act Federal funds decreased compared with levels in previous years. This decrease in the use of other Federal funds was likely related to the strict 2-year obligation limit specified for Recovery Act funds: these funds had to be used first due to their short period of availability. In 2012 and thereafter, as most of the Recovery Act funds had been expended, expenditures using non-Recovery Act Federal funds returned to pre-2009 levels. Federal funding from 2004 to 2014 grew faster than did State or local funding.

As shown in *Exhibit 2-27*, rail modes consume a higher percentage of total transit capital investment than fixed-route bus modes for two reasons: (1) the higher cost of building fixed guideways and rail stations, and (2) fixed-route bus systems typically do not pay to build or maintain the roads on which they run. In 2014, $12.8 billion, or 72.3 percent of total transit capital expenditures, were invested in rail modes of transportation, compared with $4.6 billion, or 26.1 percent of the total, which was invested in nonrail modes. This investment distribution has been consistent over the past decade.

Exhibit 2-27: Urban Transit Capital Expenditures by Mode and Type, 2014

Rail Capital Expenditures, in Millions								
Type		**Commuter Rail**	**Heavy Rail**	**Light Rail**	**Hybrid Rail**	**Streetcar Rail**	**Other Rail[1]**	**Total Rail**
Guideway		$1,202	$1,907	$3,033	$1	$110	$34	**$6,287**
Rolling Stock		$663	$682	$307	$1	$42	$10	**$1,704**
Systems		$393	$692	$226	$1	$2	$20	**$1,333**
Maintenance Facilities		$125	$226	$116	$0	$21	$1	**$490**
Stations		$312	$1,656	$222	$10	$5	$3	**$2,208**
Fare Revenue Collection Equipment		$24	$24	$13	$0	$2	$0	**$63**
Administrative Buildings		$13	$59	$1	$0	$0	$0	**$73**
Other Vehicles		$10	$22	$8	$0	$3	$3	**$46**
Other Capital Expenditures[2]		$64	$440	$11	$1	$49	$5	**$570**
Total		**$2,807**	**$5,708**	**$3,936**	**$15**	**$233**	**$76**	**$12,774**
Percentage of Total		15.9%	32.3%	22.3%	0.1%	1.3%	0.4%	72.3%
Nonrail Capital Expenditures, in Millions								
Type	**Fixed-Route Bus**	**Bus Rapid Transit**	**Commuter Bus**	**Demand Response**	**Ferryboat**	**Trolley Bus**	**Vanpool**	**Total Nonrail**
Guideway	$99	$35	$14	$0	$0	$6	$0	**$154**
Rolling Stock	$2,150	$16	$119	$176	$139	$10	$34	**$2,644**
Systems	$324	$8	$6	$21	$1	$6	$0	**$365**
Maintenance Facilities	$553	$3	$13	$12	$6	$0	$0	**$586**
Stations	$268	$7	$14	$0	$103	$1	$0	**$394**
Fare Revenue Collection Equipment	$95	$4	$0	$3	$0	$0	$0	**$102**
Administrative Buildings	$121	$0	$0	$6	$0	$1	$0	**$129**
Other Vehicles	$40	$0	$0	$2	$5	$0	$0	**$47**
Other Capital Expenditures[2]	$177	$4	$2	$10	$1	$0	$0	**$195**
Total	**$3,827**	**$77**	**$169**	**$229**	**$255**	**$24**	**$35**	**$4,617**
Percentage of Total	21.7%	0.4%	1.0%	1.3%	1.4%	0.1%	0.2%	26.1%
Total Expenditures for Rail and Nonrail Modes, in Millions								
Type							**Total Rail and Nonrail**	**Percent of Total**
Guideway							**$6,441**	36.4%
Rolling Stock							**$4,349**	24.6%
Systems							**$1,698**	9.6%
Maintenance Facilities							**$1,076**	6.1%

Stations								
Fare Revenue Collection Equipment							**$164**	0.9%
Administrative Buildings							**$202**	1.1%
Other Vehicles							**$93**	0.5%
Other Capital Expenditures[2]							**$765**	4.3%
Agencies operating less than 30 peak vehicles[3]							**$283**	1.6%
Guideway							**$6,441**	36.4%
Rolling Stock							**$4,349**	24.6%
Total							**$17,674**	**100.0%**

[1] Includes Alaska railroad, cable car, inclined plane, and monorail/automated guideway.

[2] Capital expenditures not elsewhere included. These expenditures include furniture and equipment that are not an integral part of buildings and structures; they also include shelters, signs, and passenger amenities (e.g., benches) not in passenger stations.

[3] Agencies operating fewer than 30 peak vehicles do not report capital data by mode and type of expenditure.

Note: Table does not include aerial tramway, demand taxi, or público.

Source: National Transit Database.

Fluctuations in the levels of capital investment in different types of transit assets reflect normal rehabilitation and replacement cycles and new investment. Capital investment expenditures have been reported to the National Transit Database (NTD) only at the level of detail in *Exhibit 2-27* since 2002. Prior to 2002 the data were not as detailed.

Total guideway investment was $6.4 billion in 2014, and total investment in systems was $1.7 billion. Guideway includes at-grade rail, elevated structures, tunnels, bridges, track, and power systems for all rail modes, as well as paved highway lanes dedicated to fixed-route buses. Investment in systems by transit operators includes groups of devices or objects forming a network, most notably for train control, signaling, and communications.

How does FTA fund major transit construction projects?

FTA provides funding for the design and construction of light rail, heavy rail, commuter rail, streetcar, bus rapid transit, and ferry projects through a discretionary grant program known as Capital Investment Grants. Title 49 U.S.C. Section 5309 provides funds for new transit systems, extensions to current systems, and capacity expansion projects on existing transit lines currently at or over capacity. These types of projects are known more commonly as “New Starts,” “Small Starts,” and “Core Capacity” projects.

To receive funds from the Capital Investment Grant program, the proposed project must emerge from the metropolitan or statewide planning process and proceed through a multiyear, multistep process outlined in law, which includes a detailed evaluation and rating of the project by FTA. FTA evaluates proposed projects based on financial criteria and project justification criteria as prescribed by statute.

Under current law, Capital Investment Grant funding may not exceed 80 percent of a project’s total capital cost. New Starts have a 51 percent limit for CIG funding (SS and CC are 80%)—with an 80 percent cap for total Federal contribution. Generally, however, the Capital Investment Grant program share of such projects averages about 50%, due to the overwhelming demand for funds nationwide. Funds are typically provided over a multiyear period rather than all at once, due to the size of the projects and the size of the overall annual program funding level.

Most, but not all, major transit capital projects are constructed using Capital Investment Grant program funds. Some project sponsors choose to use other sources instead, such as FTA Urbanized Area Formula funds, FTA discretionary Ferry Program funds, and other discretionary grant program funds from the Department of Transportation. In 2014, total investment in vehicles, stations, and maintenance facilities was $4.3 billion, $2.6 billion, and $1.1 billion, respectively. “Vehicles” include the bodies and chassis of transit vehicles and their attached fixtures and appliances, but do not include fare collection equipment and movement control equipment (such as radios) for revenue vehicles. “Stations” include station buildings, platforms, shelters, parking and other forms of access, and crime prevention and security equipment at stations. “Facilities” include the purchase, construction, and rehabilitation of administrative and maintenance facilities. Facilities also include investment in building structures, climate control, parking, yard track, vehicle and facilities maintenance equipment, furniture, office equipment, and computer systems.

“Other capital costs” include those associated with general administration facilities, furniture, equipment that is not an integral part of buildings and structures, data processing equipment, and shelters located at on-street bus stops. “Data processing equipment” includes computers and peripheral devices for which the sole use is in data processing operations.

Exhibit 2-28 shows yearly capital expenditures for rehabilitation or expansion by mode. Rehabilitation expenses are those dollars used to replace service directly or to maintain existing service. Expansion expenses are those used to increase service. Example expansion expenses include procuring additional buses to create a new route, building a new rail line, or constructing an additional rail station on an existing rail line.

Exhibit 2-28: Urban Capital Expenditures Applied by Rehabilitation or Expansion by Mode, 2004–2014

	Expenditures (Millions of Constant 2014 Dollars)											Average Annual Rate of Change 2014/2004
	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	
Rail Rehabilitation	$7,595	$7,256	$7,173	$7,572	$8,496	$8,256	$6,744	$6,156	$5,697	$6,868	$6,721	**-1.2%**
Rail Expansion	$3,471	$2,963	$3,655	$3,986	$4,957	$5,579	$6,205	$5,428	$6,806	$5,944	$6,053	**5.7%**
Rail Total	**$11,066**	**$10,219**	**$10,828**	**$11,557**	**$13,453**	**$13,835**	**$12,948**	**$11,584**	**$12,504**	**$12,812**	**$12,774**	**1.4%**
Nonrail Rehabilitation	$4,225	$3,606	$3,622	$3,353	$3,556	$4,239	$4,487	$4,309	$4,288	$4,077	$4,272	**0.1%**
Nonrail Expansion	$528	$507	$417	$580	$618	$497	$547	$567	$561	$532	$345	**-4.2%**
Nonrail Total	**$4,752**	**$4,113**	**$4,039**	**$3,933**	**$4,174**	**$4,736**	**$5,034**	**$4,875**	**$4,849**	**$4,610**	**$4,617**	**-0.3%**
Rehabilitation Total	$11,820	$10,862	$10,795	$10,925	$12,052	$12,494	$11,231	$10,465	$9,985	$10,945	$10,993	**-0.7%**
Expansion Total	$3,998	$3,470	$4,072	$4,565	$5,575	$6,077	$6,751	$5,994	$7,367	$6,476	$6,398	**4.8%**
Grand Total	**$15,818**	**$14,332**	**$14,867**	**$15,490**	**$17,627**	**$18,571**	**$17,983**	**$16,459**	**$17,353**	**$17,421**	**$17,391**	**1.0%**

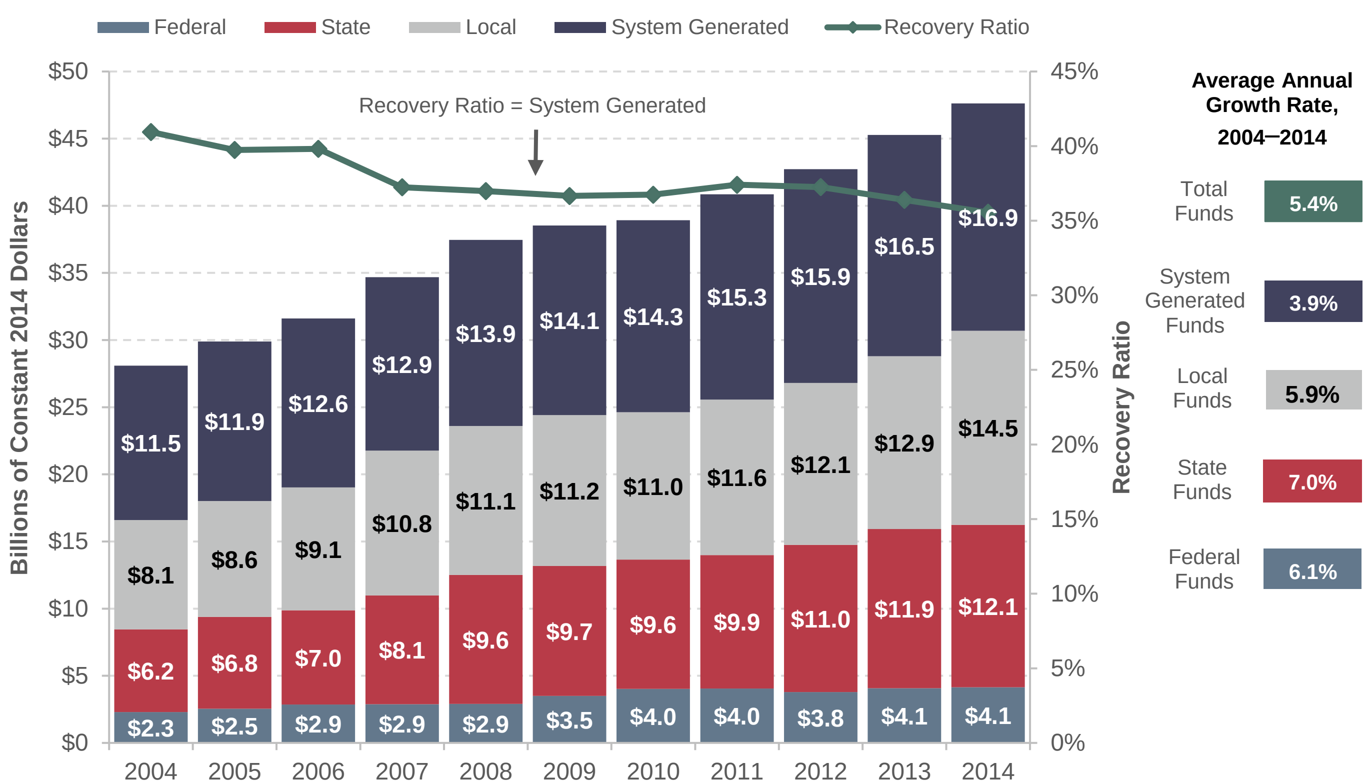
Source: National Transit Database.

After adjusting for inflation (constant dollars), total capital expenditures from 2004 to 2014 increased by an annual average of 1.0 percent. Although rehabilitation expenses over this period have decreased slightly, service expansion investment, particularly in rail modes, increased considerably. Expenses for rail expansion had the largest increase over this time, with an average annual of 5.7 percent.

Operating Expenditures

Transit operating expenditures include wages, salaries, fuel, spare parts, preventive maintenance, support services, and certain leases used in providing transit service. As indicated in *Exhibit 2-29*, $47.5 billion was available for operating expenses in 2014, the Federal share of which increased from the 2004 level of 8.2 percent to 8.7 percent in 2014. The largest share of Federal funds applied to operating expenditures comes from the Urbanized Area Formula Program (Title 49 U.S.C. Section 5307), which contributed 62 percent of all Federal funds. This program includes operating assistance for urbanized areas with populations less than 200,000, systems with fewer than 100 vehicles in urbanized areas (UZAs) with populations over 200,000, and capital funds eligible for operating assistance, such as preventive maintenance. Funds for the Rural Program (Title 49 U.S.C. Section 5311) contributed 13 percent, and funds from the State of Good Repair Program (Title 49 U.S.C. Section 5337), 9 percent. The remaining 15 percent included FTA, Department of Transportation, and other Federal funds. The share generated from system revenues decreased from 40.9 percent in 2004 to 35.5 percent in 2014. The State share increased from 21.9 percent in 2004 to 25.4 percent in 2014. The local share of operating expenditures increased marginally from 29.0 percent in 2004 to 30.4 percent in 2014.

Exhibit 2-29: Sources of Funds for Transit Operating Expenditures, 2004–2014[1]



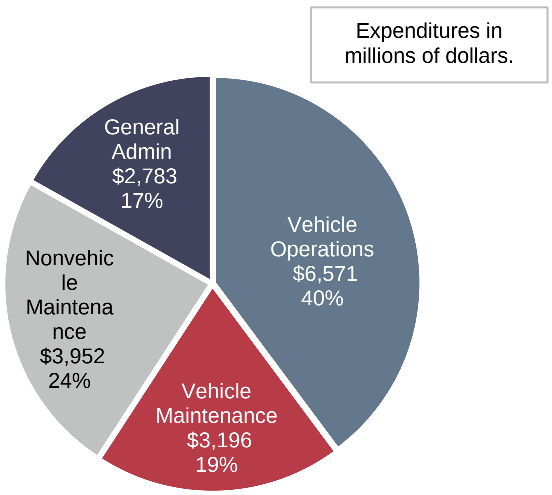
[1] Data prior to 2007 do not include rural expenditures.

Source: Transit Economic Requirements Model (TERM) and National Transit Database.

Operating Expenditures by Type of Cost

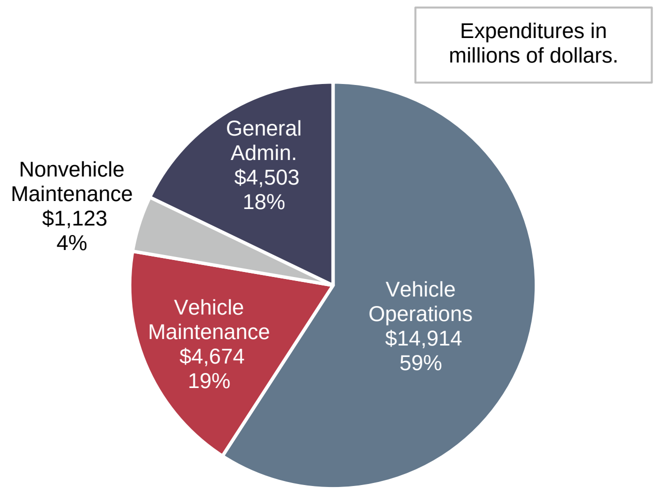
Exhibits 2-30 and *2-31* illustrate how nonrail (e.g., bus) and rail transit operations have inherently different cost structures because, in most cases, roads used by nonrail transit operators are not maintained by the transit provider, but tracks are. A significantly higher percentage of expenditures for rail modes of transportation is classified as nonvehicle maintenance, corresponding to the repair and maintenance costs of fixed guideway systems.

Exhibit 2-30: Rail Operating Expenditures by Type of Cost



Source: National Transit Database.

Exhibit 2-31: Nonrail Operating Expenditures by Type of Cost, 2014



Note: Does not include rural agencies and agencies operating fewer than 30 peak vehicles.

Source: National Transit Database.

Operating Expenditures per Vehicle Revenue Mile

Operating expenditures per vehicle revenue mile (VRM) is one measure of financial or cost efficiency. As shown in *Exhibit 2-32*, operating expenditures per VRM for all transit modes combined were $10.11 in 2014. The average annual increase in operating expenditures per VRM for all modes combined between 2004 and 2014 was 0.9 percent in constant dollars.

Exhibit 2-33 shows labor financial indicators for two groups of aggregate data: Top 10 agencies (by ridership) as of 2014, and the national total of all urban agencies in the United States. Total fares per vehicle revenue mile for the top 10 agencies combined are approximately 60 percent greater than the total for all other agencies combined. The recovery ratios for both the top 10 and the national total decreased between 2004 and 2014, as the fare per revenue mile ratios increased at a lower average rate than the cost per revenue mile.

Ridership grew at a rate greater than the rate of increase in service miles or operating expenses over the 10 year period. As cost and service effectiveness of these agencies grew, farebox revenues increased roughly in the same proportion, resulting in recovery ratios greater than the national average. As shown in *Exhibit 2-34*, analysis of the NTD reports for the top 10 transit agencies ranked by population shows that the growth in operating expenses is led by the cost of fringe benefits, which have been increasing at a rate of 1.3 percent per year above inflation (constant dollars) since 2004. By comparison, average salaries at these 10 agencies decreased at an inflation-adjusted rate of 0.8 percent per year in that period. FTA does not collect data on the different components of fringe benefits, but increases in the cost of medical insurance typically drive growth rates in fringe benefits across the economy and likely drive the growth in this category.

Efficiency, Cost Effectiveness, and Service Effectiveness

Cost Efficiency is the relationship between cost inputs such as labor, fuel, capital, etc. to service outputs such as vehicle miles and hours. Common metrics include labor expenses per hour, and materials and services per mile.

Cost Effectiveness is the relationship between cost inputs to service consumption, such as linked trips (number of boardings) and unlinked trips (one trip from origin to destination regardless of how many modes were used), and passenger miles. Common metrics are operating cost per trip and per passenger mile.

Service Effectiveness links service outputs to service consumption. Common metrics are trips per hour, passenger miles per revenue mile (load factor), etc.

Exhibit 2-32: Urban Operating Expenditures per Vehicle Revenue Mile, 2004–2014

Mode	Expenditures (Millions of Constant 2014 Dollars)						Total
	Heavy Rail	Commuter Rail	Light Rail[1]	Fixed-Route Bus[2]	Demand Response[3]	Other[4]	
2004	$9.50	$16.04	$16.69	$9.50	$4.69	$5.81	$9.22
2005	$9.92	$16.00	$17.43	$9.70	$4.69	$5.50	$9.37
2006	$9.80	$15.42	$17.21	$9.85	$4.84	$4.58	$9.37
2007	$10.53	$15.41	$16.12	$10.01	$4.60	$5.83	$9.54
2008	$10.28	$15.29	$16.03	$10.16	$4.58	$5.41	$9.49
2009	$10.44	$16.05	$17.44	$10.33	$4.66	$5.05	$9.63
2010	$10.68	$15.90	$18.04	$10.48	$4.80	$4.91	$9.76
2011	$11.03	$15.84	$17.67	$10.41	$4.57	$4.64	$9.65
2012	$11.28	$16.04	$17.84	$10.44	$4.57	$4.73	$9.72
2013	$12.69	$16.47	$17.46	$10.50	$4.48	$4.60	$9.97
2014	$13.16	$16.76	$18.02	$10.61	$4.43	$4.58	$10.11
Average Annual Rate of Change 2014/2004	**3.3%**	**0.4%**	**0.8%**	**1.1%**	**-0.6%**	**-2.4%**	**0.9%**

[1] Includes light rail, hybrid rail, and streetcar rail.

[2] Includes bus, bus rapid transit, and commuter bus.

[3] Includes demand response and demand response taxi.

[4] Includes aerial tramway, Alaska railroad, cable car, ferryboat, inclined plane, monorail/automated guideway, público, trolley bus, and vanpool.

Note: annual changes in operating expense per capacity-equivalent VRM and unadjusted motor bus operating expenditures are consistent with those shown in Exhibit 2-32.

Source: National Transit Database.

Exhibit 2-33: Top 10 vs All Other Urban Agencies in the United States[1]

Report Year	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Average Annual Change	Change 2004–2014
Top 10 Fares per VRM	$5.2	$5.1	$5.2	$5.2	$5.2	$5.2	$5.4	$5.8	$5.9	$6.1	$6.1	**1.5%**	**17.9%**
Top 10 Cost per VRM	$11.5	$11.7	$11.9	$12.3	$12.0	$12.2	$12.4	$12.7	$13.0	$13.9	$14.2	**1.9%**	**23.3%**
Top 10 Recovery Ratio	45.0%	43.9%	44.0%	41.9%	43.0%	42.4%	43.2%	46.0%	45.0%	44.0%	43.0%	**-0.4%**	**-4.4%**
National Fares per VRM	$3.3	$3.2	$3.3	$3.0	$3.0	$3.0	$3.1	$3.2	$3.3	$3.4	$3.3	**0.1%**	**1.6%**
National Cost per VRM	$7.2	$7.6	$7.9	$7.6	$7.9	$8.0	$8.2	$8.4	$8.7	$9.2	$9.4	**2.5%**	**31.9%**
National Recovery Ratio	36.2%	35.3%	36.1%	34.0%	34.2%	34.3%	34.7%	36.7%	36.6%	36.5%	35.0%	**-0.3%**	**-3.4%**

[1] Recovery Ratio calculation and cost per mile include only mode expenses. They do not include reconciling cash expenditures.

Source: National Transit Database.

Exhibit 2-34: Urban Growth in Labor Costs—Largest 10 Agencies, 2004–2014[1]

	Average Cost per Vehicle Mile (Constant 2014 Dollars)												
Cost Component	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**% Growth Since 2004**	**Average Annual Rate of Change**
Salaries	$5.6	$5.4	$5.5	$5.5	$5.1	$5.2	$5.2	$5.3	$5.2	$5.0	$5.2	**-7.4%**	**-0.8%**
Fringe Benefits	$3.7	$3.8	$3.8	$4.1	$3.6	$3.8	$4.0	$4.2	$4.3	$4.0	$4.2	**13.3%**	**1.3%**
Total Labor Cost	**$9.3**	**$9.2**	**$9.3**	**$9.6**	**$8.8**	**$9.0**	**$9.2**	**$9.5**	**$9.4**	**$9.0**	**$9.3**	**0.9%**	**0.1%**

[1] Metropolitan Transportation Authority New York City, Chicago Transit Authority, Los Angeles County Metropolitan Transportation Authority, Washington Metropolitan Area Transit Authority, Massachusetts Bay Transportation Authority, Southeastern Pennsylvania Transportation Authority, New Jersey Transit Corporation, San Francisco Municipal Railway, Metropolitan Atlanta Rapid Transit Authority, and Maryland Transit Administration.

Note: Labor costs data are available only for a subset of agencies, and thus no national totals are included.

Source: National Transit Database.

Average Fares and Operating Costs, on a Per Mile Basis, for the Nation's 10 Largest Transit Agencies

After adjusting for inflation, fares per mile have increased by 1.7 percent from 2004 to 2014, while the average cost per mile has increased by 1.6 percent. The result is a 0.1 percent increase in the "fare recovery ratio," which is the percentage of operating costs that passenger fares cover. The 2014 average fare recovery ratio of these 10 agencies, which are all rail, was 32.7 percent. These agencies are more cost and service effective than the national average, which means that ridership grows at a rate greater than the rate of increase in service miles or operating expenses.

Operating expenditures per capacity-equivalent VRM are a better measure of comparing cost efficiency among modes than operating expenditures per VRM, because the former measure adjusts for passenger-carrying capacities. As illustrated in *Exhibit 2-35*, rail systems are more cost-efficient in providing service than are nonrail systems, once investment in rail infrastructure has been completed (indeed, this is one of the explicit tradeoffs that agencies consider when deciding whether to construct or expand an urban rail system). Based on operating costs alone, heavy rail is the most efficient at providing transit service, and demand-response systems are the least efficient.

Exhibit 2-35: Transit Operating Expenditures per Capacity-Equivalent Vehicle Revenue Mile by Mode, 2004–2014

Mode	Expenditures (Constant 2014 Dollars)						Total
	Heavy Rail	Commuter Rail	Light Rail[1]	Fixed-Route Bus[2]	Demand Response[3]	Other[4]	
2004	$3.83	$6.27	$6.20	$9.14	$22.59	$10.03	$7.08
2005	$4.00	$6.01	$6.18	$9.43	$22.84	$10.41	$7.23
2006	$3.90	$5.69	$6.24	$9.71	$23.75	$9.75	$7.25
2007	$4.23	$5.60	$5.85	$9.59	$19.38	$11.37	$7.33
2008	$4.16	$5.59	$5.89	$9.76	$19.84	$12.50	$7.41
2009	$4.21	$5.83	$6.26	$9.91	$20.41	$12.54	$7.56
2010	$4.33	$5.80	$6.46	$10.02	$19.53	$12.15	$7.65
2011	$4.46	$5.76	$5.98	$9.95	$20.19	$11.29	$7.65
2012	$4.56	$5.73	$6.12	$10.07	$19.65	$11.94	$7.72
2013	$5.47	$5.78	$5.77	$10.21	$19.55	$12.04	$8.07
2014	$5.47	$5.68	$5.72	$10.41	$21.10	$11.88	$8.20
Average Annual Rate of Change 2014/2004	**3.6%**	**-1.0%**	**-0.8%**	**1.3%**	**-0.7%**	**1.7%**	**1.5%**

[1] Includes light rail, hybrid rail, and streetcar rail.

[2] Includes bus, bus rapid transit, and commuter bus.

[3] Includes demand response and demand response taxi.

[4] Includes aerial tramway, Alaska railroad, cable car, ferryboat, inclined plane, monorail/automated guideway, público, trolleybus, and vanpool.

Source: National Transit Database.

Operating Expenditures per Passenger Mile

Operating expense per passenger mile is an indicator of the cost-effectiveness of providing a transit service. It shows the relationship between service inputs as expressed by operating expenses and service consumption as measured in passenger miles traveled. Operating expenditures per passenger mile for all transit modes combined increased at an average annual rate of 0.4 percent between 2004 and 2014 when adjusted for constant dollars (from $0.70 to $0.73). These data are shown in *Exhibit 2-36*.

Exhibit 2-36: Urban Operating Expenditures per Passenger Mile, 2004–2014

Mode	Expenditures (Constant 2014 Dollars)						Total
	Heavy Rail	Commuter Rail	Light Rail[1]	Fixed-Route Bus[2]	Demand Response[3]	Other[4]	
2004	$0.41	$0.44	$0.71	$0.95	$3.74	$0.65	$0.70
2005	$0.43	$0.47	$0.70	$0.94	$3.74	$0.62	$0.72
2006	$0.42	$0.43	$0.67	$0.92	$3.90	$0.59	$0.70
2007	$0.42	$0.41	$0.69	$0.95	$3.81	$0.68	$0.69
2008	$0.40	$0.43	$0.66	$0.94	$3.73	$0.63	$0.69
2009	$0.41	$0.45	$0.71	$0.96	$3.83	$0.64	$0.71
2010	$0.42	$0.46	$0.76	$0.98	$3.94	$0.62	$0.73
2011	$0.41	$0.44	$0.71	$0.96	$3.85	$0.60	$0.70
2012	$0.41	$0.46	$0.71	$0.93	$3.91	$0.60	$0.70
2013	$0.46	$0.46	$0.73	$0.94	$3.95	$0.59	$0.71
2014	$0.47	$0.49	$0.75	$0.96	$3.93	$0.59	$0.73
Average Annual Rate of Change 2014/2004	**1.3%**	**1.0%**	**0.6%**	**0.2%**	**0.5%**	**-0.9%**	**0.4%**

[1] Includes light rail, hybrid rail, and streetcar rail.

[2] Includes bus, bus rapid transit, and commuter bus.

[3] Includes demand response and demand response taxi.

[4] Includes aerial tramway, Alaska railroad, cable car, ferryboat, inclined plane, monorail/automated guideway, público, trolley bus, and vanpool.

Note: Does not include rural agencies because they do not report passenger miles to the NTD.

Source: National Transit Database.

Farebox Recovery Ratios

The farebox recovery ratio represents farebox revenues as a percentage of total transit operating costs net of reconciling cash expenses. Reconciling items are expense items where accounting practices vary as a result of local ordinances and conditions. The most common expenses under reconciling items are depreciation and amortization, interest payments and leases and rentals. It measures users' contributions to the variable cost of providing transit services and is influenced by the number of riders, fare structure, rider profile, and the transit agency's ability to effectively control operating expenses.. Low regular fares, high availability and use of discounted fares, high transfer rates, and relatively higher operating expenses tend to result in lower farebox recovery ratios. Farebox recovery ratios for 2004 to 2014 are provided in *Exhibit 2-37*. The average farebox recovery ratio over this period for all transit modes combined was 35.8 percent in 2014. Heavy rail had the highest average farebox recovery ratio in 2014 at 59.3 percent. Farebox recovery ratios for total costs are not provided because capital investment costs are not evenly distributed across years. Rail modes have farebox recovery ratios for total costs that are significantly lower than for operating costs alone because of these modes' high level of capital costs.

Exhibit 2-37: Urban Farebox Recovery Ratio of Operating Costs by Mode, 2004–2014

Mode	Heavy Rail	Commuter Rail	Light Rail[1]	Fixed-Route Bus[2]	Demand Response[3]	Other[4]	Total
2004	61.3%	47.0%	26.2%	29.1%	10.4%	37.3%	36.3%
2005	58.4%	47.3%	25.4%	28.4%	10.4%	36.2%	35.3%
2006	60.9%	49.5%	27.4%	28.6%	10.1%	40.3%	36.0%
2007	56.8%	49.5%	26.6%	26.6%	8.6%	35.9%	34.0%
2008	59.4%	50.3%	29.3%	26.3%	7.5%	32.9%	34.2%
2009	60.2%	48.0%	28.2%	26.7%	7.8%	35.4%	34.3%
2010	62.3%	48.6%	28.1%	26.8%	8.0%	37.2%	34.7%
2011	66.0%	52.1%	29.7%	28.0%	7.4%	38.0%	36.7%
2012	64.6%	51.8%	29.0%	28.2%	7.7%	40.1%	36.6%
2013	60.5%	50.8%	30.7%	28.5%	7.8%	40.4%	36.6%
2014	59.3%	50.1%	28.2%	27.7%	7.6%	40.4%	35.8%
Average Annual Rate of Change 2014/2004	**-0.3%**	**0.6%**	**0.7%**	**-0.5%**	**-3.2%**	**0.8%**	**-0.1%**

[1] Includes light rail, hybrid rail, and streetcar rail.

[2] Includes bus, bus rapid transit, and commuter bus.

[3] Includes demand response and demand response taxi.

[4] Includes aerial tramway, Alaska railroad, cable car, ferryboat, inclined plane, monorail/automated guideway, público, trolleybus, and vanpool.

Source: National Transit Database.

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CHAPTER 3

Travel

National and Household Travel Trends

Over the past 100 years, the national transportation system has transformed the economy and society in profound ways. Highway transportation facilitates the production and movement of commodities, supports trade in goods and services, and shapes the landscape of the Nation in the formation of industrial clusters and urban centers. Households and individuals benefit from improved mobility, expanded employment opportunities, and an increasing selection of consumer goods, all facilitated by the Nation’s highways, bridges, and transit systems.

This chapter will first describe national trends in surface transportation, including travel on highways and public transit. Because passenger vehicles are the largest component of vehicle miles traveled (VMT), the discussion on highway travel will focus on household-level analysis. Trends and patterns of freight movement will be presented in detail in Part III of this report.

Significant changes in travel behavior can be associated with demographic, economic, technological, and social change. These changes affect both commuting and leisure travel. This chapter includes a section examining the distribution of household travel across income levels. Previous C&P Reports discussed other factors that affect travel patterns. The 2010 C&P Report discussed trends in demographics and immigration. Travel trends of two major age groups—baby boomers and millennials—were analyzed in the 2013 C&P Report. The 2015 C&P Report focused on emerging technologies related to travel, including broadband access, electronic payment systems, the sharing economy, and telecommuting.

Key Takeaways

- Vehicle miles traveled (VMT) has rebounded from the 2008–2009 recession. Nationally, transit passenger miles traveled reached 55.7 billion, and unlinked passenger trips 10.5 billion.
- In 2014, licensed drivers accounted for about 70 percent of the population, and there have been more vehicles than licensed drivers since 2000. The average number of vehicles per household increased over the past three decades, as more households owned more than two vehicles.
- In 2009, Americans took 191 billion person trips for all purposes. Driving is the dominant mode of travel. Single-occupant vehicles accounted for 42 percent of all person trips, followed by carpools (40 percent), walking (10 percent), bicycle (2 percent), and transit (2 percent).
- From 1995 to 2009, people logged lower mileage and average annual driving distance decreased.

Data Sources

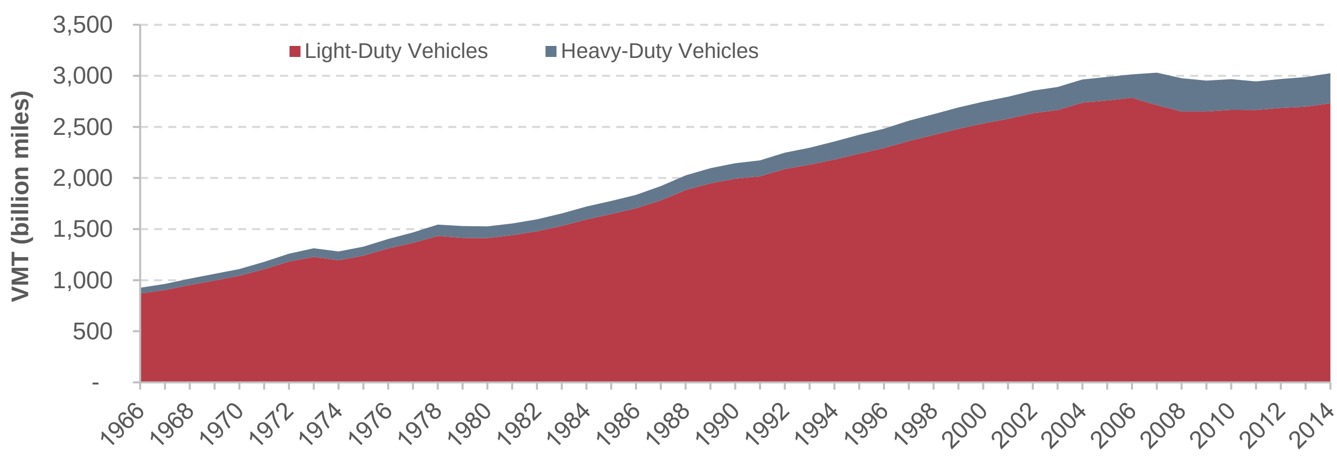
Data used in this chapter were compiled from multiple sources. Historical data are presented as far back as possible to reflect the long-term trends. Three nationally representative household surveys were used in this analysis: The annual American Community Surveys (ACS) for 2005–2014 (vehicle ownership 2000–2014), the Consumer Expenditure Surveys (CES) for selected years for 1972–2014, and the FHWA-managed survey series—the Nationwide Personal Transportation Survey (NPTS) for 1995 and the National Household Travel Survey (NHTS) for 2001 and 2009. These surveys capture household socioeconomic condition such as annual income. They also cover different aspects of household travel behavior: ACS focuses on commuter travel, CES on spending, and NPTS and NHTS on the purpose, length, and other details of each trip segment. These surveys supplement each other and enabled readers to attain a deeper understanding of household travel and its association with household income level. Information on the latest available year is reported in this C&P Report, which was 2014 for ACS and CES and 2009 for NHTS. Sometimes information for a selected year may be reported for data comparability. For example, data from ACS of 2009 are presented alongside data from NHTS 2009 in examining mode choice.

Highway Vehicle Miles Traveled

VMT reflects the movement of vehicles on U.S. highways. Historically, national VMT experienced strong and continuous growth from the construction of the Interstate System in the 1960s to mid-2000s, followed by a period of stagnation and recovery after the recession hit in 2008 (*Exhibit 3-1*). In 2014, total VMT was 3.03 trillion miles, about the same level as in 2007.

Exhibit 3-1 shows that the composition of VMT has changed over time. The proportion of VMT from heavy-duty vehicles (trucks and buses) increased from 6 percent of total VMT in 1966 to 10 percent in 2014. While VMT of both light- and heavy-duty vehicles has grown rapidly since 1966, VMT of heavy-duty vehicles, propelled by surging freight movement, has grown at a faster rate. Light-duty vehicles (passenger cars, light trucks, vans, and sport utility vehicles) represented about 90 percent of national VMT in 2014.

Exhibit 3-1: Light Duty and Heavy Duty VMT Trends, 1966–2014



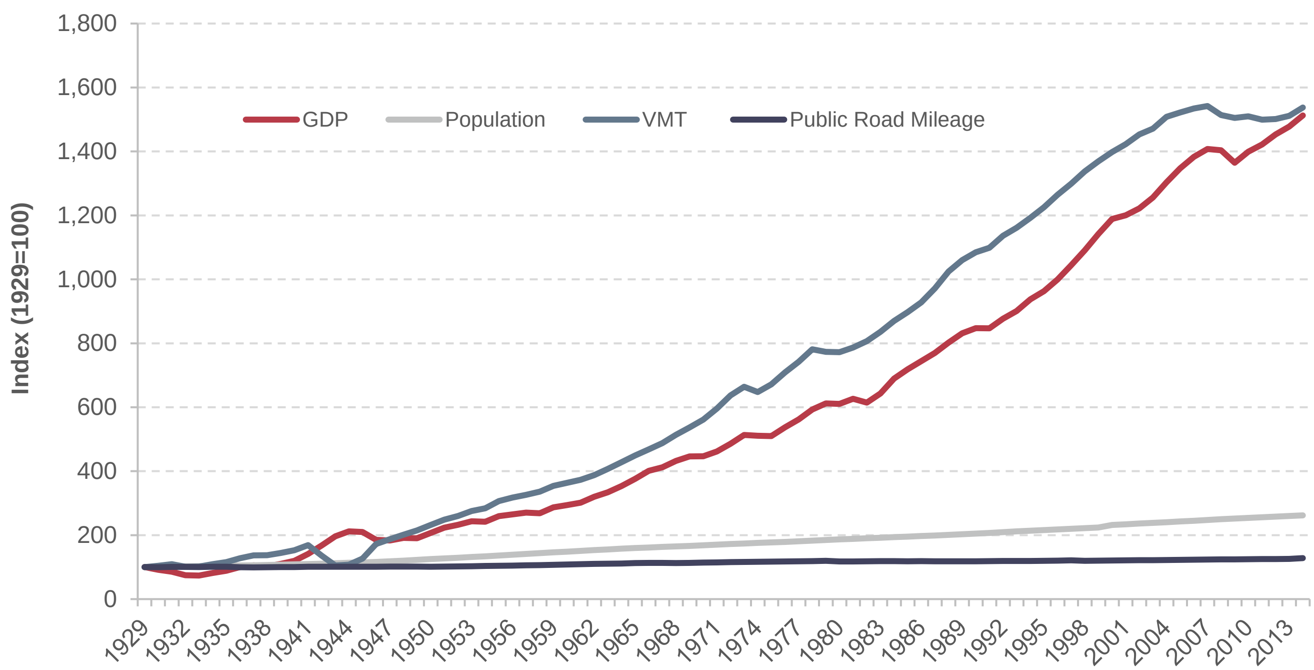
Note: Light-duty vehicles include passenger cars, motorcycles, light trucks, vans, and sport utility vehicles. Heavy-duty vehicles include single-unit trucks, combination trucks, and buses.

Source: Highway Statistics Table VM-1.

Highway VMT Compared with Other Indicators

Since 1929, national VMT growth has outpaced expansion of the economy and the U.S. population. On average, VMT rose by 3.3 percent per year from 1929–2014, while national real gross domestic product (GDP) and population grew at annualized rates of 3.2 percent and 1.1 percent, respectively. Given a system of public roads that increased its mileage by 0.3 percent per annum over this 85-year period, the steep rise of VMT indicates intensified road use by American drivers (*Exhibit 3-2*).

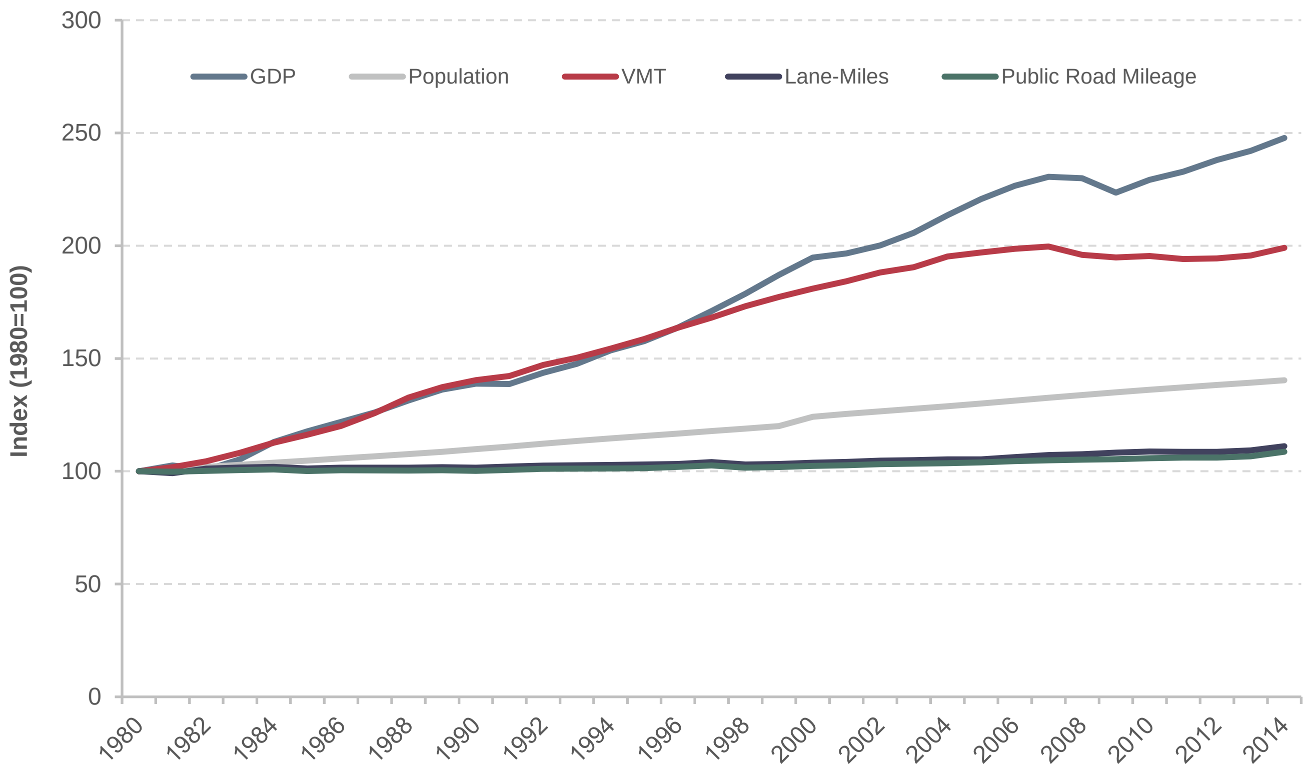
Exhibit 3-2: Growth of Real GDP, Population, VMT, and Road Length, 1929–2014



Source: VMT and public road mileage from Highway Statistics, GDP from Bureau of Economic Analysis, and population from Census Bureau.

Before its peak in 2007, VMT tracked closely with economic growth. After 2007, however, U.S. travel trends did not follow the trends of GDP as closely. This divergence was especially noticeable after the last recession in 2008–2009. After bottoming out in 2009, economic activity picked up again at 2.1 percent per annum over the period of 2009–2014, but VMT rose at a far more modest rate of 0.4 percent annually (*Exhibit 3-3*). The physical stock of roads, measured in public road mileage, expanded at a much lower rate from 2009–2014 (0.6 percent) compared with trends in socioeconomic indicators such as GDP or population.

Exhibit 3-3: Growth of Real GDP, Population, VMT, Road Length, and Lane-Miles, 1980–2014



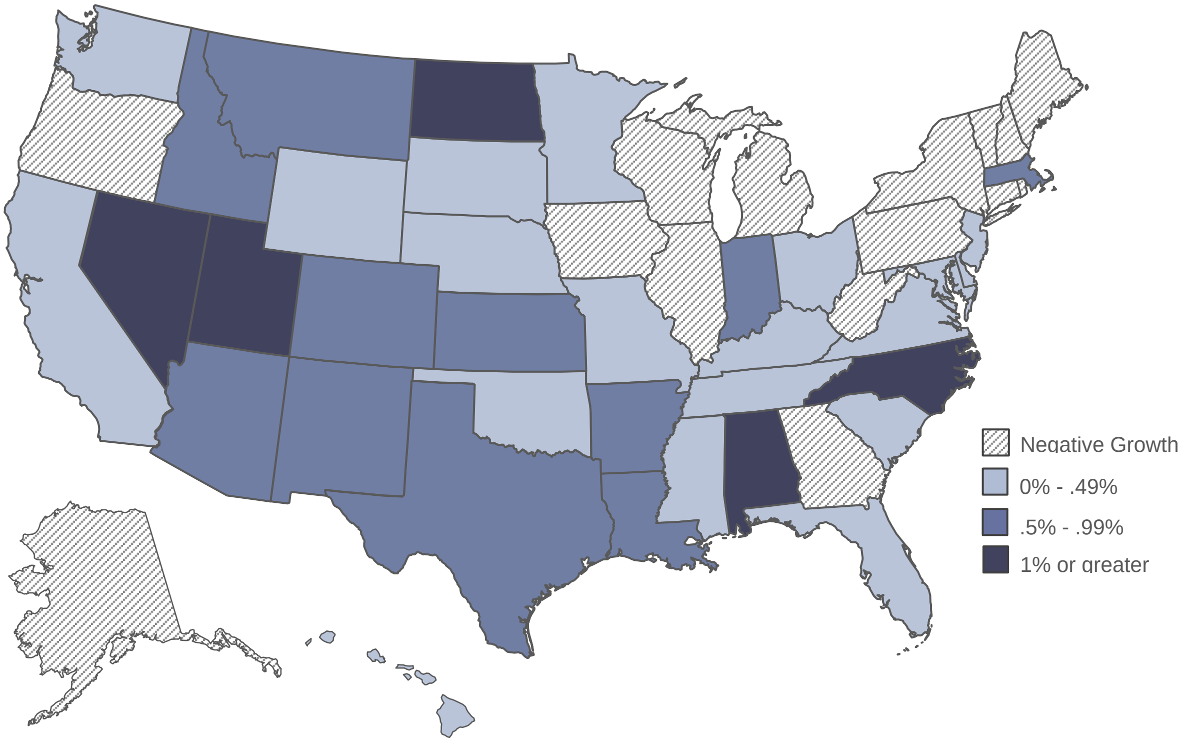
Note: Lane-miles data not available prior to 1980.

Source: VMT, public road mileage and lane-miles from Highway Statistics, GDP from Bureau of Economic Analysis, and population from Census Bureau.

Spatial Distribution of VMT

Comparing the level of VMT in 2004 with the level in 2014, several northern and western States experienced brisk growth: North Dakota, Nevada, and Utah all exhibited annual VMT growth rates above 1 percent, along with North Carolina and Alabama (*Exhibit 3-4*). States in the Northeast and the Great Lakes regions reported negative VMT growth, consistent with lesser economic growth: annual GDP growth rate was the lowest in these regions between 2004 and 2014, less than half of the national average. VMT also dropped in Georgia, Oregon, and Alaska.

Exhibit 3-4: VMT Annual Growth by State, 2004–2014

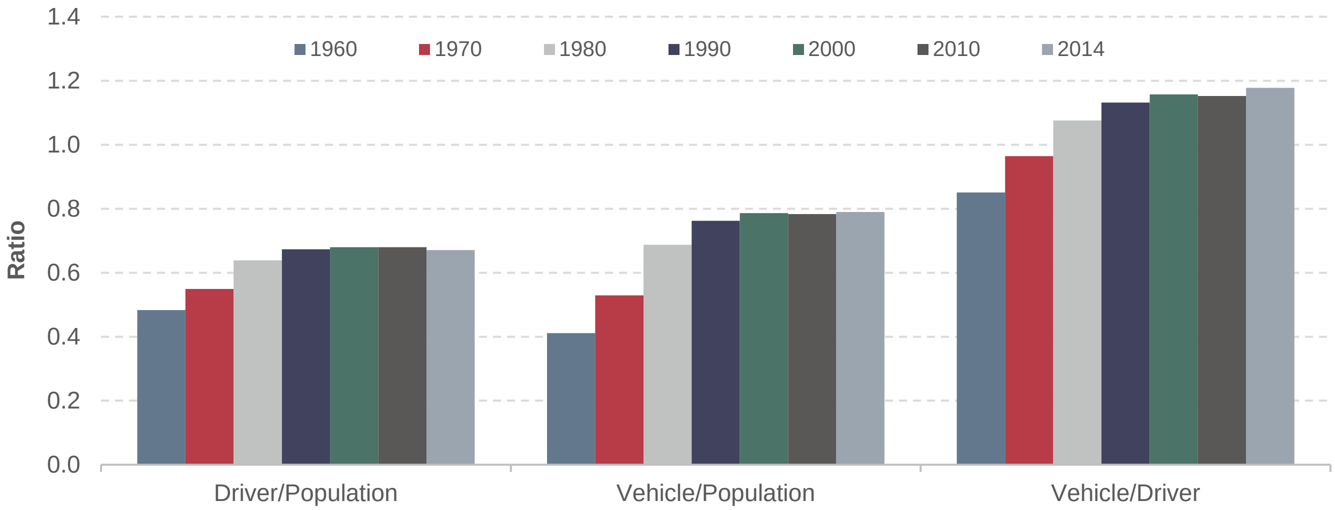


Source: Highway Statistics.

Licensed Drivers and Registered Vehicles

The number of drivers and registered vehicles are two indicators related to travel on the highway system. Since the 1960s the numbers of licensed drivers and vehicles has continued to climb, but the growth rate in licensed drivers has lagged behind total population growth. The data in *Exhibit 3-5* indicate that the share of licensed drivers in the total population grew steadily from 1960 to 1990. Afterward, the licensure level stabilized at 0.7, suggesting about 70 percent of the population held valid driver's licenses. Private vehicle ownership, measured as the number of vehicles per person, has expanded at roughly the same pace as population growth since the turn of this century, with the ratio of vehicles to total population plateauing at slightly below 0.8 since the 1990s. Drivers used to have very limited options about which household vehicle to drive in 1960, because there were fewer automobiles than licensed drivers (the vehicle-to-driver ratio was below 1.0). The situation has reversed since 1980, with the average ratio of vehicles per licensed driver remaining close to 1.2, indicating on average more than one vehicle available per licensed driver.

Exhibit 3-5: Ratios of Drivers, Vehicles and Population, Selected Years



Note: Licensed drivers and vehicle registration not available prior to 1960.

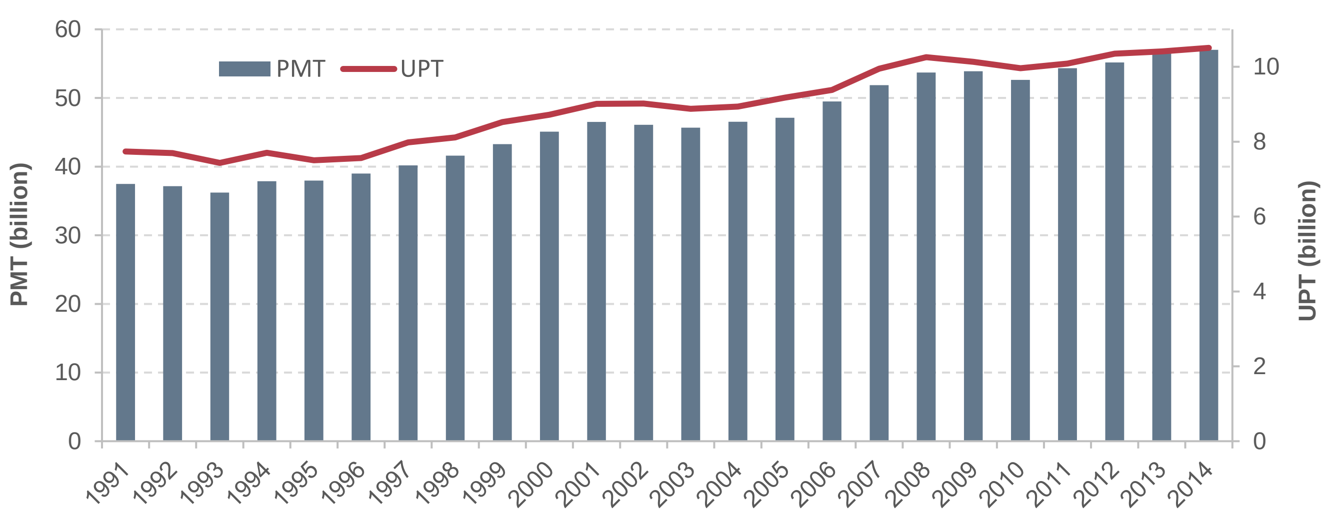
Source: Highway Statistics.

Transit Travel Trends

Two indicators are used in this chapter to measure the movement of passengers through transit systems: passenger miles traveled (PMT) and unlinked passenger trips (UPT). A UPT refers to a journey on one transit vehicle. PMT is estimated based on the number of UPTs and average trip length.

As shown in *Exhibit 3-6*, UPT trends since 1991 have generally mirrored those of PMT, increasing and decreasing in the same years. From 1991 to 2014 PMT increased by 1.8 percent annually, outpacing UPT, which grew by 1.3 percent per year. This was reflected in an increase in average passenger trip lengths. In 1991 the average transit trip was 4.8 miles. By 2014, the average transit trip increased to 5.4 miles.

Exhibit 3-6: PMT and UPT in Billions, 1991–2014



Source: National Transit Database, Federal Transit Administration.

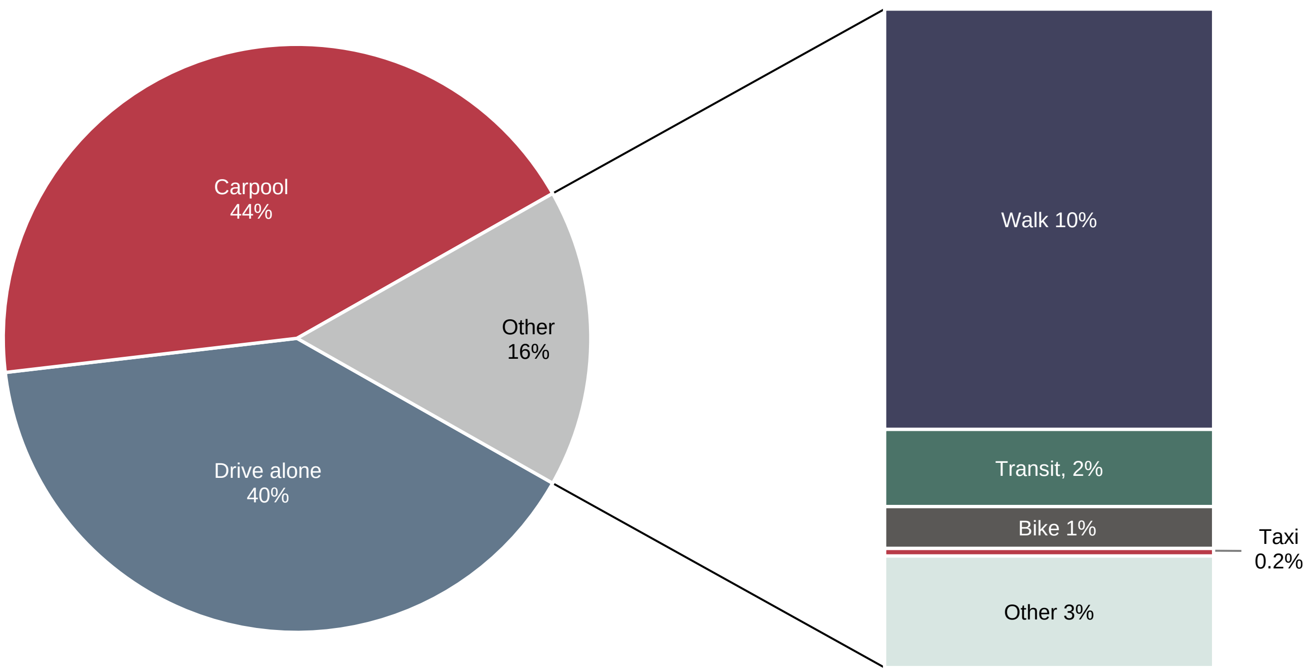
Mode Choice

Choice of travel modes is critical in understanding household and individual travel behavior, which has great implications in transportation policy design. Mode use can inform policy makers on the need for highway and transit infrastructure and services or multimodal transportation hubs. It is also a key input in many public policies, including those related to safety, emissions, and fuel consumption.

A person trip is defined in the NHTS as a trip from one address to another by one person in any mode of transportation. This is the most basic and universal measure of personal travel. In 2009, Americans took 191 billion person trips; 84 percent were in personal vehicles (*Exhibit 3-7*).

Single-occupant vehicles (a person driving alone) accounted for 40 percent of all person trips, and carpools (two or more persons sharing a vehicle) an additional 44 percent. The remaining 16 percent of person trips were made using modes other than personal vehicles, such as walking, transit, biking, and taxi. People walked to their destinations in about 10 percent of personal trips and biked in about 1 percent. Trips made through transit accounted for about 2 percent of total person trips. Trips made via other modes such as ferry, intercity train, or airplanes were less common.

Exhibit 3-7: Person Trips By Transportation Modes in 2009



Source: National Household Travel Survey 2009.

The dominant role of vehicles was more pronounced when measured by person miles traveled. Person miles traveled refers to the number of miles traveled by each person on a trip; it accounts for all miles traveled by all people during one shared trip. In 2009, about half of total person miles traveled were in shared passenger vehicles (carpool), followed by 39 percent of miles traveled driving alone (*Exhibit 3-8*). Walking or transit represented a small portion of person miles traveled, each contributing about 1 percent of total person miles traveled. This is partially due to trip distance variations by mode and location. For example, the average distance was above 5 miles per trip when traveling in vehicles, either driving alone, carpooling, or taking a taxi. On the other hand, trips made by active modes, such as walking or biking, were for much closer destinations: a walk trip only averaged 0.7 miles and a bike trip 2.2 miles. Most transit trips are likely taking place in heavily congested urban corridors.

Exhibit 3-8: Travel by Mode in 2009

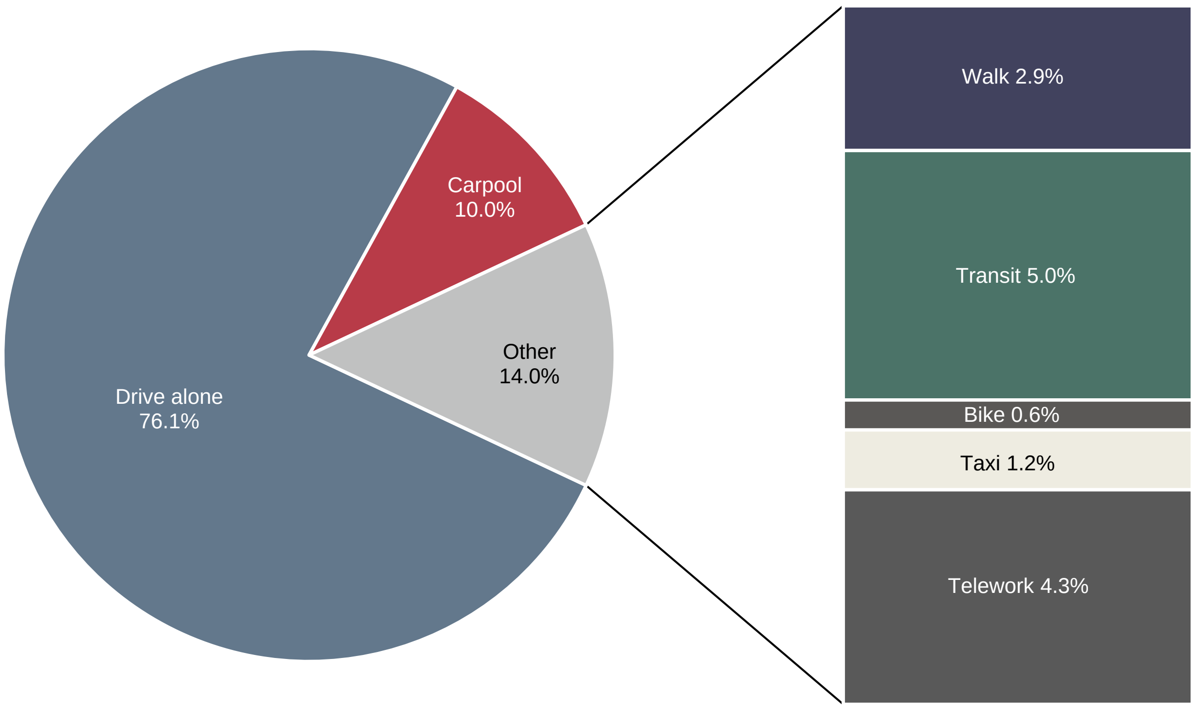
Mode	Percent of total person trips	Percent of total person miles	Average trip distance (miles per trip)
Drive alone	40%	39%	9.3
Carpool	44%	50%	10.8
Walk	10%	1%	0.7
Transit	2%	1%	7.2
Bike	1%	0.2%	2.2
Taxi	0.2%	0.1%	5.2
Other	3%	9%	30.8
All	**100%**	**100%**	**9.5**

Source: National Household Travel Survey 2009.

Although commuting was responsible for only 27.8 percent of total estimated VMT in the 2009 NHTS, it has significant influence on many aspects of travel planning. Work trips are usually the anchor of overall travel because commuting often determines the travel schedule of an individual or a household. The geographic distribution of noncommuting trips often falls in the area between home and work. Trips to and from work shape peak transportation needs, define infrastructure capacity requirements, and affect congestion time and length, travel time delay, and travel time reliability.

Exhibit 3-9 shows that solo automobile travel was the primary mode for commuters. NHTS reported that 84 percent of person trips were vehicle-based in 2009, comparable with findings from the American Community Survey (ACS) conducted in the same year. ACS estimated that approximately the same proportion of trips (86 percent) was made in private vehicles for commuting. According to ACS, a larger share of workers commuted driving alone (76.1 percent of all workers) in 2009, compared with 40 percent for trips of all purposes in 2009 as reported in NHTS in *Exhibit 3-7*. About 5 percent of workers traveled to work using transit, making transit the largest commuting mode not using personal vehicles. People walked in 10 percent of person trips for all purposes, but walking to work made up only 2.9 percent of commuting trips. About 4.3 percent of workers chose to work from home.

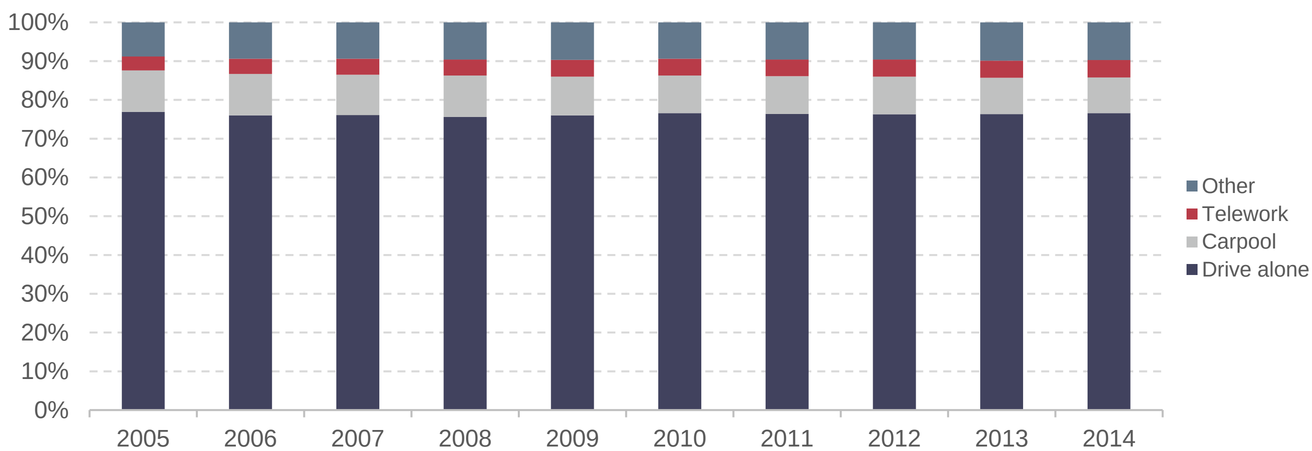
Exhibit 3-9: Workers By Commuting Modes in 2009



Source: American Community Survey 2009.

Examined over a longer period, the share of workers driving alone remained constant at 76–77 percent since 2005 (*Exhibit 3-10*). Carpooling became less popular: its share of workers slipped from 10.7 percent in 2005 to 9.2 percent in 2014. Together, about 87 percent of all trips to work were in private vehicles, but average vehicle occupancy for commuting declined continuously over time due to the reduced utilization of carpooling.

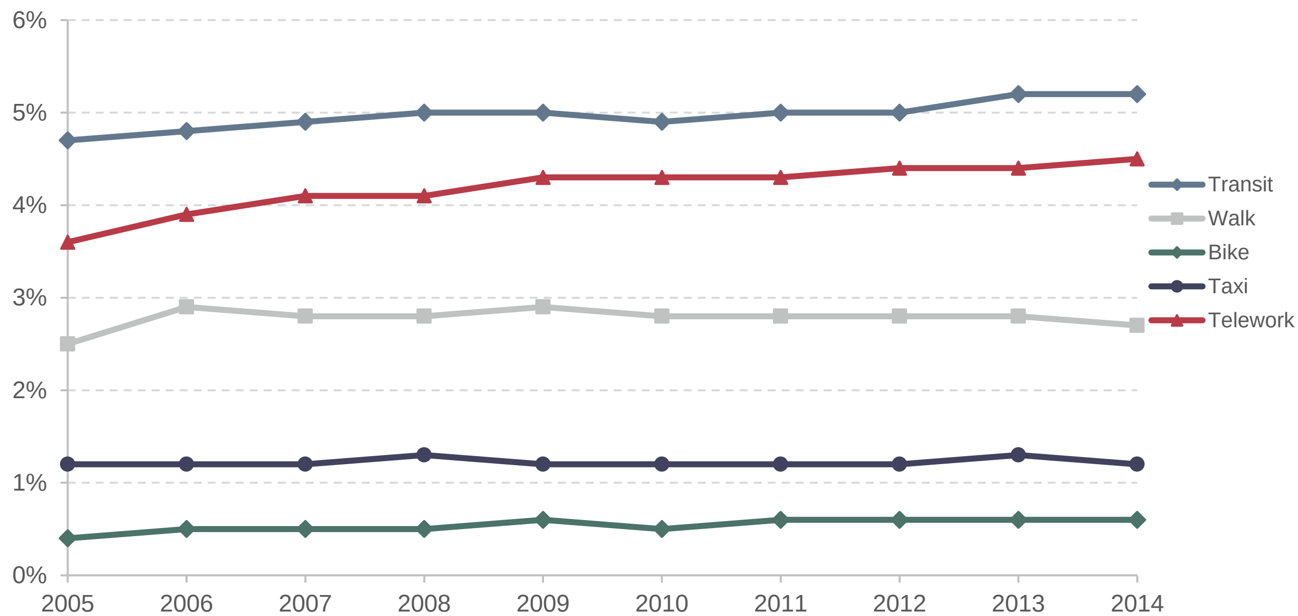
Exhibit 3-10: Share of Worker Commuting Modes, 2005–2014



Source: American Community Surveys.

Nonvehicular modes, including telework, ("Other" in *Exhibit 3-10* above) accounted for a modest share of modes used across the total labor force (less than 15 percent of workers in 2014). The proportion of workers who opted to telework on average expanded from 3.6 percent in 2005 to 4.5 percent in 2014, while the share of workers using transit rose from 4.7 percent to 5.2 percent over the same period (*Exhibit 3-11*). Workers who commute by walking or biking are still a small part of the entire commuting labor force, and their mode shares barely changed during the study period.

Exhibit 3-11: Share of Worker Non-Vehicle Commuting Modes, 2005–2014



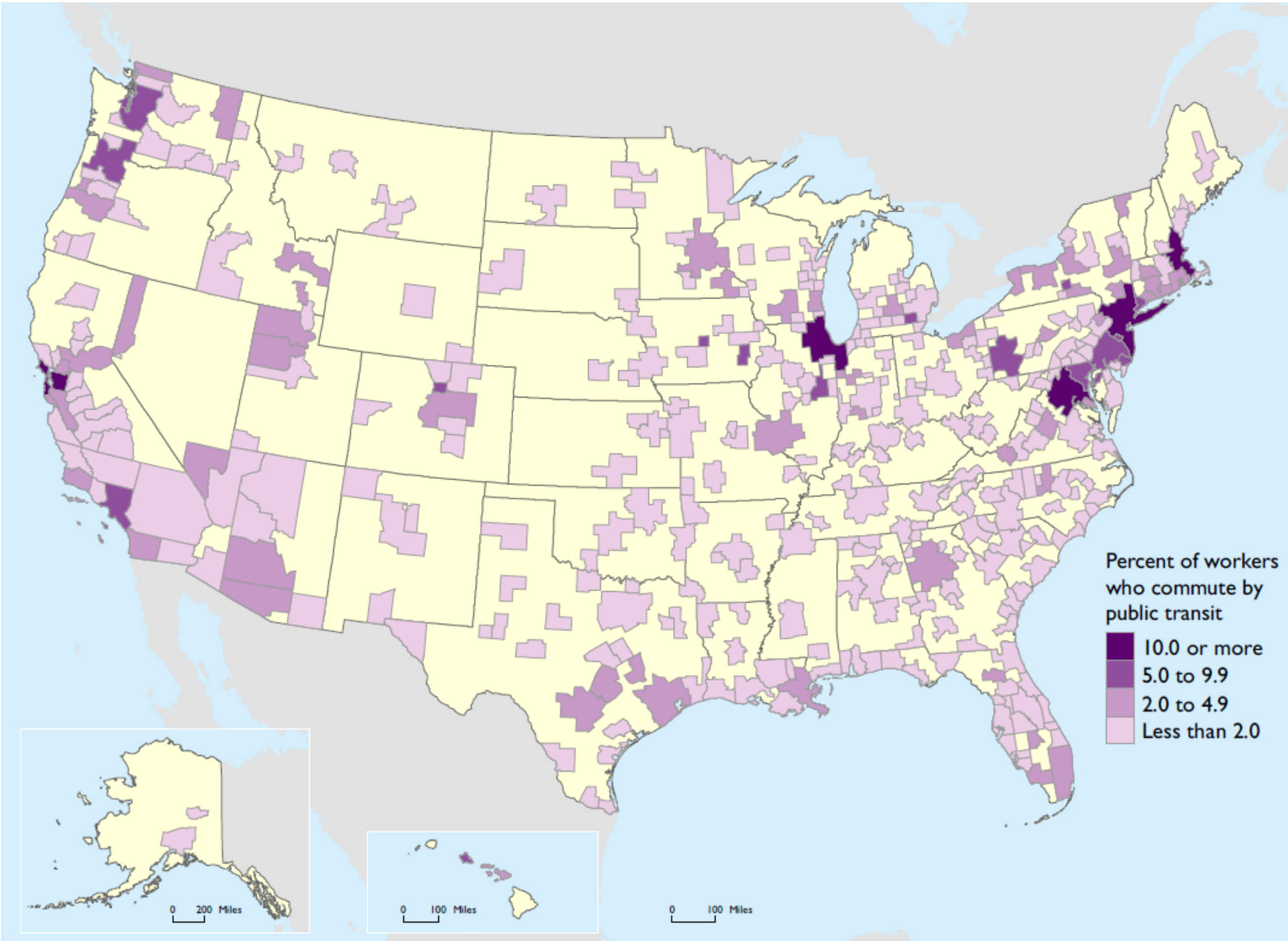
Source: American Community Surveys.

Transit Share of Commute Trips Since 2014

In 2015, the share of workers that commuted using transit was 5.2 percent, similar to the transit share of commute trips in 2013 and 2014. However, the share of workers that commuted via transit subsequently declined to 5.1 percent in 2016 and 5.0 percent in 2017.

Exhibit 3-12 shows the market share of transit by metro area for workers 16 years or older. The data were estimated based on a 5-year aggregate sample derived from the American Community Survey for the period 2010–2014. A high share of workers who commuted by public transit (the dark color in the exhibit) was concentrated along the coastal and Chicago metropolitan areas to meet demands from high population densities and dynamic economies.

Exhibit 3-12: Percent of Workers Commuting by Public Transportation in Metro Areas, 2010–2014



Source: U.S. Department of Commerce, Census Bureau, 2010–2014 American Community Survey 5-Year Estimates, available at (www.census.gov/acs as of March 2016).

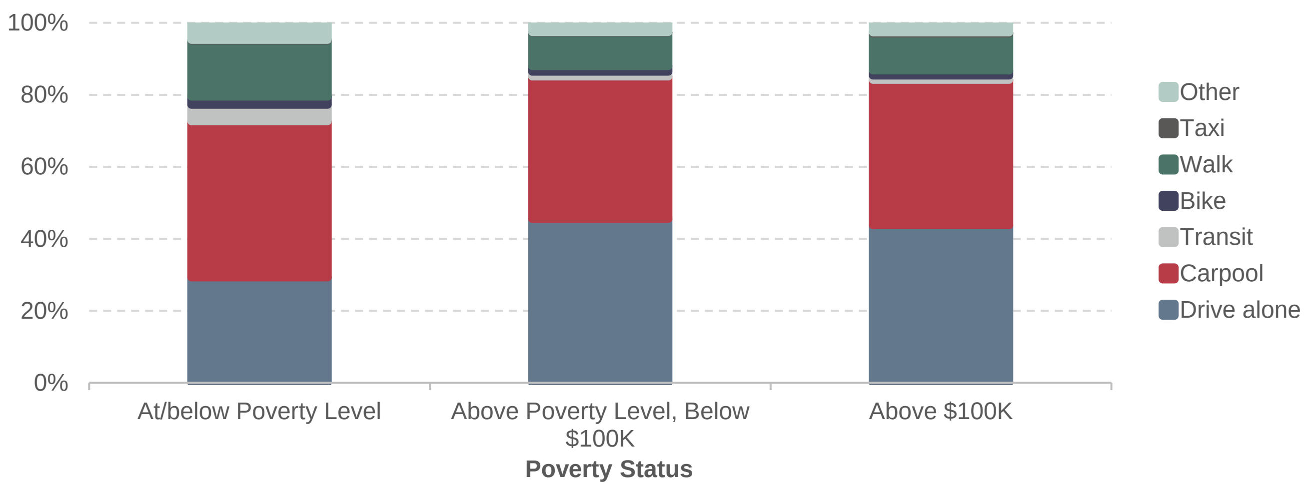
Impact of Income Distribution on Travel

Income is a crucial factor in determining mode use. For low-income households at or below the poverty level,[7] 74 percent of all-purpose trips were in private vehicles (47 percent by sharing vehicles and 27 percent by driving alone; see *Exhibit 3-13*). In contrast, households with annual income levels above poverty but below $100,000 used private vehicles for 86 percent of their all-purpose trips (drive-alone or carpooling). Walking accounted for a higher share of person trips among low-income households (15 percent) than among middle- and high-income households (9–10 percent). Given the relative short travel distance of walking trips, the reliance on walking implies lower mobility for the low-income population.

Key Takeaways

- Income is a crucial factor in determining travel behavior.
- High-income populations usually own more vehicles, drive farther, and represent a relatively larger proportion of national VMT and person miles traveled than the rest of the population.
- The affluent population also spends more on transportation, especially on new vehicles and air travel. The divergence between travel spending by the highest income group and that of the rest of the population has widened over time.

Exhibit 3-13: Person Trips by Modes and Poverty Status, 2009

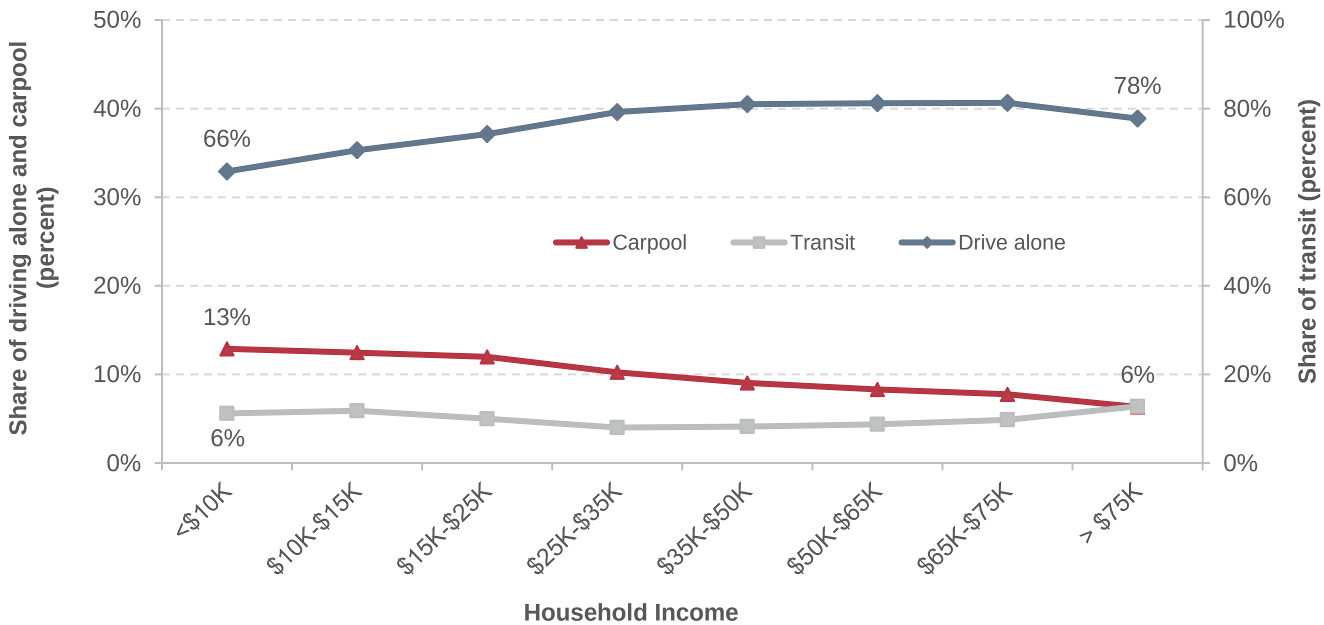


Source: National Household Travel Survey 2009.

[7] The poverty level is defined per the poverty guidelines issued each year in the Federal Register by the Department of Health and Human Services. It varies by family size and is used for administrative purposes such as determining financial eligibility for certain Federal programs. Poverty guidelines include adjustments in the poverty measure that account for increments across family size and are widely used by many federal programs for administrative purposes. In 2009, the poverty level ranged from $10,830 in one-person households to $37,010 for households with eight persons. The poverty guidelines also adjust for location by providing alternative income levels for Alaska and Hawaii. The Federal Register notice of the 2009 poverty guidelines is available at (https://aspe.hhs.gov/2009-poverty-guidelines-federal-register-notice).

The pattern of mode use across household annual income levels was similar among workers' commuting trips in the same year from ACS (*Exhibit 3-14*). Lower income groups often resorted to non-drive-alone means of transportation, such as carpooling, to go to work. The commuting shares for workers driving to and from work alone rose from 66 percent in the lowest income group to 78–81 percent in the higher income groups, while the share of workers who carpooled shrank steadily. Although driving alone remained the main means of commuting, higher income groups had a greater tendency to use transit to go to work than the middle-income group, which is indicative of higher income white-collar workers taking advantage of available transit serving clusters of jobs in downtown urban areas.

Exhibit 3-14: Workers by Commuting Modes and Household Income, 2009



Source: American Community Survey 2009.

Exhibit 3-15 shows the commuting market share of transit for the top 10 urbanized areas, ranked by their market shares. Most of these areas have large populations and high population density, and account for the majority of transit service in the United States (Concord, California and Bridgeport-Stamford, New York-Connecticut are smaller, but are also suburban areas of the larger San Francisco and New York metropolitan areas, respectively, with direct heavy rail and/or commuter rail access into the urban cores).

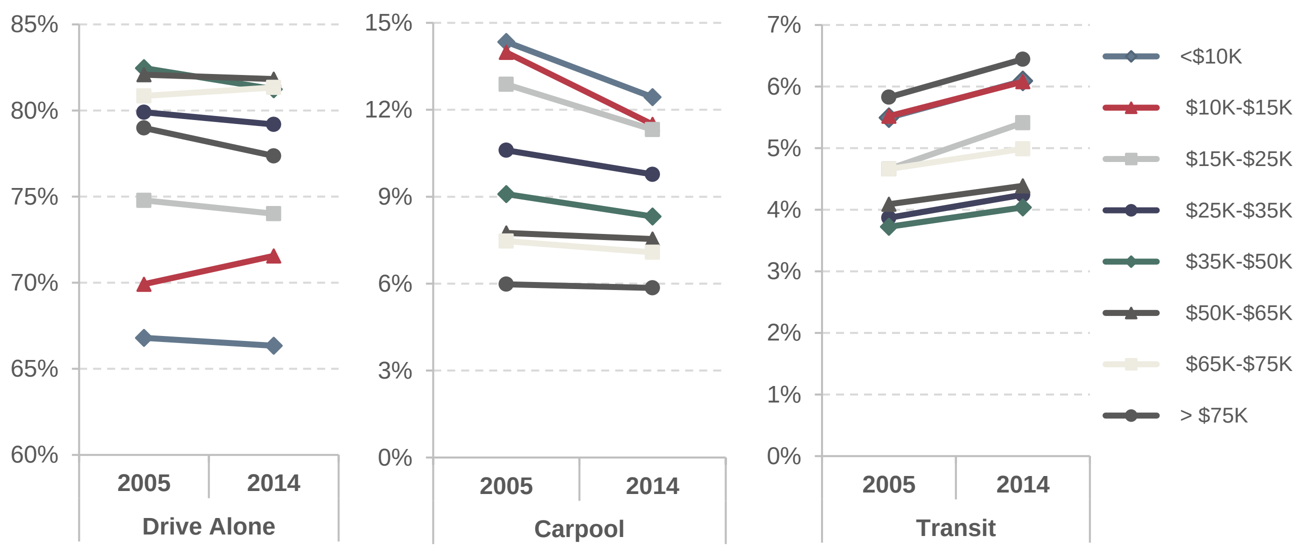
Exhibit 3-15: Commuting Market Share of Public Transportation for the Top 10 Urbanized Areas

Rank	Urbanized Area	Market Share
1	New York–Newark, NY–NJ–CT	32.1%
2	San Francisco–Oakland, CA	17.8%
3	Washington, DC–VA–MD	16.4%
4	Boston, MA–NH–RI	13.3%
5	Chicago, IL–IN	12.5%
6	Philadelphia, PA–NJ–DE–MD	10.4%
7	Concord, CA	10.0%
8	Bridgeport–Stamford, CT–NY	9.8%
9	Seattle, WA	9.4%
10	Urban Honolulu, HI	9.2%

Note: Urbanized area refers to a Census-designated urban area with 50,000 residents or more.
Source: American Community Survey 2010–2014.

Workers became less dependent on private vehicles in the decade of 2005–2014. The share of workers driving a private vehicle alone contracted in most cases (*Exhibit 3-16*). For example, 66.8 percent of workers with household annual income below $10,000 (approximately 13.4 million workers) chose to drive alone to work in 2005, but this share declined to 66.3 percent (13.2 million workers) in 2014. The shares of workers using carpooling as the means of transportation to work shrank in both low- and high-income households.

Exhibit 3-16: Change in Share of Commuting Mode by Household Income, 2005–2014

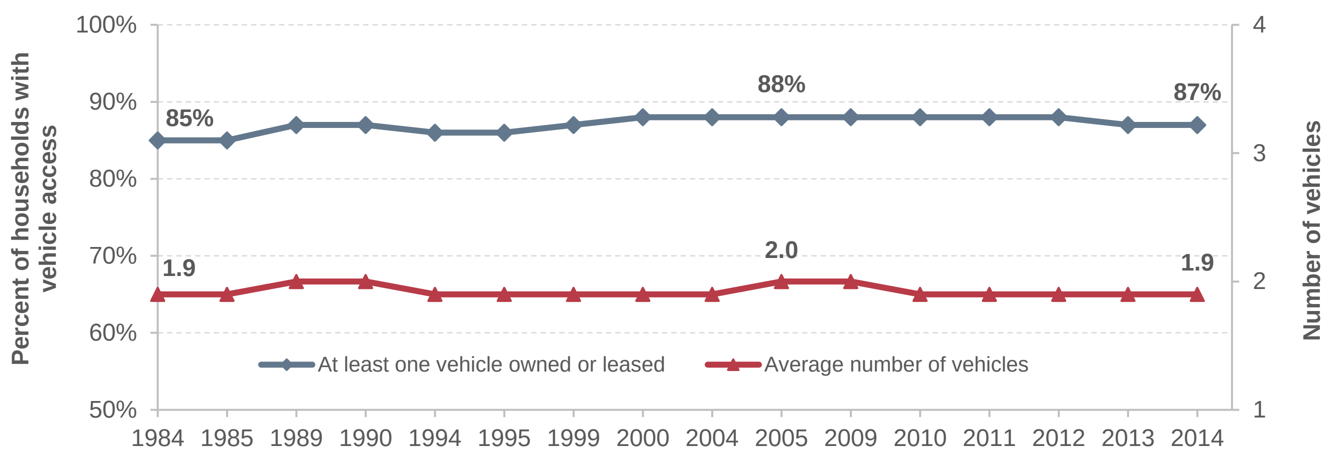


Source: American Community Surveys.

Access to Vehicles

Exhibit 3-17 presents the trend in household vehicle access, which has remained stable over 30 years. The share of households that owned or leased at least one vehicle has fluctuated within a tight band of 87–88 percent since the 1990s. The average number of vehicles in a household remained roughly constant at around 1.9 for most of the study period.

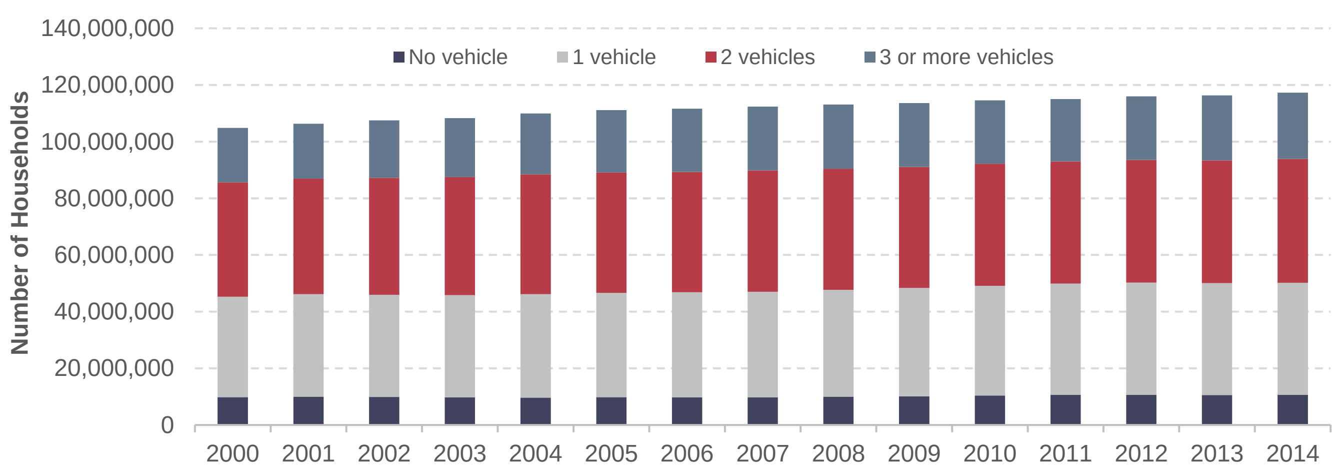
Exhibit 3-17: Household Vehicle Access, 1984–2014



Source: Consumer Expenditure Surveys.

The average number of vehicles that households could access increased marginally from 1.66 in 2000 to 1.68 in 2014, while the total number of vehicles in the country went up from 174 million to 197 million (*Exhibit 3-18*). This fleet expansion was driven primarily by an increase in the number of households with three or more vehicles, expanding from 19 to 23 million. Households with a single vehicle rose at a rate above the national average, partly attributable to the rising number of single-member households.

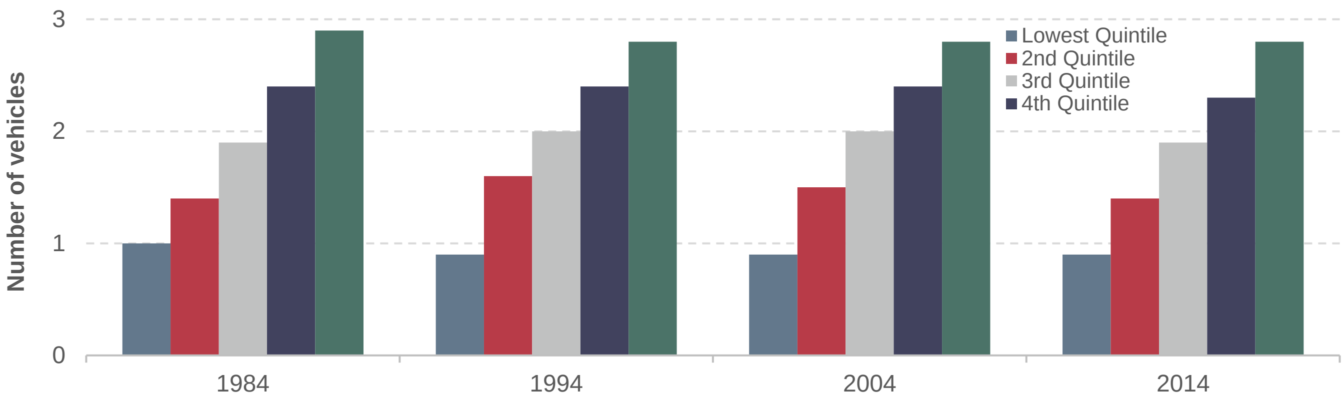
Exhibit 3-18: Number of Vehicles Available to the Households, 2000–2014



Source: American Community Surveys.

Motor vehicles are very expensive purchases, and it would thus be natural to expect that higher income households would have greater vehicle access (the number of vehicles in the household) than lower income households. *Exhibit 3-19* demonstrates a sharp increase in vehicle access across the spectrum of household annual income levels. The bottom 20 percent of income earners generally had the lowest number of vehicles, averaging less than one automobile per household. The number of vehicles per household increased steadily as income moved from low-income quintiles to high-income quintiles. Average household vehicle access was below 1.0 for the lowest income quintile, but reached 2.8 vehicles per household for the highest income quintile.

Exhibit 3-19: Average Number of Vehicles per Household by Income Quintile, Selected Years

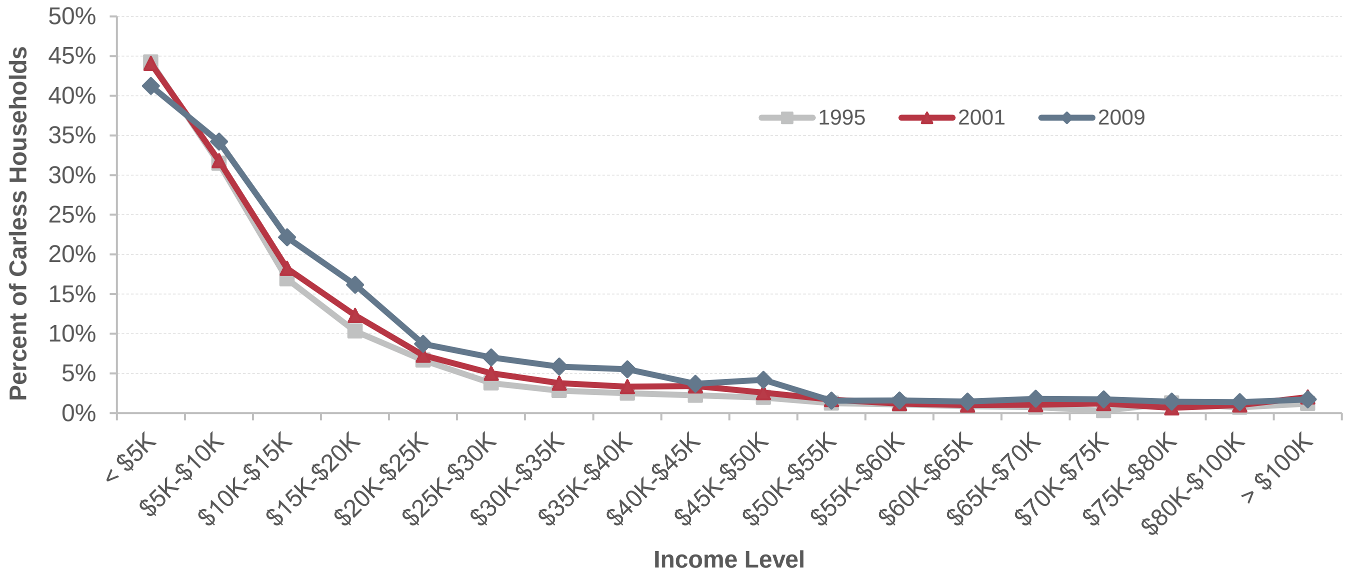


Source: Consumer Expenditure Surveys.

Owning or leasing vehicles (vehicle access) was found to be positively correlated with household income, and poor households were less likely to have access to a household vehicle. Among households facing absolute poverty with annual incomes below $5,000, more than 40 percent lacked a private vehicle (*Exhibit 3-20*). The share of carless households quickly dwindled along income brackets. Less than 2 percent of households reported not having a vehicle when household income reached $50,000. Another notable trend is that the share of households without vehicle access increased from 1995 to 2009 (except for the extremely low-income group), suggesting that many low- and middle-income households are increasingly dependent on other modes—biking, walking, ride sharing, and transit—to move around.

Carless households were concentrated in households with fewer financial resources. An annual income level of $50,000 represents an approximate midpoint: about half (54 percent) of households earned less than this amount in 2009, and the other half (46 percent) earned more. About 91 percent of all households without vehicles in 2009 fell in the lower income group, and only 9 percent in the higher income group (*Exhibit 3-21*).

Exhibit 3-20: Percent of Carless Households by Income Level, 1995–2009



Source: National Household Travel Surveys.

The issue of household vehicle availability is particularly acute among households at extremely low income levels. For example, households with annual income below $5,000 represented 3 percent of total households in 2009, but they accounted for 14 percent of carless households. In this income bracket, more than one-third of households (41 percent) did not own or lease a vehicle. The proportion of carless households diminished quickly to below 10 percent once income reached above $20,000, although this share was still high compared with 2 percent among households with income above $50,000.

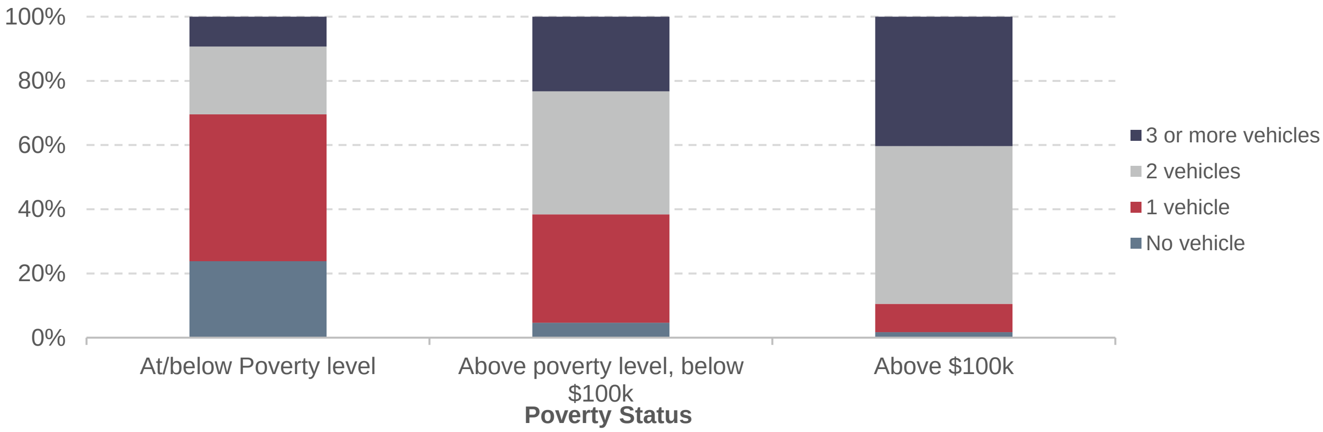
Exhibit 3-21: Carless Households by Income Group, 2009

Income Group	Share of total households	Share of total carless households	Share of the income bracket
< $5K	3%	14%	41%
$5K-$10K	5%	22%	34%
$10K-$15K	7%	18%	22%
$15K-$20K	7%	13%	16%
$20K-$25K	5%	6%	9%
$25K-$30K	7%	6%	7%
$30K-$35K	4%	3%	6%
$35K-$40K	6%	4%	6%
$40K-$45K	4%	2%	4%
$45K-$50K	6%	3%	4%
<$50K Total	54%	91%	14%
>$50K	46%	9%	2%
Total	**100%**	**100%**	**8%**

Source: National Household Travel Survey 2009.

The close relationship between household income and vehicle access was even more evident after factoring in the adjustments for household size and location used to determine poverty status. In *Exhibit 3-22*, around 24 percent of households at or below poverty level had no vehicle. The share of households without a vehicle fell below 5 percent for households whose adjusted annual income were above poverty threshold but below $100,000, and less than 2 percent for households with adjusted annual income above $100,000.

Exhibit 3-22: Household Vehicle Access by Poverty Status, 2009

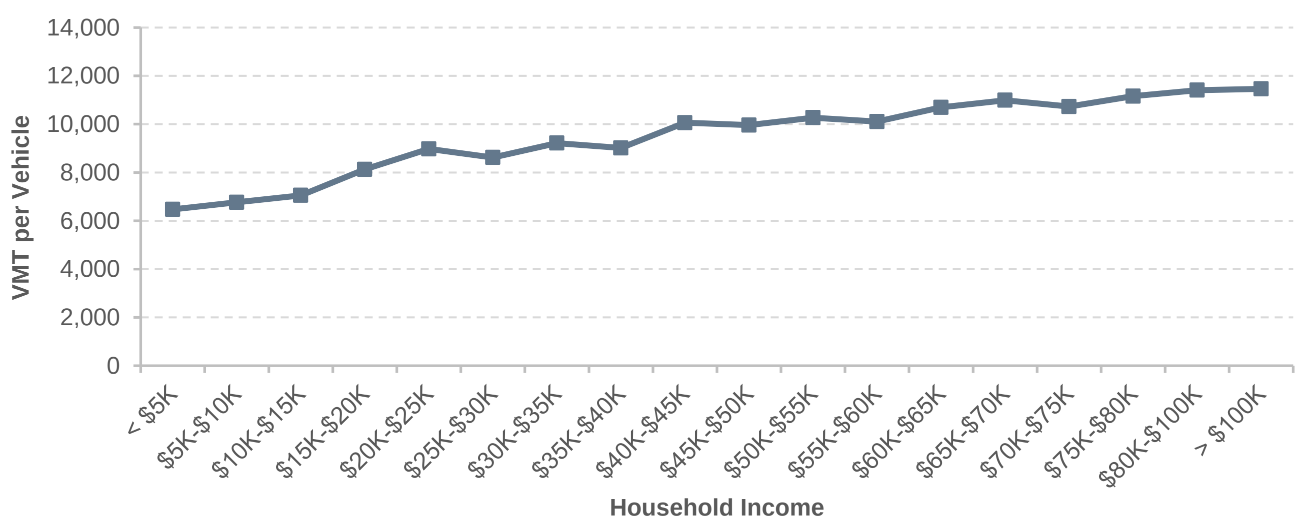


Source: National Household Travel Survey 2009.

VMT and Person Miles Traveled

The discussion above on vehicle ownership points out a positive correlation between household income and vehicle access, with carless households concentrated in low-income groups. *Exhibit 3-23* shows that there is also a strong income effect on VMT. Average annual VMT per vehicle rose rapidly among low-income households, but this comparative growth slowed as household annual income reached $35,000–$40,000.

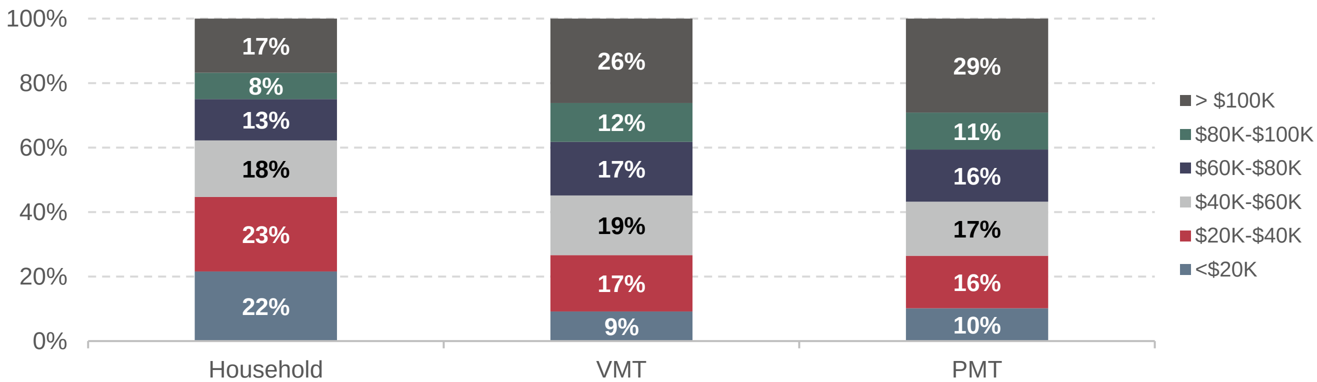
Exhibit 3-23: Average Annual VMT per Vehicle, 2009



Source: National Household Travel Surveys.

Exhibit 3-24 further underscores the uneven distribution of road use by annual household income groups in 2009. The wealthiest group (annual household income above $100,000) represented 17 percent of households, but represented 26 percent of total national VMT and 29 percent of total person miles traveled. At the other end of the income range, about 22 percent of households were classified as lowest income, with annual incomes below $20,000. This group of households drove much less, contributing only 9 percent of national VMT and 10 percent of person miles traveled. This skewed distribution indicates that the poor did not benefit as much from highway connectivity as did their wealthy counterparts, partly due to limited vehicle availability.

Exhibit 3-24: Distribution of Households, VMT, and Person Miles Traveled by Income, 2009



Source: National Household Travel Survey 2009.

Trip Characteristics

Exhibit 3-25 shows a decline in travel time and distance from 2001 to 2009. Drivers spent slightly less time traveling on average in 2009, including time spent in vehicles. Trips were also likely to be shorter: the average miles driven per driver per day decreased from 33 miles in 2001 to 29 miles in 2009. This decrease was due partly to weakening economic conditions and a high unemployment rate during the recession that was underway in 2009.

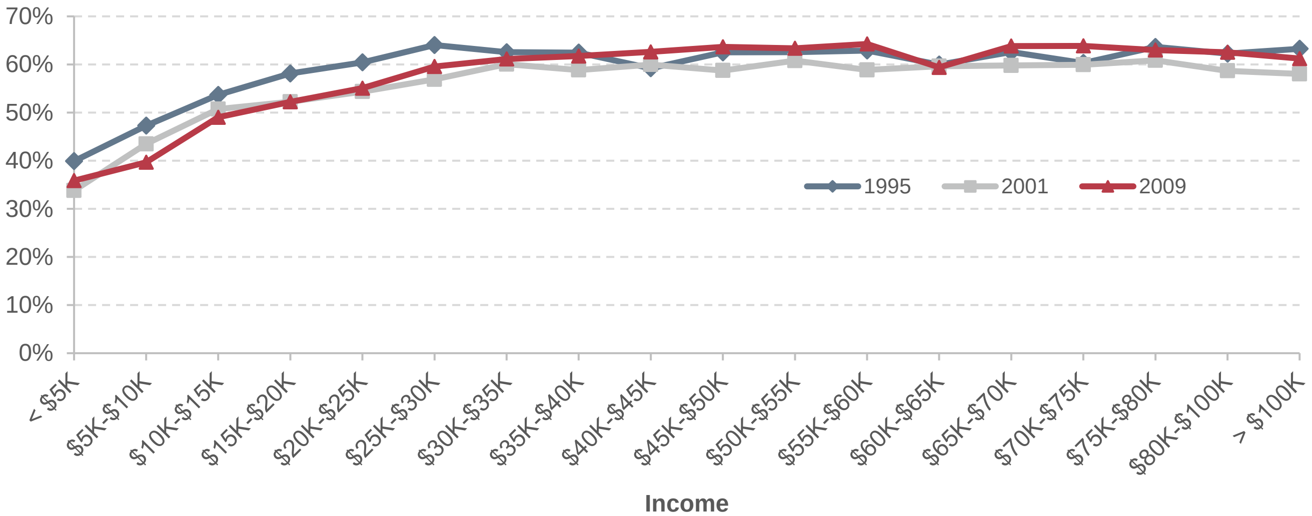
Exhibit 3-25: Trip Characteristics, 2001–2009

	2001	2009
Average Time Spent Traveling Per Day (Minutes)	88	86
Average Time Spent in Vehicle Per Day (Minutes)	83	80
Average Miles Driven Per Day Per Driver (Miles)	33	29

Source: National Household Travel Surveys.

Nationwide, more than 60 percent of person trips were vehicle trips. This share was much lower for low-income groups than for high income groups (*Exhibit 3-26*). The share of vehicle trips increased from the lowest income levels to households earning between $25,000 and $30,000, and then remained roughly constant as income increased to the highest category of over $100,000. People earning less than $5,000 in 2009 reported that about 36 percent of person trips were made in vehicles. The share of vehicle trips increased to 60 percent when household income reached $30,000.

Exhibit 3-26: Share of Travel Day Person Trips Made by Vehicle, by Income, 1995–2009

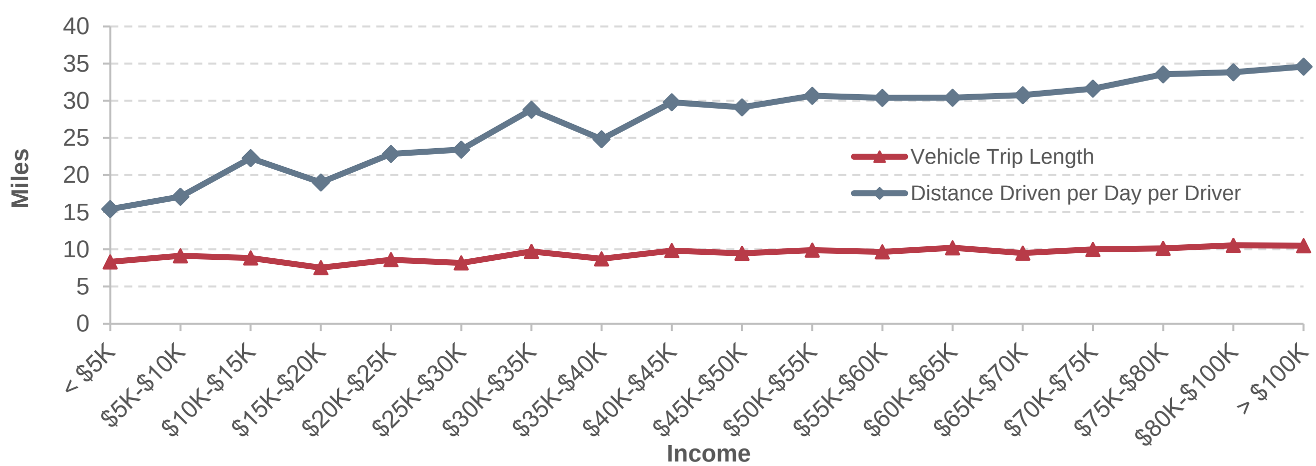


Source: National Household Travel Surveys.

Vehicle trips represented a less important mode for trips among low-income residents over time. For example, about 40 percent of person trips were made by vehicle in 1995 in the sample of households with income below $5,000 (in nominal terms in the survey year); by 2009 only 36 percent of person trips by households in this income group were vehicle trips. In other words, low-income groups were shifting toward nonvehicular options to move around.

Average distances of vehicle trips also differed across the levels of annual household income. An average vehicle trip was 8.3 miles for the lowest income group (below $5,000), and rose to over 10 miles when household annual income surpassed $70,000, an increase of more than 25 percent (*Exhibit 3-27*). More affluent drivers tended to drive farther. Average high-income drivers (household annual income above $70,000) drove more than 30 miles per day, approximately twice the distance driven by drivers from households with income below $10,000.

Exhibit 3-27: Vehicle Travel Distances and Income, 2009

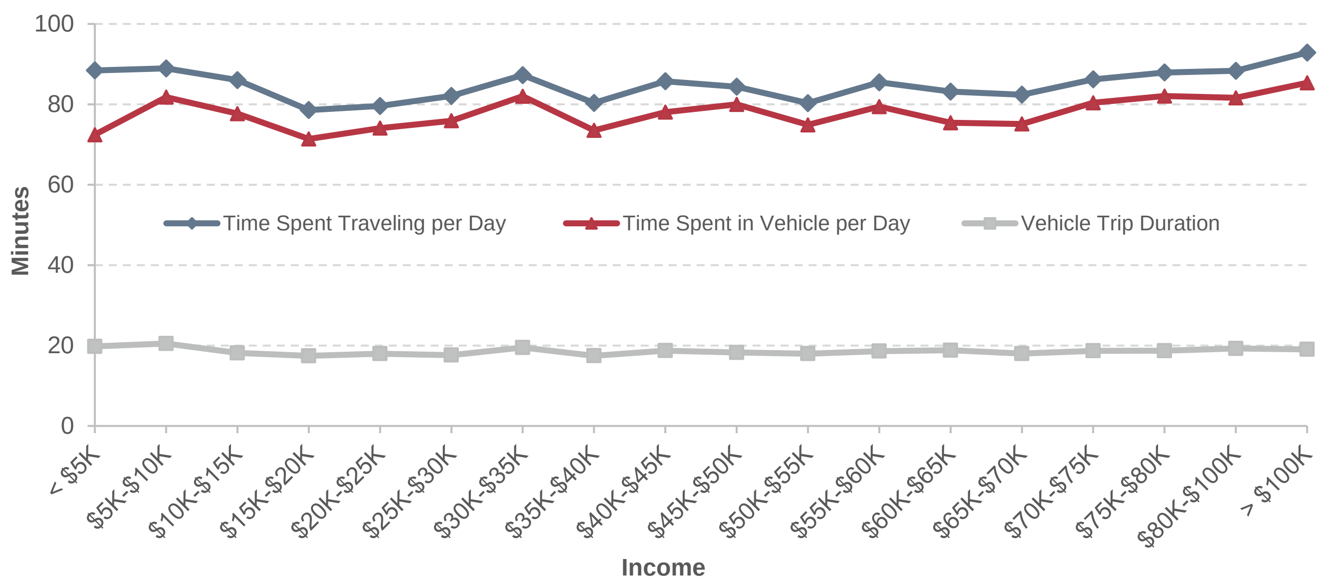


Source: National Household Travel Survey 2009.

Generally speaking, there was no obvious correlation between income and time spent traveling per day, as shown in the top line of *Exhibit 3-28*, although higher-income groups did spend more time in vehicles. Average time spent in vehicle per day (middle line of *Exhibit 3-28*) increased by 18 percent when household income shifted tenfold from $10,000 to $100,000. At the same time, average vehicle trip duration remained steady. The poor households spent approximately the same amount of time traveling but were less time-reliant on vehicles. If the poor chose to travel in vehicles, their average trip duration was similar to that of their wealthy counterparts. On the other hand, the higher income households tended to spend more time traveling in vehicles than did their low-income neighbors, despite spending approximately the same amount of time traveling per day.

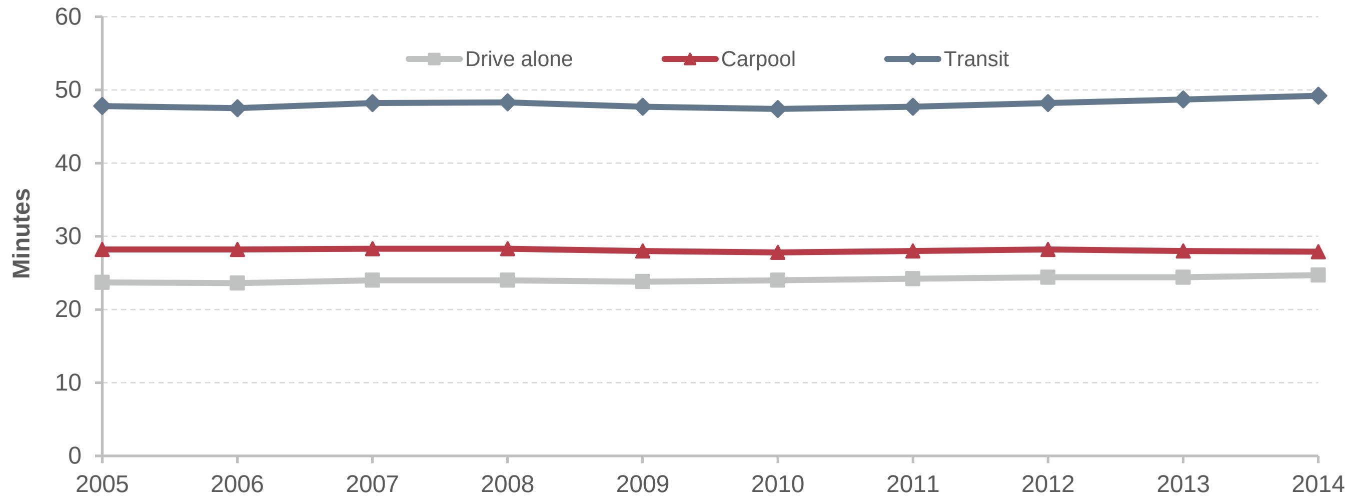
There is a clear distinction in commute time by the modes of travel. It took approximately 48 minutes, on average, for the population using transit to travel to work (*Exhibit 3-29*). The commute time was about half that for people commuting in vehicles, averaging about 24 minutes for driving alone and 28 minutes in shared vehicles. (It should be noted that a significant portion of transit ridership is occurring in congested urban corridors where vehicle travel times may be closer to transit travel times.) The average commute travel time grew longer in recent years: an average transit trip averaged 47.8 minutes in 2005 and rose to 49.2 minutes in 2014. Factors such as transit service availability and commute distance could influence the commute time. Congestion on highways also worsened over the same period: average vehicle commute time decreased by 1.0 minutes per trip for a single occupancy vehicle. Average travel time to work by carpooling dipped by 0.3 minutes per trip, less than the decrease in commute time by driving alone.

Exhibit 3-28: Vehicle Travel Time and Income, 2009



Source: National Household Travel Survey 2009.

Exhibit 3-29: Average Travel Time to Work, 2005–2014

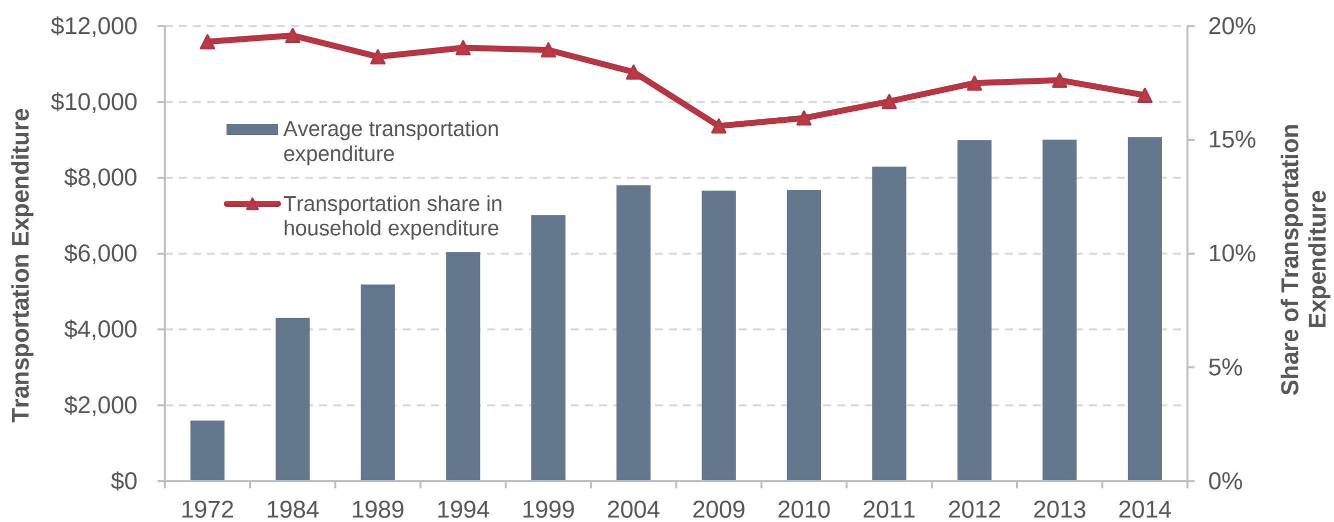


Source: American Community Surveys.

Transportation Expenditures

According to the Consumer Expenditure Survey, transportation is the second-largest household expenditure item (after housing expenses) for an average American household, and together housing and transportation make up about half of household expenditures. Although the nominal amount spent on transportation surged (multiplied by almost six times in nominal terms) from 1972 to 2014, transportation's share of total household expenditure declined over this period, dipping sharply between 2004 and 2009 (coinciding with the 2008–2009 recession) and then rebounding (but not fully recovering to pre-recession levels). The trends in *Exhibit 3-30* imply that while both total and transportation expenditure grew, transportation spending grew at a slower pace than total household expenditures.

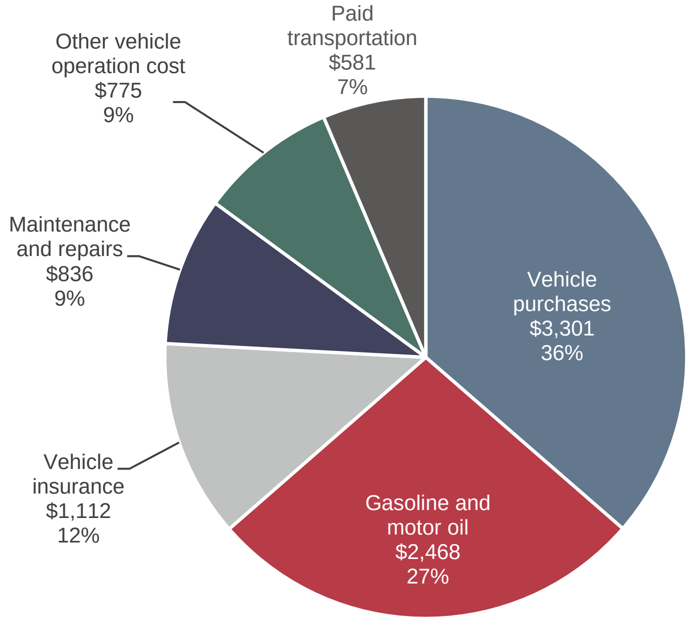
Exhibit 3-30: Transportation Component of Household Expenditure, 1972–2014



Source: Consumer Expenditure Survey.

Exhibit 3-31 provides the composition of annual transportation expenditures by main spending categories in 2014. Vehicle purchase was the top-ticket item at $3,301, representing 36 percent of overall transportation expenditure. Each year, an average household spent $2,468 on gasoline and motor oil, about 27 percent of transportation expenditure. Vehicle operation costs comprised another 30 percent of transportation expenditure, including 12 percent for insurance and 9 percent for maintenance and repairs. Paid transportation (all the modes that required a ticket purchase for use, including transit, intercity bus, rail, air, cruise ships, and taxi) made up 7 percent of annual household transportation expenditure, or $581.

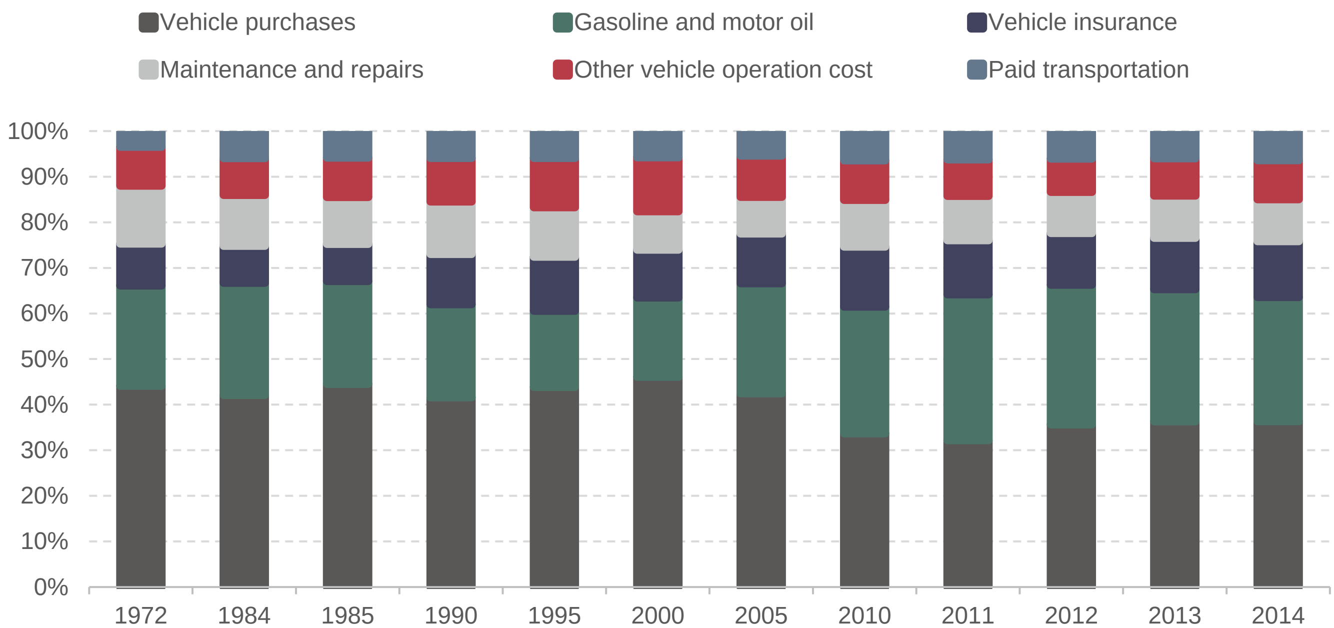
Exhibit 3-31: Composition of Household Transportation Expenditure, 2014



Source: Consumer Expenditure Surveys.

The composition of transportation expenditure items changed over time. Vehicle purchases accounted for around 45 percent of transportation expenditure from 1972 to 1999, then declined to around 36 percent in the period of 2012–2014 (*Exhibit 3-32*). The share of fuel costs expanded from 22 percent in 1972 to above 30 percent in 2011–2012. A higher portion of transportation budgets went to fuel purchase around 2012, when fuel price reached its height. Fuel cost represented 27 percent of transportation spending in 2014. Over time, purchased transportation expenditure increased from $63 in 1972 to $581 in 2014 (growing by 9.2 times in nominal terms), and the rampant growth in this category outstripped that of overall transportation spending (growing by 5.7 times in nominal terms).

Exhibit 3-32: Composition of Household Transportation Expenditure, 1972–2014



Source: Consumer Expenditure Surveys.

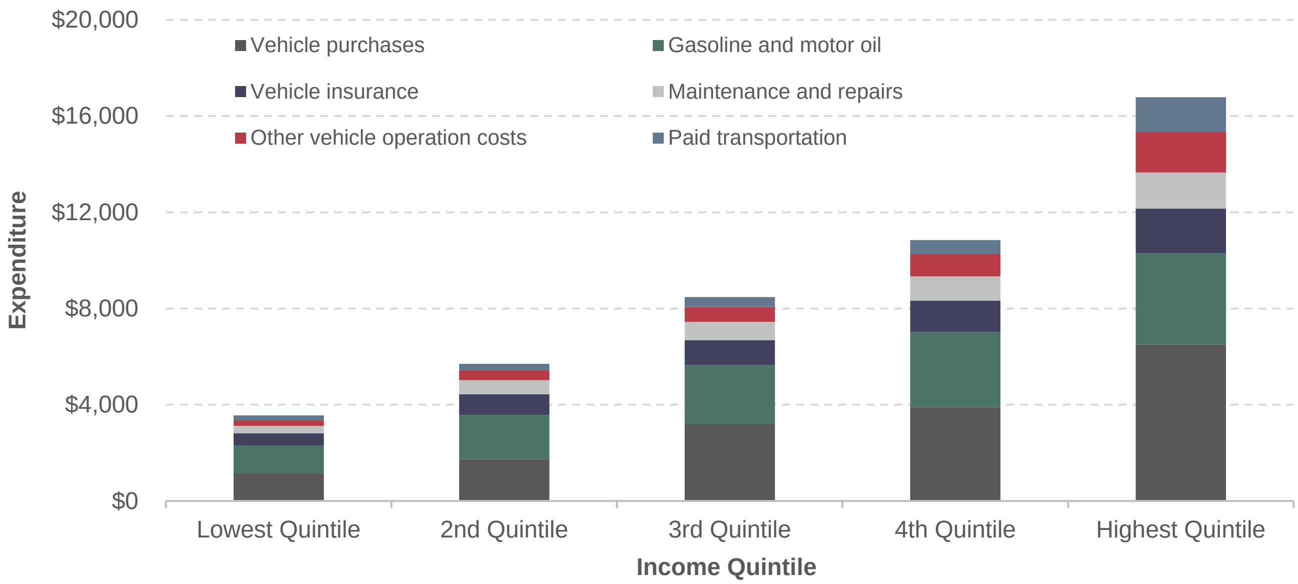
Historically, expenditures for transportation followed a standard pattern when examined across income quintiles: the level of transportation expenditure increased as household income rose, as did the share of transportation in total expenditure (*Exhibit 3-33*). High-income households tended to spend more on transportation than did their low-income peers. For example, the average annual transportation expenditure for households in the highest 20 percent of income (highest quintile) was $16,788 in 2014, which was 4.7 times the amount spent by households in the lowest income quintile ($3,555). This ratio of expansion is slightly higher than the ratio of the average household incomes between the two groups (4.4).

The composition of transportation expenditure also changes across income levels. Affluent households in the highest income quintile spent almost 40 percent of their transportation budgets on purchasing vehicles, and 23 percent on gasoline. Low-income households generally exhibited the opposite pattern, allocating a lower portion of their transportation budget to purchasing vehicles (32 percent) but a higher portion for gasoline (33 percent). At the same time, the condition of purchased vehicles also changed. In the top income quintile, new vehicles captured almost 60 percent of total vehicle purchase expenditure ($3,856), with the remaining 40 percent ($2,551) for used vehicles. This pattern was reversed for the bottom income quintile, where about one-third of vehicle purchase budget ($411) was spent on purchases of new cars and trucks, and two-thirds ($738) on used vehicles.

Purchased transportation also accounted for a larger portion of high-income households' transportation expenditure. The lowest income quintile reported an average spending of $207 on transportation purchase that required a ticket (including transit, intercity bus, rail, air, cruise ships, and taxi) in 2014. The amount increased to $583 for a typical household in the 4th income quintile, or 5 percent of transportation expenditure. Purchased transportation more than doubled to $1,456 for households in the highest quintile, accounting for 9 percent of transportation spending. This pattern suggests that purchased transportation has been treated as a discretionary good whose consumption increases with income. Intercity travel—mostly air travel—was more popular among high-income groups, leading to higher purchased transportation expenditures from more expensive recreational travel.

Exhibit 3-33: Average Transportation Expenditure and its Components, by Income Quintile, 2014

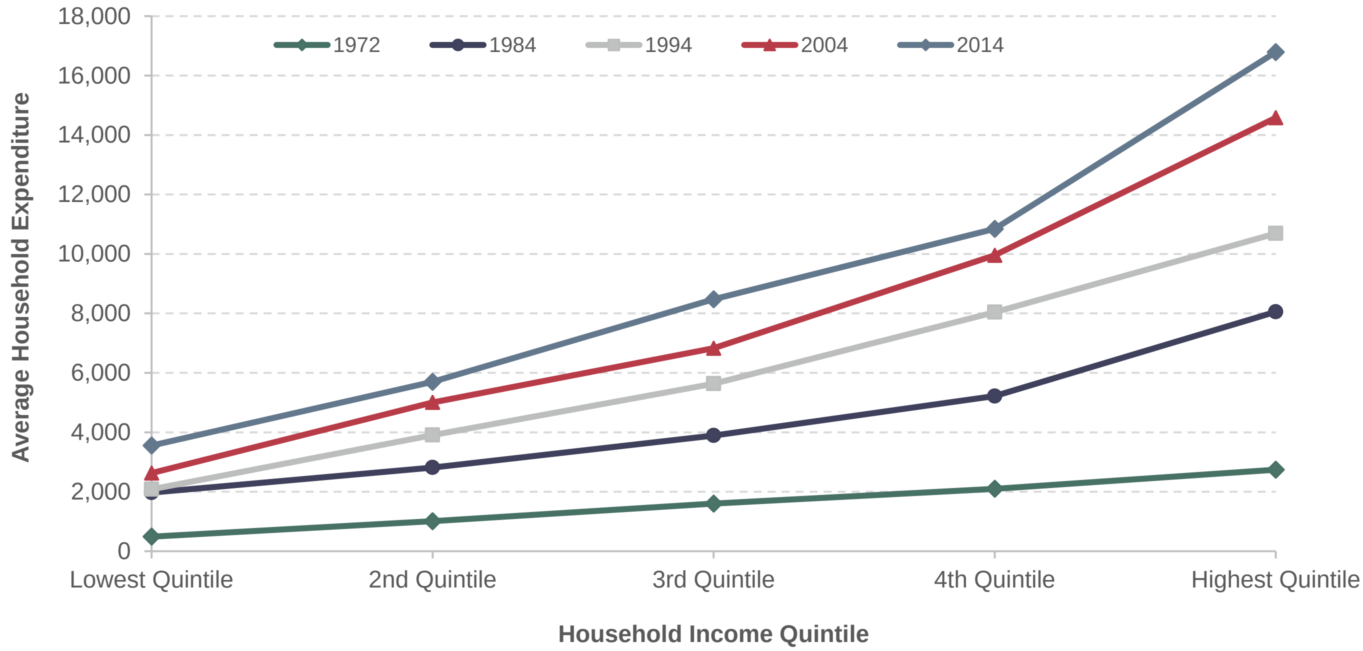
	Lowest Quintile	2nd Quintile	3rd Quintile	4th Quintile	Highest Quintile	Ratio Between Highest and Lowest Quintile
Total Expenditure	$23,713	$33,546	$45,395	$60,417	$104,363	4.4
Transportation Expenditure	$3,555	$5,696	$8,475	$10,844	$16,788	4.7
Share of Transportation in Total Expenditure	15%	17%	19%	18%	16%	0.0
Vehicle Purchases	$1,149	$1,737	$3,207	$3,905	$6,503	5.7
New vehicle	$411	$550	$1,327	$1,661	$3,856	9.4
Old vehicle	$738	$1,162	$1,812	$2,183	$2,551	3.5
Gasoline and Motor Oil	$1,160	$1,842	$2,437	$3,111	$3,789	3.3
Vehicle Insurance	$501	$853	$1,038	$1,311	$1,857	3.7
Maintenance and Repairs	$311	$590	$761	$1,009	$1,507	4.8
Other Vehicle Operation Costs	$228	$426	$621	$925	$1,674	7.3
Paid Transportation	$207	$250	$412	$583	$1,456	7.0



Source: Consumer Expenditure Survey 2014.

Average household expenditures for all income quintiles has risen over time (*Exhibit 3-34*). In each year, the higher earning quintiles had higher expenditures. However, the divergence between the highest income group and the rest of the population widened over time, as demonstrated in the kinked line between the 4th and 5th quintile. This can be attributed mainly to new vehicle purchase and purchased transportation, as discussed above.

Exhibit 3-34: Average Household Expenditure on Transportation by Income Quintile, 1972–2014



Source: Consumer Expenditure Surveys.

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CHAPTER 4
Mobility and Access

Highway Mobility and Access

Transportation infrastructure, such as highways, bridges, and public transportation, provides lasting economic benefits to the Nation and its citizens over decades through improved mobility. Mobility increases productivity through enhanced employment opportunities, lower business costs, and faster product deliveries, which are essential drivers of business expansion and economic growth. In addition, consumers benefit from the increase in available product variety and convenience of product delivery.

In urban areas, congestion is often the biggest impediment to maintaining transportation mobility. Despite past capacity expansions on highways, the system has had difficulties keeping up with rising mobility demands and thus congestion has worsened over time. This deficiency in capacity and reliability can have economic costs, such as reduced or missed opportunities and lower quality of life.

This section discusses the problem of congestion and the Federal Highway Administration's (FHWA's) diversified strategies to reduce it, followed by a discussion of mobility issues pertaining to the geometric design of highways and bridges. Operational performance of public transit will be presented later in this chapter. Freight-specific mobility issues are addressed in Part III, Chapters 11 and 12.

Key Takeaways

- Travel Time Index averaged 1.32 for Interstate highways and 1.37 for other freeways and expressways in 2015, meaning that the average peak-period trip took 32 and 37 percent longer than the same trip under free-flow traffic conditions.
- Planning Time Index averaged 2.52 for Interstate highways and 2.98 for other freeways and expressways in 2015, meaning that ensuring on-time arrival 95 percent of the time required planning for 2.52 and 2.98 times the travel time under free-flow traffic conditions.
- Travel Time Index was 1.45 in the largest metropolitan areas with population above 5 million, but 1.18 in metropolitan areas with populations of 1–2 million in 2015.
- Congestion wasted 6.8 billion hours of travel time and 3 billion gallons of fuel in 2014.
- Total cost of congestion rose from $136 billion in 2004 to $160 billion in 2014, despite a decrease in congestion during the economic recession in 2009–2010.

Congestion

Congestion on highways and bridges occurs when traffic demand approaches or exceeds the available capacity of the system. "Recurring" congestion refers to congestion routinely taking place at roughly the same place and time—usually during peak traffic periods—due to insufficient infrastructure or physical capacity, such as roadways without enough lanes to accommodate high levels of demand. The congested highway is in a condition of degraded service, causing additional and unnecessary delay for motorists. Recurring congestion may extend beyond traditional peak traffic windows and create delays for motorists who arrive before or after the traditional rush hour period.

"Nonrecurring" congestion refers to less predictable congestion occurring due to factors such as accidents, construction, inclement weather, and surging demand associated with special events. Such disruptions can take away part of the roadway from use and dramatically reduce the available capacity and/or reliability of the entire transportation system. About half the total congestion occurrences on roadways is recurring, with the other half nonrecurring.

No definition or measurement of exactly what constitutes congestion has been universally accepted. Generally, transportation professionals examine congestion from several perspectives, such as delays and variability. Increased traffic volumes and additional delays caused by crashes, poor weather, special events, or other nonrecurring incidents lead to increased travel times. This report examines congestion through indicators of duration and severity, including travel time, congestion hours, and planning time.

Measuring Congestion

The National Performance Management Research Data Set (NPMRDS) is FHWA's official data source for measuring congestion and is provided to States and metropolitan planning organizations (MPOs) on a monthly basis for their performance measurement activities. It is a compilation of vehicle probe-based travel time data of observed travel times, date/time, direction, and location for freight, passenger, and other traffic. The data are collected from a variety of sources including mobile devices, connected autos, portable navigation devices, commercial fleet, and sensors. The NPMRDS provides historical average travel times in 5-minute intervals by traffic segment in both rural and urban areas on the National Highway System, as well as over 25 key Canadian and Mexican border crossings. Based on the NPMRDS, the *Urban Congestion Reports* estimate mobility, congestion, and reliability on Interstate highways and other limited-access highways in the 52 largest metropolitan areas.

An alternative source of congestion measures is the *Urban Mobility Scorecard* developed by the Texas Transportation Institute. The report's estimated congestion trends are based on the speed data provided by INRIX®, which contains historical traffic information on freeways and other major roads and streets. Data are collected from more than 1.5 million global positioning system (GPS)-enabled vehicles and mobile devices for every 15-minute period every day for all major U.S. metropolitan areas.

Both the *Urban Congestion Reports* and the *Urban Mobility Scorecard* report traffic system performance indicators, such as the Travel Time Index (TTI), congested hours, and the Planning Time Index (PTI). However, these congestion measures differ in coverage and estimation methodology. Consequently, the values of these measures in one report could deviate from the other, despite the similarities of their names.

The *Urban Congestion Report* from NPMRDS provides selected congestion measures starting in 2012 for the Interstate functional class and starting in 2013 for the Other Freeway and Expressway functional class, while time series data in the *Urban Mobility Scorecard* started in 1982. (See Chapter 1 for a description of functional classes.) The boundaries of the 52 metropolitan areas used in the *Urban Congestion Report* are based on metropolitan statistical areas with populations above 1,000,000 in 2010. The *Urban Mobility Scorecard* includes data for 471 U.S. urbanized areas (defined by the Census Bureau as an urban area of 50,000 or more people).

In the *Urban Congestion Report*, the peak period includes the AM peak period (6 a.m. to 9 a.m.) and PM peak period (4 p.m. to 7 p.m.) on weekdays. For purposes of computing free-flow speed, the off-peak period is defined as 9 a.m. to 4 p.m. and 7 p.m. to 10 p.m. on weekdays, as well as 6 a.m. to 10 p.m. on weekends. The free-flow speed is calculated as the 85th percentile of off-peak speeds based on the previous 12 months of data. A road is classified as congested if traveling speed is below 90 percent of free-flow speed on weekdays (6 a.m. to 10 p.m.).

The *Urban Mobility Scorecard* assigned peak hours as 6 a.m. to 10 a.m. and 3 p.m. to 7 p.m. on weekdays, and the free-flow travel time is calculated during the light traffic hours (for example, 10 p.m. to 5 a.m.). Congestion occurs if traveling speed is below a congestion threshold, usually defined as the free-flow speed with an upper limit of 65 mph on the freeways.

Both NPMRDS and the Texas Transportation Institute use vehicle miles traveled as weights to aggregate values. This report presents congestion measures mainly from the aggregate 52 metropolitan areas derived from NPMRDS, supplemented with information from the *Urban Mobility Scorecard* for longer-term analysis.

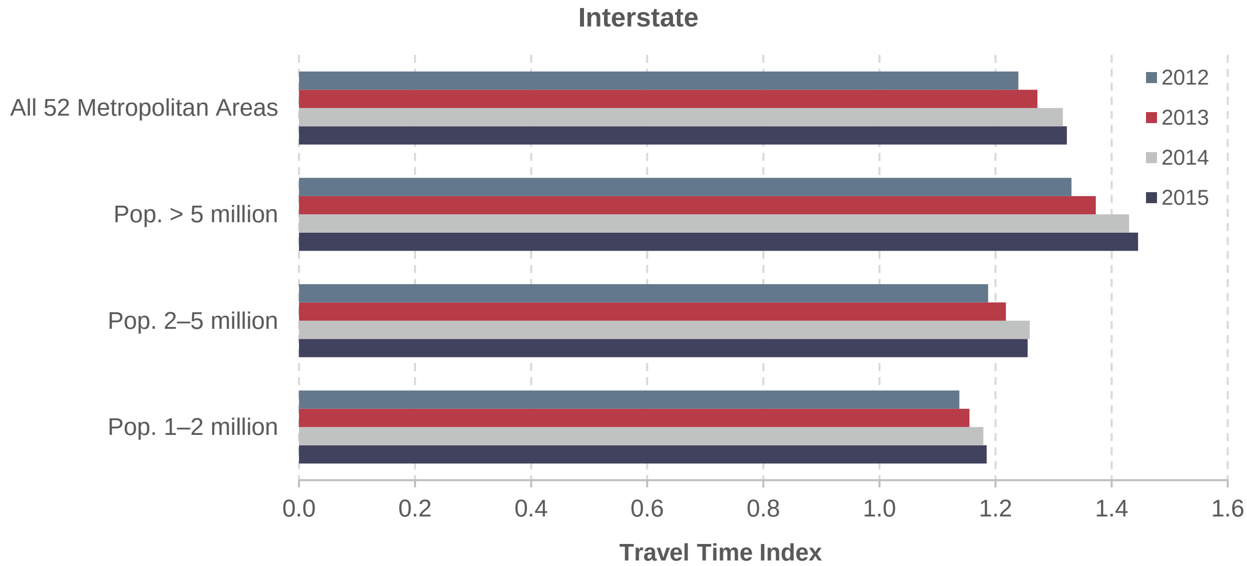
Travel Time Index

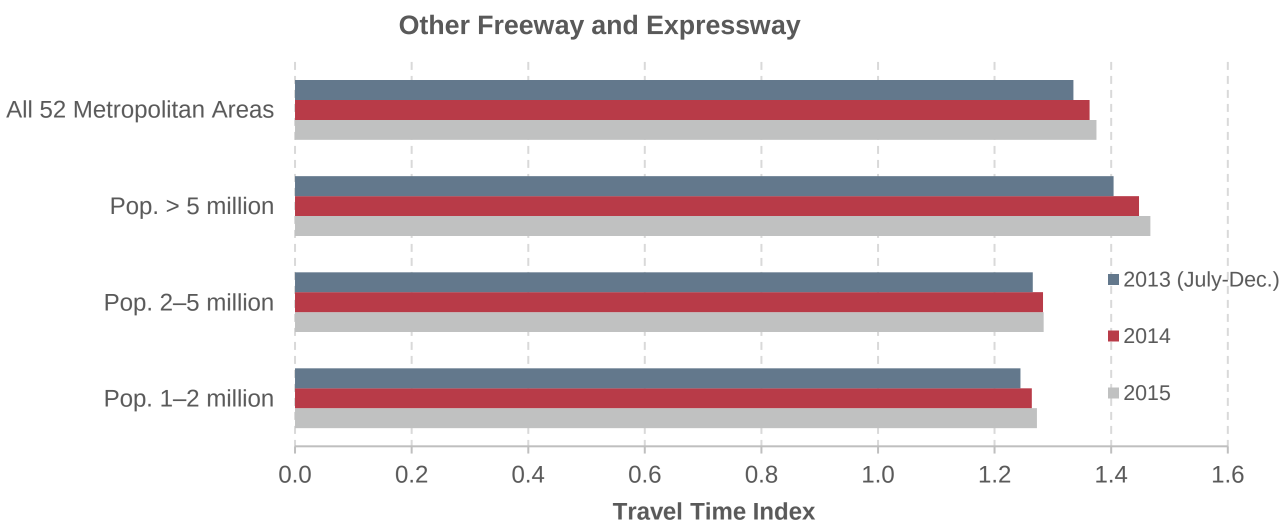
TTI is a performance indicator used to examine congestion severity. This index is calculated as the ratio of the peak-period travel time to the free-flow travel time for the AM and PM peak periods on weekdays. The value of TTI is always greater than or equal to 1, with a higher value indicating more severe congestion. For example, a value of 1.30 indicates that a 60-minute trip on a road that is not congested would take 78 minutes (30 percent longer) during the period of peak congestion.

Exhibit 4-1 indicates that the average driver spent roughly one-third more time during the congested peak time compared with traveling the same distance during the non-congested period. Congestion became more pronounced over time, as TTI climbed continuously from 2012 to 2015. TTI increased from 1.24 in 2012 to 1.32 in 2015 on Interstate highways and 1.34 in 2013 to 1.37 in 2015 for other freeways and expressways.

Residents in the largest metropolitan areas tend to experience more severe congestion, and those with more moderate populations usually report better mobility. For example, a trip that normally takes 60 minutes on the Interstate highway system during off-peak time in 2015 would have taken 71.1 minutes (18 percent longer, or TTI 1.18) on average during the peak period in a metropolitan area with population between 1 and 2 million. The same trip would take an average of 75.3 minutes (26 percent longer, or TTI 1.26) in a medium-sized metropolitan area with a population of 2–5 million and an average of 86.7 minutes (TTI 1.45) in a metropolis with more than 5 million residents. In 2015, TTI was 1.27, 1.28, and 1.47 on other freeways and expressways in metropolitan areas with population between 1 and 2 million, metropolitan areas with population between 2 and 5 million, and metropolitan areas with population greater than 5 million, respectively.

Exhibit 4-1: Travel Time Index for 52 Metropolitan Areas, 2012–2015





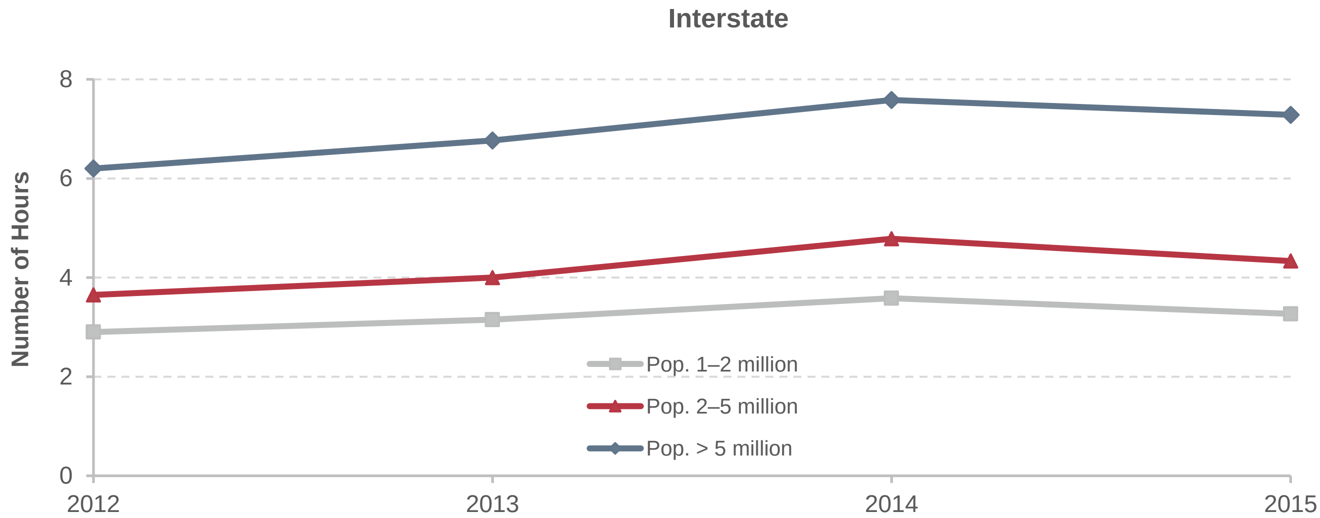
Note: TTI is averaged across metropolitan areas, road sections, and periods weighted by VMT using volume estimates derived from FHWA's HPMS over the 52 largest metropolitan areas. Data cover all Interstate highways (Interstate functional class) and other limited-access highways (Other Freeway and Expressway functional class) in these areas. Data on Interstate highways start in January 2012 and other freeways and expressways start in July 2013. Population is from United States Census Bureau 2014 Metropolitan Statistical Areas Population Estimates for 2010.

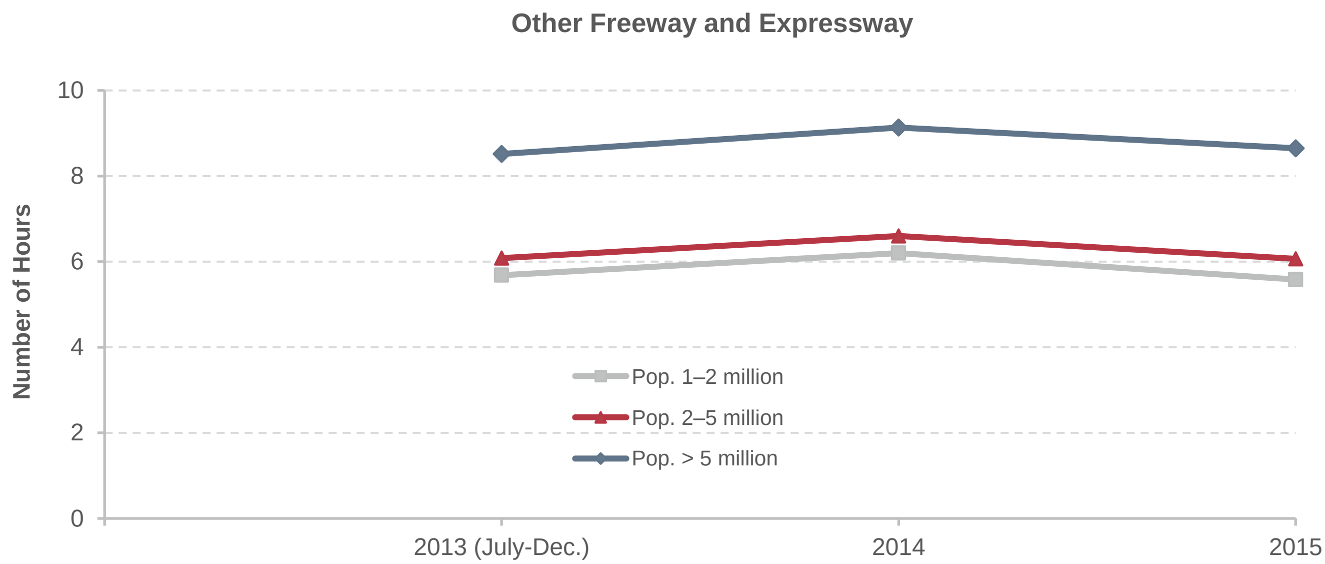
Source: FHWA staff calculation from the NPMRDS.

Congested Hours

Congested Hours is another performance indicator computed from NPMRDS for the 52 largest metropolitan areas in the United States. It is computed as the average number of hours when road sections are congested from 6 a.m. to 10 p.m. on weekdays. This is different from the TTI, which only looks at congestion in a set time window for these areas. It is worth noting that congested hours climbed to a high level in 2014 then decreased in 2015 (see *Exhibit 4-2*). On both Interstate highways and other freeways and expressways, the lines for different-sized metropolitan areas tend to move in tandem.

Exhibit 4-2: Congested Hours per Weekday for 52 Metropolitan Areas, 2012–2015





Note: Congested hours are averaged across metropolitan areas, road sections, and periods weighted by VMT using volume estimates derived from FHWA's HPMS over the 52 largest areas. Data cover all Interstate highways (Interstate functional class) and other limited-access highways (Other Freeway and Expressway functional class) in these areas. Data on Interstate highways start in January 2012 and other freeways and expressways start in July 2013. Population is from United States Census Bureau 2014 Metropolitan Statistical Areas Population Estimates for 2010.

Source: FHWA staff calculation from the NPMRDS.

Similar to the trend for TTI, longer congestion was observed in larger metropolitan areas, where average congested hours exceeded 6 hours on Interstate highways and 8 hours on other freeways and expressways on weekdays. Residents in metropolitan areas with population between 1 and 2 million experienced the lowest congested hours, averaging 3.3 hours on Interstate highways and 5.6 hours on other freeways and expressways in 2015, which was only 45 percent and 65 percent of the congested hours in metropolitan areas with more than 5 million population.

In 2015, Interstate highways in metropolitan areas with population above 5 million recorded 7.3 hours of congestion on an average weekday, which is 68 percent higher than the 4.3 hours in a typical metropolitan area with 2–5 million population. In metropolitan areas with populations of 1–2 million, Interstate highways were congested for an average of 3.3 hours, less than half of the average congested hours in the metropolitan areas with more than 5 million population. Road congestion was much worse on other freeways and expressways, where the average hours of congestion were 19–71 percent higher than those on Interstate highways, for the 52 metropolitan areas with population above 1 million, respectively.

Planning Time Index

Most travelers are less tolerant of unexpected delays than everyday congestion. Although drivers dislike everyday congestion, they may have an option to alter their schedules to accommodate it, or are otherwise able to factor it into their travel and residential location choices. Unexpected delays, however, often have larger consequences and cause more disruptions in business operations and people’s lives. Travelers also tend to better remember spending more time in traffic due to unanticipated disruptions, rather than the average time for a trip throughout the year.

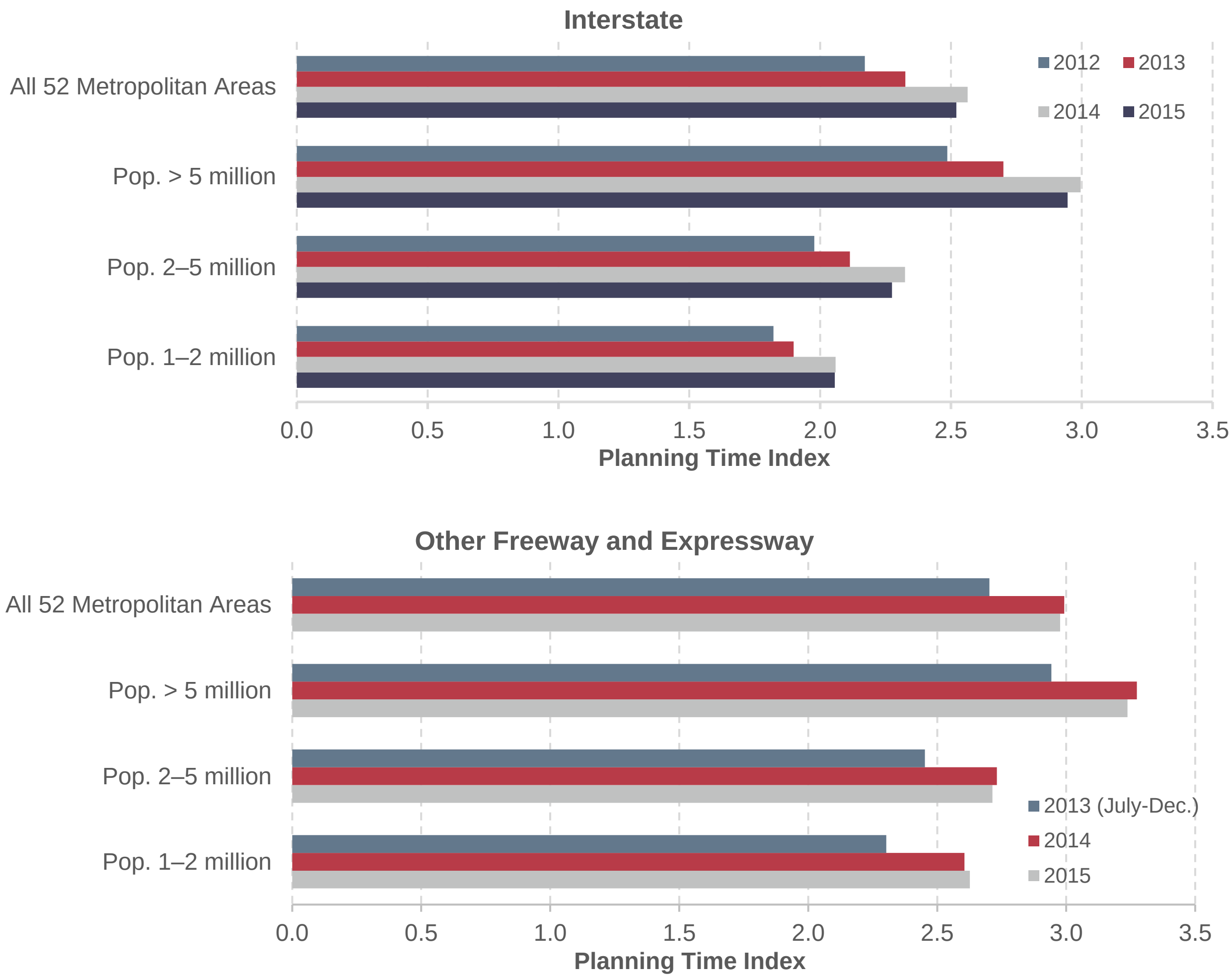
Compared with simple average measures of congestion, such as TTI or Congested Hours, measures of travel time reliability—the certainty (or variability) of travel conditions from day to day—provide a different perspective of improved travel beyond a simple average travel time. From an economic perspective, low reliability requires travelers to budget extra time in planning trips or to suffer the consequences of being delayed. Hence, travel time reliability influences travel decisions.

Transportation reliability measures primarily compare high-delay days with average-delay days. The simplest methods usually identify days that exceed the 95th percentile in terms of travel times and estimate the severity of delay on specific routes during the heaviest traffic days of each year. (These days could be spread over the course of a year or could be concentrated in the same month or week, such as a week with severe weather.) The Planning Time Index (PTI), used to measure travel time reliability in this report, is defined as the ratio of the 95th percentile of travel time during the AM and PM peak periods and the free-flow travel time. For example, a PTI of 1.60 means that, for a trip that takes 60 minutes in light traffic, a traveler should budget a total of 96 (60 × 1.60) minutes to ensure on-time arrival for 19 out of 20 trips (95 percent of the trips).

Exhibit 4-3 indicates that ensuring on-time arrival 95 percent of the time on Interstate highways in 2015 required planning for 2.52 times the travel time that would be necessary under free-flow traffic conditions (i.e., PTI was 2.52). Travel time reliability was worse, on average, on other freeways and expressways with PTI valued at 2.98.

Similar to average travel time during congested periods measured in TTI, PTI was consistently higher in the largest metropolitan areas with greater than 5 million population than in their less populated counterparts. In 2015, the average PTI was 2.95 on Interstate highways in major cities with more than 5 million residents, which was 30–43 percent higher than the index for those in metropolitan areas with population of 2–5 million (PTI was 2.27) and in metropolitan areas with population of 1–2 million (PTI was 2.06). Similarly, PTI in 2015 on other freeways and expressways in metropolitan areas with population more than 5 million was 3.24, much higher than those in metropolitan areas with populations of 1–2 million (2.63) and with populations of 2–5 million (2.71). Travel time reliability fluctuated in metropolitan areas: PTI swelled from 2012 through 2014 then reversed the trend marginally in 2015, regardless of the size of the metropolitan area.

Exhibit 4-3: Planning Time Index for 52 Metropolitan Areas, 2012–2015



Note: PTI is averaged across metropolitan areas, road sections, and periods weighted by VMT using volume estimates derived from FHWA's HPMS over the 52 largest metropolitan areas. Data cover all Interstate highways (Interstate functional class) and other limited-access highways (Other Freeway and Expressway functional class) in these areas. Data on Interstate highways start in January 2012 and other freeways and expressways start in July 2013. Population is from United States Census Bureau 2014 Metropolitan Statistical Areas Population Estimates for 2010.

Source: FHWA staff calculation from the NPMRDS.

Congestion in 52 Metropolitan Areas

Exhibits 4-4, 4-5, and 4-6 present estimated TTI, congested hours, and PTI in 2015 for the 52 largest metropolitan areas covered by the NPMRDS. Six metropolitan areas did not have sufficient data coverage on the Other Freeway and Expressway functional class.

The highest Interstate TTI was observed in major metropolitan areas in California, including Los Angeles, San Francisco, and San Jose, where over 50 percent more time was needed to travel during peak hours (TTI around 1.50) than off-peak. These areas also reported the highest PTI values, greater than 3.0, implying that more than three times the amount of free-flow travel time was needed for on-time arrivals. Interstate highways were congested during half or more of the 16-hour period from 6 a.m. to 10 p.m. on weekdays in major cities, including Los Angeles (9 hours); New York (8 hours); Denver (7.8 hours); Chicago (7.5 hours); Portland, Oregon (7.2 hours); San Francisco (7.2 hours); and Washington, DC (7.1 hours).

Exhibit 4-4: Congestion for Metropolitan Areas with Population Greater Than 5 Million, 2015

Metropolitan Area	Travel Time Index		Planning Time Index		Congested Hours	
	Interstate	Other Freeway and Expressway	Interstate	Other Freeway and Expressway	Interstate	Other Freeway and Expressway
Atlanta, GA	1.27	1.41	2.29	3.22	3:49	6:18
Chicago, IL	1.39	1.22	2.51	2.52	7:32	9:16
Dallas-Fort Worth, TX	1.33		2.93		6:15	
Houston, TX	1.40		3.05		5:49	
Los Angeles, CA	1.66	1.58	3.56	3.60	9:04	8:27
Miami, FL	1.25	1.38	2.49	2.95	4:47	5:55
New York, NY	1.31	1.38	2.40	2.95	7:57	10:19
Philadelphia, PA	1.25	1.14	2.25	1.97	5:13	4:50
Washington, DC	1.43	1.40	2.91	3.54	7:05	9:05

Note: TTI, PTI, and congested hours are averaged across road sections, and periods are weighted by VMT using volume estimates derived from FHWA's HPMS in the 9 metropolitan areas with population above 5 million. Data cover all Interstate highways (Interstate functional class) and other limited-access highways (Other Freeway and Expressway functional class) in these areas. Data on Interstate highways start in January 2012 and other freeways and expressways start in July 2013. All roads are combined in the Interstate functional class for Dallas-Fort Worth, TX and Houston, TX. Population is from United States Census Bureau 2014 Metropolitan Statistical Areas Population Estimates for 2010.

Source: FHWA staff calculation from the NPMRDS.

Exhibit 4-5: Congestion for Metropolitan Areas with Population 2–5 Million, 2015

Metropolitan Area	Travel Time Index		Planning Time Index		Congested Hours	
	Interstate	Other Freeway and Expressway	Interstate	Other Freeway and Expressway	Interstate	Other Freeway and Expressway
Baltimore, MD	1.24		2.25		5:07	
Boston, MA	1.42		3.01		6:22	
Charlotte, NC	1.19	1.31	2.00	3.94	3:00	9:21
Cincinnati, OH	1.17	1.16	1.99	2.28	3:06	7:02
Cleveland, OH	1.14	1.15	1.90	2.16	2:35	4:17
Denver, CO	1.42	1.26	2.98	2.93	7:46	7:08
Detroit, MI	1.20	1.21	2.38	2.75	4:00	5:08
Kansas City, MO	1.12	1.15	1.76	2.31	2:29	5:29
Minneapolis-St. Paul, MN	1.26	1.37	2.35	2.82	5:00	7:39
Orlando, FL	1.33	1.06	2.54	1.64	6:40	1:39
Phoenix, AZ	1.27	1.24	2.23	2.56	3:01	3:48
Pittsburgh, PA	1.13	1.20	1.80	2.71	2:46	8:48
Portland, OR	1.47	1.53	3.03	3.79	7:13	9:23
Riverside-San Bernardino, CA	1.20	1.43	1.84	2.78	4:48	7:18
Sacramento, CA	1.17	1.33	1.86	2.78	3:44	4:57
San Antonio, TX	1.19	0.00	2.18	0.00	3:28	0:00
San Diego, CA	1.26	1.29	2.45	2.89	3:39	5:47
San Francisco, CA	1.51	1.49	3.24	3.42	7:12	7:29
San Juan, PR	1.49	0.00	2.66	0.00	3:22	0:00
Seattle, WA	1.44	1.32	2.82	2.83	6:50	9:34
St Louis, MO	1.15	1.18	1.98	3.25	2:59	6:16
Tampa, FL	1.22	1.17	2.21	2.42	2:45	3:23

Note: TTI, PTI, and congested hours are averaged across road sections, and periods are weighted by VMT using volume estimates derived from FHWA's HPMS in 22 metropolitan areas with population 2–5 million. Data cover all Interstate highways (Interstate functional class) and other limited-access highways (Other Freeway and Expressway functional class) in these areas. Data on Interstate highways start in January 2012 and other freeways and expressways start in July 2013. All roads are combined in the Interstate functional class for Dallas-Fort Worth, TX and Houston, TX. Population is from United States Census Bureau 2014 Metropolitan Statistical Areas Population Estimates for 2010.

Source: FHWA staff calculation from the NPMRDS.

Exhibit 4-6: Congestion for Metropolitan Areas with Population 1–2 Million, 2015

Metropolitan Area	Travel Time Index		Planning Time Index		Congested Hours	
	Interstate	Other Freeway and Expressway	Interstate	Other Freeway and Expressway	Interstate	Other Freeway and Expressway
Austin, TX	1.39		2.88		5:06	
Birmingham, AL	1.04		1.35		0:37	
Buffalo, NY	1.15	1.20	1.91	2.18	4:47	9:17
Columbus, OH	1.13	1.17	1.85	2.37	2:23	4:39
Hartford, CT	1.15	1.13	1.93	2.05	2:53	4:07
Indianapolis, IN	1.11	1.25	1.55	2.89	2:43	12:19
Jacksonville, FL	1.14	1.25	1.87	3.23	2:35	8:56
Las Vegas, NV	1.17	1.21	1.92	2.15	3:13	4:04
Louisville, KY	1.15	1.22	2.02	3.46	3:18	5:14
Memphis, TN	1.17	1.22	1.80	2.59	3:56	6:05
Milwaukee, WI	1.23	1.17	2.27	1.92	3:55	3:33
Nashville, TN	1.19	1.19	2.03	2.23	2:58	5:32
New Orleans, LA	1.12	1.58	1.95	5.51	2:51	11:46
Oklahoma City, OK	1.12	1.12	1.78	1.98	2:31	3:07
Providence, RI	1.17	1.20	1.98	2.28	4:08	7:56
Raleigh, NC	1.12	1.13	1.83	2.07	2:11	3:17
Richmond, VA	1.06	1.12	1.51	1.73	1:38	5:26
Rochester, NY	1.08	1.17	1.64	1.96	2:27	5:33
Salt Lake City, UT	1.15	1.15	1.90	2.15	3:00	5:43
San Jose, CA	1.49	1.42	3.54	3.17	5:56	5:18
Virginia Beach, VA	1.22	1.23	2.52	2.77	5:34	7:55

Note: TTI, PTI, and congested hours are averaged across road sections, and periods are weighted by VMT using volume estimates derived from FHWA's HPMS in 21 metropolitan areas with population 1–2 million. Data cover all Interstate highways (Interstate functional class) and other limited-access highways (Other Freeway and Expressway functional class) in these areas. Data on Interstate highways start in January 2012 and other freeways and expressways start in July 2013. All roads are combined in the Interstate functional class for Dallas-Fort Worth, TX and Houston, TX. Population is from United States Census Bureau 2014 Metropolitan Statistical Areas Population Estimates for 2010.

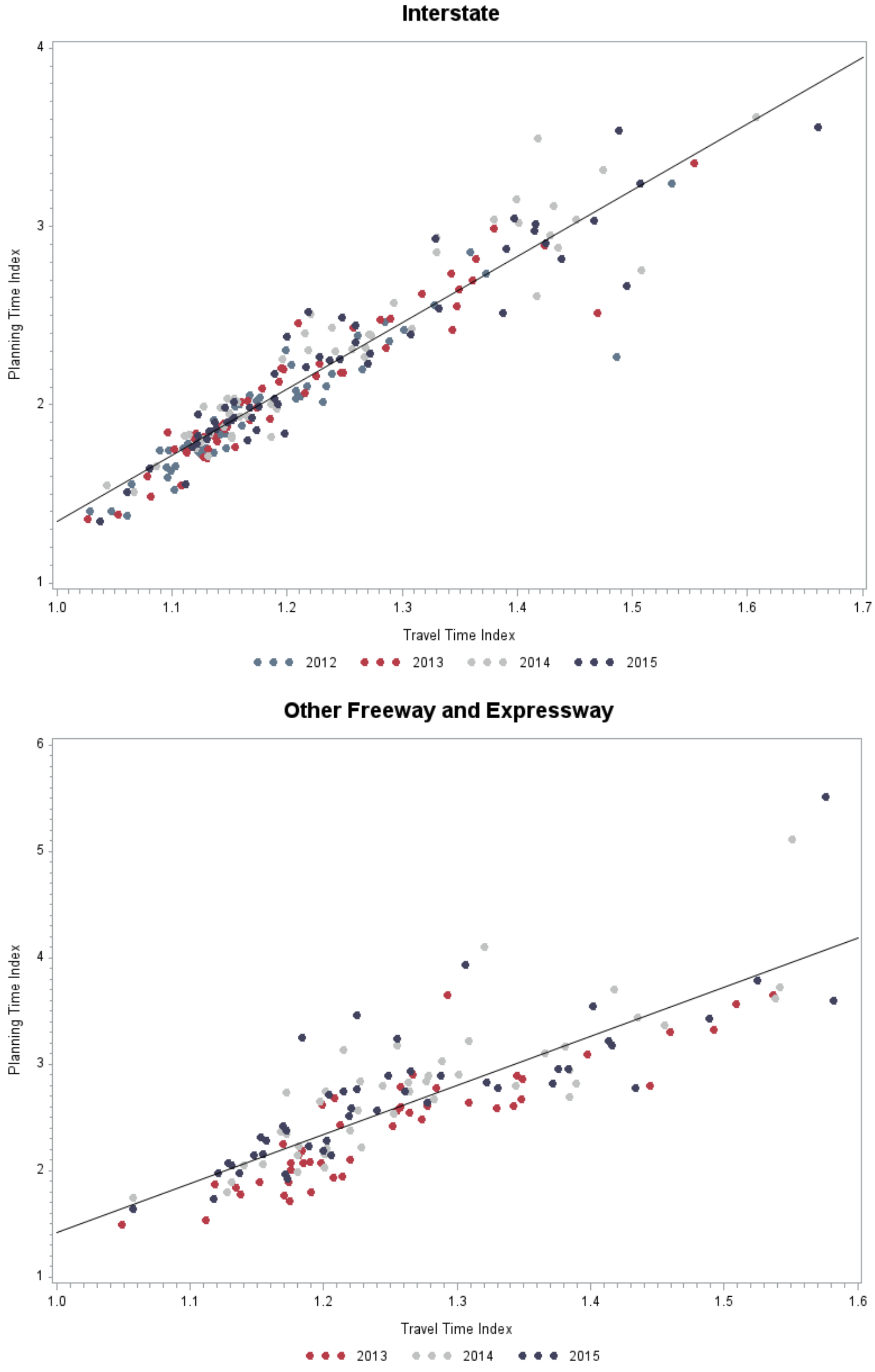
Source: FHWA staff calculation from the NPMRDS.

Severe congestion on other freeways and expressways spread to some smaller metropolitan areas. During peak hours, congestion forced drivers to spend more than 50 percent more time on other freeways and expressways in Los Angeles, New Orleans, and Portland. Large PTI values in New Orleans, Charlotte, and Portland highlighted highly inconsistent and unpredictable traffic condition in those areas. In addition to New York City, Chicago, and Washington, DC, users in Indianapolis, Seattle, and Buffalo also experienced more than 9 hours of congestion on other freeways and expressways.

The least-congested Interstate highways were found in Birmingham and Richmond, and the least-congested other freeways and expressways were in Orlando and Richmond. Measured in the length of highway congestion time, roads were congested for less than 2 hours per day in Orlando.

Exhibit 4-7 presents the linear correlation between TTI and PTI. It indicates that higher levels of recurring congestion are associated with non-recurring congestion as well. Freeways that routinely experience severe congestion are also more vulnerable to extreme congestion when conditions deteriorate unexpectedly.

Exhibit 4-7: Correlation between TTI and PTI in 52 Metropolitan Areas, 2012–2015



Note: TTI and PTI are averaged across metropolitan areas, road sections, and periods weighted by VMT using volume estimates derived from FHWA's HPMS over the 52 largest metropolitan areas. Data cover all Interstate highways (Interstate functional class) and other limited-access highways (Other Freeway and Expressway functional class) in these areas. Data on Interstate highways start in January 2012 and other freeways and expressways start in July 2013. Population is from United States Census Bureau 2014 Metropolitan Statistical Areas Population Estimates for 2010.

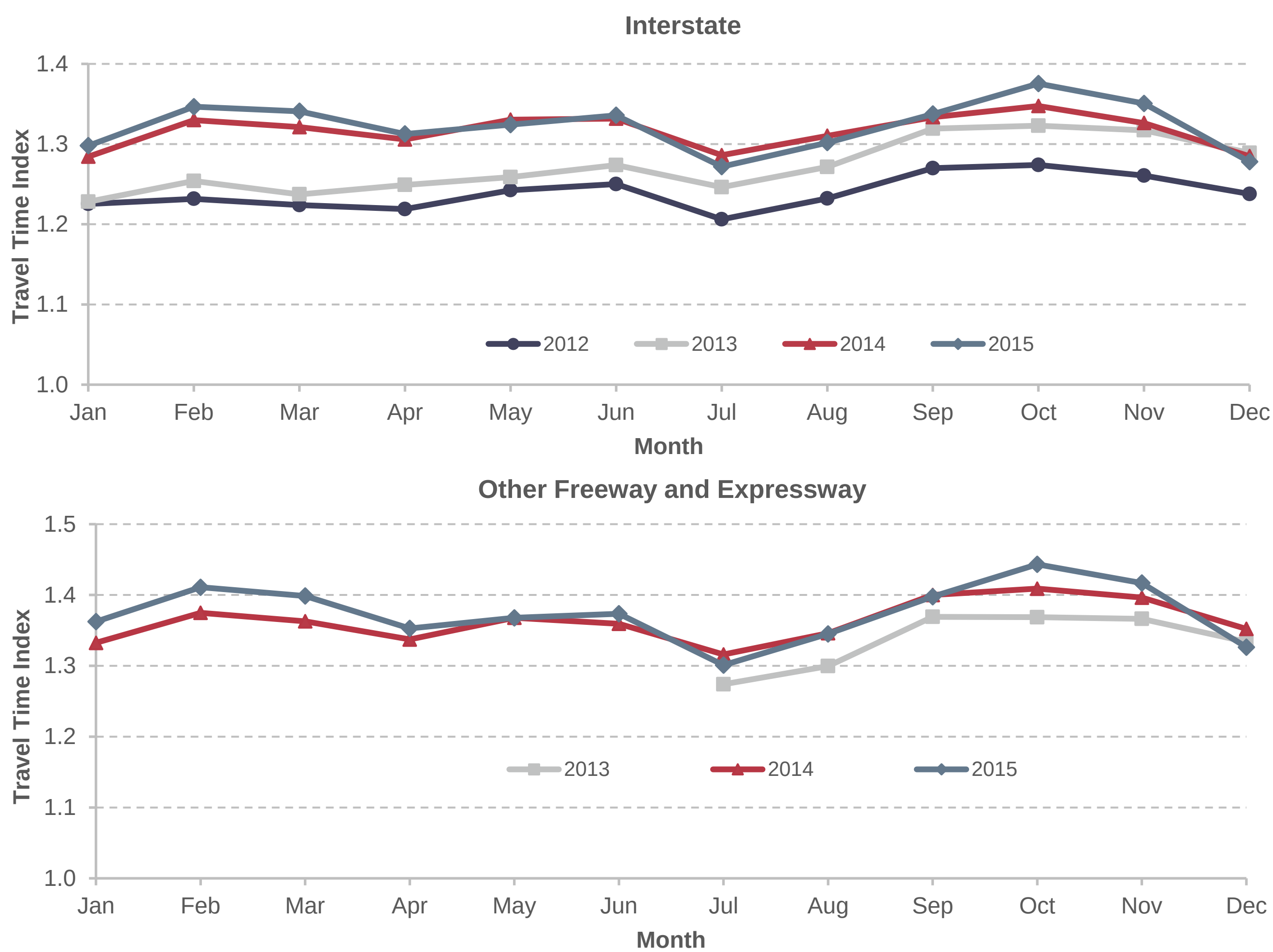
Source: FHWA staff calculation from the NPMRDS.

The correlation coefficient between TTI and PTI was 0.946 on Interstate highways and 0.830 on other freeways and expressways. The high and positive values of correlation coefficients suggest a strong linear relationship between TTI and PTI, especially on Interstate highways. There appears to be no significant year-to-year variation in the distribution of the ratios between PTI and TTI on the graph.

Seasonal Patterns in Congestion and Reliability

Road congestion varies over the course of a year. For each year from 2012 to 2015, TTI on Interstate highways fluctuated slightly in the first half of the year, dropped to a lower level in July, quickly rose to the highest yearly value in October, and dropped again in the last two months of the year (see *Exhibit 4-8*).

Exhibit 4-8: Monthly Travel Time Index in 52 Metropolitan Areas, 2012–2015



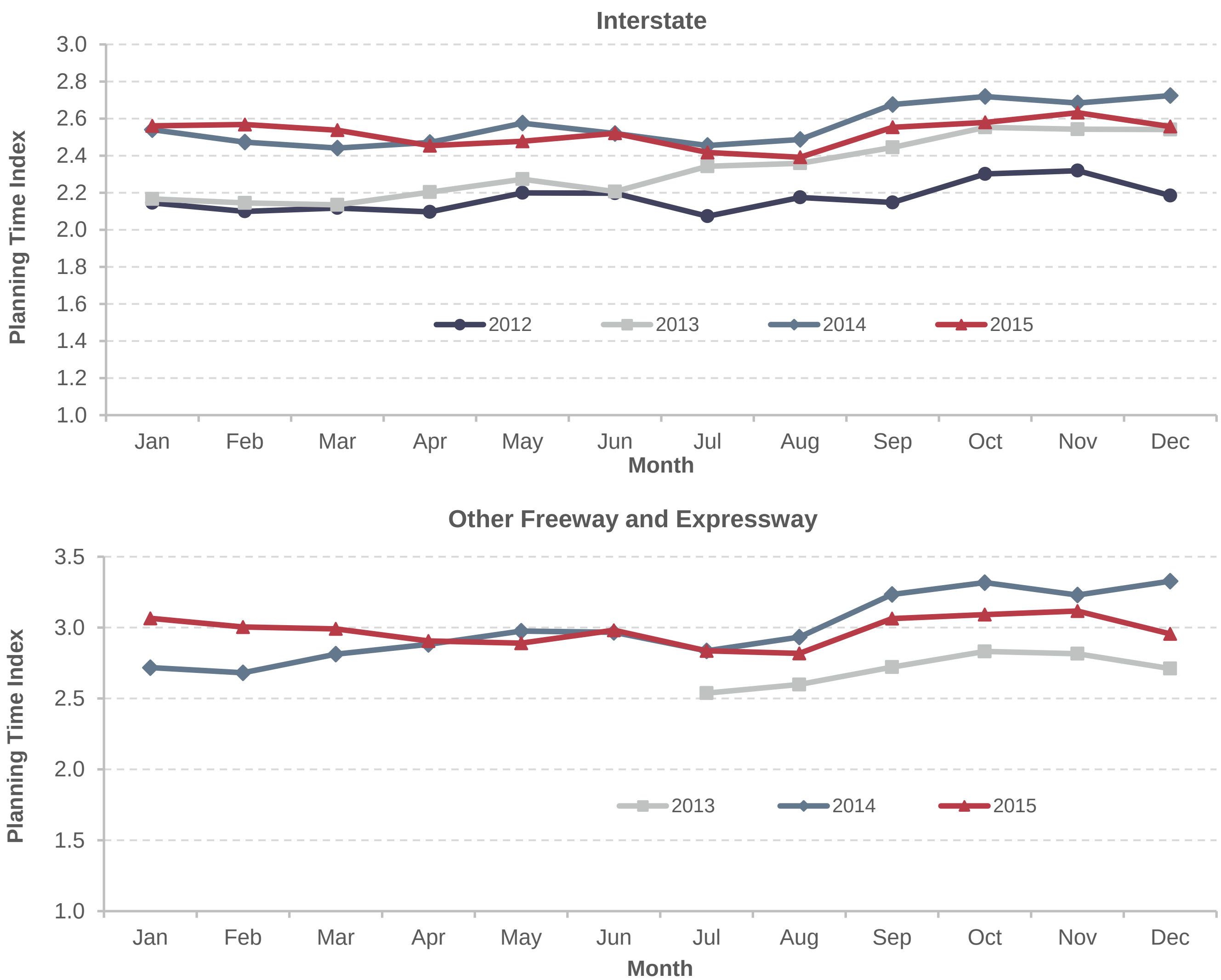
Note: TTI is averaged across metropolitan areas, road sections, and periods weighted by VMT using volume estimates derived from FHWA's HPMS over the 52 largest metropolitan areas. Data cover all Interstate highways (Interstate functional class) and other limited-access highways (Other Freeway and Expressway functional class) in these areas. Data on Interstate highways start in January 2012 and other freeways and expressways start in July 2013. Population is from United States Census Bureau 2014 Metropolitan Statistical Areas Population Estimates for 2010.

Source: FHWA staff calculation from the NPMRDS.

This is consistent with the public's perception of better travel conditions in summer during vacation season, with congestion rising in September as schools are again in session. Additionally, the line for Interstate TTI in 2012 was the lowest in the graph, but the highest in 2015, confirming the results in *Exhibit 4-1* where TTI rose over time.

PTI generally fluctuated less in the first half of the year than the second, for each year from 2012 to 2015. PTI reached its lowest point in July or August, implying more consistency in travel times during the summer months (See *Exhibit 4-9*). The upward trend of PTI in the second half of the year implies that travel time reliability worsened in fall and winter. This seasonal pattern is more evident on other freeways and expressways, where PTI swelled to a yearly high in October or November.

Exhibit 4-9: Monthly Planning Time Index in 52 Metropolitan Areas, 2012–2015



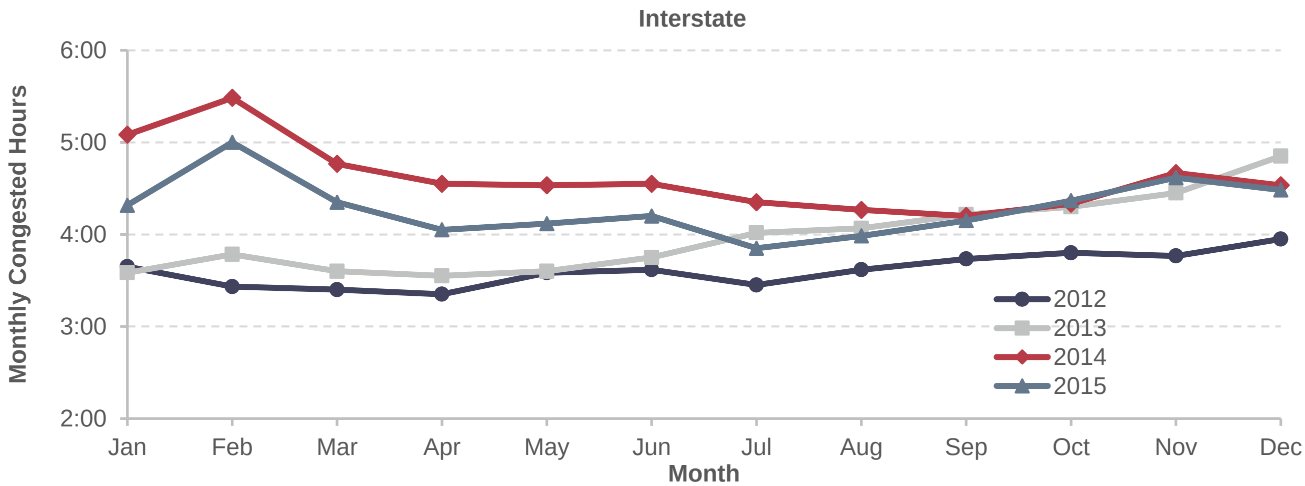
Note: PTI is averaged across metropolitan areas, road sections, and periods weighted by VMT using volume estimates derived from FHWA's HPMS over the 52 largest metropolitan areas. Data cover all Interstate highways (Interstate functional class) and other limited-access highways (Other Freeway and Expressway functional class) in these areas. Data on Interstate highways start in January 2012 and other freeways and expressways start in July 2013. Population is from United States Census Bureau 2014 Metropolitan Statistical Areas Population Estimates for 2010.

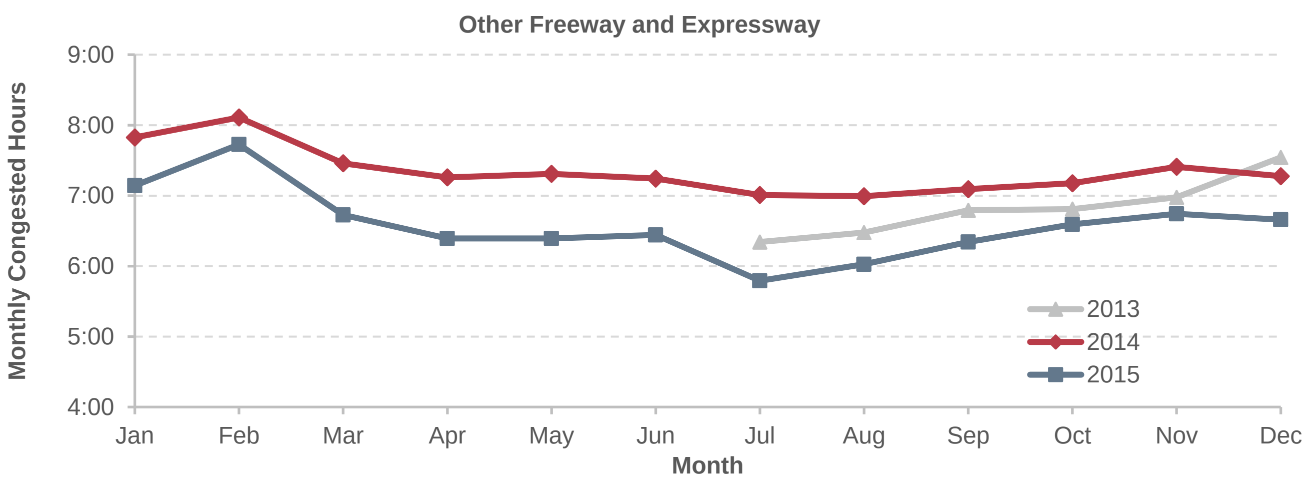
Source: FHWA staff calculation from the NPMRDS.

Travel conditions tended to be stable in the first half of the year, as both TTI and PTI exhibited low volatility. Between July and September, peak-hour travel conditions worsened substantially due to decreased speed, extended travel time, and extra time to ensure on-time arrival. In the last quarter, although average travel time during peak hours decreased, the uncertainty of traffic flow remained elevated.

Congested Hours revealed a different monthly pattern. Highways usually experienced longer periods of congestion in winter months and shorter periods of congestion in warmer months (see *Exhibit 4-10*). Average length of congestion was lower on Interstate highways than on other freeways and expressways.

Exhibit 4-10: Monthly Congested Hours in 52 Metropolitan Areas, 2012–2015





Note: Congested hours are averaged across metropolitan areas, road sections, and periods weighted by VMT using volume estimates derived from FHWA's HPMS over the 52 largest metropolitan areas. Data cover all Interstate highways (Interstate functional class) and other limited-access highways (Other Freeway and Expressway functional class) in these areas. Data on Interstate highways start in January 2012 and other freeways and expressways start in July 2013. Population is from United States Census Bureau 2014 Metropolitan Statistical Areas Population Estimates for 2010.

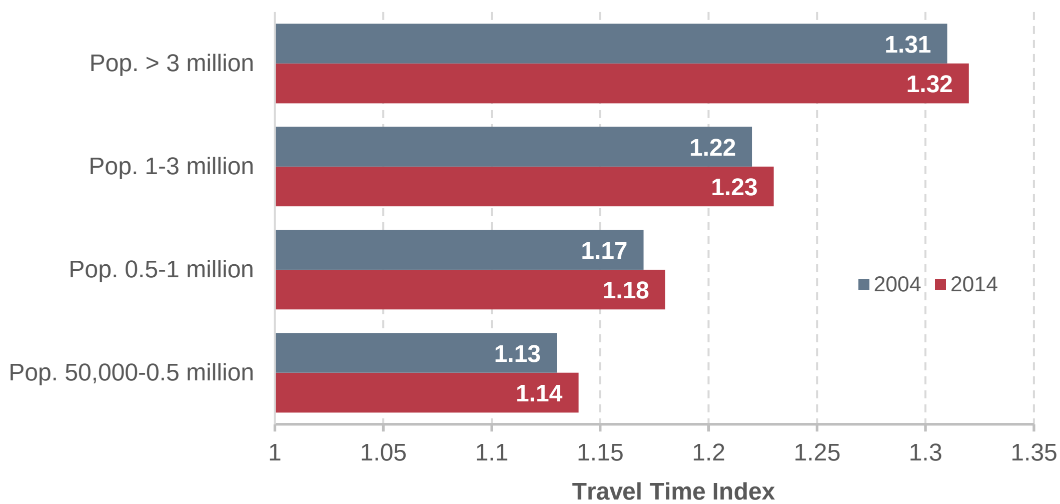
Source: FHWA staff calculation from the NPMRDS.

Congestion Trends

Since the NPMRDS provides data starting only in 2012, the *Urban Mobility Scorecard* (which includes data back to 1982) is best used to examine longer-term congestion trends. It is important to note that congestion measures from the *Urban Mobility Scorecard* were calculated using a different methodology and a different data source than the NPMRDS and thus are not comparable with the indicators reported above, although they represent similar concepts. This section focuses on examining congestion development from 2004 to 2014 and is based exclusively on the latest *Urban Mobility Scorecard*.

Compared with 2004, travelers experienced somewhat longer delays in 2014, as TTI for 471 urbanized areas increased from 1.25 to 1.26 *(Exhibit 4-11)*. Average TTI increased for all sizes of urbanized areas, including small urbanized areas with populations between 50,000 and 500,000.

Exhibit 4-11: Travel Time Index for Urbanized Areas, 2004–2014



Source: Texas Transportation Institute (2015); population is based on the U.S. Census Bureau estimates.

People living in large urbanized areas with more than 1 million population tended to spend more travel time during peak hours than people living in small and medium urban areas with population below 1 million. Average TTI was 1.32 in 2014 in very large urbanized areas with population above 3 million, much higher than that of urbanized areas with population between 0.5 and 1 million (1.18) or urbanized areas with population below 0.5 million (1.14).

Cost of Delay

Congestion adversely affects the American economy and results in loss of time, fuel, and missed opportunities. When travel time increases or reliability decreases, businesses need to increase average inventory levels to compensate, leading to higher overall costs. Congestion imposes an economic drain on businesses, and the resulting increased costs negatively affect producer and consumer prices.

The *Urban Mobility Scorecard* reported on travel delay and its associated costs. Travel delay, the amount of extra time spent traveling due to congestion, was calculated at the individual roadway section level and for both weekdays and weekends. Annual delay per auto commuter is a measure of the extra travel time endured throughout the year by auto commuters who make trips during the peak period. Each auto commuter logged 42 additional hours traveling during the peak traveling period in 2014, as shown in *Exhibit 4-12*. Over the 10-year period of 2004–2014, total delay time increased from 6.1 billion hours in 2004 to 6.8 billion hours in 2014. Although national VMT grew at an annualized rate of 0.2 percent (see Chapter 1), annual average commuter delay rose by 1 hour—equivalent to 0.7 billion hours for the country. Combining wasted time with approximately 3 billion gallons of wasted fuel, the total cost of congestion was estimated to reach $160 billion in 2014, $24 billion higher than 2004. (Average cost of time was assumed to be $17.67 per hour in 2014 constant dollars, which differs from the value used in the analyses reflected in Part II of this report.)

Exhibit 4-12: National Congestion Measures, 2004–2014

Year	Delay per Commuter (Hours)	Total Delay (Billions of Hours)	Total Cost (Billions of 2014 Dollars)
2004	41	6.1	$136
2005	41	6.3	$143
2006	42	6.4	$149
2007	42	6.6	$154
2008	42	6.6	$152
2009	40	6.3	$147
2010	40	6.4	$149
2011	41	6.6	$152
2012	41	6.7	$154
2013	42	6.8	$156
2014	42	6.8	$160

Source: Texas Transportation Institute (2015).

Empirical studies have identified demographic and economic growth as main drivers of traffic (hence congestion). The cost of congestion rose by 1.1 percent per year from 2004 to 2014, above population growth of 0.9 percent but commensurate with the pace of economic growth of 1.2 percent (see Chapter 3). Automobile and truck congestion currently imposes a relatively small cost on the economy (about 0.8 percent of gross domestic product). But if the current trend continues, congestion could be detrimental to future economic expansion.

Congestion Mitigation

Highway congestion is generally caused by an imbalance between travel demand and available capacity, reflecting inefficient use of existing capacity and unmet capacity needs. Vehicle "throughput" on a highway is the number of vehicles that get through over a specific period, such as an hour. Once highway traffic exceeds a certain threshold level, vehicle travel speeds drop below free flow speeds and congestion occurs. In project planning, programming, and selection processes, transportation planners and operators need to consider the extra economic costs of delayed and unreliable travel on highway users.

Mitigation options for recurring congestion include capacity expansion (i.e., increasing the number of lanes), operational improvements (such as traffic signal retiming and ramp meters), and travel demand management (incentives to shift demand). Strategies to mitigate nonrecurring delays usually include actions to reduce the incidence of disruptions and expedite the restoration of roadway capacity.

Congestion can also be caused by operational deficiencies when the existing operational control system is not working as designed, or when substandard roadway geometrics prevent efficient traffic flow. One operational mitigation approach is to adjust supply and demand through congestion pricing using tolls or fees. Technology-based operational solutions are another approach to reducing congestion. Examples of such applications include connected vehicles, integrated corridor management, and Intelligent Transportation Systems (ITS), which can include vehicle detection technologies, vehicle monitoring and tracking technologies, communications technologies, dynamic message signs, video camera technology, and Road Weather Information System (RWIS) applications.

Congestion pricing projects can be grouped into two broad categories: (1) projects involving tolls, and (2) projects not involving tolls. Strategies involving tolls are of five types, the first two of which involve "partial" pricing of one or more lanes on existing toll-free facilities:

- high occupancy toll (HOT) lanes (partial facility pricing);
- express toll lanes (partial facility pricing);
- pricing on entire roadway facilities;
- zone-based pricing, including cordon and area pricing; and
- regionwide pricing.

Strategies not involving tolls may include:

- parking pricing;
- priced vehicle sharing and dynamic ridesharing; and
- pay as you drive.

FHWA's congestion pricing website (https://ops.fhwa.dot.gov/congestionpricing/index.htm) provides information and resources to help State agencies and practitioners implement congestion pricing projects and incorporate pricing into transportation planning. It also presents some examples of projects using congestion pricing strategies.

Advanced Transportation and Congestion Management Technologies Deployment Program

The Fixing America's Surface Transportation (FAST) Act established the Advanced Transportation and Congestion Management Technologies Deployment Program to make annual competitive grants for the development of model deployment sites for large-scale installation and operation of advanced transportation technologies to improve safety, efficiency, system performance, and infrastructure return on investment in both large and small local communities across the country.

ATCMTD Grants

The grants under this program will enable cities and rural communities to draw upon advanced technologies to tackle universal issues such as reducing congestion, connecting people to mass transit, and enhancing safety. Communities receiving grants in FY2016 include:

- Pittsburgh, Pennsylvania, received nearly $11 million to deploy smart traffic signal technology—proven to reduce congestion at street lights by up to 40 percent—along major travel corridors.
- Denver, Colorado, will use some of its approximately $6 million grant to deploy connected vehicle technologies, helping to alleviate the congestion caused by a daily influx of 200,000 commuters each workday.

Highway and Bridge Geometry

Previous editions of the C&P Report discussed geometric issues as part of the chapter dealing with physical conditions. For this edition, this material has been moved in recognition of the impact that highway and bridge geometry can have on mobility. While design standards for both roads and bridges have evolved to facilitate the movement of passengers and goods through the network, some facilities have not been updated to meet current standards or certain situations (such as prohibitively expensive potential right-of-way acquisition costs) might prevent the owners from completely adhering to the standards. It is important to note that facilities built to outdated standards are not necessarily poorly maintained. This section discusses geometric issues as they pertain to functionally obsolete bridges, roadway alignment, and lane width.

Functionally Obsolete Bridges

Functional obsolescence is generally determined by the geometrics of a bridge in relation to the geometrics required by current design standards. Functional obsolescence generally results from changing traffic demands on the structure. The classification of "functionally obsolete" is determined by the National Bridge Inventory (NBI) appraisal ratings for structural evaluation, waterway adequacy, deck geometry, alignment of the approach roadway, and underclearances. Appraisal ratings are used to compare existing characteristics of a bridge to the current standards used for highway and bridge design. Existing bridges constructed before the establishment of more stringent design standards are more likely to be classified as functionally obsolete when compared with newer bridges.

Facilities, including bridges, will generally conform to the design standards in place at the time they are designed. Over time, design requirements improve. For example, a bridge designed in the 1930s would have shoulder widths that conform with 1930s design standards. Current design standards, however, are based on different criteria, and current safety standards require wider bridge shoulders. The difference between the required, current-day shoulder width and the shoulder width designed in the 1930s represents a deficiency. The magnitudes of such deficiencies determine whether a bridge is classified as functionally obsolete.

Across all roadway bridges in the Nation, the share of functionally obsolete bridges by bridge count decreased from 15.2 percent in 2004 to 13.8 percent in 2015, as shown in *Exhibit 4-13*. When weighted by average daily traffic (ADT), the share of functionally obsolete bridges decreased slightly from 21.9 percent in 2004 to 21.7 percent in 2015. The share remained at 20.5 percent when weighted by deck area.

Exhibit 4-13: Functionally Obsolete Bridges—All Bridges, 2004–2015

	2004	2006	2008	2010	2012	2014	2015
Count							
Total Bridges	594,100	597,561	601,506	604,493	607,380	610,749	611,845
Functionally Obsolete	90,076	89,591	89,189	85,858	84,748	84,525	84,124
Percent Functionally Obsolete							
By Bridge Count	15.2%	15.0%	14.8%	14.2%	14.0%	13.8%	13.8%
Weighted by Deck Area	20.5%	20.3%	20.5%	19.8%	20.1%	20.3%	20.5%
Weighted by ADT	21.9%	21.9%	22.2%	21.5%	21.3%	21.4%	21.7%

Source: National Bridge Inventory.

Exhibit 4-14 provides the share of functionally obsolete bridges on the National Highway System (NHS). The share of functionally obsolete bridges on the NHS based on bridge count decreased slightly from 16.9 percent in 2004 to 16.8 percent in 2015. Weighted by deck area, the share of functionally obsolete bridges increased from 20.9 percent in 2004 to 22.5 percent in 2015. The share of functionally obsolete bridges based on ADT increased from 19.8 percent in 2004 to 20.4 percent in 2015. The share of functionally obsolete bridges on the NHS in 2015 was 16.8 percent, compared with 13.8 percent for all bridges systemwide.

Exhibit 4-14: Functionally Obsolete Bridges on the National Highway System, 2004–2015

	2004	2006	2008	2010	2012	2014	2015
Count							
Total Bridges	115,103	115,202	116,523	116,669	117,485	143,165	143,139
Functionally Obsolete	19,408	19,368	19,707	19,061	19,075	24,098	24,026
Percent Functionally Obsolete							
By Bridge Count	16.9%	16.8%	16.9%	16.3%	16.2%	16.8%	16.8%
Weighted by Deck Area	20.9%	20.8%	21.4%	20.3%	21.0%	22.3%	22.5%
Weighted by ADT	19.8%	20.1%	20.5%	19.7%	19.5%	20.3%	20.4%

Source: National Bridge Inventory.

Most functionally obsolete bridges are located in urban environments. As shown in *Exhibit 4-15*, urban minor arterials had the highest share of functionally obsolete bridges at 27.2 percent in 2015. In the rural setting, Interstate bridges had the highest share of functionally obsolete bridges at 11.5 percent.

It should be noted that "functionally obsolete" is a legacy classification that was used to implement the Highway Bridge Program, which was discontinued as a standalone program with the enactment of MAP-21. As a result, fiscal year 2015 was the last year in which outstanding Highway Bridge Program funds could be obligated on eligible projects, including ones with bridges that were once classified as functionally obsolete. In the absence of a programmatic reason to collect the data necessary to support this classification, some of the data needed to compute it have been removed from the NBI, and future editions of the C&P Report thus will not contain this information.

Exhibit 4-15: Functionally Obsolete Bridges by Functional Class, 2004–2015

	Percentages of Functionally Obsolete Bridges by Year						
Functional System	**2004**	**2006**	**2008**	**2010**	**2012**	**2014**	**2015**
Rural							
Interstate	12.8%	12.0%	11.8%	11.6%	11.6%	11.5%	11.5%
Other Principal Arterial	9.9%	9.4%	9.3%	8.5%	8.3%	8.0%	7.8%
Minor Arterial	11.6%	11.0%	10.6%	10.2%	9.7%	9.4%	9.3%
Major Collector	11.0%	10.5%	10.1%	9.3%	8.9%	8.7%	8.5%
Minor Collector	12.1%	11.9%	11.4%	10.6%	10.4%	10.2%	9.9%
Local	13.2%	12.8%	12.4%	11.7%	11.3%	11.3%	11.2%
Subtotal Rural	12.2%	11.7%	11.4%	10.7%	10.4%	10.2%	10.1%
Urban							
Interstate	23.3%	23.6%	23.9%	23.0%	22.9%	23.1%	22.8%
Other Freeway and Expressway	23.2%	23.1%	22.9%	22.0%	22.1%	22.4%	22.3%
Other Principal Arterial	25.4%	24.5%	24.5%	23.8%	23.4%	22.7%	22.5%
Minor Arterial	29.3%	29.4%	29.3%	28.6%	28.2%	27.5%	27.2%
Collector	28.6%	28.7%	28.5%	28.1%	27.4%	26.8%	26.5%
Local	22.0%	21.9%	21.4%	20.5%	20.7%	20.0%	19.9%
Subtotal Urban	25.1%	25.0%	24.9%	24.2%	24.0%	23.6%	23.4%
Total	**15.2%**	**15.0%**	**14.8%**	**14.2%**	**14.0%**	**13.9%**	**13.7%**

Source: National Bridge Inventory.

Roadway Alignment

The term "roadway alignment" refers to the curvature and grade of a roadway, i.e., the extent to which it bends left or right and/or slopes up or down. The term "horizontal alignment" relates to curvature (the sharpness of curves), while the term "vertical alignment" relates to gradient (the steepness of slopes). Alignment adequacy affects the level of service and safety of the highway system. Inadequate alignment can result in speed reductions and impaired sight distance. Truck speeds are particularly affected by inadequate vertical alignment. Alignment adequacy is evaluated on a scale from Code 1 (best) to Code 4 (worst).

Alignment adequacy is more important on roads with higher travel speeds or higher volumes (e.g., the Interstate System). Because alignment generally is not a major issue in urban areas, only rural alignment statistics are presented in this section. The amount of change in roadway alignment over time is gradual and occurs only during major reconstruction of existing roadways. New roadways are constructed to meet current vertical and horizontal alignment criteria, and thus generally have no alignment problems except under extreme conditions.

As shown in *Exhibit 4-16,* in 2014, approximately 80.7 percent of rural Interstate System miles were classified as Code 1 (best) and 17.0 percent as Code 4 (worst) for horizontal alignment. On rural minor arterial, 65.6 percent of miles were classified as Code 1 and 22.6 percent classified as Code 4 for horizontal alignment. As for vertical alignment, 85.6 percent of rural Interstate miles met appropriate design standards (Code 1) and only 0.2 percent were in Code 4. The shares were 67.4 percent in Code 1 and 4.9 percent in Code 4 on rural minor arterial.

The distributional pattern indicates that, while the majority of rural highways met the appropriate curve and grade standard in 2014, there were more highways with unsafe or uncomfortable curves or limited speed (horizontal alignment) than highways with grades that could affect traveling speed (vertical alignment). Additionally, highways in higher functional classes, like Interstate, reported a high proportion of roads with better alignment than their counterparts in lower functional classes.

Exhibit 4-16: Percentage of Rural Highway Alignment by Functional Class, 2014

	Code 1	Code 2	Code 3	Code 4
Horizontal				
Interstate	80.7%	0.7%	1.5%	17.0%
Other Freeway and Expressway	68.9%	2.5%	1.9%	26.7%
Other Principal Arterial	68.3%	7.9%	5.3%	18.5%
Minor Arterial	65.6%	5.8%	6.0%	22.6%
Major Collector	77.1%	1.1%	1.3%	20.5%
Vertical				
Interstate	85.6%	13.1%	1.1%	0.2%
Other Freeway and Expressway	87.7%	9.4%	1.7%	1.2%
Other Principal Arterial	72.3%	18.5%	6.5%	2.7%
Minor Arterial	67.4%	18.7%	9.0%	4.9%
Major Collector	89.7%	5.3%	3.1%	1.8%

Code 1	All curves and grades meet appropriate design standards.
Code 2	Some curves or grades are below design standards for new construction, but curves can be negotiated safely at prevailing speed limits. Truck speed is not substantially affected.
Code 3	Infrequent curves or grades occur that impair sight distance or severely affect truck speeds. May have reduced speed limits.
Code 4	Frequent grades occur that impair sight distance or severely affect truck speeds. Generally, curves are unsafe or uncomfortable at prevailing speed limit, or the speed limit is severely restricted due to the design speed limits of the curves.

Source: Highway Performance Monitoring System.

Lane Width

Travel lanes are striped to define the intended path of travel for vehicles along a corridor. Lane width affects highway capacity, traffic operation, speed, and safety. Wider travel lanes (11–13 feet) create a more forgiving buffer to drivers, especially in high-speed environments. Narrow lanes (less than 10 feet) have less capacity and can increase the potential for crashes and side-swipe collisions. There are recommended widths for different types of lanes. The American Association of State Highway and Transportation Officials (AASHTO) provides guidance for lane widths: 12 feet for freeways, 10–12 feet for arterial and collector roads, and 9–12 for local roads (https://safety.fhwa.dot.gov/geometric/pubs/mitigationstrategies/chapter3/3_lanewidth.cfm).

As with roadway alignment, lane width is more crucial on functional classifications that have higher travel volumes and speed limits. *Exhibit 4-17* shows that approximately 95.2 percent of rural Interstate System miles and 98.0 percent of urban Interstate System miles had minimum 12-foot lane widths in 2014. Highways on Other Freeway and Expressway (including Interstate) also generally met the lane width standard, with associated shares at 97.0 percent in rural areas and 96.4 in urban areas.

Highways of lower functional classification were less likely to meet the lane width standard. In 2014, approximately 52.0 percent of urban collectors had lane widths of 12 feet or greater, but approximately 19.4 percent had 11-foot lanes and 21.1 percent had 10-foot lanes; the remaining 7.6 percent had lane widths of 9 feet or less. Among rural major collectors, 41.6 percent had lane widths of 12 feet or greater, but approximately 27.5 percent had 11-foot lanes and 22.7 percent had 10-foot lanes. Roughly 8.3 percent of rural major collector mileage had lane widths of 9 feet or less.

Exhibit 4-17: Lane Width by Functional Class, 2014

	≥12 foot	11 foot	10 foot	9 foot	<9 foot
Rural					
Interstate	95.2%	4.6%	0.1%	0.1%	0.0%
Other Freeway and Expressway	97.0%	3.0%	0.0%	0.0%	0.0%
Other Principal Arterial	89.3%	9.2%	1.4%	0.2%	0.0%
Minor Arterial	71.2%	19.3%	8.9%	0.7%	0.1%
Major Collector	41.6%	27.5%	22.7%	6.1%	2.2%
Urban					
Interstate	98.0%	1.4%	0.3%	0.1%	0.1%
Other Freeway and Expressway	96.4%	2.8%	0.8%	0.0%	0.0%
Other Principal Arterial	81.8%	13.0%	4.5%	0.4%	0.3%
Minor Arterial	65.9%	19.1%	12.0%	2.1%	0.9%
Collector	52.0%	19.4%	21.1%	5.7%	1.9%

Source: Highway Performance Monitoring System.

Transit Mobility and Access

The basic goal of all transit operators is to connect people to the places they want to go in a safe and efficient manner, while minimizing travel times, making effective use of vehicle capacity, and providing reliable performance. The Federal Transit Administration (FTA) collects data on average speed, how full the vehicles are on average (utilization), and how often they break down (mean distance between failures) to characterize how well transit service meets these goals. These data are reported here; transit safety data are reported in Chapter 5.

The following analysis presents data on average operating speeds, average number of passengers per vehicle, average percentage of seats occupied per vehicle, average distance traveled per vehicle, and mean distance between vehicle failures. Average speed, seats occupied, and distance between failures provide metrics for evaluating efficiency and customer service issues; passengers per vehicle and miles per vehicle are primarily effectiveness and efficiency measures, respectively. Financial efficiency metrics, including operating expenditures per revenue mile or passenger mile, are discussed in Chapter 2.

This chapter also discusses transit accessibility for persons with disabilities and the elderly. Transit access and accessibility are central elements of a multimodal transportation system that meets the needs of people of all ages and abilities. Analysis is presented on the progress made to improve accessibility to transit for the elderly and disabled through enforcement of the Americans with Disability Act of 1990 (ADA) by evaluating the number of ADA-accessible transit services. This chapter concludes with an analysis of transit system coverage (route-miles), frequency (wait time) and infrastructure resilience.

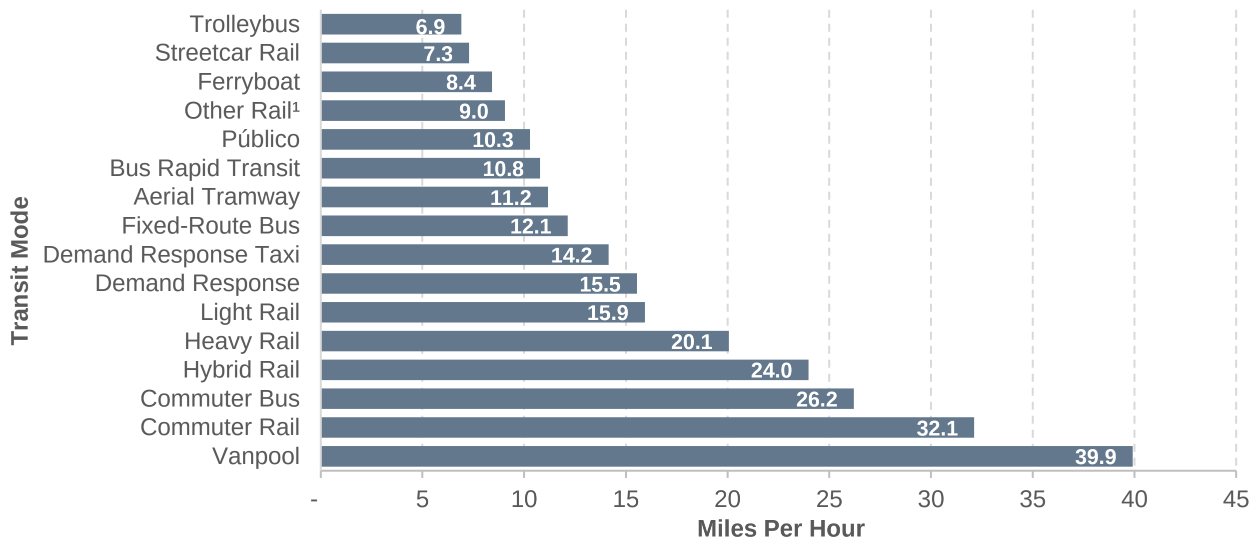
Key Takeaways

- The average speed of transit modes varies considerably. Modes such as trolleybus and streetcar operate mostly in mixed traffic rights-of-way, serving downtown areas. The average speed of these modes is less than 10 mph.
- Rail modes operate at average speeds of over 15 mph, and modes with a long-distance commuter orientation such as commuter rail average over 30 mph.
- The average vehicle occupancy of heavy rail systems increased by 16 percent, from 23 passengers per car in 2004 to 28 in 2014, more than any other mode.
- The length of the rail network increased annually at an average of 2.5 percent per year. Light rail and commuter rail systems accounted for most of this increase.
- The mean distance between vehicle failures of fixed-route bus systems decreased by 9 percent, from 4,040 miles in 2004 to 3,673 in 2014.
- Based on data from 2009, 44.5 percent of transit passengers wait 5 minutes or less for transit vehicles to arrive and 73.2 percent wait 10 minutes or less. Another 8.0 percent wait 21 minutes or more.
- The level of ADA accessibility to transit service vehicles rose from 93 percent in 2004 to 96 percent in 2014.

Average Operating (Passenger-Carrying) Speeds

Average vehicle operating speed is an approximate measure of the in-vehicle service experienced by transit riders; it is not a measure of the operating speed of transit vehicles between stops. More specifically, average operating speed is a measure of the speed passengers experience from the time they enter a transit vehicle to the time they exit it, including dwell times at stops. It does not include the time passengers spend waiting or transferring. Average vehicle operating speed is calculated for each mode by dividing annual vehicle revenue miles by annual vehicle revenue hours for each agency in each mode, as reported to NTD. When an agency contracts with a service provider or provides the service directly, the speeds for each service within a mode are calculated and weighted separately. *Exhibit 4-18* presents the results of these average speed calculations.

Exhibit 4-18: Average Speeds for Passenger-Carrying Transit Modes, 2014



[1] Includes monorail/automated guideway, cable car, and inclined plane.

Source: National Transit Database.

The number of and distance between stops and the time required for boarding and alighting of passengers strongly influence the average speed of a transit mode. Fixed-route bus service, which typically makes frequent stops, has a relatively low average speed. In contrast, commuter rail has sustained high speeds between infrequent stops, and thus a relatively high average speed. Vanpools also travel at high speeds, usually with only a few stops at each end of the route. Modes using exclusive guideway (including HOV lanes) can offer more rapid travel time than similar modes that do not. Heavy rail, which travels exclusively on dedicated guideway, has a higher average speed than streetcar, which often shares its guideway with mixed traffic. These average speeds have not changed significantly over the past decade.

One of the reasons for creating new modal categories in the NTD for commuter bus and hybrid rail in 2011 was the significantly higher speeds these systems attain. For example, commuter bus systems typically operate with very few intermediate stops, and often use limited-access highways, allowing them to achieve average speeds more than double those of traditional fixed-route bus systems.

Hybrid rail systems typically operate in a suburban environment with longer distances between stops, allowing them to achieve average speeds that are significantly higher than those for light rail.

It is worth noting that the bus rapid transit systems in the NTD are currently reporting an average speed that is slightly lower than that of regular fixed-route bus and light rail. This is in part because bus rapid transit systems typically operate in the highest-density urban environments where speeds are lower. Nevertheless, the average speed for bus rapid transit is still nearly 50 percent higher than that of streetcar rail, which also tends to operate in the highest-density areas.

System Capacity

Exhibit 4-19 provides reported vehicle revenue miles (VRMs) for both rail and nonrail modes. These numbers show the actual number of miles each mode travels in revenue service. (A mode is in revenue service when it is open to the general public and running with the expectation of carrying passengers who directly pay fares, or whose fares are subsidized by public policy, or provide payment through some contractual arrangement).

VRMs provided by fixed-route bus services and rail services show consistent growth, with light rail and vanpool miles growing somewhat faster than the other modes. Overall, the number of VRMs has increased by 28.8 percent since 2004, with an average annual rate of change of 2.6 percent.

Exhibit 4-19: Rail and Nonrail Vehicle Revenue Miles, 2004–2014

Mode	Vehicle Revenue Miles (in Millions)						Average Annual Rate of Change 2014 to 2004
	2004	2006	2008	2010	2012	2014	
Rail	**962**	**997**	**1,052**	**1,056**	**1,056**	**1,109**	**1.4%**
Heavy Rail	625	634	655	647	638	657	0.5%
Commuter Rail	269	287	307	315	318	339	2.3%
Light Rail[1]	67	73	86	92	99	112	5.3%
Other Rail[2]	2	3	3	2	1	1	-4.8%
Nonrail	**2,591**	**2,671**	**3,167**	**3,231**	**3,269**	**3,467**	**3.0%**
Fixed-Route Bus[3]	1,891	1,910	2,025	1,994	1,977	2,044	0.8%
Demand Response[4]	560	606	945	1,008	1,042	1,155	7.5%
Ferryboat	3	2	3	3	3	3	1.9%
Trolleybus	13	12	11	12	11	11	-1.7%
Vanpool	78	110	158	181	207	228	11.3%
Other Nonrail[5]	45	32	25	32	27	25	-5.8%
Total	**3,553**	**3,668**	**4,218**	**4,287**	**4,325**	**4,575**	**2.6%**

[1] Includes light rail, hybrid rail, and streetcar rail.

[2] Includes Alaska railway, monorail/automated guideway, cable car, and inclined plane.

[3] Includes bus, commuter bus, and bus rapid transit.

[4] Includes demand response and demand response taxi.

[5] Includes aerial tramway and públicos.

Source: National Transit Database.

Transit system capacity, particularly in cross-modal comparisons, is typically measured by capacity-equivalent VRMs. This parameter measures the distances transit vehicles travel in revenue service and adjusts them by the passenger-carrying capacity of each transit vehicle type, with the average carrying capacity of fixed-route bus vehicles representing the baseline. To calculate capacity-equivalent VRMs, the number of revenue miles for a vehicle is multiplied by the bus-equivalent capacity of that vehicle. *Exhibit 4-20* identifies average vehicle capacity by mode.

Exhibit 4-21 shows the 2014 capacity-equivalent factors for each mode. VRMs for each mode are multiplied by a capacity-equivalent factor to calculate capacity-equivalent VRMs. These factors are equal to the average full-seating and full-standing capacities of vehicles in active service for each transit mode divided by the average full-seating and full-standing capacities of all motor bus vehicles in active service. The average capacity of the national fixed-route bus fleet changes slightly from year to year as the proportion of large, articulated, and small buses varies. The average capacity of bus mode fleet in 2014 was 36 seated and 59 seating and standing.

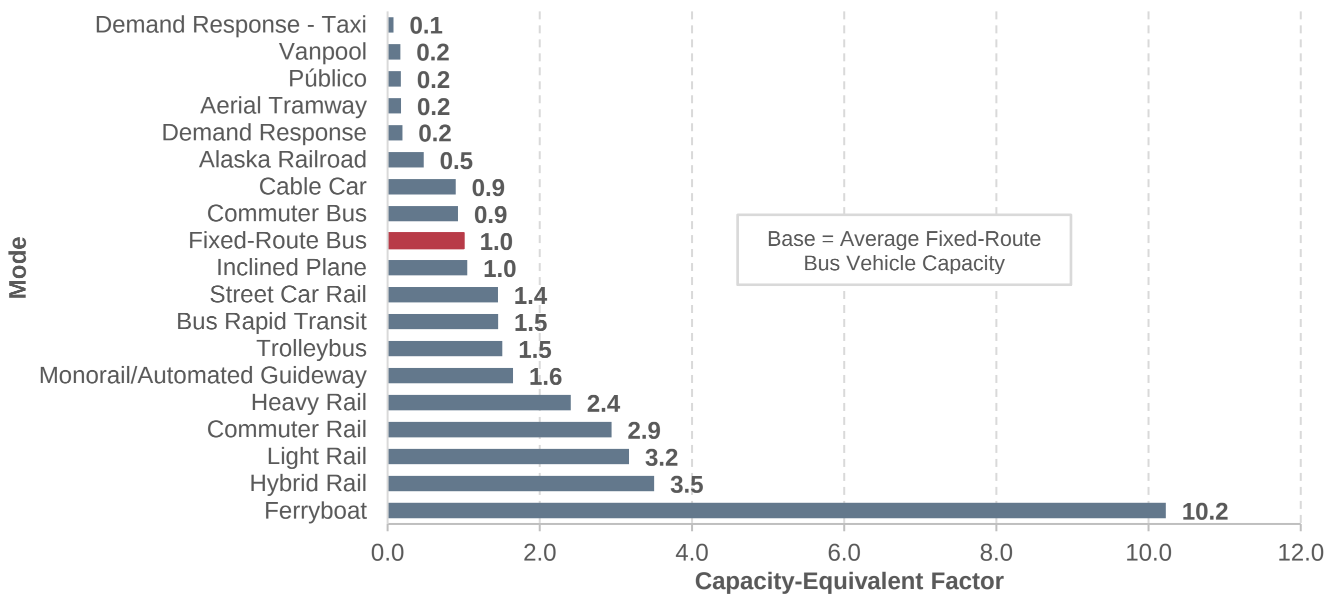
Exhibit 4-20: Average Vehicle Capacity by Mode

Mode	Active Fleet	Average Seating Capacity	Total Capacity (Seating and Standing)
Bus	68,345	36	59
Demand Response	52,393	11	11
Vanpool	15,395	10	10
Heavy Rail	11,841	51	141
Commuter Rail	7,211	110	174
Commuter Bus	6,553	46	58
Demand Response - Taxi	6,534	5	5
Publico	2,310	10	10
Light Rail	2,129	65	189
Trolleybus	761	45	81
Bus Rapid Transit	655	49	82
Streetcar Rail	361	46	92
Ferryboat	179	432	586
Monorail/Automated Guideway	163	27	91

Note: Modes not included: hybrid rail, cable car, aerial tramway and inclined plane.

Source: National Transit Database.

Exhibit 4-21: Capacity-Equivalent Factors (Seating plus Standing) by Mode



Note: Factors based on seating plus standing capacity. Data do not include agencies that qualified for and opted to use the small systems waiver of the National Transit Database.

Source: National Transit Database.

Exhibit 4-22 shows total capacity-equivalent VRMs. Other rail modes show the most rapid expansion in capacity-equivalent VRMs from 2004 to 2014, followed by light rail, demand-response, and commuter rail. Annual VRMs for monorail/automated guideway more than doubled, resulting in an increase in capacity-equivalent VRMs for the "other" rail category. Total capacity-equivalent revenue miles increased from 4,520 million in 2004 to 5,438 million in 2014, an increase of 20 percent.

Exhibit 4-22: Capacity-Equivalent Vehicle Revenue Miles, 2004–2014

Mode	2004	2006	2008	2010	2012	2014	Average Annual Rate of Change 2014 to 2004
Rail	**2,418**	**2,576**	**2,703**	**2,714**	**2,760**	**2,932**	**1.9%**
Heavy Rail	1,550	1,592	1,621	1,599	1,580	1,582	0.2%
Commuter Rail	687	777	844	860	887	996	3.8%
Light Rail[1]	180	201	235	252	284	345	6.7%
Other Rail[2]	3	6	4	3	9	9	13.8%
Nonrail	**2,076**	**2,091**	**2,265**	**2,259**	**2,253**	**2,349**	**1.2%**
Fixed-Route Bus[3]	1,891	1,910	2,025	1,994	1,979	2,038	0.7%
Demand Response[4]	105	113	158	176	182	218	7.5%
Ferryboat	33	22	32	35	35	35	0.5%
Trolleybus	20	18	16	17	16	17	-1.7%
Vanpool	15	20	27	30	34	38	9.8%
Other Nonrail[5]	12	8	6	8	7	4	-9.4%
Total	**4,494**	**4,667**	**4,968**	**4,973**	**5,013**	**5,281**	**1.6%**

[1] Includes light rail, hybrid rail, and streetcar rail.

[2] Includes Alaska railway, monorail/automated guideway, cable car, and inclined plane.

[3] Includes bus, commuter bus, and bus rapid transit.

[4] Includes demand-response and demand-response taxi.

[5] Includes aerial tramway and público.

Note: 2012 data do not include agencies that qualified for and opted to use the small systems waiver of the National Transit Database.

Source: National Transit Database.

Vehicle Use

Vehicle Occupancy

Exhibit 4-23 shows vehicle occupancy by mode for selected years from 2004 to 2014. Vehicle occupancy is calculated by dividing passenger miles traveled (PMT) by VRMs, resulting in the average passenger load in a transit vehicle. From 2004 to 2014, average passenger load for most major transit modes have not changed significantly.

An important metric of vehicle occupancy is weighted average seating capacity utilization. This average is calculated by dividing passenger load by the average number of seats in the vehicle (or passenger car for rail modes). The weighting factor is the number of active vehicles in the fleet. *Exhibit 4-20* shows the average seating capacity for some modes are vanpool, 10; heavy rail, 51; light rail, 65; ferryboat, 432; commuter rail, 110; fixed-route bus, 36; demand-response, 11.

As shown in *Exhibit 4-24*, the average seating capacity utilization ranges from 10.9 percent for demand-response to 59.2 percent for vanpools. At first glance, the data seem to indicate excess seating capacity for all modes. Several factors, however, explain these apparent low utilization rates. For example, the low utilization rate for fixed-route bus, which operates in large and small urbanized areas, can be explained partially by low average passenger loads in urbanized areas. Other factors could include high passenger demand in one direction, and small or very small demand in the opposite direction during peak periods; and sharp drops in loads beyond segments of high demand, with limited room for short turns, and other factors.

Exhibit 4-23: Average Vehicle Occupancy: Passenger Miles per Vehicle Revenue Mile, 2004–2014

Mode	2004	2006	2008	2010	2012	2014
Rail						
Heavy Rail	23.0	23.2	25.7	25.3	27.5	27.9
Commuter Rail	36.1	36.1	35.6	34.2	35.0	34.3
Light Rail[1]	23.7	25.6	24.1	23.7	25.2	24.0
Other Rail[2]	9.4	8.8	9.3	10.7	8.1	9.2
Non-Rail						
Fixed-Route Bus[3]	10.0	10.7	10.8	10.7	11.2	11.1
Demand-Response[4]	1.3	1.2	1.2	1.2	1.2	1.1
Ferryboat	126.7	111.9	118.1	119.3	125.2	127.8
Trolleybus	13.3	13.9	14.3	13.6	14.3	14.3
Vanpool	5.9	6.2	6.3	6.0	6.1	5.9
Other Nonrail[5]	5.8	5.5	5.5	5.2	5.3	5.2

[1] Includes light rail, hybrid rail, and streetcar rail.

[2] Includes Alaska railway, monorail/automated guideway, cable car, and inclined plane.

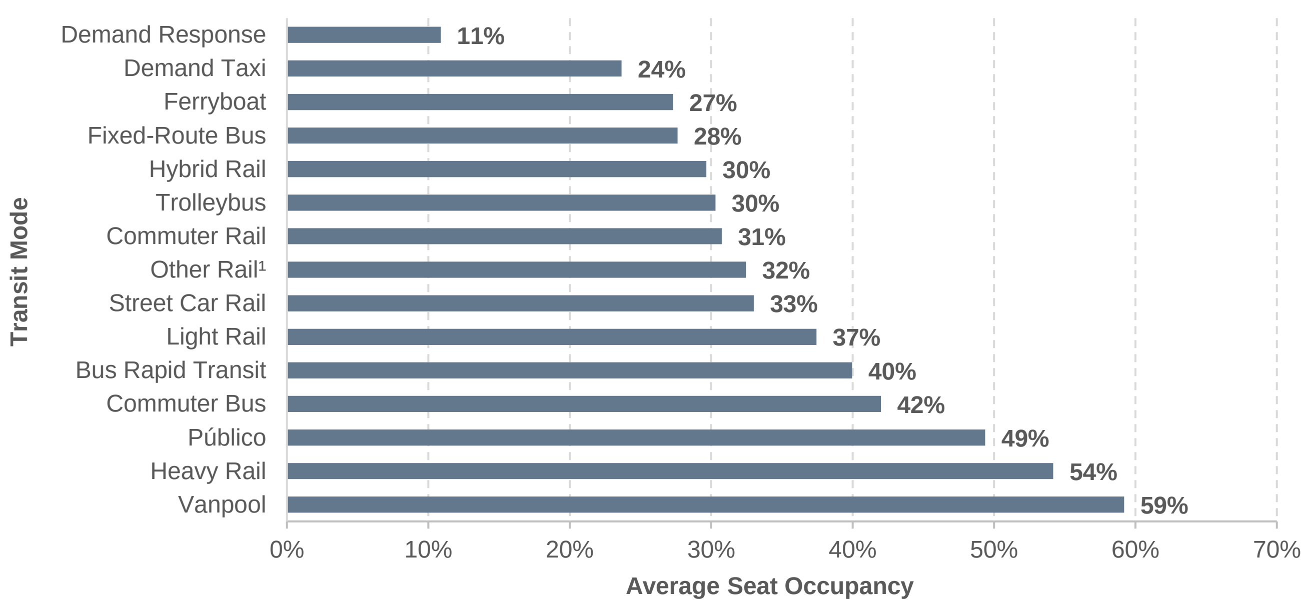
[3] Includes bus, commuter bus, and bus rapid transit.

[4] Includes demand-response and demand-response taxi.

[5] Includes aerial tramway and público.

Source: National Transit Database.

Exhibit 4-24: Average Seat Occupancy Rates for Passenger-Carrying Transit Modes, 2014



[1] Includes cable car, inclined plane, and monorail/automated guideway.

Note: Aerial tramway mode has substantial standing capacity that is not considered here, but which can allow the measure of the percentage of seats occupied to exceed 100 percent for a full vehicle.

Note: Does not include agencies that qualified for and opted to use the small systems waiver of the National Transit Database.

Source: National Transit Database.

Vehicles also tend to be relatively empty at the beginning and ends of their routes. For many commuter routes, a vehicle that is crush-loaded (i.e., filled to maximum capacity) on part of the trip ultimately might only achieve an average occupancy of around 35 percent (as shown by analysis of the Washington Metropolitan Area Transit Authority peak period data).

Vehicle Use

Revenue miles per active vehicle (service use), defined as average distance traveled per vehicle in service, can be measured by the ratio of VRMs per active vehicles in the fleet. *Exhibit 4-25* provides vehicle service use by mode for selected years from 2004 to 2014. Heavy rail, generally offering long hours of frequent service, had the highest vehicle use during this period. Vehicle service use for vanpool and demand-response shows an increasing trend. Vehicle service use for other nonrail modes appears to be relatively stable over the past few years with no apparent trends in either direction.

Exhibit 4-25: Vehicle Service Utilization: Average Annual Vehicle Revenue Miles per Active Vehicle by Mode, 2004–2014

Mode	Vehicle Revenue Miles (Thousands of Miles)						Average Annual Rate of Change 2014 to 2004
	2004	2006	2008	2010	2012	2014	
Rail							
Heavy Rail	57	57	58	57	56	57	-0.1%
Commuter Rail	41	43	45	45	44	46	1.2%
Light Rail[1]	40	40	44	43	42	46	1.4%
Nonrail							
Fixed-Route Bus[2]	30	30	31	31	31	28	-0.5%
Demand-Response[3]	20	22	29	28	28	20	0.3%
Ferryboat	27	22	22	25	23	20	-2.6%
Trolleybus	21	19	19	20	20	20	-0.4%
Vanpool	14	14	14	15	15	15	0.7%

¹ Includes light rail, hybrid rail, and streetcar rail.

² Includes bus, bus rapid transit, and commuter bus.

³ Includes demand-response and demand-response taxi.

Note: 2014 data do not include agencies that qualified and opted to use the small systems waiver of the National Transit Database.

Note: Rail category does not include Alaska railroad, cable car, inclined plane, or monorail/automated guideway. Nonrail category does not include aerial tramway or público.

Source: National Transit Database.

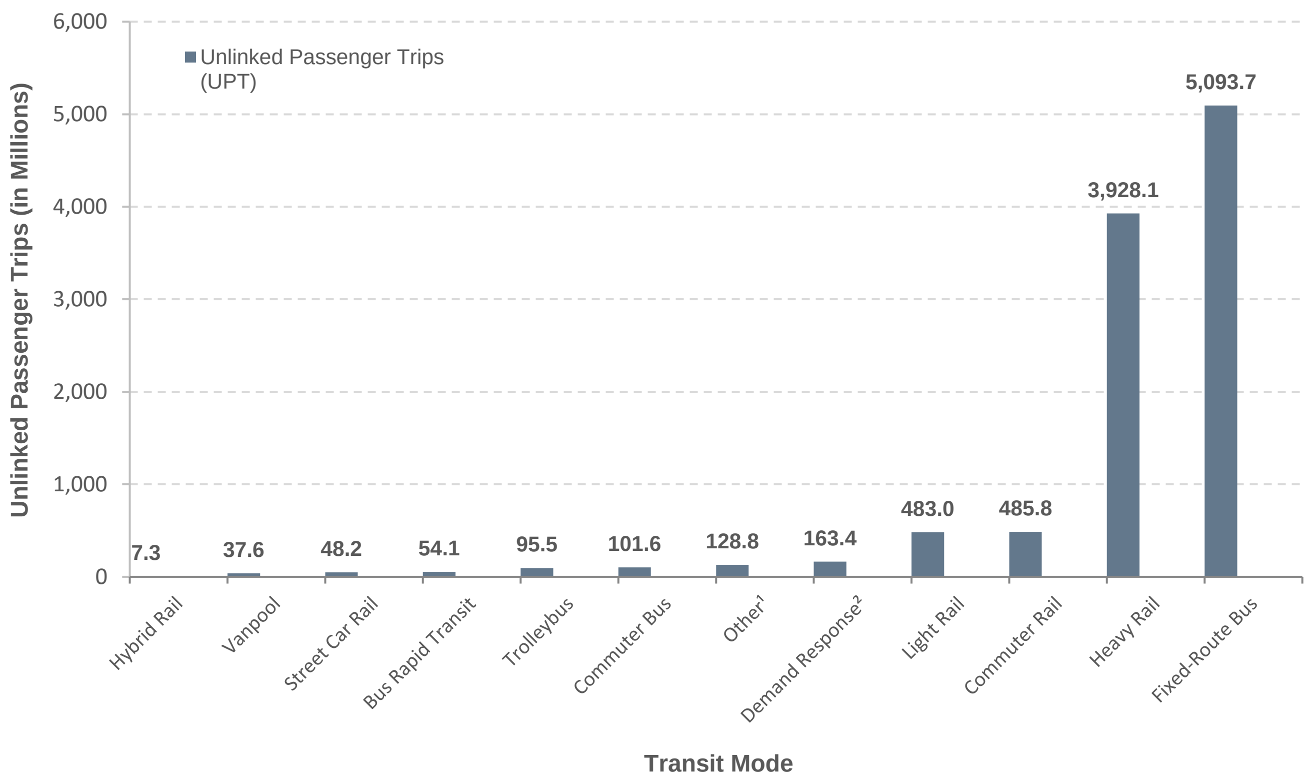
Ridership

The two primary measures of transit ridership are unlinked passenger trips and PMT. An unlinked passenger trip, sometimes called a boarding, is defined as a journey on one transit vehicle. PMT is calculated based on unlinked passenger trips and estimates of average trip length. Either measure provides a similar picture of ridership trends because average trip lengths, by mode, have not changed substantially over time. Comparisons across modes, however, could differ substantially, depending on which measure is used, due to large differences in the average trip length for the various modes.

Unlinked Passenger Trips and Passenger Miles

Exhibits 4-26 and *4-27* show the distribution of unlinked passenger trips (UPT) and PMT by mode. In 2014, urban transit systems provided 10.6 billion unlinked trips and 57.0 billion PMT across all modes. The fixed-route bus and heavy rail modes continue to be the largest segments of both measures. Commuter rail supports relatively more PMT due to its greater average trip length (23.9 miles compared with 3.7 for fixed-route bus, 4.7 for heavy rail, and 5.2 for light rail).

Exhibit 4-26: Unlinked Passenger Trips by Mode, 2014



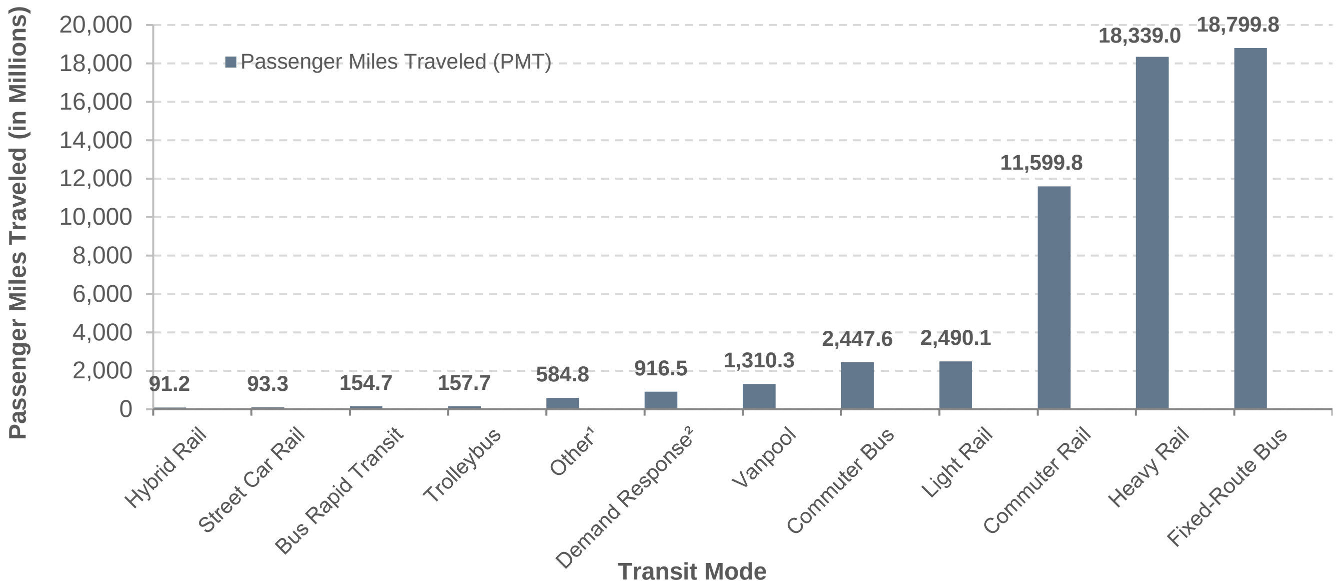
[1] Includes aerial tramway, Alaska railroad, cable car, ferryboat, inclined plane, monorail/automated guideway, and público.

[2] Includes demand-response and demand-response taxi.

Source: National Transit Database.

Exhibit 4-28 provides total PMT for selected years between 2004 and 2014, showing steady growth in all major modes. The light rail, other rail, and vanpool modes grew at the highest rates. Growth in demand-response (up 2.7 percent per year) could be a response to demand from the growing number of elderly citizens. Light rail (up 5.4 percent per year) enjoyed increased capacity during this period due to expansions and addition of new systems. The rapidly increasing popularity of vanpools (up 11.1 percent per year), particularly the surge between 2006 and 2008 (up 44 percent over that period), can be partially attributed to rising gas prices: regular gasoline sold for more than $4 per gallon in July of 2008. FTA has also encouraged vanpool reporting during this period, successfully enrolling many new vanpool systems to report to NTD.

Exhibit 4-27: Passenger Miles Traveled by Mode, 2014



[1] Includes aerial tramway, Alaska railroad, cable car, ferryboat, inclined plane, monorail/automated guideway, and público.

[2] Includes demand-response and demand-response taxi.

Source: National Transit Database.

Exhibit 4-28: Transit Passenger Miles Traveled, 2004–2014

Mode	Passenger Miles (in Millions)						Average Annual Rate of Change 2014 to 2004
	2004	2006	2008	2010	2012	2014	
Rail	**25,668**	**26,972**	**29,882**	**29,380**	**31,176**	**32,672**	**2.4%**
Heavy Rail	14,354	14,721	16,850	16,407	17,516	18,339	2.5%
Commuter Rail	9,715	10,359	10,925	10,774	11,121	11,600	1.8%
Light Rail[1]	1,576	1,866	2,081	2,173	2,489	2,675	5.4%
Other Rail[2]	22	25	26	26	50	59	10.4%
Nonrail	**20,941**	**22,346**	**23,721**	**23,245**	**23,991**	**24,312**	**1.5%**
Fixed-Route Bus[3]	18,989	20,390	21,197	20,569	21,142	21,402	1.2%
Demand-Response[4]	703	752	842	873	885	916	2.7%
Ferryboat	354	175	390	389	402	414	1.6%
Trolleybus	173	164	161	159	162	158	-0.9%
Vanpool	459	689	992	1,087	1,254	1,310	11.1%
Other Nonrail[5]	265	176	138	169	145	112	-8.3%
Total	**46,609**	**49,318**	**53,603**	**52,625**	**55,167**	**56,985**	**2.0%**
Percent Rail	55.1%	54.7%	55.7%	55.8%	56.5%	57.3%	

[1] Includes light rail, hybrid rail, and streetcar rail.

[2] Includes Alaska railway, monorail/automated guideway, cable car, and inclined plane.

[3] Includes bus, commuter bus, and bus rapid transit.

[4] Includes demand-response and demand-response taxi.

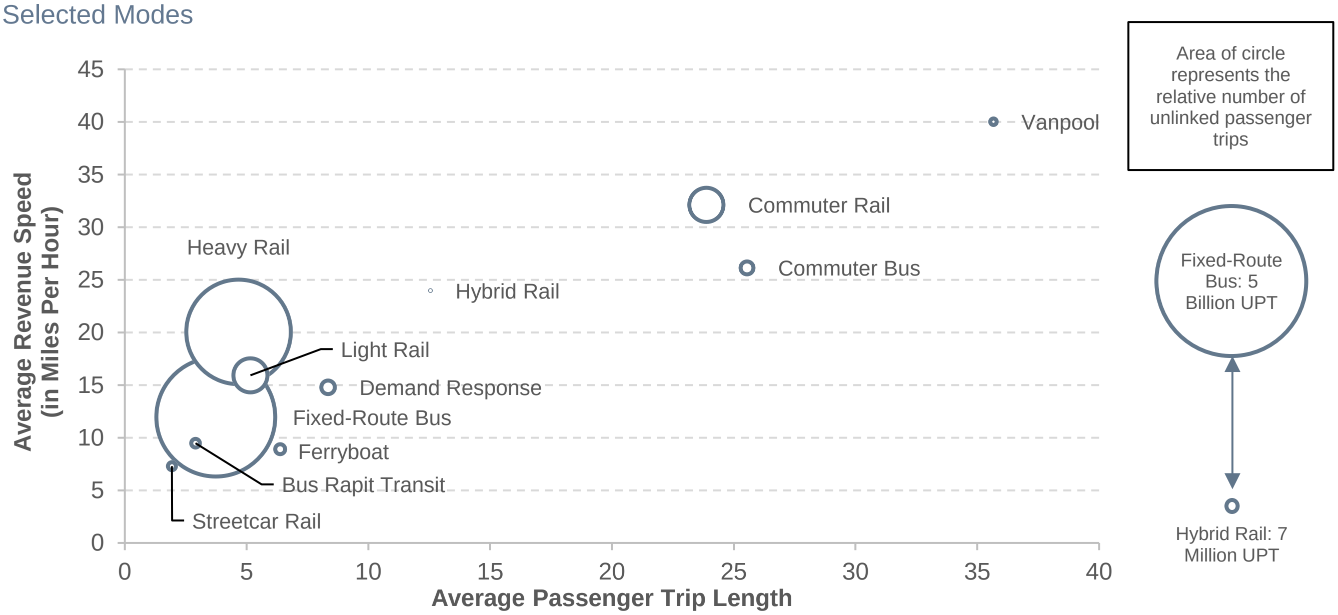
[5] Includes aerial tramway and público.

Source: National Transit Database.

Average Trip Length

Exhibit 4-29 depicts average passenger trip length (defined as PMT per unlinked passenger trips) versus revenue speed (defined as VRMs per vehicle revenue hours), and unlinked passenger trips for transit modes. Note that average passenger trip length is the average distance traveled of one unlinked trip. Most riders use more than one mode to commute from origin to destination (linked trip), which could include other transit modes, car, or other modes such as bicycle, walking, etc. Therefore, the average trip length of an individual mode as depicted in *Exhibit 4-29* is the lower bound of the total average distance traveled. The total trip distance is a function of a linked trip factor that varies from mode to mode and is not available in the NTD to better capture the scope of transit service in the United States.

Exhibit 4-29: Transit Urban Average Unlinked Passenger Trip Length vs. Average Revenue Speed for Selected Modes



Source: National Transit Database.

A linked passenger trip is a trip from origin to destination on the transit system. Even if a passenger must make several transfers during a one-way journey, the trip is counted as one linked trip on the system. Unlinked passenger trips count each boarding as a separate trip regardless of transfers. A linked factor is the ratio of linked per unlinked trip. Thus, a factor of 1 means that the passenger did not make any intermodal or intramodal transfers.

Demand-response and vanpool systems are modes with linked factors close to 1; that is, the average trip length of one unlinked trip should be close to the total length of the linked trip. This is because vanpools and demand-response are "by-demand" modes, and the routes can be set up to optimize the proximity from the origin and destination.

Commuter bus and commuter rail, on the other hand, are fixed-route modes, and a high percentage of commuters require other modes to reach their final destinations. Additionally, commuter bus and commuter rail are not as fast as vanpools due to more frequent stops near areas of attraction and generation of trips, among other factors. Hybrid rail, introduced in 2011, was reported prior to 2011 as commuter rail and light rail. Hybrid rail has quite different operating characteristics than commuter rail and light rail. It has higher average station density (stations per track mileage) than commuter rail and a lower average station density than light rail. This results in revenue speeds that are lower than commuter rail and higher than light rail. Hybrid rail has smaller average peak-to-base ratio (number of trains during peak service per number of trains during midday service) than commuter rail, which indicates higher demand at off-peak hours.

Several modes (heavy rail, light rail, fixed-route bus, bus rapid transit, streetcar, and ferryboat) cluster within a narrow range for average passenger trip length (less than 5 miles) and a wider range for average revenue speed (10 to 20 miles per hour). Heavy rail and light rail have higher average speed than nonrail modes for operating in exclusive rights-of-way. The modes in this cluster serve areas with high population density and significant average number of boarding and alighting per station or stop, which results in shorter average trip lengths than modes with a commuter orientation. These modes should have similar link factors but smaller than commuter rail and commuter bus.

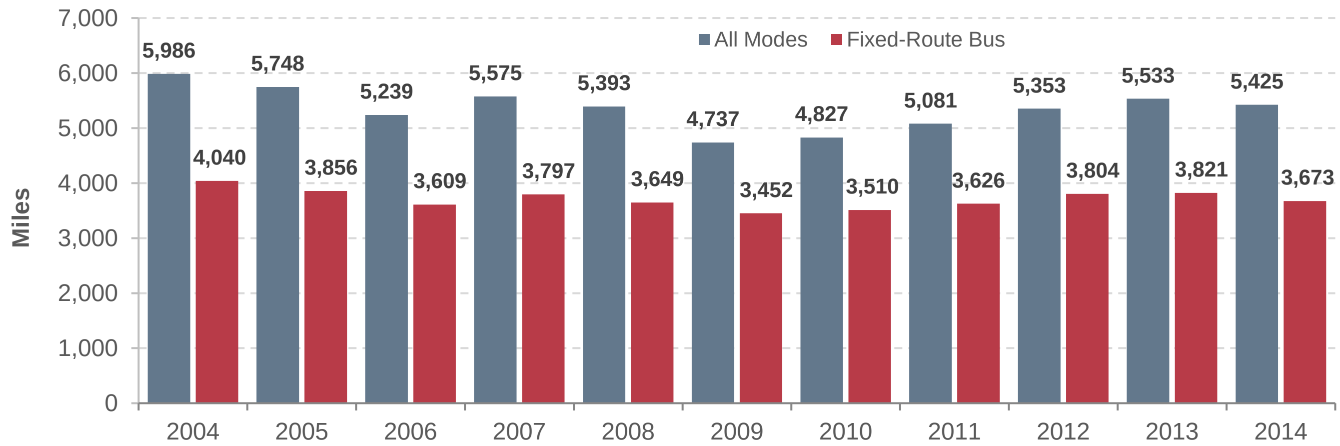
Vehicle Reliability

Vehicle reliability data available in the NTD relate solely to vehicle service interruptions due to major and minor mechanical failures. By definition, major mechanical failures prevent the vehicle from continuing the trip. Passengers are thus transferred to the next vehicle or a spare vehicle is sent to pick up these passengers. Minor mechanical failures do not prevent the vehicle from continuing the trip, but local policies may require termination of the trip anyway.

Mean distance between failures is defined as the ratio of service miles per number of major mechanical failures, by mode. The larger the ratio, the more reliable is the service.

Mean distance between failures is shown in *Exhibit 4-30*. The mean distance between failures is calculated by the ratio of VRMs per mechanical (major) and other (minor) failures for directly operated vehicles in urban areas. FTA does not collect data on delays due to guideway conditions, which would include congestion for roads and slow zones (due to system or rail problems) for track. Miles between failures for all modes combined decreased 21 percent between 2004 and 2009. Between 2006 and 2014, the ratio increased steadily at roughly 2.8 percent annually to reach a level similar to that before 2006. The trend for fixed-route bus is nearly identical to all modes combined.

Exhibit 4-30: Mean Distance Between Urban Vehicle Failures, 2004–2014



Note: Only directly operated vehicle data were used to calculate mean distance between failures.
Note: 2014 data do not include agencies that qualified and opted to use the small systems waiver of the National Transit Database.
Source: National Transit Database.

Transit System Characteristics for Americans with Disabilities and the Elderly

DOT seeks to promote accessible transportation systems that meet the needs of people of all ages and abilities through ADA compliance. The ADA is a comprehensive civil rights law that prohibits discrimination based on disability. Compliance with the ADA is a condition of eligibility to receive certain Federal funding. Title II of ADA applies to all programs, services, and activities provided or made available by public entities, including State and local governments or any of their instrumentalities or agencies. The scope of Title II coverage extends to the entire operations of a public entity and includes public transportation services, vehicles, and facilities; airport services and facilities; intercity rail travel, railcars, and facilities; passenger vessel services and facilities; and roadway facilities, including sidewalks and pedestrian crosswalks.

FTA reviews grant applications for evidence of ADA compliance in capital projects and vehicle acquisition. FTA also conducts triennial reviews for compliance with Federal requirements of ADA. In addition, FTA conducts approximately 8–10 targeted, in-depth compliance reviews each year to determine compliance with specific ADA provisions, including paratransit requirements, fixed-route accessibility, and rail station accessibility. In Fiscal Year 2016, FTA published comprehensive guidance to transit agencies on how to comply with ADA's provisions. This guidance, FTA Circular 4710.1, thoroughly explains ADA requirements for public transit, providing real-life situations as examples of good practices for the transit industry to ensure accessible services for riders.

ADA requirements ensure that transit services, vehicles, and facilities are accessible to and usable by persons with disabilities, including wheelchair users, and provide for complementary paratransit service for those individuals whose disabilities prevent the use of an accessible fixed-route system.

Exhibit 4-31 presents the change in the level of ADA accessibility of transit service vehicles from 2004 to 2014. The level of accessibility of the Nation's transit bus fleet rose from 93 percent in 2004 to 96 percent in 2014. The most significant increase was commuter rail passenger and self-propelled cars, from approximately 50 percent in 2004 to over 80 percent in 2014. In 2004, commuter rail had the smallest share of ADA-accessible passenger cars compared with other rail modes such as heavy rail and light rail.

Exhibit 4-32 depicts the trends in total active commuter rail fleet and ADA-accessible fleet for 2004–2014. The data show that the ADA-accessible commuter rail fleet increased steadily from 2004 to 2012, at an average rate of approximately 88 passenger cars per year, while the total fleet increased at an average of 78 percent per year. This corresponded to a period that saw a geographic expansion of service, with the introduction of four new systems. Some of the largest agencies replaced or rehabilitated their old fleets during this period, bringing the accessibility rate from 54 percent to 76 percent in just 2 years. Due to the long service life of rail vehicles, 100 percent fleet accessibility is a long-term goal that will not be achievable until the last inaccessible cars from the oldest fleets are retired or remanufactured. In the case of remanufacturing, there are provisions for inaccessible cars to remain in service if making them accessible would harm the structural integrity of the vehicles.

Exhibit 4-31: ADA Accessibility by Vehicle Type, 2004–2014

Vehicle Type	Active Fleet 2004	ADA Fleet 2004	ADA Fleet Share 2004	Active Fleet 2014	ADA Fleet 2014	ADA Fleet Share 2014	Increase in Fleet	% Increase in Share
Buses, Cutaways, and Over-the-road Buses	66,198	64,892	98.0%	78,204	77,130	98.6%	18.1%	0.6%
Vans (Demand-Response Service)	11,934	10,593	88.8%	12,324	10,687	86.7%	3.3%	-2.0%
Heavy Rail Passenger Cars	10,965	10,418	95.0%	11,623	11,272	97.0%	6.0%	2.0%
Articulated Buses	2,591	2,586	99.8%	4,886	4,885	100.0%	88.6%	0.2%
Commuter Rail Passenger Coaches	3,439	1,724	50.1%	3,675	3,044	82.8%	6.9%	32.7%
Commuter Rail Self-Propelled Passenger Cars	2,441	1,340	54.9%	2,912	2,478	85.1%	19.3%	30.2%
Light Rail Vehicles and Streetcars	1,665	1,257	75.5%	2,340	2,014	86.1%	40.5%	10.6%
All Other Rail Vehicles[1]	752	653	86.8%	916	861	94.0%	21.8%	7.2%
All Other Non-Rail Vehicles[2]	844	711	84.2%	897	829	92.4%	6.3%	8.2%
Total	**100,829**	**94,174**	**93.4%**	**117,777**	**113,200**	**96.1%**	**16.8%**	**2.7%**

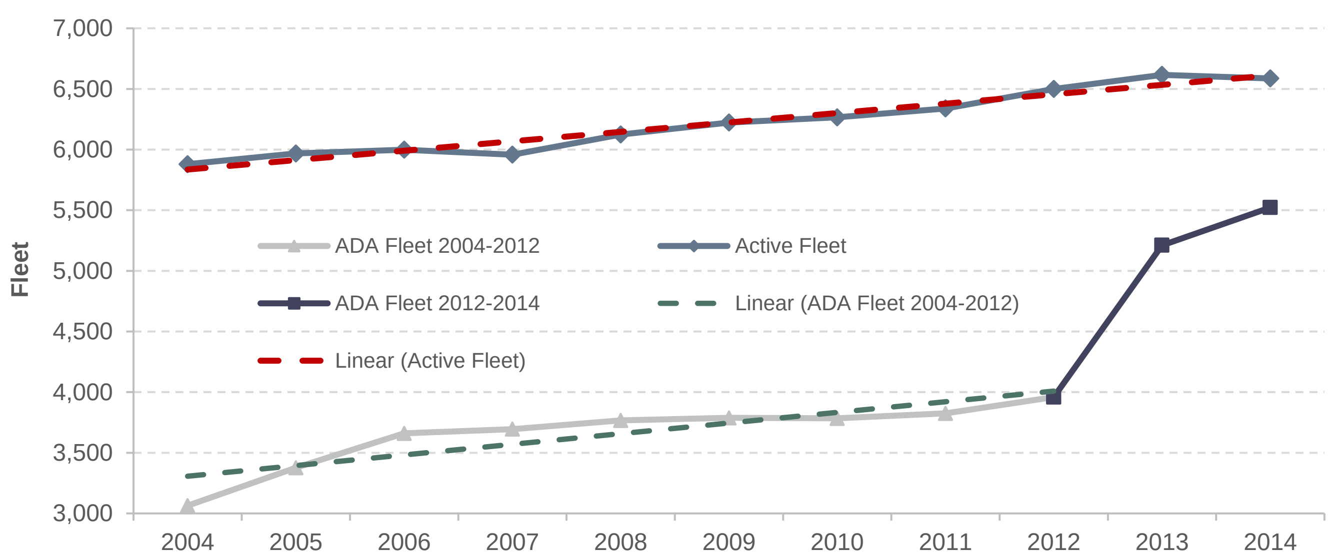
[1] Monorail vehicles, automated guideway vehicles, Inclined plane vehicles, and cable cars.

[2] Ferryboats, trolleybuses, school buses and other vehicles.

Source: National Transit Database.

The ADA requires that new transit facilities and alterations to existing facilities be accessible to and usable by persons with disabilities, including wheelchair users. *Exhibit 4-33* presents the change in the number of urban transit ADA-compliant stations and percentage of total ADA-compliant stations by mode. In 2014, 78.3 percent of total transit stations were either 100 percent accessible or self-certified as accessible, an increase from 70 percent in 2004.

Exhibit 4-32: Total Active Fleet and ADA Fleet for Commuter Rail, 2004–2014



Source: National Transit Database.

Exhibit 4-33: ADA Accessibility of Stations, 2004 and 2014

Mode Category	2004 Stations	2004 ADA Stations	2004 ADA Stations Share	2014 Stations	2014 ADA Stations	2014 ADA Stations Share
Fixed Route Bus	1,459	1,334	91.4%	1,736	1,683	96.9%
Other Non-Rail[1]	82	76	92.7%	106	96	90.6%
Commuter Rail	1,153	666	57.8%	1,245	849	68.2%
Heavy Rail	1,023	428	41.8%	1,130	558	49.4%
Light Rail	723	589	81.5%	828	762	92.0%
Other Rail[2]	62	60	96.8%	216	171	79.2%
Total	**4,502**	**3,153**	**70.0%**	**5,261**	**4,119**	**78.3%**

[1] Includes ferryboat and trolleybus.

[2] Includes hybrid rail, automated guideway, monorail, and inclined plane.

Source: National Transit Database.

The ADA also required existing rail transit systems to identify "key" rail stations that would be made accessible by July 26, 1993. Rail stations identified as "key" have the following characteristics:

- The number of passengers boarding exceeds the average number of passengers boarding on the rail system by at least 15 percent.
- The station is a major point where passengers shift to other transit modes.
- The station is at the end of a rail line, unless it is close to another accessible station.
- The station serves a "major" center of activities, including employment or government centers, institutions of higher education, and major health facilities.

Although the statute established a deadline of July 23, 1993, for completion of alterations to these key stations, it also permitted the Secretary of Transportation to grant extensions until July 26, 2020, for stations that required extraordinarily expensive structural modifications to achieve compliance. Of the 680 stations designated as key, 607 were accessible and fully compliant, 22 were accessible but not fully compliant, and 45 were self-certified as accessible as of November 16, 2017, but had not yet been certified as fully compliant by FTA. "Accessible but not fully compliant" means that these stations are functionally accessible (i.e., persons with disabilities, including wheelchair users, can make use of the station), but minor outstanding issues must be addressed for the station to be fully compliant; example issues include missing or misallocated signage and parking-lot striping errors.

In addition to the services that urban and rural transit operators provide through FTA's core Formula programs, approximately 4,800 providers operate in rural and urban areas through FTA's Formula Grants for Special Services for the Elderly and Disabled. This funding supports primarily demand-response services. Of these, FTA estimates that approximately 700 providers offer public transportation service to the public. The remainder are primarily nonprofit social service organizations, for which transportation is a secondary activity relative to their primary mission. Nevertheless, services provided by these private organizations help relieve the demand for trips on demand-response public transportation services. Nonprofit providers include religious organizations, senior citizen centers, rehabilitation centers, nursing homes, community action centers, sheltered workshops, and coordinated human services transportation providers. FTA estimates that approximately 40 percent of these providers are true public transit providers, and will begin reporting asset inventory data for the NTD in 2018.

Transit System Coverage and Frequency

The extent of the Nation's transit system is measured in directional route miles, or simply "route miles." Route miles measure the distance covered by a transit route. Transit routes that use the same road or track, but in the opposite direction, are counted separately. Data associated with route miles are not collected for demand-response and vanpool modes because these transit modes do not travel along specific predetermined routes. Route mile data are also not collected for jitney services because these transit modes often have highly variable route structures.

Exhibit 4-34 shows directional route miles by mode over the past 10 years. Growth in both rail (28.4 percent) and nonrail (10.7 percent) route miles is evident over this period. The average 7.9-percent rate of annual growth for light rail clearly outpaces the rate of growth for all other modes due to the large increase in new systems in the past 10 years.

The frequency of transit service varies considerably based on location and time of day. Transit service is more frequent in urban areas and during rush hours, corresponding to the places and times with the highest demand for transit. Studies have found that transit passengers consider the time spent waiting for a transit vehicle to be less well spent than the time spent traveling in a transit vehicle. The higher the degree of uncertainty in waiting times, the less attractive transit becomes as a means of transportation—and the fewer users it will attract. To minimize this problem, many transit systems have recently begun implementing technologies to track vehicle location (automatic vehicle location systems) that, combined with data on operating speeds, enable agencies to estimate the amount of time required for arrival of vehicles at stations and stops. This information is displayed in platforms and bus stops in real time. By knowing the waiting time, passengers are less frustrated and could be more willing to use transit.

Exhibit 4-34: Transit Directional Route Miles, 2004–2014

Mode	2004	2006	2008	2010	2012	2014	Average Annual Rate of Change 2014 to 2004
Rail	**9,572**	**9,812**	**10,797**	**11,340**	**12,001**	**12,290**	**2.5%**
Heavy Rail	1,590	1,617	1,617	1,617	1,622	1,622	0.2%
Commuter Rail	6,130	6,268	7,094	7,532	7,674	7,795	2.4%
Light Rail[1]	881	956	1,114	1,220	1,709	1,877	7.9%
Other Rail[2]	971	971	971	971	996	996	0.3%
Non-Rail	**215,812**	**226,497**	**228,851**	**235,995**	**239,539**	**238,831**	**1.0%**
Fixed-Route Bus[3]	214,956	225,863	227,796	234,920	238,291	237,654	1.0%
Ferryboat	430	209	599	619	793	719	5.3%
Trolleybus	425	425	456	456	456	458	0.7%
Total	**225,383**	**236,309**	**239,648**	**247,335**	**251,540**	**251,121**	**1.1%**
Percent Nonrail	95.8%	95.8%	95.5%	95.4%	95.2%	95.1%	

[1] Includes light rail, hybrid rail, and streetcar rail.

[2] Includes Alaska railway, monorail/automated guideway, cable car, and inclined plane.

[3] Includes bus, commuter bus, and bus rapid transit.

Note: Nonrail excludes demand-response and demand-response taxi, aerial tramway, and público.

Note: 2012 data do not include agencies that qualified and opted to use the small systems waiver of the National Transit Database.

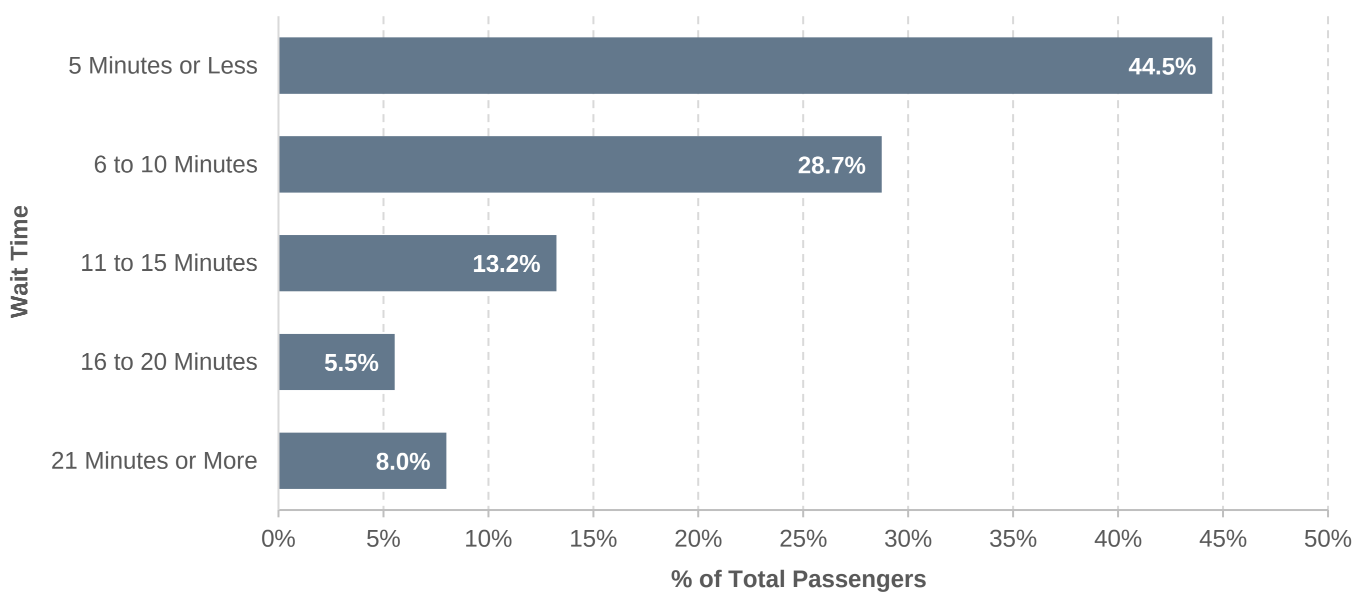
Source: National Transit Database.

Transit System Resilience

Transit systems are managed to be resilient because they are required to operate through all but the worst weather on a daily basis. Most are instrumental in community emergency-response plans. Dispatchers and vehicle operators receive special training for these circumstances. All bus systems maintain a small fleet of spare buses that enables them to schedule maintenance activities while maintaining regular service levels. These "spare buses" also can be used to replace damaged vehicles on short notice. Rail systems have contingency plans for loss of key assets and most can muster local resources to operate bus bridges in emergencies. Operationally speaking, transit providers are some of the most resilient community institutions. Much transit infrastructure, however, has not yet been upgraded to address current or projected changes in climate. FTA does not collect systematic data on these upgrades, but significant grant money has been made available for transit systems to upgrade their structures and guideways to be more resistant to extreme precipitation events, sea level rise, storm surge, heat waves, and other environmental stressors. Efforts to improve resilience have been particularly evident in the aftermath of Superstorm Sandy and its impact on the Mid-Atlantic area. Addressing such issues is a common use of FTA grant funds.

Exhibit 4-35 shows findings on wait times from the 2009 FHWA National Household Travel Survey. The survey found that 44.5 percent of passengers who ride transit wait 5 minutes or less and 73.2 percent wait 10 minutes or less. The survey also found that 8.0 percent of passengers wait 21 minutes or more. Several factors influence passenger wait times, including the frequency and reliability of service and passengers' awareness of timetables. These factors are interrelated. For example, passengers could intentionally arrive earlier for service that is infrequent, compared with equally reliable services that are more frequent. Overall, waiting times of 5 minutes or less are clearly associated with good service that is either frequent, reliably provided according to a schedule, or both. Wait times of 5 to 10 minutes are most likely consistent with adequate levels of service that are both reasonably frequent and generally reliable. Wait times of 21 minutes or more indicate that service is likely less frequent or less reliable.

Exhibit 4-35: Distribution of Passengers by Wait Time



Source: National Household Travel Survey, FHWA, 2009.

Access to Transit

In 2011, The Brookings Institution published *Missed Opportunity: Transit and Jobs in Metropolitan America*.[8] To date, this is the most comprehensive study of physical access to transit systems in the United States. To investigate the effectiveness of transit in providing access to employment, Brookings Metropolitan Policy Program researchers compiled and compared transit data from the largest 100 metropolitan areas as measured by population. This database includes geospatial and schedule details of routes for 371 transit providers in 2008, in addition to income and employment data at the neighborhood level. It provides indicators to measure the effectiveness and accessibility of transit services.

Averaged across the 100 metropolitan areas examined by Brookings, nearly 70 percent of working-age people lived in a neighborhood with transit service. This equals approximately 128 million working-age people. Conversely, this also means about 39 million working-age people did not live near transit access. There was significant variation in the percentage of people covered by transit services among the top 100 metro areas. (See *Exhibit 4-36*).

Accessibility to transit depends to some extent on geographical constraints such as mountains, deserts, and other natural obstacles. These constraints, which in some cases promote a more compact urban form that promotes accessibility, affect western cities more than they do eastern cities. Metro areas in the West provided 85 percent of working-age people with access to transit service, compared with 78 percent in the Northeast, 63 percent in the Midwest, and just 55 percent in the South. These differences can be attributed to metropolitan age, local geography, and local public policies.

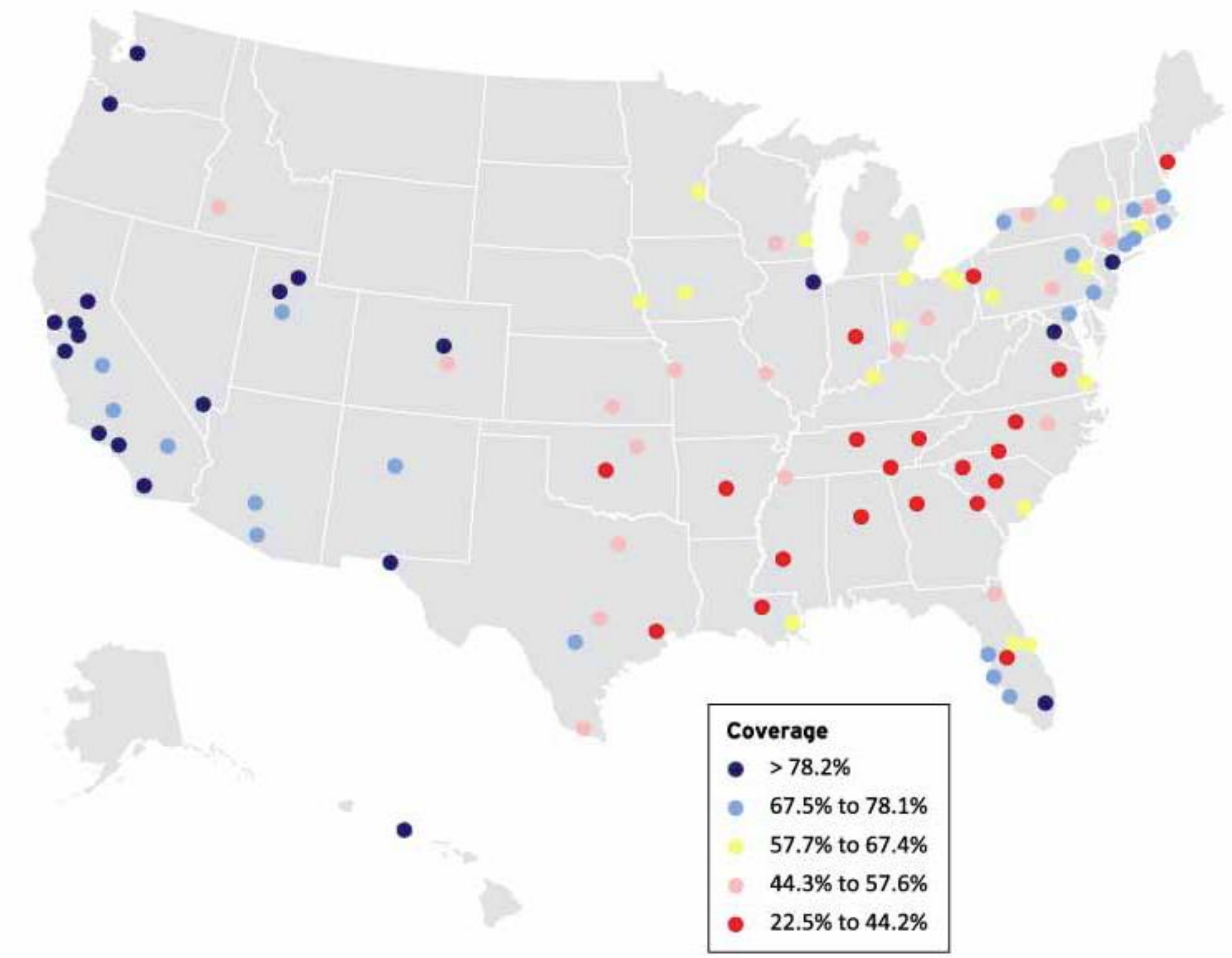
Despite the differences in overall coverage across the metro areas, Brookings found similarities throughout coverage areas. Neighborhood income level is a determining factor in access to transit. In low-income areas, 89 percent of working-age people have access to transit, compared to 70 percent for middle-income and 53 percent for high-income neighborhoods. Population density is also a significant determining factor, with 94 percent of city residents having access to transit compared to 58 percent of suburban residents. Just as important as transit access is the frequency of service vehicles. During Monday morning commutes, city transit service is more frequent, with an average of 6.9 minutes between vehicles, as opposed to 12.6 minutes for suburban, with an average across all metro areas of 10.1 minutes.

National Transit Map

In 2016, the Federal Transit Administration partnered with the Bureau of Transportation Statistics to begin collection of data for a National Transit Map. Participation in the National Transit Map is voluntary, but the goal is to collect route and schedule information for every fixed-route transit provider in the country. Data are collected using the General Transit Feed Specification (GTFS) data model, and the information will be updated multiple times per year from the GTFS data that transit systems are already making publicly available. Eventually, the National Transit Map will allow FTA to replicate the analyses first completed in the "Missed Opportunities" report, and also to eventually develop national performance measures for access to fixed-route transit. As of February 12, 2019, the National Transit Map included 60,955 routes, 493,718 bus stops, and train stations for 241 agencies. The National Transit Map is available at (https://www.rita.dot.gov/bts/ntm).

[8] (https://www.brookings.edu/research/missed-opportunity-transit-and-jobs-in-metropolitan-america/)

Exhibit 4-36: 2010 Share of Working-Age Residents with Access to Transit, 100 Metropolitan Areas



Source: Brookings Institution, Missed Opportunity: Transit and Jobs in Metropolitan America, May 2011 report citing Brookings Institution analysis of transit agency data and Nielson Pop-Facts 2010 data.

Access to Employment

Many transit trips are used for commuting to work, and the Brookings report investigated the types of jobs with access to transit. Brookings found that, within a 90-minute transit commute, 30 percent of metro area jobs could be accessed by residents. This average increased to 36 percent for residents of low-income areas, dropping to 28 percent for middle-income and 23 percent for high-income. The types of jobs accessible to transit were split into categories based on the educational attainment of their workers. About a quarter of low- and middle-skilled jobs were accessible by transit, compared with about a third of high-skilled jobs. This speaks to the concentration of higher-skilled jobs in urban centers, and points to an issue where the individuals who are most dependent on transit have the least access. For example, low-income suburban areas had transit access to only 22 percent of low- and middle-skilled jobs.

CHAPTER 5
Safety

Highway Safety

Safety is the U.S. Department of Transportation's (DOT's) top priority. Three operating administrations within DOT have specific responsibilities for addressing highway safety:

- The Federal Highway Administration (FHWA) focuses on infrastructure safety design and operations.
- The National Highway Traffic Safety Administration (NHTSA) oversees vehicle safety standards and administers driver behavior programs.
- The Federal Motor Carrier Safety Administration (FMCSA) works to reduce crashes, injuries, and fatalities involving large trucks and buses.

This balance of coordinated efforts, coupled with a comprehensive focus on shared, reliable safety data, enables these three DOT administrations to concentrate on their areas of expertise while working toward the Nation's safety goals and encourages a more unified endeavor.

This chapter provides data on fatalities and injuries as well as information on FHWA safety programs. FHWA provides technical assistance and expertise to Federal, State, Tribal, and local governments for researching, designing, and implementing safety improvements in roadway infrastructure. FHWA supports improvements in safety elements as part of road and bridge construction and system preservation projects. The Highway Safety Improvement Program (HSIP) is FHWA's primary infrastructure safety funding program. It uses a performance-driven, strategic approach to achieve significant reductions in fatalities and serious injuries on all public roads for all road users, including pedestrians and bicyclists. The HSIP also helps States improve their roadway safety data. Additionally, the HSIP supports railway-highway grade crossing safety through set-aside funding. Use of HSIP funds is driven by a statewide coordinated plan, developed in cooperation with a broad range of multidisciplinary stakeholders, which provides a comprehensive framework for safety. This data-driven State Strategic Highway Safety Plan (SHSP) defines State safety goals and integrates the four "E's"—engineering, education, enforcement, and emergency services. The SHSP guides States and their collection of data in the use of HSIP and other funds to resolve safety problems and save lives.

Key Takeaways

- DOT's top priority is to make the U.S. transportation system the safest in the world.
- There has been great progress in reducing overall roadway-related fatalities and injuries during the past two decades despite increases in population and travel. During the past decade alone, highway fatalities have decreased by nearly 25 percent.
- During the last five years, fatalities involving pedestrian and bicyclists have increased nearly 15 percent and, on average, account for almost 17 percent of all traffic fatalities.
- As DOT moves toward the vision of zero deaths and injuries on our Nation's roadways, improvements in data, better safety analysis tools, and implementation of legislative mandates will be essential.
- FHWA's Focused Approach to Safety addresses the most critical safety challenges surrounding roadway departures, intersections, and pedestrian/bicyclist-involved crashes, which account for nearly 90 percent of traffic fatalities. Focused Approach thus represents an opportunity to reduce fatalities and serious injuries significantly.

Highway Fatalities and Injuries

Statistics discussed in this section are drawn primarily from the Fatality Analysis Reporting System (FARS). FARS is a nationwide census providing DOT, Congress, and the American public with data regarding fatal motor vehicle traffic crashes. NHTSA, which has a cooperative agreement with States to provide information on fatal crashes, maintains FARS. FARS data are combined with exposure data from other sources to produce fatal crash rates. The most frequently used exposure data are estimates of vehicle miles traveled (VMT) that FHWA collects through the Highway Performance Monitoring System (HPMS). The HPMS is a national-level information system that includes data on the extent, condition, performance, use and operating characteristics of the Nation's highways.

In addition to FARS, NHTSA estimates injuries nationally through the National Automotive Sampling System (NASS), which is composed of two systems: the General Estimates System and the Crashworthiness Data System. Datasets in these systems provide a statistically based annual estimate of total nonfatal injury crashes. It is important to note that safety statistics in this section, compiled in 2016 using data through 2014, represent a "snapshot in time" during the preparation of this report. As a result, some statistics might not precisely correspond to those in other, more recently compiled data and reports.

In 2014, 5.8 million motor vehicle crashes on our Nation's roadways were reported to police. The crashes ranged in severity, as shown in *Exhibit 5-1*. Of those crashes, 30,056 involved at least one fatality. In this same year, approximately 1.5 million crashes resulted in injuries that were not life-threatening, and 4.3 million crashes resulted in damage or harm to property alone. From 2004 to 2014, fatal crashes decreased by 21.8 percent, injury crashes decreased by 15.3 percent, and property-damage-only crashes increased by 3.8 percent.

Exhibit 5-1: Crashes by Severity, 2004–2014

Year	Crash Severity						Total Crashes	
	Fatal		Injury		Property Damage Only			
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
2004	38,444	0.6	1,789,046	30.0	4,126,283	69.3	5,953,773	100.0
2005	39,252	0.7	1,753,835	29.6	4,132,826	69.7	5,925,913	100.0
2006	38,648	0.7	1,677,165	29.3	4,007,220	70.0	5,723,033	100.0
2007	37,435	0.6	1,651,565	28.6	4,076,939	70.7	5,765,939	100.0
2008	34,172	0.6	1,573,910	28.3	3,953,040	71.1	5,561,122	100.0
2009	30,862	0.6	1,460,500	27.7	3,782,288	71.7	5,273,650	100.0
2010	30,296	0.6	1,452,378	27.9	3,724,801	71.5	5,207,475	100.0
2011	29,867	0.6	1,426,592	27.8	3,669,122	71.6	5,125,581	100.0
2012	31,006	0.6	1,511,184	28.0	3,860,976	71.5	5,403,166	100.0
2013	30,203	0.6	1,470,861	26.9	3,973,629	72.6	5,474,693	100.0
2014	30,056	0.5	1,515,893	26.0	4,282,261	73.5	5,828,210	100.0

Source: Fatality Analysis Reporting System/National Center for Statistics and Analysis, NHTSA.

Exhibit 5-2 displays trends in motor vehicle fatality counts, fatality rates, injury counts, and injury rates from 1980 to 2014. The motor vehicle fatality count was above 51,000 in 1980 and then dropped to less than 43,000 in 1983. The fatality count declined to less than 40,000 in 1992 for the first time in decades but remained above 40,000 every year from 1993 through 2007. *Exhibit 5-2* shows significant declines in fatality counts in recent years. Between 2004 and 2014, there was an overall 23.6-percent reduction in fatalities. During that period, a 1.6-percent increase in fatalities occurred in 2005, and a 4.0-percent increase occurred in 2012. Of note is that the large decline in fatalities from 2004 through 2011 included the timing of the implementation of FHWA's HSIP and the 2008–2009 economic recession.

In addition to the fatality counts shown in *Exhibit 5-2*, fatality rates are shown for two different measures of exposure: rates expressed in terms of population and rates in terms of VMT. Fatality rates per 100 million (100M) VMT provide a metric that enables transportation professionals to consider fatalities in terms of the additional exposure associated with driving more miles. The fatality rates per 100,000 population shown in *Exhibit 5-2* express exposure in terms of people's likelihood of being killed in a motor vehicle crash, regardless of the amount of highway travel. Such data are also often stratified to examine in greater depth how different demographic groups, such as male drivers aged 16–20 versus male drivers aged 21–44, experience different fatality rates.

Exhibit 5-2: Summary of Fatality and Injury Rates, 1980–2014

Year	Fatalities	Resident Population (Thousands)	Fatality Rate per 100,000 Population	Vehicle Miles Travelled (Millions)	Fatality Rate per 100 Million VMT	Injured	Injury Rate per 100,000 Population	Injury Rate per 100 Million VMT
1980	51,091	227,225	22.48	1,525,104	3.35			
1982[1]	43,945	231,664	18.97	2,496,875	1.76			
1984	44,257	235,825	18.77	1,722,062	2.57			
1986	46,087	240,133	19.19	1,836,135	2.51			
1988	47,087	244,499	19.26	2,029,612	2.32	3,416,000	1,397	168
1990	44,599	249,439	17.88	2,144,183	2.08	3,231,000	1,295	151
1992[2]	39,250	254,995	15.39	2,242,857	1.75	3,070,000	1,204	137
1994	40,716	260,327	15.64	2,353,526	1.73	3,266,000	1,255	139
1996	42,065	265,229	15.86	2,482,202	1.69	3,483,000	1,313	140
1998	41,501	270,248	15.36	2,628,148	1.58	3,192,000	1,181	121
2000	41,945	281,422	14.90	2,749,803	1.53	3,077,000	1,093	112
2002	43,005	288,369	14.91	2,855,756	1.51	2,813,000	975	99
2003	42,884	290,810	14.75	2,890,893	1.48	2,776,000	955	96
2004	42,836	293,655	14.59	2,962,513	1.45	2,652,000	903	90
2005	43,510	296,410	14.68	2,989,807	1.46	2,579,000	870	86
2006	42,708	299,398	14.26	3,014,116	1.42	2,453,000	819	81
2007	41,259	301,621	13.68	3,029,822	1.36	2,381,000	789	79
2008	37,423	304,060	12.31	2,973,509	1.26	2,250,000	740	76
2009	33,883	307,007	11.04	2,953,501	1.15	2,117,000	690	72
2010	32,999	308,746	10.69	2,967,266	1.11	2,105,000	682	71
2011	32,479	311,592	10.42	2,950,402	1.10	2,061,000	661	70
2012	33,782	313,914	10.76	2,968,815	1.14	2,157,000	687	73
2013	32,894	316,129	10.41	2,988,323	1.10	2,110,000	667	71
2014	32,744	318,857	10.27	3,025,656	1.08	2,154,000	676	71

[1] Fatalities subsequently dropped to 42,589 in 1983.

[2] Fatalities subsequently rose to 40,150 in 1993.

Source: Fatality Analysis Reporting System/National Center for Statistics and Analysis, NHTSA.

Traffic Fatality Trends Since 2014

Although this report focuses primarily on data through 2014, more recent data show that 35,484 people died in crashes on U.S. roadways during 2015, followed by an increase to 37,806 in 2016 and a decline to 37,133 in 2017. The 8.4-percent increase from 2014 to 2015 was the largest annual increase observed since a 9.4-percent increase from 1963 to 1964. The fatality rate per 100 million VMT increased to 1.15 in 2015 and 1.19 in 2016, then dropped to 1.16 in 2017.

The number of vehicle occupant fatalities increased from 22,307 in 2014 to 24,973 in 2017, a 12.0-percent increase. Motorcyclist fatalities increased from 4,594 in 2014 to 5,172 in 2017, which represents a 12.5-percent increase. Pedestrian fatalities increased more sharply to 5,494 in 2015 and 6,080 in 2016 before dropping slightly to 5,977 in 2017, an overall increase of 21.7 percent from 2014 to 2017. Pedalcyclist fatalities increased to 783 in 2017 (a 7.4-percent increase). Non-motorist fatalities overall rose to 6,556 in 2015, then further up to 7,193 in 2016 before declining to 6,988 in 2017; this represents a 19.6 percent increase from 2014 to 2017.

The fatality rate per 100,000 population was 22.48 in 1980. This rate dropped to 17.88 in 1990 and to 14.90 in 2000. Except for 2012, the fatality rate per population steadily decreased from 2004 to 2014. In 2004, the fatality rate per 100,000 population was 14.59; it decreased to 10.27 in 2014, a 29.6-percent reduction over the 10-year period.

The fatality rate, expressed in terms of VMT, was 5.50 deaths per 100M VMT in 1966. That rate fell below 5.00 in 1970 and to less than 4.00 since 1974. Due to significant progress in traffic safety in the United States, the motor vehicle fatality rate has continued to decline. The rate has remained less than 2.00 since 1992. In 2003, the rate dropped below 1.50 and continued to drop from 1.45 in 2004 to 1.08 in 2014, which is the lowest rate on record (*Exhibit 5-2*).

Every Day Counts Initiative

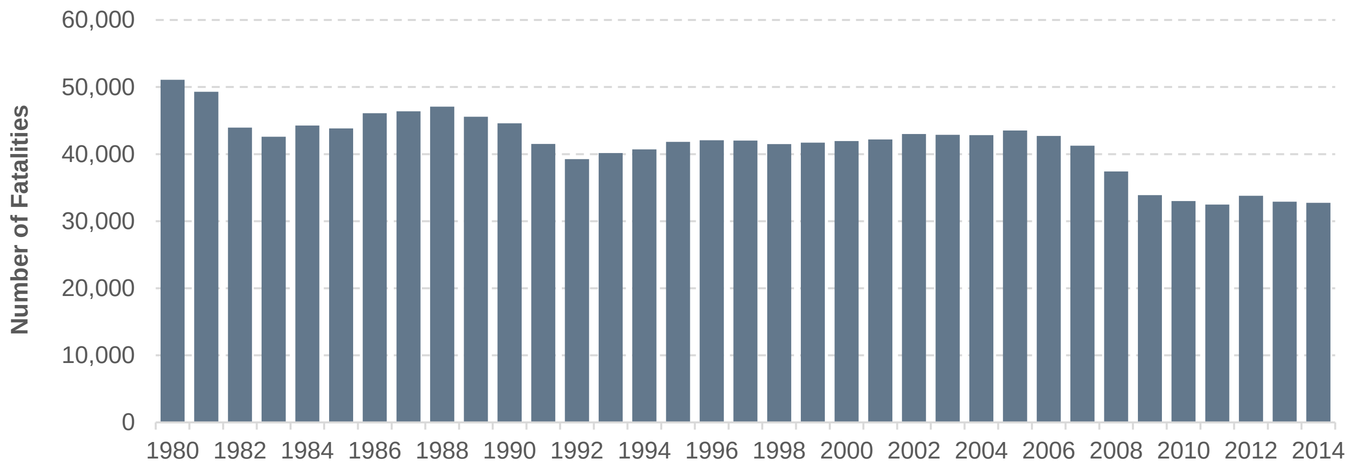
The overall decline in roadway fatalities over the past several years may be attributable to a variety of factors, including advances in vehicle crash avoidance and occupant protection, demographic and behavioral changes, and highway infrastructure improvements. FHWA-related developments over this time have included an increase in the HSIP spending rate and roadway safety infrastructure improvements such as SafetyEdge℠, Innovative Intersection and Interchange Geometrics, High Friction Surface Treatments, the use of data and analytical tools, Road Safety Audits, and the collection and sharing of notable practices across the country. The improvements in infrastructure include some of the innovative technologies being deployed as part of FHWA's Every Day Counts (EDC) initiative.

FHWA launched EDC in cooperation with the American Association of State Highway and Transportation Officials (AASHTO) to expedite the delivery of highway projects and to address the challenges presented by limited budgets. The EDC initiative is a State-based model to identify and rapidly deploy proven but underutilized innovations to shorten the project delivery process, enhance roadway safety, reduce congestion, and improve environmental sustainability. EDC-1 occurred in 2011–2012, followed by EDC-2 in 2013–2014 and EDC-3 in 2015–2016. EDC-4 is planned for 2017–2018.

Also shown in *Exhibit 5-2* are the national estimates for people nonfatally injured in motor vehicle crashes. A historic low of 2,061,000 injured was reached in 2011 with an injury rate of 70 per 100M VMT. In 2014, the injury count rose to 2,154,000, and the rate rose slightly to 71 per 100M VMT. Since 2004, the number of people injured in motor vehicle crashes has decreased by 18.8 percent, though there were annual increases in 2012 and 2014 of 4.7 percent and 2.1 percent, respectively.

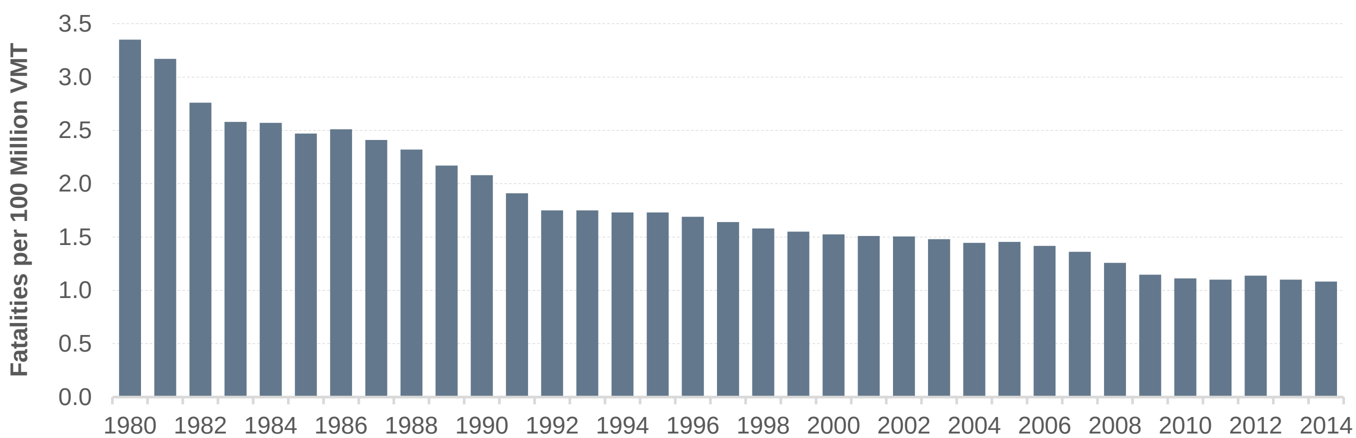
The trends since 1980 of the fatality counts and fatality rates, as discussed above and shown in *Exhibit 5-2*, are displayed graphically in *Exhibits 5-3* and *5-4*. *Exhibit 5-3* shows the number of motor vehicle fatalities from 1980 to 2014. *Exhibit 5-4* shows the motor vehicle fatality rates per 100M VMT from 1980 to 2014.

Exhibit 5-3: Fatalities, 1980–2014



Source: Fatality Analysis Reporting System/National Center for Statistics and Analysis, NHTSA.

Exhibit 5-4: Fatality Rates, 1980–2014



Source: Fatality Analysis Reporting System/National Center for Statistics and Analysis, NHTSA.

Fatalities by Roadway Functional System

The previous section presents overall counts and rates for both fatalities and injuries. This section focuses on how fatality counts and fatality rates differ between rural and urban roadway functional systems. *Exhibit 5-5* displays fatality counts and *Exhibit 5-6* displays fatality rates for 2004 through 2014.

Exhibit 5-5: Fatalities by Functional System, 2004–2014

Functional System	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Percent Change 2004 to 2014
Rural Areas (under 5,000 in population)												
Interstate	3,227	3,248	2,887	2,677	2,422	2,045	2,113	1,969	1,835	1,994	1,762	-45.4%
Other Principal Arterial	5,167	4,821	4,554	4,786	4,395	4,652	3,986	4,050	4,219	4,152	4,044	-21.7%
Minor Arterial	5,043	4,483	4,346	4,186	3,507	2,957	3,015	2,989	3,482	3,258	3,316	-34.2%
Major Collector	5,568	5,757	5,675	5,637	5,084	4,568	4,171	4,182	4,220	3,873	3,673	-34.0%
Minor Collector	1,787	1,635	1,650	1,487	1,421	1,342	1,143	989	958	874	829	-53.6%
Local	4,162	4,443	4,294	4,327	4,060	3,626	3,540	3,454	3,452	3,485	3,024	-27.3%
Unknown Rural	225	200	240	154	98	133	121	136	201	104	143	-36.4%
Total Rural	**25,179**	**24,587**	**23,646**	**23,254**	**20,987**	**19,323**	**18,089**	**17,769**	**18,367**	**17,740**	**16,791**	**-33.3%**
Urban Areas (5,000 or more in population)												
Interstate	2,602	2,734	2,663	2,685	2,300	2,049	2,124	2,159	2,150	2,101	2,332	-10.4%
Other Freeway and Expressway	1,673	1,735	1,690	1,497	1,538	1,321	1,232	1,277	1,150	1,061	1,125	-32.8%
Other Principal Arterial	4,847	5,364	5,447	5,021	4,504	4,005	4,294	4,142	4,538	4,605	4,951	2.1%
Minor Arterial	3,573	3,836	3,807	3,596	3,128	2,829	2,945	2,858	3,065	2,972	3,069	-14.1%
Collector	1,385	1,426	1,513	1,467	1,256	1,158	1,069	1,137	1,236	1,114	1,219	-12.0%
Local	3,290	3,458	3,622	3,612	3,461	3,098	2,978	2,969	3,195	3,249	3,127	-5.0%
Unknown Urban	211	74	49	30	31	41	17	33	37	17	94	-55.5%
Total Urban	**17,581**	**18,627**	**18,791**	**17,908**	**16,218**	**14,501**	**14,659**	**14,575**	**15,371**	**15,119**	**15,917**	**-9.5%**
Unknown Rural or Urban	76	296	271	97	218	59	251	135	44	35	36	-52.6%
Total Fatalities	**42,836**	**43,510**	**42,708**	**41,259**	**37,423**	**33,883**	**32,999**	**32,479**	**33,782**	**32,894**	**32,744**	**-23.6%**

Source: Fatality Analysis Reporting System/National Center for Statistics and Analysis, NHTSA.

In 2014, rural roads accounted for 30.4 percent of travel and 51.3 percent of roadway fatalities, whereas urban roads accounted for 69.6 percent of travel and 48.6 percent of roadway fatalities. From 2004 to 2014, the number of fatalities on rural roads decreased from 25,179 to 16,791, resulting in a 33.3-percent reduction. Over the same period, the number of fatalities on urban roads decreased from 17,581 to 15,917, a 9.5-percent reduction.

These declines varied greatly by roadway functional system as shown in *Exhibit 5-5*. For example, rural interstate fatalities decreased by 45.4 percent from 2004 to 2014, whereas those on rural principal arterials decreased by 21.7 percent. In urban areas, interstate fatalities decreased by 10.4 percent, whereas those on urban freeways and expressways decreased by 32.8 percent and those on urban principal arterials increased by 2.1 percent during the same period.

Similar to the overall fatality numbers, fatality rates trended downward during the same period. *Exhibit 5-6* shows the fatality rates per 100M VMT for rural and urban functional systems between 2004 and 2014. During that time, the fatality rate in rural areas declined by 22.6 percent, and, in urban areas, the fatality rate declined by 18.3 percent. Among urban roads, urban Interstate highways were the safest functional system, with a fatality rate of 0.45 in 2014, whereas urban principal arterials and urban local roads had the highest fatality rate of 1.06. Among rural roads, Interstates had the lowest fatality rate of 0.76, whereas local roads had the highest fatality rate of 2.40. Since 2004, rural minor collectors had the largest decline with a 43.8-percent reduction followed by urban freeways and expressways with a 38.2-percent reduction.

Locally Owned Road Safety

More than 30,000 local agencies own and operate 75 percent of the Nation's roadways. Agency practitioners have varying levels of transportation safety expertise and often perform several duties in addition to those related to transportation safety. FHWA developed Road Safety 365: A Workshop for Local Governments, to help local practitioners routinely identify safety issues along their roadways and provide ideas on how to address them.

Exhibit 5-6: Fatality Rates by Functional System, 2004–2014

Functional System	2004	2006	2008	2009	2010	2012	2014	Percent Change 2004 to 2014
Rural Areas (under 5,000 in population)								
Interstate	1.21	1.12	1.00	0.85	0.86	0.75	0.76	-37.1%
Other Principal Arterial	2.14	1.96	1.98	2.10	1.77	1.89	1.88	-11.9%
Minor Arterial	2.99	2.67	2.31	1.96	2.00	2.34	2.36	-21.1%
Major Collector	2.77	2.94	2.73	2.58	2.37	2.40	2.31	-16.6%
Minor Collector	2.97	2.84	2.58	2.49	2.14	1.81	1.67	-43.8%
Local	3.14	3.22	3.08	2.68	2.67	2.65	2.40	-23.4%
Total Rural	**2.35**	**2.28**	**2.12**	**1.97**	**1.84**	**1.88**	**1.82**	**-22.6%**
Urban Areas (5,000 or more in population)								
Interstate	0.57	0.56	0.48	0.43	0.44	0.44	0.45	-21.3%
Other Freeway and Expressway	0.80	0.78	0.69	0.60	0.56	0.51	0.49	-38.2%
Other Principal Arterial	1.08	1.17	0.97	0.88	0.94	0.99	1.06	-2.0%
Minor Arterial	0.99	1.01	0.83	0.75	0.79	0.83	0.79	-20.5%
Collector	0.85	0.87	0.72	0.65	0.59	0.69	0.59	-30.1%
Local	1.29	1.36	1.28	1.16	1.09	1.16	1.06	-17.8%
Total Urban	**0.93**	**0.95**	**0.82**	**0.73**	**0.74**	**0.77**	**0.76**	**-18.3%**
Total Fatality Rate	**1.45**	**1.42**	**1.26**	**1.15**	**1.11**	**1.14**	**1.08**	**-25.5%**

Source: Fatality Analysis Reporting System/National Center for Statistics and Analysis, NHTSA.

Despite the overall decreases in fatality rates on both urban and rural functional systems, with the exception of 2012, rural roads remained far more dangerous than urban roads, evidenced by a fatality rate that was 2.39 times higher (1.82 per 100M VMT on rural roads compared to 0.76 on urban roads). In 2014, the fatality rate on rural local roads was 2.27 times higher than that of urban local roads (2.40 per 100M VMT compared to 1.06). Several factors collectively comprise the safety challenges on rural roads, including the roadway, behavioral factors, and emergency services issues. Addressing the challenges associated with non-Interstate roads can be made more difficult by the diversity of ownership: States maintain Interstate roads, whereas other roads are maintained by either the State or a variety of local organizations, including cities and counties.

Vision: Toward Zero Deaths and Serious Injuries on the Nation's Roadways

The DOT strategic goal on safety is "Reduce transportation-related fatalities and serious injuries across the transportation system." To help accomplish this goal, FHWA oversees the HSIP, a core Federal-aid program, the goal of which is to achieve a significant reduction in traffic fatalities and serious injuries on all public roads, including non-State-owned public roads and roads on Tribal lands. The HSIP requires a data-driven, strategic approach to improving highway safety on all public roads that focuses on performance. By improving data and promoting analysis and evaluation, implementing programs based on current highway safety knowledge, and conducting research to expand that knowledge base, FHWA continues to move toward zero deaths on the Nation's roadways.

FHWA coordinates with States as they develop SHSPs. As a major component and requirement of the HSIP, an SHSP is a statewide coordinated safety plan, developed by a State department of transportation in cooperation with a broad range of safety stakeholders. An SHSP analyzes highway safety problems, identifies a State's key safety needs, and guides decisions toward strategies and investments with the most potential to save lives and prevent injuries. The SHSP enables highway safety programs and partners in the State to work together to align goals, leverage resources, and collectively address the State's safety challenges. FHWA requires SHSPs to be updated every five years to ensure States use current data for problem identification and evidence-based strategies that have the most potential to save lives and prevent injuries.

To support their SHSPs, States must have a safety data system to identify problems and analyze countermeasures on all public roads; adopt strategic and performance-based goals; advance data collection, data analysis, and data integration capabilities; determine priorities for correcting the identified safety problems; and establish evaluation procedures.

Road to Zero

FHWA, NHTSA, and FMCSA are working with the National Safety Council (NSC) on a national road safety leadership initiative titled Road to Zero (RTZ). This initiative involves a national coalition of organizations and individuals with a commitment to eliminating road deaths within the next 30 years. RTZ is focusing on both short-term activities, including funding for innovative safety activities, and on a long-term vision for zero traffic fatalities. Activities are guided by a steering committee made up of 11 organizations representing the vehicle, the driver, and the roadway. Operational leadership is provided by NSC and FHWA, while NHTSA and FMCSA provide an advisory and supportive role.

Improved Data

FHWA promotes improved data, analysis methods, and evaluation capabilities, that collectively make a major contribution toward advancements in highway safety. Better data and enhanced ways to analyze the data produce valuable information for local, State, national, and private transportation safety stakeholders. These improvements also help members of the highway safety community reduce traffic fatalities, injuries, and property-damage-only crashes.

The FHWA Roadway Safety Data Program works to develop, evaluate, and deploy life-saving countermeasures; advances the use of scientific methods and data-driven decisions; and promotes an integrated, multidisciplinary approach to safety. The program helps improve safety data and expand capabilities for analysis and evaluation. The effectiveness of safety programs is directly linked to the availability and analysis of reliable crash and roadway data.

During 2012, FHWA completed a roadway safety data capabilities assessment in each State. The assessment identified opportunities for improvement that the Roadway Safety Data Program has since addressed through development of guidance and informational resources and the delivery of technical assistance, webinars, and peer exchanges. FHWA is conducting another roadway safety data capabilities assessment in each State during 2017–2018. This assessment will be useful to States as they implement and achieve performance goals.

Improved Safety Analysis Tools

FHWA provides and supports a wide range of data and safety analysis tools for State and local highway agency practitioners. These tools help practitioners understand safety problems on their roadways, link crashes to their roadway environments, and select and apply appropriate countermeasures. The tools' capabilities range from simple to complex. Some provide general information; others enable complex analysis of crashes under specific conditions or with specific roadway features.

One valuable safety analysis tool is the Highway Safety Manual (HSM), published by AASHTO and developed through cooperative research initiated by FHWA. The document's primary focus is the introduction and development of analytical tools for predicting the impact of transportation project and program decisions on road safety. The HSM provides improved information and tools that facilitate roadway planning, design, operations, and maintenance decisions based on precise consideration of their safety consequences.

To support use of HSM methods, FHWA has delivered training, developed informational resources, and offered technical assistance for States and local highway agency practitioners. In addition, cooperative research initiated by FHWA has developed safety analysis tools, including the Interactive Highway Safety Design Model, the Systemic Safety Project Selection Tool, and the Crash Modification Factors Clearinghouse. These tools greatly advance the abilities of State and local highway agencies to incorporate explicit, quantitative consideration of safety into their planning and project development decision-making.

Legislative Mandates

The Moving Ahead for Progress in the 21st Century Act (MAP-21) reauthorizing legislation identified the need for improved and more robust safety data for better safety analysis to support the development of States' HSIPs and SHSPs. MAP-21 built on and refined many of the highway, transit, bicycle, and pedestrian programs and policies FHWA administers.

MAP-21 supports DOT's safety initiative: it continued the successful HSIP, doubling funding for infrastructure safety and strengthening the linkage among safety programs at FHWA, NHTSA, and FMCSA. It also continued to build on other aggressive safety efforts, including the Department's fight against distracted driving and its push to improve transit and motor carrier safety.

The Fixing America's Surface Transportation (FAST) Act (Pub. L. No. 114-94) was enacted into law on December 4, 2015—the first Federal law in over a decade to provide long-term funding certainty for surface transportation infrastructure planning and investment. The FAST Act maintains FHWA's focus on safety, keeps intact the established structure of FHWA's various highway-related programs, continues efforts to streamline project delivery and, for the first time, provides a dedicated source of Federal funds for freight projects. With the enactment of the FAST Act, States and local governments are now moving forward with critical transportation projects with the confidence that they will have a Federal partner over the long term.

In 2016, FHWA published the HSIP and Safety Performance Management Measures (Safety PM) Final Rules in the *Federal Register*. The HSIP Final Rule updates the existing HSIP requirements under Title 23 of the Code of Federal Regulations (CFR) Part 924 to be consistent with the MAP-21 Act and the FAST Act and to clarify existing program requirements. Specifically, the HSIP Final Rule contains three major policy changes related to: (1)

HSIP report content and schedule; (2) the SHSP update cycle; and (3) the subset of the Model Inventory of Roadway Elements (MIRE), also known as the MIRE fundamental data elements. Transportation Performance Management rulemakings are discussed more broadly in the Introduction to Part I.

The Safety PM Final Rule adds Part 490 to Title 23 of the CFR to implement the performance management requirements of 23 U.S.C. (United States Code) §150, including the specific safety performance measure requirements for the purpose of carrying out the HSIP to assess serious injuries and fatalities on all public roads. The Safety PM Final Rule establishes five performance measures as the 5-year rolling averages for: (1) Number of Fatalities, (2) Rate of Fatalities per 100 million VMT, (3) Number of Serious Injuries, (4) Rate of Serious Injuries per 100 million VMT, and (5) Number of Nonmotorized Fatalities and Nonmotorized Serious Injuries. The Safety PM Final Rule also establishes the process for State departments of transportation and metropolitan planning organizations (MPOs) to establish and report their safety targets and the process that FHWA will use to assess whether State departments of transportation have met or made significant progress toward meeting their safety targets. In addition, the Safety PM Final Rule also establishes a common national definition for serious injuries.

Together, these regulations will improve data, foster transparency and accountability, and allow safety progress to be tracked at the national level. They will inform State department of transportation and MPO planning, programming, and decision-making for the greatest possible reduction in fatalities and serious injuries.

Focused Approach to Safety

When a crash occurs, it is generally the result of many contributing factors. The roadway, vehicle, and road users are all factors that have an impact on the safety of the Nation's highway system. FHWA collaborates with other agencies to understand more clearly the relationship among all contributing factors, and to address crosscutting ones, but focuses on infrastructure design and operation to address roadway factors.

In 2014, FHWA examined crash data to identify the most common crash types relating to roadway characteristics. The FHWA established three focus areas to address these factors: roadway departures, intersections, and pedestrian/bicyclist-involved crashes. These three areas were selected because they account for nearly 90 percent of traffic fatalities and represent an opportunity to significantly reduce the number of fatalities and serious injuries. FHWA manages the Focused Approach to Safety program to address the most critical safety challenges surrounding these crashes. Through this program, FHWA focuses its technical assistance and resources on States and cities with high fatality counts and fatality rates in one or more of these three categories.

In 2014, roadway departure, intersection, and pedestrian/bicyclist-involved fatalities accounted for 54.4 percent, 26.5 percent, and 17.8 percent, respectively, of the 32,744 fatalities. Note that these three categories overlap. For example, when a roadway departure crash includes a pedestrian fatality, that crash would be accounted for in both the roadway departure and the pedestrian-related crash categories below. *Exhibit 5-7* shows how the number of fatalities for these crash types has changed between 2004 and 2014. During this period, roadway departure fatalities decreased by 26.7 percent, intersection-related fatalities decreased by 21.5 percent, and pedestrian/bicyclist-involved fatalities increased by 5.0 percent.

Because a combination of factors can influence the fatalities shown in *Exhibit 5-7*, FHWA has developed targeted programs that include collaborative and comprehensive efforts to address all three areas. The Focused Approach to Safety works to address the most critical safety challenges by devoting additional effort to high-priority States and targeting technical assistance and resources. More information is available at (http://safety.fhwa.dot.gov/fas/).

Exhibit 5-7: Fatalities by Crash Type, 2004–2014

Crash Type	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Percent Change 2004 to 2014
Roadway Departures[1,2]	23,702	24,311	23,996	23,598	21,239	19,378	18,850	18,273	18,963	18,311	17,818	-24.8%
Intersection-Related[1,2]	10,471	10,606	10,213	9,885	8,956	8,316	8,636	8,317	8,851	8,677	8,692	-17.0%
Pedestrian/Bicycle-Related[1,2]	5,509	5,803	5,722	5,516	5,273	4,863	5,075	5,284	5,741	5,692	5,814	5.5%

[1] Some fatalities may overlap; for example, some intersection-related fatalities may involve pedestrians.

[2] Crash types use the 2014 Focus Approach to Safety definitions.

Source: Fatality Analysis Reporting System/National Center for Statistics and Analysis, NHTSA.

Roadway Departures

In 2014, the number of roadway departure fatalities was 17,818, which accounted for 54.4 percent of all traffic fatalities. From 2004 to 2014, roadway departure fatalities decreased by 24.8 percent. A roadway departure crash is defined as a nonintersection crash that occurs after a vehicle crosses an edge line or a center line, or otherwise leaves the traveled way. In some cases, a vehicle crosses the center line and strikes another vehicle, hitting it head-on or sideswiping it. In other cases, the vehicle leaves the roadway and strikes one or more constructed or natural objects, such as utility poles, embankments, guardrails, trees, or parked vehicles.

Roadway Departure Focus States and Countermeasures

Roadway Departure Focus States are eligible for additional resources and assistance. These States are selected based on an assessment of roadway departure fatalities over a 3-year period compared with expected roadway departure fatalities. The current list of Roadway Departure States includes Alabama, Arizona, Florida, Hawaii, Kentucky, Louisiana, Mississippi, South Carolina, Tennessee, Texas, and West Virginia. FHWA offers technical assistance to these States in the form of crash data analysis and implementation plan development.

Many States have developed Roadway Departure Implementation Plans, which are designed to address State-specific safety issues related to roadway departures on both State and local roadways—to the extent that relevant crash data can be obtained and are appropriate based on consultation with State and local agencies and the FHWA Division Office. The plans identify cost-effective countermeasures, deployment levels, and funding needs to reduce the number and severity of roadway departure crashes in the State by a targeted amount consistent with SHSP goals. Each plan quantifies the costs and benefits of a roadway departure-focused initiative and provides an approach for implementation. FHWA also provides outreach to these States through webinars, technical support, and training courses.

Three proven safety countermeasures for reducing roadway departure crashes are:

- Longitudinal rumble strips and stripes on two-lane rural roads: Milled or raised elements on the pavement intended to alert inattentive drivers through vibration and sound that their vehicles have left the travel lane;
- Enhanced delineation and friction for horizontal curves: Signs and pavement deployed to warn the driver in advance of the curve, with pavement friction to reduce skidding due to excessive approach speed into the curve to keep the vehicle in their lane; and
- SafetyEdge[SM]: Technology that shapes the edge of a paved roadway in a way that eliminates tire scrubbing, a phenomenon that contributes to losing control of a vehicle.

Intersections

Estimates indicate that the United States has more than 3 million intersections, most of which are nonsignalized (controlled by stop or yield signs), and a small proportion of which are signalized (controlled by traffic signals). Intersections are planned points of conflict in any roadway system. People—some in motor vehicles, others walking or biking—cross paths as they travel through, or turn from, one route to another. Areas where different paths separate, cross, or join are known as conflict points, and these are always present in intersections.

In 2014, 26.5 percent of fatalities were related to intersections, with 36.7 percent occurring in rural areas and 63.3 percent occurring in urban areas, as shown in *Exhibit 5-8*. From 2004 to 2014, intersection-related fatalities decreased by 17.0 percent. The geometric design of an intersection and corresponding application of traffic control devices can substantially reduce the likelihood of crashes, resulting in fewer crashes, injuries, and fatalities. Furthermore, when the speed of motor vehicles through intersections can be reduced, the severity of crashes that do occur will also be lessened.

Exhibit 5-8: Intersection-Related Fatalities by Functional System, 2014

	Fatalities	
	Count	**Percent of Total**
Rural Areas (under 5,000 in population)		
Principal Arterials	1,049	12.2%
Minor Arterials	714	8.3%
Collectors (Major and Minor)	852	9.9%
Locals	550	6.4%
Total Rural Areas	**3,165**	**36.7%**
Urban Areas (5,000 or more in population)		
Principal Arterials	2,476	28.7%
Minor Arterials	1,349	15.7%
Collectors (Major and Minor)	423	4.9%
Locals	1,204	14.0%
Total Urban Areas	5,452	63.3%
Total Fatalities[1]	**8,617**	**100.0%**

[1] Total excludes 75 intersection-related fatalities not identified by functional class.

Source: Fatality Analysis Reporting System/National Center for Statistics and Analysis, NHTSA.

Intersection Focus States and Countermeasures

Intersection Focus States are eligible for additional resources and assistance based on an assessment of intersection fatalities over a 3-year period compared with expected fatalities. The current list of Intersection Focus States includes Arizona, Florida, Louisiana, Nevada, New Jersey, New York, South Carolina, Tennessee, and Texas.

As part of the Focused Approach to Safety, FHWA works with States to advance their SHSP strategies for intersection safety. These efforts include pursuing systemic intersection safety improvements, advancing innovative intersection designs (such as roundabouts, J-turns, and diverging diamond interchanges), and encouraging the development of intersection control evaluation policies and procedures. FHWA also assists these States on timely intersection safety matters through webinars, technical support, and training courses.

Five proven countermeasures associated specifically with intersection safety are:

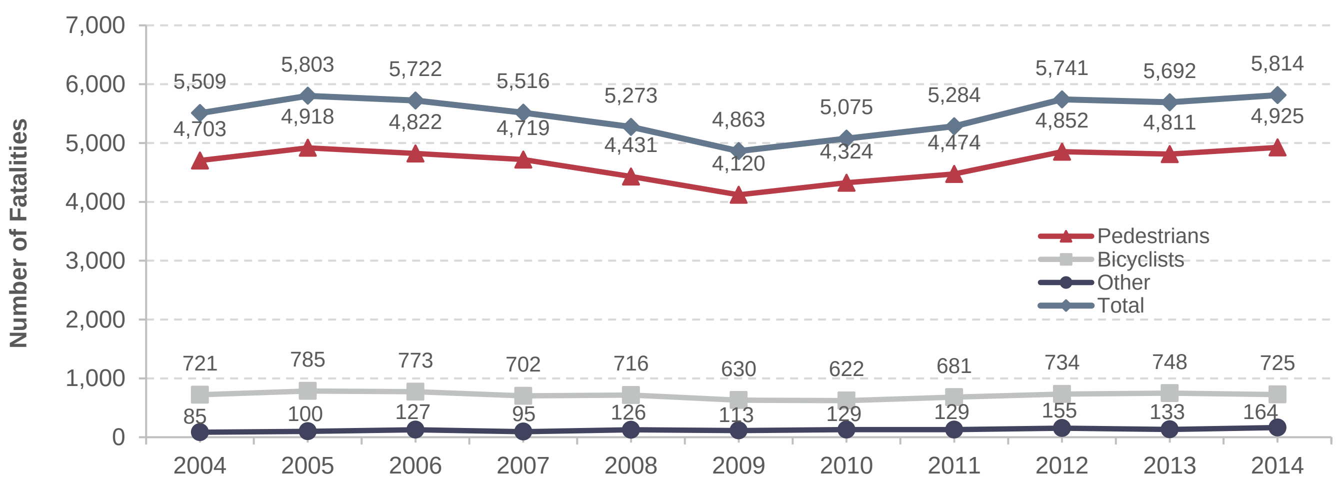
- Roundabouts: A modern circular intersection defined by a set of specific operational principles; designed to create a low-speed environment, high operational performance, and a reduction of conflict points;
- Corridor access management: A set of techniques useful for managing access to highways, major arterials, and other roadways, and that result in reduced crashes, fewer vehicle conflicts, and improved movement of traffic; and
- Backplates with retroreflective border: A device added to traffic signal indications to improve the conspicuity and visibility of the illuminated face of the signal.
- Pedestrian hybrid beacons: Pedestrian-activated warning device located on the roadside or on mast arms over midblock pedestrian crossings; and
- Road diets: A roadway reconfiguration that involves converting an undivided four-lane roadway into three lanes comprising two through-lanes and a center two-way left turn lane.

Pedestrians, Bicyclists, and Other Nonmotorists

The term nonmotorist is defined to be those transportation system users who are not in, or on, traditional motor vehicles on public roadways. This includes persons traveling by foot, children in strollers, skateboarders (including motorized), roller skaters, persons on scooters, persons in wagons, persons in wheelchairs (both nonmotorized and motorized), persons riding bicycles or other pedalcycles (including those with a low-powered electric motor weighing under 100 pounds, with a top motor-powered speed not in excess of 20 miles per hour), persons in motorized toy cars, and persons on two-wheeled, self-balancing types of devices. In 2014, 17.8 percent of the fatalities were nonmotorists. *Exhibit 5-9* shows that in 2014, 4,925 pedestrians, 725 bicyclists, and 164 other nonmotorists were killed, totaling 5,814 nonmotorists fatalities.

Since 2004, nonmotorist fatalities have risen by 5.5 percent. From 2006 to 2009, fatalities showed a steady decline of 15.0 percent, but beginning in 2009 that trend began to shift and resulted in a 19.6-percent increase, with a slight decrease of 0.9 percent occurring in 2013. Pedestrian fatalities rose from 4,120 in 2009 to 4,925 in 2014. Bicyclist fatalities rose from 630 in 2009 to 725 in 2014.

Exhibit 5-9: Pedestrian, Bicyclist, and Other Nonmotorist Traffic Fatalities, 2004–2014



Source: Fatality Analysis Reporting System/National Center for Statistics and Analysis, NHTSA.

In 2016, the Safety PM Final Rule established a new performance measure for the number of nonmotorized fatalities and the number of nonmotorized serious injuries. This combined measure of nonmotorized fatalities and nonmotorized serious injuries will lead to the availability of more data on nonmotorized serious injuries in the future. Additionally, the Safety PM Final Rule established a single, national definition for States to report serious injuries per the Model Minimum Uniform Crash Criteria (MMUCC) 4th Edition attribute for “Suspected Serious Injury (A)” found in the “Injury Status” element. This action will serve to standardize serious injury data to ensure a consistent, coordinated, and comparable serious injury data system that will help stakeholders at the State and national levels address highway safety challenges.

Pedestrian and Bicyclist Safety Focus States and Cities and Countermeasures

In July 2014, FHWA expanded its pedestrian focus area to include bicyclist and other nonmotorist fatalities. This change was incorporated into the Focused Approach to Safety in 2015.

FHWA designates focus States and focus cities for the pedestrian and bicycle focus area based on the number of pedestrian and bicyclist fatalities or the pedestrian and bicyclist fatality rate per population over a 3-year period.

The Focused Approach to Safety has helped focus States and cities raise awareness of pedestrian and bicyclist safety problems and generate momentum for addressing pedestrian and bicyclist issues. Focused Approach has provided courses, conference calls, web conferences, data analysis, and technical assistance for the development of State and local pedestrian and bicyclist safety action plans.

Focused Approach offers free technical support and training courses to focus States and cities, as well as free bimonthly webinars on a comprehensive, systemic approach to preventing pedestrian and bicyclist crashes. Training is also available at a cost to non-focus States and cities through the Pedestrian and Bicycle Information Center, made possible by the National Highway Institute.

FHWA promotes three proven countermeasures associated specifically with pedestrian safety:

- Median and pedestrian crossing islands in urban and suburban areas: A refuge area in the middle of the roadway, enhancing pedestrian crossing visibility and reducing the speed of vehicles approaching the crossing;
- Pedestrian hybrid beacons: Pedestrian-activated warning device located on the roadside or on mast arms over midblock pedestrian crossings; and
- Road diets: A roadway reconfiguration that involves converting an undivided four-lane roadway into three lanes comprising two through-lanes and a center two-way left turn lane.

Transit Safety

This section summarizes national trends in safety and security incidents such as injuries, fatalities, and related performance ratios reported in the National Transit Database (NTD).

NTD compiles safety data for all transit modes, except for commuter rail systems. Those systems are regulated by the Federal Railroad Administration (FRA), which also collects data on their safety performance. This section presents statistics and counts of basic aggregate data such as injuries and fatalities for those systems. For 2014, data were received from 62 rail transit systems, 639 urban fixed-route bus providers, and 372 rural agencies. Reported events occurred on transit property or vehicles, involved transit vehicles, or affected persons using public transportation systems.

Agencies operating 30 or fewer vehicles in peak service are exempted from reporting detailed safety data by mode and victim type. However, these agencies account for a very small share of the national data.

Incidents, Fatalities, and Injuries

A transit agency records an incident for a variety of events occurring on transit property or inside vehicles, involving transit vehicles, or affecting persons using the transit system. Included among these events are any that result in significant property damage, one or more reported injuries, one or more reported fatalities, or some combination thereof. From 2002 to 2007, the definition of significant property damage was total property damage exceeding $7,500 (in current-year dollars, not indexed to inflation); this threshold increased to $25,000 in 2008.

Key Takeaways

- The total number of transit fatalities in 2014 (excluding commuter rail) was 236 people, of which 23 were passengers.
- Transit rail fatalities increased by 33% from 2004 to 2014.
- Most rail fatalities in transit are due to collisions. In 2014, 147 people, or 62%, died as a result of collisions, mostly with other vehicles and people.
- Transit rail fatalities occur mostly at transit stations. In 2014, 82 people died at transit stations, or 35% of all transit rail fatalities. These deaths are due primarily to suicides.
- Most bus fatalities occur on roadways, mainly at intersections. In 2014, 74 people died on roadways, or 31% of all fatalities.
- Altogether, rail modes accounted for 57% of non-commuter rail fatalities, and bus accounted for 43%. However, rail accounted for 31% of injuries, whereas bus accounted for 68%.
- There were 23,890 non-commuter rail injuries in 2014. These injuries required medical assistance away from the scenes of the accidents.
- In 2014, 85 people died in commuter rail accidents, a 21% increase from 2004 (70 people). Thus, the total number of fatalities in transit, including commuter rail, increased by 5%, from 306 in 2004 to 321 in 2014.

What sort of events result in a recorded transit incident?

A transit agency records an incident for any event occurring on transit property, on board or involving transit vehicles, or to persons using the transit system, that results in one of the following:

- One or more confirmed fatalities within 30 days of the incident;
- One or more injuries requiring immediate transportation away from the scene for medical attention;
- Total property damage to transit property or private property exceeding $25,000;
- Evacuation for life safety reasons;
- Mainline derailment (that is, occurring on a revenue service line, regardless of whether the vehicle was in service or out of service); or
- Fire.

Additionally, a transit agency records an incident whenever certain security situations occur on transit property, such as:

- Robbery, burglary, or theft;
- Rape;
- Arrest or citation, such as for trespassing, vandalism, fare evasion, or assault;
- Cybersecurity incident;
- Hijacking; or
- Nonviolent civil disturbance that disrupts transit service.

Injury and fatality data in NTD are segmented by the types of persons involved in incidents. Passengers are defined as persons traveling, boarding, or alighting a transit vehicle. Patrons are individuals who are in a rail station or at a bus stop but are not necessarily boarding a transit vehicle. Employees are individuals who work for the transit agency, including both staff and contractors. Public includes pedestrians, occupants of other vehicles, and other persons.

Any event for which an injury or fatality is reported is considered an incident. An injury is reported when a person has been transported immediately from the scene for medical care. A transit-related fatality is reported for any death occurring within 30 days of a transit incident that is confirmed to be a result of that incident. These statistics, however, do not include fatalities resulting from medical emergencies on transit vehicles.

An incident is also recorded when property damage exceeds $25,000, regardless of whether the incident resulted in injuries or fatalities.

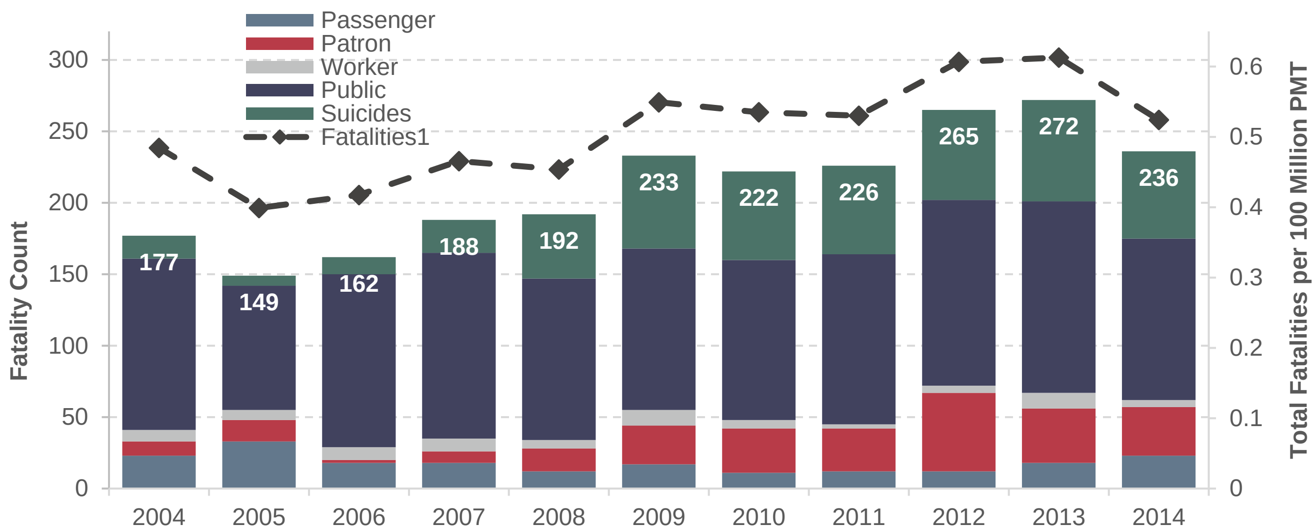
What types of injuries and fatalities are reported?

Person types are defined as:

- Passengers: Individuals on board a transit vehicle or boarding or alighting a transit vehicle.
- Patrons: Individuals waiting for or leaving transit at stations; in mezzanines; on stairs, escalators, or elevators; in parking lots; or on other transit-controlled property.
- Public: All others who come into contact with the transit system, including pedestrians, automobile drivers, and trespassers.
- Workers: Transit agency employees or contractors engaged in operations or maintenance but not construction of new transit infrastructure.
- Suicides: Individuals who come into contact with the transit system intending to harm themselves.

Exhibit 5-10 shows data on fatalities, both in total fatalities and fatalities per 100 million passenger miles traveled (PMT) for FTA-oversight systems. From 2004 to 2014, the number of fatalities per 100 million PMT remained relatively static, following a significant increase in fatalities between 2011 and 2012, and a peak of 134 fatalities in 2013.

Exhibit 5-10: Annual Transit Fatalities, Including Suicides, 2004–2014[1]



[1] Per 100 million PMT Including suicides

Note: Fatality totals include both directly operated (DO) and purchased transportation (PT) service types.

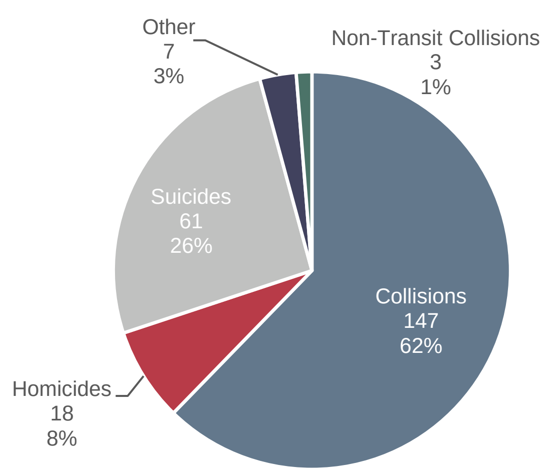
Source: National Transit Database - Transit Safety and Security Statistics and Analysis Reporting.

The interaction between public transit and pedestrians, cyclists, and motorists at rail grade crossings, pedestrian crosswalks, and intersections largely influences overall transit safety performance. Most fatalities and injuries result from interaction with the public on busy city streets, trespassing on transit rights-of-way and facilities, and suicide. Pedestrian fatalities accounted for approximately 24 percent of all transit fatalities in 2014.

Exhibit 5-11 depicts fatalities by event type in 2014. Fatalities in transit are due mostly to collisions and suicides. These two categories accounted for 88 percent of all fatalities in 2014. Collisions are mostly with vehicles at grade crossings. The number of deaths due to homicide accounted for only 8 percent of fatalities, mostly involving nonusers of transit.

Exhibit 5-12 shows fatalities by location type for bus and rail modes. Over 70 percent of bus fatalities occur at roadways, and most victims are the public. In 2013, FTA, in partnership with Operation Lifesaver, made grant funds available to transit and local government agencies to develop safety education and public awareness

Exhibit 5-11: 2014 Transit Fatality Event Types[1]



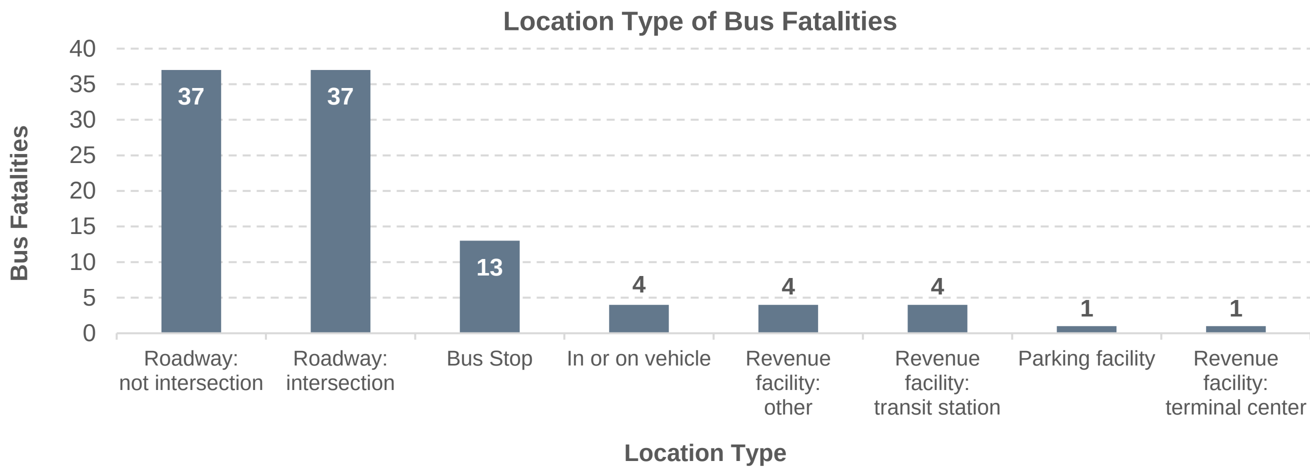
[1] Exhibit includes data for all transit modes, excluding commuter rail.

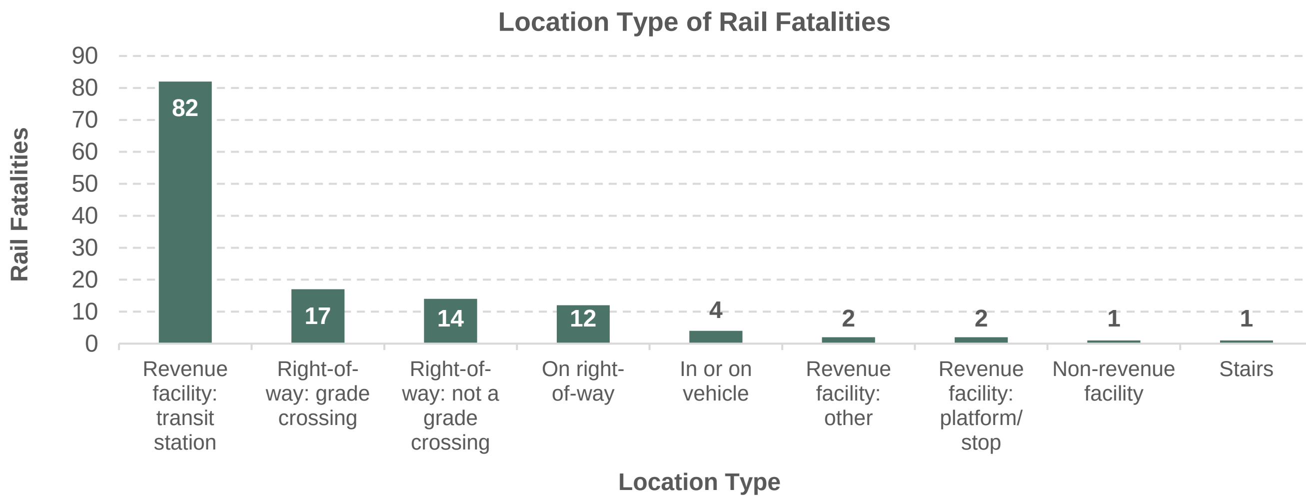
Note: Other Event Type includes fatalities due to smoke inhalation, slips & falls, electric shock events, and trespassers with an unknown cause of death.

Source: National Transit Database.

initiatives for rail transit to ensure that people are safe near trains, tracks, and at crossings. Such awareness is increasingly important for drivers and pedestrians as rail transit expands into new communities across the country. To receive a grant, projects must provide a 25 percent match and focus on safety education or public awareness initiatives in communities with rail transit systems (commuter rail, light rail, and streetcar) using Operation Lifesaver-approved materials.[i]

Exhibit 5-12: Location Type of Rail and Bus Fatalities, 2014

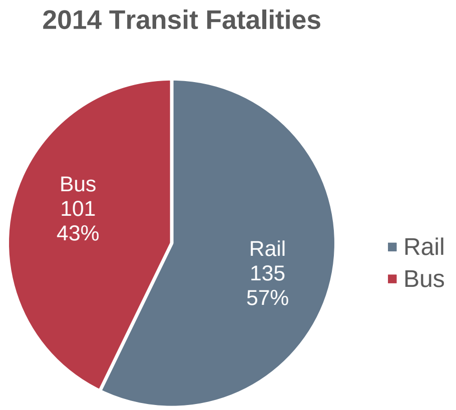


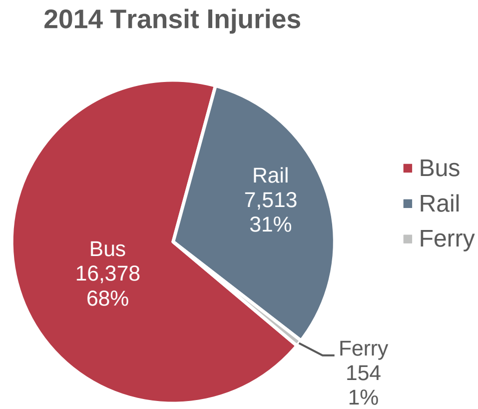


Source: National Transit Database - Transit Safety and Security Statistics and Analysis Reporting.

Exhibit 5-13 depicts the split of fatalities and injuries for rail modes and fixed-route bus. Rail fatalities account for 60 percent of fatalities but include virtually all suicides, which account for a significant share of all transit fatalities as shown in *Exhibit 5-11*. Rail service includes modes with distinct operating technologies and demand profiles. For example, the most common type of accidents involve people walking along sidewalks by light rail and streetcar systems. Transit passengers account for a small share of fatalities and injuries. On the other hand, other vehicle occupants (in collision accidents) and collisions with pedestrian in crossings account for 50 percent of bus fatalities.

Exhibit 5-13: Transit Fatalities and Injuries by Mode, 2014

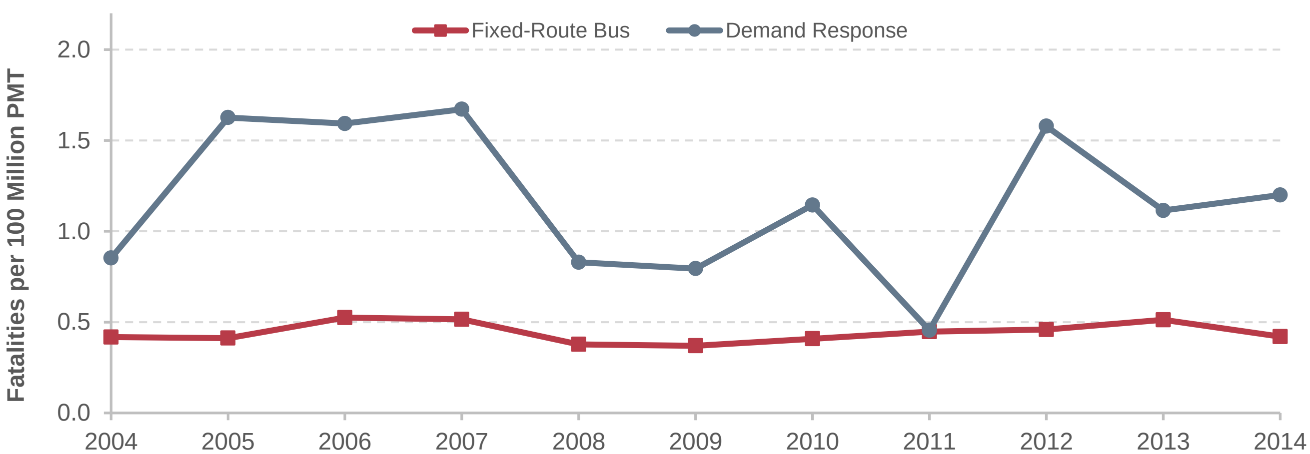




Source: National Transit Database - Transit Safety and Security Statistics and Analysis Reporting.

Exhibit 5-14 shows fatalities per 100 million PMT for fixed-route bus and demand-response (including suicides). The fatality rate for demand-response transit is more volatile than for fixed-route bus. This observation is not unexpected, as fewer people use demand-response transit and even one or two more fatalities in a year can make the rate jump significantly. Fatality rates have not changed significantly for fixed-route bus. Note that the absolute number of fatalities is not comparable across modes because of the wide range of PMT on each mode.

Exhibit 5-14: Annual Transit Fatality Rates by Highway Mode, 2004–2014

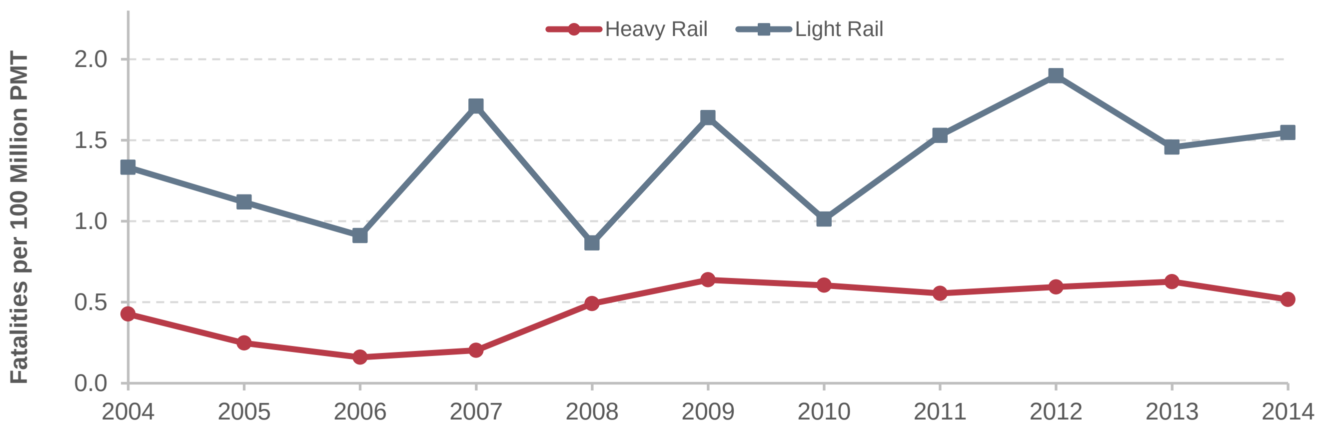


Note: Fatality totals include both DO and PT service types.

Source: National Transit Database.

Exhibit 5-15 shows fatalities per 100 million PMT for heavy rail and light rail (including suicides). Heavy-rail fatality rates remained relatively stable from 2004 through 2014. Suicides represent a large share of fatalities for heavy rail—approximately 69 percent in 2014. Light rail experienced more incidents than did heavy rail, as many systems are streetcars operating in nondedicated guideways.

Exhibit 5-15: Annual Transit Fatality Rates by Rail Mode, 2004–2014



Note: Fatality totals include both DO and PT service types.

Source: National Transit Database.

The analysis that follows shows data for all major modes reported in NTD with the exception of commuter rail. Safety data for commuter rail are included in FRA's Rail Accident/Incident Reporting System (RAIRS). The RAIRS database records fatalities that occurred because of a commuter rail collision, derailment, or fire. The database also includes a category called "not otherwise classified," which includes fatalities that occurred because of a slip, trip, or fall. Before 2011, RAIRS did not include a separate category for suicides, which *are* reported in NTD for all modes. Therefore, for comparative purposes, suicides are excluded from this analysis.

Exhibit 5-16 shows incidents and injuries per 100 million PMT reported in NTD for the two main highway modes in transit, fixed-route bus and demand-response, and two main rail modes, heavy rail and light rail. The data in *Exhibit 5-16* suggest that the incidents in highway modes (fixed-route bus and demand-response) decreased between 2004 and 2014. Injuries for fixed-route bus remained relatively flat, especially compared with injuries for demand-response transit, given per 100 million PMT. Data for rail modes show a decreasing trend in incidents per 100 million PMT; decreasing from 2010 through 2014 for heavy rail and 2005 through 2014 for light rail. As for injuries per 100 million PMT, heavy-rail-involved injuries have decreased since 2010, whereas light-rail-involved injuries have decreased since 2005.

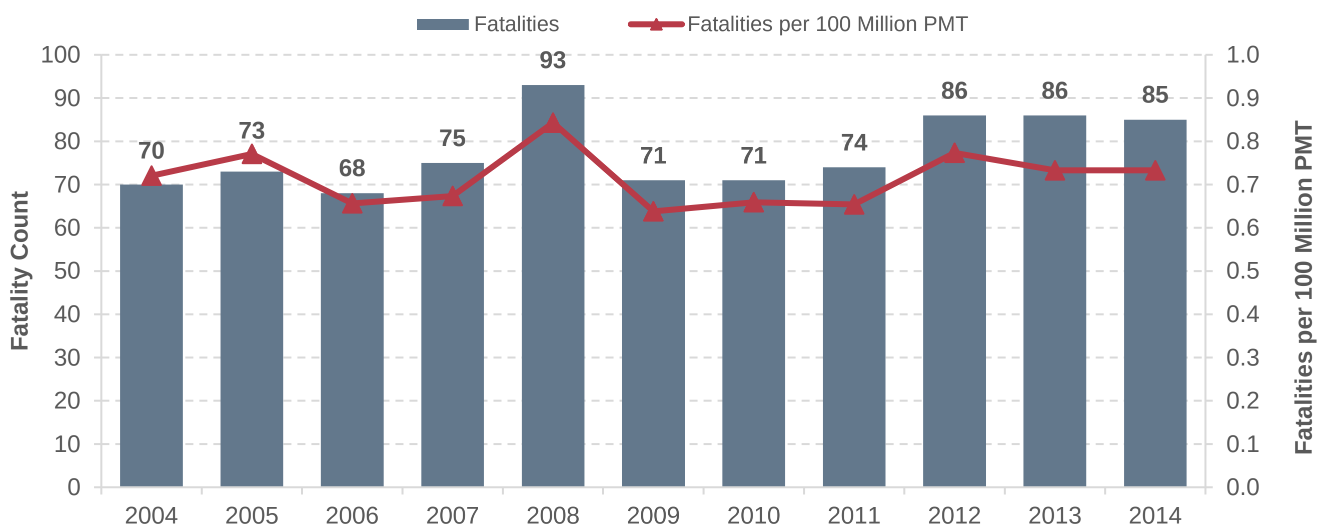
Exhibit 5-16: Transit Incidents and Injuries by Mode, 2004–2014

Analysis Parameter	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Incidents Per 100 Million PMT											
Fixed-Route Bus	66.2	65.6	69.6	66.9	54.1	58.3	55.3	46.3	45.2	47.6	49.1
Heavy Rail	43.8	39.4	42.9	43.5	53.3	53.2	54.6	49.4	48.6	49.9	41.2
Light Rail	59.5	66.1	60.7	61.3	48.6	45.8	40.1	39.7	36.9	40.7	41.4
Demand Response	292.3	326.8	375.1	404.1	204.3	194.8	165.2	151.8	142.5	154.0	165.3
Injuries Per 100 Million PMT											
Fixed-Route Bus	70.5	68.1	62.6	68.9	66.9	72.3	72.0	62.9	62.7	65.3	66.9
Heavy Rail	43.8	39.4	42.9	43.5	53.3	53.2	54.6	49.4	48.6	49.9	41.2
Light Rail	59.5	66.1	60.7	61.3	48.6	45.8	40.1	39.7	36.9	40.7	41.4
Demand Response	292.3	326.8	375.1	404.1	204.3	194.8	165.2	151.8	142.5	154.0	165.3

Source: National Transit Database.

Exhibit 5-17 shows the number of fatalities, and the fatality rate, for commuter rail. These data were obtained from FRA's RAIRS (suicides not included). In 2014, 175 fatalities (excluding suicides) were recorded in NTD for all modes except commuter rail. The fatality rate per 100 million transit PMT (excluding suicides and commuter rail) was 0.39. For commuter rail, however, the total number of fatalities in 2014 was 85, with a fatality rate of 0.73—significantly higher than the national aggregate rate for transit. The national rate with suicides included is 0.53, which is less than the rate for commuter rail.

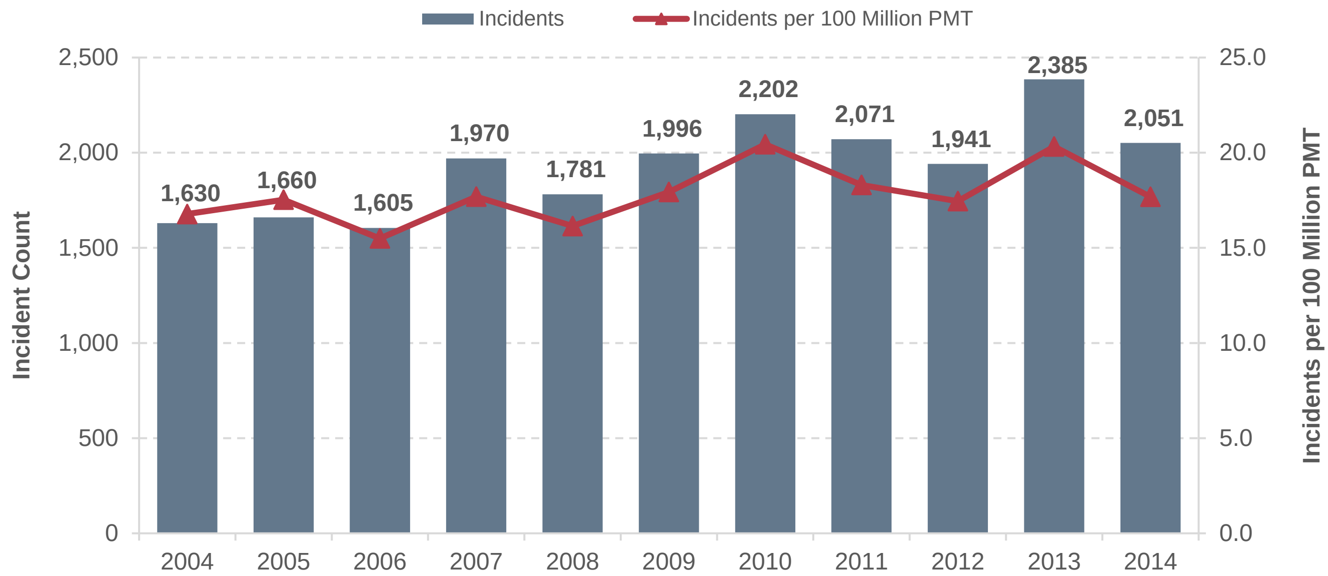
Exhibit 5-17: Commuter Rail Fatalities, 2004–2014



Source: Federal Railroad Administration Rail Accident/Incident Reporting System.

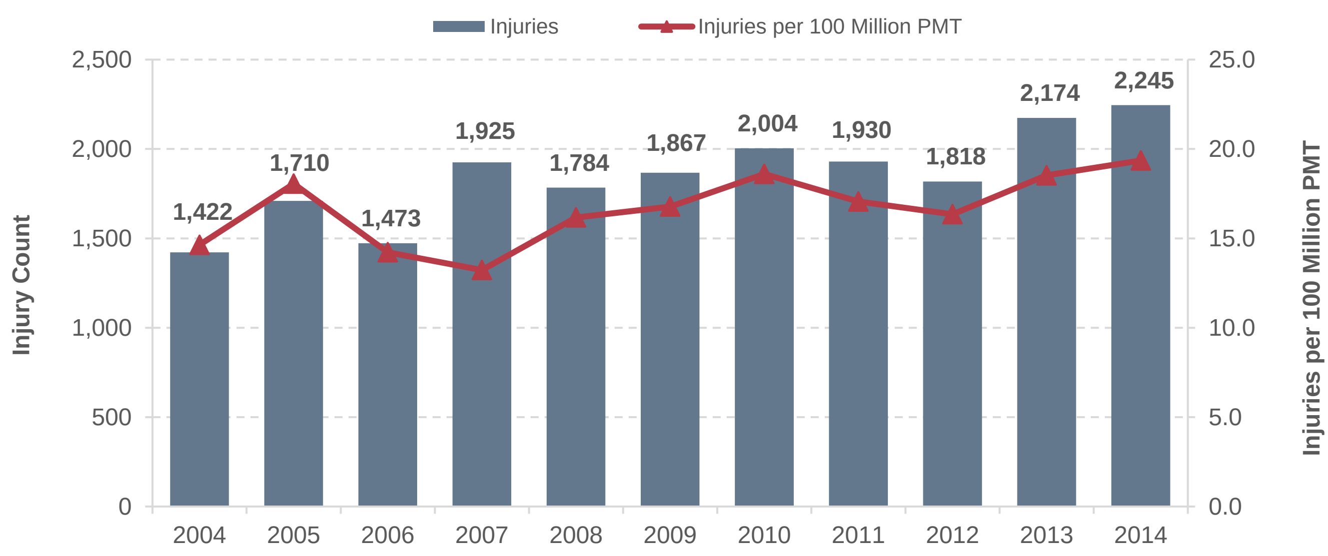
Exhibits 5-18 and *5-19* show the number of commuter rail incidents and the number of injuries per 100 million PMT, respectively. Although commuter rail has a very low number of incidents per PMT, commuter rail incidents are far more likely to result in fatalities than incidents occurring on any other mode. One contributing factor could be that the average speed of commuter rail vehicles is considerably higher than the average speeds of other modes (except vanpools). The number of both incidents and injuries declined from 2007 to 2008, steadily increased through 2010, then declined again between 2011 and 2012 before increasing in 2013. Injuries continued to increase through 2014, whereas incidents decreased through 2014. The average rates of increase for commuter rail fatalities, incidents, and injuries from 2004 to 2014 are 2.7 percent, 3.1 percent, and 5.5 percent, respectively.

Exhibit 5-18: Commuter Rail Incidents, 2004–2014



Source: Federal Railroad Administration Rail Accident/Incident Reporting System.

Exhibit 5-19: Commuter Rail Injuries, 2004–2014



Source: Federal Railroad Administration Rail Accident/Incident Reporting System.

[i] 2014 Annual Report: The U.S. Department of Transportation's (DOT) Status of Actions Addressing the Safety Issue Areas on the National Transportation Safety Board's Most Wanted List.

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CHAPTER 6

Infrastructure Conditions

Highway Infrastructure Conditions

Pavement and bridge conditions directly affect vehicle operating costs because deteriorating pavement and bridge decks increase wear and tear on vehicles, resulting in higher repair costs. Poor pavement conditions on higher functional classification roadways, such as the Interstate System, tend to result in higher user costs related to vehicle speed. For example, a vehicle hitting a pothole at 65 miles per hour on an Interstate highway could accelerate wear and tear faster than hitting the same pothole at 25 miles per hour. Alternatively, poor pavement can increase travel time costs if poor road conditions force drivers to reduce speed.

Poor bridge conditions can lead to the imposition of weight limits, which can increase travel time costs by forcing trucks to seek alternative routes. If a bridge's condition deteriorates to the point where it must be closed, all traffic would need to use alternative routes, potentially significantly increasing travel time costs. Highway user costs include vehicle operating costs, crash costs, and travel time costs, and are discussed in greater detail in Chapter 10.

Key Takeaways

- In 2014, approximately 47.0 percent of vehicle miles traveled (VMT) on Federal-aid highways was on pavements with good ride quality. Only 17.3 percent of VMT on Federal-aid highways was on pavements with poor ride quality.
- In 2014, 11.4 percent of VMT on the National Highway System (NHS) was on pavements with poor ride quality.
- In 2015, 47.3 percent of all bridges were classified as in good condition. Only 8.3 percent of all bridges were classified as in poor condition.
- On the NHS, 3.7 percent of all bridges were classified as in poor condition.

As discussed in the Introduction to Part I, as part of the implementation of the Transportation Performance Management (TPM) framework established by the Moving Ahead for Progress in the 21st Century (MAP-21) and continued under the Fixing America's Surface Transportation (FAST) Act, a Final Rule for Pavement and Bridge Performance Measures (PM-2) was published on January 18, 2017. This rule defines pavement and bridge condition performance measures, along with minimum condition standards, target establishment, progress assessment, and reporting requirements. This edition of the C&P Report continues a gradual shift toward reporting pavement and bridge measures consistent with those specified in the PM-2 rule.

The Highway Performance Monitoring System (HPMS) is the source for all pavement-related data presented in this section. The HPMS includes information on the International Roughness Index (IRI), which is an indicator of the ride quality experienced by drivers. It also contains information on other pavement distresses, including faulting at the joints of concrete pavements, the amount of rutting on asphalt pavements, and amount of cracking on both concrete and asphalt pavements.

The National Bridge Inventory (NBI) is a record of data reported to FHWA from the States, Federal agencies, and Tribal governments on the condition of the Nation's bridges. There are four primary data items used to determine bridge condition: deck, superstructure, substructure, and culvert condition ratings. The HPMS and NBI are discussed in greater detail later in this section (see Data Sources section).

Tunnels

Under MAP-21, FHWA was charged with establishing a national tunnel inspection program. In 2015, development began on the National Tunnel Inventory database system, and inventory data were collected for all highway tunnels reported. Concurrently, FHWA implemented an extensive program to train inspectors nationwide on tunnel inspection and condition evaluation.

Tunnel condition data will be collected annually, beginning in 2018, and will be available for inclusion in future C&P Reports. See (https://www.fhwa.dot.gov/bridge/tunnel/).

Factors Affecting Pavement and Bridge Performance

Pavement and bridge conditions are affected both by environmental conditions and traffic volumes. Environmental conditions include factors such as freeze-thaw cycles, in which water from melted snow or ice seeps into cracks in a pavement and then freezes, causing cracks to expand, and ultimately contributing to the formation of potholes. Significant weather events such as hurricanes and tornadoes also present a risk to the Nation's infrastructure; system resilience is discussed in further detail later in this chapter. Pavement and bridge deterioration accelerates on facilities with high traffic volumes, particularly facilities used by large numbers of heavy trucks. At certain points in the life cycle of an infrastructure asset, deterioration can happen rapidly because the impacts of traffic and the environment are cumulative. Deterioration can be mitigated through a variety of actions, including reconstruction, rehabilitation, and preventive maintenance. If corrective actions are not taken in a timely manner, deterioration of the pavement and bridges could continue until they can no longer remain in service.

Constructing new facilities or major rehabilitation is a relatively expensive undertaking. Such actions might not be economically justified until a pavement section or bridge has deteriorated to a poor condition. Such considerations are reflected in the investment scenarios presented in Part II of this report. Preventive maintenance actions are less expensive than rehabilitation and can be used to maintain and improve the quality of a pavement section or a bridge. Preventive maintenance actions, however, are less enduring than reconstruction or rehabilitation actions, and more aggressive actions would eventually need to be taken to preserve pavement and bridge quality.

Summary of Current Highway and Bridge Conditions

Exhibit 6-1 identifies criteria for "good," "fair," and "poor" classifications for several individual pavement distresses, based on the information laid out in the PM-2 rule. The rule also established criteria for overall pavement ratings, based on combinations of ratings for individual distresses; for a section of pavement to be rated in good condition, its ratings for all three relevant distresses (ride quality, cracking, and rutting for asphalt pavements; ride quality, cracking, and faulting for concrete pavements) must be rated as good. For a section of pavement to be rated as poor, at least two of the relevant distresses must be rated as poor. Any pavements not rated as good or poor are classified as fair.

Exhibit 6-1: Condition Rating Classifications Used in the 23rd C&P Report

Condition Metric	Rating Criteria	Good	Fair	Poor
Pavement Ride Quality	The International Roughness Index (IRI) measures the cumulative deviation from a smooth surface in inches per mile.	IRI < 95	IRI 95 to 170	IRI > 170
Pavement Ride Quality (alternative)[1]	For roads functionally classified as urban minor arterials, rural or urban major collectors, or urban minor collectors, States can instead report a Present Serviceability Rating (PSR) on a scale of 0 to 5.	PSR ≥ 4.0	PSR > 2.0 and < 4.0	PSR ≤ 2.0
Pavement Cracking (Asphalt)	For asphalt pavements, cracking is measured as the percentage of the pavement surface in the wheel path in which interconnected cracks are present.	< 5%	5% to 20%	> 20%
Pavement Cracking (Jointed Plain Concrete)	For jointed plain concrete pavements cracking is measured as the percent of cracked concrete panels in the evaluated section.	< 5%	5% to 15%	> 15%
Pavement Cracking (Continuous Reinforced Concrete)	For Continuous Reinforced Concrete pavements, cracking is measured as the percent of cracking for the evaluated section.	< 5%	5% to 10%	> 10%
Pavement Rutting (Asphalt Pavements only)	Rutting is measured as the average depth in inches of any surface depression present in the vehicle wheel path.	< 0.20	0.20 to 0.40	> 0.40
Pavement Faulting (Concrete Pavements only)	Faulting is measured as the average vertical displacement in inches between adjacent jointed concrete panels.	< 0.10	0.10 to 0.15	> 0.15
Bridge Deck Condition	Ratings are on a scale from 0 “Failed” to 9 “Excellent.”	≥ 7	5 to 6	≤ 4
Bridge Superstructure Condition	Ratings are on a scale from 0 “Failed” to 9 “Excellent.”	≥ 7	5 to 6	≤ 4
Bridge Substructure Condition	Ratings are on a scale from 0 “Failed” to 9 “Excellent.”	≥ 7	5 to 6	≤ 4
Culvert Condition	Ratings are on a scale from 0 “Failed” to 9 “Excellent.”	≥ 7	5 to 6	≤ 4

[1] Under the PM-2 rule, PSR can be reported in lieu of IRI, rutting, and faulting for any component of the NHS with a posted speed limit under 40 miles per hour (e.g., border crossings, toll plazas).

Source: (https://www.federalregister.gov/documents/2017/01/18/2017-00550/national-performance-management-measures-assessing-pavement-condition-for-the-national-highway)

While this chapter does not include statistics for overall pavement condition ratings, it does include data on the ratings for the individual distresses for 2014. Data presented for the 2004 to 2014 period are limited to ride quality only, as data collection for the other pavement distresses began in 2010. While the PM-2 rule only requires that targets be set for the Interstate and non-Interstate components of the NHS, this chapter applies the same criteria to pavements on all Federal-aid highways. (HPMS does not collect condition data for the three-quarters of road mileage that is not on Federal-aid highways.)

The structurally deficient bridge classification criteria prior to the PM-2 rule consisted of the evaluation of six individual metrics: Deck Condition, Superstructure Condition, Substructure Condition, Culvert Condition, Structural Evaluation, and Waterway Adequacy. If one of these metrics was below the pertinent trigger value, the bridge was rated as structurally deficient. The PM-2 rule redefined the criteria for structurally deficient and made it equal to the criteria to classify bridges as in poor condition. The PM-2 rule considers only the first four of these metrics (Deck Condition, Superstructure Condition, Substructure Condition, and Culvert Condition); if any one of these criteria is rated poor, the bridge is classified as poor. A bridge is classified as good only if all of these metrics are rated as good. While the PM-2 rule only requires that targets be set for NHS bridges, this chapter applies the same criteria to all bridges.

The classification of a bridge as in poor condition or structurally deficient does not imply that the bridge is unsafe. Instead, the classification indicates the extent to which a bridge has deteriorated from its original condition when first built. A bridge with a classification of poor might experience reduced performance in the form of lane closures or load limits. If a bridge inspection determines a bridge to be unsafe, it is closed.

Weighted Versus Raw Counts

This section presents some pavement condition data based on actual miles of pavement and other data weighted by either lane miles or vehicle miles traveled (VMT). Some bridge data are presented based on actual bridge counts, while other data are weighted by bridge deck area or bridge traffic.

While raw counts are simplest to compute, weighting by VMT or bridge traffic gives a better sense of the extent to which poor pavement or bridge conditions are affecting the traveling public. Weighting by lane-miles or deck area aligns better with the costs that agencies would incur to improve existing pavements or bridges (i.e., it costs more to reconstruct a four-lane road than a two-lane road). The PM-2 rule requires that targets be set on a lane-mile-weighted basis for pavements and a deck area-weighted basis for bridges.

Current Pavement Conditions

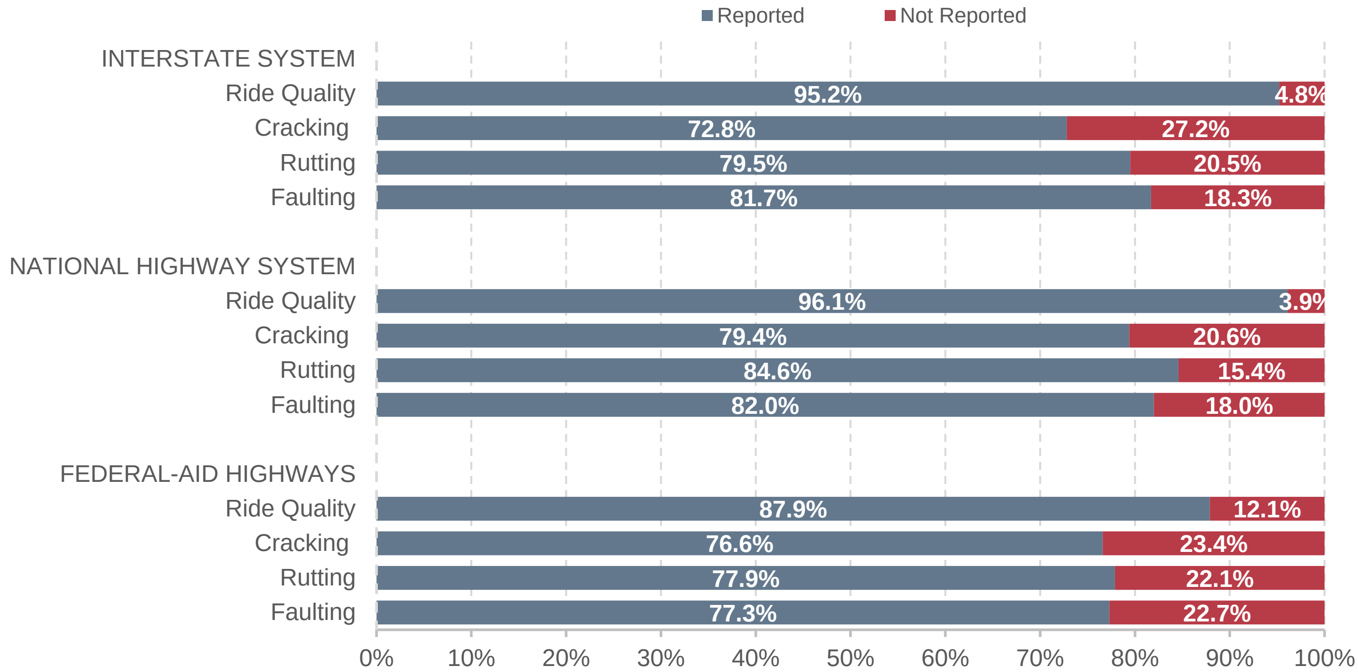
While HPMS data reporting requirements for IRI date back many years (on a universe or sample basis, depending on the type of roadway), and data reporting for cracking, rutting, and faulting date back to 2010, as of 2014, there were a number of highway sections for which these data were omitted. In some cases, States provided an alternative pavement serviceability rating (PSR) as permitted for certain types of roads; in others, no condition data were provided. *Exhibit 6-2* identifies the percentage of HPMS highway segments for which data were reported in 2014 for each distress type for Interstate highways, the NHS, and Federal-aid highways.

All subsequent exhibits on pavement condition presented in this chapter are based only on those road segments for which distress data were reported. However, it should be noted that the conditions of road segments for which data were missing might not fully align with those for which data were reported, in the aggregate.

As shown in *Exhibit 6-3,* approximately 78.5 percent of pavements on the Interstate System (weighted by lane miles) were rated as having good ride quality (roughness) in 2014; 19.7 percent had fair ride quality, and 1.8 percent had poor ride quality. The shares of pavement rated good for cracking, rutting, and faulting were 72.0 percent, 76.4 percent and 67.4 percent, while the shares rated poor were 4.8 percent, 1.0 percent, and 15.5 percent, respectively.

For NHS pavements, *Exhibit 6-4* shows that 60.1 percent of lane miles were rated as having good ride quality in 2014; 30.9 percent had fair ride quality; and 8.9 percent had poor ride quality. Comparing the results of *Exhibit 6-3* to those of *Exhibit 6-4* reveals that pavement ride quality on the Interstate portion of the NHS is better than on the non-Interstate portion of the NHS.

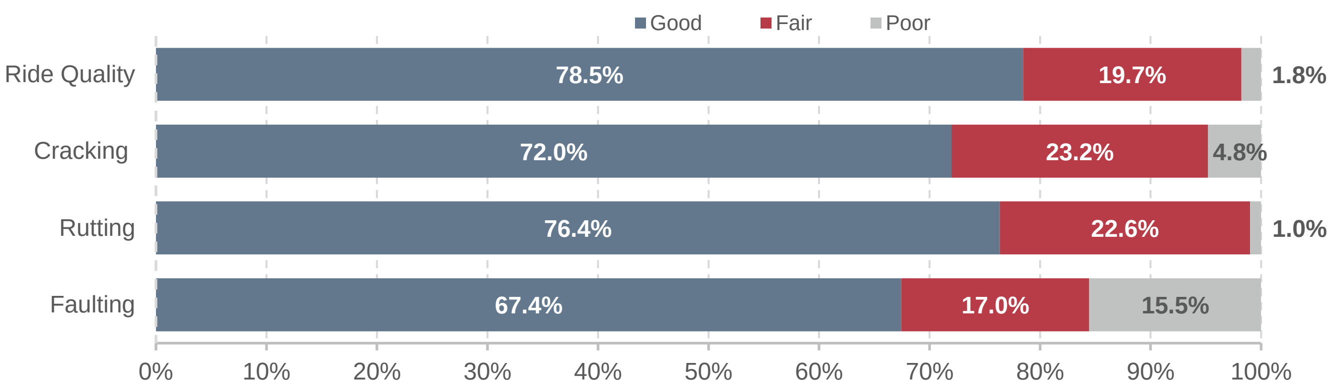
Exhibit 6-2: Percentage of Pavement Data Reported



Note: Based on percentage of HPMS highway segments with data reported and not reported.

Source: Highway Performance Monitoring System.

Exhibit 6-3: Interstate Pavement Condition, Weighted by Lane Miles, 2014

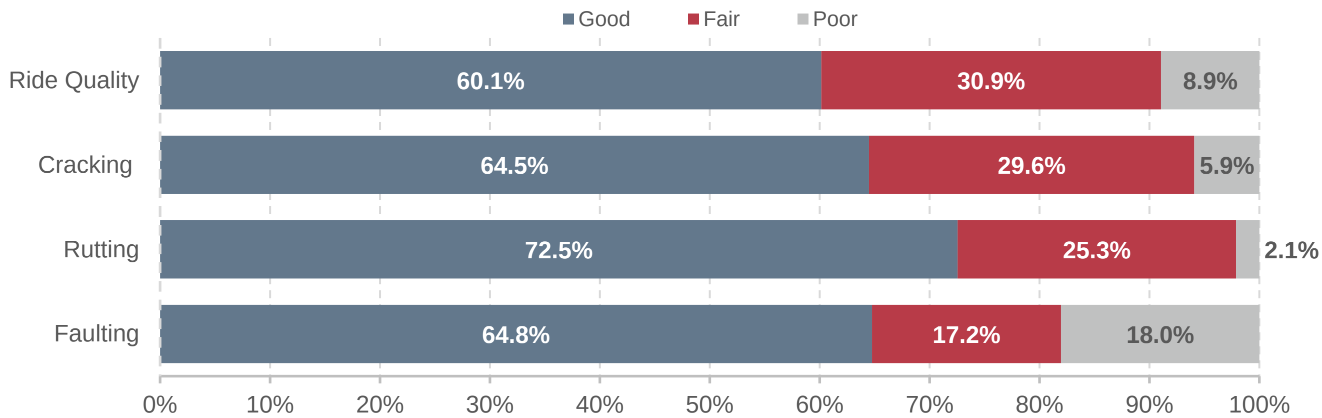


Source: Highway Performance Monitoring System.

The lane mile-weighted shares of cracking, rutting, and faulting pavement rated good for the NHS were 64.5 percent, 72.5 percent, and 64.8 percent in 2014, all below the comparable values for Interstate highways. The share of NHS lane miles rated poor in 2014 was 5.9 percent for cracking, 2.1 percent for rutting, and 18.0 percent for faulting pavement.

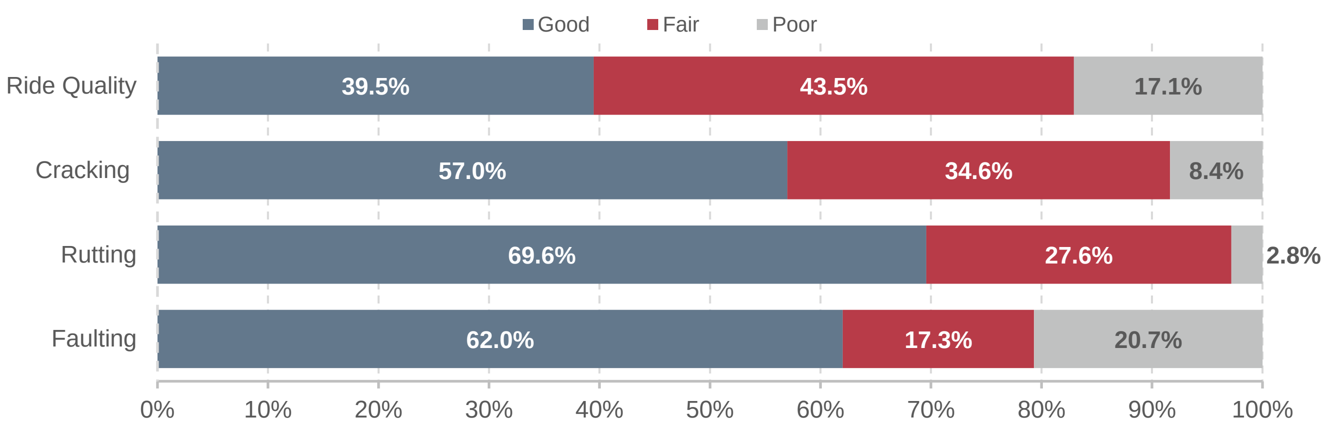
Exhibit 6-5 shows the percentage of Federal-aid highway lane miles rated good was 39.5 percent for ride quality, 57.0 percent for cracking, 69.6 percent for rutting, and 62.0 percent for faulting. All of these shares are below those reported in *Exhibit 6-4* for the NHS. The percentage of Federal-aid lane miles rated poor was 17.1 percent for ride quality, 8.4 percent for cracking, 2.8 percent for rutting, and 20.7 percent for faulting; all of these values are higher than the comparable values for the NHS.

Exhibit 6-4: NHS Pavement Condition, Weighted by Lane Miles, 2014



Source: Highway Performance Monitoring System.

Exhibit 6-5: Federal-aid Highway Pavement Condition, Weighted by Lane Miles, 2014



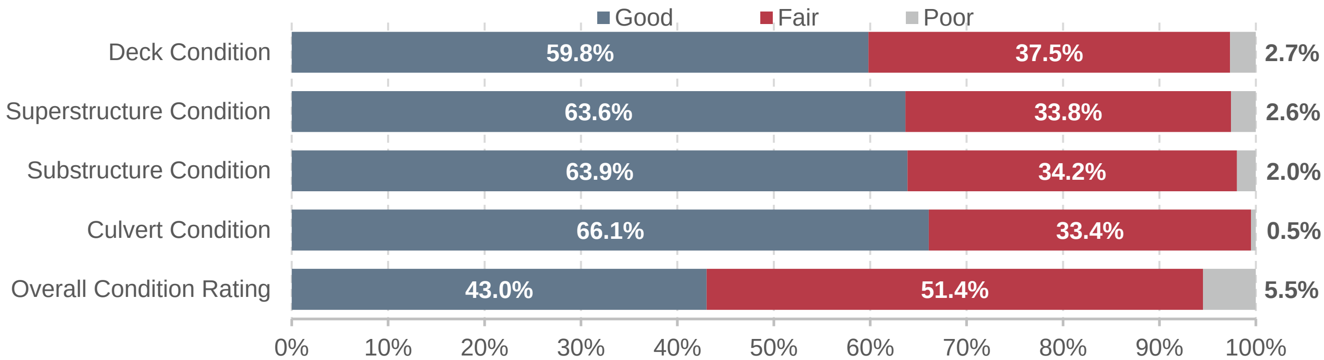
Source: Highway Performance Monitoring System.

Current Bridge Condition

The deck-area weighted share of NHS bridges with decks in good condition is shown in *Exhibit 6-6* as 59.8 percent for 2015; the shares for superstructure and substructure were 63.6 percent and 63.9 percent, respectively. The share of NHS culverts in good condition was 66.1 percent in 2015. Applying the PM-2 classification rules (all individual bridge components rated good) results in an overall share of 43.0 percent of NHS deck area rated as good.

The deck-area weighted share of NHS bridges with decks in poor condition was 2.7 percent for 2015; the shares for superstructure and substructure were 2.6 percent and 2.0 percent, respectively; the share for culverts was 0.5 percent. Applying the PM-2 classification rules (any of the individual bridge components rated poor) results in an overall share of 5.5 percent of NHS deck area rated as poor.

Exhibit 6-6: NHS Bridge Conditions, Weighted by Deck Area, 2015

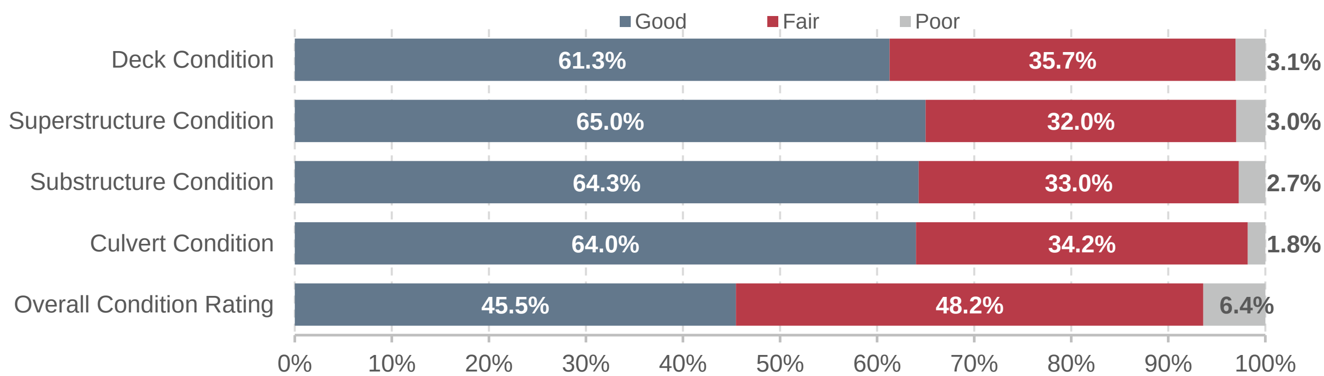


Source: National Bridge Inventory.

Exhibit 6-7 shows deck-area weighted condition data for all bridges. The shares of deck area rated good for deck, superstructure, and substructure were 61.3 percent, 65.0 percent, and 64.3 percent, respectively. For all culverts for which data were reported, the share rated as good was 64.0 percent in 2015. Applying the PM-2 classification rules results in an overall share of 45.5 percent of all deck area rated as good.

The deck-area weighted share of all bridges with decks in poor condition was 3.1 percent for 2015; the shares for superstructure, substructure, and culverts were 3.0 percent, 2.7 percent, and 1.8 percent, respectively. Applying the PM-2 classification rules results in an overall share of 6.4 percent of deck area rated as poor.

Exhibit 6-7: Systemwide Bridge Conditions, Weighted by Deck Area, 2015



Source: National Bridge Inventory.

Historical Trends in Pavement and Bridge Conditions

This section presents data on changes in pavement ride quality since 2004, as well as changes in the portion of bridges rated good, fair, poor, and structurally deficient. As noted earlier, data on other pavement distresses were not collected for this full period. Pavement ride quality data are only available for Federal-aid highways.

Increases in the number of bridges and miles of roadway bridges can influence condition measures computed as shares. New roads and bridges rated in good condition can help bring up the overall average, even if the condition of existing roads and bridges remains the same or declines. However, the addition of new assets also puts strain on budgets to maintain all assets, making it more challenging to keep overall average conditions from declining.

National Highway System Pavement and Bridge Trends

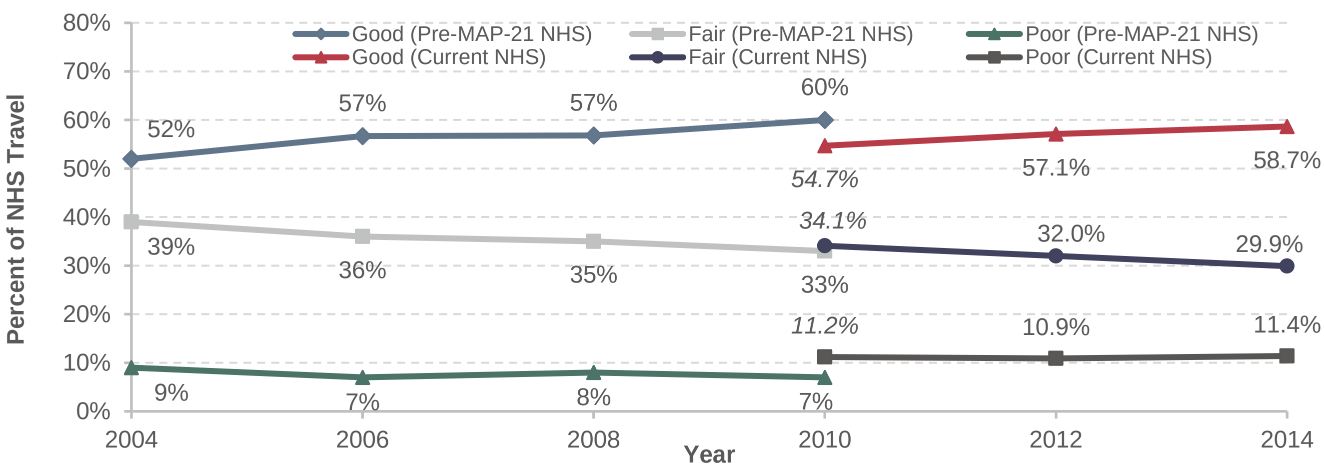
In 1998, DOT began establishing annual targets for pavement ride quality. Since 2006, the metric reflected in DOT performance-planning documents has been the share of VMT on the NHS on pavements with good ride quality. Consequently, the pavement discussion in this section focuses on VMT-weighted measures. The bridge discussion focuses on deck-area weighted measures to be consistent with DOT performance-planning documents.

MAP-21 expanded the NHS to include most of the principal arterial mileage that was not previously included in the system. Although 2012 was the first year for which HPMS data were collected based on this expanded NHS, *Exhibit 6-8* includes estimates for 2010 that were presented in the 2013 C&P Report. As reflected in a comparison of the actual 2010 values with these estimates, expanding the NHS reduced the percentage of NHS VMT on pavements with good ride quality and increased the percentage of NHS VMT on pavements with poor ride quality. On average, the additional routes added to the NHS had rougher pavements than the routes that were already part of the NHS.

The share of VMT on NHS pavements with good ride quality rose from 52 percent in 2004 to 60 percent in 2010, based on the pre-expansion NHS, and from an estimated 54.7 percent in 2010 to 58.7 percent in 2014, based on the post-expansion NHS. Combining the trends for these two separate periods translates into an average increase of more than 1 percentage point per year. From 2004 to 2010, the share of VMT on NHS pavements with poor ride quality declined from 9 percent to 7 percent; this share increased slightly from an estimated 11.2 percent to 11.4 percent from 2010 to 2014.

Exhibit 6-9 shows the performance of bridges on the NHS from 2004 through 2015. The share of total deck area of bridges rated poor declined from 8.7 percent in 2004 to 5.8 percent in 2014 and to 5.5 percent in 2015. The deck area of bridges in good condition also declined, from 43.8 percent in 2004 to 42.2 percent in 2014, before rebounding to 43.0 percent in 2015; the share of bridges classified as fair (i.e., not good or poor) increased over this period.

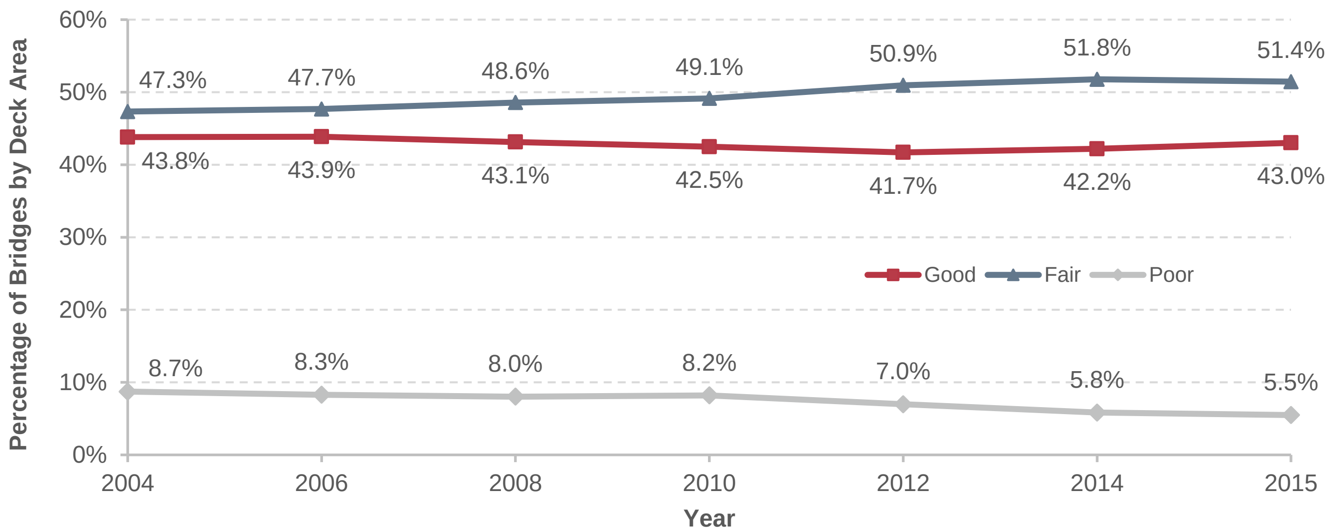
Exhibit 6-8: NHS Pavement Ride Quality, Weighted by VMT, 2004–2014[1]



[1] Data for odd-numbered years omitted. Italicized 2010 values shown for the current NHS are estimates as presented in the 2013 C&P report. Exact values cannot be determined as the 2010 HPMS data were collected based on the pre-MAP-21 NHS. Values for the pre-MAP-21 NHS are shown as whole percentages to be consistent with how they were reported at the time in DOT performance planning documents.

Source: Highway Performance Monitoring System.

Exhibit 6-9: NHS Bridge Condition Ratings by Deck Area, 2004–2015[1]



[1] Odd-numbered years omitted (except for 2015).

Source: National Bridge Inventory.

The expansion of the NHS under MAP-21 also increased the number of bridges; this is the major driver of the significant increase in the number of NHS bridges shown in *Exhibit 6-10*, from 117,485 in 2012 to 143,165 bridges in 2014. Even with the expansion, the number of structurally deficient bridges on the NHS decreased from 6,617 in 2004 to 5,951 in 2014 and to 5,479 in 2015. The number of NHS bridges in poor condition decreased from 6,395 bridges in 2004 to 5,825 bridges in 2014 and 5,358 in 2015. The total percentage of structurally deficient bridges by deck area decreased from 8.9 percent in 2004 to 6.0 percent in 2014 and to 5.6 percent in 2015.

Exhibit 6-10: NHS Bridges Rated Structurally Deficient or Poor, 2004–2015

	2004	2006	2008	2010	2012	2014	*2015*
Count							
Total Bridges	115,103	115,202	116,523	116,669	117,485	143,165	*143,139*
Structurally Deficient Bridges	6,617	6,339	6,272	5,902	5,237	5,951	*5,479*
Poor Bridges	6,395	6,166	6,126	5,781	5,121	5,825	*5,358*
Percent Structurally Deficient							
By Bridge Count	5.7%	5.5%	5.4%	5.1%	4.5%	4.2%	*3.8%*
Weighted by Deck Area	8.9%	8.4%	8.2%	8.3%	7.1%	6.0%	*5.6%*
Weighted by ADT	6.8%	6.6%	6.4%	6.0%	5.1%	4.3%	*4.0%*
Percent Poor							
By Bridge Count	5.6%	5.4%	5.3%	5.0%	4.4%	4.1%	*3.7%*
Weighted by Deck Area	8.7%	8.3%	8.0%	8.2%	7.0%	5.8%	*5.5%*
Weighted by ADT	6.7%	6.5%	6.3%	5.9%	5.0%	4.2%	*3.9%*

Source: National Bridge Inventory.

Federal-aid Highways Pavement Ride Quality Trends

Exhibit 6-11 details pavement ride quality on Federal-aid highways. The share of pavement mileage with good ride quality decreased from 43.1 percent in 2004 to 38.4 percent in 2014, but weighting the ride quality data by VMT produces significantly different results. During the same period, the share of VMT on Federal-aid highways with good ride quality increased from 44.2 percent to 47.0 percent. The implication is that pavement investment is likely being directed to parts of the system that are serving the most travelers, but that some less-traveled parts of the system are lagging behind.

Trends in terms of poor ride quality have consistently worsened based on either mileage or VMT. From 2004 to 2014 the share of miles with pavement ride quality classified as poor increased from 13.4 percent to 22.2 percent; over the same period, the share of Federal-aid highway VMT on pavements with poor ride quality increased from 15.1 percent to 17.3 percent.

Exhibit 6-11: Pavement Ride Quality on Federal-aid Highways, 2004–2014[1]

	2004	2006	2008	2010	2012	2014
By Mileage						
Good	43.1%	41.5%	40.7%	35.1%	36.4%	38.4%
Fair	43.6%	42.7%	43.5%	44.9%	43.9%	39.4%
Poor	13.4%	15.8%	15.8%	20.0%	19.7%	22.2%
Weighted by VMT						
Good	44.2%	47.0%	46.4%	50.6%	44.9%	47.0%
Fair	40.7%	39.0%	39.0%	31.4%	38.4%	35.7%
Poor	15.1%	14.0%	14.6%	18.0%	16.7%	17.3%

[1] Due to changes in data reporting instructions, data for 2010 and beyond are not fully comparable to data for 2008 and prior years.
Source: Highway Performance Monitoring System.

Impact of Revised HPMS Reporting Guidance

Between 2008 and 2010, the percentage of pavement mileage with good ride quality declined from 40.7 percent to 35.1 percent, while the share of mileage with poor ride quality rose from 15.8 percent to 20.0 percent. These results should be interpreted with the understanding that the HPMS guidance for reporting IRI changed beginning with the 2009 data submittal. The revised instructions directed States to include measurements of roughness captured on bridges and railroad crossings; the previous instructions called for such measurements to be excluded from the reported values. This change would tend to increase the measured IRI on average, which reflects the roughness experienced when driving over railroad tracks and associated with open-grated bridges and expansion joints on the bridge decks.

A source of recent data variability is that States have begun reporting ride quality data for shorter section lengths, which would tend to increase the variability of reported ratings. For example, a short segment of pavement in significantly better or worse conditions than an adjacent segment is now more likely to be classified as good or poor, whereas, prior to 2009, it might have been averaged in with neighboring segments, yielding a classification of fair.

Systemwide Bridge Condition Trends

Exhibit 6-12 shows that, based on unweighted bridge counts, the share of bridges rated as good fell from 48.2 percent in 2004 to 47.1 percent in 2014, before rising back to 47.3 percent in 2015. The comparable shares weighted by deck area and by bridge traffic were a bit lower (45.5 percent and 45.8 percent, respectively, in 2015), but showed a similar pattern across this period.

Exhibit 6-12: Systemwide Bridge Conditions, 2004–2015

	2004	2006	2008	2010	2012	2014	*2015*
Count							
Total Bridges	594,100	597,561	601,506	604,493	607,380	610,749	*611,845*
Bridges in Good Condition	286,152	287,969	287,317	286,534	287,194	287,701	*289,158*
Bridges in Fair Condition	241,176	246,309	252,217	258,277	262,878	269,734	*271,690*
Bridges in Poor Condition	65,105	62,297	61,002	59,305	57,049	52,905	*50,917*
Structurally Deficient Bridges	79,971	75,422	72,883	70,431	66,749	61,365	*58,791*
Percent Good							
By Bridge Count	48.2%	48.2%	47.8%	47.4%	47.3%	47.1%	*47.3%*
Weighted by Deck Area	46.1%	46.1%	45.8%	45.2%	44.7%	44.7%	*45.5%*
Weighted by ADT	46.4%	45.6%	44.7%	44.4%	44.0%	44.5%	45.8%
Percent Fair							
By Bridge Count	40.6%	41.2%	41.9%	42.7%	43.3%	44.2%	*44.4%*
Weighted by Deck Area	44.3%	44.7%	45.3%	46.0%	47.3%	48.3%	*48.2%*
Weighted by ADT	46.1%	47.1%	48.2%	48.9%	50.2%	50.6%	49.8%
Percent Poor							
By Bridge Count	11.0%	10.4%	10.1%	9.8%	9.4%	8.7%	*8.3%*
Weighted by Deck Area	9.4%	9.0%	8.8%	8.7%	7.8%	6.7%	*6.4%*
Weighted by ADT	7.3%	7.1%	7.0%	6.5%	5.7%	4.7%	*4.4%*
Percent Structurally Deficient							
By Bridge Count	13.5%	12.6%	12.1%	11.7%	11.0%	10.0%	*9.6%*
Weighted by Deck Area	10.1%	9.6%	9.3%	9.1%	8.2%	7.1%	*6.7%*
Weighted by ADT	7.6%	7.4%	7.2%	6.7%	5.9%	4.9%	*4.6%*

Source: National Bridge Inventory.

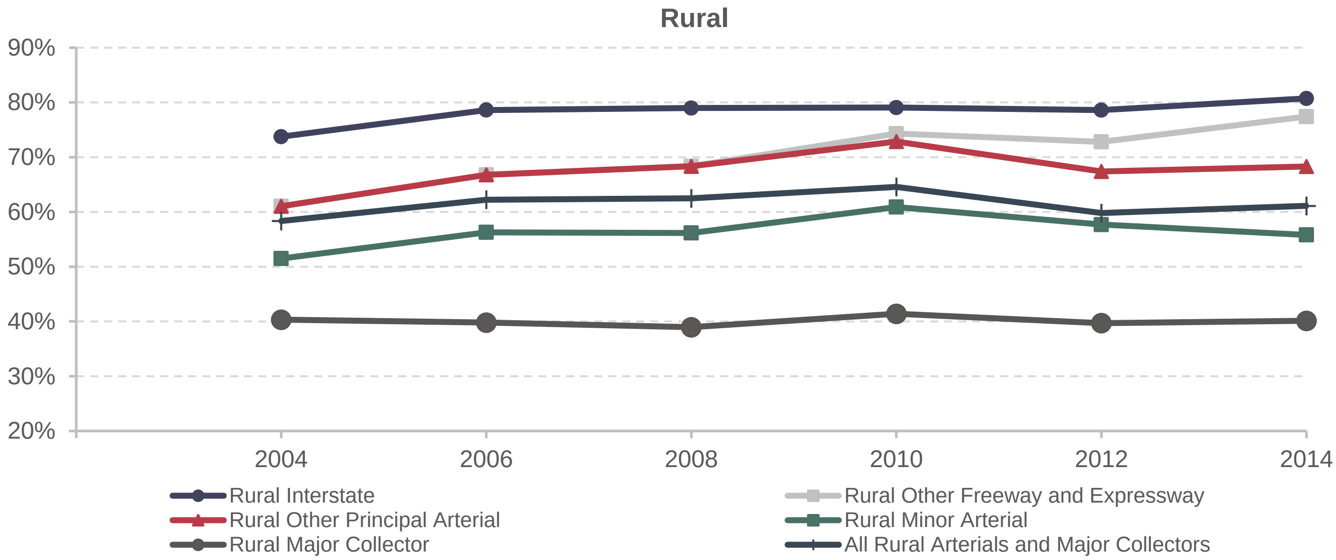
The share of bridges classified as poor dropped from 11.0 percent in 2004 to 8.7 percent in 2014, dropping further to 8.3 percent in 2015. The share of bridges weighted by deck area rated poor was lower (9.4 percent in 2004, dropping to 6.7 percent in 2014 and 6.4 percent in 2015), suggesting that larger bridges are in better shape on average than smaller ones. The share of bridges weighted by average daily traffic (ADT) rated poor was even lower (7.3 percent in 2004, dropping to 4.7 percent in 2014 and 4.4 percent in 2015), suggesting that well-traveled bridges are in better shape on average than less traveled ones.

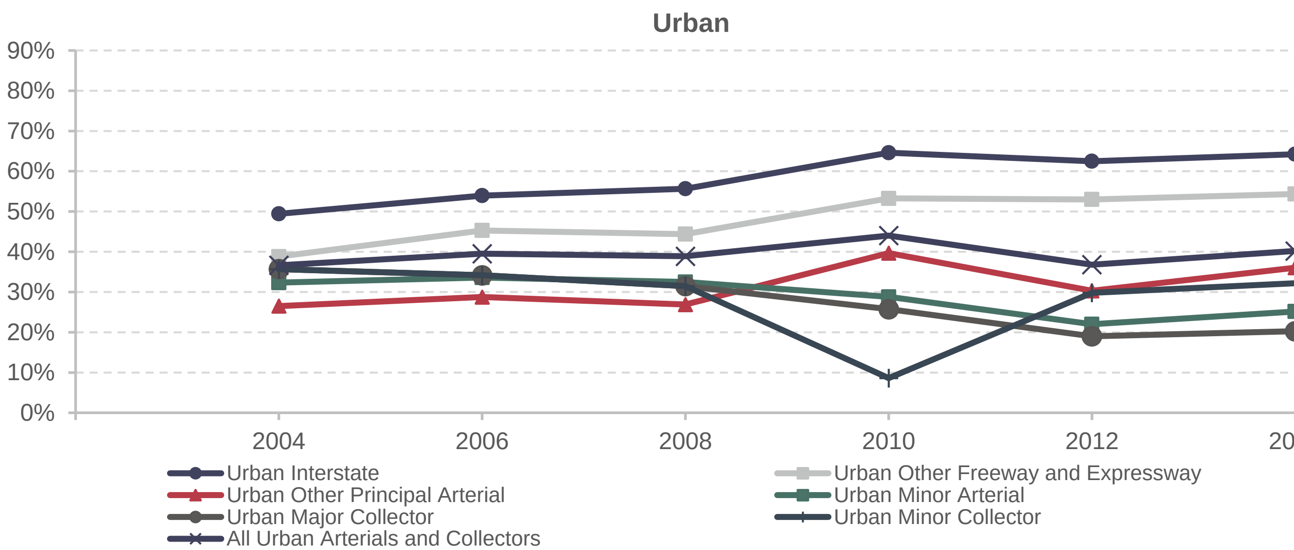
The share of bridges rated structurally deficient follows a similar pattern to those classified as poor; the numbers are uniformly higher (13.5 percent in 2004, falling to 10.0 percent in 2014 and 9.6 percent in 2015), as the structurally deficient classification also takes into account the structural evaluation and waterway adequacy appraisals from the NBI, which are not considered in the PM-2 rule definition of “poor.”

Pavement and Bridge Conditions by Functional Class

Although changes in HPMS reporting procedures in 2009 make identifying trends over the full 10-year period shown in *Exhibit 6-13* and *Exhibit 6-14* more challenging, it is still possible to draw some significant conclusions from the data. Rural Interstates have the best ride quality of all functional systems, with 80.7 percent of VMT on pavements with good ride quality in 2014, up from 73.7 percent in 2004. The share of urban Interstate System VMT on pavements with good ride quality from 2004 to 2014 rose sharply from 49.4 percent to 64.2 percent.

Exhibit 6-13: Pavement Ride Quality Rated Good, by Functional Class, Weighted by VMT, 2004–2014[1]





[1] Odd-numbered year data omitted. Prior to 2010, Rural Other Freeway and Expressway was included as part of Rural Other Principal Arterial; Urban Major Collector and Minor Collector were combined into a single category called Urban Collector.

Source: HPMS.

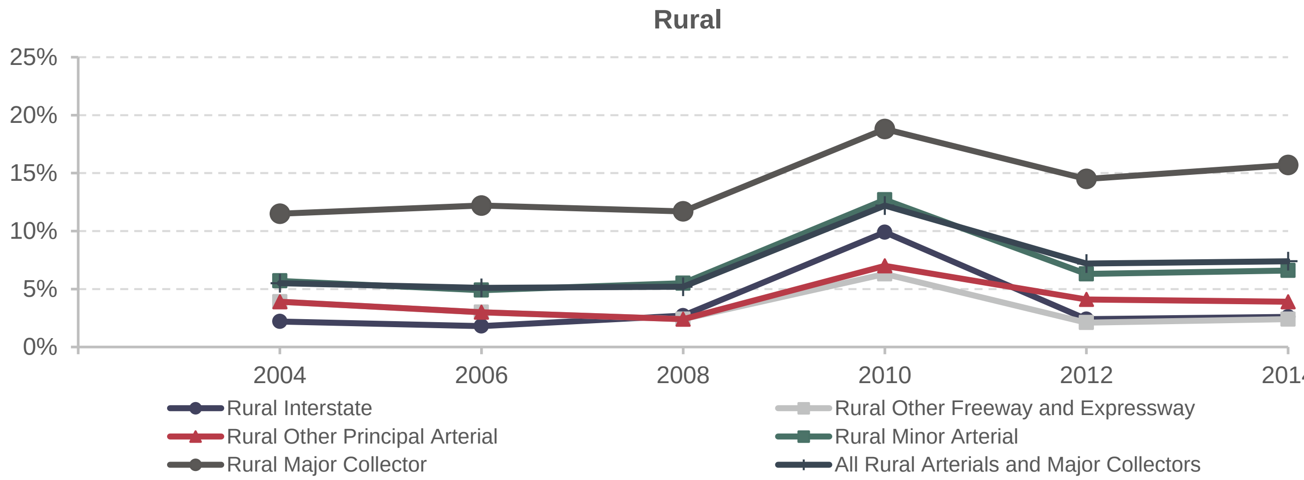
The share of rural arterial and major collector VMT on pavements with good ride quality rose from 58.3 percent in 2004 to 61.1 percent in 2014, while the comparable share of urban arterial and collector VMT rose from 35.6 percent to 40.2 percent. As noted in Chapter 1, rural areas include more miles of roadway than do urban areas, but roads in urban areas carry more VMT. Hence, rural ride quality has a greater impact on national measures of pavement condition based on mileage, whereas urban ride quality has a greater impact on national measures weighted on VMT. Higher-ordered functional systems (Interstate and other arterials) have a relatively greater impact on national measures weighted by lane miles than do lower-ordered functional systems (collectors), as these types of roadways have more lanes, on average.

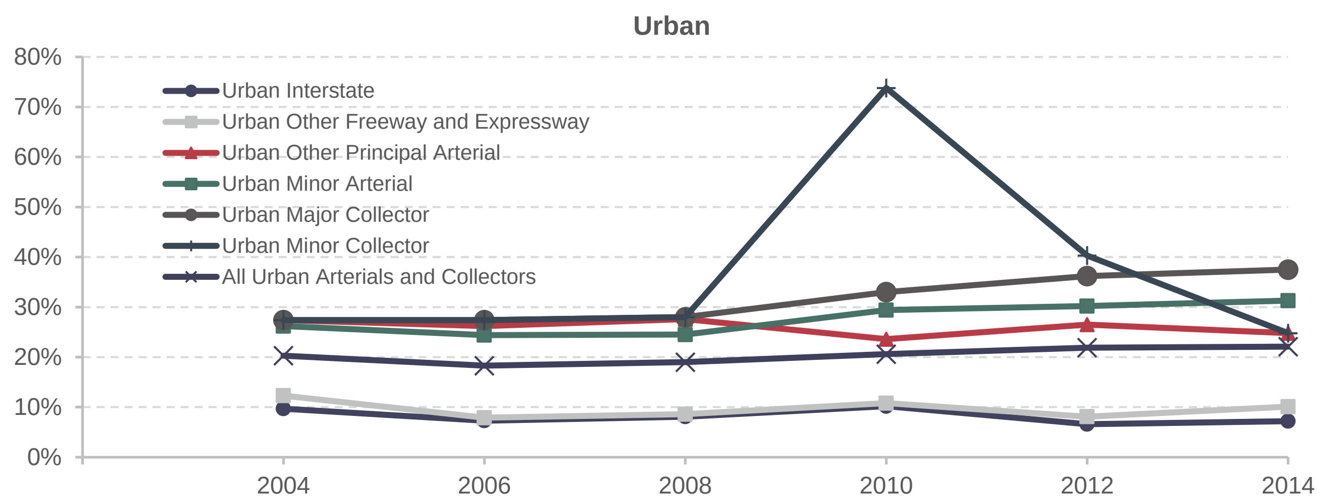
In general, it can be seen in *Exhibit 6-13* that roads with higher functional classifications have better ride quality than lower-ordered systems. Among the rural functional classifications, the percentage of VMT on pavements with good ride quality in 2014 ranged from 80.7 percent for rural Interstates to 40.1 percent for rural major collectors. A similar pattern is evident among most urban functional classifications, as the percentage of VMT on pavements with good ride quality in 2014 ranged from 64.2 percent for urban Interstates to 20.3 percent for urban major collectors. An exception to this general pattern was that urban minor collectors showed a higher percentage of VMT on pavements with good ride quality than did urban major collectors and urban minor arterials in 2014. It should be noted, however, that the urban minor collector category is relatively new (prior to 2010, it had been included with urban major collectors in a combined urban collector classification), and some States may not yet have adapted their data to align with the new classification structure.

Exhibit 6-14 shows share of pavements with poor ride quality by functional class. In 2014, urban major collectors had the highest percentage of VMT on poor ride quality pavements at 37.5 percent, up from 27.4 percent in 2004. Rural Interstate had the lowest VMT-weighted share of pavements with poor ride quality in 2004 at 2.2 percent, which rose to 2.6 percent by 2014. The lowest of share of VMT on poor ride quality pavements in 2014 was on “rural other freeways and expressways” at 2.4 percent; the comparable value for 2004 is unknown, as prior to 2010 these types of facilities were included in the “rural other principal arterial” category. The VMT-weighted share of VMT on all rural arterials and major collectors combined rose from 5.5 percent in 2004 to 7.4 percent in 2014; the comparable share for all urban arterials and collectors rose from 20.3 percent to 22.1 percent over this period.

Within rural areas, lower-ordered functional systems generally had higher shares of pavements with poor ride quality than did high-ordered systems. The share of VMT on rural major collector pavement with poor ride quality rose from 11.5 percent in 2004 to 15.7 percent in 2014. This pattern was generally evident in urban areas as well, with the exception of urban minor collectors, whose VMT-weighted share of poor pavement ride quality was 24.8 percent in 2014, tying that of urban other principal arterials. Among the urban functional classes, urban Interstate had the lowest share of VMT on pavements with poor ride quality, falling from 9.7 percent in 2004 to 7.2 percent in 2014.

Exhibit 6-14: Pavement Ride Quality Rated Poor, By Functional Class, Weighted by VMT, 2004–2014[1]





[1] Odd-numbered year data omitted. Prior to 2010, Rural Other Freeway and Expressway was included as part of Rural Other Principal Arterial; Urban Major Collector and Minor Collector were combined into a single category called Urban Collector.

Source: HPMS.

Unlike the pattern observable in *Exhibit 6-13* for pavement ride quality, the classification of bridges as good does not vary relatively consistently with functional class. *Exhibit 6-15* shows that the highest share of bridges in good condition was on rural other principal arterials, which declined slightly from 56.9 percent in 2004 to 56.4 percent in 2014, before dipping further to 56.1 percent in 2015. The lowest share of bridges in good condition in 2015 was 41.5 percent for rural Interstates, up slightly from 41.3 percent in 2014, but down significantly from 51.0 percent in 2004.

Among the urban functional classes, the highest share of bridges in good condition was on urban other freeways and expressways, falling from 54.3 percent in 2004 to 52.2 percent in 2014, before rising to 54.2 percent in 2015. The lowest share of urban bridges in good condition in 2015 was 42.2 percent for urban Interstates, up slightly from 41.1 percent in 2014 but down from 44.8 percent in 2004.

The overall percentages of rural and urban bridges classified as good were very similar across this period. Urban bridges had a slight advantage in 2004 (49.0 percent good for urban, versus 47.9 percent for rural), but rural bridges edged ahead by 2014 (47.2 percent good for rural versus 46.8 percent good for urban), before urban bridges reclaimed their advantage in 2015.

Exhibit 6-15: Bridges Rated Good, by Functional Class, 2004–2015

	2004	2006	2008	2010	2012	2014	*2015*
Functional Class	**Percent Good Condition**						
Rural							
Interstate	51.0%	49.3%	46.9%	44.5%	42.5%	41.3%	*41.5%*
Other Principal Arterial	56.9%	57.5%	56.9%	56.5%	56.5%	56.4%	*56.1%*
Minor Arterial	52.3%	51.7%	51.4%	50.4%	49.7%	49.7%	*50.0%*
Major Collector	49.3%	48.9%	48.3%	47.6%	47.8%	47.4%	*47.4%*
Minor Collector	46.3%	46.6%	46.1%	45.4%	45.4%	45.1%	*45.0%*
Local	44.9%	45.6%	45.8%	46.0%	46.2%	46.2%	*46.1%*
Subtotal Rural	**47.9%**	**48.1%**	**47.8%**	**47.4%**	**47.4%**	**47.2%**	***47.1%***
Urban							
Interstate	44.8%	43.9%	42.7%	42.5%	41.1%	41.1%	*42.2%*
Other Freeway and Expressway	54.3%	53.6%	52.6%	52.4%	52.0%	52.2%	*54.2%*
Other Principal Arterial	47.2%	47.3%	46.8%	46.1%	45.9%	45.8%	*46.3%*
Minor Arterial	48.0%	47.4%	46.5%	46.1%	45.5%	44.9%	*45.7%*
Collector	49.6%	48.5%	47.3%	47.9%	48.3%	48.1%	*48.3%*
Local	52.0%	51.8%	51.3%	50.7%	50.8%	50.6%	*50.7%*
Subtotal Urban	**49.0%**	**48.5%**	**47.7%**	**47.4%**	**47.0%**	**46.8%**	***47.6%***
Total Good	**48.2%**	**48.2%**	**47.8%**	**47.4%**	**47.3%**	**47.1%**	***47.3%***

Source: National Bridge Inventory.

Exhibit 6-16 shows share of bridges classified as poor, by functional class. As was the case for pavement ride quality in *Exhibit 6-14*, a clear pattern is discernable with the higher functional class generally having the lowest share of bridges rated poor. The exceptions are that the share for rural other principal arterial (5.2 percent in 2004, dropping to 3.0 percent in 2014 and 2.8 percent in 2015) has fallen below that for rural Interstates (4.1 percent in 2004, dropping to 3.5 percent in 2014 and 3.2 percent in 2015), while the share for urban other freeway and expressway (5.9 percent in 2004, dropping to 3.3 percent in 2014 and 3.0 percent in 2015) has remained below that for urban Interstates (6.2 percent in 2004, dropping to 3.9 percent in 2014 and 3.7 percent in 2015).

Among all functional classes, the highest share of bridges rated in poor condition was for rural local, though this was reduced from 15.7 percent in 2004 to 13.0 percent in 2014 and 12.6 percent in 2015. The lowest share of bridges rated in poor condition was on rural other principal arterials. The share of bridges rated as poor was consistently higher in rural areas (11.7 percent in 2004, dropping to 9.5 percent in 2014 and 9.2 percent in 2015) than in urban areas (8.4 percent in 2004, dropping to 6.3 percent in 2014 and 6.0 percent in 2015).

Exhibit 6-16: Bridges Rated Poor, by Functional Class, 2004–2015

Functional System	2004	2006	2008	2010	2012	2014	*2015*
	Percent Poor Condition						
Rural							
Interstate	4.1%	4.2%	4.4%	4.5%	4.1%	3.5%	*3.2%*
Other Principal Arterial	5.2%	4.9%	4.7%	4.3%	3.7%	3.0%	*2.8%*
Minor Arterial	7.9%	7.8%	7.7%	7.0%	6.3%	5.7%	*5.4%*
Major Collector	9.8%	9.4%	9.1%	8.8%	8.5%	7.9%	*7.5%*
Minor Collector	11.0%	10.6%	10.5%	10.4%	9.9%	9.4%	*9.2%*
Local	15.7%	14.7%	14.2%	14.0%	13.8%	13.0%	*12.6%*
Subtotal Rural	**11.7%**	**11.1%**	**10.9%**	**10.6%**	**10.2%**	**9.5%**	***9.2%***
Urban							
Interstate	6.2%	5.9%	5.8%	5.4%	4.7%	3.9%	*3.7%*
Other Freeway and Expressway	5.9%	5.7%	5.4%	4.9%	4.2%	3.3%	*3.0%*
Other Principal Arterial	8.9%	8.4%	8.3%	7.9%	7.4%	6.6%	*5.8%*
Minor Arterial	9.6%	9.4%	9.2%	8.7%	8.0%	7.4%	*7.1%*
Collector	10.0%	10.1%	10.0%	9.2%	8.7%	7.9%	*7.4%*
Local	9.8%	9.5%	9.4%	9.1%	8.7%	8.2%	*8.0%*
Subtotal Urban	**8.4%**	**8.2%**	**8.0%**	**7.6%**	**7.0%**	**6.3%**	***6.0%***
Total Poor	**11.0%**	**10.4%**	**10.1%**	**9.8%**	**9.4%**	**8.7%**	***8.3%***

Source: National Bridge Inventory.

Pavement and Bridge Conditions by Owner

Exhibit 6-17 shows pavement ride quality on Federal-aid highways by owner. As referenced in Chapter 1, State highway agencies owned 55.7 percent of Federal-aid highway mileage in 2014, while the Federal government owned 0.8 percent. The remaining 43.5 percent was owned by a combination of local governments and other State agencies.

Exhibit 6-17: Federal-aid Highway Pavement Ride Quality By Owner, Weighted by Lane Miles, 2014

	Federal	State Highway Agencies	Other
Federal-aid Highways[1]			
Good	63.2%	62.9%	27.7%
Fair	28.0%	29.9%	34.7%
Poor	8.8%	7.2%	37.5%

[1] Based on IRI data only, rather than a combination of IRI and PSR data.

Source: HPMS.

Weighted by lane miles, approximately 63.2 percent of federally owned routes on Federal-aid highways were classified as having good ride quality in 2014; the comparable share for State-owned Federal-aid highways was 62.9 percent. The share of Federal-aid lane miles owned by other entities with good ride quality was much lower, at 27.7 percent. Only 7.2 percent of State-owned Federal-aid highway lane miles had poor ride quality in 2014; the comparable shares for Federal and Other were 8.8 percent and 37.5 percent, respectively.

Differences in condition by owner are less dramatic for bridges than for pavements. As shown in *Exhibit 6-18*, bridges owned by local governments had a higher share rated good (47.9 percent) than State-owned

(46.7 percent) or federally owned (47.7 percent) bridges. However, local governments also had a higher share of bridges rated poor (10.8 percent) than at the State (5.8 percent poor) or Federal (7.2 percent poor) levels. The 0.2 percent of bridges that are owned by private entities or for which ownership was not identified in the NBI have considerably lower shares rated good (32.4 percent) and higher shares rated poor (24.8 percent) than bridges owned by Federal, State, or local governments.

Exhibit 6-18: Bridge Conditions, by Owner, 2015[1]

	Federal	State	Local	Private/Other[2]	Total
Percentages					
Percent Owned	1.7%	48.3%	49.8%	0.2%	100.0%
Classified as Good	47.7%	46.7%	47.9%	32.4%	47.3%
Classified as Fair	44.9%	47.6%	41.3%	42.4%	44.4%
Classified as Poor	7.2%	5.8%	10.8%	24.8%	8.3%

[1] These data only reflect bridges for which inspection data were submitted to the NBI.

[2] The National Bridge Inspection Standards apply to all structures defined as highway bridges located on all public roads. Privately-owned bridges are not required to be inspected nor data submitted to FHWA. Inspection data on some privately-owned bridges are provided voluntarily, but there is an unknown number of privately-owned highway bridges for which data are not provided to the NBI.

Source: National Bridge Inventory.

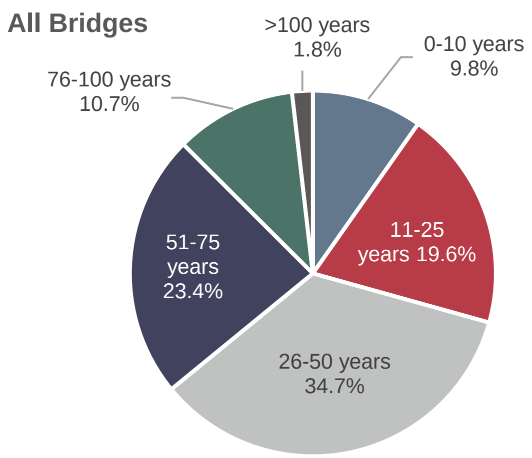
Bridge Conditions by Age

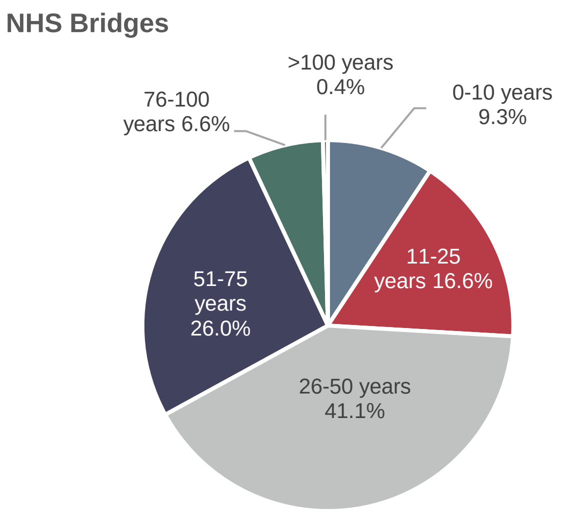
Exhibit 6-19 identifies the age composition of all highway bridges in the Nation. As of 2015, approximately 34.7 percent of the Nation's bridges were between 26 and 50 years old. For NHS bridges, 41.1 percent were in this age range, while 52.1 percent of the Interstate bridges fell into this age range. Approximately 35.9 percent of all bridges are 51 years old or older. The percentages of NHS and Interstate bridges in this group are 33.0 percent and 31.5 percent, respectively.

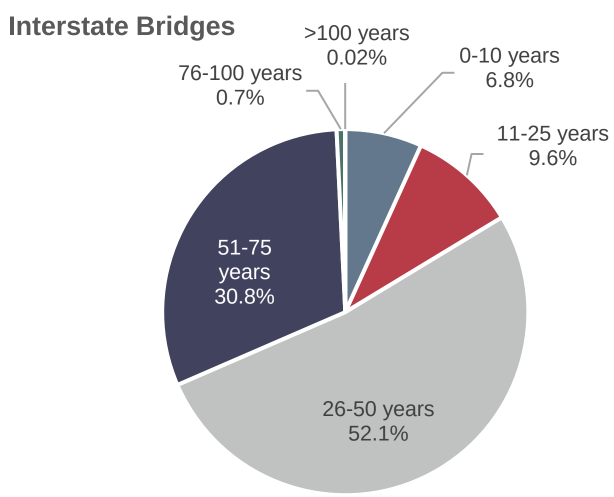
Exhibit 6-20 identifies the distribution of poor condition bridges within the age ranges presented in *Exhibit 6-19*. The percentage of bridges classified as poor generally tends to rise as bridges age. Although only 6.2 percent of bridges in the 26-to-50-year age group are rated as poor, the percentage is 12.8 percent for bridges 51 to 75 years of age and 21.3 percent for bridges 76 to 100 years of age. Similar patterns are evident in the data for NHS and Interstate System bridges, although the overall percentage of poor bridges for these systems is lower than for the national bridge population.

The age of a bridge structure is just one indicator of its serviceability, or condition under which a bridge is still considered useful. A combination of several factors influences the serviceability of a structure, including the original design; the frequency, timeliness, effectiveness, and appropriateness of the maintenance activities implemented over the life of the structure; the loading to which the structure has been subjected during its life; the climate of the area where the structure is located; and any additional stresses from events such as flooding to which the structure has been subjected. As an example, two structures built at the same time using the same design standards and in the same climate can have very different serviceability levels. The first structure might have had increased heavy truck traffic, lack of preventive maintenance of the deck or the substructure, or lack of rehabilitation work. The second structure could have had the same increases in heavy truck traffic but received timely preventive maintenance activities on all parts of the structure and proper rehabilitation activities. In this example, the first structure would have a low serviceability level, while the second structure would have a high serviceability level.

Exhibit 6-19: Bridges by Age, 2015

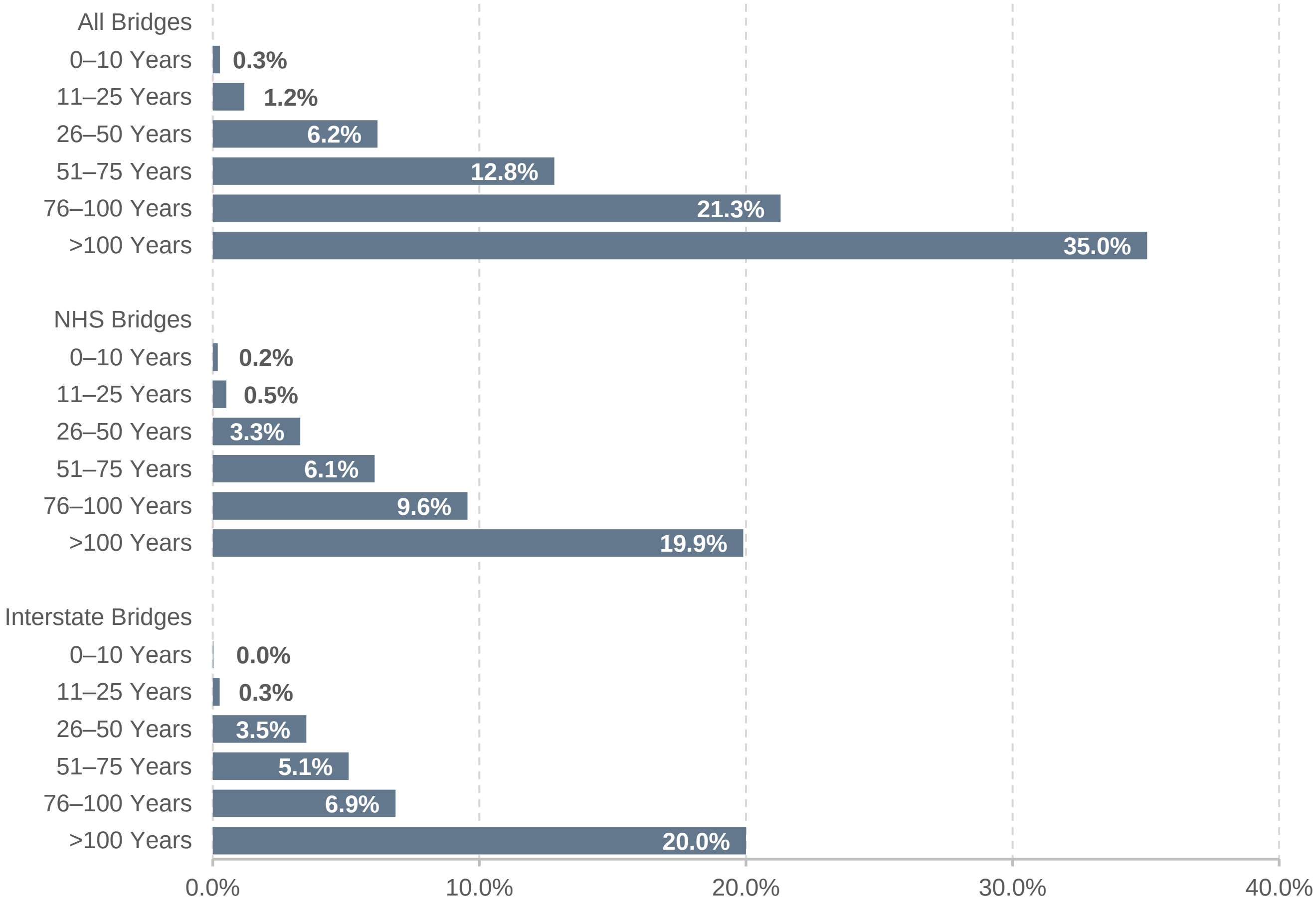






Source: National Bridge Inventory.

Exhibit 6-20: Bridges Rated Poor, by Age, 2015



Source: National Bridge Inventory.

Strategies to Achieve State of Good Repair

Transportation agencies have limited resources—both staff and budgets—when constructing or repairing roads and bridges. This constraint creates the need to work more efficiently and focus on technologies and processes that produce the best results.

Improving project delivery is a high priority for FHWA. Projects that are delivered faster and more efficiently can minimize the disruption to stakeholders that construction causes. Through its Every Day Counts initiative, FHWA is partnering with State departments of transportation and stakeholders to identify and rapidly deploy proven but underutilized innovations to shorten the project delivery process, enhance roadway safety, reduce congestion, and improve environmental sustainability.

The concept is to select projects that improve existing highways and bridges with emphasis on minimizing life-cycle costs. Applying a preservation treatment at the right time (when), on the right project (where), with quality materials and construction (how) is a critical investment strategy for optimizing infrastructure performance.

In addition to preservation actions, new construction techniques—such as ultra-high performance concrete connections for prefabricated bridge elements—can speed construction of a new bridge and result in a higher quality of construction. Planning techniques, such as the Transportation Asset Management Plan (TAMP), can aid in the strategic management of the activities to be undertaken to reach and maintain a state of good repair for all transportation facilities.

Transportation Asset Management Plan (TAMP)

In 2006, the Vermont Agency of Transportation (VTrans) began implementing its "Road to Affordability" initiative, which supported asset management principles of preserving and maintaining existing assets. It directed the agency to focus only on project elements that were functionally necessary to carry out the core purpose of a transportation project. It directed VTrans to keep within project scope and not add elements to a project using State and Federal non-earmark funds.

The Road to Affordability initiative was intended to focus on financial planning and instilling a strategic outlook towards day-to-day management activities. It required VTrans to focus on preservation of existing assets and on traveler safety, to optimize financial resources by focusing on a practical number of large projects, and to set realistic time tables for these projects and for new roadway segments while balancing the funding to reflect a focus on system priorities.

The Road to Affordability initiative was thus driven by asset management priorities. With these requirements, for several years VTrans has been developing an approach that minimizes asset life-cycle cost and extends useful life by "selecting the right treatment, for the right asset, at the right time."

With assistance from FHWA, VTrans conducted a Transportation Asset Management Gap Analysis in 2014 to identify major gaps within the agency for implementing a 10-year TAMP. The agency formed a TAMP Working Group to develop individual plans for various transportation assets. At the time of preparing this report, the agency had expanded this effort to six task force groups focused on developing a knowledge base in several different topic areas, such as customer service levels.

Source: Asset Management Financial Report Series: The Vermont Experience: A Case Study (https://www.fhwa.dot.gov/asset/plans/financial/hif17033.pdf).

Preventive Maintenance Versus Capital Improvements

Highway pavements and bridges are subject to traffic loads and environmental elements that will contribute to their deterioration over time. Preventive maintenance treatments are a tool that can slow this decline. When the right treatment is applied at the right time with quality materials and construction, these practices offer a proven, cost-effective approach to extending the overall service life of pavements and bridges with fewer costly repairs.

Preventive maintenance includes work that is planned and performed to improve or sustain the condition of the transportation facility in a state of good repair. Preventive maintenance activities generally do not add capacity or structural value but do restore or maintain the transportation facility's overall condition.

Benefits of the application of proper and timely application of preservation actions include:

- Economy. Whole-life planning for pavements and bridges defines expectations and risks for the long term and provides more stability to the cost of operating and maintaining pavements and bridges.
- Performance. Identifying preventive maintenance policies and strategies at the network level provides a cost-effective alternative for extending the performance period for pavements and bridges and reducing the need for frequent or unplanned reconstruction.

- Sustainability. A well-defined project strategy that includes preventive maintenance will aid in setting achievable performance targets.
- Flexibility. Retaining a mix of successful treatments in the preventive maintenance toolbox provides agencies greater flexibility in placing the right treatment on the right pavement or bridge at the right time.
- Savings. Improved performance and fewer failures keep a pavement and bridge network in a state of good repair at a lower cost.

In contrast, capital improvement projects involve work to improve the structural condition of the pavement or bridge. The benefit of this approach is a return of the pavement or bridge to a state of good repair through reconstruction or a major improvement through major rehabilitation work. Capital improvement is usually undertaken when a pavement or bridge cannot continue to meet the needs of the transportation network due to excessive deterioration or due to a lack of capacity. It is a more costly and time-consuming alternative than preservation.

Ultra-High Performance Concrete Connections for PBES

Prefabricated bridge elements (PBES) are structural components of a bridge that are built offsite, then brought, ready to erect, to the project location. PBES not only shorten onsite construction time—minimizing traffic impacts and increasing traveler and worker safety—but also offer superior durability.

The durability of prefabricated spans, and how quickly they can be constructed, relies on the connections between the elements. Field-cast Ultra-High Performance Concrete (UHPC) has emerged as a solution for creating connections between prefabricated concrete components with more robust long-term performance than conventional PBES connection designs.

UHPC is a steel fiber-reinforced, Portland cement-based, advanced composite material that delivers performance far exceeding conventional concrete. As UHPC performance exceeds that normally predicted from a field-cast connection, it allows the behavior of the joined prefabricated components to surpass that of conventional construction.

Compared with many solutions in current use, UHPC allows for small, simple-to-construct connections that require less volume of field-cast concrete and do not require post-tensioning. The mechanical properties of UHPC also allow for redesign of common connection details in ways that promote both ease and speed of construction. This makes using PBES simpler and more effective.

Benefits

- **Speed.** The mechanical properties of UHPC allow for redesign of common connection details in ways that promote both ease and speed of construction.
- **Simplicity.** UHPC connections are inherently less congested, simplifying fabrication and assembly.
- **Performance.** Field-cast UHPC between PBES results in robust connections that can provide better long-term performance than connections constructed by conventional methods.

Source: (https://www.fhwa.dot.gov/innovation/everydaycounts/edc_4/uhpc.cfm).

Pavement Preventive Maintenance

Pavement preventive maintenance is one of the strategies to maintain roadways in a state of good repair. Pavements deteriorate as a result of many different forces, but the predominant factors affecting pavement performance are the vehicle loads and environmental elements to which pavements are exposed over their lifetime. Today, most highway agencies accept that an effective pavement preventive maintenance program will slow the rate of pavement deterioration while also providing a safer, smoother ride to the traveling public. Pavement preventive maintenance programs based on the 3Rs—right treatment, right pavement, and right time—have been proven to extend pavement life while saving money.

The program Every Day Counts-4 is promoting quality construction and materials practices that apply to both flexible and rigid pavements. For flexible pavements, these include using improved specifications for thin asphalt surfacings, such as chip seals, scrub seals, slurry seals, microsurfacing, and ultrathin bonded wearing courses; following improved construction practices; and using the right equipment to place these treatments. Rigid pavement strategies include the rapid retrofitting of dowel bars to reduce future faulting; the use of new, fast-setting partial- and full-depth patching materials to create a long-lasting surface; advanced pavement removal techniques to accelerate patching construction times; and advancements in diamond grinding that contribute to smoother and quieter pavement surfaces with enhanced friction.

Data Sources

Pavement condition data are reported to FHWA through the HPMS. The HPMS requires reporting for Federal-aid highways only, which represent about a quarter of the Nation's road mileage but carry approximately five-sixths of the Nation's travel. States are not required to report detailed data on roads functionally classified as rural minor collectors, rural local, or urban local, which make up the remaining three-quarters of the Nation's road mileage.

HPMS contains data on multiple types of pavement distresses. Data on pavement roughness are used to assess the quality of the ride that highway users experience. For some functional systems, States can report a general Pavement Serviceability Rating value in place of an actual measurement of pavement roughness through the IRI. Other measures of pavement distress include pavement cracking, pavement rutting (surface depressions in the vehicle wheel path, generally relevant only to asphalt pavements), and pavement faulting (the vertical displacement between adjacent jointed sections on concrete pavements).

Bridge condition data are reported to FHWA through the NBI, which reflects information gathered by States, Federal agencies, and Tribal governments during their safety inspections of bridges. Most inspections occur once every 24 months. If a structure shows advanced deterioration, the frequency of inspections might increase so that the structure can be monitored more closely. Based on certain criteria, structures that are in satisfactory or better condition may be inspected between 24 and 48 months with prior FHWA approval. Approximately 83 percent of bridges are inspected every 24 months, 12 percent every 12 months, and 5 percent on a maximum 48-month cycle.

Bridge inspectors are trained to inspect bridges based on, as a minimum, the criteria in the National Bridge Inspection Standards. Inspections are required for all 611,845 bridges and culverts with spans of more than 20 feet located on public roads.

The NBI database contains condition classifications on the three primary components of a bridge: deck, superstructure, and substructure. The bridge deck is the surface on which vehicles travel and is supported by the superstructure. The superstructure transfers the load of the deck and bridge traffic to the substructure, which provides support for the entire bridge. Such classifications are not reported for the 135,810 culverts represented in the NBI, as culverts are self-contained units typically located under roadway fill, and thus do not have a deck, superstructure, or substructure. As a result, they are assigned a separate culvert rating.

Bridge Element Data

FHWA has required bridge owners to collect and report bridge condition information since the 1970s. The condition information has been in the form of general condition ratings in which a single numeric rating is assigned to the three primary components of a bridge: deck, superstructure, and substructure, or in the case of culverts, a single numeric rating is assigned to the culvert. While this rating system provides information that is valuable for categorizing the overall condition of a bridge and making high-level assessments of needs, it does not provide information on the extent and type of deterioration. Element condition data provide this information, which is valuable for refined condition and needs assessment.

Whereas there are four unique bridge components, there are more than one hundred standard bridge elements of unique type. There are element categories for decks, slabs, railings, girders, stringers, trusses, arches, floor beams, bearings, columns, piers, abutments, piles, pier caps, footings, culverts, deck joints, wearing surfaces, protective coatings, and approach slabs. Within each of these categories, there are different elements defined by the type of design and material. Therefore, element data describe the structural and protective systems that constitute a bridge. Element data collection requires identifying all unique elements present on a bridge, quantifying the size of each element in terms of square feet, linear feet, or each, and distributing the quantity among four condition states. In addition, the quantity within each condition state can be distributed among different defect types. Therefore, element data better quantify the severity, extent, and type of deterioration that supports data-driven needs assessment. The element data recording methodology and definitions are provided in the AASHTO Manual for Bridge Element Inspection.

Many States and Federal agencies have been collecting element data since the 1990s. Recognizing the value of element data, MAP-21 included a requirement that element data be collected for bridges on the NHS. These data are now reported to FHWA.

Improving the Resilience of the Nation’s Transportation System

Weather events present significant risks to the safety, reliability, and sustainability of the Nation’s transportation infrastructure and operations and can affect the life cycle of transportation systems. Storm surges can inundate coastal roads, necessitate more emergency evacuations, and require costly (and sometimes recurring) repairs to damaged infrastructure. Inland flooding can disrupt traffic, damage culverts, and reduce service life. High heat can degrade materials, resulting in shorter replacement cycles and higher maintenance costs.

Given the long life span of transportation assets, planning for system preservation and safe operation under current and future conditions constitutes responsible risk management. The FAST Act expands the scope of the metropolitan planning process to “improve the resiliency and reliability of the transportation system.” It also requires that metropolitan transportation plans contain strategies that “reduce the vulnerability of the existing transportation infrastructure to natural disasters.”

Post-Hurricane Sandy Transportation Resilience Study in NY, NJ, and CT

Hurricane Sandy hit portions of the northeastern United States in October 2012. The storm was the largest Atlantic hurricane on record, as measured by diameter, with hurricane-force winds spanning 1,100 miles (1,770 kilometers). The hurricane caused significant loss of life as well as tremendous destruction of property and critical infrastructure.

In the aftermath of the storm, and building on one of FHWA's 2011 pilot projects in New Jersey, FHWA initiated the multimodal Post-Hurricane Sandy Transportation Resilience Study in New York, New Jersey, and Connecticut. The study involved a large number of stakeholders, including State department of transportation and MPO partners in the three states.

The study leveraged lessons learned from Hurricane Sandy and other recent storms, as well as future projections, to develop feasible, cost-effective strategies to reduce and manage extreme weather vulnerabilities. The transportation agencies chose 10 regionally significant facilities—ranging from roads to bridges, rail, and ports—for engineering-informed adaptation assessments. The study used results from the storm damage assessments and the engineering-based adaptation assessments to inform a multimodal transportation vulnerability and risk assessment for the region, as well as adaptation strategies for three critical subareas.

For more information see (https://www.fhwa.dot.gov/environment/sustainability/resilience/ongoing_and_current_research/hurricane_sandy/).

The final report was published in October 2017.

For the statewide transportation planning process, the FAST Act expands the scope of consideration to include projects, strategies, and services that will improve the resilience and reliability of the transportation system. The Moving Ahead for Progress in the 21st Century Act (MAP-21) requires States to develop risk-based asset management plans for the National Highway System. On October 24, 2016, FHWA published a notice of final rulemaking in the Federal Register describing the process for developing these State risk-based asset management plans.

Transit Infrastructure Conditions

This section reports on the quantity, age, and physical condition of transit assets, which are factors that determine how well the infrastructure can support an agency's objectives and set a foundation for consistent measurement. Transit assets include vehicles, stations, guideway elements, track, rail yards, administrative facilities, maintenance facilities, maintenance equipment, power systems, signaling systems, communication systems, and structures that carry elevated or subterranean guideways. Chapter 4 addresses issues relating to the operational performance of transit systems.

FTA uses a numerical rating scale ranging from 1 to 5, detailed in *Exhibit 6-21*, to describe the relative condition of transit assets. A rating of 4.8 to 5.0, or "excellent," indicates that the asset is in nearly new condition or lacks visible defects. The midpoint of the "marginal" rating (2.5) is the threshold below which the assets are considered not in a state of good repair (SGR). At the other end of the scale, a rating of 1.0 to 1.9, or "poor," indicates that the asset needs immediate repair and does not support satisfactory transit service.

FTA uses the Transit Economic Requirements Model (TERM) to estimate the condition of transit assets for this report. This model consists of a database of transit assets and deterioration schedules that express asset conditions principally as a function of an asset's age. Vehicle condition is based on the vehicle's maintenance history and an estimate of the major rehabilitation expenditures, in addition to vehicle age. The conditions of wayside control systems and track are based on an estimate of use (revenue miles per mile of track) in addition to age. For the purposes of this report, SGR is defined using TERM's numerical condition rating scale. Specifically, this report considers an asset to be in SGR when the physical condition of that asset is at or above a condition rating value of 2.5 (the midpoint of the marginal range). An entire transit system would be in SGR if all of its assets have an estimated condition value of 2.5 or higher. The SGR benchmark presented in Chapter 8 represents the level of investment required to attain and maintain this definition of SGR by rehabilitating or replacing all assets having estimated condition ratings that are less than this minimum condition value.

Key Takeaways

- The total replacement value of transit assets was $894 billion in 2014, of which $287 billion (32 percent) was represented by nonreplaceable assets.
- Over 50 percent of the assets by replacement value were guideway elements.
- The backlog in 2014 was $98.0 billion. Systems and stations accounted for approximately 40 percent. Guideway elements accounted for only 5 percent, even though they accounted for over 50 percent of replacement value. Nearly all guideway assets are nonreplaceable; only corrective maintenance activities are carried out for these assets to bring them back to SGR. The associated costs are very small compared with the replacement value.
- The share of vehicles below the state of good repair (SGR) condition increased for all nonrail transit vehicles. In 2004, 15 percent of vehicles were not in SGR. In 2014, the share increased to 19 percent.
- For rail, the share of assets not in SGR decreased from 4.1 percent in 2004 to 3.1 percent in 2014.
- The average fleet age of all buses was 6.3 years in 2014, up from 6.1 years in 2004.
- The average fleet age of rail vehicles remained stable at 19.3 years.

Exhibit 6-21: Definitions of Transit Asset Conditions

Rating	Condition	Description
Excellent	4.8–5.0	No visible defects, near-new condition.
Good	4.0–4.7	Some slightly defective or deteriorated components.
Adequate	3.0–3.9	Moderately defective or deteriorated components.
Marginal	2.0–2.9	Defective or deteriorated components in need of replacement.
Poor	1.0–1.9	Seriously damaged components in need of immediate repair.

Source: Transit Economic Requirements Model.

In 2012, the Moving Ahead for Progress in the 21st Century Act (MAP-21) directed FTA to develop a transit asset management (TAM) rule to establish a strategic and systematic process of operating, maintaining, and improving public transportation capital assets effectively through their entire life cycle. TAM is a business model that prioritizes funding based on the condition of transit assets, to achieve or maintain transit networks in SGR.

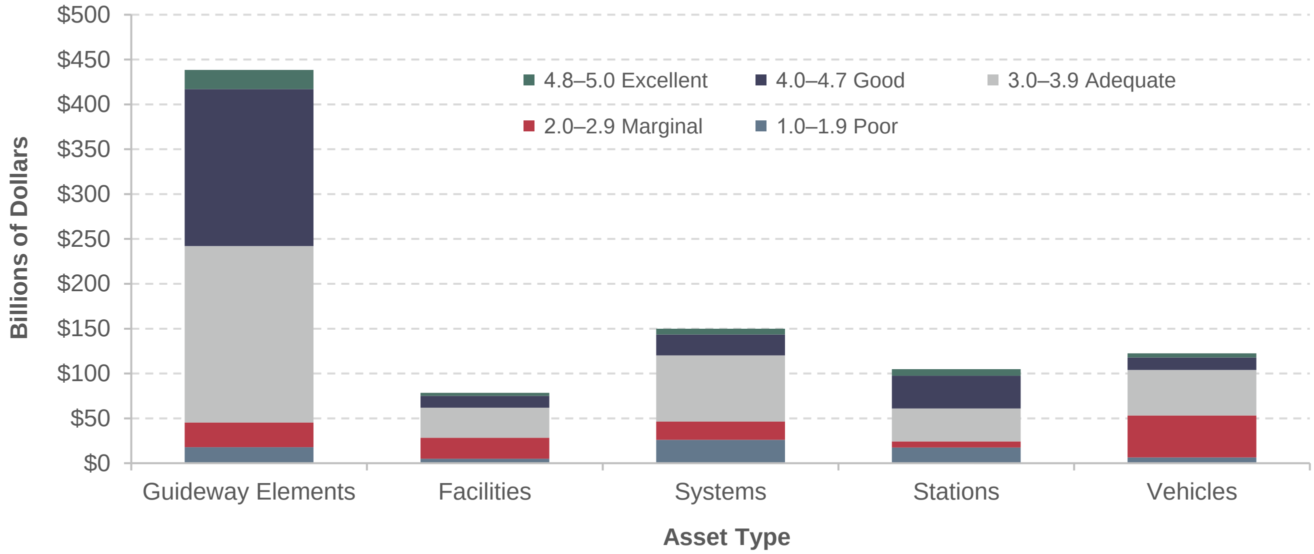
FTA has estimated typical deterioration schedules for vehicles, maintenance facilities, stations, train control systems, electric power systems, and communication systems through special on-site engineering surveys. Transit vehicle conditions also reflect the most recent information on vehicle age, use, and level of maintenance from the National Transit Database (NTD); the information used in this edition of the C&P Report is from 2014. Age information for all other assets is collected through special surveys. Average maintenance expenditures and major rehabilitation expenditures for vehicles are also available on a modal basis. When calculating conditions, FTA assumes that agency maintenance and rehabilitation expenditures for a particular mode are the same average value for all vehicles the agency operates in that mode. Because agency maintenance expenditures can fluctuate from year to year, TERM uses a 5-year average.

The deterioration schedules applied for track and guideway structures are based on special studies. Appendix C presents a discussion on the methods used to calculate deterioration schedules and the sources of data on which deterioration schedules are based.

Condition estimates in each edition of the C&P Report are based on up-to-date asset inventory information that reflects updates in TERM's asset inventory data. Annual data from NTD were used to update asset records for the Nation's transit vehicle fleets. In addition, updated asset inventory data were collected from 30 of the Nation's largest rail and fixed-route bus transit agencies to support analysis of nonvehicle needs. Because these data are not collected annually, it is not possible to provide accurate time-series analysis of nonvehicle assets. FTA is working to develop improved data in this area. Appendix C provides a more detailed discussion of TERM's data sources. *Exhibit 6-22* shows the distribution of asset conditions, by replacement value, across major asset categories for the entire U.S. transit industry.

Condition estimates for assets are weighted by the replacement value of each asset. This weighting accounts for the fact that assets vary substantially in replacement value. For example, a $1 million railcar in poor condition is a much bigger problem than a $1,000 turnstile in similar condition. To illustrate the calculation involved, the cost-weighted average of a $100 asset in condition 2.0 and a $50 asset in condition 4.0 would be (100×2.0+50×4.0)/(100+50)=2.67. The unweighted average would be (2+4)/2=3.

Exhibit 6-22: Distribution of Asset Physical Conditions by Asset Type for All Modes



Note: Includes both replaceable assets, which should be replaced once they are below condition 2.5, and nonreplaceable assets, which should be rehabilitated once they are below condition 2.5.

Source: Transit Economic Requirements Model (TERM) and National Transit Database.

The Replacement Value of U.S. Transit Assets

The total value of the transit infrastructure in the United States for 2014 was estimated at $894.2 billion (in 2014 dollars). These estimates, presented in *Exhibit 6-23*, are based on asset inventory information in TERM. They exclude the value of assets belonging to special service operators that do not report to NTD. Rail assets totaled $786.4 billion, or roughly 86 percent of all transit assets. Nonrail assets were estimated at $107.8 billion. Joint assets totaled $14.7 billion; these are assets that serve more than one mode within a single agency and can include administrative facilities, intermodal transfer centers, agency communications systems (e.g., telephone, radios, and computer networks), and vehicles used by agency management (e.g., vans and automobiles).

Note that U.S. transit asset holdings can be further broken out into replaceable vs nonreplaceable assets, with the two types of assets accounting for roughly 62 percent and 38 percent of all transit assets by value, respectively. Replaceable assets have an expected useful service life, after which the asset will require replacement. Many types of replaceable assets also require one or more rehabilitations throughout their life to ensure their full service life is attained. In contrast, nonreplaceable assets, such as subway tunnels and historic rail cars, are expected to remain in service indefinitely and hence have no planned date of retirement. For needs-assessment purposes, these assets are treated as having an infinite service life. However, all nonreplaceable assets do require periodic—in some cases annual—rehabilitation investments to maintain them in SGR. Estimates of deferred maintenance and deferred rehabilitation of nonreplaceable assets are counted toward the SGR backlog.

How Does TERM Handle Non-replaceable Assets?

The model for decay curves in TERM is designed to include four factors: age, reliability, annual maintenance expense, and annual capital investment. However, the current implementation of TERM includes only age as the sole factor for estimation of condition. The condition of non-replaceable assets is only loosely correlated to age; therefore, applying decay curves based only on age does not adequately predict their condition. Annual maintenance and capital replacement are the key factors determining condition of non-replaceable assets.

TERM invests in annual maintenance costs for non-replaceable assets. However, these investments have no effect on asset condition since the decay curves in TERM are determined solely by age. Thus, the condition of non-replaceable assets keeps decaying past the SGR threshold as the asset ages. To avoid artificially lowering the aggregate average condition ratings, non-replaceable assets are excluded from the condition statistics presented in this report.

Examples of non-replaceable assets include:

- tunnels, subway platforms and underground stations;
- bridges, viaducts, elevated walkways; and
- historic vehicles such as cable cars and vintage trolleybuses.

Note that if more granular data were available for components of non-replaceable assets such as tunnels, some of these components could be modeled as replaceable assets.

Exhibit 6-23: Estimated Value of the Nation's Transit Assets, 2014

	Value (in Billions of 2014 Dollars)			
Transit Asset	**Nonrail**	**Rail**	**Joint Assets**	**Total**
Replaceable Assets				
Maintenance Facilities	$39.0	$31.3	$8.2	**$78.4**
Guideway Elements	$3.8	$147.7	$0.0	**$151.5**
Stations	$4.3	$50.3	$0.8	**$55.4**
Systems	$5.1	$141.0	$3.9	**$150.0**
Vehicles	$51.7	$68.9	$1.3	**$121.9**
Total: Replaceable Assets	**$103.8**	**$439.2**	**$14.2**	**$557.2**
Non-Replaceable Assets				
Guideway Elements	$3.5	$282.9	$0.5	**$286.9**
Stations	$0.0	$49.4	$0.0	**$49.4**
Vehicles	$0.4	$0.2	$0.0	**$0.6**
Total: Non-Replaceable Assets	**$3.9**	**$332.6**	**$0.5**	**$337.0**
Total: All Assets	**$107.7**	**$771.8**	**$14.7**	**$894.2**

Note: The value of the asset is based on an estimated replacement value, including for assets that are estimated to be nonreplaceable.
Source: Transit Economic Requirements Model (TERM).

Transit Road Vehicles (Urban and Rural Areas)

Bus vehicle age and condition are reported by vehicle type for 2004 to 2014 in *Exhibit 6-24*. Fleet count figures since 2008 reflect the number of transit buses in both urban and rural areas. When measured across all vehicle types, the average age of the Nation’s bus fleet remained essentially unchanged, at approximately 6 years, from

2004 through 2014. Similarly, the average condition rating for all bus types (calculated as the weighted average of bus asset conditions, weighted by asset replacement value) stayed relatively constant, remaining near the bottom of the adequate range over the 10-year period. The percentage of vehicles below the SGR replacement threshold (condition level 2.5) was about 15 percent over this same period. Although this observation holds true across all vehicle types, the percentage of full-size buses (the vehicle type that supports most fixed-route bus services) below the SGR replacement threshold increased from 10.4 percent in 2012 to 16.0 percent in 2014.

The Nation's transit road vehicle fleet has grown at an average annual rate of roughly 3 percent since 2004, with most of this growth concentrated in two vehicle types: cutaways and vans. The large increase in the number of vans reflects both the needs of an aging population (paratransit services) and an increase in the popularity of vanpool services. In contrast, the number of full- and medium-sized buses has remained relatively flat since 2004.

Exhibit 6-25 presents the age distribution of the Nation's transit buses, and *Exhibit 6-26* presents the age distribution of the Nation's transit vans, minivans, and autos. Note that full-size buses and vans account for the highest proportion (roughly 49 percent) of the Nation's rubber-tire transit vehicles. Although most vans are retired by age 8 and most buses by age 15, roughly 5 to 20 percent of these fleets remain in service well after their typical retirement ages.

Exhibit 6-24: Transit Bus Fleet Count, Age, and Condition, 2004–2014

	2004	2006	2008	2010	2012	2014
Articulated Buses						
Fleet Count	3,363	3,422	3,900	4,654	4,836	5,373
Average Age (Years)	5.3	5.4	6.3	6.6	7.0	7.2
Average Condition Rating	3.5	3.3	3.2	3.2	3.2	3.2
Below Condition 2.5 (Percent)	6.6%	2.5%	1.4%	2.9%	1.7%	13.8%
Full-Size Buses						
Fleet Count	45,539	44,866	45,999	45,783	45,314	45,717
Average Age (Years)	7.3	7.4	7.9	7.8	8.0	8.4
Average Condition Rating	3.2	3.1	3.1	3.1	3.1	3.0
Below Condition 2.5 (Percent)	14.5%	11.0%	11.6%	11.0%	10.4%	16.0%
Mid-Size Buses						
Fleet Count	7,080	6,875	7,577	8,169	7,615	7,753
Average Age (Years)	8.1	8.1	8.2	7.9	7.3	7.6
Average Condition Rating	3.1	3.0	3.0	3.1	3.2	3.1
Below Condition 2.50 (Percent)	17.7%	17.0%	14.4%	14.3%	11.2%	10.3%
Small Buses						
Fleet Count	6,868	7,539	8,689	8,743	8,434	8,267
Average Age (Years)	5.5	6.1	6.5	6.7	6.7	7.1
Average Condition Rating	3.3	3.2	3.1	3.1	3.1	3.0
Below Condition 2.5 (Percent)	12.0%	11.4%	15.8%	18.4%	19.6%	22.7%
Cutaways						
Fleet Count	8,481	9,427	19,477	23,268	26,983	26,753
Average Age (Years)	4.2	4.3	4.6	4.1	4.4	4.8
Average Condition Rating	3.5	3.5	3.4	3.6	3.4	3.3
Below Condition 2.5 (Percent)	13.7%	13.0%	18.6%	16.4%	15.4%	16.7%

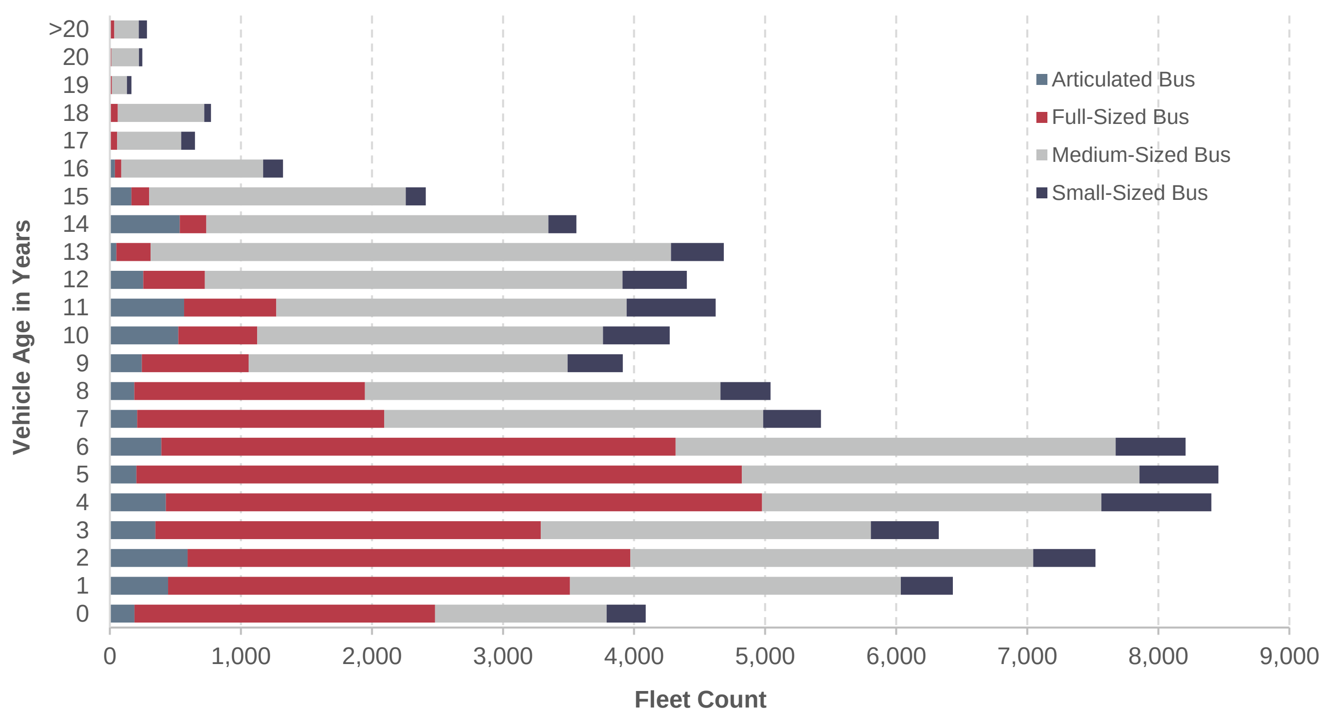
	2004	2006	2008	2010	2012	2014
Subtotal: Bus						
Total Fleet Count	71,331	72,129	85,642	90,617	93,182	93,863
Weighted Average Age (Years)	6.7	6.8	7.0	6.7	6.7	7.1
Weighted Average Condition Rating	3.2	3.2	3.2	3.2	3.2	3.1
Below Condition 2.5 (Percent)	14.1%	11.5%	13.4%	13.0%	12.3%	16.2%
Vans						
Fleet Count	17,698	20,714	28,846	30,650	28,759	29,207
Average Age (Years)	3.4	3.2	3.7	3.6	3.8	3.8
Average Condition Rating	3.4	3.5	3.4	3.4	3.3	3.3
Below Condition 2.5 (Percent)	18.9%	19.1%	25.3%	20.8%	25.7%	27.2%
Total: Bus and Van						
Total Fleet Count	89,029	92,843	114,488	121,267	121,941	123,070
Weighted Average Age (Years)	6.1	6.0	6.1	5.9	6.0	6.3
Weighted Average Condition Rating	3.3	3.2	3.2	3.3	3.2	3.2
Below Condition 2.5 (Percent)	15.1%	13.2%	16.4%	15.0%	15.5%	18.8%

Note: Table excludes NTD records with no Date Built values.

Note: Rural fleet not included in period 2004–2007 due to lack of data.

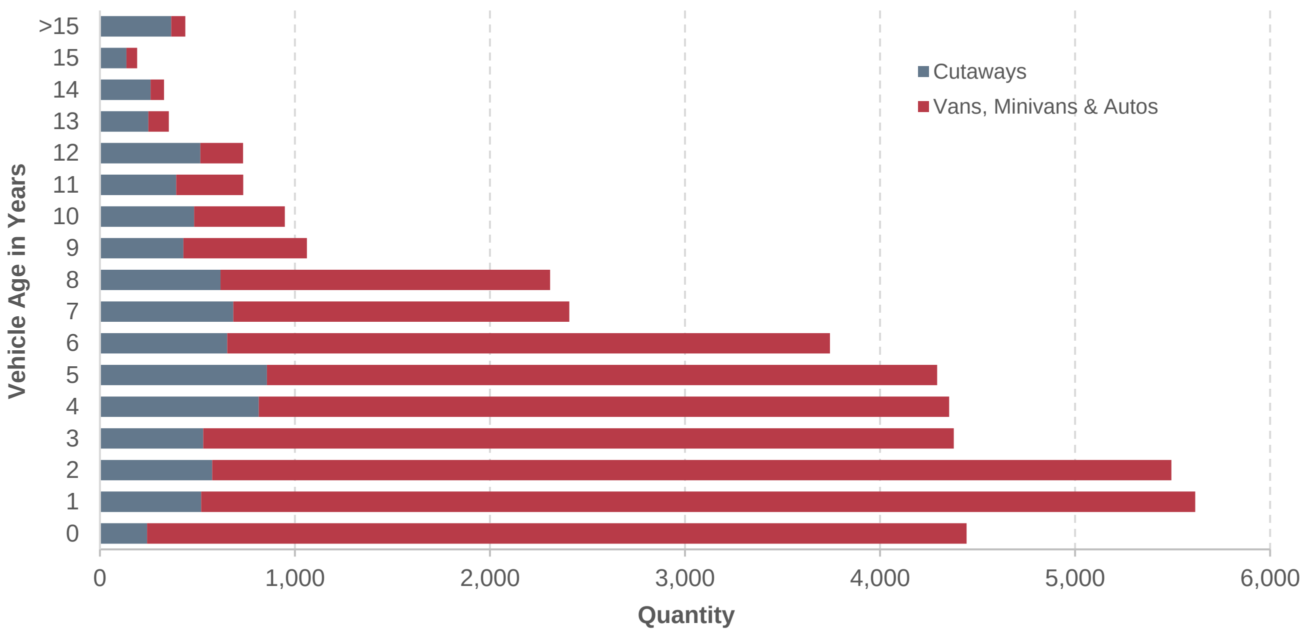
Sources: Transit Economic Requirements Model (TERM); National Transit Database.

Exhibit 6-25: Age Distribution of Fixed-Route Buses, 2014



Source: Transit Economic Requirements Model (TERM) and National Transit Database.

Exhibit 6-26: Age Distribution of Vans, Minivans, Autos, and Cutaways, 2014



Source: Transit Economic Requirements Model (TERM) and National Transit Database.

Note that the share of the bus fleet with an average age below their expected average useful life (*Exhibit 6-25)* was quite high in 2014. Most of the buses in the national fleet were 8 years old or less.

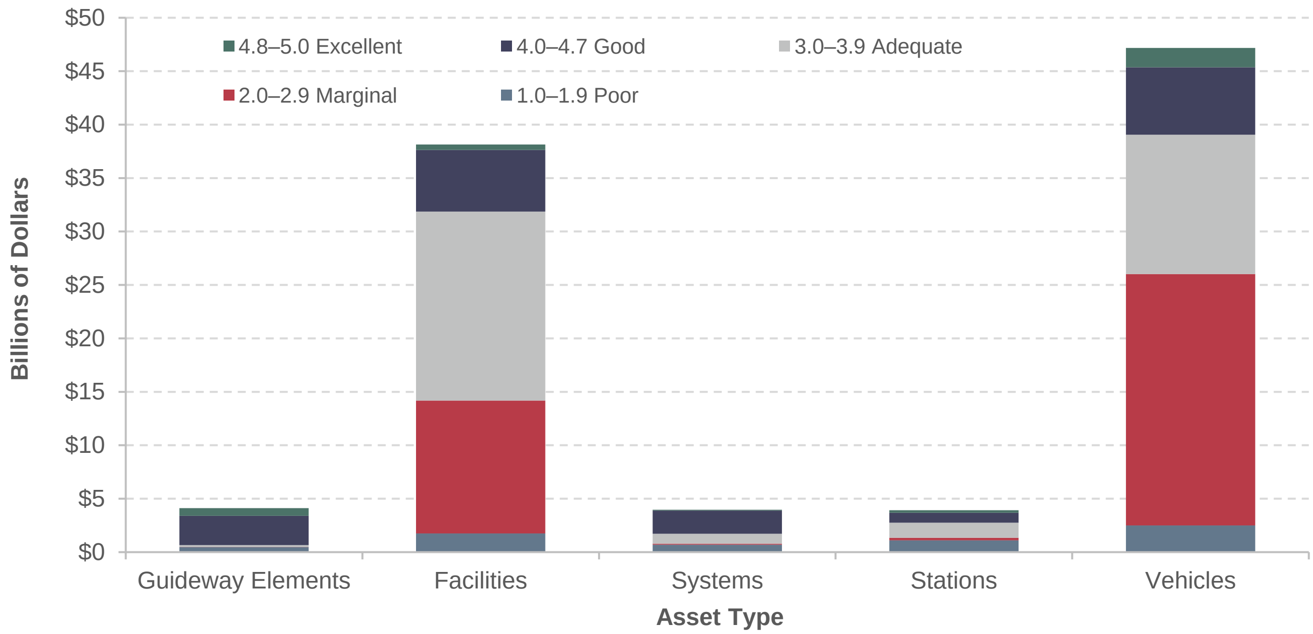
Cutaway, Small, and Mid-sized Buses

A distinction should be made between cutaway, small, and mid-sized buses. By definition, small buses are vehicles between 28 and 32 feet long, operating mostly as fixed-route. Cutaways are buses less than 28 feet in length, operating mostly in demand-response service. Mid-size buses are vehicles between 32 and 38 feet long.

Other Bus Assets (Urban and Rural Areas)

The more comprehensive capital asset data described above enable reporting of a more complete picture of the overall condition of bus-related assets. *Exhibit 6-27* shows TERM estimates of current conditions for the major categories of fixed-route bus assets. Vehicles comprise roughly half of all fixed-route bus assets, and maintenance facilities make up roughly one-third. Roughly one-third of bus maintenance facilities are rated below condition 3.0, compared to roughly one-half for bus, paratransit, and vanpool vehicles.

Exhibit 6-27: Distribution of Estimated Asset Conditions by Asset Type for Fixed-Route Bus



Source: Transit Economic Requirements Model (TERM).

Rail Vehicles

NTD compiles annual data on all rail vehicles; these data are shown in *Exhibit 6-28*, broken down by major category. Measured across all rail vehicle types, the average age of the Nation's rail fleet has remained essentially unchanged, between 19 and 20 years old, since 2004. The average condition of all rail vehicle types (calculated as the weighted average of vehicle conditions, weighted by vehicle replacement cost) is also relatively unchanged, remaining near 3.5 since 2004. The percentage of vehicles below the SGR replacement threshold (condition 2.5) has remained between 2.8 and 4.2 percent since 2004. Note that, although this observation holds across all vehicle types, the analysis suggests that most vehicles in lesser condition occur in the light and heavy rail fleets. Moreover, most light rail vehicles with an estimated condition of less than 2.5 are historic streetcars and trolley cars with an average age of 75 years. Given their historic vehicle status, the estimated condition of these vehicles (determined primarily by age) should be viewed as a rough approximation, relative to all other reported rail vehicles.

Exhibit 6-28: Rail Fleet Count, Age, and Condition, 2004–2014

	2004	2006	2008	2010	2012	2014
Commuter Rail Locomotives						
Fleet Count	710	740	790	822	877	898
Average Age (Years)	17.8	16.7	19.6	19.4	17.8	19.5
Average Condition Rating	3.7	4.0	3.6	3.6	3.7	3.7
Below Condition 2.50 (Percent)	0.0%	0.0%	0.0%	0.0%	1.8%	1.8%
Commuter Rail Passenger Coaches						
Fleet Count	3,513	3,671	3,539	3,711	3,758	3,742
Average Age (Years)	17.7	16.8	19.9	19.1	20.2	18.9
Average Condition Rating	3.8	4.1	3.6	3.7	3.6	3.6
Below Condition 2.50 (Percent)	0.0%	0.0%	0.0%	0.0%	0.4%	4.7%
Commuter Rail Self-Propelled Passenger Coaches						
Fleet Count	2,470	2,933	2,665	2,659	2,930	2,945
Average Age (Years)	23.6	14.7	18.9	19.7	19.7	17.5
Average Condition Rating	3.7	3.8	3.7	3.7	3.6	3.7
Below Condition 2.50 (Percent)	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Heavy Rail						
Fleet Count	11,046	11,075	11,570	11,648	11,587	11,859
Average Age (Years)	19.8	22.3	21.0	18.8	19.9	20.7
Average Condition Rating	3.4	3.3	3.3	3.4	3.4	3.4
Below Condition 2.50 (Percent)	5.6%	5.5%	6.1%	5.2%	3.7%	11.4%
Light Rail[1]						
Fleet Count	1,884	1,832	2,151	2,222	2,241	2,416
Average Age (Years)	16.5	14.6	17.1	18.1	14.6	17.8
Average Condition Rating	3.6	3.7	3.6	3.5	3.6	3.5
Below Condition 2.50 (Percent)	9.3%	6.4%	7.1%	6.9%	6.3%	2.8%
Total Rail						
Total Fleet Count	19,623	20,251	20,715	21,062	21,393	21,860
Weighted Average Age (Years)	19.5	19.3	20.1	18.9	19.3	19.6
Weighted Average Condition Rating	3.5	3.6	3.5	3.5	3.5	3.5
Below Condition 2.50 (Percent)	4.1%	3.6%	4.2%	3.6%	2.8%	3.1%

[1] Excludes vintage streetcars.

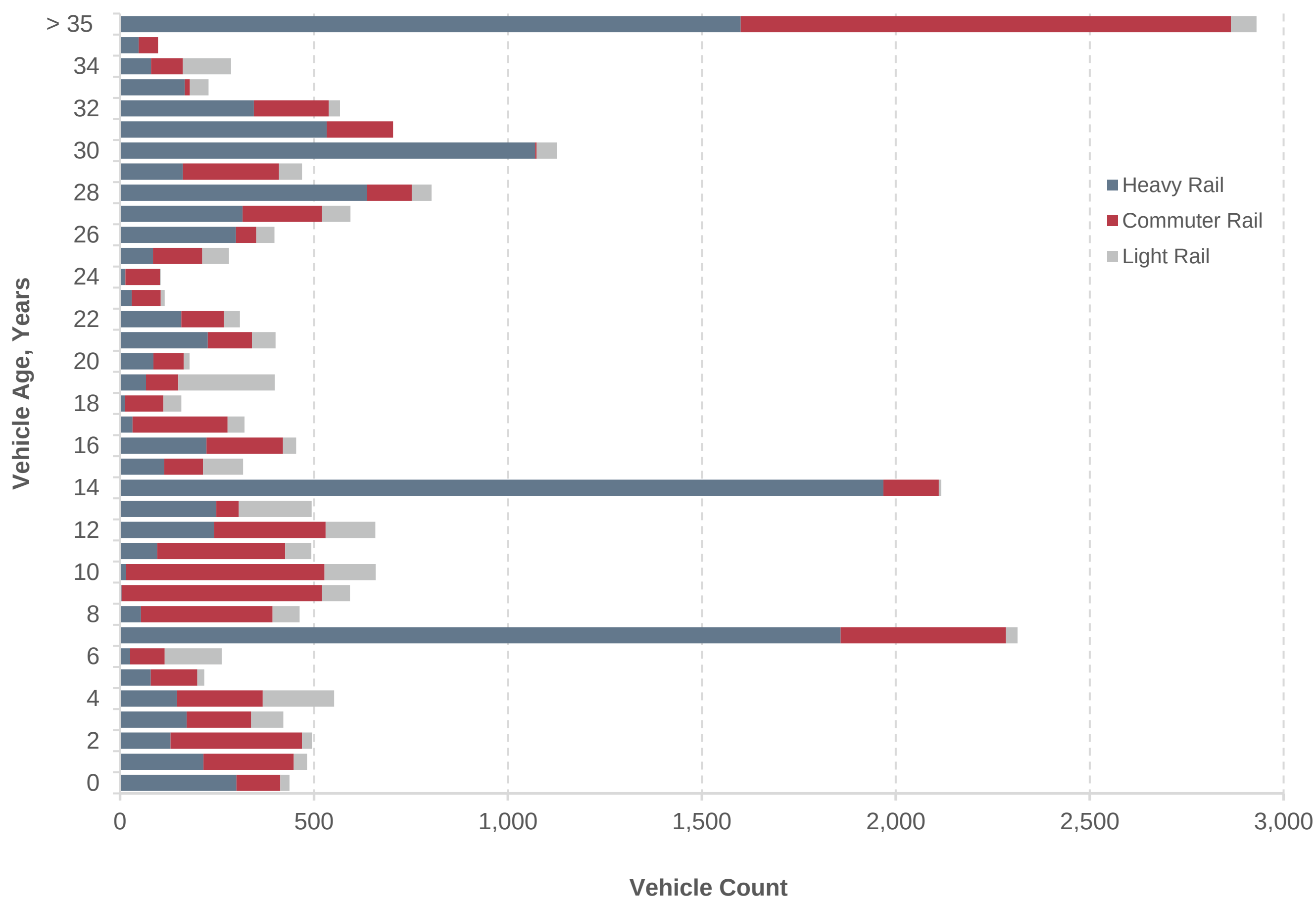
Source: Transit Economic Requirements Model and National Transit Database.

From 2004 to 2014, the Nation's rail transit fleet grew at an average annual rate of roughly 1.8 percent. This rate of growth was due largely to the rate of increase in the heavy rail fleet (which represents slightly more than half the total fleet and grew at an average annual rate of 1.4 percent over this period). In contrast, the annual rate of increase in commuter rail locomotive and commuter rail self-propelled passenger coach fleets has been appreciably higher, averaging approximately 3.4 percent and 3.1 percent, respectively, while accounting for only 4 and 13 percent of the total fleet count during the 10-year period. The higher growth rates for these rail transit types may again reflect recent rail transit investments in small and medium-sized urban areas where the size and population density do not justify the greater investment needed for heavy rail construction.

Exhibit 6-29 presents the age distribution of the Nation's heavy rail, light rail, and commuter rail transit vehicles. Heavy rail vehicles account for more than half the Nation's rail fleet, whereas light rail, a mode more frequently found in smaller rail markets, accounts for only 11 percent of rail vehicles. Roughly one-third of heavy rail and commuter rail vehicles are more than 25 years old—with close to 3,000 heavy and commuter rail vehicles exceeding 35 years in age. Just under half (49 percent) of all rail vehicles, including 51 percent of commuter rail vehicles and 57 percent of heavy rail vehicles, are located in the greater New York City area (which includes portions of New Jersey and Connecticut), the Nation's largest transit market.

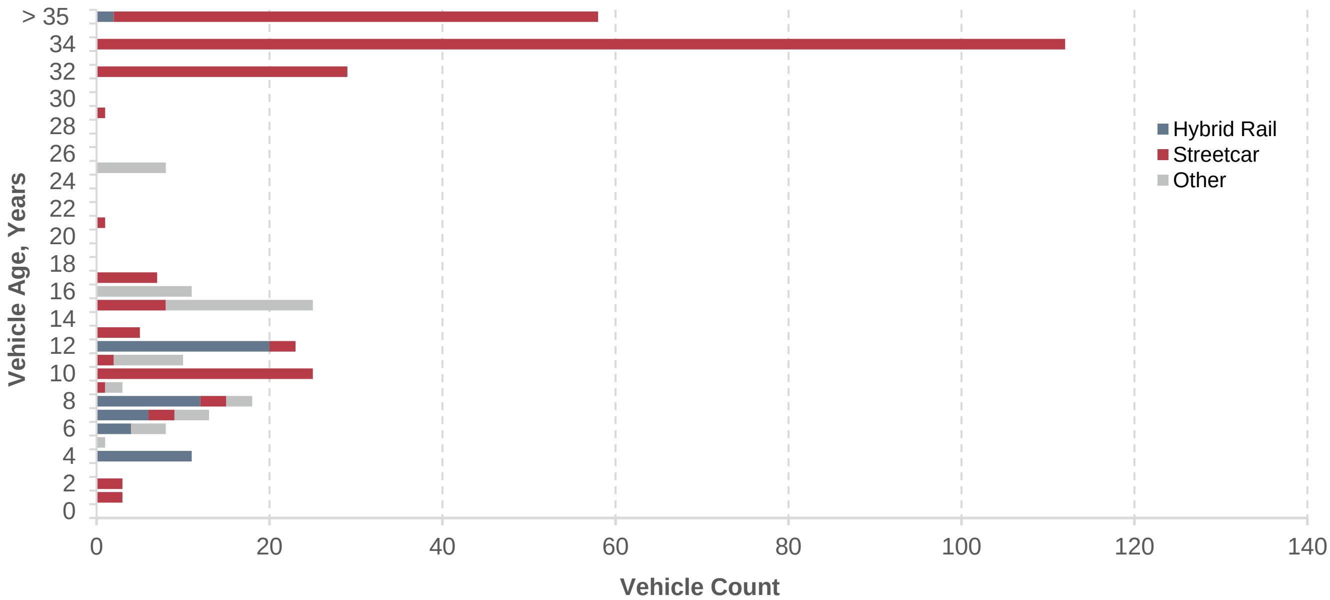
Comparing the results in *Exhibit 6-29* with the age distribution of transit buses and vans in *Exhibit 6-25* and *Exhibit 6-26,* rail vehicles lack the relatively clear pattern of preferred retirement age that is found in buses and vans. *Exhibit 6-30* presents the age distribution of the Nation's hybrid rail, streetcar, and other rail transit vehicles. Streetcar rail vehicles account for nearly two-thirds of the vehicles presented in *Exhibit 6-30*, while hybrid rail vehicles account for 13 percent. Roughly three-fourths of streetcar rail vehicles are more than 25 years old, with about one-fourth being more than 35 years old (23 percent of all vehicles > 35 years old).

Exhibit 6-29: Age Distribution of Heavy, Commuter, and Light Rail Transit Vehicles, 2014



Source: Transit Economic Requirements Model (TERM).

Exhibit 6-30: Age Distribution of Hybrid Rail, Streetcar, and Other Rail Transit Vehicles, 2014



Source: Transit Economic Requirements Model (TERM).

Other Rail Assets

Assets associated with nonvehicle transit rail can be divided into four general categories: guideway elements, systems, stations, and facilities. TERM estimates of the condition distribution for each category are shown in *Exhibit 6-31*.

Exhibit 6-31: Distribution of Asset Physical Conditions by Asset Type for All Rail

Source: Transit Economic Requirements Model (TERM) and National Transit Database.

The largest category by replacement value is guideway elements. These elements consist of tracks, ties, switches, ballasts, tunnels, and elevated structures. The replacement value of this category is $431.1 billion, of which $17.4 billion is rated below condition 2.0 (4 percent) and $27.0 billion is rated between conditions 2.0 and 3.0.

Although maintaining these assets is among the larger expenses associated with rail transit, FTA does not collect detailed data on these elements, in part because the elements are difficult to categorize into discrete sections having common life expectancies. Service life for track, for example, depends highly on the amount of use it receives and its location.

Systems, which consist of power, communication, and train control equipment, have a replacement value of $141.5 billion, of which $24.7 billion is rated below condition 2.0 (17 percent) and $19.1 billion is rated between conditions 2.0 and 3.0. This category is another for which many assets are difficult to characterize in terms of standard types and life expectancies. As a result, FTA has only limited data from which to make needs projections.

Stations have a replacement value of $100.0 billion, of which $16.3 billion is rated below condition 2.0 and $6.5 billion is rated between conditions 2.0 and 3.0.

Facilities, consisting principally of maintenance and administration buildings, have a replacement value of $31.5 billion. The value of facilities rated below condition 2.0 is $2.4 billion, and that of facilities between conditions 2.0 and 3.0 is $8.3 billion.

Almost half of rail transit vehicles are in heavy rail systems. Heavy rail represents $522.6 billion (67 percent) of the total transit rail replacement cost of $774.9 billion. Heavy rail serves some of the Nation's oldest and largest transit systems, including Boston, New York, Washington, San Francisco, Philadelphia, and Chicago.

The condition distribution of heavy rail assets, which represent the largest share of U.S. rail transit assets, is shown in *Exhibit 6-32*. *Exhibit 6-33* shows the average age and condition of nonvehicle transit assets for fixed-route bus and rail modes reported for 2014.

While *Exhibit 6-31* depicts the replacement value of national transit assets by category for rail modes, *Exhibit 6-33* provides additional data such as average fleet age, average condition, and percentage of assets below the SGR threshold (rating below 2.5).

Exhibit 6-32: Distribution of Asset Physical Conditions by Asset Type for Heavy Rail

Source: Transit Economic Requirements Model (TERM) and National Transit Database.

Exhibit 6-33: Non-Vehicle Transit Assets: Age and Condition, 2014

Category	Mode Type	Average Age	Avg. Condition	Percent Below Condition 2.5
Facilities	Rail	35.9	3.3	24%
	Fixed-Route Bus	30.8	3.2	7%
	All	**32.9**	**3.2**	**14%**
Guideway Elements	Rail	66.4	3.0	37%
	Fixed-Route Bus	25.1	4.4	7%
	All	**65.6**	**3.0**	**37%**
Stations	Rail	59.0	2.8	54%
	Fixed-Route Bus	23.9	3.2	27%
	All	**57.4**	**2.8**	**53%**
Systems	Rail	33.7	3.2	21%
	Fixed-Route Bus	24.6	3.4	19%
	All	**33.1**	**3.2**	**21%**

Source: Transit Economics Requirement Model (TERM).

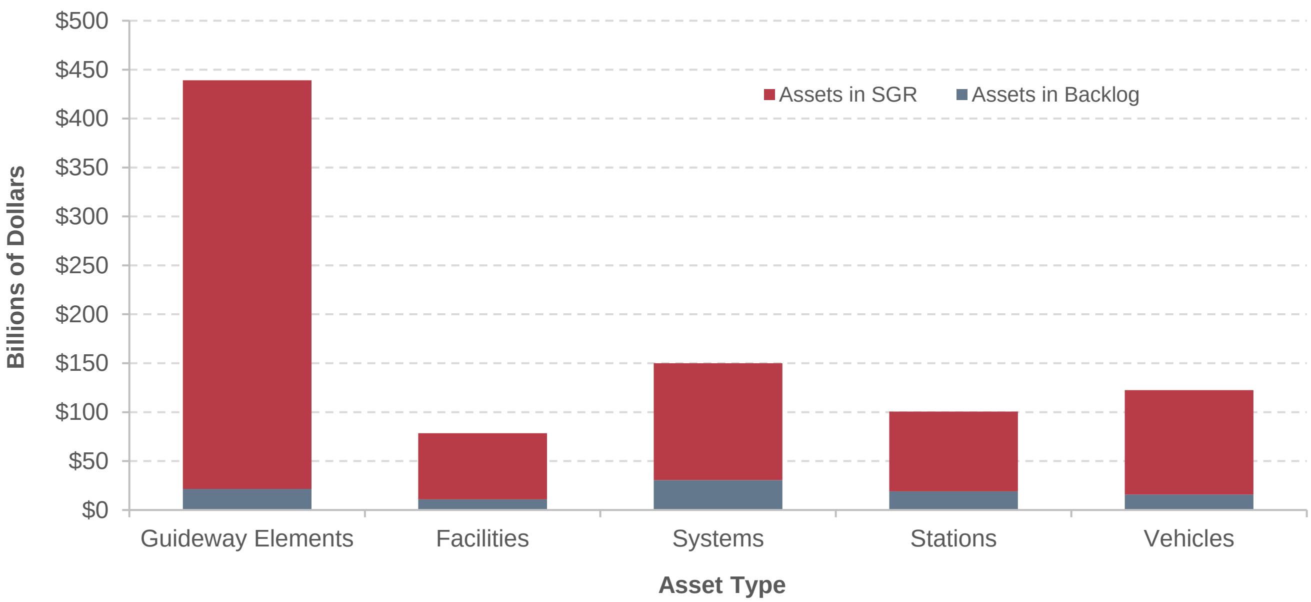
Asset Conditions and SGR

The preceding discussion in this Section focused on the value of transit assets in excellent, good, adequate, marginal, or poor condition. The remaining discussion considers the value of assets in SGR versus those assets with deferred reinvestment needs (i.e., a reinvestment "backlog"). This discussion is intended to help facilitate an understanding of the similarities and differences between the condition distributions presented above with the proportions of assets in or out of SGR. This assessment of the value of transit assets in SGR versus assets in the reinvestment backlog was estimated using FTA's TERM. Specifically, this analysis determines the value of assets in the reinvestment backlog as follows:

- Replaceable Assets: The estimated value of replaceable assets that may require replacement (are below condition 2.5) plus the value of replaceable assets with deferred rehabilitation and capital maintenance needs.
- Nonreplaceable Assets: The estimated value of nonreplaceable assets with deferred rehabilitation and capital maintenance needs.

Exhibit 6-34 presents the value of transit assets in SGR versus those assets in the reinvestment backlog, segmented by asset type. Based on this analysis, roughly $790 billion or 89 percent of all transit assets are in SGR, with the remaining $98.0 billion (13 percent) making up the reinvestment backlog. The backlog consists of $21.5 billion for guideway, $11.0 billion for facilities, $30.6 billion for systems, $19.1 billion for stations, and $15.8 billion for vehicles. Comparing *Exhibit 6-34* with the condition distribution in *Exhibit 6-22* helps to highlight the relationship between these two charts. Specifically, the value of assets in the backlog for each asset category exceeds the value of assets below condition 2.0 in *Exhibit 6-22*. This is as expected, as the backlog includes the value of all replaceable assets below condition 2.5 plus a (much smaller) amount for assets with deferred rehabilitation and capital maintenance needs.

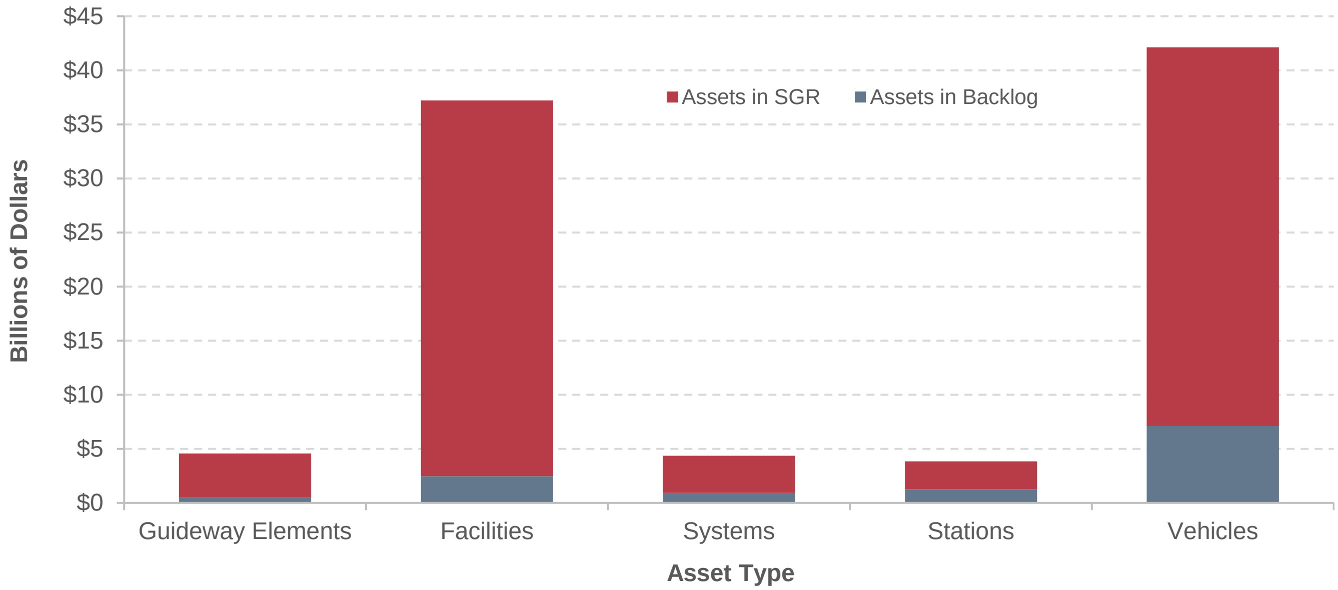
Exhibit 6-34: Value of U.S. Transit Assets in SGR vs Backlog by Asset Type



Source: Transit Economic Requirements Model (TERM) and National Transit Database.

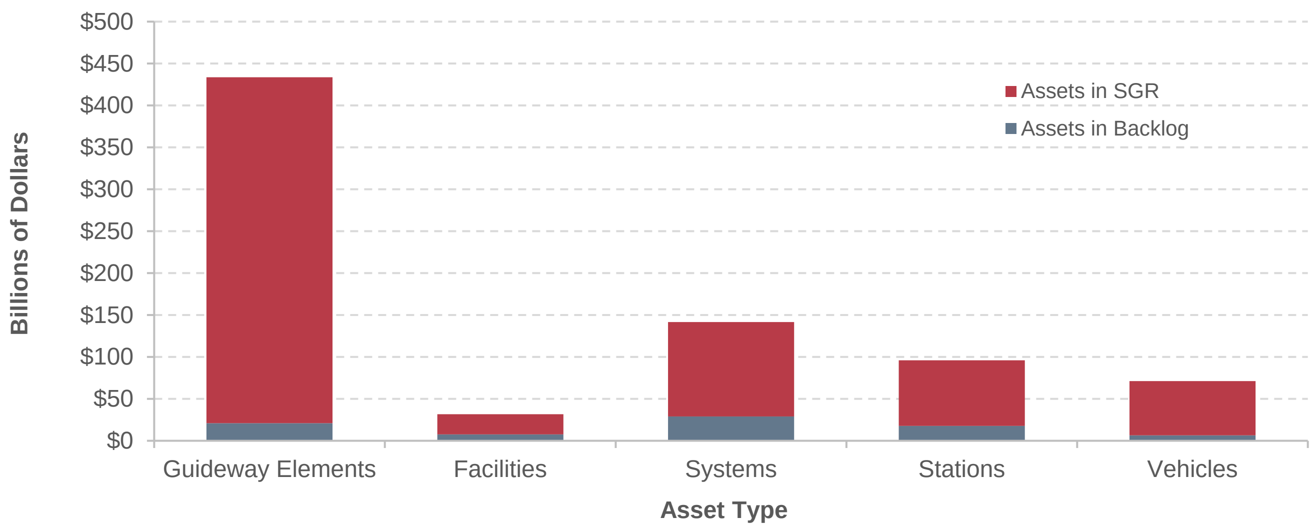
Exhibit 6-35 and *Exhibit 6-36* provide a similar presentation of transit assets in SGR versus those in the backlog, here segmented by fixed-route bus and all rail assets, respectively. *Exhibit 6-35* highlights the fact that 86 percent of fixed-route-bus asset value and 78 percent of the bus backlog are concentrated in vehicle fleet and facilities holdings. The value of rail assets in SGR and the backlog are similar to those found for all transit assets in *Exhibit 6-36*, demonstrating rail's large share of total transit asset value. Based on these two charts, the reinvestment backlog constitutes 13 percent of fixed-route-bus asset holdings and 11 percent of rail asset holdings (by value).

Exhibit 6-35: Value of U.S. Transit Assets in SGR vs Backlog by Asset Type for Fixed-Route Bus



Source: Transit Economic Requirements Model (TERM) and National Transit Database.

Exhibit 6-36: Value of U.S. Transit Assets in SGR vs Backlog by Asset Type for Rail



Sources: Transit Economic Requirements Model (TERM); National Transit Database.

PART II

Investing for the Future

Introduction

Chapters 7 through 10 present and analyze several possible scenarios for future capital investment in highways, bridges, and transit. In each of these 20-year scenarios, the investment level is an estimate of the spending that would be required to achieve a certain specified level of system performance. **This report does not attempt to address issues of cost responsibility.** The scenarios do not address how much different levels of government might contribute to funding the investment, nor do they directly address the potential contributions of different public or private revenue sources.

The four investment-related chapters in Part II measure investment levels in constant 2014 dollars, except where noted otherwise. The chapters consider scenarios for investment from 2015 through 2034 that are geared toward maintaining some indicator of physical condition or operational performance at its 2014 level, or achieving some objective linked to benefits versus costs. The average annual investment level over the 20 years from 2015 through 2034 is presented for each analyzed scenario.

Chapter 7, **Selected Capital Investment Scenarios**, defines the core scenarios and examines the associated projections for condition and performance. It also explains how the projections are derived by supplementing the modeling results with assumptions about nonmodeled investment. **The analyzed scenarios are intended to be illustrative and do not represent comprehensive alternative transportation policies; the U.S. Department of Transportation (DOT) does not endorse any scenario as a target level of investment.**

Chapter 8, **Supplemental Scenario Analysis**, explores some implications of the scenarios presented in Chapter 7 and contains some additional policy-oriented analyses. As part of this analysis, highway projections from previous editions of the C&P Report are compared with actual outcomes to illuminate the value and limitations of the projections presented in this edition. Chapter 9, **Sensitivity Analysis**, explores the impacts on scenario projections of changes to several key assumptions, such as the discount rate and the future rate of growth in travel demand.

Lastly, Chapter 10, **Impacts of Investment**, explores the impacts of alternative levels of possible future investment on various indicators of conditions and performance and explains the derivation of the scenario projections from results obtained with the models that have been developed over the years to support the C&P Report. These models have evolved over time to incorporate recent research, new data sources, and improved estimation techniques; their current versions are described in Appendices A (highways), B (bridges), and C (transit). Even collectively, however, their scope does not cover all capital investment in these types of surface transportation infrastructure.

The combination of engineering and economic analysis in this part of the C&P Report is consistent with the movement of transportation agencies toward asset and performance management, value engineering, and greater consideration of cost-effectiveness in decision-making. The economic approach to transportation investment is discussed at the end of this section.

Capital Investment Scenarios

The projections for the 20-year capital investment scenarios shown in this report reflect complex technical analyses that attempt to predict the potential impacts of capital investment on the future conditions and performance of the transportation system. These scenarios are illustrative, and DOT does not endorse any of them as a target level of investment. Where practical, supplemental information is included to describe the impacts of other possible investment levels.

The investment scenarios project the impact that particular levels of combined Federal, State, local, and private investment might have on the overall conditions and performance of highways, bridges, and transit. Although Chapter 2 provides information on the portions of highway investment that have come from different levels of government in the past, the report makes no specific recommendations about what these portions, or the portion from the private sector, should be in the future.

The system condition and performance projections in this report's capital investment scenarios represent what could be achievable assuming a particular level of investment, rather than what would be achieved. The models used to develop the projections generally assume that, when funding is constrained, the benefit-cost ratio (BCR) establishes the order of precedence among potential capital projects, with projects having higher BCRs selected first. In actual practice, the BCR generally omits some types of benefits and costs because of difficulties in valuing them monetarily, and these other benefits and costs can and do affect project selection. In addition, actual project selection can be guided by political or other considerations outside benefit-cost analysis.

A last prefatory caveat is that "investment" refers throughout this report to capital spending, which does not include spending on maintenance (although in popular parlance, capital spending on rehabilitation is sometimes described as "maintenance"). Additional discussion of the distinction between capital and maintenance spending is contained in Chapter 2 of this report.

Highway and Bridge Investment Scenarios

Projections for future conditions and performance under alternative potential levels of investment in highways and bridges combined are presented as scenarios in Chapter 7 and developed from projections in Chapter 10 using separate models and techniques for highway preservation and capacity expansion and for bridge preservation. Investments in bridge repair, rehabilitation, and replacement are modeled by the National Bridge Investment Analysis System (NBIAS); those in capacity expansion and the highway resurfacing and reconstruction component of system rehabilitation are modeled by the Highway Economic Requirements System (HERS). Some elements of highway investment spending are modeled by neither HERS nor NBIAS. Chapter 7 factors these elements into the investment levels associated with each scenario using scaling procedures external to the models. The scenario investment levels are estimates of the amount of future capital spending required to meet the performance goals specified in the scenarios.

For all Federal-aid highways, the National Highway System, and the Interstate System separately, Chapter 10 presents model-based projections of highway conditions and performance under alternative assumptions about future investment levels. Chapter 7 also maintains this disaggregation in the projections for the Improve Conditions and Performance scenario described below. However, due to data limitations, the scenario projections in Chapter 7 also rely heavily on assumptions to incorporate nonmodeled investment. Although the NBIAS database includes information on all bridges, the Highway Performance Monitoring System (HPMS) database, on which the HERS model relies, includes detailed information only on Federal-aid highways; for the scenarios based on all roads, non-model-based estimates must be generated for roads functionally classified as rural minor collectors, rural local, or urban local. In addition, HERS lacks information that would be needed to model some types of investment, such as safety-focused projects (e.g., adding rumble strips).

The Sustain 2014 Spending scenario projects the potential impacts of sustaining capital spending at 2014 base-year levels in constant-dollar terms over the 20-year period 2015 through 2034. The Maintain Conditions and Performance scenario also assumes that capital spending in constant-dollar terms remains flat between 2015 and 2034—not at the 2014 level, but at the level that would result in selected performance indicators having the same values in 2034 as in 2014. For this edition of the C&P Report, the HERS component of the scenario is defined as the lowest level of investment required at a minimum to maintain each of two performance indicators—average pavement roughness and average delay per vehicle mile traveled (VMT)—at their base-year level or better. For the NBIAS component, the benchmark performance indicator is the percentage of deck area on bridges that is in poor condition.

What are the implications of the Improve Conditions and Performance scenario for non-capital spending?

Exhibit 2-6 (see Chapter 2) shows that maintenance and other non-capital costs of highways are substantial, comprising roughly half of all highway expenditures. Since capital investments in infrastructure generally have implications for future maintenance requirements, one important question about the Improve Conditions and Performance scenario is how this capital investment level would affect future maintenance costs.

In the HERS model, maintenance spending per mile is estimated based on pavement condition and strength, with maintenance costs rising as pavement condition declines. Maintenance costs are also estimated to increase in proportion to the number of lanes. As such, increases in capital spending on rehabilitation projects generally reduce the need for future maintenance spending, by improving pavement condition. Conversely, capacity expansion projects increase the number of lanes that need to be maintained and thus imply higher future maintenance costs, all other things being equal. The NBIAS model similarly estimates higher maintenance costs as bridge condition declines, and NBIAS does not simulate capacity expansion projects.

The Improve Conditions and Performance scenario includes roughly three times more annual spending on system rehabilitation improvements (see Chapter 7, *Exhibit 7-4*). Because of this weighting toward rehabilitation, the overall impact of the scenario is to reduce rather than increase future maintenance costs. Specifically, HERS estimates that the Improve Conditions and Performance scenario would reduce maintenance costs from an initial level of $1,393 per mile to $1,052 per mile at the end of the 20-year forecast period, a reduction of 24.5 percent.

Other non-capital costs, such as administration and highway patrol, are not captured in the HERS model, but do not necessarily vary strongly with changes in capital investment. The increased investment under the Improve Conditions and Performance scenario would likely result in additional planning costs, though once a project reaches the preliminary engineering stage such costs would be included as part of the estimated capital investment. To the extent that increased spending under this scenario were financed through the issuance of bonds, this would tend to increase future bond interest and bond redemption expenses.

The investment levels for the Improve Conditions and Performance scenario are estimates of what would be needed to fund all cost-beneficial highway and bridge improvements. This scenario represents an "investment ceiling" above which further investment would not be cost-beneficial, even if available funding were unlimited. The portion of this funding that is directed toward pavement and bridge rehabilitation (as opposed to capacity expansion) is described as the State of Good Repair benchmark.

Types of Capital Spending Projected by HERS and NBIAS

The types of investments HERS and NBIAS evaluate can be related to the system of highway functional classification introduced in Chapter 1 and to the broad categories of capital improvements introduced in Chapter 2 (system rehabilitation, system expansion, and system enhancement). NBIAS relies on the National Bridge Inventory (NBI) database, which covers bridges on all highway functional classes and evaluates improvements that generally fall within the system rehabilitation category.

How closely do the types of capital improvements modeled in HERS and NBIAS correspond to the specific capital improvement type categories presented in Chapter 2?

Exhibit 2-12 (see Chapter 2) provides a crosswalk between a series of specific capital improvement types for which data are routinely collected from the States and three major summary categories: system rehabilitation, system expansion, and system enhancement. The types of improvements covered by HERS and NBIAS are assumed to correspond with the system rehabilitation and system expansion categories. As in *Exhibit 2-12*, HERS splits spending on "reconstruction with added capacity" among these categories.

For some of the detailed categories in *Exhibit 2-12*, the assumed correspondence is close overall but not exact. In particular, the extent to which HERS covers construction of new roads and bridges is ambiguous. Although not directly modeled in HERS, such investments are often motivated by a desire to alleviate congestion on existing facilities in a corridor, and thus would be captured indirectly by the HERS analysis in the form of additional normal-cost or high-cost lanes. The costs per mile assumed in HERS for high-cost lanes are based on typical costs of tunneling, double-decking, or building parallel routes, depending on the functional class and area population size for the section being analyzed. To the extent that investments in the "new construction" and "new bridge" improvement types identified in Chapter 2 are motivated by desires to encourage economic development or accomplish other goals aside from the reduction of congestion on the existing highway network, such investments would not be captured in the HERS analysis.

Some other comparability issues include:

- Some of the relocation expenditures identified in *Exhibit 2-12* may be motivated by considerations beyond those reflected in the curve and grade rating data that HERS uses in computing the benefits of horizontal and vertical realignments.
- The bridge expenditures that Exhibit 2-12 counts as system rehabilitation could include work on bridge approaches and ancillary improvements that NBIAS does not model.
- HERS and NBIAS are assumed not to capture improvements that count as system enhancement spending, including the spending on the "safety" category in *Exhibit 2-12*. Some safety deficiencies, however, might be addressed as part of broader pavement and capacity improvements modeled in HERS.
- The HERS operations preprocessor described in Appendix A includes capital investments in operations equipment and technology that would fall under the definition of the "traffic management/engineering" improvement type in Chapter 2. These investments are counted among the nonmodeled system enhancements because they are not evaluated within the benefit-cost framework that HERS applies to system preservation and expansion investments.

HERS evaluates pavement improvements—resurfacing or reconstruction—and highway widening; the types of improvements included in these categories roughly correspond to system rehabilitation and system expansion as described in Chapter 2. In estimating the per-mile costs of widening improvements, HERS recognizes a typical number of bridges and other structures that would need modification. Thus, the estimates from HERS are considered to represent system expansion costs for both highways and bridges. Coverage of the HERS analysis is limited, however, to Federal-aid highways, as the Highway Performance Monitoring System (HPMS) sample does not include data for rural minor collectors, rural local roads, or urban local roads.

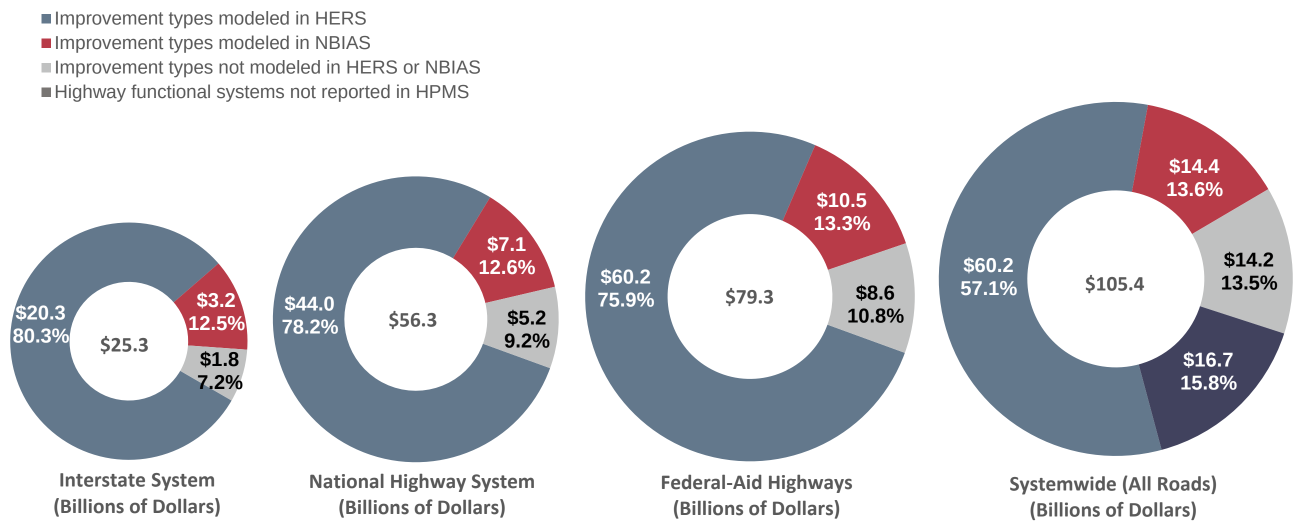
The term "nonmodeled spending" refers in this report to spending on highway and bridge capital improvements that are not evaluated in HERS or NBIAS; such spending is not included in the analyses presented in Chapter 10, but the capital investment scenarios presented in Chapter 7 are adjusted to account for them. Nonmodeled spending includes capital improvements on highway classes omitted from the HPMS sample and, hence, the HERS model. The development of the future investment scenarios for the highway system as a whole thus required supplementary estimation outside the HERS modeling process.

Nonmodeled spending also includes types of capital expenditures classified in Chapter 2 as system enhancements, which neither HERS nor NBIAS currently evaluates. Although HERS incorporates assumptions about future operations investments, the capital components of which would be classified as system enhancements, the model does not directly evaluate the need for these deployments. In addition, HERS does not identify specific safety-oriented investment opportunities, but instead considers the ancillary safety impacts of capital investments that are directed primarily toward system rehabilitation or capacity expansion. The HPMS database contains no information on the locations of crashes and safety devices, such as guardrails or rumble strips, limiting the model.

Exhibit II-1 shows that, systemwide in 2014, highway capital spending was $105.4 billion. Of that spending, $60.2 billion was for the types of improvement that HERS models, and $14.4 billion was for the types of improvement NBIAS models. The other $30.9 billion, which was for nonmodeled highway capital spending, was divided between system enhancement expenditures and capital improvements to classes of highways not reported in HPMS.

Because the HPMS sample data are available only for Federal-aid highways, the percentage of capital improvements classified as nonmodeled spending is lower for Federal-aid highways than is the case systemwide. Of the $79.3 billion spent by all levels of government on capital improvements to Federal-aid highways in 2014, 75.9 percent was within the scope of HERS, 13.3 percent was within the scope of NBIAS, and 10.8 percent was for spending captured by neither. The percentage distribution differs somewhat for the Interstate System, with a slightly higher share within the scope of HERS and NBIAS (80.3 percent and 12.5 percent, respectively) and a smaller share captured by neither (7.2 percent).

Exhibit II-1: Distribution of 2014 Capital Expenditures by Investment Type



Source: Highway Statistics 2014 (Table SF-12A) and unpublished FHWA data.

Highway Economic Requirements System

Simulations conducted with HERS provide the basis for this report's analysis of investment in highway resurfacing and reconstruction and for highway and bridge capacity expansion. HERS uses incremental benefit-cost analysis to evaluate highway improvements based on data from HPMS. HPMS includes State-supplied information on current roadway characteristics, conditions, performance, and anticipated future travel growth for a nationwide sample of roughly 120,000 highway sections. HERS analyzes individual sample sections only as a step toward providing results at the national level; the model does not provide definitive improvement recommendations for individual sections.

The frame for which sections are sampled is the TOPS (Table of Potential Samples), in which each section is relatively homogeneous over its length as to traffic volume, geometrics, cross-section, and condition. For each State, the sampling is designed to enable statistically reliable estimation for each urbanized area, and at the statewide level for rural and for small urban areas. For each of these geographic categories, stratified random samples are drawn by traffic volume group. (The sampling methodology is further detailed in the HPMS Field Manual (https://www.fhwa.dot.gov/policyinformation/hpms/fieldmanual/).)

HERS simulations begin with evaluations of the current state of the highway system using data from the HPMS sample. These data provide information on pavements, roadway geometry, traffic volume and composition (percentage of trucks), and other characteristics of the sampled highway sections. For sections with one or more identified deficiencies, the model then considers potential improvements, including resurfacing, reconstruction, alignment improvements, and widening or adding travel lanes. HERS selects the improvement (or combination of improvements) with the greatest net benefits, with benefits defined as reductions in direct highway user costs, agency costs for highway maintenance, and societal costs from vehicle emissions of pollutants. The model allocates investment funding only to those sections for which at least one potential improvement is projected to produce benefits exceeding construction costs.

HERS normally considers highway conditions and performance over a period of 20 years from the base ("current") year—the most recent year for which HPMS data are available. This analysis period is divided into four equal funding periods. After analyzing the first funding period, HERS updates the database to reflect the projected outcomes of the first period, including the effects of the selected highway improvements. The updated database is then used to analyze conditions and performance in the second period, the database is updated again, and so on through the fourth and final period.

Operations Strategies

HERS considers the impacts of certain types of highway operational improvements that feature intelligent transportation systems. The operations strategies HERS currently evaluates are:

- **Freeway management:** ramp metering, electronic roadway monitoring, variable message signs, integrated corridor management, variable speed limits, queue warning systems, lane controls.
- **Incident management:** detection, verification, response.
- **Arterial management:** upgraded signal control, electronic monitoring, variable message signs.
- **Traveler information:** 511 systems, advanced in-vehicle navigation systems with real-time traveler information.

In contrast with improvements that expand or rehabilitate highways, HERS does not analyze the benefits and costs of these operational improvements. Thus, the model does not estimate the needs for investment in operational improvements. Instead, a separate preprocessor estimates the impacts of these operations strategies on the performance of highway sections where they are deployed. The analyses presented in this chapter assume a package of investments that continue existing deployment trends. HERS does not currently model applications of various developing vehicle-to-vehicle and vehicle-to-infrastructure communications because it is not yet possible to predict reliably the impacts and patterns of their deployment.

Operations improvements vs. capacity improvements in HERS

Because HERS does not perform benefit-cost analysis for highway operational improvements, the scenarios in the C&P Report simply assume certain strategies for their future deployment. In this edition, the assumption is that deployment will continue at a rate consistent with existing patterns. The previous two editions made the same assumption, but also presented sensitivity analyses that alternatively assumed: (1) a more aggressive deployment strategy over 20 years, and (2) a full deployment strategy (implementing the aggressive deployments over 5 years. The analyses estimated the impacts of these alternatives on the overall levels of scenario spending, including spending on capacity expansion and pavement preservation—which HERS subjects to benefit-cost analysis— and on deployments of operational improvements. In both the Maintain and Improve scenarios, these impacts showed small increases in overall spending in the 2013 C&P Report, and small decreases in the 2015 C&P Report. The differences in estimated spending impacts between the 2013 C&P and 2015 C&P Reports could have many causes, and they are not indications of whether more aggressive deployment of operational improvements would be cost-beneficial.

Travel Demand Elasticity

A key feature of the HERS economic analysis is the influence of the cost of travel on demand for travel. HERS represents this relationship as a travel demand elasticity that relates demand, measured by vehicle miles traveled (VMT), to changes in the average user cost of travel that result from either: (1) changes in highway conditions and performance as measured by travel delay, pavement condition, and crash costs, relative to base year levels; the elasticity mechanism reduces travel demand when these changes are for the worse (e.g., an increase in travel delay) and increase travel demand when they are improvements (e.g., better pavement condition); or (2) deviations from the price projections built into the baseline demand forecasts. This report considers the latter deviations only in Chapter 9 where one of the sensitivity tests alters the projections for motor fuel prices.

HERS also allows the induced demand predicted through the elasticity mechanism to influence the cost of travel to highway users. For example, a 10-percent reduction in travel cost per mile would be predicted to induce a 6 percent increase in VMT in the short term, and a larger increase—just under 12 percent—5 years later, as travelers are able to make additional responses to the change in costs. On congested sections of highway, the initial congestion relief afforded by an increase in capacity will reduce the average user cost per VMT, which in turn will stimulate demand for travel; this increased demand will in turn reverse some of the initial congestion relief. The elasticity feature operates likewise with respect to improvements in pavement quality by allowing for induced traffic that adds to pavement wear. (Conversely, an initial increase in user costs can start a causal chain with effects in the opposite direction.) By capturing these offsets to initial impacts on highway user costs, HERS can estimate the net impacts.

National Bridge Investment Analysis System

The scenario estimates relating to bridge repair and replacement shown in this report are derived primarily from NBIAS. NBIAS can synthesize element-level data from the general condition ratings reported for individual bridges in the NBI. The analyses presented in this report are based on synthesized element-level data. Examples of bridge elements include the bridge deck, a steel girder used for supporting the deck, a concrete pier cap on which girders are placed, a concrete column used for supporting the pier cap, or a bridge railing.

NBIAS uses a probabilistic approach to model bridge deterioration for each synthesized bridge element. It relies on a set of transition probabilities to project the likelihood that an element will deteriorate from one condition state to another over a given period. This information, along with details on the cost of maintenance, repair, and rehabilitation (MR&R) actions, is used to predict lifecycle costs of maintaining existing bridges, and to develop MR&R policies specifying what MR&R action to perform based on the existing condition of a bridge element. Notwithstanding the use of the term “maintenance”, the MR&R actions are actually capital improvements, and preventive maintenance (e.g., cleaning scuppers, washing bridges) is not modeled.

Another key input to the model is the overall objective assumed for MR&R policies. The State of Good Repair strategy, although the most aggressive of the available MR&R policies, generates results more consistent with agency practices and recent trends in bridge conditions compared with the other three strategies evaluated (see Appendix B). Therefore, the State of Good Repair strategy has been adopted for use in the baseline analyses presented in this chapter and in Chapter 7.

The State of Good Repair strategy aims to improve all bridges to good condition that can be sustained through ongoing investment. MR&R investment is front-loaded under the State of Good Repair strategy, as large MR&R investments are required in the early years of the forecast period to improve bridge conditions, while smaller MR&R investments are needed in the later years to sustain bridge conditions. Under this analysis, replacement of a bridge is recommended if a bridge evaluation results in lower lifecycle costs compared with the recommended MR&R work.

To estimate functional improvement needs, NBIAS applies a set of improvement standards and costs to each bridge in the NBI. The system then identifies potential improvements—such as widening existing bridge lanes, raising bridges to increase vertical clearances, and strengthening bridges to increase load-carrying capacity—and evaluates their potential benefits and costs. NBIAS evaluates potential bridge replacements by comparing their benefits and costs with what could be achieved through MR&R work alone. Appendix B discusses NBIAS in detail.

Transit Investment Scenarios

The transit section of Chapter 10 evaluates the impact of varying levels of capital investment on various measures of condition and performance, while the transit section of Chapter 7 provides a more in-depth analysis of specific investment scenarios.

The Sustain 2014 Spending scenario projects the potential impacts of sustaining preservation and expansion spending at 2014 base-year levels in constant-dollar terms over the 20-year period of 2015 through 2034. The scenario applies benefit-cost analysis to prioritize investments within this constrained budget target.

The State of Good Repair benchmark projects the level of investment needed to bring all assets to a state of good repair over the next 20 years, defined as asset condition ratings of 2.5 or higher on a 5-point scale (Chapter 6 discusses these ratings). This scenario does not apply a benefit-cost test and focuses solely on the preservation of existing assets.

The Low-Growth and High-Growth scenarios each add a system expansion component to the system preservation needs associated with the State of Good Repair benchmark. The goal of these scenarios is to preserve existing assets and expand the transit asset base to support projected ridership growth over 20 years, based on forecasts linked to the average annual growth experienced between 1999 and 2014. The Low-Growth scenario projects ridership growth at 0.3 percent per year below the historical trend (over 15 years), while the High-Growth scenario incorporates a more extensive expansion of the existing transit asset base to support ridership growth at 0.3 percent per year above the historical trend. Both scenarios incorporate a benefit-cost test for evaluating potential investments; thus, their system preservation components are somewhat smaller than the level identified in the State of Good Repair benchmark.

Types of Capital Spending Projected by TERM

TERM is an analysis tool that uses algorithms based on engineering and economic concepts to forecast total capital investment needs for the U.S. transit industry through a 20-year time horizon. Specifically, TERM is designed to forecast the following types of investment needs:

- **Preservation**: The level of investment in the rehabilitation and replacement of existing transit capital assets required to attain specific investment goals (e.g., to attain a state of good repair [SGR]) subject to potentially limited capital funding.
- **Expansion**: The level of investment in the expansion of transit fleets, facilities, and rail networks required to support projected growth in transit demand (i.e., to maintain performance at current levels as demand for service increases).

Recent Investment in Transit Preservation and Expansion

As reported to NTD, the level of transit capital expenditures peaked in 2009 at $16.8 billion, experienced a slight decrease in 2011 to $15.6 billion, and increased again in 2014 to $17.7 billion (see *Exhibit II-2*). Although the annual transit capital expenditures averaged $15.2 billion from 2004 to 2014, expenditures averaged $16.8 billion in the most recent 5 years of NTD reporting (2010–2014). Furthermore, even though capital expenditures for preservation purposes in 2014 increased by $0.5 billion relative to prior-year levels, capital expenditures for expansion purposes remained the same as in 2013.

Exhibit II-2: Annual Transit Capital Expenditures, 2004–2014

Year	(Billions of Current-Year Dollars)			(Billions of Constant 2014 Dollars)		
	Preservation	Expansion	Total	Preservation	Expansion	Total
2004	$9.4	$3.2	$12.6	$11.8	$4.0	$15.8
2005	$9.0	$2.9	$11.8	$10.9	$3.5	$14.3
2006	$9.2	$3.5	$12.7	$10.8	$4.1	$14.9
2007	$9.6	$4.0	$13.6	$10.9	$4.6	$15.5
2008	$11.0	$5.1	$16.0	$12.1	$5.6	$17.6
2009	$11.3	$5.5	$16.8	$12.5	$6.1	$18.6
2010	$10.3	$6.2	$16.6	$11.2	$6.8	$18.0
2011	$9.9	$5.7	$15.6	$10.5	$6.0	$16.5
2012	$9.7	$7.1	$16.8	$10.0	$7.4	$17.4
2013	$10.8	$6.4	$17.1	$10.9	$6.5	$17.4
2014	$11.0	$6.4	$17.4	$11.0	$6.4	$17.4
Average	**$10.1**	**$5.1**	**$15.2**	**$11.1**	**$5.5**	**$16.7**

Source: National Transit Database.

Preservation Investments

TERM estimates current and future preservation investment needs by first assessing the age and current condition of the Nation's existing stock of transit assets. (The results of this analysis were presented in Chapter 6 of this report.) TERM then uses this information to assess both current reinvestment needs (i.e., the reinvestment backlog) and the expected level of ongoing investment required to meet the life-cycle needs of the Nation's transit assets over the next 20 years, including all required rehabilitation and replacement activities.

Condition-Based Reinvestment

Rather than relying on age alone in assessing the timing and cost of current and future reinvestment activities, TERM uses a set of empirical asset deterioration curves that estimate asset condition (both current and future) as a function of asset type, age, past rehabilitation activities, and, depending on asset type, past maintenance and utilization levels. An asset's estimated condition at the start of each year over the 20-year forecast horizon determines the timing of specific rehabilitation and replacement activities. Asset condition declines as the asset ages, triggering reinvestment events at different levels of deterioration and ultimately leading to outright replacement.

Financial Constraints, the Investment Backlog, and Future Conditions

TERM is designed to estimate investment needs with or without annual capital funding constraints. When run without funding constraints, TERM estimates the total level of investment required to complete all rehabilitation and replacement needs the model identifies at the time those investment needs come due (hence, with unconstrained analyses after any initial deferred investment is addressed, investment backlog is not appreciable). In contrast, when TERM is run in a financially constrained mode, sufficient funding might not be available to cover the reinvestment needs of all assets. In this case, some reinvestment activities would be deferred until sufficient funds become available. The lack of funds to address all reinvestment needs for some or all of the 20 years of the model forecast results in varying levels of investment backlog during this period. Most analyses presented in this chapter were completed using funding constraints. Similarly, TERM's ability to estimate asset conditions—both current and future—allows for assessment of how future asset conditions are likely to improve or decline given varying levels of capital reinvestment. Finally, note that TERM's benefit-cost analysis is used to determine the order in which reinvestment activities are completed when funding capacity is limited, with investments having the highest benefit-cost ratios addressed first.

Expansion Investments

In addition to ongoing reinvestment in existing assets, most transit agencies invest in the expansion of their vehicle fleets, maintenance facilities, fixed guideway, and other assets. Investments in expansion assets can be considered as serving two distinct purposes. First, the demand for transit services typically increases over time in line with population growth, employment, and other factors. To maintain current levels of performance in the face of expanding demand, transit operators must similarly expand the capacity of their services (e.g., by increasing the number of vehicles in their fleets). Failure to accommodate this demand would result in increased vehicle crowding, increased dwell times at passenger stops, and decreased operating speeds for existing services. Second, transit operators also invest in expansion projects with the aim of improving current service performance. Such improvements include capital expansion projects (e.g., a new light rail segment) to reduce vehicle crowding or increase average operating speeds. TERM is designed to assess investment needs and impacts for both types of expansion investments.

To assess the level of investment required to maintain existing service quality, TERM estimates the rate of growth in transit vehicle fleets required to maintain current vehicle occupancy levels given the projected growth rate in transit passenger miles. In addition to assessing the level of investment in new fleet vehicles required to support this growth, TERM forecasts investments in the expansion of other assets needed to support projected fleet growth, including bus maintenance facilities and—in the case of rail systems—additional investment in guideway, track work, stations, maintenance facilities, train control, and traction power systems. Asset expansion investment needs are assessed on a mode-by-mode basis for all agencies reporting to NTD. Cost-benefit constraints, however, prevent TERM from investing in asset expansion for those agency modes having lower ridership (per vehicle) than the national average.

Comparisons Between Report Editions

The base year of the analysis typically advances two years between successive editions of this biennial report. During this period, changes in many real-world factors can affect the investment scenario estimates. Among these factors are construction costs and other prices, conditions and performance of the highway and transit systems, expansion of the system asset base, and changes in technology (such as improvements in motor vehicle fuel economy). Although relevant to all scenarios, the implications of these changes are particularly significant for scenarios aimed at maintaining base-year conditions. Comparability across C&P Report editions is also limited by changes over time in analytical tools, data sets used in generating the scenarios, and scenario definitions. For example, the projected rates of highway traffic growth—key inputs to HERS and NBIAS—have changed considerably. These and other key changes are discussed in Chapters 7, 8, and 10.

The Economic Approach to Transportation Investment Analysis

The economic approach to transportation investment entails analysis and comparison of benefits and costs. Investments that yield benefits for which the values exceed their costs increase societal welfare and are thus considered "economically efficient," or "cost-beneficial." While the *1968 National Highway Needs Report to Congress* began as a mere "wish list" of State highway needs, the approach to estimating investment needs in the C&P Report has become more economic and in other ways more sophisticated over the subsequent editions.

As the focus of national highway investment changed from system expansion to management of the existing system during the 1970s, national engineering standards were defined and applied to identify system deficiencies, and the investments necessary to remedy these deficiencies were estimated. By the end of the decade, a comprehensive database, the HPMS, had been developed to enable monitoring of highway system conditions and performance nationwide.

In the early 1980s, a sophisticated simulation model, the HPMS Analytical Process (HPMS-AP), became available to evaluate the impact of alternative investment strategies on system conditions and performance. The procedures used in HPMS-AP were based on engineering principles. Engineering standards were applied to determine which system attributes were considered deficient, and improvement option packages were developed using standard engineering countermeasures for given deficiencies, but without consideration of comparative economic benefits and costs.

In 1988, the Federal Highway Administration embarked on a long-term research and development effort to produce an alternative simulation procedure combining engineering principles with economic analysis. The product of this effort, the HERS model, was first used to develop one of the two highway investment scenarios presented in the 1995 C&P Report. In subsequent reports, HERS has been used to develop all the highway investment scenarios.

Executive Order 12893, "Principles for Federal Infrastructure Investments," issued on January 26, 1994, directs that Federal infrastructure investments should be based on a systematic analysis of expected benefits and costs. This order provided additional momentum for the shift toward developing analytical tools that incorporate economic analysis into the evaluation of investment requirements.

In the 1997 C&P Report, the Federal Transit Administration introduced the Transit Economics Requirements Model (TERM). TERM incorporates benefit-cost analysis into its determination of transit investment levels. The 2002 C&P Report incorporated economic analysis into bridge investment modeling for the first time with the introduction of NBIAS.

The Economic Approach in Theory and Practice

Effective use of the economic approach to investment appraisal requires adequate consideration of the range of possible benefits and costs and of the range of possible investment alternatives.

Which Benefits and Costs Should Be Considered?

A comprehensive benefit-cost analysis of a transportation investment considers all impacts of potential significance for society and values them in monetary terms, to the extent feasible. For some types of impacts, monetary valuation is facilitated by the existence of observable market prices. Such prices are generally available for inputs to the provision of transportation infrastructure, such as concrete for building highways or buses purchased for a transit system. The same is true for some types of benefits from transportation investments, such as savings in business travel time, which are conventionally valued at a measure of average hourly labor cost of the travelers.

For some other types of impacts for which market prices are not directly observable, monetary values can be reasonably inferred from behavior or expressed preferences. In this category are savings in nonbusiness travel time and reductions in risk of crash-related fatality or other injury. As discussed in Chapter 9 (under "Value of a Statistical Life"), what is inferred is the amount that people typically would be willing to pay per unit of improvement, such as, per hour of nonbusiness travel time saved. These values are combined with estimates of the magnitude of the improvement (or, as may happen, deterioration).

For other impacts, monetary valuation may not be possible because of problems with reliably estimating the magnitude of the improvement, placing a monetary value on the improvement, or both. Even when possible, reliable monetary valuation may require time and effort that would be out of proportion to the likely importance of the impact concerned. Benefit-cost analyses of transportation investments thus typically will omit valuing certain impacts that are difficult to monetize but, nevertheless, could be of interest.

Each of the models used in this report—HERS, NBIAS, and TERM—omits various types of investment impacts from its benefit-cost analyses. To some extent, this omission reflects the national coverage of the models' primary databases. Although consistent with this report's focus on the Nation's highways and transit systems, such broad geographic coverage requires some sacrifice of detail to stay within feasible budgets for data collection. In the future, technological progress in data collection and growing demand for data for performance management systems for transportation infrastructure likely will yield national databases that are more comprehensive and of better quality.

In addition, DOT will continue to explore other avenues for addressing impacts not captured by the suite of models used for the C&P Report. One approach is to have the models represent impacts in ways that are sufficiently simplified to demand no more data than are available. This approach was taken to represent within HERS the impacts of traffic disruptions resulting from road construction. Another effect the DOT models do not consider, but which could be significant for some transportation investments, is the boost to economic competition that results when travel times within and between regions are lessened. Faced with stiffer competition from rivals in other locations, producers may become more efficient and reduce their prices.

What Alternatives Should Be Analyzed?

Benefit-cost analyses of transportation investments need to include a sufficiently broad range of investment alternatives to be able to identify which is optimal. For transit and highway projects, this evaluation can entail consideration of cross-modal alternatives. Transit and highway projects can be complementary, as when the addition of high-occupancy toll lanes to a freeway allows for new or improved express bus services; they can also be substitutes, as when construction of a light rail line lessens the demand for travel on a parallel freeway. In contrast, both HERS and TERM focus on investment in just one mode. To incorporate a cross-modal perspective properly would require a major investment of time and resources, entailing major changes to the benefit-cost methodologies and the addition of considerable detail to the supporting databases. (As was noted earlier, the models' databases necessarily sacrifice detail to make national-level coverage feasible.) Opportunities for future development of HERS, TERM, and NBIAS, including efforts to allow feedback between the models, were discussed in Appendix D of the 2013 C&P Report.

Beyond related cross-modal investment possibilities, economic evaluations of investments in highways or transit should also attempt to consider related public choices, such as policies for travel demand management and local zoning, or investment in other infrastructure. Several previous editions of the C&P Report presented HERS modeling of highway investment combined with systemwide highway congestion pricing. Although the results indicated that pricing could substantially reduce the amount of highway investment that would be cost-beneficial, a review of the methodology in 2010 revealed significant limitations, which reflected in part the lack of transportation network detail in the HPMS database.

A more limited form of congestion pricing is tolling on designated express lanes within a full access-controlled highway. When the tolling includes a discount or exemption for high-occupancy vehicles, such facilities are termed HOT (High-Occupancy Toll) lanes. Over the past three decades, tolled express lanes have been implemented in urban areas across the United States. Future versions of the HERS model could include a capability to analyze the costs and benefits of tolled express lanes and their effects on investment needs.

Measurement of Costs and Benefits in "Constant Dollars"

Benefit-cost analyses normally measure all benefits and costs in "constant dollars," that is, at the prices prevailing in some base year, typically near the year when the analysis is released. Future price changes can be difficult to forecast, and benefits and costs measured in base-year prices ensure consistency when comparing benefits and costs.

In the simplest form of constant-dollar measurement, any quantity is converted to a dollar value at that quantity's base-year price. Future savings in gallons of gasoline, for example, are monetized at the average price per gallon of gasoline in the base year (with the price measured net of excise tax, as in HERS). This approach, still quite common in benefit-cost analysis, was the general practice in pre-2008 editions of the C&P Report. It assumes any future inflation will change all prices in equal proportion, so that the ratios among prices will remain constant at their base-year levels.

An alternative approach to constant dollar measurement factors in future changes in relative prices. This is warranted when such changes are significant, pertain to the relative price of a quantity important to the analysis, and can be predicted with sufficient confidence. What constitutes sufficient confidence is a judgment call, but some predictions carry official weight. The Energy Information Administration's *Annual Energy Outlook* forecasts changes in constant dollar motor-fuel prices up to 25 years out. Starting with the 2008 C&P Report, the highway investment scenarios have incorporated these forecasts.

Uncertainty in Transportation Investment Modeling

The three investment analysis models used in this report are deterministic, not probabilistic, in that they provide a single projected value of total investment for a given scenario rather than a range of likely values. As a result, only general statements can be made about the element of uncertainty in these projections, based on the characteristics of the process used to develop them; specific information about confidence intervals cannot be developed. As was indicated previously, the analysis in Chapter 9 of this edition of the C&P Report enables uncertainty to be addressed by analyzing the sensitivity of the scenario projections to variation in the underlying parameters (e.g., discount rates, value of time saved, statistical value of lives saved). As much as possible, the range of variation considered in these tests corresponds to the range considered plausible in the corresponding research literature or to ranges recommended in authoritative guidance. The sensitivity tests address only some of the elements of uncertainty in the scenario projections. In some cases, the uncertainty extends beyond the value of a model parameter to the entire specification of the equations in which the parameters are embedded.

The relative level of uncertainty differs among the various projections made in this report. The projections for absolute levels of condition and performance indicators entail more uncertainty than do the relative differences among these levels according to an assumed level of investment. For example, if speed limits were changed in the future, contrary to the HERS modeling assumption of no change from the base-year speed limits, this could reduce the accuracy of the model's projections for average speed. At the same time, projections of how the amount of future investments in highways affects average speed could be relatively accurate. Although investments in highway capacity expansion increase average speed, the increase will occur primarily under conditions of congestion when average speeds can be well below even the current speed limit. Under such conditions, an increase in the speed limit might have a negligible effect on the congestion reduction benefits of adding lanes.

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CHAPTER 7

Capital Investment Scenarios

Highway Capital Investment Scenarios

This section presents future investment scenarios that build on the Chapter 10 analyses of alternative levels of future investment in highways and bridges. Each scenario includes projections for system conditions and performance based on simulations using the Highway Economic Requirements System (HERS) and National Bridge Investment Analysis System (NBIAS). The combined scope of the two models covers system rehabilitation investments for bridges on all roads, system rehabilitation investments for pavements on Federal-aid highways, and system expansion investments on Federal-aid highways. Each scenario scales up the total amount of simulated investment to account for capital improvements (highway and bridge investments) that are outside the scopes of the models, and for which limited information is available on the benefits and costs of individual investments. Such "non-modeled" investments (sometimes called "other" in the exhibits), account for 29.3 percent of the spending in each scenario. Later in this chapter, transit investment scenarios are explored that, like those of this section, start with 2014 as the base year and cover the 20-year period through 2034. **All scenarios are illustrative, and none is endorsed as a target level of funding**.

Supplemental analyses relating to these scenarios, including comparisons with the investment levels presented for comparable scenarios in previous C&P Reports, are the subject of Chapter 8. A series of sensitivity analyses that explore the implications of alternative technical assumptions for the scenario investment levels is presented in Chapter 9. The introduction to Part II provides essential background information relating to the technical limitations of the analysis, which are discussed further in the appendices.

Key Takeaways

- Three illustrative 20-year scenarios are considered: Sustain 2014 Spending, Maintain Conditions and Performance, and Improve Conditions and Performance. Each scenario relates to total highway capital spending by all levels of government combined, and the private sector, stated in constant 2014 dollars.
- The Improve Conditions and Performance scenario assumes that $95.9 billion would be provided for all projects that meet or exceed a benefit-cost ratio of 1.0, and that $39.8 billion would be provided for projects not included in the models and that may or may not be cost-beneficial, for an average annual capital investment of $135.7 billion in total.
- Approximately 29 percent of the investment required under the Improve Conditions and Performance scenario would go toward addressing an existing backlog of cost-beneficial investments of $786.4 billion. The rest would address new needs arising from 2015 through 2034.
- The Maintain Conditions and Performance scenario over the 20-year period of analysis would require 2.9 percent less average annual funding than actual 2014 highway capital spending of $105.4 billion.

Scenarios Selected for Analysis

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

Key Limitations of HERS Model

The HERS model relies on various assumptions about travel behavior and associated travel costs as well as the benefits and costs of infrastructure improvements. Research is conducted on an ongoing basis to assess the accuracy of these assumptions, and when possible the HERS model assumptions are adjusted to more accurately reflect real-world dynamics. Substantial changes in the HERS model assumptions from the 2015 C&P Report are described in Appendix A. In particular, updates to the HERS model for this report include adjustments to improvement costs per mile, pavement condition modeling, value of travel time savings, and highway operation strategies.

Each scenario pairs an assumed level of total investment in the types of improvements modeled by HERS with an assumed level of investment in the types of improvements modeled by NBIAS; these levels are drawn from those considered in Chapter 10. Together, the scopes of HERS and NBIAS cover spending on highway expansion and pavement improvements on Federal-aid highways (HERS) and spending on bridge rehabilitation on all roads (NBIAS). In the absence of data required for other types of highway and bridge investment (those not modeled in HERS or NBIAS), each scenario simply assumes that the percentage of highway and bridge investment spent on nonmodeled investments remains at the 2014 percentage (29.3 percent).

The objective of the Sustain 2014 Spending scenario is to predict the impact on highway conditions and performance after 20 years, if highway capital spending remains constant (adjusted for inflation) over that period. The Maintain Conditions and Performance scenario seeks to identify the level of investment needed to keep overall system conditions and performance unchanged after 20 years. The Improve Conditions and Performance scenario seeks to identify the level of investment needed to address all potential investments estimated to be cost-beneficial. *Exhibit 7-1* describes the derivation of each of these scenarios in greater detail.

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

Scenario Component	Sustain 2014 Spending Scenario	Maintain Conditions and Performance Scenario	Improve Conditions and Performance Scenario	State of Good Repair Benchmark
HERS-Derived	Sustain spending on types of capital improvements modeled in HERS at 2014 levels in constant dollar terms over next 20 years.	Set spending at the lowest level at which (1) projected average IRI in 2034 matches (or is better than) the value in 2014 and (2) projected average delay per VMT in 2034 matches (or is better than) the value in 2014.	Set spending at the level sufficient to fund all cost-beneficial potential projects (i.e., those with a benefit-cost ratio greater than or equal to 1.0).	Subset of Improve Conditions and Performance scenario; includes spending on system rehabilitation; excludes spending on system capacity.
NBIAS-Derived	Sustain spending on types of capital improvements modeled in NBIAS at 2014 levels in constant dollar terms over the next 20 years.	Set spending at the level at which the projected percentage of deck area on bridges in poor condition in 2034 matches that in 2014.	Set spending at the level sufficient to fund all cost-beneficial potential projects.	Includes all NBIAS-derived spending included in the Improve Conditions and Performance scenario.
Other (Nonmodeled)	Sustain spending on types of capital improvements not modeled in HERS or NBIAS at 2014 levels in constant dollar terms over the next 20 years.	Set spending at the level necessary so that the nonmodeled share of total highway and bridge investment will remain the same as in 2014.	Set spending at the level necessary so that the nonmodeled share of total highway and bridge investment will remain the same as in 2014.	Subset of Improve Conditions and Performance scenario; includes spending on system rehabilitation; excludes spending on system capacity and system enhancement.

Exhibit 7-1 also references a critical subset of the Improve Conditions and Performance scenario, the State of Good Repair benchmark. This benchmark represents the level of investment that would be necessary to address all cost-beneficial investments that would improve the physical conditions of existing highway infrastructure assets.

The projections for conditions and performance in each scenario are estimates of what could be achieved with a given level of investment assuming an economically driven approach to project selection. (The project selection method is explained in Chapter 10). The projections do not necessarily represent what would be achieved given current decision-making practices. Consequently, comparing the relative conditions and performance outcomes across the different scenarios might be more illuminating than focusing on the specific projections for each scenario individually.

Changes in Scenario Definitions Relative to the 2015 C&P Report

The key differences between the scenarios presented in this report relative to those in the 2015 C&P Report are:

- As the base year of the analysis for this report is 2014 rather than 2012, the Sustain 2014 Spending scenario replaces the Sustain 2012 Spending scenario analyzed in the 2015 C&P Report.
- The investment pattern assumed for Maintain Conditions and Performance scenario in this report is "flat" (i.e., the same level of investment would occur in each year), rather than "ramped" (i.e., investment would grow at a constant annual percentage). Also, the NBIAS-derived component of the scenario targets the share of total bridge deck area that is on bridges rated as "poor," rather than the share of bridges rated as structurally deficient or functionally obsolete. (See Chapters 6 and 10.)
- The Improve Conditions and Performance scenario (and the State of Good Repair benchmark) used in this report address cost-beneficial investments immediately, rather than gradually addressing them over 20 years based on ramped investment pattern.

Scenario Spending Levels and Sources

Exhibit 7-2 summarizes capital investment levels associated with each 20-year scenario and benchmark, stated in constant 2014 dollars. The Sustain 2014 Spending scenario fixes average annual investment to actual 2014 levels for each investment period, resulting in annual investment of $105.4 billion, or approximately $2.1 trillion over 20 years.

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

Scenario and Comparison Parameter	Capital Investment for 2015 through 2034 (Billions of $2014)		Percent Difference Relative to 2014	Investment Pattern
	20-Year Total	Average Annual		
Sustain 2014 Spending Scenario	$2,108.5	**$105.4**	0.0%	Flat
Maintain Conditions and Performance Scenario	$2,048.0	**$102.4**	-2.9%	Flat
Improve Conditions and Performance Scenario	$2,714.9	**$135.7**	28.8%	Variable
State of Good Repair Benchmark*	$1,767.9	**$88.4**		

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

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

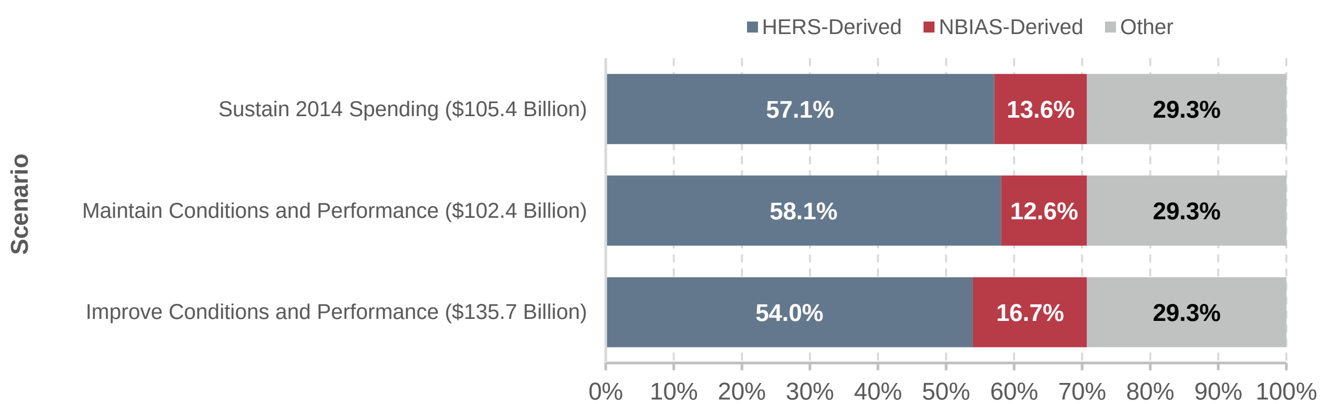
The estimated level of annual investment needed to achieve the objectives of the Maintain Conditions and Performance scenario is $102.4 billion, 2.9 percent less than actual 2014 spending. This suggests that current levels of investment would be sufficient to keep overall conditions and performance from worsening over time. However, some individual measures of conditions and performance (aside from those specifically targeted by the scenario definition) would likely improve over 20 years, while others would likely see some deterioration. It should also be noted that, because it is focused on conditions and performance for the overall system, this scenario might sometimes entail improvement and sometimes deterioration in average conditions and performance on subsets of some networks.

Achieving the objectives of the Improve Conditions and Performance scenario would require an estimated average annual spending level of $135.7 billion, which exceeds the 2014 level by 28.8 percent. Because there is an existing backlog of cost-beneficial investments that have not previously been addressed, the Improve Conditions and Performance scenario results in higher levels of investment in the early years of the analysis and lower levels in the latter years. This investment pattern is discussed in greater detail in Chapter 10. The total needed to address both the existing backlog and additional cost-beneficial investments needed to address issues that arise over the next 20 years is estimated to be approximately $2.7 trillion; the backlog is quantified later in this section.

The average annual investment level associated with the State of Good Repair benchmark is $88.4 billion, which is the total amount of investment in pavement and bridge rehabilitation that is projected to be cost-beneficial. This benchmark is the rehabilitation portion of the investment in the Improve Conditions and Performance scenario. In determining the level of investment under this benchmark, HERS and NBIAS screen out through benefit-cost analysis any assets that might have outlived their original purpose, rather than automatically reinvesting in all assets in perpetuity. With national consensus lacking on exactly what constitutes a "state of good repair" for highway assets, alternative benchmarks with different objectives could be equally valid from a technical perspective. (Note that the Transit State of Good Repair Benchmark presented later in this chapter does not apply a benefit-cost screen.)

The sources of the estimates of average annual investment levels are presented in *Exhibit 7-3*. The HERS-derived component, which accounts for most of the total investment in each scenario, represents spending on pavement rehabilitation and capacity expansion on Federal-aid highways.

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



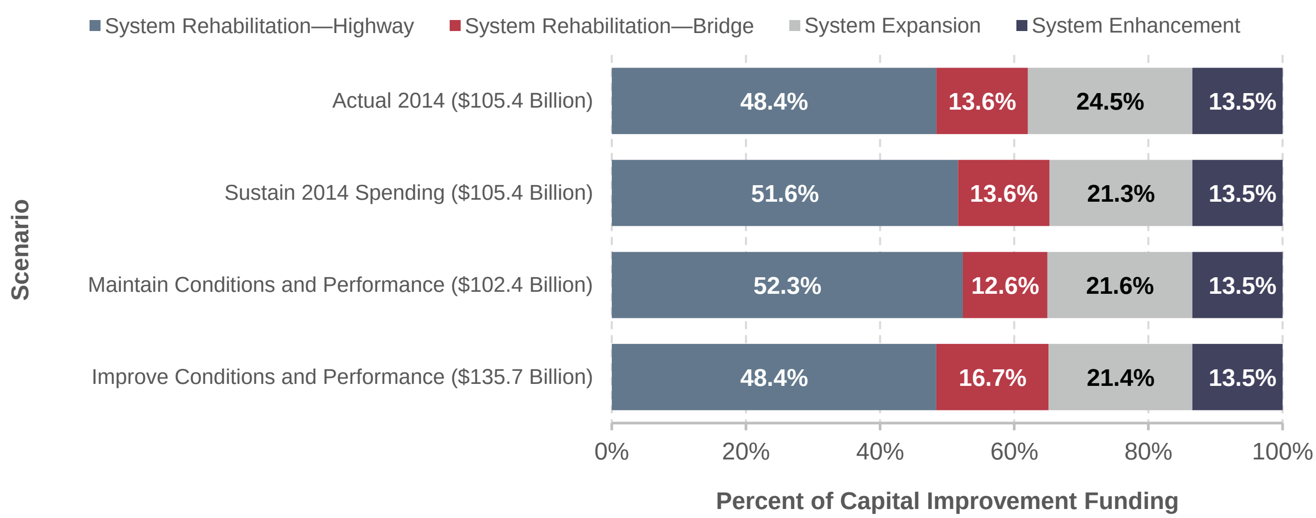
Sources: Highway Economic Requirements System and National Bridge Investment Analysis System.

The NBIAS-derived component represents rehabilitation spending on all bridges, including those not on Federal-aid highways. The Other (nonmodeled) spending, which accounted for 29.3 percent of total investment in 2014, is assumed to comprise the same share in all systemwide scenarios. The nonmodeled share includes most expenditures off of Federal-aid highways (the HERS analysis is limited to Federal-aid highways only) and expenditures classified in Chapter 2 as system enhancements (safety enhancements, traffic operation improvements, and environmental enhancements). As discussed in the Introduction to Part II, the nonmodeled share is much lower for major system subsets, such as Federal-aid highways, the NHS, and Interstate highways.

Systemwide Scenario Spending Patterns and Conditions and Performance Projections

Exhibit 7-4 compares the distributions from each scenario for investment spending by improvement type with the actual distribution of capital spending in 2014. Comparing the Sustain 2014 Spending scenario to the actual 2014 spending distribution, HERS modeling results support less spending on system expansion and more spending on highway rehabilitation than currently occurs. At the higher levels of spending attempted in the Improve Conditions and Performance scenario, the modeling results suggest spending devoting a greater share of investment to bridge system rehabilitation relative to highway system rehabilitation and system expansion.

Exhibit 7-4: Systemwide Highway Capital Investment Scenarios for 2015 Through 2034: Distribution by Capital Improvement Type Compared with Actual 2014 Spending



Average Annual Distribution by Capital Improvement Type (Billions of 2014 Dollars)				
Capital Improvement Type	Actual 2014 Spending Distribution	Sustain 2014 Spending Scenario	Maintain Conditions & Performance Scenario	Improve Conditions & Performance Scenario
System Rehabilitation—Highway	$51.0	$54.4	$53.6	$65.7
System Rehabilitation—Bridge	$14.4	$14.4	$12.9	$22.7
System Rehabilitation—Total	**$65.4**	**$68.8**	**$66.5**	**$88.4**
System Expansion	$25.9	$22.5	$22.1	$29.1
System Enhancement	$14.2	$14.2	$13.8	$18.3
Total, All Improvement Types	**$105.4**	**$105.4**	**$102.4**	**$135.7**

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

In the Improve Conditions and Performance scenario, annual spending on highway and bridge rehabilitation averages $88.4 billion, considerably more than the $65.4 billion of such spending in 2014. This result suggests that achieving a state of good repair on the Nation's highways by implementing all cost-beneficial system rehabilitation improvements would require either a significant increase in overall highway and bridge investment or a significant redirection of investment from other types of improvements toward system rehabilitation (the latter of which could involve prioritizing less cost-beneficial rehabilitation improvements over more cost-beneficial expansion investments).

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

Under the Sustain 2014 Spending scenario, the share of vehicle miles traveled (VMT) on Federal-aid highways with poor ride quality would be reduced from 17.3 percent in 2014 to 13.9 percent in 2034, while the share on pavements with good ride quality would rise slightly from 47.0 percent to 47.5 percent. Average International Roughness Index (IRI) would decrease (improve) by 0.3 percent in 2034 relative to 2014, while the average delay per VMT would decrease (improve) by 18.5 percent. The share of bridges (weighted by deck area) that are rated as poor would drop from 6.8 percent in 2014 percent to 4.7 percent in 2034, while the share rated as good would rise from 44.3 percent to 52.8 percent.

The cells shaded in *Exhibit 7-5* are the values relevant to the definition of the Maintain Conditions and Performance scenario. The cell showing 6.8 percent of bridges (as measured by deck area) rated in poor condition in 2034 is highlighted, as it matches the actual value for that metric in 2014. The cell showing that the average change in VMT-weighted IRI is 0.0 percent is highlighted, showing that this metric is unchanged relative to the actual 2014 value.

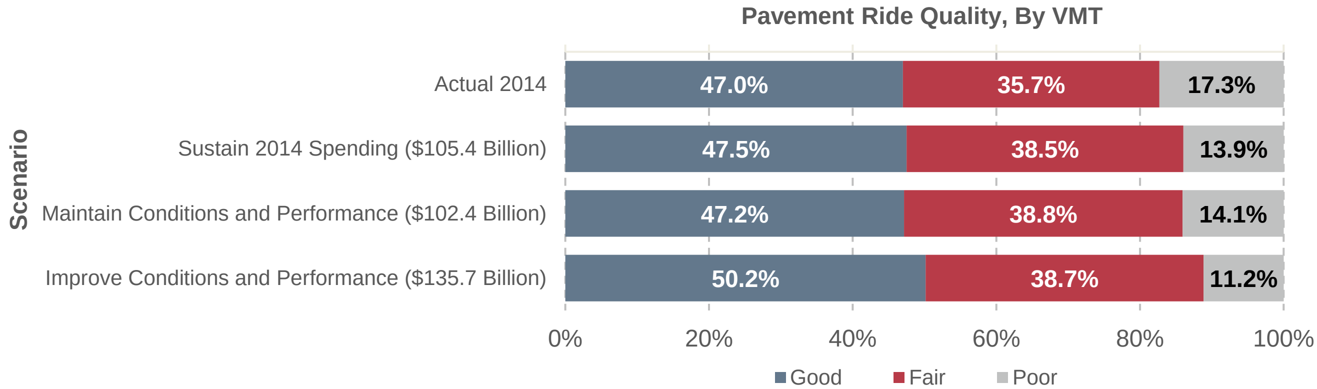
VMT-Weighting vs. Deck Area-Weighting

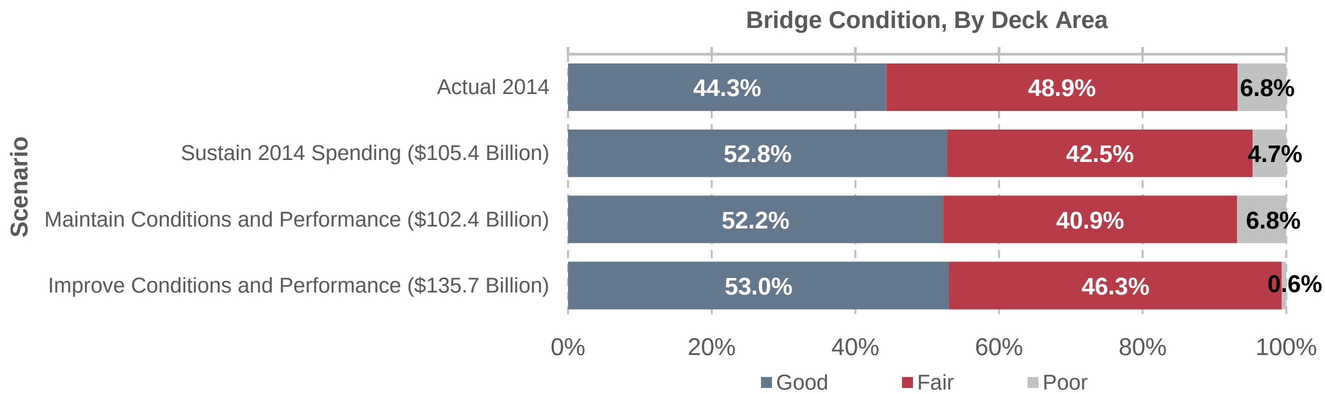
The performance indicators presented in *Exhibit 7-5* were drawn from the more detailed analysis of the impacts of alternative investment levels presented in Chapter 10. The pavement and delay statistics presented in terms of VMT were derived from HERS while the bridge condition statistics weighted by deck area were derived from NBIAS. While weighting by use is more relevant from an economic perspective, FHWA has traditionally reported bridge performance statistics on a deck area-weighted basis rather than weighting by average daily traffic.

Under the PM-2 rule referenced in the Introduction to Part I and Chapter 6, States will be setting performance targets for pavements on a lane mile-weighted basis and setting performance targets for bridges on a deck area-weighted basis. For consistency purposes, future C&P reports will place a greater emphasis on lane-mile weighted measures for pavements.

Under the Improve Conditions and Performance scenario, the share of VMT on Federal-aid highways with poor ride quality would be reduced to 11.2 percent in 2034, while the share on pavements with good ride quality would rise to 50.2 percent. Average IRI would decrease (improve) by 5.6 percent over the 20-year period, while the average delay per VMT would decrease (improve) by 19.3 percent. The share of bridges (weighted by deck area) that are rated as in poor condition is projected to drop to 0.6 percent in 2034, while the share rated as good would rise to 53.0 percent.

Exhibit 7-5: Systemwide Highway Capital Investment Scenarios for 2015 Through 2034: Projected Impacts on Selected Highway Performance Measures





Highway Performance Measure	Actual 2014 Values	Sustain 2014 Spending Scenario	Maintain Conditions & Performance Scenario	Improve Conditions & Performance Scenario
Pavement Ride Quality and Bridge Conditions (Good/Fair/Poor)[1]				
Percent of VMT on pavements with good ride quality[1]	47.0%	47.5%	47.2%	50.2%
Percent of VMT on pavements with fair ride quality[1]	35.7%	38.5%	38.8%	38.7%
Percent of VMT on pavements with poor ride quality[1]	17.3%	13.9%	14.1%	11.2%
Percent of bridges rated as good condition, by deck area	44.3%	52.8%	52.2%	53.0%
Percent of bridges rated as fair condition, by deck area	48.9%	42.5%	40.9%	46.3%
Percent of bridges rated as poor condition, by deck area	**6.8%**	4.7%	**6.8%**	0.6%
Projected Changes by 2034 Relative to 2014 for Selected Indicators				
Percent change in average IRI (VMT-weighted)[1]	0.0%	-0.3%	**0.0%**	-5.6%
Percent change in average delay per VMT[1]	0.0%	-18.5%	-18.4%	-19.3%

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

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

Improve Conditions and Performance Scenario

The manner in which the Improve Conditions and Performance scenario is defined makes it easier to drill down further into the results than is the case for the Maintain Conditions and Performance scenario. For example, looking at the Maintain Conditions and Performance scenario output on a functional class basis could be misleading, as conditions and performance could improve on some functional classes while declining on others.

Thus, the investment levels identified for each functional class on a systemwide analysis would differ from those obtained by analyzing each functional class separately to determine the investment level to maintain its overall conditions and performance at base-year levels. This limitation does not apply to the Improve Conditions and Performance scenario; since the objective of the scenario is to make all cost-beneficial investments, one would obtain the same result for each functional class whether analyzed separately or as part of a systemwide run.

Spending by System

Exhibit 7-6 compares the distribution of spending for the Improve Conditions and Performance scenario by system, and by capital improvement type against the actual 2014 spending. As noted in Chapter 1, the Interstate Highway System is a subset of the National Highway System, which is a subset of Federal-aid highways, which is a subset of the overall highway network (all roads).

About 49.4 percent of the Improve Conditions and Performance scenario spending goes for improvements to the NHS, while 23.2 percent goes for improvements to Interstate highways.

Spending on all capital improvement types for Interstate highways under the Improve Conditions and Performance scenario is 24.3 percent higher than actual 2014 spending. The Improve Conditions and Performance scenario would increase spending for all systems and capital improvement types except for highway system rehabilitation spending on Interstate highways, which decreases by 17.3 percent relative to the actual amount spent in 2014.

The largest gaps (in percentage terms) for each system are in system rehabilitation for bridges, which range from 58.3 percent for all roads to 150.4 percent for Interstate highways, compared with actual 2014 spending. Spending on system expansion in the Improve Conditions and Performance scenario increases modestly by 12.5 percent for all roads compared with actual 2014 spending, while for Interstate highways the increase is significantly higher at a 58.5 percent increase. In considering the implications of these gaps, it is important to note that they pertain to just a single year's spending (2014), which may not be fully consistent with longer term trends, particularly as one drills down into smaller and smaller subsets of the overall system.

Exhibit 7-6: Improve Conditions and Performance Scenario for 2015 Through 2034: Distribution by System and by Capital Improvement Type Compared with Actual 2014 Spending

System Component	System Rehabilitation			System Expansion	System Enhancement	Total	Percent of Total
	Highway	Bridge	Total				
Average Annual Investment in Billions of 2014 Dollars							
Interstate Highway System	$11.9	$7.9	$19.9	$9.3	$2.3	$31.4	23.2%
National Highway System	$29.6	$12.8	$42.3	$18.5	$6.2	$67.0	49.4%
Federal-aid Highways	$49.0	$18.4	$67.4	$24.2	$11.1	$102.7	75.7%
All Public Roads	$65.7	$22.7	$88.4	$29.1	$18.3	$135.7	100.0%
Percent Above Actual 2014 Capital Spending by All Levels of Government Combined							
Interstate Highway System	-17.3%	150.4%	12.8%	58.5%	24.3%	24.3%	
National Highway System	9.5%	79.5%	24.1%	8.9%	19.0%	19.0%	
Federal-aid Highways	28.7%	74.5%	38.6%	9.7%	29.6%	29.6%	
All Public Roads	28.7%	58.3%	35.2%	12.5%	28.8%	28.8%	

Note: The "NBIAS-Derived" share includes all outlays classified as "System Rehabilitation: Bridge." The "HERS-Derived" share includes most outlays classified as "System Rehabilitation: Highway" and "System Expansion" except for the portions spent off of Federal-aid Highways, which are classified as "Other." The "Other" category also includes all outlays classified as "System Enhancement."

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

Spending by Improvement Type and Highway Functional Class

Exhibit 7-7 presents the distribution by improvement type and highway functional class for the Improve Conditions and Performance scenario compared with actual 2014 spending for Federal-aid highways.

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

The Improve Conditions and Performance scenario would shift funds away from rural other principal arterials and minor arterials to other roadway types relative to what occurred in 2014, but would result in higher spending for all other functional classes. Spending on rural roads would increase by 5.7 percent from actual 2014 spending to $29.7 billion, while spending on urban roads would increase by 42.6 percent to $73.0 billion.

The largest percentage reduction in spending occurs from decreases in rural road system expansion spending, which is reduced by 63.1 percent (from $6.9 billion to $2.5 billion) compared with actual 2014 spending. This indicates that HERS finds sustaining spending in rural expansion at current levels over 20 years not to be cost-beneficial. In contrast, the Improve Conditions and Performance scenario suggests that a 42.6-percent increase (from $15.2 to $21.7 billion) in funding for system expansion of urban roads would be cost-beneficial.

Significant reductions in some types of urban spending in the Improve Conditions and Performance scenario relative to 2014 occur as well. Spending on system rehabilitation of urban Interstate roads would be reduced by 20.3 percent, system expansion of urban other principal arterial roads by 33.2 percent, and system rehabilitation on urban other principal arterial bridges by 9.1 percent.

Spending on system rehabilitation for rural roads increases by 8.6 percent (from $15.6 billion to $16.9 billion) in the Improve Conditions and Performance scenario compared with actual 2014 spending, but that increase is significantly lower than the 42.6-percent increase (from $22.5 billion to $32.1 billion) in spending for system rehabilitation needed for urban roads. Bridges on both rural and urban roads, however, require substantial system rehabilitation spending, to achieve the goals of the scenario. The Improve Conditions and Performance scenario calls for 129.6-percent and 52.9-percent increases in system rehabilitation spending over actual 2014 spending for rural and urban bridges, respectively.

The Improve Conditions and Performance scenario suggests that the largest funding gaps (in percentage terms) are for bridge rehabilitation on the rural portion of the Interstate System (368.8 percent), system expansion for urban other freeways and expressways (167.7 percent), and highway system rehabilitation on urban minor arterials (117.5 percent).

Exhibit 7-7: Improve Conditions and Performance Scenario for Federal-aid Highways: Distribution of Average Annual Investment for 2015 Through 2034 Compared with Actual 2014 Spending by Functional Class and Improvement Type

Average Annual National Investment on Federal-aid Highways (Billions of 2014 Dollars)						
Functional Class	System Rehabilitation Highway	System Rehabilitation Bridge	System Rehabilitation Total	System Expansion	System Enhancement	Total
Rural Arterials and Major Collectors						
Interstate	$4.2	$2.3	$6.6	$0.6	$0.9	$8.0
Other Principal Arterial	$5.9	$1.3	$7.2	$1.0	$0.9	$9.0
Minor Arterial	$3.1	$1.1	$4.2	$0.3	$0.8	$5.4
Major Collector	$3.7	$2.1	$5.8	$0.7	$0.8	$7.3
Subtotal	**$16.9**	**$6.8**	**$23.7**	**$2.5**	**$3.4**	**$29.7**
Urban Arterials and Collectors						
Interstate	$7.7	$5.6	$13.3	$8.7	$1.5	$23.5
Other Freeway and Expressway	$3.4	$1.5	$4.9	$4.7	$0.9	$10.5
Other Principal Arterial	$9.0	$2.1	$11.1	$3.4	$2.2	$16.8
Minor Arterial	$8.1	$1.6	$9.7	$3.5	$1.7	$14.8
Collector	$3.9	$0.8	$4.6	$1.3	$1.3	$7.3
Subtotal	**$32.1**	**$11.6**	**$43.7**	**$21.7**	**$7.7**	**$73.0**
Total, Federal-aid highways[1]	**$49.0**	**$18.4**	**$67.4**	**$24.2**	**$11.1**	**$102.7**

Percent Above Actual 2014 Capital Spending on Federal-aid Highways by All Levels of Government Combined						
Functional Class	System Rehabilitation Highway	System Rehabilitation Bridge	System Rehabilitation Total	System Expansion	System Enhancement	Total
Rural Arterials and Major Collectors						
Interstate	-11.3%	368.8%	24.5%	-53.8%	29.6%	11.1%
Other Principal Arterial	34.6%	109.3%	43.7%	-73.4%	29.6%	-4.0%
Minor Arterial	1.9%	37.6%	9.4%	-75.6%	29.6%	-6.0%
Major Collector	8.9%	99.2%	30.1%	0.3%	29.6%	26.6%
Subtotal	**8.6%**	**129.6%**	**27.8%**	**-63.1%**	**29.6%**	**5.7%**
Urban Arterials and Collectors						
Interstate	-20.3%	109.9%	7.9%	89.5%	29.6%	30.0%
Other Freeway and Expressway	103.4%	104.2%	103.7%	167.7%	29.6%	115.5%
Other Principal Arterial	87.1%	-9.1%	56.0%	-33.2%	29.6%	19.9%
Minor Arterial	117.5%	43.3%	100.1%	45.3%	29.6%	74.1%
Collector	48.0%	4.9%	38.4%	3.1%	29.6%	28.7%
Subtotal	**42.6%**	**52.9%**	**45.2%**	**42.6%**	**29.6%**	**42.6%**
Total, Federal-aid highways[1]	**28.7%**	**74.5%**	**38.6%**	**9.7%**	**29.6%**	**29.6%**

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

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

Highway and Bridge Investment Backlog

The investment backlog represents all highway and bridge improvements that could be economically justified for immediate implementation, based solely on the current conditions and operational performance of the highway system (without regard to potential future increases in VMT or potential future physical deterioration of infrastructure assets). Unlike NBIAS, HERS does not routinely produce rolling backlog figures over time as an output, but is equipped to do special analyses to identify the base-year backlog. Under this scenario analysis, any potential improvement that would correct an existing pavement or capacity deficiency and that has a benefit-cost ratio greater than or equal to 1.0 is considered part of the current highway and bridge investment backlog.

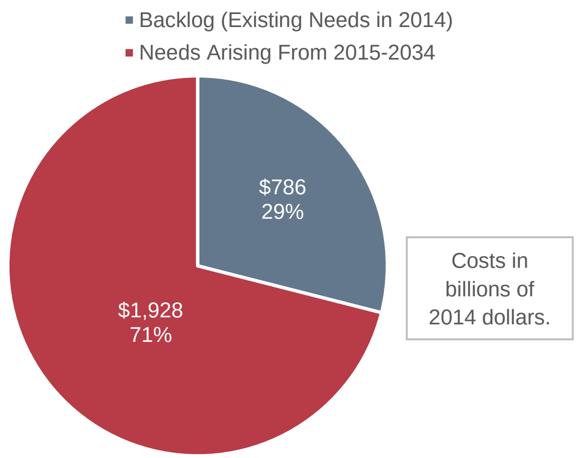
Conceptually, the backlog represents a subset of the investment levels reflected in the Improve Conditions and Performance scenario. Exhibit 7-2 had identified an average annual investment level of $135.7 billion for this scenario, for a 20-year total of approximately $2.7 trillion. Of this total, $786.4 billion (29.0 percent) is attributable to the existing backlog as of 2014, while the remainder is attributable to additional projected pavement, bridge, and capacity needs that might arise over the next 20 years (see *Exhibit 7-8*).

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

Exhibit 7-9 presents an estimated distribution of the $786.4 billion backlog for 2014, by type of capital improvements. Similar to the process used to derive the capital investment scenario estimates, an adjustment factor was applied to the backlog values computed by HERS and NBIAS to account for nonmodeled capital improvement types. The values shown in italics are nonmodeled; NBIAS was used to compute the values in the System Rehabilitation – Bridge column, while all other values in the table were derived from HERS.

Of the estimated $786.4 billion total backlog, approximately $123.4 billion (15.7 percent) is for the Interstate System, $327.2 billion (41.6 percent) is for the NHS, and $596.7 billion (75.9 percent) is for Federal-aid highways.

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



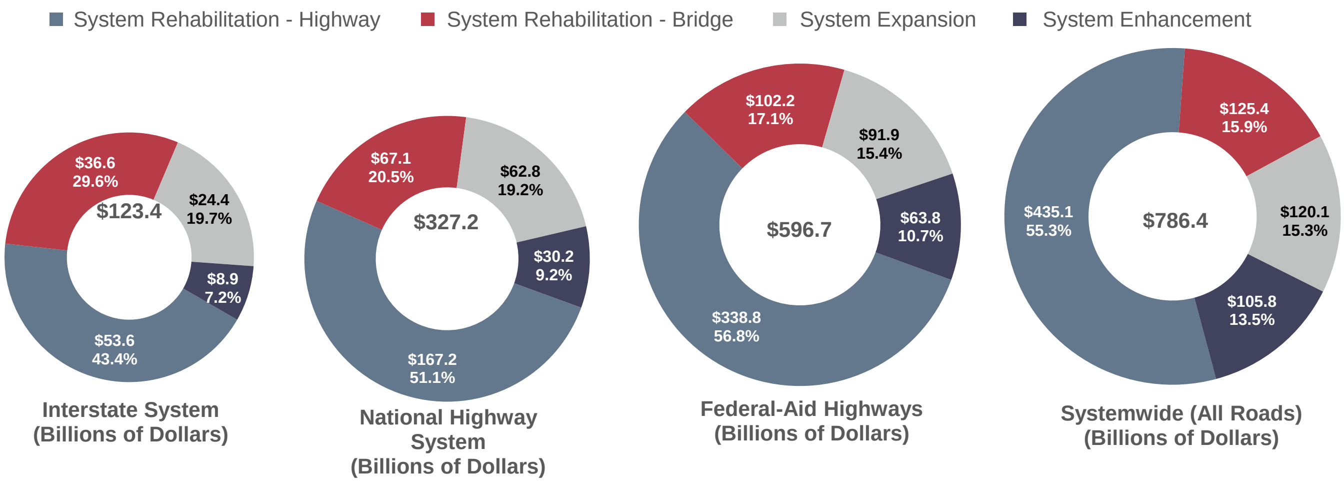
Source: Highway Economic Requirements System and National Bridge Investment Analysis System.

Why does the bridge backlog presented in Exhibit 7-9 differ from bridge backlog figures estimated by some other organizations?

One major reason for such differences is that the $125.4 billion backlog estimated by NBIAS is not intended to constitute a complete bridge investment estimate backlog. The NBIAS figures relate only to investment needs associated with the condition of existing structures, and not capacity expansion needs. The backlog HERS estimates includes estimates of capacity-related needs for highways and bridges combined.

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

Exhibit 7-9: Estimated Highway and Bridge Investment Backlog, by System and Improvement Type, as of 2014



System Component	Billions of 2014 Dollars[1]						Percent of Total
	System Rehabilitation			System Expansion	System Enhancement	Total	
	Highway	Bridge	Total				
Federal-aid Highways—Rural	$95.1	$35.0	$130.2	$16.3	*$19.6*	$166.1	21.1%
Federal-aid Highways—Urban	$243.6	$67.2	$310.8	$75.6	*$44.2*	$430.5	54.7%
Federal-aid Highways—Total	**$338.8**	**$102.2**	**$441.0**	**$91.9**	***$63.8***	**$596.7**	**75.9%**
Non-Federal-aid Highways	*$96.3*	$23.1	$119.5	*$28.2*	*$42.0*	$189.7	24.1%
All Public Roads	**$435.1**	**$125.4**	**$560.4**	**$120.1**	**$105.8**	**$786.4**	**100.0%**
Interstate System	$53.6	$36.6	$90.1	$24.4	*$8.9*	$123.4	15.7%
National Highway System	$167.2	$67.1	$234.2	$62.8	*$30.2*	$327.2	41.6%

[1] Italicized values are estimates for those system components and capital improvement types not modeled in HERS or NBIAS, such as system enhancements and pavement and expansion improvements to roads functionally classified as rural minor collector, rural local, or urban local for which HPMS data are not available to support a HERS analysis.

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

Approximately 71.2 percent ($560.4 billion) of the total backlog is attributable to system rehabilitation needs, 15.3 percent ($120.1 billion) is for system expansion, and 13.5 percent ($105.8 billion) for system enhancement. The share of the total backlog attributable to system rehabilitation is roughly similar across all highway systems.

The $786.4-billion estimated backlog is weighted toward urban areas; approximately 54.7 percent of this total is attributable to Federal-aid highways in urban areas. As noted in Chapter 6, average pavement ride quality on Federal-aid highways is worse in urban areas than in rural areas; urban areas also face relatively greater problems with congestion than do rural areas. Very little of the backlog spending (just 2.1 percent) is targeted toward system expansion on rural Federal-aid highways.

Transit Capital Investment Scenarios

Chapter 10 considers the impacts of varying levels of capital investment on transit conditions and performance. This chapter provides in-depth analysis of three specific investment scenarios, as outlined in *Exhibit 7-10*. The Sustain 2014 Spending scenario assesses the effects on asset conditions and system performance that would result from sustaining 2014 expenditure levels over the next 20 years. Given that current expenditures are generally less than are required to maintain current condition and performance levels, this scenario reflects the magnitude of the expected declines in condition and performance should current capital investment rates be maintained. The Low-Growth and High-Growth scenarios both assess the required levels of reinvestment to (1) preserve existing transit assets at a condition rating of 2.5 or higher and (2) expand transit service capacity to support differing levels of ridership growth while passing TERM's benefit-cost test.

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

Key Takeaways

Backlog

The backlog is estimated at $98.8 billion in 2014.

An estimated $18.4 billion in annual reinvestment would be required to fully eliminate the SGR backlog by 2034.

Current Investment

If the level of investment in preservation is maintained at the 2014 level ($11.3 billion), the backlog would be projected to climb from $98.2 billion to $116.2 billion by 2034 (an increase of $18.0 billion or 19 percent).

Expansion Investment Scenarios

In addition to $18.4 billion annually to eliminate the backlog in 2034, the following investment levels in expansion would be required for the Low- and High-Growth scenarios.

- Low-Growth Scenario – The Low-Growth scenario forecasts $6.0 billion per year investment in new assets to accommodate an estimated annual ridership increase of 1.2 percent (20 percent below historical growth).
- High-Growth Scenario – In the High-Growth scenario, investments of $8.1 billion are needed to support a ridership increase of 1.8 percent per year (20 percent higher than historical growth).

TERM's estimates for capital expansion needs in the Low- and High-Growth scenarios are driven by the projected growth in passenger miles traveled (PMT) based on the trend rate of growth in PMT, calculated as the compound average annual PMT growth by FTA region, urbanized area (UZA) stratum, and mode over the most recent 15-year period. For example, all bus operators located in the same FTA region in UZAs of the same population stratum are assigned the same growth rate. Use of the 10 FTA regions captures regional differences in PMT growth, while use of population strata (greater than 1 million; 1 million to 500,000; 500,000 to 250,000; and less than 250,000) captures differences in urban area size. Perhaps more importantly, the approach also recognizes differences in PMT growth trends by transit mode. Over the past decade, the rate of PMT growth has differed markedly across transit modes: highest for heavy rail, vanpool, and demand-response, and low to flat for motor bus. These differences are accounted for in the expansion need projections for the Low- and High-Growth scenarios.

Exhibit 7-10: SGR Benchmark and Transit Investment Scenarios

Scenario Aspect	SGR	Sustain 2014 Spending	Low Growth	High Growth
Description	Level of investment to attain and maintain SGR over next 20 years (no assessment of expansion needs)	Sustain preservation and expansion spending at 2014 levels over next 20 years	Preserve existing assets and expand asset base to support historical rate of ridership growth less 0.3%, which equals to 1.2%	Preserve existing assets and expand asset base to support historical rate of ridership growth plus 0.3%, which equals to 1.8%
Objective	Requirements to attain SGR (as defined by assets in condition 2.5 or better)	Assess impact of constrained funding on condition, SGR backlog, and ridership capacity	Assess unconstrained preservation and capacity expansion needs assuming low ridership growth	Assess unconstrained preservation and capacity expansion needs assuming high ridership growth
Apply Benefit-Cost Test?	No	Yes[1]	Yes	Yes
Preservation?	Yes[2]	Yes[2]	Yes[2]	Yes[2]
Expansion?	No	Yes	Yes	Yes

[1] To prioritize investments under constrained funding.

[2] Replace at condition 2.5.

Exhibit 7-11 summarizes the analysis results for each scenario. Note that each scenario presented in *Exhibit 7-11* imposes the same asset condition replacement threshold (i.e., assets are replaced at condition rating of 2.5 when budget is sufficient) when assessing transit reinvestment needs. Hence, the differences in the total preservation expenditure amounts across each scenario primarily reflect the impact of either (1) an imposed budget constraint (Sustain 2014 Spending scenario) or (2) application of TERM's benefit-cost test. (The SGR Benchmark does not apply the benefit-cost test.) A brief review of the national-level needs analysis in *Exhibit 7-11* reveals the following:

- **SGR Benchmark:** The level of expenditures required to attain and maintain an SGR over the upcoming 20 years, which would cover preservation needs but excludes expansion investments, is 4.0 percent higher than that currently expended on asset preservation and expansion combined.
- **Sustain 2014 Spending scenario:** Total spending under this scenario is well below that of the other scenarios, indicating that sustaining recent spending levels is insufficient to attain the investment objectives of the SGR Benchmark, the Low-Growth scenario, or the High-Growth scenario. This result suggests future increases in the size of the SGR backlog and a likely increase in the number of transit riders per peak vehicle—including an increased incidence of crowding—in the absence of increased expenditures.
- **Low- and High-Growth scenarios[9]:** The level of investment to address expected preservation and expansion needs is estimated to be roughly 26 to 41 percent higher than that currently expended by the Nation's transit operators. Preservation and expansion needs are highest for UZAs exceeding 1 million in population. (These UZAs are listed in Chapter 1, Exhibit 1-16).

[9] The Low-Growth and High-Growth scenarios in this report are based on 15-year ridership trends as of 2014, the cut-off year for this report. The Department does note that transit ridership has, in fact, not increased since 2014 through the early months of 2019. The causes of the decreased transit ridership since 2014 will be analyzed in the next edition of this report. The ridership trends since that time will also be incorporated into the capital investment needs forecasts presented in future editions of this report.

Exhibit 7-11: Annual Average Cost by Investment Scenario, 2014–2034

Mode, Purpose, and Asset Type	SGR Benchmark	Sustain 2014 Spending	Low Growth	High Growth
Urbanized Areas Over 1 Million in Population[1]				
Nonrail[2]				
Preservation	$5.1	$3.3	$4.5	$4.5
Expansion	NA	$0.4	$0.4	$0.8
Subtotal Nonrail[3]	**$5.1**	**$3.7**	**$4.9**	**$5.3**
Rail				
Preservation	$11.5	$6.6	$11.4	$11.4
Expansion	NA	$5.5	$5.2	$6.6
Subtotal Rail[3]	**$11.5**	**$12.2**	**$16.5**	**$18.0**
Total, Over 1 Million in Population[3]	***$16.6***	***$15.9***	***$21.4***	***$23.3***
Urbanized Areas Under 1 Million in Population and Rural				
Nonrail[2]				
Preservation	$1.6	$1.3	$1.5	$1.5
Expansion	NA	$0.5	$0.5	$0.7
Subtotal Nonrail[3]	**$1.6**	**$1.7**	**$1.9**	**$2.1**
Rail				
Preservation	$0.2	$0.1	$0.1	$0.1
Expansion	NA	$0.0	$0.0	$0.0
Subtotal Rail[3]	**$0.2**	**$0.1**	**$0.1**	**$0.1**
Total, Under 1 Million and Rural[3]	***$1.8***	***$1.8***	***$2.0***	***$2.2***
Total[3]	**$18.4**	**$17.7**	**$23.4**	**$25.5**

[1] Includes 37 urbanized areas.

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

[3] Note that totals may not sum due to rounding.

Source: Transit Economic Requirements Model.

The following subsections present more details on the assessments for each scenario.

Sustain 2014 Spending Scenario

In 2014, as reported to the National Transit Database (NTD) by transit agencies, transit operators spent an average of $17.7 billion annually on capital projects (see Chapter 10, Impact of Preservation Investments on Transit Backlog and Conditions section and the corresponding discussion). Of this amount, $11.3 billion was dedicated to preserving existing assets, while the remaining $6.4 billion was dedicated to investing in asset expansion—to support ongoing ridership growth and to improve service performance. The Sustain 2014 Spending scenario considers the expected impact on the long-term physical condition and service performance of the Nation's transit infrastructure if these average expenditure levels were to be sustained in current dollar terms through 2034. Similar to the discussion in Chapter 10, the analysis considers the impacts of asset-preservation investments separately from those of asset expansion.

TERM's Funding Allocation: The following analysis of the Sustain 2014 Spending scenario relies on TERM's allocation of 2014-level preservation and expansion expenditures to the Nation's existing transit operators, their modes, and their assets over the upcoming 20 years, as depicted in *Exhibit 7-12*. As with other TERM analyses involving the allocation of constrained transit funds, TERM allocates limited funds based on the results of the model's benefit-cost analysis, which ranks potential investments based on their assessed benefit-cost ratios (with the highest-ranked investments funded first). Note that this TERM benefit-cost-based allocation of funding between assets and modes could differ from the allocation that local agencies actually pursue, assuming that total spending is sustained at current levels over 20 years.

Exhibit 7-12: Sustain 2014 Spending Scenario: Average Annual Investment by Asset Type, 2014–2034

Asset Type	Average Annual Investment (Billions of 2014 Dollars)		
	Preservation	Expansion	Total
Rail			
Guideway Elements	$2.5	$1.0	$3.5
Facilities	$0.0	$0.2	$0.2
Systems	$2.3	$0.2	$2.5
Stations	$0.2	$0.8	$1.0
Vehicles	$1.8	$2.0	$3.7
Other Project Costs	$0.0	$1.3	$1.3
Subtotal Rail*	**$6.7**	**$5.5**	**$12.3**
Subtotal UZAs Over 1 Million[1]	**$6.6**	**$5.5**	**$12.2**
Subtotal UZAs Under 1 Million and Rural[1]	**$0.1**	**$0.0**	**$0.1**
Nonrail			
Guideway Elements	$0.0	$0.0	$0.0
Facilities	$0.0	$0.1	$0.1
Systems	$0.1	$0.0	$0.1
Stations	$0.0	$0.0	$0.0
Vehicles	$4.5	$0.7	$5.2
Other Project Costs	$0.0	$0.0	$0.0
Subtotal Nonrail*	**$4.6**	**$0.9**	**$5.5**
Subtotal UZAs Over 1 Million[1]	**$3.3**	**$0.4**	**$3.7**
Subtotal UZAs Under 1 Million and Rural[1]	**$1.3**	**$0.5**	**$1.7**
Total	**$11.3**	**$6.4**	**$17.7**
Total UZAs Over 1 Million	**$9.9**	**$6.0**	**$15.9**
Total UZAs Under 1 Million and Rural	**$1.4**	**$0.5**	**$1.8**

[1] Note that totals may not sum due to rounding.

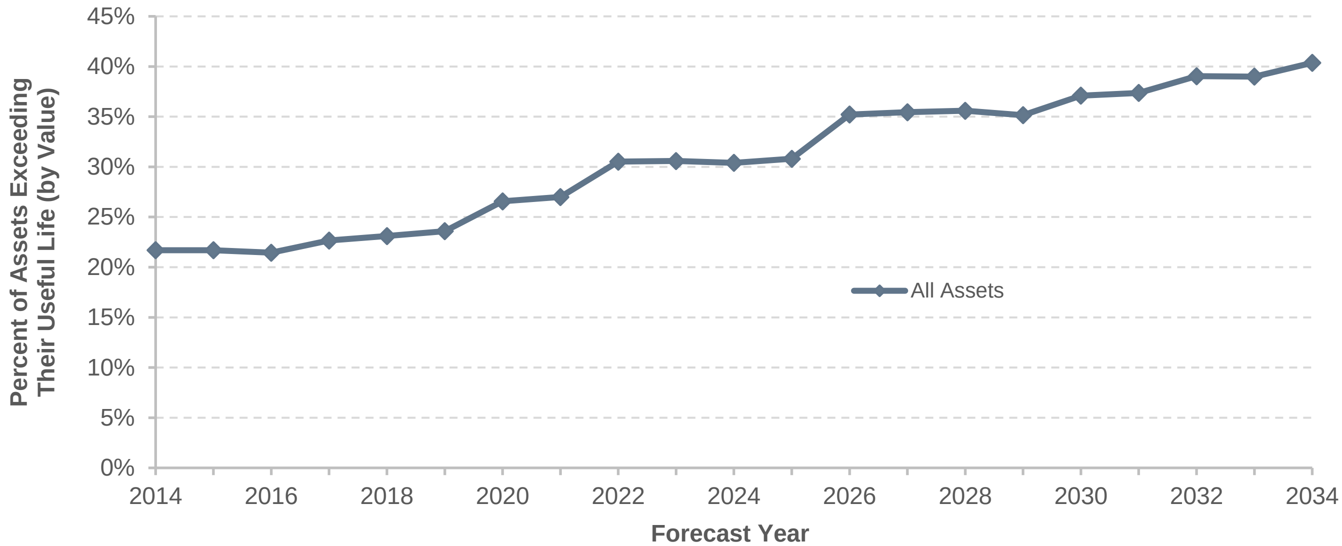
Source: Transit Economic Requirements Model and FTA staff estimates.

Preservation Investments

As noted above, transit operators spent an estimated $11.3 billion in 2014 rehabilitating and replacing existing transit infrastructure. Based on current TERM analyses, this level of reinvestment is less than that required to address the anticipated reinvestment needs of the Nation's existing transit assets. If sustained over the forecasted 20 years, this level would result in an overall decline in the condition of existing transit assets and an increase in the size of the investment backlog. One impact of this underinvestment is shown in *Exhibit 7-13,* which presents the proportion of existing transit assets (by value) that are estimated to exceed their useful life.

Under the Sustain Spending scenario, this amount is projected to increase from 22 percent of all transit assets in 2014 to roughly 40 percent in 2034.

Exhibit 7-13: Sustain 2014 Spending Scenario: Percentage of Assets Exceeding Useful Life, 2014–2034

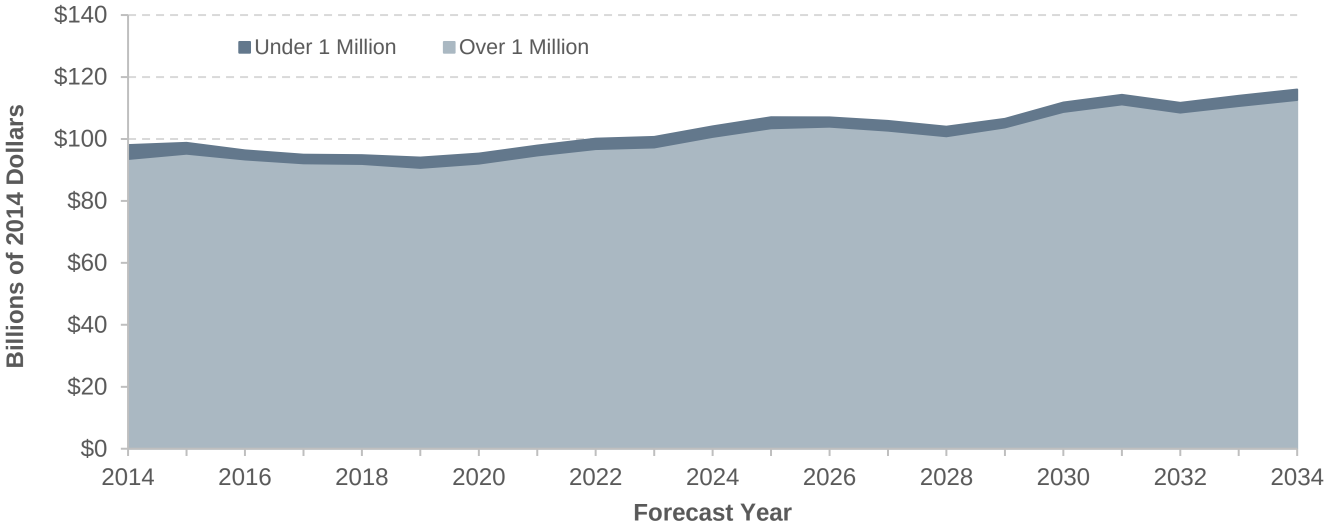


Note: The proportion of assets exceeding their useful life is measured based on asset replacement value, not asset quantities.
Source: Transit Economic Requirements Model.

Finally, *Exhibit 7-14* presents the projected change in the size of the investment backlog if reinvestment levels are sustained at the 2014 level of $11.3 billion, in constant dollar terms. As described in Chapter 10, the investment backlog represents the level of investment required to replace all assets that exceed their useful life and to address all rehabilitation activities that are currently past due. Rural and smaller urban needs are estimated using NTD records for vehicle ages and types, and from records generated for rural smaller urban agency facilities based on counts from NTD. The generated records for rural facilities include estimated facility size, replacement cost, and date built. Each estimated value was substantially revised for this C&P Report for two reasons: (1) The replacement costs for facilities used in previous reports were much higher than the costs rural and smaller urban agencies typically face; and (2) Some values for the year a facility was built, known as "date-built values," were much greater (i.e., the facilities were older) than is typical. For this report, facility size and cost were reassessed based on agency fleet size and facility cost per vehicle. The age range used to generate date-built values also was tightened to recognize a more realistic distribution of facility ages, based on sample data. These changes significantly reduced the value of these assets and size of the rural and smaller urban backlogs. As the current rate of capital reinvestment would be insufficient to address the projected replacement needs of the existing stock of transit assets, the size of that backlog would be projected to increase from the currently estimated level of $98.0 billion to roughly $116 billion by 2034.

The chart in *Exhibit 7-14* also divides the backlog amount according to size of transit service area, with the lower portion showing the backlog for UZAs having populations greater than 1 million and the upper portion showing the backlog for all other UZAs and rural areas combined. This segmentation highlights the significantly higher existing backlog for those UZAs serving the largest number of transit riders. Regardless of the actual allocation, the 2014 expenditure level of $11.3 billion, if sustained, clearly is not sufficient to prevent a further increase in the backlog needs of one or more of these UZA types.

Exhibit 7-14: Projected Backlog under the Sustain 2014 Spending Scenario, 2014–2034



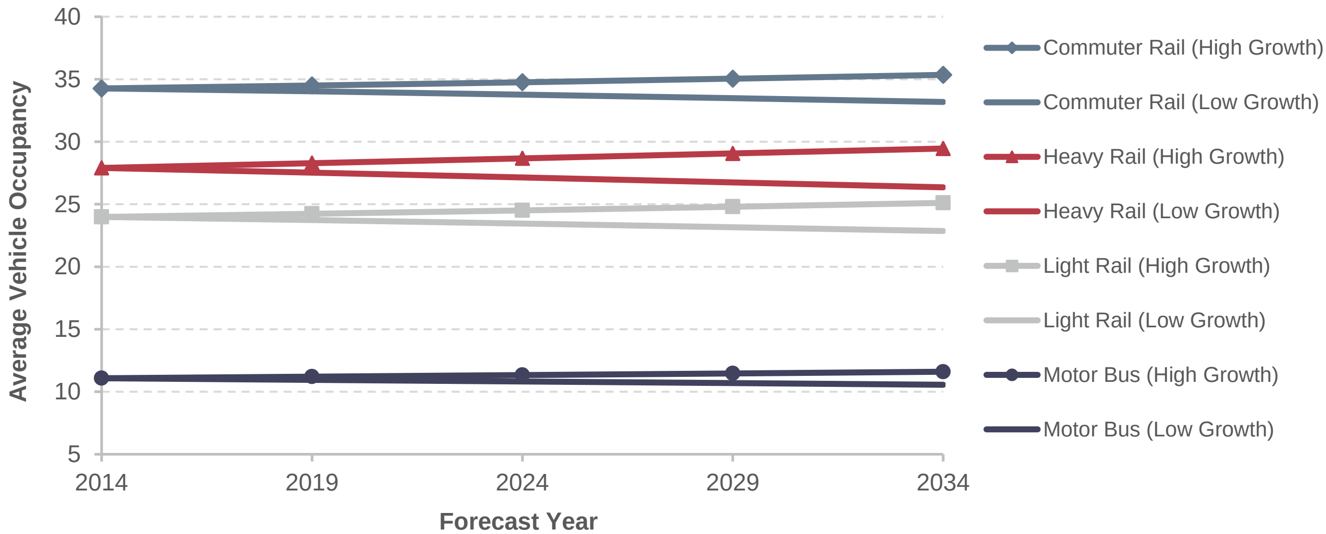
Source: Transit Economic Requirements Model.

Expansion Investments

In addition to the average $11.3 billion spent on preserving transit assets in 2014, transit agencies spent an average of $6.4 billion on expansion investments to support ridership growth and improve transit performance. This section considers the impact of sustaining the 2014 level of expansion investment on future ridership capacity and vehicle utilization rates under the assumptions of both lower and higher growth rates in ridership (i.e., the Low-Growth and High-Growth scenarios).

As considered in Chapter 10, the 2014 rate of investment in transit expansion is not sufficient to expand transit capacity at a rate equal to the rate of growth in travel demand, as projected by the historical trend rate of increase. Under these circumstances, transit capacity utilization (the average number of riders per transit vehicle) should be expected to increase, with the level of increase determined by actual growth in demand. Although the impact of this change could be minimal for systems that currently have lower-capacity utilization, service performance on some higher-utilization systems likely would decline as riders experience increased vehicle crowding and service delays. *Exhibit 7-15* illustrates this potential impact. It presents the projected change in vehicle occupancy rates by mode from 2014 through 2034 (reflecting the impacts of spending from 2014 through 2034) under both the Low-Growth and High-Growth scenarios in transit ridership, assuming that transit agencies continue to invest an average of $6.4 billion per year on transit expansion. Under the Low-Growth scenario, capacity utilization decreases across each of the four modes depicted here, indicating that investment is sufficient or higher than needed to maintain current occupancy levels. For the High-Growth scenario, however, the average number of riders per transit vehicle rises steadily across each mode. Chapter 8 provides more detail on the methodology for both the Low- and High-Growth scenarios.

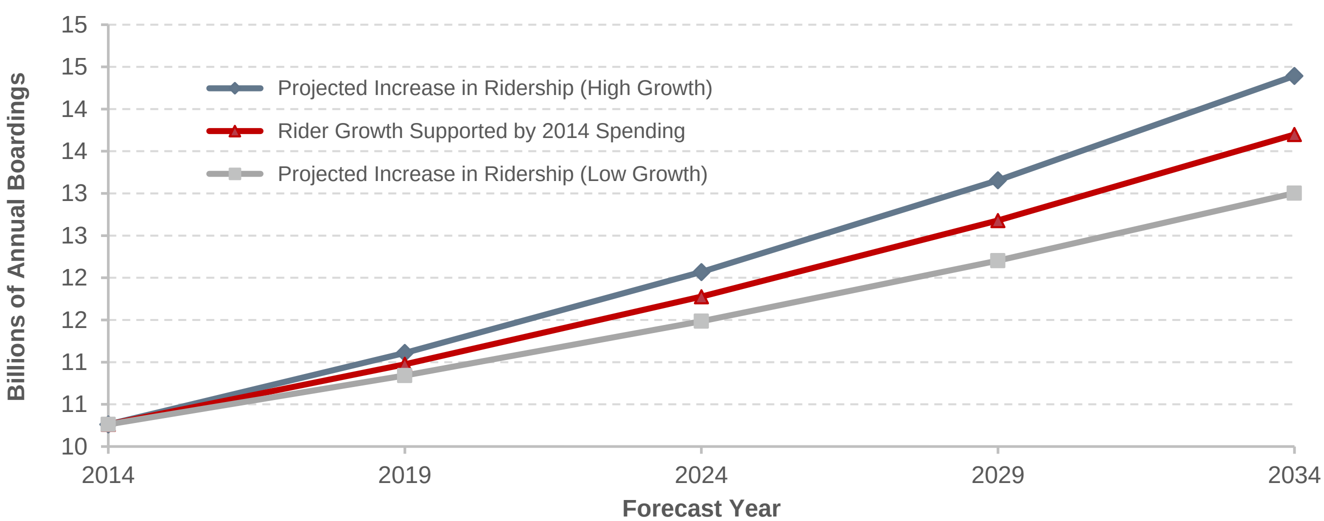
Exhibit 7-15: Sustain 2014 Spending Scenario: Capacity Utilization by Mode Forecast, 2014–2034



Source: Transit Economic Requirements Model.

Exhibit 7-16 presents the projected growth in transit riders that the 2014 level of investment (keeping vehicle occupancy rates constant) can accommodate compared with the potential growth in total ridership under both the Low-Growth and High-Growth scenarios. The $6.4 billion level of investment for expansion can support ridership growth that is similar to the ridership increases projected in the Low-Growth scenario, but is short of that required to support continued ridership under the High-Growth scenario (i.e., without impacting service performance).

Exhibit 7-16: Projected Versus Currently Supported Ridership Growth



Source: Transit Economic Requirements Model.

State of Good Repair Benchmark

The Sustain 2014 Spending scenario considered the impacts of sustaining transit spending at current levels, which appear to be insufficient to address either deferred investment needs (which are projected to increase) or the projected growth in transit ridership (without a reduction in service performance). In contrast, this section focuses on the level of investment required to eliminate the investment backlog over the next 20 years and to provide for sustainable rehabilitation and replacement needs once the backlog has been addressed. Specifically, the SGR Benchmark estimates the level of annual investment required to replace assets that currently exceed their useful lives, to address all deferred rehabilitation activities (yielding an SGR where the asset has a condition rating of 2.5 or higher), and to address all future rehabilitation and replacement activities as they come due. The SGR Benchmark considered here uses the same methodology as that described in FTA's *National State of Good Repair Assessment*, released June 2012.

What is the definition of state of good repair (SGR)?

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

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

SGR Investment Levels

Annual reinvestment levels under the SGR Benchmark are presented in *Exhibit 7-17*. Under this benchmark, an estimated $18.4 billion in annual expenditures would be required over the next 20 years to bring the condition of all existing transit assets to an SGR. Of this amount, roughly $12.1 billion (66 percent) is required to bring rail assets to SGR. Note that a large proportion of rail reinvestment spending would be associated with guideway elements (primarily aging elevated and tunnel structures) and rail systems (including train control, traction power, and communications systems) that are past their useful lives and potentially are technologically obsolete. Bus-related reinvestment spending under this benchmark is primarily associated with aging vehicle fleets.

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

Exhibit 7-17: SGR Benchmark: Average Annual Investment by Asset Type, 2014–2034

Asset Type	Average Annual Investment (Billions of 2014 Dollars) Urban Area Type		
	Over 1 Million Population	Under 1 Million Population	Total
Rail			
Guideway Elements	$3.3	$0.1	$3.4
Facilities	$0.8	$0.0	$0.9
Systems	$3.0	$0.0	$3.0
Stations	$2.2	$0.0	$2.2
Vehicles	$2.5	$0.1	$2.6
Subtotal Rail[1]	**$11.9**	**$0.3**	**$12.1**
Nonrail			
Guideway Elements	$0.1	$0.0	$0.1
Facilities	$0.9	$0.1	$1.0
Systems	$0.3	$0.0	$0.3
Stations	$0.2	$0.0	$0.2
Vehicles	$3.3	$1.4	$4.6
Subtotal Nonrail[1]	**$4.8**	**$1.5**	**$6.2**
Total[1]	**$16.6**	**$1.8**	**$18.4**

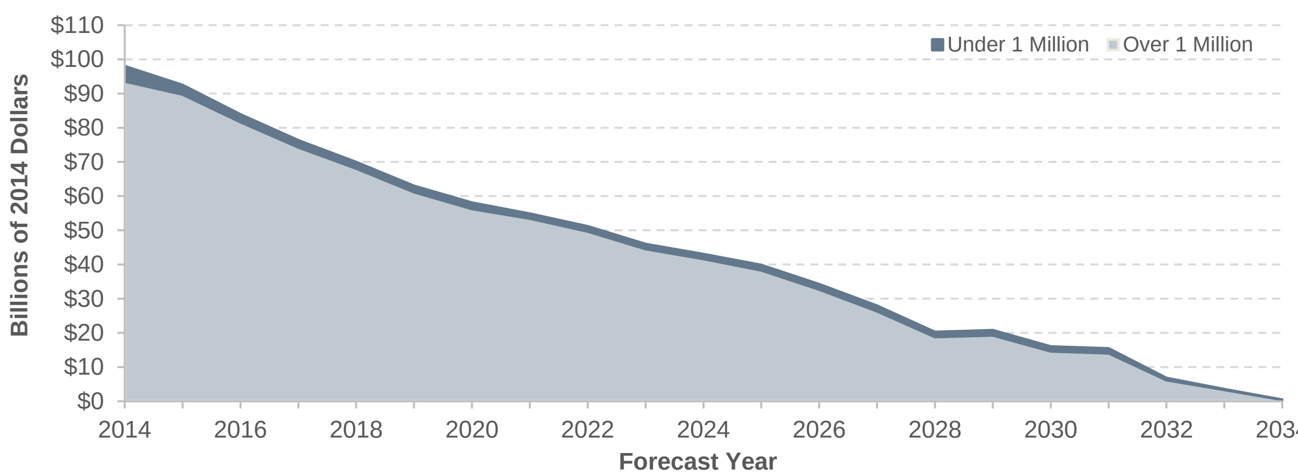
[1] Note that totals may not sum due to rounding.

Source: Transit Economic Requirements Model.

Impact on the Investment Backlog

A key objective of the SGR Benchmark is to determine the level of investment required to attain and then maintain an SGR across all transit assets over the next 20 years, including elimination of the existing investment backlog. *Exhibit 7-18* shows the estimated impact of the $17.5 billion in annual expenditures under the SGR Benchmark on the existing investment backlog over the 20-year forecast period (compare these data with *Exhibit 7-14*). Given this level of expenditures, the backlog is projected to be eliminated by 2034, with most of this drawdown addressing reinvestment in UZAs having populations greater than 1 million.

Exhibit 7-18: Investment Backlog: State of Good Repair Benchmark ($17.5 Billion Annually)

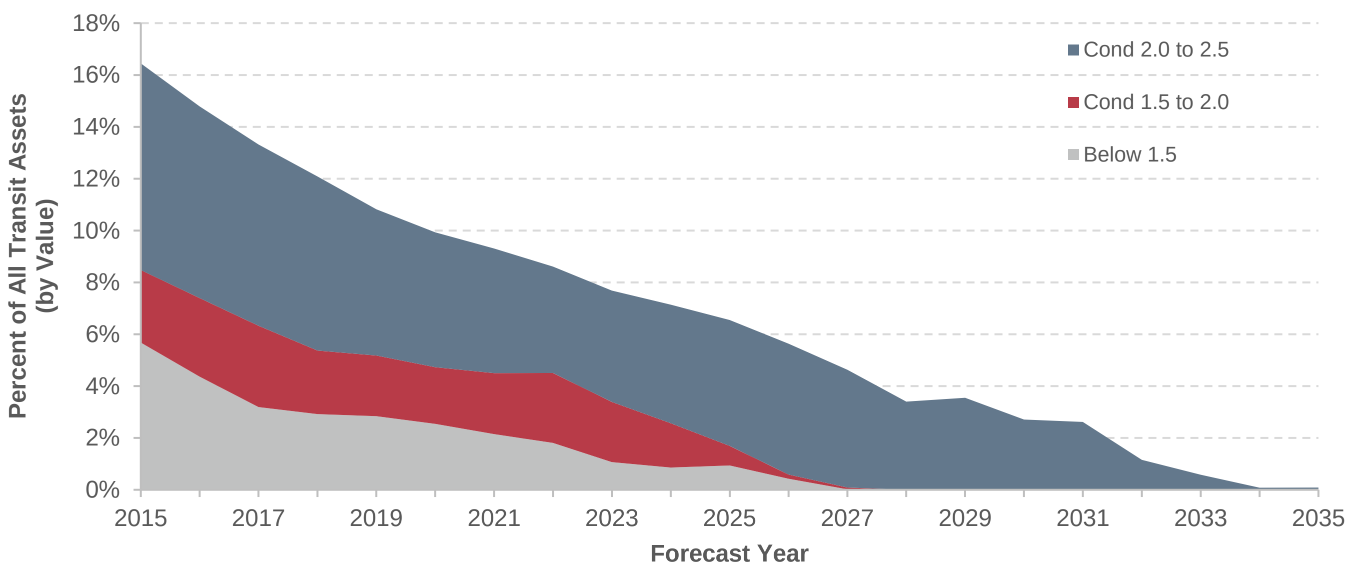


Source: Transit Economic Requirements Model.

Impact on Conditions

In drawing down the investment backlog, the annual capital expenditures of $17.5 billion under the SGR Benchmark also would lead to the replacement of assets with an estimated condition rating of 2.5 or less. Within TERM's condition rating system, these assets would include those in marginal condition having ratings less than 2.5 and all assets in poor condition. *Exhibit 7-19* shows the current distribution of asset conditions for assets estimated to be in a rating condition of 2.5 or less (with assets in poor condition divided into two subgroups). Note that this graphic excludes both tunnel structures and subway stations in tunnel structures because these are considered assets that require ongoing capital rehabilitation expenditures but that are never actually replaced. As with the investment backlog, the proportion of assets at condition rating 2.5 or lower is projected to decrease under the SGR Benchmark from roughly 16 percent of assets in 2015 to less than 1 percent by 2035. Once again, this replacement activity would remove from service those assets with higher occurrences of service failures, technological obsolescence, and lower overall service quality. Importantly, the assets with a condition rating of less than 2.5 presented in *Exhibit 7-19* capture only a subset of assets in the SGR backlog as depicted in *Exhibit 7-18*. Specifically, the total SGR backlog (*Exhibit 7-18*) includes not just those assets in need of replacement (i.e., those at less than condition 2.5), but also those assets in need of rehabilitation or other form of capital reinvestment.

Exhibit 7-19: Proportion of Transit Assets Not in State of Good Repair (Excluding Tunnel Structures)



Source: Transit Economic Requirements Model.

Low-Growth and High-Growth Scenarios

The SGR Benchmark considered the level of investment required to bring existing transit assets to an SGR, but in doing so did not consider either (1) the economic feasibility of these investments (investments were not required to pass TERM's benefit-cost test) or (2) the level of expansion investment required to support projected ridership growth. The Low-Growth scenario and High-Growth scenario address both of these issues. Specifically, these scenarios use the same rules to assess when assets should be rehabilitated or replaced that were applied in the SGR Benchmark (e.g., with assets being replaced at condition 2.5), but also require that these preservation and expansion investments pass TERM's benefit-cost test. In general, some reinvestment activities do not pass this test (i.e., have a benefit-cost ratio less than 1), which can result from low ridership benefits, higher capital or operating costs, or a mix of these factors. Excluding investments that do not pass the benefit-cost test has the effect of reducing total estimated needs.

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

Low- and High-Growth Assumptions

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

Within this new framework, the Low-Growth scenario is defined as the trend rate of growth (by FTA region, population stratum, and mode) less 0.3 percent, while the High-Growth scenario is defined as the trend rate of growth plus 0.3 percent. Hence, the Low-Growth and High-Growth scenarios differ by a full 0.6 percent in annual growth.

Low- and High-Growth Scenario Investment Levels

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

Low-Growth Investment Levels

Assuming the relatively low ridership growth in the Low-Growth scenario, investment needs for system preservation and expansion are estimated to average roughly $23.4 billion each year for the next two decades. Of this amount, roughly 74 percent is for preserving existing assets and approximately $11.5 billion is associated with preserving existing rail infrastructure alone. Note that the approximate $1 billion difference between the $18.4 billion in annual preservation spending under the SGR Benchmark and the $17.4 billion in preservation spending under the Low-Growth scenario is due entirely to the application of TERM's benefit-cost test under the Low-Growth scenario. Finally, expansion needs in this scenario total $6.0 billion annually, with 86 percent of that amount associated with rail expansion costs.

High-Growth Investment Levels

In contrast, total investment needs under the High-Growth scenario are estimated to be $25.5 billion annually, a 9-percent increase over the total investment needs under the Low-Growth scenario. The High-Growth scenario total includes $17.5 billion for system preservation and an additional $8.1 billion for system expansion. Note that system preservation costs are higher under the High-Growth scenario because the higher growth rate leads to a larger expansion of the asset base compared with that under the Low-Growth scenario. Under this scenario, investment in expansion of rail assets is still larger than that for nonrail expansion (81 percent for rail and 19 percent for nonrail). Under the High-Growth scenario, however, rail takes 81 percent of total expansion investment versus 85 percent of expansion needs under the Low-Growth scenario.

Exhibit 7-20: Low- and High-Growth Scenarios: Average Annual Investment by Asset Type, 2014–2034

	Average Annual Investment (Billions of 2014 Dollars)					
	Low-Growth			High-Growth		
Asset Type	**Preservation**	**Expansion**	**Total**	**Preservation**	**Expansion**	**Total**
Rail						
Guideway Elements	$3.3	$1.0	$4.2	$3.3	$1.2	$4.5
Facilities	$0.8	$0.2	$1.0	$0.8	$0.2	$1.1
Systems	$3.0	$0.2	$3.2	$3.0	$0.3	$3.3
Stations	$2.2	$0.7	$2.9	$2.2	$0.9	$3.1
Vehicles	$2.2	$1.8	$4.0	$2.2	$2.5	$4.7
Other Project Costs	$0.0	$1.2	$1.2	$0.0	$1.5	$1.5
Subtotal Rail[1]	**$11.5**	**$5.2**	**$16.6**	**$11.5**	**$6.6**	**$18.1**
Subtotal UZAs Over 1 Million[1]	**$11.4**	**$5.2**	**$16.5**	**$11.4**	**$6.6**	**$18.0**
Subtotal UZAs Under 1 Million and Rural[1]	**$0.1**	**$0.0**	**$0.1**	**$0.1**	**$0.0**	**$0.1**
Nonrail						
Guideway Elements	$0.1	$0.0	$0.1	$0.1	$0.1	$0.1
Facilities	$0.9	$0.1	$1.0	$0.9	$0.2	$1.1
Systems	$0.2	$0.0	$0.2	$0.2	$0.0	$0.2
Stations	$0.2	$0.0	$0.2	$0.2	$0.0	$0.2
Vehicles	$4.6	$0.7	$5.2	$4.6	$1.1	$5.7
Other Project Costs	$0.0	$0.0	$0.0	$0.0	$0.1	$0.1
Subtotal Nonrail*	**$5.9**	**$0.9**	**$6.8**	**$5.9**	**$1.5**	**$7.4**
Subtotal UZAs Over 1 Million[1]	**$4.5**	**$0.4**	**$4.9**	**$4.5**	**$0.8**	**$5.3**
Subtotal UZAs Under 1 Million and Rural[1]	**$1.6**	**$0.5**	**$2.0**	**$1.5**	**$0.7**	**$2.1**
Total Investment[1]	**$17.4**	**$6.0**	**$23.4**	**$17.5**	**$8.1**	**$25.5**
Total UZAs Over 1 Million[1]	**$15.8**	**$5.6**	**$21.4**	**$15.9**	**$7.4**	**$23.3**
Total UZAs Under 1 Million and Rural[1]	**$1.7**	**$0.5**	**$2.1**	**$1.6**	**$0.7**	**$2.2**

[1] Note that totals may not sum due to rounding.

Source: Transit Economic Requirements Model.

Impact on Conditions and Performance

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

Similarly, the impact of the Low- and High-Growth rate expansion investments on transit ridership was considered in *Exhibit 7-16*. That analysis demonstrated the significant difference in the level of ridership growth supported by the High-Growth scenario compared with either the current level of expenditures (average $5.9 billion annually in 2014 for UZAs with populations greater than 1 million) or the rate of growth supported under the Low-Growth scenario.

Scenario Impacts Comparison

Finally, this subsection summarizes and compares many of the investment impacts associated with each of the three analysis scenarios and the SGR Benchmark considered above. Although much of this comparison is based on measures already introduced above, this discussion also considers a few additional investment impact measures. These comparisons are presented in *Exhibit 7-21*. Note that the first column of data in *Exhibit 7-21* presents the current values for each of these measures (as of 2014). The subsequent columns present the estimated future values in 2034, assuming the levels, allocations, and timing of expenditures associated with each of the three investment scenarios and the SGR Benchmark.

Exhibit 7-21 includes the following measures:

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

Exhibit 7-21: Scenario Investment Benefits Scorecard

Measure	Baseline 2014 Actual Spending, Conditions and Performance	SGR	Sustain 2014 Spending	Low Growth	High Growth
Average Annual Expenditures (Billions of 2014 Dollars)					
Preservation	$10.3	$18.4	$11.3	$17.4	$17.5
Expansion	$7.0	NA	$6.4	$6.0	$8.1
Total	**$17.3**	**$18.4**	**$17.7**	**$23.4**	**$25.6**
Conditions (Existing Assets)					
Average Physical Condition Rating	3.1	3.0	2.8	3.3	3.4
Investment Backlog (Billions of Dollars)	$98.0	$0.0	$109.2	$0.0	$0.0
Investment Backlog (% of Replacement Costs)	12.0%	0.0%	13.4%	0.0%	0.0%
Backlog Ratio[1]	7.3	0.0	8.1	0.0	0.0
Performance					
Ridership Impacts of Expansion Investments (2014)					
New Boardings Supported by Expansion (Billions)	NA	NA	3.7	3.0	4.6
Total Projected Boardings in 2034 (Billions)	NA	NA	14.0	13.4	14.9
Fleet Performance					
Revenue Service Disruptions per Thousand PMT	9.5	9.8	9.5	9.8	9.8
Fleet Maintenance Cost per Revenue Vehicle Mile	$1.91	$1.92	$1.89	$1.92	$1.92

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

Source: Transit Economic Requirements Model.

Scorecard Comparisons

Exhibit 7-21 summarizes a review of the scorecard results for each of the three investment scenarios and the SGR Benchmark reveals the impacts discussed below.

Preservation Impacts

Continued reinvestment at the 2014 annual spending level is likely to yield a decline in overall asset conditions (from 3.1 in 2014 to 2.8 in 2034) and an increase in the size of the investment backlog (from $98.0 billion in 2014 to $109.2 billion in 2034). Continued reinvestment at the 2014 annual spending level, however, likely will cause no change in service disruptions per thousand passenger miles and a decrease in maintenance costs per vehicle revenue mile. In contrast, with the exception of overall asset conditions, opposite results occur under the SGR Benchmark, the Low-Growth scenario, and the High-Growth scenario. Note that the overall condition rating measures of 3.0, 3.3, and 3.4 under the SGR Benchmark, the Low-Growth scenario, and the High-Growth scenario, respectively, represent sustainable condition levels for the Nation's existing transit assets over the long term. This is in contrast to the current measure of roughly 3.1, which would be difficult to maintain over the long term without replacing many asset types prior to the conclusion of their expected useful lives.

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

Expansion Impacts

Although continued expansion investment at the 2014 annual spending level appears sufficient to support a low rate of increase in transit ridership to about 3.7 billion new boardings in 2034, higher rates of growth to nearly 4.6 billion new boardings in 2034 suggest that a significantly higher rate of expansion investment (nearly $1 billion more annually in expansion investment) would be required to avoid a decline in overall transit performance (e.g., in the form of increased crowding on high-utilization systems) if future transit ridership growth were to exceed historical levels.

CHAPTER 8
Supplemental Analysis

Highway Supplemental Analysis

This chapter 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. This section also includes a look back at the projections reported in the 1995 C&P Report and compares them with actual performance over 20 years.

Next, this chapter explores alternative assumptions about the timing of investment over the 20-year analysis period. The following section also discusses the impacts that switching to a new cost inflation index series, the National Highway Construction Cost Index (NHCCI) 2.0, have had on estimated investment needs on highways and bridges. 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 have continually declined since the 2008 C&P Report.
- The gap between the average annual investment level under the Maintain Conditions and Performance scenario and base-year spending shrank in this edition but remains negative (i.e., base-year spending is bigger).
- The 1995 C&P Report predicted urban VMT that was close to actual traffic in 2013, but overpredicted rural VMT.
- Actual spending from 1994 through 2013 was lower than the amount estimated as being required to maintain conditions and performance in the 1995 C&P Report, consistent with deterioration in operational performance (e.g., increases in congestion) observed since 1993. However, physical conditions (pavement quality, bridge condition) have nevertheless improved since 1993.
- 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.
- Applying the recently updated version of the National Highway Construction Cost Index (NHCCI), rather than the original NHCCI values, substantially changed the average annual investment levels associated with the Maintain Conditions and Performance scenario but not the Improve Conditions and Performance scenario.

Comparison of Scenarios with Previous Reports

Each edition of this report presents various 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 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 and the Improve Conditions and Performance scenario presented in Chapter 7.

Comparison With 2015 C&P Report

While there are some minor definitional differences between the capital investments scenarios presented in this 23rd edition of the C&P Report and the 2015 edition, the general concepts behind the Maintain Conditions and Performance scenario and the Improve Conditions and Performance scenario remain the same. The time periods analyzed differ, as this report covers a 20-year period of 2015 through 2034, rather than of 2013 through 2032 in the 2015 C&P Report.

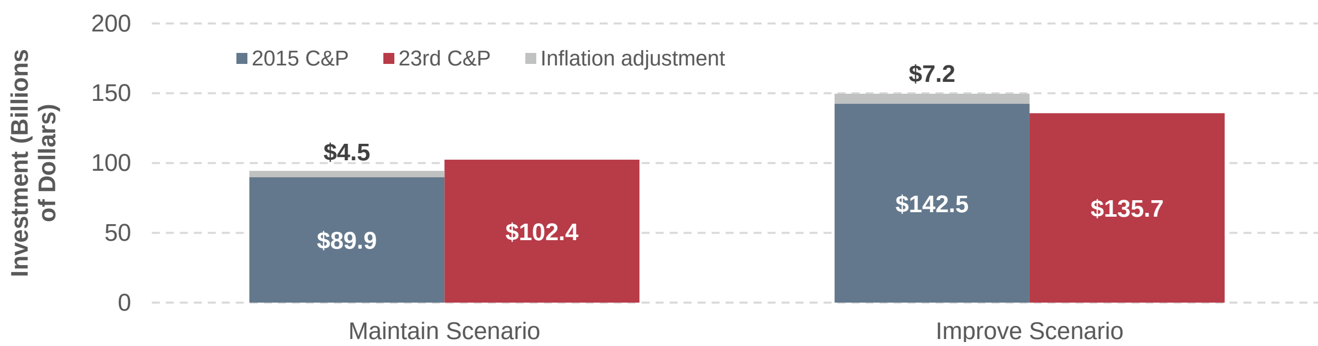
The Maintain Conditions and Performance scenario identifies a level of investment associated with keeping overall conditions and performance at their base-year levels in 20 years. As discussed in Chapter 7, instead of assuming investment would grow at a constant rate, for the 23rd edition the investment level is set to stay at a fixed level in constant dollar terms over the analysis period. The target of the Maintain scenario component derived from the National Bridge Investment Analysis System (NBIAS) was changed from maintaining the percentage of total deck area on bridges classified as structurally deficient or functionally obsolete in the 2015 C&P Report to maintaining the share of total deck area on bridges classified as poor in this current edition. This change incorporates new metrics established under the PM-2 rulemaking described in the Introduction to Part I and Chapter 3. The PM-2 rule redefined the criteria for the structurally deficient classification and made it equal to the criteria used to classify bridges as in poor condition. As referenced in Chapter 4, functionally obsolete bridges are no longer identified in the National Bridge Inventory (NBI).

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. Rather than gradually addressing these projects over 20 years based on a ramped investment pattern, the scenario in this 23rd edition assumes that cost-beneficial investments will be addressed immediately as they are identified.

As discussed in Chapter 2, in this edition highway construction costs were converted to constant dollars using the Federal Highway Administration's (FHWA's) NHCCI 2.0, which increased by 5.0 percent between 2012 and 2014. Consequently, adjusting the 2015 C&P Report's scenario figures from 2012 constant dollars to 2014 dollars causes the observed and projected highway construction costs to increase by 5 percent. *Exhibit 8-1* shows that the 2015 C&P Report estimated the average annual investment level in the current Maintain Conditions and Performance scenario at $89.9 billion in 2012 dollars; adjusting for inflation shifts this figure to $94.4 billion in 2014 dollars. The comparable amount for the Maintain Conditions and Performance scenario presented in Chapter 7 of this edition is $102.4 billion in 2014 dollars, approximately 8.5 percent higher than the adjusted 2015 C&P Report estimate.

Similarly, the average annual investment level in the 2015 C&P Report for the Improve Conditions and Performance scenario was estimated to be $142.5 billion in 2012 dollars, the equivalent of $149.7 billion in 2014 dollars after adjusting for inflation. The comparable amount for the Improve Conditions and Performance scenario presented in Chapter 7 of this edition is $135.7 billion, 9.3 percent lower than the adjusted annual investment level based on the 2015 C&P Report.

Exhibit 8-1: Selected Highway Investment Scenario Projections from this 23rd Edition Compared with Projections from the 2015 C&P Report



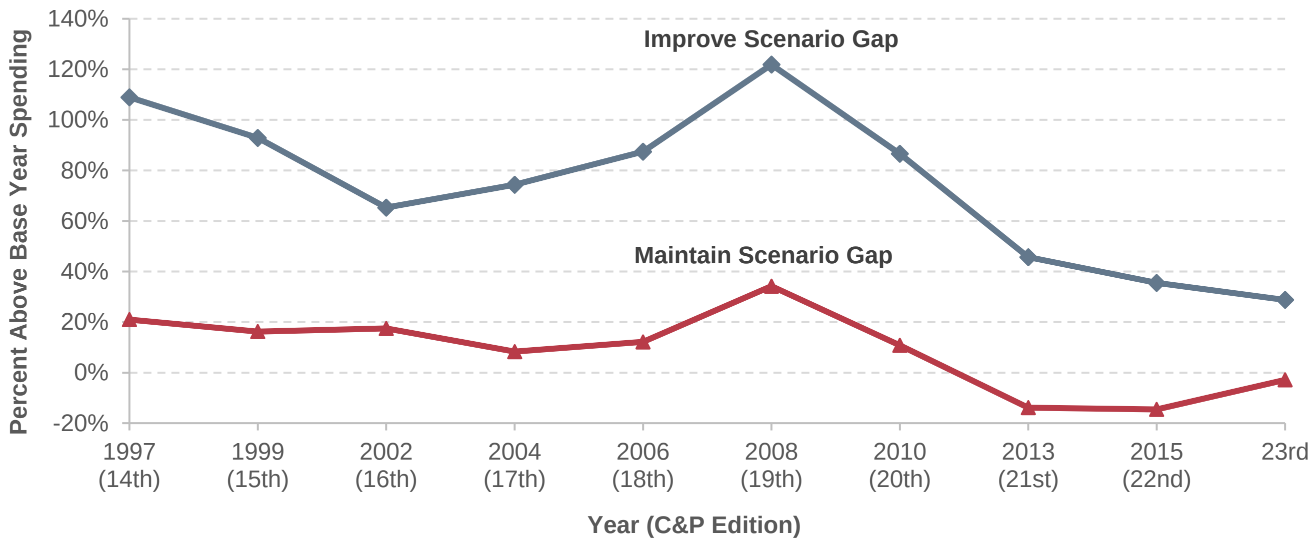
Note: Inflation adjustment refers to the investment levels for the highway and bridge scenarios adjusted for inflation using the FHWA National Highway Construction Cost Index.

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

Comparisons of Implied Funding Gaps

Exhibit 8-2 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 exceeds the base-year level of investment. The scenarios examined are this report's Maintain Conditions and Performance scenario and Improve Conditions and Performance scenario and their counterparts in previous C&P Reports.

Exhibit 8-2: Comparison of Average Annual Highway and Bridge Investment Scenario Estimates with Base-Year Spending, 1997 to 23rd C&P Editions



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. The values shown for this report reflect the Maintain Conditions and Performance and the Improve Conditions and Performance scenarios. Negative numbers signify that the investment scenario estimate was lower than base-year spending.

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

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 dramatically differed 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 Conditions and Performance scenario. The primary "Improve" scenario follows a similar trend, where the funding gap has dropped steadily since its peak in the 2008 C&P Report.

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). On the other hand, the decreases in the gaps presented in recent editions coincided with subsequent declines in construction costs. As discussed in greater detail later in this section, the adoption of NHCCI 2.0 in this edition had a downward impact on construction costs in the Improve scenario and an upward impact in the "Maintain" scenario.

The differences among C&P Report editions in the implied gaps reported in *Exhibit 8-2* are not a consistent 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 of the scenarios (the “Maintain” or “Improve” scenarios, or their equivalents); other refinements have reduced this level. For example, the small deviations of investment level from base-year spending in this edition can be partially attributed to the change in the calculation of the cost index.

Comparisons with 1995 C&P Report

The 1995 C&P Report provided forecasts for vehicle miles traveled (VMT) as well as for required investment to maintain and improve system conditions and performance over the period of 1993 to 2013. Comparing projections from previous C&P Reports with what actually happened can provide useful insights in assessing the information presented in this 23rd edition.

Travel Forecasts Compared with Actual Travel Growth

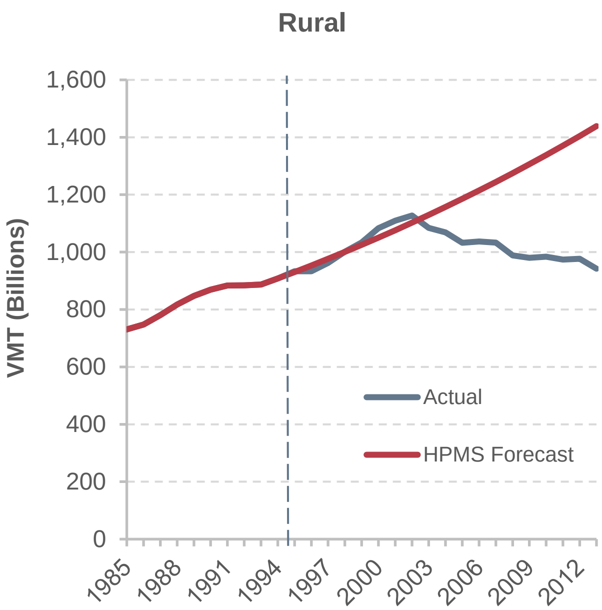
Transportation professionals agree that projecting future traffic is essential for evaluating investment needs based on travel demand models. However, forecasting is extremely difficult because of uncertainties in factors such as economic conditions, demographic shifts, and policy changes. Deviation from actual VMT can occur when the prediction models fail to capture changes in traveler behavior, such as changed preferences or new technologies.

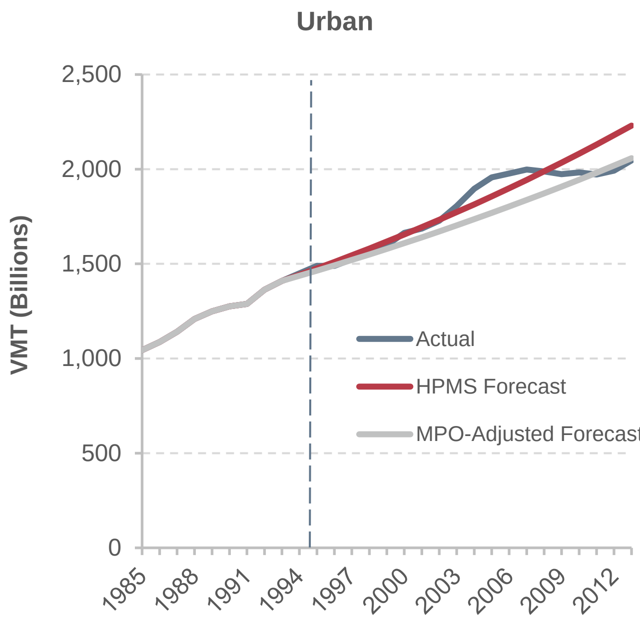
The 1995 C&P Report provided two travel forecasts: the Highway Performance Monitoring System (HPMS) forecast and a forecast that was consistent with projections by metropolitan planning organizations (MPOs). HPMS predicted that traffic would grow by 2.23 percent per annum from 1993 to 2013 on highway sections in the 33 most populous urbanized areas. The MPOs derived another travel forecast based on local planning processes to reflect potential future policy changes and social, fiscal, and environmental constraints on capacity expansion. The HPMS travel forecast was thus adjusted using a factor to generate an MPO-consistent forecast for the underlying investment requirement estimation. The HPMS forecast of VMT growth was adjusted downward and highway travel was projected to increase at a dampened rate of 1.50 percent per annum, instead of 2.23 percent in the HPMS forecast, in the 33 most populous urbanized areas. No adjustments were made to the HPMS sections outside those urbanized areas. The overall impact on the national level VMT forecasts for all urbanized areas was a reduction from 2.32 percent per annum in HPMS to 1.91 percent. The impact on the VMT forecast for all rural and urban travel combined was a reduction from 2.37 percent per annum value from HPMS to a 2.15 percent per annum value.

The 1995 C&P Report noted that the average annual VMT growth rate was 3.5 percent from 1966 to 1993. While the 1995 report’s projected growth rate of 2.15 percent from 1993 to 2013 was a step downward, it significantly overestimated actual VMT growth over that period, which was 1.33 percent per annum. This finding is consistent with an analysis of travel forecasts for all editions, presented in the 2015 C&P Report, which suggested that States have tended to underestimate future VMT during times of rapid travel growth and tended to overestimate future VMT at times when travel growth was slowing.

As shown in *Exhibit 8-3*, the overprediction of future travel in the 1995 C&P Report is more noticeable in rural VMT: the HPMS forecast projected annual growth of 2.45 percent in rural VMT between 1993 and 2013, far above the actual annual VMT growth rate of 0.30 percent. In urban areas (including both small urban areas and urbanized areas), actual VMT increased at 1.88 percent per year from 1993 to 2013, almost exactly equal to the MPO-adjusted forecast of 1.91 percent for all urbanized areas and well below the HPMS forecasts of 2.32 percent for all urbanized areas and 2.37 percent for small urban areas. Although the comparison is complicated by altered classification of some highways from rural to urban due to changes in urban boundaries that have occurred since 1993, the models used to develop the scenario estimates would not have taken such changes into account in their estimates of rural versus urban investment needs.

Exhibit 8-3: Rural and Urban VMT Projections from the 1995 C&P Report Compared with Actual VMT, 1985–2013





Note: HPMS forecast is 20-year forecast of future highway VMT in the HPMS submitted by States. MPO forecast is adjusted 20-year travel forecast in the 33 most populous urbanized areas of HPMS highway sections. A factor was applied to each target year HPMS travel forecast to ensure the adjusted average compound annual travel growth rate through 2013 was the same as the average compound annual travel growth rate projected by the MPOs for highways in the 33 urbanized areas. No adjustments were made to HPMS sections outside the 33 urbanized areas.

Source: 1995 Status of the Nation's Highways and Bridges: Conditions and Performance Report to Congress; Highway Statistics various years, Table VM202.

Scenario Investment Levels Compared to Actual Spending

Exhibit 8-4 shows the estimated average annual and cumulative 20-year highway and bridge needs associated with the two scenarios presented in the 1995 C&P Report. The cumulative values are also adjusted for inflation to 2014 constant dollars using the FHWA composite Bid Price Index (BPI) over the period of 1994–2003 and the NHCCI 2.0 for subsequent years.

Assuming an annual travel growth rate of 2.15 percent, the 1995 C&P Report estimated the average annual cost to maintain overall 1993 highway conditions and performance through 2013 at $54.8 billion in 1993 dollars. The cumulative 20-year value was $1.096 trillion in 1993 dollars, equivalent to $2.366 trillion 2014 constant dollars after inflation adjustment. The average annual cost of the “Improve” scenario, called “economic efficiency” in the report, was estimated at $74.0 billion 1993 dollars, with a cumulative value of $3.195 trillion in 2014 constant dollars. The estimated spending requirements under both scenarios in the 1995 C&P Report exceeded the actual cumulative capital outlay of $2.063 trillion in 2014 constant dollars. Actual capital outlay was 15 percent below the estimate under the Maintain Conditions and Performance scenario, and 55 percent below the estimate under the Improve Conditions and Performance scenario. (It should be noted that the scenarios presented in the 1995 C&P Report were not adjusted to account for types of capital spending that were not modeled in the report; these gaps between the scenario investment levels and actual spending would be larger if nonmodeled spending had been taken into account.)

Exhibit 8-4: 1995 C&P Report Highway and Bridge Investment Scenario Estimates Versus Cumulative Spending, 1994 Through 2013

	1994–2013 Projection From 1995 C&P Report		Adjusted for Inflation
	Average Annual (Billions of 1993 Dollars)	Cumulative 20 Years (Billions of 1993 Dollars)	Cumulative 20 Years (Billions of 2014 Dollars)
20-Year Highway Capital Investment Scenarios (Assuming 2.15 Percent Annual VMT Growth from 1994 to 2013)			
Maintain Conditions and Performance Scenario	$54.8	$1,096.0	$2,366.0
Improve Conditions and Performance Scenario	$74.0	$1,480.0	$3,195.0
Actual 20-Year Highway Capital Investment (VMT Grew 1.33 Percent per Year from 1993 to 2013)			
Cumulative Capital Outlay, 1994 through 2013[1]			$2,063.0

[1] Highway capital outlay by all levels of government combined totaled $1.467 trillion in nominal dollar terms over the 20-year period from 1994 through 2013. This equates to $2.063 trillion in constant 2014 dollars.

Sources: 1995 Status of the Nation's Highways and Bridges: Conditions and Performance Report to Congress; Highway Statistics, various years, Tables HF-10A, HF-10, PT-1, and SF-12A; and unpublished FHWA data.

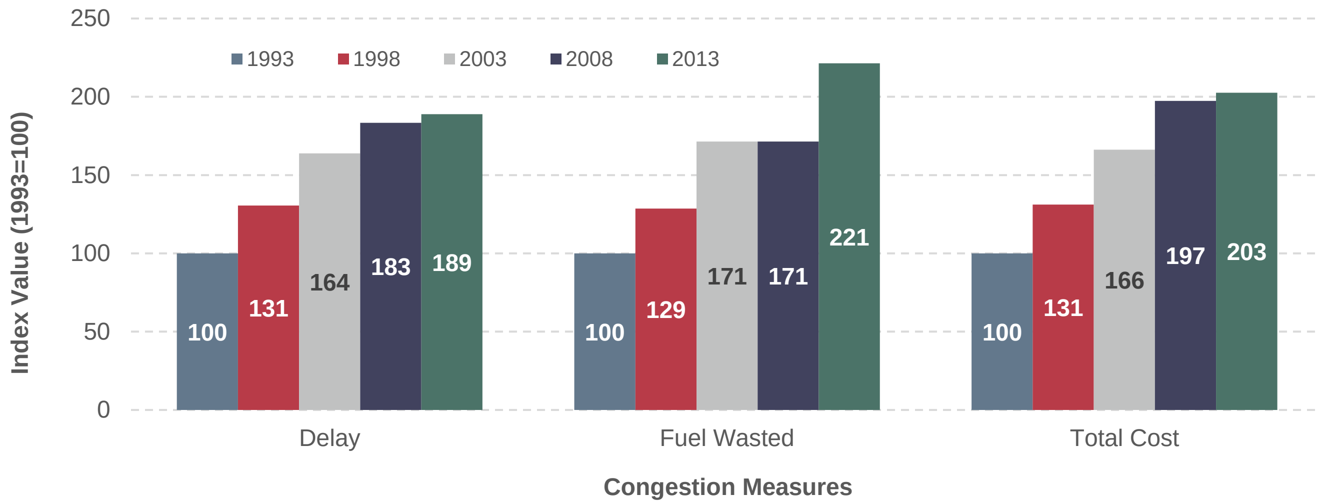
Changes in Operational Performance

The gap between actual spending from 1994 through 2013 and the spending in the 20-year Maintain Conditions and Performance scenario from the 1995 C&P Report adjusted for inflation would suggest that overall system conditions and performance should have deteriorated over time. The 1995 C&P Report measured operational performance using indicators such as levels of service and volume-to-service-flow ratios that are not reported in the current report, rendering direct comparison impossible. However, as discussed in Chapter 4, the Texas A&M Transportation Institute produces a set of congestion measures for the Nation's 471 urbanized areas that facilitate comparison over time. Congestion worsened quickly over the 20-year period, leading to lower productivity and wasted fuel. Total annual delay was 89 percent higher in 2013 than in 1993 due to congestion (*Exhibit 8-5*). Congestion also resulted in a surge of 121 percent in wasted fuel. Collectively, the societal cost of congestion increased by 103 percent from 1993 to 2013. This increase in delay far outpaced the 30 percent expansion of VMT during the same period.

The 1995 C&P Report aggregated bridge data into functional system groupings of Interstate, other arterial, and collector. *Exhibit 8-6* compares these data with data from Chapter 4 of this report aggregated into the same groupings. (See the "Functionally Obsolete Bridges" section in Chapter 4 for a discussion of the criteria used to classify a bridge as functionally obsolete.) Based on bridge count, the percentage of bridges classified as functionally obsolete increased in urban areas from 1994 to 2014, though the percentage in rural areas declined.

Coupled with the results shown in *Exhibit 8-5*, this suggests that capital investment over the 20-year period was not sufficient to maintain operational performance at base-year levels (1993 for pavements, 1994 for bridges) in urban areas. This appears consistent with the gap identified in *Exhibit 8-4* between actual 20-year spending and the investment level identified for the Maintain Conditions and Performance scenario in the 1995 C&P Report.

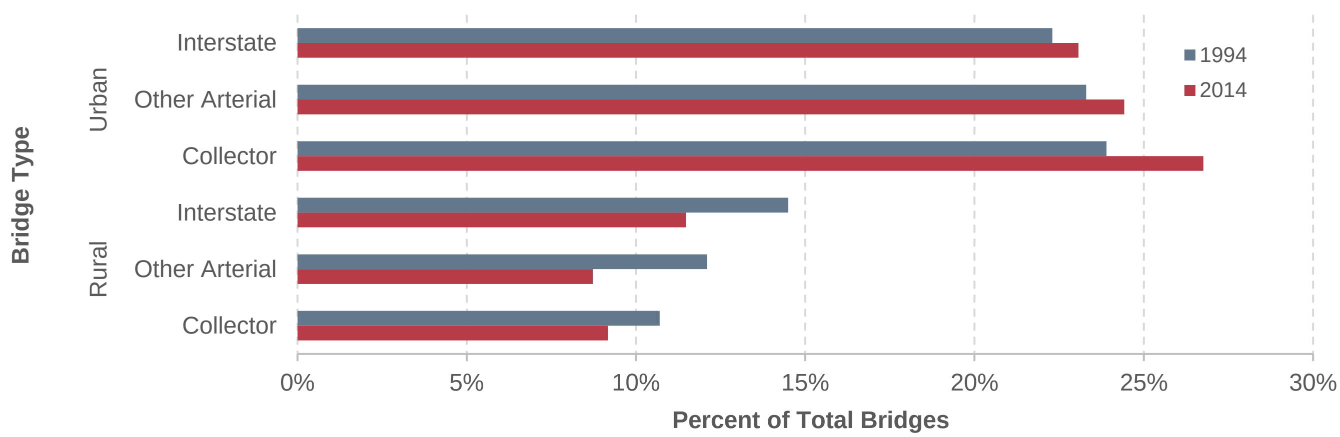
Exhibit 8-5: Growth of Delay, Fuel Wasted, and Congestion Cost in Urbanized Areas (Relative to 1993 Values), 1993–2013



Note: To facilitate comparisons of trends, each performance metric was mathematically converted so that its value for the year 1993 would be equal to 100.

Source: Texas Transportation Institute 2015 Urban Mobility Scorecard (2015), https://mobility.tamu.edu/ums/report/.

Exhibit 8-6: Percentage of Functionally Obsolete Bridges, 1994 and 2014

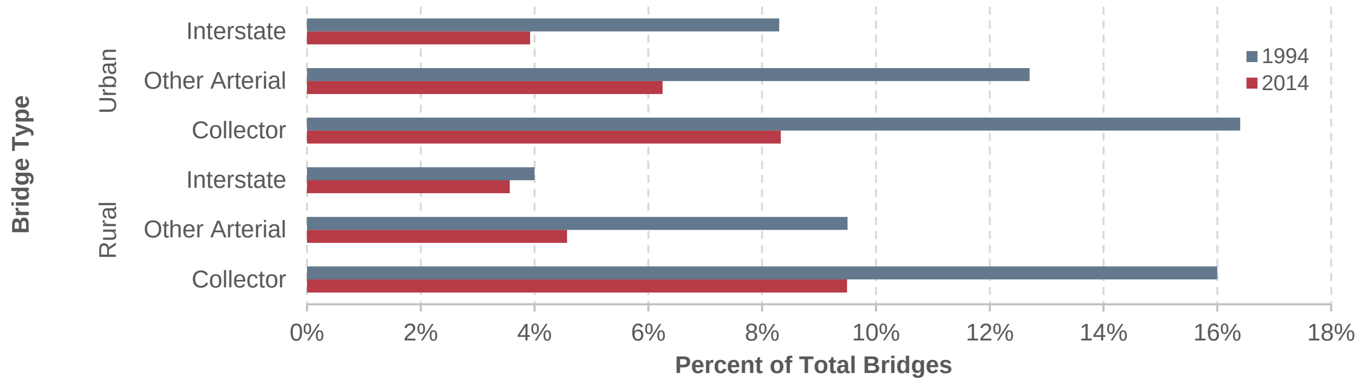


Source: 1995 Status of the Nation's Highways and Bridges: Conditions and Performance Report to Congress; National Bridge Inventory.

Changes in Physical Condition

While operational performance as measured by congestion got worse during the 20-year analysis period, key measures of physical conditions improved. *Exhibit 8-7* shows significant declines in the percentage of bridges classified as structurally deficient on the Nation's highways. (See the Summary of Current Highway and Bridge Conditions section in Chapter 6 for a discussion of the criteria used to classify bridges as structurally deficient.) The largest declines were on bridges on urban Interstates, other urban arterials, and other rural arterials, where the share of structurally deficient bridges was cut by more than half from 1994 to 2014. The smallest improvement occurred on rural Interstate bridges (where the percentage of bridges classified as structurally deficient declined from 4.0 percent in 1994 to 3.6 percent in 2014), but these bridges were in the best shape to start with among the functional classes.

Exhibit 8-7: Percentage of Structurally Deficient Bridges, 1994 and 2014



Source: 1995 Status of the Nation's Highways and Bridges: Conditions and Performance Report to Congress; National Bridge Inventory.

Functional Obsolete Bridge Trends vs. Structurally Deficient Bridge Trends

Although the share of bridges classified as structurally deficient declined in both rural and urban areas from 1994 to 2014, this was not the case for bridges classified as functionally obsolete, where the share declined in rural areas but rose in urban areas. In some cases, the lack of available right-of-way in urban areas may make it cost-prohibitive to bring a bridge up to current design standards relative to the volume of traffic that it carries. This can result in situations in which a bridge rehabilitation or replacement project corrects a structural deficiency while leaving the bridge functionally obsolete.

If a bridge has issues that would warrant classification as both structurally deficient and functionally obsolete, the standard NBI convention is to identify the bridge as structurally deficient because structural deficiencies are considered more critical.

The categories of pavement condition shown in the 1995 C&P Report differ from those in this report; the 1993 data reported in *Exhibit 8-8* have been regrouped to be consistent with the good, fair, and poor classifications based on International Roughness Index (IRI) thresholds referenced in Chapter 6 of this edition.

Pavement ride quality improved remarkably on rural arterials and on higher functional classes of urban areas. For example, the percentage of VMT on pavement identified as good, with an IRI score below 95, increased from 56.6 percent of rural Interstate in 1993 to 80.7 percent in 2014. The trend of better ride quality in higher functional classes remains unchanged in urban areas. Furthermore, the percentage of travel on pavement identified as poor also declined. About 5.6 percent of rural Interstate was rated as poor in 1994; this share fell to 2.6 percent in 2014.

Coupled with the results shown in *Exhibit 8-7*, this suggests that capital investment over the 20-year period was more than sufficient to maintain physical conditions at base-year levels (1993 for pavements, 1994 for bridges), despite having been less than the investment level identified for the Maintain Conditions and Performance scenario in the 1995 C&P Report. However, as noted above (see Changes in Operational Performance section), capital investment over the 20-year period was not sufficient to maintain operational performance at base-year levels.

Exhibit 8-8: Percentages of Vehicle Miles Traveled on Pavements with Good and Poor Ride Quality by Functional System, 1993 and 2014

Functional System	Good (IRI<95)		Poor (IRI>170)[1]	
	1993	2014	1993	2014
Rural Interstate	56.6%	80.7%	5.6%	2.6%
Rural Other Freeway and Expressway[2]		77.4%		2.4%
Rural Other Principal Arterial[2]		68.3%		3.9%
Rural Other Principal Arterial[2]	46.8%		29.4%	
Rural Minor Arterial	40.5%	55.8%	28.0%	6.6%
Rural Major Collector	43.0%	40.1%	17.5%	15.7%
Urban Interstate	45.8%	64.2%	8.9%	7.2%
Urban Other Freeway and Expressway	38.6%	54.3%	36.7%	10.1%
Urban Other Principal Arterial	37.8%	36.0%	39.8%	24.8%
Urban Minor Arterial	38.7%	25.2%	20.5%	31.3%
Urban Collector[2]	35.1%		24.9%	
Urban Major Collector[2]		20.3%		37.5%
Urban Minor Collector[2]		32.2%		24.8%

[1] HPMS pavement reporting requirements were modified in 2009 to include bridges; features such as open grated bridge decks or expansion joints can greatly increase the IRI for a given section.

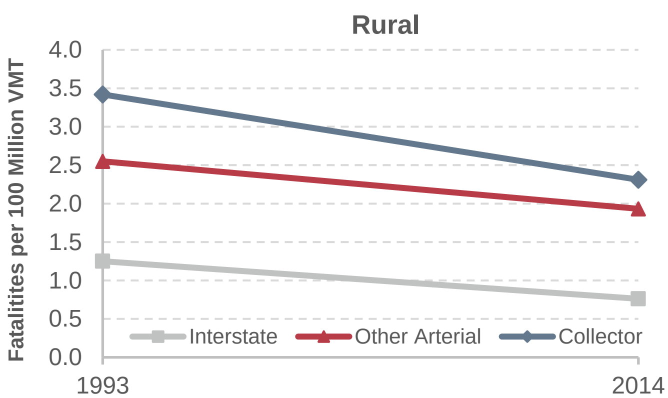
[2] The HPMS functional classifications were revised in 2010. Rural Other Freeways and Expressways were split out of the Rural Other Principal Arterial category, and Urban Collector was split into Urban Major Collector and Urban Minor Collector.

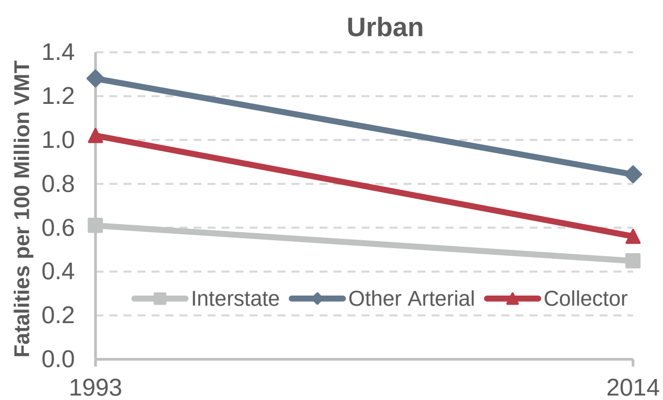
Source: 1995 Status of the Nation's Highways and Bridges: Conditions and Performance Report to Congress; Highway Performance Monitoring System.

Fatality Rate Trends

While the models used to develop the Maintain Conditions and Performance scenario for the 1995 C&P Report did not consider the full range of potential investments that would impact highway safety, it is important to note the considerable improvements that have subsequently occurred. *Exhibit 8-9* displays rates of highway fatalities resulting from vehicle crashes for the years 1993 and 2014, for rural and urban highways respectively. As discussed in Chapter 5, fatality rates are commonly measured as the number of persons fatally injured per 100 million VMT. Fatality rates declined for each of the functional system categories during these two decades, consistent with an overall improvement in highway safety, even though actual highway spending over this period was less than the investment level identified for the Maintain Conditions and Performance scenario in the 1995 C&P Report.

Exhibit 8-9: Fatality Rates by Functional System, 1993 and 2014





Source: 1995 Status of the Nation's Highways and Bridges: Conditions and Performance Report to Congress; Fatality Analysis Reporting System/National Center for Statistics and Analysis, NHTSA.

Timing of Investment

The investment-performance analyses presented in this report focus mainly on how alternative average annual investment levels over 20 years might impact system performance at the end of this period. Within this period, the timing of investment can significantly influence system performance. The following discussion explores the impacts 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, where the spending levels are set flat in the Sustain 2014 Spending scenario and the Maintain Conditions and Performance scenario and BCR-driven in the Improve Conditions and Performance scenario.

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 analysis measures future investment in real terms; thus, the distribution of spending among funding periods is driven by the annual growth of spending. To ensure higher overall growth rates for a given amount of total investment, a smaller portion of the 20-year total investment would occur in the earlier years than in the later years. All scenarios presented in the 2015 C&P Report were ramped.

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. The Maintain Conditions and Performance scenario and the Sustain 2014 Spending scenario presented in Chapter 7 each assume flat spending. 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 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.

Alternative Timing of Investment in HERS

This section presents information regarding how the timing of investment would impact the distribution of spending among the four 5-year funding periods considered in HERS and how these spending patterns could impact performance. Because the timing of investment is varied for any given capital investment level, pavement condition and delay per VMT will change accordingly.

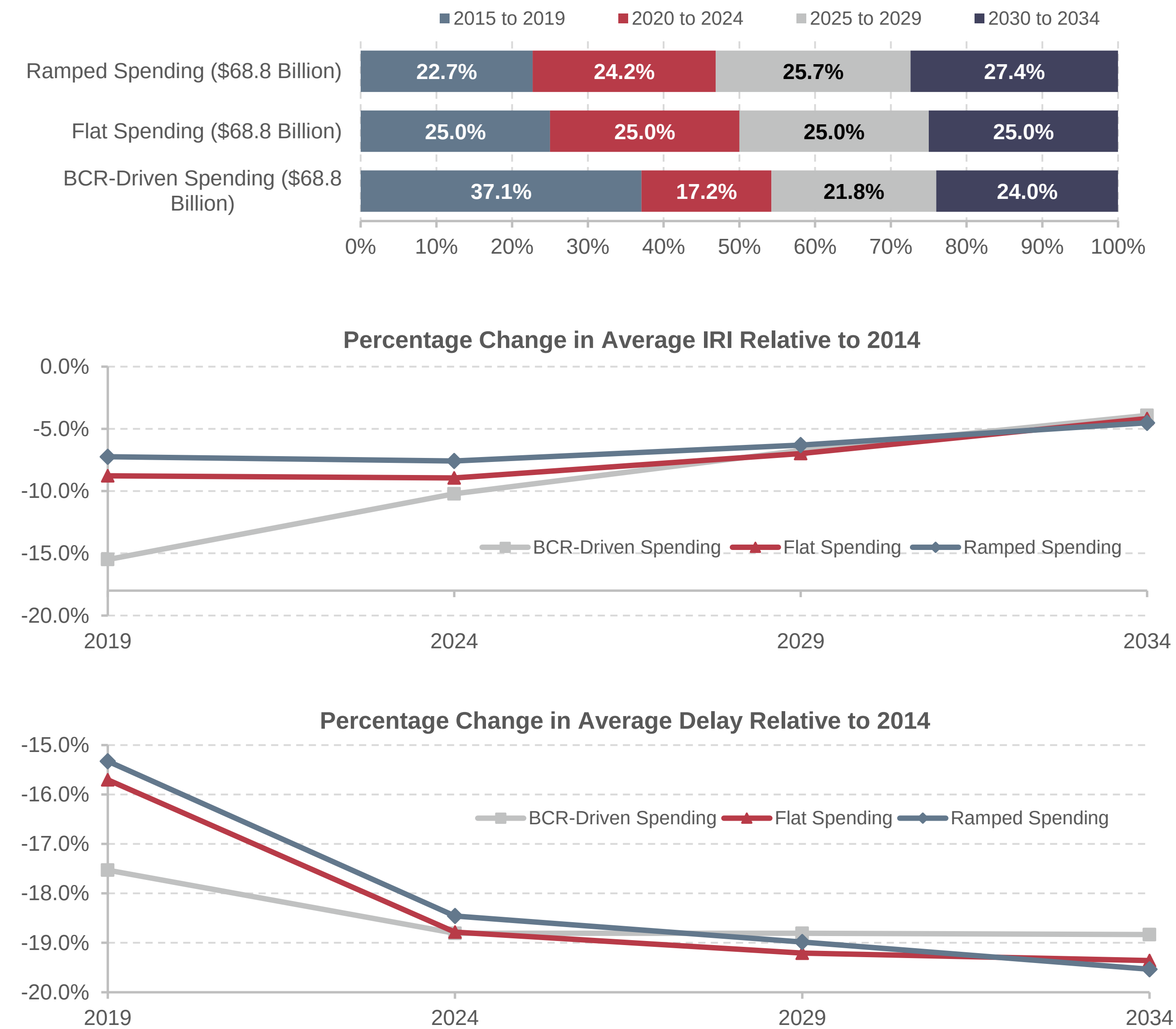
Alternative Investment Patterns

Exhibit 8-10 indicates how alternative assumptions regarding the timing of investment would impact the distribution of spending among the four 5-year funding periods considered in HERS, and how these spending patterns could affect pavement condition (measured using the IRI) and average delay per VMT. Three investment patterns—ramped spending, flat spending, and BCR-driven spending—were analyzed based on a uniform average annual investment level of $68.8 billion.

As shown in the top panel of *Exhibit 8-10*, the level of investment grows over time in the ramped spending case, assuming a constant growth of real investment. Under this scenario, annual investment would grow by 1.26 percent per year, which totals $1.376 trillion over 20 years or $68.8 billion per year in constant 2014 dollars. Only 22.7 percent of the total 20-year investment occurs in the first 5-year period, 2015 to 2019, while 27.4 percent of total investment occurs in the last 5-year period, 2030 to 2034. Under the flat spending alternative, investment is equally distributed over time so that each 5-year period accounts for exactly one-quarter of the total 20-year investment, and annual spending is at $68.8 billion in 2014 constant dollars.

The BCR-driven spending alternative displays a different investment pattern. A high proportion of total spending, 37.1 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 to 17.2 percent of the total 20-year need. 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.

Exhibit 8-10: Impact of Investment Timing on HERS Results For a Selected Investment Level—Effects on Pavement Roughness and Delay per VMT



Source: Highway Economic Requirements System.

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 2017.

The middle panel of *Exhibit 8-10* presents percentage changes of average pavement roughness as measured by IRI compared with the 2014 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 15.5 percent from its 2014 level. The improvement under the BCR-driven spending alternative shrinks to 3.9 percent by the last 5-year period. Steady pavement improvement over time is achieved in ramped spending and flat spending assumptions. In the first 10 years, average IRI decreases by 8.8–8.9 percent (relative to the 2014 level) under the flat spending case. The benefit of pavement improvement quickly declined to 4.2 percent by the last 5-year period. The ramped spending assumption leads to a 7.2-percent drop in average IRI in the first 5-year period and further improvement in pavement afterward, but the improvement is not as pronounced as for the flat spending alternative. The decreases of average IRI are similar by 2034 under all three cases, despite an initial large improvement in pavement condition in the BCR-driven case.

The bottom panel of *Exhibit 8-10* illustrates the progress in average delay reduction across three investment cases. The percentage change of average delay, relative to its 2014 level, remains negative, indicating 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, 17.5 percent, and the ramped spending the smallest reduction, 15.3 percent. The percentages of delay reduction grow over time under all three cases, suggesting sustained benefits through capital investment to improve capacity. The percentage change of average delay is stable under BCR-driven spending. By the end of the 20-year analysis period, the difference between projected average delay and the 2014 delay will be approximately 19 percent under all three alternatives.

These results show that the BCR-driven approach achieves the highest IRI and delays reduction 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 additional benefits that highway users would accrue over time if system conditions and performance were improved earlier in the 20-year analysis period.

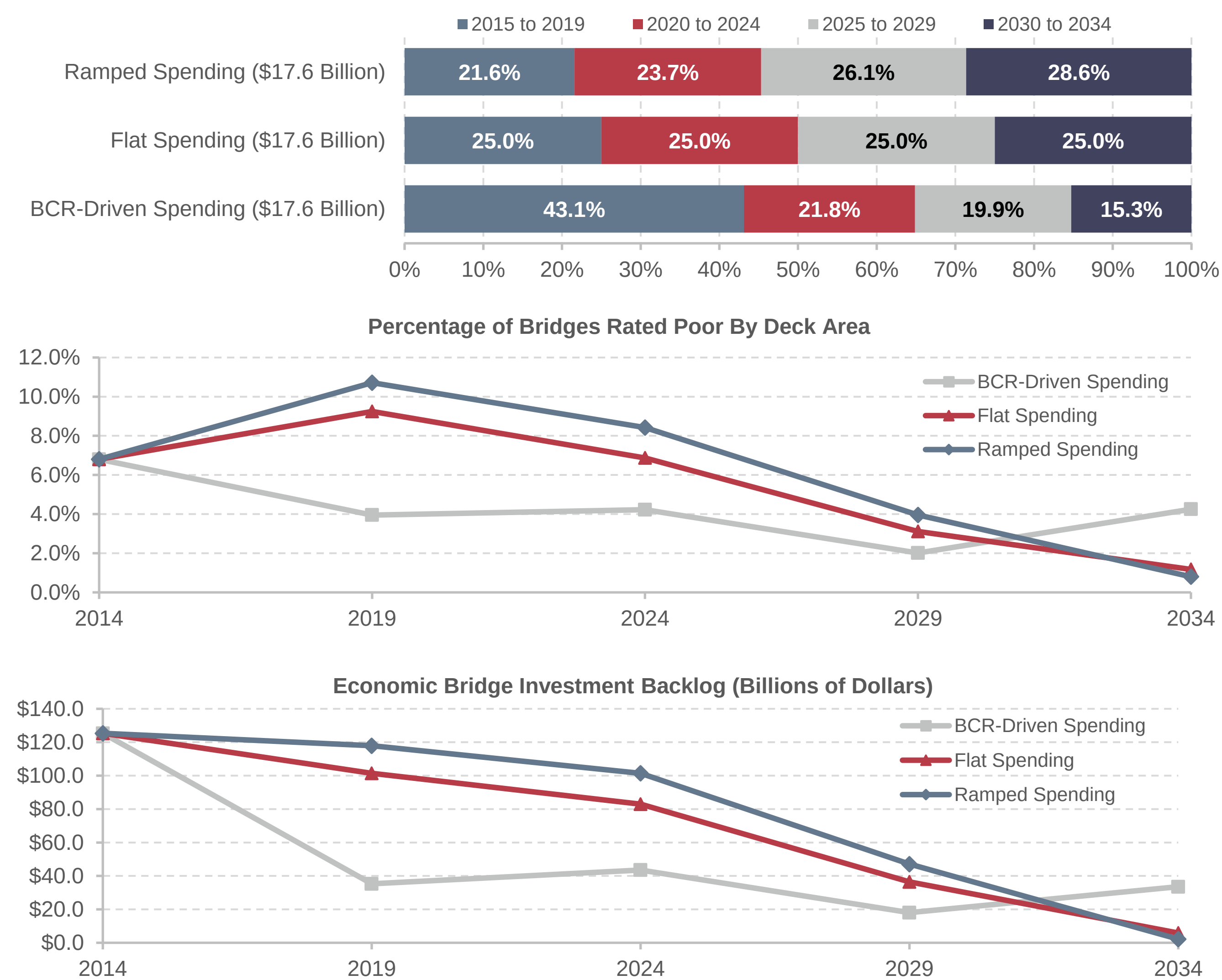
Alternative Timing of Investment in NBIAS

Exhibit 8-11 identifies the impacts of alternative investment timing on the share of bridges that are structurally deficient by deck area using the three investment assumptions described above: ramped spending, flat spending, and BCR-driven spending. An average annual investment level of $17.6 billion was assumed for each alternative analyzed.

Similar to the results of pavement investment in HERS presented earlier, investment timing has an impact on structurally deficient bridges. The ramped case for the NBIAS Improve Conditions and Performance scenario assumes constant annual spending growth of 1.9 percent, with a total 20-year investment of $352 billion and an average annual investment of $17.6 billion in constant 2014 dollars. The top panel of *Exhibit 8-11* indicates that more investment occurs in the later years under the ramped case of gradual and constant growth—from 21.6 percent in the initial 5-year period to 28.6 percent in the last 5-year period. The BCR-driven spending case requires a large portion of the total 20-year investment in the first 5-year period (43.1 percent) and declines sharply to 15.3 percent in the last 5-year period. Spending levels remain constant in the flat spending case.

A different investment pattern produces substantially different outcomes. The middle panel of *Exhibit 8-11* shows that the greatest bridge improvement in the first 5-year period occurs under the BCR-driven spending assumption, as the share of structurally deficient bridges by deck area drops from 6.8 percent in 2014 to 4.0 percent in 2019. During the same period, the share of structurally deficient bridges increases to 9.2 percent under the flat spending assumption and 10.7 percent under the ramped spending assumption. In the next 15 years, however, this pattern is reversed. At an average annual investment level of $17.6 billion, NBIAS projects that the lowest share of structurally deficient bridges in 2034 would be achieved under the ramped spending approach with only 0.8 percent of bridges that are structurally deficient, compared with 1.2 percent assuming flat spending and 4.2 percent for the BCR-driven spending alternative.

Exhibit 8-11: Impact of Investment Timing on NBIAS Results For a Selected Investment Level—Effects on Bridges Rated as Poor and Economic Bridge Investment Backlog



Source: National Bridge Investment Analysis System.

The economic bridge investment backlog also exhibits different trends under the alternative investment timing. The lower panel of *Exhibit 8-11* indicates that, from 2014 to 2019, the average backlog declines significantly under the BCR-driven alternative, with slower declines under the flat spending alternative and ramped spending. The rate of decline is determined by the investment timing. High bridge investment in later years under ramped spending leads to a small economic backlog of $2.2 billion in 2014 constant dollars by 2034, while the projected backlog would be $5.9 billion and $33.5 billion under the flat spending and BCR-driven spending assumptions, respectively.

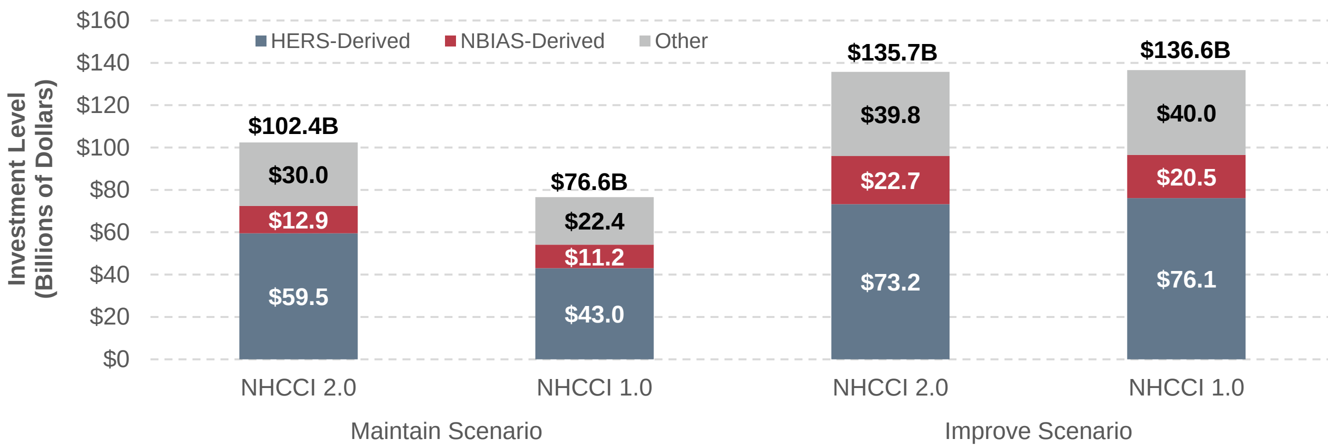
Change in Past Construction Cost Inflation Estimates

As described in Chapter 2, the average annual change in highway construction costs was calculated based on the new FHWA NHCCI in 2003–2014, called NHCCI 2.0. The NHCCI 2.0 shows much more growth in highway construction cost than did the original NHCCI (NHCCI 1.0). *Exhibit 8-12* demonstrates the impact on needs estimation from different cost inflation assumptions.

NHCCI 1.0 showed index values of 124.8 for rural highways and 121.1 for urban highways in 2014. Using the same base quarter (2003 Q1=100), NHCCI 2.0 shows much higher values of 168.6 for rural (35.1 percent higher than NHCCI 1.0) and 168.9 for urban highways (39.5 percent higher) in 2014.

These changes in the NHCCI had implications for the HERS and NBIAS analyses, since they are used to inflate cost data collected in previous years. In the case of HERS, the NHCCI was used to inflate a set of typical costs per mile for different types of highway pavement and capacity improvements that date back to 2002. For NBIAS, the NHCCI was used to inflate estimates of typical costs for certain types of bridge maintenance, repair, and rehabilitation costs that date back to 2008 (estimated bridge replacement costs do not rely on the NHCCI). The switch to the higher index values in NHCCI 2.0 resulted in higher construction costs and reduced the number of projects that were estimated to be cost-beneficial; that is, those with a BCR greater than or equal to 1.

Exhibit 8-12: Impact of Using NHCCI 2.0 to Inflate Historical Capital Costs on Highway Investment Scenario Average Annual Investment Levels



Note: The NHCCI 2.0 levels shown correspond to the systemwide scenarios presented in Chapter 7. The investment levels shown are average annual values for the period from 2015 through 2034.

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

The index change had a more significant impact on the average annual investment levels for the Maintain Condition and Performance scenario than for the Improve Conditions and Performance scenario. The average annual investment level associated with the Maintain Conditions and Performance scenario in Chapter 7 was

$102.4 billion per year in constant 2014 dollars, based on NHCCI 2.0. Alternatively, the average annual investment level would have been $76.6 billion if NHCCI 1.0 were used. The Maintain Conditions and Performance scenario requires HERS and NBIAS to keep overall conditions and performance at 2014 levels over 20 years. Given higher construction costs from switching to NHCCI 2.0, it is expected that the investment will increase substantially to meet these pre-set targets of conditions and performance.

Under the Maintain Conditions and Performance scenario, the change was more significant from the HERS-derived component, where annual investment needs rose from $43.0 billion using NHCCI 1.0 to $59.5 billion using NHCCI 2.0, a 38.4 percent increase. The NBIAS-derived component estimated that annual investment would increase by 15.6 percent when updated to the new NHCCI 2.0. Much of the relative difference in the impacts on HERS versus NBIAS can be attributed to the fact that only a portion of the NBIAS unit costs are affected by the NHCCI, and those were affected for a shorter period of time.

The switch from NHCCI 1.0 to NHCCI 2.0 had a much smaller impact on the Improve Conditions and Performance scenario, as the average annual investment level dropped from $136.6 billion to $135.7 billion. The average annual investment level for the HERS-derived portion of this scenario would be $2.9 billion (3.8 percent) lower using NHCCI 2.0, while the NBIAS-derived portion would be $2.2 billion (11.2 percent) higher.

Under the Improve Conditions and Performance scenario, there will be fewer eligible projects that meet the BCR threshold, but each project that is implemented would be more expensive. Hence, while the overall average annual investment level was not significantly affected by switching to the NHCCI 2.0, the total number of projects implemented was reduced, as was their cumulative impact on overall system conditions and performance.

Transit Supplemental Analysis

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 discusses the following topics:

- asset condition forecasts under three scenarios: (1) Sustain 2014 Spending, (2) Low-Growth, and (3) High-Growth; in addition, the analysis includes a discussion of the State of Good Repair benchmark;
- a comparison of recent historical passenger miles traveled (PMT) growth rates with the revised Low-Growth and High-Growth scenario projections;
- 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- and High-Growth scenarios.
- A comparison of backlog estimates across recent C&P Reports.

Key Takeaways

The national condition level of transit assets in 2014 stood at 3.1 (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- and High-Growth Investment Scenarios: Under these scenarios, after an initial jump, the average condition in 2034 is projected to be in the 3.3–3.5 range, a slight increase from the 2014 level.
- Sustain 2014 Spending: Under this scenario, the average condition is predicted to decrease consistently from the 2014 level (3.1) to 2.8, in the top of the marginal condition range (2.0–2.9). The main reason for this result is that assets past their useful life are not initially replaced because investment in replacement is constrained, and insufficient to fully address the backlog.
- To support a ridership increase in the range of 3.0 to 4.6 billion additional annual boardings by 2034, the following expansion investments would be required:
  - Fleet: 60,400 to 85,900 additional vehicles (35 percent to 49 percent increase from 2014)
  - Rail Guideway: 2,300 to 2,800 additional route miles (18 percent to 23 percent increase)
  - Stations: 2,800 to 4,300 additional stations (83 percent to 130 percent increase)

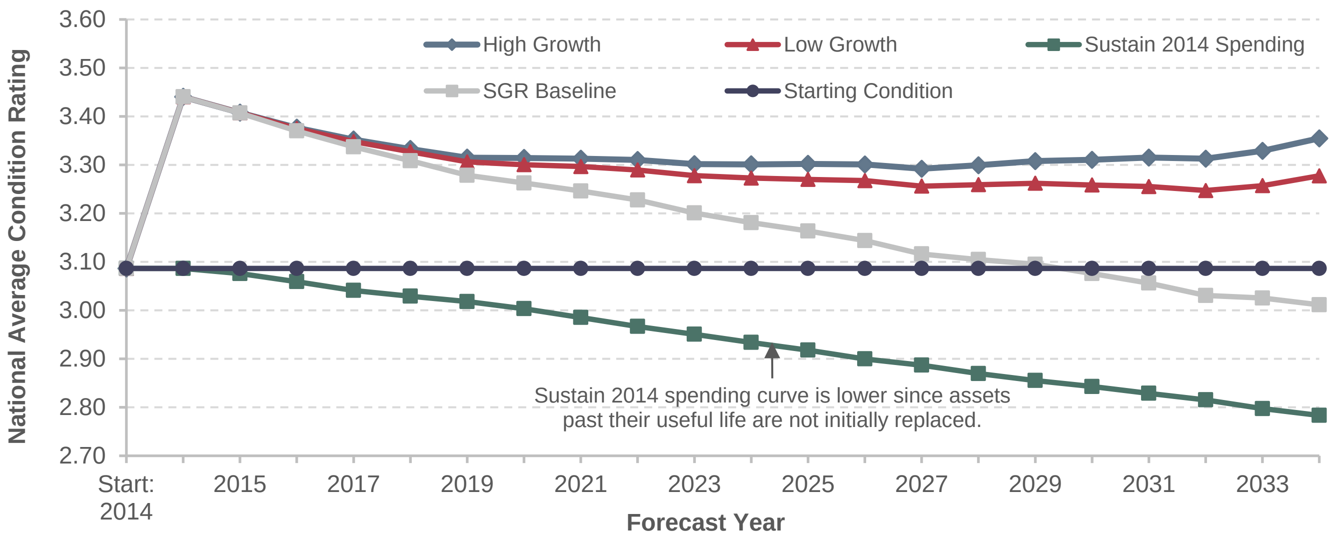
New Technologies in Bus Fleets

The projected backlog in 2034 might increase slightly if bus fleets running on standard diesel engines are replaced by alternative compressed natural gas (CNG) fleets and/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 8-13 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 Sustain 2014 Spending, Low-Growth, and High-Growth scenarios each make investments in additional assets whereas the SGR benchmark reinvests only in existing assets. Note that the estimated current average condition of the Nation's transit assets is 3.09. As discussed in Chapter 7, expenditures under the financially constrained Sustain 2014 Spending scenario are not sufficient to address potential replacement needs as they arise, leading to a predicted increase in the investment backlog. This increasing backlog is a key driver in the decline in average condition of transit assets, as shown for this scenario in *Exhibit 8-13.*

Exhibit 8-13: Asset Condition Forecast for All Existing and Expansion Transit Assets

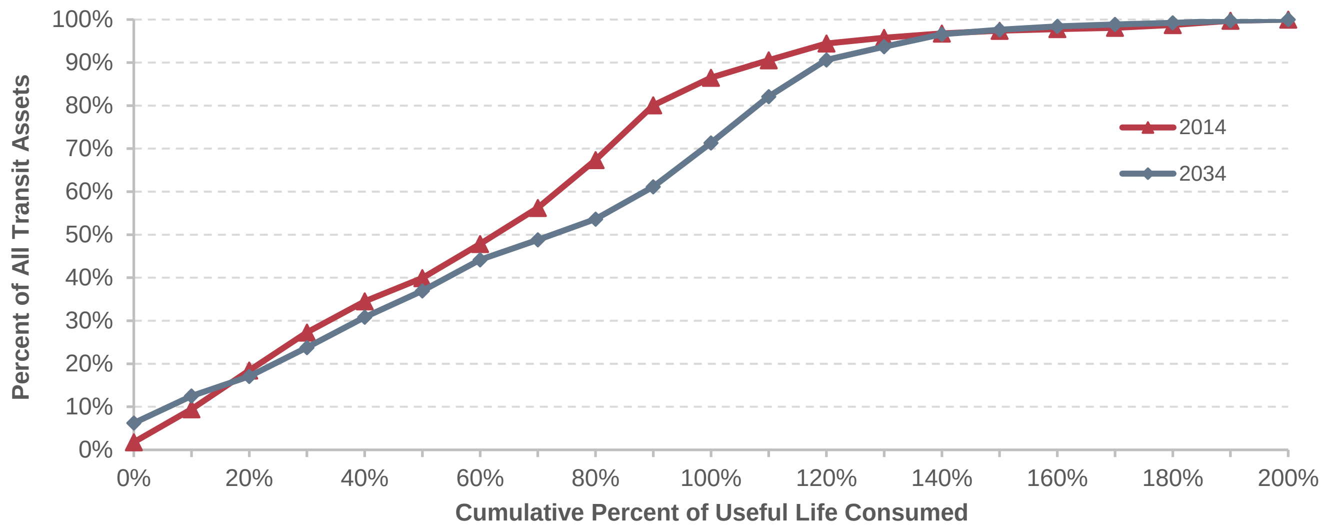


Source: Transit Economic Requirements Model.

Under the Sustain 2014 Spending scenario, some rehabilitation actions and replacing of assets are assumed to occur at later ages, in worse conditions, and potentially well after the end of their useful life, as shown in *Exhibit 8-14*. Expenditures on asset reinvestment for the Sustain 2014 Spending scenario are insufficient to address ongoing reinvestment needs, leading to an increase in the size of the backlog. Note that the forecast for 2034 for the Sustain 2014 Spending scenario shown in *Exhibit 8-14* indicates that a larger portion assets under this scenario will be closer to or beyond the end of their useful lives, when compared with the other scenarios.

In contrast to the Sustain 2014 Spending scenario, the SGR benchmark is financially (and economically) unconstrained, relying solely on engineering considerations to estimate the level of investment required to both eliminate the current investment backlog and to address all ongoing reinvestment needs as they arise such that all assets remain in an SGR (i.e., a condition of 2.5 or higher). Despite adopting the objective of maintaining all assets in an SGR throughout the forecast period, average conditions under the SGR benchmark ultimately decline to levels below the current average condition value of 3.09.

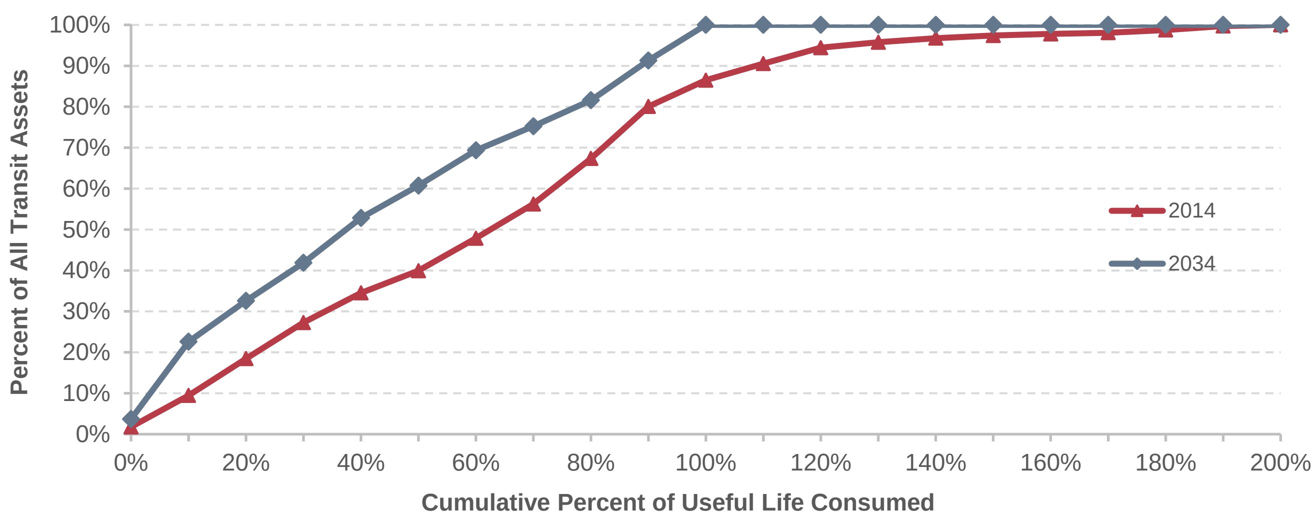
Exhibit 8-14: Sustain 2014 Spending Scenario: Cumulative Distribution of Transit Asset Ages Relative to their Expected Useful Life



Source: Transit Economic Requirements Model.

This result, although perhaps counterintuitive, is explained by a high proportion of long-lived assets (e.g., guideway structures, facilities, and stations) that currently have high average condition ratings and a significant amount of useful life remaining, as shown in *Exhibit 8-15*. The exhibit shows the distribution of all transit assets (equal to approximately $858 billion in 2014) in relation to their expected useful life. Eliminating the current SGR backlog replaces or rehabilitates a significant number of over-age assets (resulting in an initial jump in asset conditions). The ongoing aging of the longer-lived assets, however, ultimately will draw the average asset conditions down to a long-term condition level that is consistent with the objective of SGR (and hence sustainable) but ultimately slightly below current average aggregate conditions.

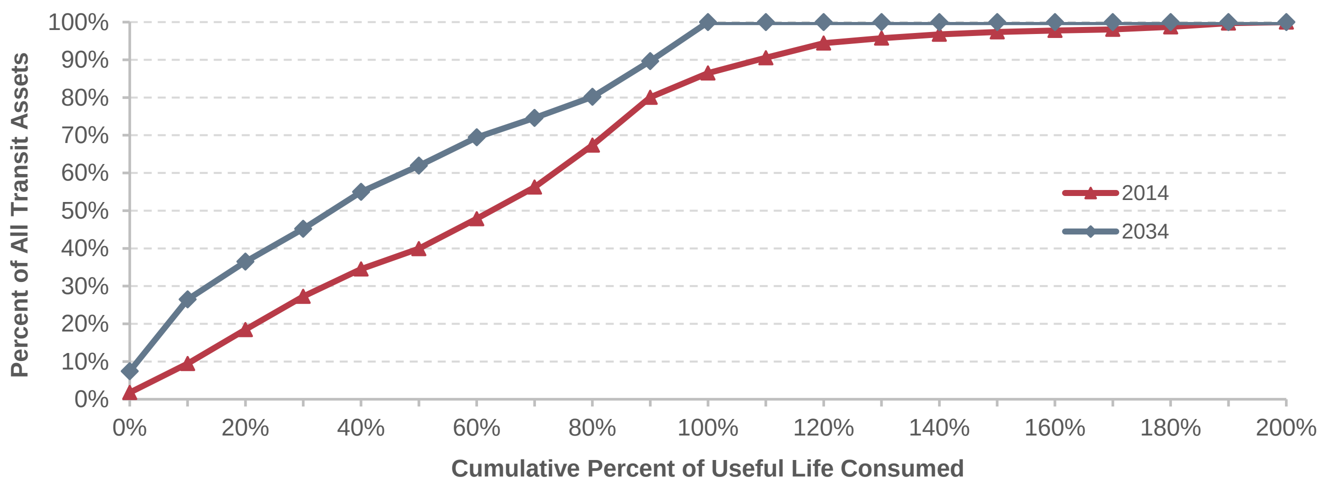
Exhibit 8-15: SGR Baseline Scenario: Cumulative Distribution of Transit Asset Ages Relative to their Expected Useful Life



Source: Transit Economic Requirements Model.

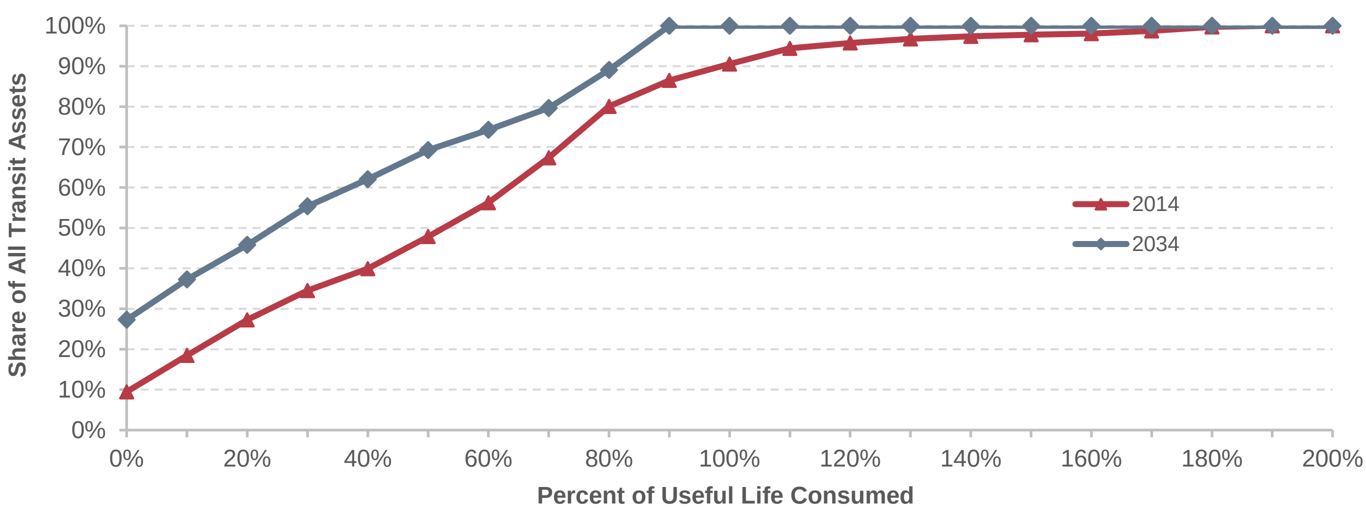
To underscore these findings, note that the Low- and High-Growth scenarios include unconstrained investments in both asset replacements and asset expansions. Hence, not only would older assets be replaced at an aggressive reinvestment rate under this scenario, but new expansion assets would also be continually added to support ongoing growth in travel demand. Although initially insufficient to arrest the decline in average conditions completely, the impact of these expansion investments ultimately would reverse the decline in average asset conditions in the final years of the 20-year projections. A higher proportion of long-lived assets with more useful life remaining in 2034 than in 2014 also would result, as illustrated in *Exhibit 8-16* and *Exhibit 8-17*, respectively. Furthermore, the High-Growth scenario (*Exhibit 8-17*) adds newer expansion assets at a higher rate than does the Low-Growth scenario (*Exhibit 8-16*), ultimately yielding higher average condition values for that scenario (and average condition values that exceed the current average of 3.09 throughout the entire forecast period).

Exhibit 8-16: Low Growth Scenario: Cumulative Distribution of Transit Asset Ages



Source: Transit Economic Requirements Model.

Exhibit 8-17: High Growth Scenario: Cumulative Distribution of Transit Asset Ages Relative to their Expected Useful Life



Source: Transit Economic Requirements Model.

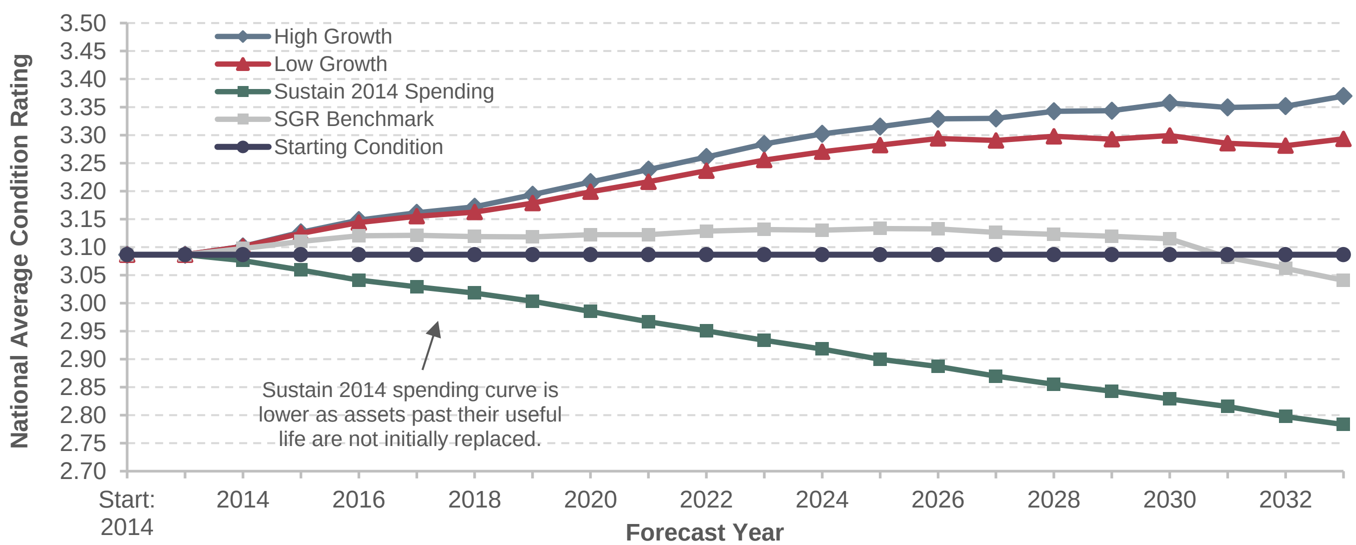
Alternative Methodology

When current transit investment practices are considered, the level of investment needed to eliminate the SGR backlog in 1 year is likely infeasible. Thus, the SGR Benchmark, Low-Growth, and High-Growth scenarios' financially unconstrained assumptions (e.g., spending of unlimited transit investment funds each year) are unrealistic. As indicated in *Exhibit 8-13*, 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 to have all three scenarios use a financially constrained reinvestment rate to eliminate the SGR backlog by year 20 while maintaining the collective national transit assets at a condition rating of 2.5 or higher. This analysis indicates that investing $17.5 billion annually in preservation would eliminate the backlog in 20 years.

Exhibit 8-18 presents the condition projections for the two scenarios and the benchmark using this alternative methodology. The Low- and High-Growth scenarios and SGR Benchmark scenario are financially constrained so the investment strategies result in replacing assets at later ages, in worse conditions, and potentially after the end of their useful lives.

Exhibit 8-18: Asset Condition Forecast for All Existing and Expansion Transit Assets, Using Alternative Methodology



Source: Transit Economic Requirements Model.

Impact 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. Although such options offer clear environmental benefits (and compressed natural gas might decrease operating costs), acquisition costs for these vehicle types are 20 to 60 percent higher than diesel. 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.

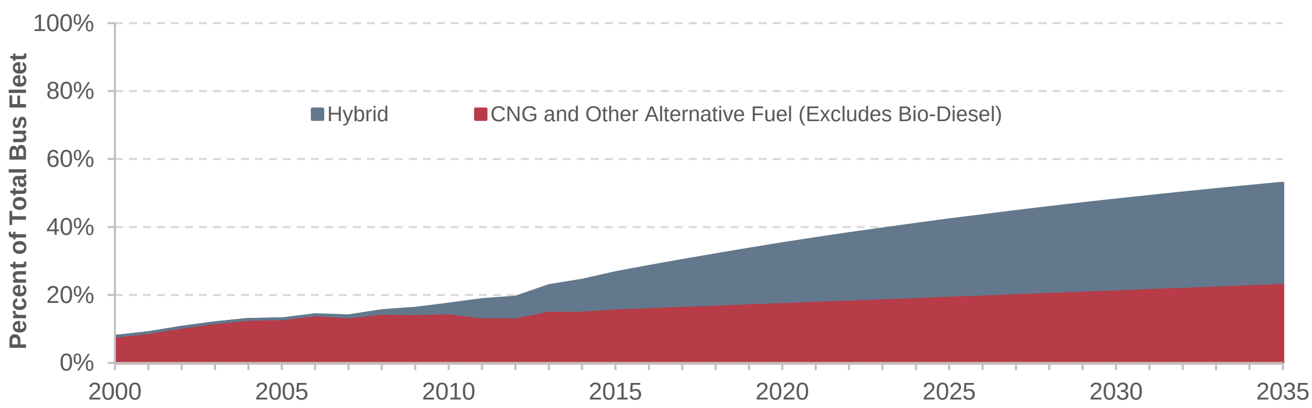
In addition to improvements in preexisting asset types, transit operators periodically expand their existing asset stock to introduce new asset types that take advantage of technological innovations. Examples include investments in intelligent transportation system technologies such as real-time passenger 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.

Impact of Compressed Natural Gas and Hybrid Buses on Future Investment Scenarios

To provide a better sense of the impact of new technology adoption on long-term needs, the analysis below presents estimates of the long-term cost impact of the shift from diesel to compressed natural gas and hybrid buses on long-term capital investment (including the possible consequences of not capturing this impact in the Transit Economic Requirements Model's (TERM) needs estimates). This assessment does not consider the full range of operational, environmental, or other potential costs and benefits arising from this shift, and hence it does not evaluate the merits of any decisions to invest in specific technologies.

Exhibit 8-19 presents historical (2000–2014) and forecast (2015–2035) estimates of the share of transit buses that rely on compressed natural gas, other alternative fuels, and on hybrid power sources. The forecast estimates assume the current trend rate of increase in alternative and hybrid vehicle shares, as observed from 2007 to 2014. Based on this projection, the share of vehicles powered by these alternative fuels is estimated to increase from 24.4 percent in 2014 to 52.9 percent in 2035. During the same period, the share of hybrid buses is estimated to increase from 9 percent to 29 percent. This results in diesel shares declining from roughly 75.6 percent today to about 47 percent by 2035.

Exhibit 8-19: Hybrid and Alternative Fuel Vehicles: Share of Total Bus Fleet, 2000–2035



Source: Transit Economic Requirements Model.

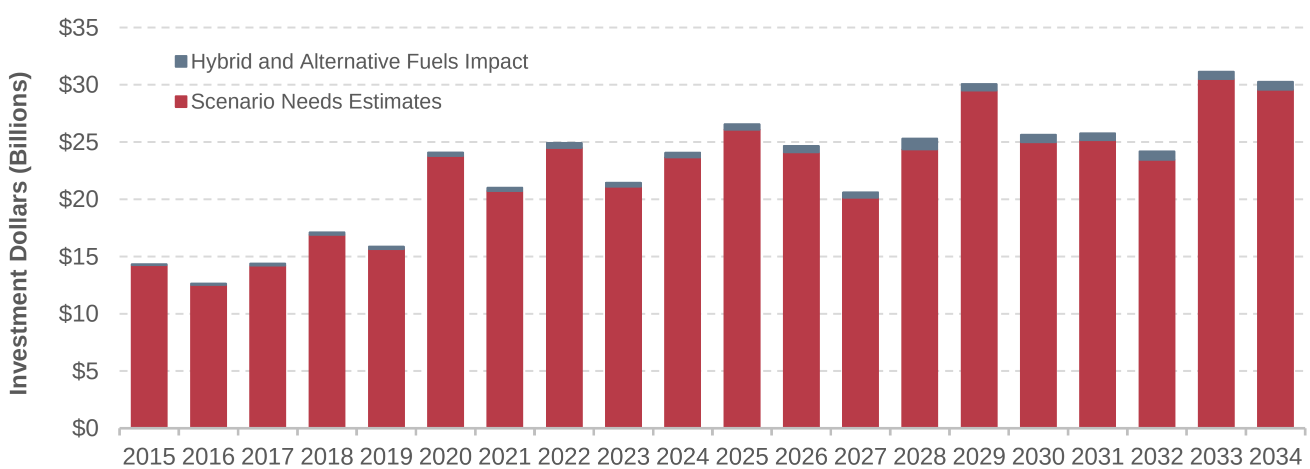
Impact on Costs

According to a 2007 report by the Federal Transit Administration (FTA), *Transit Bus Life Cycle Cost and Year 2007 Emissions Estimation*, the average unit cost of an alternative-fuel bus plus its share of cost for the required fueling station is 15.5 percent higher than that of a standard diesel bus of the same size. Similarly, hybrid buses cost an average of 65.9 percent more than standard diesel buses of the same size. When combined with the current and projected mix of bus vehicle types presented above in *Exhibit 8-19*, these cost assumptions yield an estimated increase in average capital costs for bus vehicles of 14.3 percent from 2014 to 2035 (using the mix of bus types from 2014 as the basis of comparison). (Note that this cost increase represents a shift in the mix of bus types purchased and not the impact of underlying inflation, which will affect all vehicle types, including diesel, alternative fuels, and hybrid.) Reductions in operating costs due to the new technology are not shown in this analysis of capital needs, but are presumably part of the motivation for agencies that purchase these vehicles.

Impact on Investment Scenarios

What, then, is the impact of this cost increase on long-term transit capital investment under the scenarios presented in Chapter 7? *Exhibit 8-20* presents the impact of this potential cost increase on annual transit investment as estimated for the Low-Growth scenario presented in Chapter 7. For this scenario, the cost impact is negligible in the early years of the projection period but grows over time as the proportion of buses using alternative fuel and hybrid power increases. (Note that the investment backlog is not included in this depiction.) The impact on total investment needs for Chapter 7 investment scenarios (Low-Growth and High-Growth) and the SGR Benchmark scenario are presented in dollar and percentage terms in *Exhibit 8-21*. Note that the shift to alternative fuels and hybrid buses is estimated to increase average annual replacement investment costs by $0.1 billion to $0.4 billion, yielding no greater than a 0.15 percent increase in investment costs. To provide perspective for these estimated amounts, noting the following is helpful: (1) the shift from diesel to alternative-fuel and hybrid buses is only one of several technology changes that might affect long-term transit reinvestment needs, but (2) reinvestment in transit buses likely represents the largest share of transit needs subject to this type of significant technological change. Hence, the impact of all new technology adoptions (not accounted for in the Chapter 7 scenarios and including new bus propulsion systems) might add 5–10 percent to long-term transit capital investment requirements.

Exhibit 8-20: Impact of Shift to Vehicles Using Hybrid and Alternative Fuels on Investment Needs: Low-Growth Scenario



Source: Transit Economic Requirements Model.

Exhibit 8-21: Impact of Shift from Diesel to Alternative Fuels and Hybrid Vehicles on Average Annual Investment Scenarios

Measure	SGR Baseline	Low Growth	High Growth
Average Annual Needs ($ Billions)	$0.36	$0.43	$0.45
Percent Increase	1.26%	1.41%	1.48%

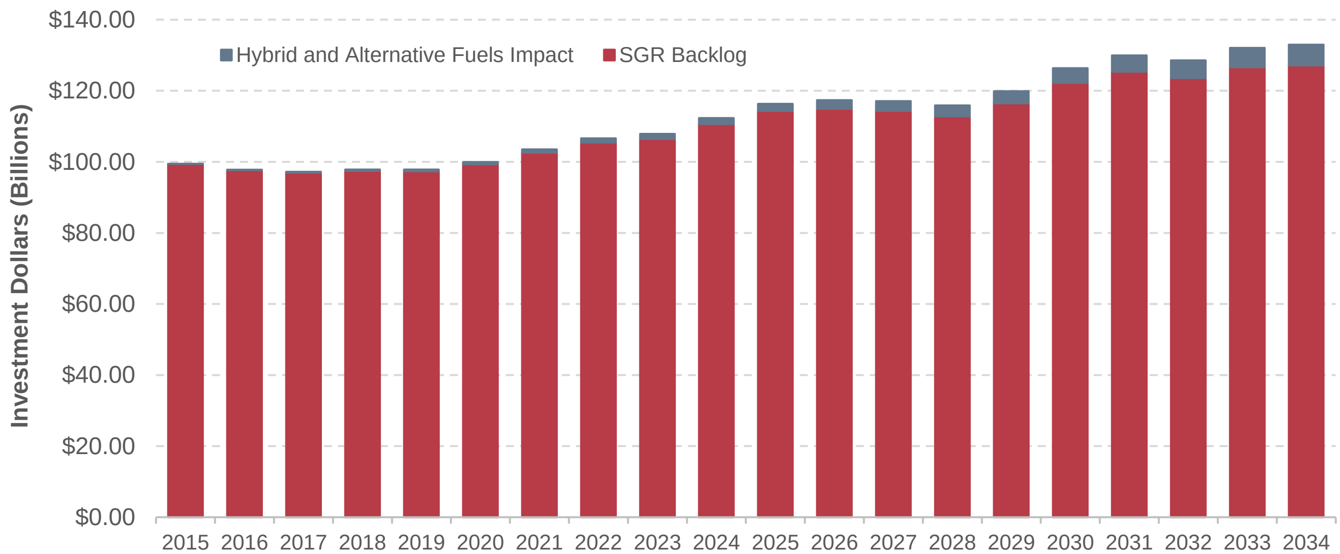
Source: Transit Economic Requirements Model.

Impact on Backlog

Finally, in addition to affecting unconstrained capital needs, the shift from diesel to hybrid and alternative-fuel vehicles also can affect the size of the future backlog. For example, *Exhibit 8-22* shows the estimated impact of this shift on the SGR backlog as estimated for the Sustain 2014 Spending scenario from Chapter 7. Under this scenario, long-term spending is capped at current levels such that any increase in costs over the analysis period must necessarily be added to the backlog. Moreover, given that the useful lives of buses as estimated by TERM are roughly 7–14 years, all existing and many expansion vehicles will need to be replaced over the 20-year analysis period. This means that any increase in costs for this asset type will be added to the backlog for the period of analysis.

As with the analysis above, *Exhibit 8-22* suggests that the initial impact of the shift to hybrid and alternative-fuel vehicles is small but increases over time as the share of the Nation's bus fleet made up by these vehicle types increases. By 2034, this shift is estimated to increase the size of the backlog to $123.5 billion versus $116.2 billion under the original Sustain 2014 Spending scenario, an increase of $7.3 billion or 6.3 percent.

Exhibit 8-22: Impact of Shift to Vehicles Using Hybrid and Alternative Fuels on Backlog Estimate: Sustain Average 2000 to 2014 Spending Scenario



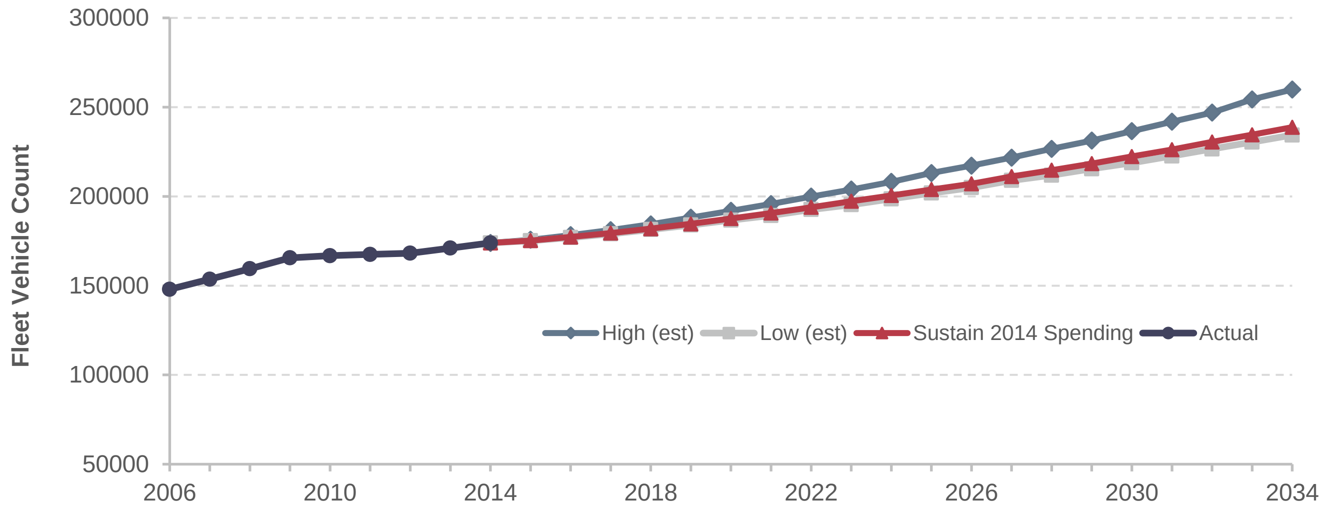
Source: Transit Economic Requirements Model.

Forecasted Expansion Investment

This section compares key characteristics of the national transit system in 2014 to their forecasted TERM results over the next 20 years for different scenarios. It also includes expansion projections of fleet size, guideway route miles, and stations broken down by scenario to understand better the expansion investments that TERM forecasts.

TERM's projections of fleet size are presented in *Exhibit 8-23*. The projections for the Low- and High-Growth scenarios create upper and lower targets around the projected Sustain 2014 Spending scenario to preserve existing transit assets at a condition rating of 2.5 or higher and expand transit service capacity to support differing levels of ridership growth while passing TERM's benefit-cost test.

Exhibit 8-23: Projection of Fleet Size by Scenario



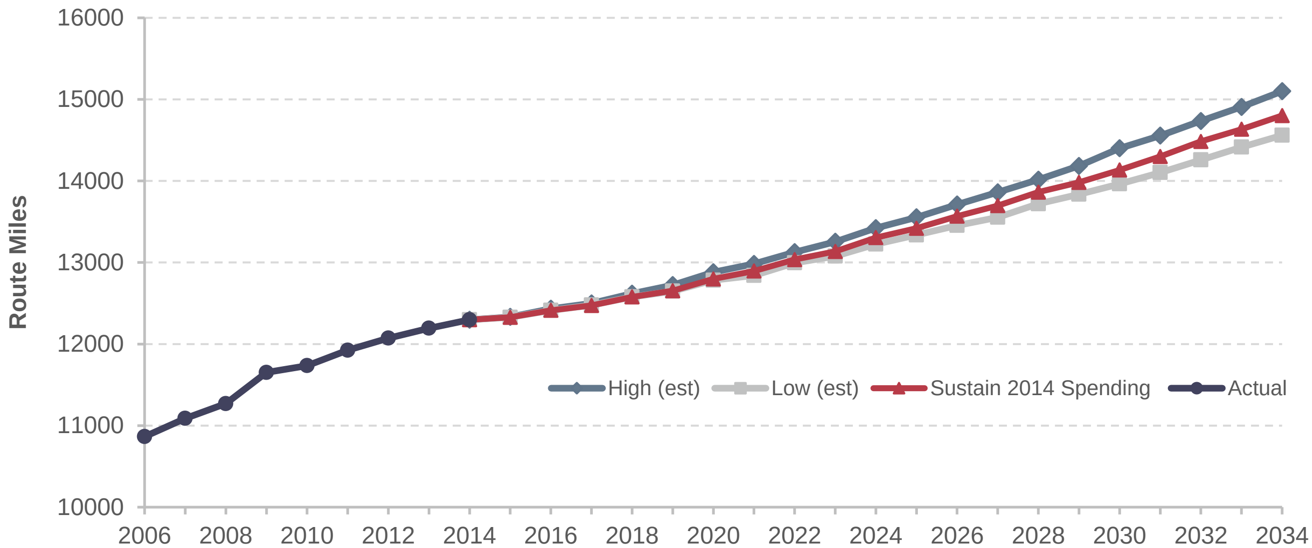
Note: Data through 2014 are actual; data after 2014 are estimated based on trends.
Source: Transit Economic Requirements Model.

The projected guideway route miles for the Sustain 2014 Spending scenario are less than those for the projected High-Growth scenario, as shown in *Exhibit 8-24*. (Note that TERM's projections of guideway route miles for the Sustain 2014 Spending and Low-Growth scenarios are nearly identical.)

TERM's expansion projections of stations by scenario needed to preserve existing transit assets at a condition rating of 2.5 or higher and to expand transit service capacity to support differing levels of ridership growth (while passing TERM's benefit-cost test) are presented *Exhibit 8-25*. TERM's Low-Growth estimates generally are in line with the historical trend, indicating that expansion projections of stations under the Low-Growth scenario could maintain current transit conditions.

For each scenario, TERM estimates future investment in fleet size, guideway route miles, and stations for each of the next 20 years. *Exhibit 8-26* presents TERM's projection for total fixed guideway route miles under the Low-Growth scenario by rail mode. TERM projects different investment needs for each year, which are added to the 2014 actual total stock.

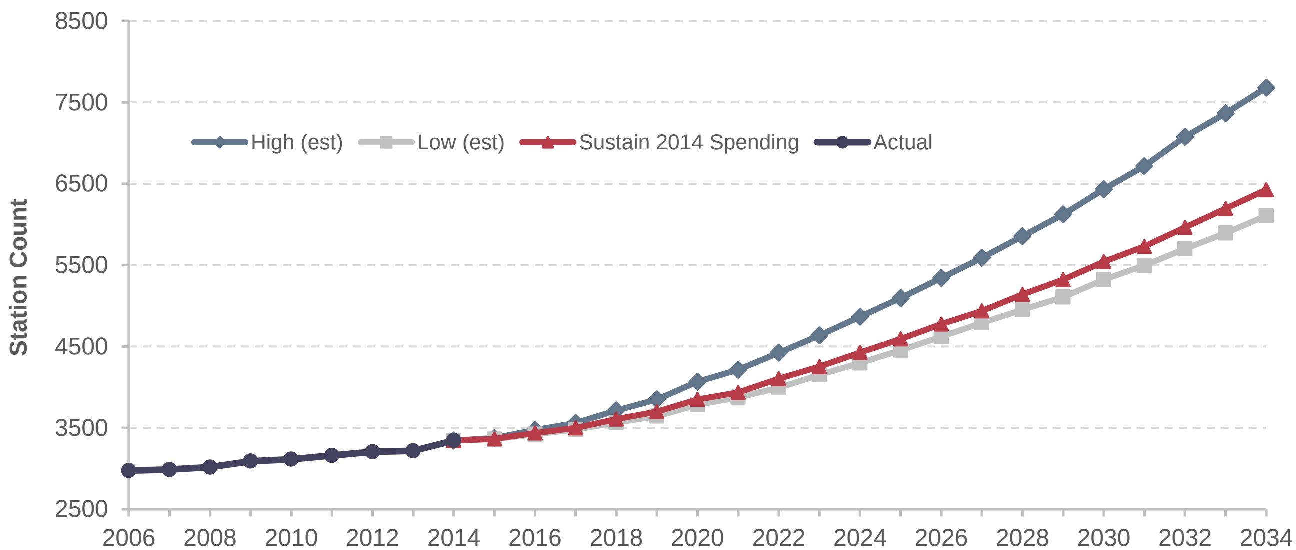
Exhibit 8-24: Projection of Guideway Route Miles by Scenario



Note: Data through 2014 are actual; data after 2014 are estimated based on trends.

Source: Transit Economic Requirements Model.

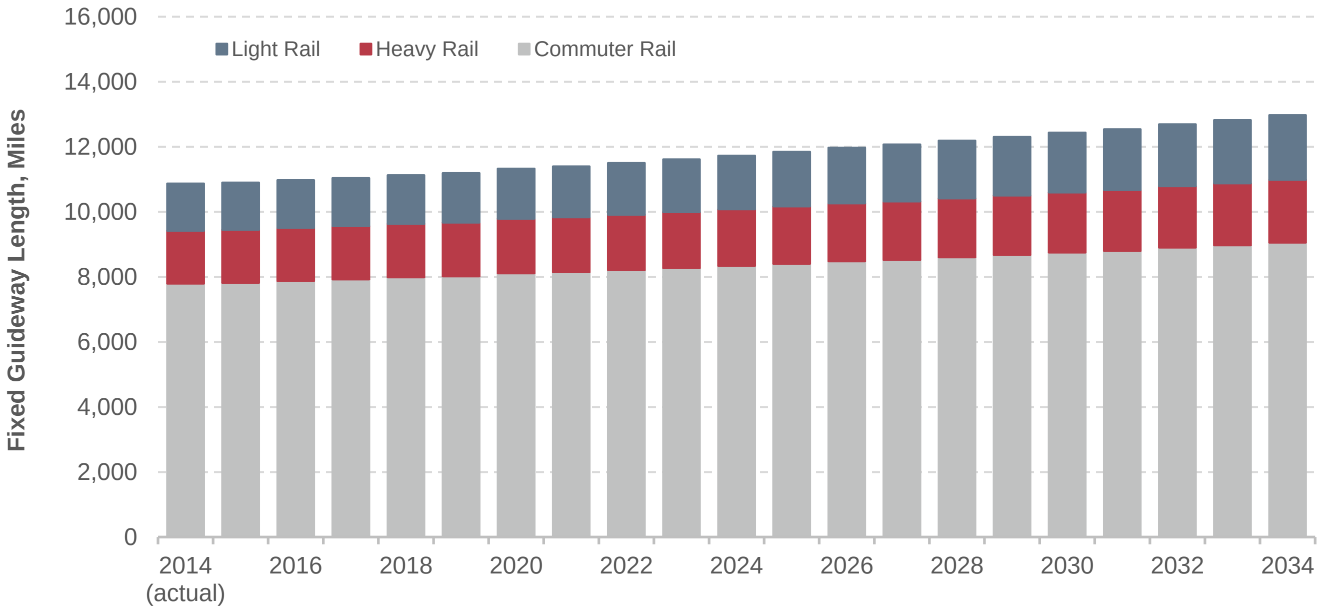
Exhibit 8-25: Projection of Rail Stations by Scenario



Note: Data through 2014 are actual; data after 2014 are estimated based on trends.

Source: Transit Economic Requirements Model.

Exhibit 8-26: Stock of Fixed Guideway Miles by Year Under Low-Growth Scenario, 2014–2034



Source: Transit Economic Requirements Model.

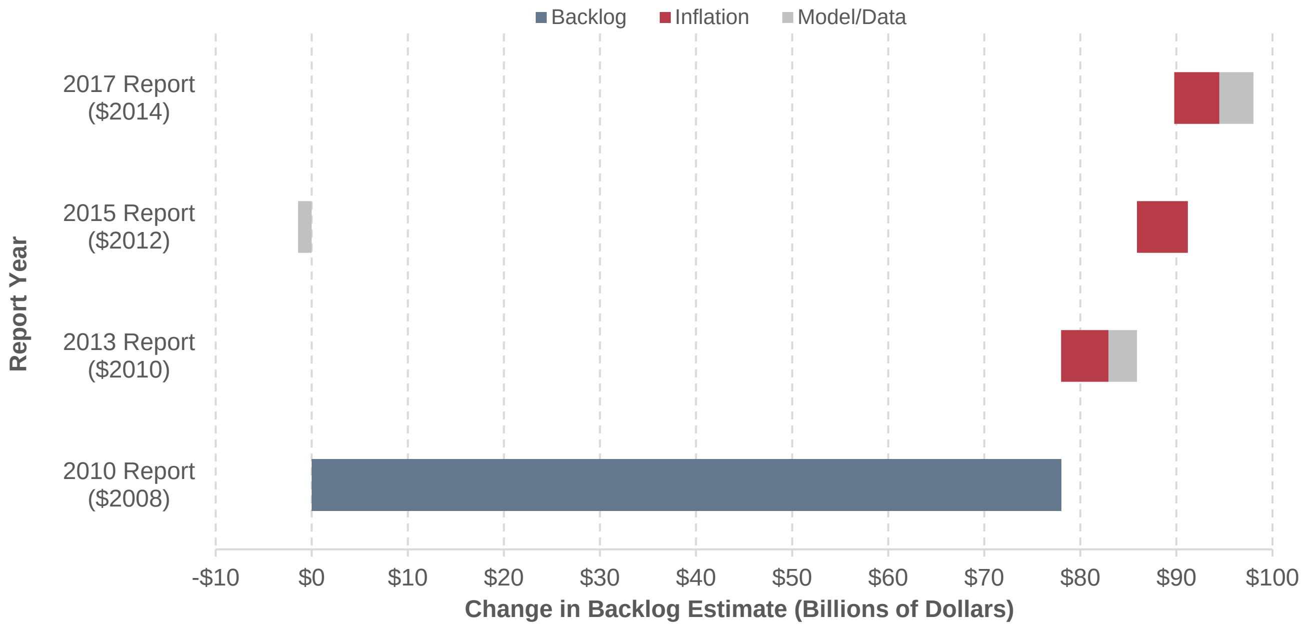
Backlog Estimates across Recent C&P Reports

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 2017 reports (74 percent) is caused by inflation, as shown in *Exhibit 8-27*.
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 8-27: Change in Backlog Estimate Since the 2010 Report



Source: Transit Economic Requirements Model.

CHAPTER 9
Sensitivity Analysis

Highway Sensitivity Analysis

Sound practice in investment modeling includes analyzing the sensitivity of key results to changes in the underlying assumptions. For the Maintain Conditions and Performance scenario and the Improve Conditions and Performance scenario presented in Chapter 7, this section analyzes how changes in some of the underlying assumptions would affect the estimate of the average annual levels of highway investment. Some of the key economic assumptions include:

- value of traveler time savings in the 2014 base year,
- value of statistical life,
- discount rate used to convert future costs and benefits into present-value equivalents, and
- projected growth in aggregate traffic volumes.

Key Takeaways

- The Improve Conditions and Performance scenario is highly sensitive to the real discount rate assumed in the analysis. Substituting in a 3-percent discount rate for the 7-percent discount rate assumed in the baseline would increase its average annual investment requirements by 28.2 percent.
- Both HERS and NBIAS are more sensitive to changes in the assumed value of time than to the assumed value of a statistical life.
- Directly applying the future traffic projections reported by States via HPMS and NBI would increase the average annual investment levels for both the Maintain Conditions and Performance and Improve Conditions and Performance scenarios by approximately 10 percent, relative to the baseline VMT growth assumption derived from a national VMT forecasting model.

An important outcome of the HERS results is that, under both baseline and sensitivity test assumptions, the Maintain Conditions and Performance scenario is equivalent to one in which the metric to be maintained is simply average pavement roughness. As defined, the Maintain Conditions and Performance scenario sets HERS-related spending at the lowest level at which the 2034 projections for each of two measures—the average International Roughness Index (IRI) and average delay per vehicle miles traveled (VMT)—indicate conditions and performance that match or surpass those in the 2014 base year. In each of this report's simulations of this scenario, however, the binding constraint was to maintain average IRI. (The level of HERS-related spending that just sufficed to meet this constraint resulted in a decrease in average delay per VMT below the level in 2014.) For this reason, and because travel time delay depends much more on highway capacity than on pavement condition, any change to HERS assumptions that causes the model to reduce the share of spending for system expansion projects also will decrease the HERS component of spending in the Maintain Conditions and Performance scenario (and vice versa).

Alternative Economic Analysis Assumptions

For application in benefit-cost analyses of programs and actions under their purview, the U.S. Department of Transportation (DOT) periodically issues guidance on valuing changes in travel time and traveler safety, and the Office of Management and Budget (OMB) provides guidance on the discount rate to be used. Recognizing the uncertainty regarding these values, the guidance documents include both specific recommended values and ranges of values to be tested. The analyses presented in Chapters 7 and 10 of this report are based on the primary recommendations in DOT and OMB guidance for these economic inputs, whereas the analyses presented in this chapter rely on recommended alternative values to be used for sensitivity testing.

Value of Travel Time Savings

The value of travel time savings is a key parameter in benefit-cost analysis of transportation investments. For HERS and NBIAS, the Federal Highway Administration (FHWA) estimates average values per vehicle hour traveled by vehicle type. Primarily, these values reflect the benefits from savings in the time travelers spend in vehicles, also taking into account that vehicles can have multiple occupants. Time used for travel represents a cost to society and the economy because that time could be used for other more enjoyable or productive purposes. For heavy trucks, FHWA makes additional allowances for the benefits from freight arriving at its destination faster and from the opportunities for more intensive vehicle utilization when trips can be accomplished in less time. Even for these types of vehicles, however, the value of travel time savings estimated by FHWA primarily reflects the benefits from the freeing of travelers' time—the time of the truck driver and other vehicle occupants.

For valuation of traveler time, the analysis in this report follows DOT's guidance on valuing travel time saved in 2014. In the analyses presented in Chapters 7 and 10, traveler time savings are valued per person hour at $12.30 for personal travel and between $27 and $32 for business travel. The value for personal travel is set in the guidance at 50 percent of hourly household income, calculated as median annual household income divided by 2,080, the annual work hours of someone working 40 hours every week. The values for business travel are set at the relevant estimate of average hourly labor compensation (wages plus supplements). The variation in these values by vehicle type indicates, for example, that truck drivers typically earn less than business travelers in light-duty vehicles. (For details on the derivation of these values, see Appendix A.)

These values per person hour of travel are estimates subject to considerable uncertainty. Even when personal and business travel purposes are distinguished, estimating an average value of travel time is complicated by substantial variation in the value of travel time among individuals and, even for a given individual, among trips. Contributing to such variation are differences in incomes, employment status and earnings, attitudes, conditions of travel (e.g., the level of traffic congestion), and other factors. Moreover, studies that estimate values of travel time often are difficult to compare because of differences in data and methodology.

In view of these uncertainties, DOT guidance calls for sensitivity tests that set values of travel time lower or higher than for the baseline. For personal travel time, these values are 35 percent and 60 percent of median hourly household income, rather than 50 percent as assumed in the baseline. For business travel time, these values are 80 percent and 120 percent of average hourly labor compensation, rather than the baseline assumption of 100 percent.

Exhibit 9-1 shows the effects of these variations on spending levels in the two scenarios reexamined in this chapter. For the NBIAS-derived component of spending, the effects are small (at most 2.1 percent), consistent with bridge capacity expansion being outside the model's scope. Except where they would eliminate long detours caused by vehicle weight restrictions on a bridge, the bridge preservation actions evaluated by NBIAS would have minimal effect on travel times.

For the HERS-derived component of spending, the percentage reductions with lower values of traveler time are close to 6 percent in the Maintain Conditions scenario and 10 percent in the Improve Conditions scenario. In the Improve Conditions and Performance scenario, the goal is to exploit all opportunities for cost-beneficial investments, which become fewer when the travel time savings are valued less. In the Maintain Conditions and Performance scenario, valuing travel time savings less decreases the share of spending that HERS allocates to capacity expansion, making funds available for the system preservation improvements that reduce pavement roughness. For this reason, and because the binding constraint in this scenario is maintaining average pavement roughness, the required level of HERS-related spending decreases. Conversely, that spending increases when the higher values of time are assumed.

Exhibit 9-1: Impact of Alternative Value of Time Assumptions on Highway Investment Scenario Average Annual Investment Levels

	Maintain Conditions and Performance Scenario		Improve Conditions and Performance Scenario	
Alternative Time Valuation Assumptions for Personal and Business Travel as Percentage of Hourly Earnings	**Billions of 2014 Dollars**	**Percent Change From Baseline**	**Billions of 2014 Dollars**	**Percent Change From Baseline**
Baseline[1] (Personal–50%; Business–100%)	**$102.4**		**$135.7**	
HERS-Derived Component	$59.5		$73.2	
NBIAS-Derived Component	$12.9		$22.7	
Other (Nonmodeled) Component	$30.0		$39.8	
Lower (Personal–35%; Business–80%)	**$97.2**	**-5.0%**	**$124.8**	**-8.0%**
HERS-Derived Component	$56.0	-5.9%	$66.0	-9.9%
NBIAS-Derived Component	$12.7	-1.2%	$22.2	-2.1%
Other (Nonmodeled) Component	$28.5	-5.0%	$36.6	-8.0%
Higher (Personal–60%; Business–120%)	**$106.7**	**4.2%**	**$143.8**	**5.9%**
HERS-Derived Component	$62.4	4.9%	$78.6	7.3%
NBIAS-Derived Component	$13.1	1.3%	$23.0	1.3%
Other (Nonmodeled) Component	$31.3	4.2%	$42.1	5.9%

[1] The baseline levels shown correspond to the systemwide scenarios presented in Chapter 7. The investment levels shown are average annual values for the period from 2015 through 2034.

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

Nonmodeled Highway Investments

The HERS-derived component of each scenario represents spending on pavement rehabilitation and capacity expansion on Federal-aid highways. The NBIAS-derived component represents rehabilitation spending on all bridges, including those off the Federal-aid highways. The nonmodeled component corresponds to system enhancement spending, plus pavement rehabilitation and capacity expansion on roads not classified as Federal-aid highways.

In the Sustain 2014 Spending scenario presented in Chapter 7, the values for these HERS and NBIAS components sum to $74.6 billion. In 2014, nonmodeled spending accounted for 29.3 percent of total investment and is assumed to form the same share in all scenarios presented in Chapter 7.

Likewise, for the sensitivity analysis for the Maintain Condition and Performance and the Improve Condition and Performance scenarios presented in this section, the nonmodeled component is set at 29.3 percent of the total investment level. As the combined levels of the HERS-derived and NBIAS-derived scenario components increase or decrease, the nonmodeled component changes proportionally. Consequently, the percentage change in the nonmodeled component of each alternative scenario relative to the baseline always matches the percentage change in the total investment level for that scenario.

Value of Traveler Safety

One of the most challenging questions in benefit-cost analysis is what monetary cost to place on injuries of various severities. Few people would consider any amount of money to be adequate compensation for a person's being seriously injured, much less killed. On the other hand, people can attach a value to changes in their risk of suffering an injury, and indeed such valuations are implicit in their everyday choices. For example, a traveler may face a choice between two travel options that are equivalent except that one carries a lower risk of fatal injury but costs more. If the additional cost is $1, a traveler who selects the safer option is manifestly willing to pay at least $1 for the added safety—what economists call "revealed preference." Moreover, if the difference in risk is, say, one in a million, then a million travelers who select the safer option are collectively willing to pay at least $1 million for a risk reduction that statistically can be expected to save one of their lives. In this sense, the "value of a statistical life" among this population is at least $1 million.

Based on the results of various studies of individual choices involving money versus safety tradeoffs, some government agencies estimate an average value of a statistical life for use in their regulatory and investment analyses. Although agencies generally base their estimates on a synthesis of evidence from various studies, the decision as to which value is most representative is never clear-cut, thus warranting sensitivity analysis. DOT issued guidance in 2014 recommending a value of $9.4 million for analyses with a base year of 2014, as is the case in this C&P Report. The guidance also required that regulatory and investment analyses include sensitivity tests using alternative values of $5.2 million as the lower bound and $13.0 million for the upper bound. For nonfatal injuries, the guidance sets values per statistical injury as percentages of the value of a statistical life; these vary by the level of severity, from 0.3 percent for a "minor" injury to 59.3 percent for a "critical" injury. (The injury levels are from the Maximum Abbreviated Injury Scale.)

Impact of Alternatives on HERS Results

HERS contains equations for each highway functional class to predict crash rates per VMT and parameters to determine the number of fatalities and nonfatal injuries per crash. The model assigns to crashes involving fatalities and other injuries an average cost consistent with DOT guidance, including the use of alternative values for sensitivity tests. As shown in *Exhibit 9-2*, the sensitivity tests reveal only minor impacts on the average annual requirement for HERS-related investment; relative to a baseline in which the value of a statistical life is set at $9.4 million, increasing or decreasing that value by about $3.9 million alters the estimated investment requirement by well under 2 percent in each case. One reason for this relative insensitivity is that crash costs are estimated in HERS to form a small share of total highway user costs. In addition, from Chapter 10's discussion of "Impact of Future Investment on Highway User Costs," it emerges that the crash costs are less sensitive than travel time and vehicle operating costs to changes in the level of total investment within the scope of HERS. (Data limitations preclude that scope from including highway improvements that primarily target safety issues.) For NBIAS-related investment, the sensitivity of the estimated annual spending requirement to the tested variations in the value of a statistical life is even less than for HERS-related investment.

Exhibit 9-2: Impact of Alternative Value of a Statistical Life Assumptions on Highway Investment Scenario Average Annual Investment Levels

Alternative Value of Statistical Life Assumptions (2014 Dollars)	Maintain Conditions and Performance Scenario		Improve Conditions and Performance Scenario	
	Billions of 2014 Dollars	Percent Change From Baseline	Billions of 2014 Dollars	Percent Change From Baseline
Baseline[1] ($9.4 Million)	**$102.4**		**$135.7**	
HERS-Derived Component	$59.5		$73.2	
NBIAS-Derived Component	$12.9		$22.7	
Other (Nonmodeled) Component	$30.0		$39.8	
Lower ($5.2 Million)	**$100.9**	**-1.4%**	**$133.6**	**-1.6%**
HERS-Derived Component	$58.5	-1.7%	$72.0	-1.7%
NBIAS-Derived Component	$12.9	-0.2%	$22.5	-1.1%
Other (Nonmodeled) Component	$29.6	-1.4%	$39.2	-1.6%
Higher ($13.0 Million)	**$103.1**	**0.7%**	**$137.1**	**1.0%**
HERS-Derived Component	$59.9	0.7%	$74.0	1.0%
NBIAS-Derived Component	$13.0	0.7%	$23.0	1.0%
Other (Nonmodeled) Component	$30.2	0.7%	$40.2	1.0%

[1] The baseline levels shown correspond to the systemwide scenarios presented in Chapter 7. The investment levels shown are average annual values for the period from 2015 through 2034.

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

Discount Rate

Benefit-cost analyses apply a discount rate to future streams of costs and benefits, which effectively weighs benefits and costs expected to arise further in the future less than those that would arise sooner. The baseline investment scenarios estimated by HERS, NBIAS, and the Transit Economic Requirements Model (TERM) use a discount rate of 7 percent; this means that deferring a benefit or cost for a year reduces its real value by approximately 6.5 percent (1/1.07). This choice of real discount rate conforms to the "default position" in the 1992 OMB guidance on discount rates, in Circular A-94, for benefit-cost analyses of Federal programs or policies. That guidance also suggests testing the sensitivity of the analysis to variations in the discount rate. The sensitivity tests in this section include the use of the 3-percent discount rate as an alternative to the 7-percent rate used in the baseline simulations.

For infrastructure improvements, including those that HERS and NBIAS consider, the normal sequence is for an initial period in which net benefits are negative, reflecting the costs of construction, followed by many years of positive net benefits, reflecting the benefits of improved infrastructure in place. Because the benefits from the use of the improved facilities materialize further in the future than the costs of construction, a reduction in the discount rate increases the weight attached to those benefits relative to the construction costs, resulting in a higher benefit-cost ratio. Moreover, with all potential projects now having a higher benefit-cost ratio, the indicated amount of investment will increase when the investment objective is to exhaust all opportunities for implementing cost-beneficial projects. Accordingly, *Exhibit 9-3* shows that in the Improve Conditions and Performance scenario, a reduction in the assumed annual discount rate from 7 percent to 3 percent increases the total level of investment by 28.2 percent, due almost entirely to an increase in the HERS component; the NBIAS component increases only slightly.

Exhibit 9-3: Impact of Alternative Discount Rate Assumption on Highway Investment Scenario Average Annual Investment Levels

Alternative Assumptions About Discount Rate	Maintain Conditions and Performance Scenario		Improve Conditions and Performance Scenario	
	Billions of 2014 Dollars	Percent Change From Baseline	Billions of 2014 Dollars	Percent Change From Baseline
Baseline[1] (7% discount rate)	**$102.4**		**$135.7**	
HERS-Derived Component	$59.5		$73.2	
NBIAS-Derived Component	$12.9		$22.7	
Other (Nonmodeled) Component	$30.0		$39.8	
Alternative (3% discount rate)	**$101.5**	**-0.9%**	**$174.0**	**28.2%**
HERS-Derived Component	$59.4	-0.2%	$99.9	36.4%
NBIAS-Derived Component	$12.3	-4.4%	$23.1	1.6%
Other (Nonmodeled) Component	$29.7	-0.9%	$51.0	28.2%

[1] The baseline levels shown correspond to the systemwide scenarios presented in Chapter 7. The investment levels shown are average annual values for the period from 2015 through 2034.

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

For the Maintain Conditions and Performance scenario, the reduction in the discount rate has more complex effects within the models. At any given level of HERS-related spending, the model determines that allocating a slightly higher share to system preservation projects would be cost-beneficial; this is because, in HERS, benefits arising relatively late in the project life cycle tend to be more important for system rehabilitation than for system expansion projects. Because the preservation share of spending increases, the $59.4 billion of spending from the baseline (7-percent discount rate) would more than suffice to maintain IRI at the base-year level. Thus, a reduction in the discount rate leads the model to marginally reduce spending in the Maintain Conditions and Performance scenario.

The NBIAS-derived component of spending in the Maintain Conditions and Performance scenario is somewhat more sensitive to the discount rate. Reducing the discount rate from 7 percent to 3 percent causes this component to decrease by 4.4 percent.

Traffic Growth Projections

For each of 100,000+ sections of highway in its sample, the Highway Performance Monitoring System (HPMS) requires from States an estimate of traffic volume in the base year and a forecast of traffic volume in a subsequent year, typically 20 years after the base year. The section-specificity of the forecasts allows States to factor in local conditions, constituting an advantage for their use in HERS, which evaluates highway improvement options section-by-section. In the C&P Report editions from 1995 (the first to use HERS) through 2010, the HERS simulations relied exclusively on these HPMS forecasts to project future traffic. The disadvantages to this approach have been: (a) the ambiguity as to how the forecasts are derived, which makes it difficult to evaluate them and to judge how to incorporate them within HERS; and (b) the apparent slowness of the States to factor into their forecasts recent changes in the trend rate of national VMT growth (as discussed in the 2015 C&P Report, Chapter 9).

In light of these concerns, C&P Report editions from 1999 onward have included simulations that used alternatives to the HPMS forecasts. Before the 2015 edition, FHWA would first compute the average annual rate of national VMT growth implied by the HPMS forecasts, and then select one or two alternative values for this growth rate that seemed plausible based on recent trends in VMT, population forecasts, or other factors;

these alternative values were not obtained, however, through formal modeling. Next, the HPMS section-level forecasts were adjusted upward or downward proportionally, as needed to conform to the alternative value for nationwide VMT growth.

Originally, the C&P Reports presented the estimates of investment needs based on the alternative forecasts as sensitivity tests, and the estimates based solely on the HPMS forecasts as the primary findings. The 2013 edition, in contrast, gave these estimates equal importance, presenting them as pertaining to high and low traffic growth scenarios. The HPMS forecasts used in that edition implied national VMT growth rate averaging 1.85 percent, whereas the recent trend rate of national growth VMT growth, used for the low growth scenario, was 1.36 percent.

The 2015 edition of the C&P Report further de-emphasized the national VMT growth implied by the HPMS-based forecasts by using it for sensitivity testing only, and basing the primary modeling results on an alternative forecast. In contrast with the more subjective selection of alternative forecasts in earlier editions, the 2015 edition relied on the model-based forecasts in the *FHWA National Vehicle Miles Traveled Projection*, which was first released in May 2014. The Volpe National Transportation Systems Center developed the supporting model, which forecasts future changes in passenger and freight VMT based on predicted changes in demographic and economic conditions. Built on economic theory, the national total VMT model establishes a separate but structurally similar econometric model for each of three vehicle categories—light-duty vehicles, single-unit trucks, and combination trucks—using time series data beginning in the 1960s. These econometric models include underlying factors that strongly influence user demand for travel, such as demographic characteristics, economic activity, employment, cost of driving, road miles, and transit service availability. Documentation for the supporting model is posted at (http://www.fhwa.dot.gov/policyinformation/tables/vmt/vmt_model_dev.cfm).

The HERS and NBIAS analyses presented elsewhere in this C&P Report source their national-level forecasts of VMT exclusively from the May 2017 release of the *FHWA National Vehicle Miles Traveled Projection*. For all vehicle types, this release forecasts that VMT growth will average 1.07 percent annually over 20 years starting in 2015. HPMS section-level forecasts are scaled to this overall forecast. This results in an overall annual growth rate of 1.157% for rural HPMS sections and 1.014% for urban sections. When applied to 2014 levels of VMT, as has been done for this report's modeling, these growth rates imply that national VMT will total 3.76 trillion by 2034—up from 3.04 trillion in 2014—with 3.16 trillion occurring on Federal-aid highways. This result is shown in *Exhibit 9-4* together with corresponding VMT projections based on the section-level forecasts in the HPMS, which imply that VMT would grow between 2014 and 2034 at an average annual rate of 1.40 percent. At that growth rate, national VMT would grow to 4.01 trillion by 2034, with 3.37 trillion occurring on Federal-aid highways.

This report's modeling also uses the breakdown by vehicle category in the FHWA econometric forecasts. The National Bridge Inventory (NBI) includes State-supplied forecasts of traffic on each bridge, and the HPMS does likewise for each sampled highway section, but neither database disaggregates these forecasts by vehicle category. In this report, as in the 2015 edition, a scaling factor is applied for each vehicle category to produce forecasts that combine the strength of the HPMS and NBI forecasts (section- and bridge-level specificity that captures differences in growth prospects caused by local factors) with the strengths of the FHWA econometric forecasts (greater rigor and transparency, and breakdowns by vehicle category).

Exhibit 9-4: Projected Average Percent Growth per Year in Vehicle Miles Traveled by Vehicle Class, 2015–2034

Vehicle Class	Baseline Growth Rate	Basis	Low-Growth Growth Rate	Basis	High-Growth Growth Rate	Basis
Passenger Vehicles	1.01%	May 2017 Econometric Model Forecast	0.81%	May 2016 Econometric Model Forecast	1.40%	HPMS Section-level Traffic Projections, Aggregated
Single-Unit Trucks	1.72%	May 2017 Econometric Model Forecast	1.73%	May 2016 Econometric Model Forecast	1.40%	HPMS Section-level Traffic Projections, Aggregated
Combination Trucks	1.46%	May 2017 Econometric Model Forecast	2.08%	May 2016 Econometric Model Forecast	1.40%	HPMS Section-level Traffic Projections, Aggregated
All Vehicles	1.07%	May 2017 Econometric Model Forecast	0.92%	May 2016 Econometric Model Forecast	1.40%	HPMS Section-level Traffic Projections, Aggregated

Sources: FHWA National Vehicle Miles Traveled Projection; Highway Performance Monitoring System.

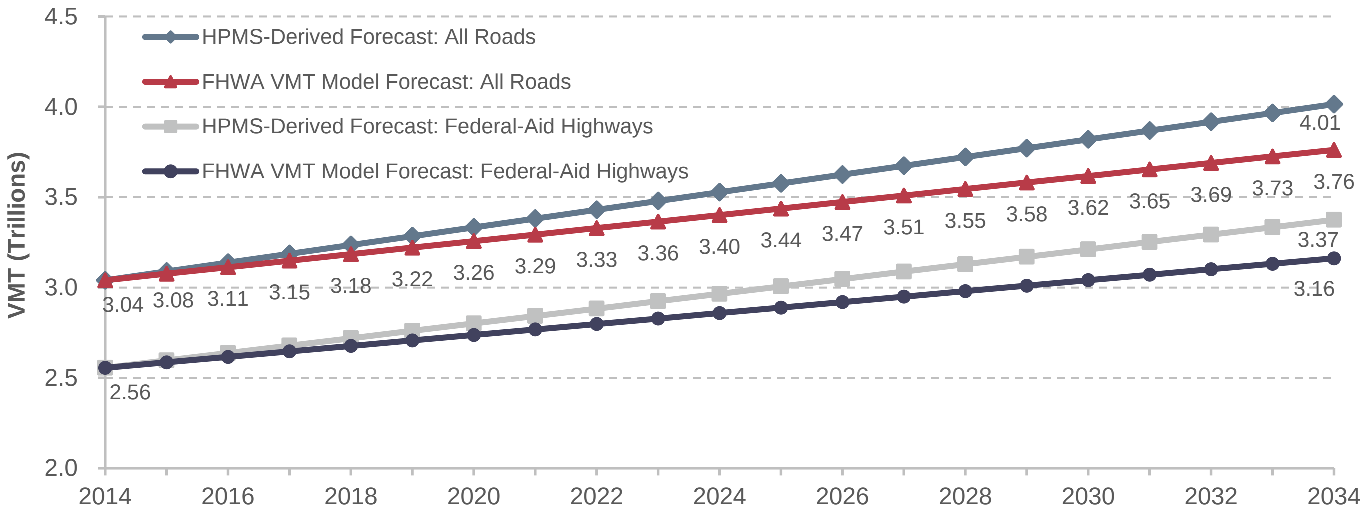
Sensitivity Analysis

Exhibit 9-5 compares this report's baseline assumptions about VMT growth with alternative assumptions used in the sensitivity tests that follow. The average growth rates over 2015–2034 in the set of "low-growth" forecasts are the baseline forecasts from the May 2016 release of the *FHWA National Vehicle Miles Traveled Projection*. These are lower than the baseline forecasts in the May 2017 release, which are used as the baseline forecasts in this C&P Report, because of revisions to the methodology and the incorporation of additional data. For vehicles combined, the change was from 0.92 percent in the 2016 release to 1.07 percent in the 2017 release. In both sets of forecasts, average annual traffic growth is considerably higher for trucks than for passenger vehicles—in the baseline, 1.72 percent for single-unit trucks and 1.46 percent for combination trucks, versus 1.01 percent for passenger vehicles.

The "high-growth" sensitivity test simply uses the traffic forecasts in the HPMS and NBI without adjustment. These imply an average annual VMT growth rate of 1.40 percent on highways and only slightly higher for bridges (*Exhibit 9-6*). Because neither of these databases forecast traffic by vehicle category, the assumed growth rate is the same across all three categories.

In the Improve Conditions and Performance scenario, replacing the baseline traffic growth assumptions with the low-growth assumptions reduces by 4.0 percent the HERS component of the estimated investment level needed to achieve the scenario's objective of funding all cost-beneficial improvements (*Exhibit 9-6*). The modest magnitude of this reduction reflects partly that the difference in the annual growth rates is relatively small (0.15 percent per year). Another factor is that while the low-growth case features lower traffic growth for passenger vehicles and for all vehicle categories combined, it assumes significantly higher growth for combination trucks, which generate much of the need for pavement preservation spending because of heavy axle loads. For all investment components of the Improve Conditions and Performance scenario, the change from baseline to low traffic growth assumptions reduces the estimated investment requirement by a still more modest 3.4 percent; this is because the impact on the NBIAS component is only a 1.4-percent reduction. For the Maintain Conditions and Performance scenario, this same sensitivity test has even less effect on the required investment level: a 1.4-percent reduction for all components of investment.

Exhibit 9-5: Annual Projected Highway VMT Based on HPMS-Derived Forecasts or FHWA VMT Forecast Model



Sources: Highway Performance Monitoring System; FHWA Forecasts of Vehicle Miles Traveled (VMT), May 2017.

Exhibit 9-6: Impact of Alternative Travel Growth Forecasts on Highway Investment Scenario Average Annual Investment Levels

Alternative Assumptions About Future Annual VMT Growth[1]	Maintain Conditions and Performance Scenario		Improve Conditions and Performance Scenario	
	Billions of 2014 Dollars	Percent Change From Baseline	Billions of 2014 Dollars	Percent Change From Baseline
Baseline[2] (Tied to May 2017 Forecast—1.07% per year)	**$102.4**		**$135.7**	
HERS-Derived Component	$59.5		$73.2	
NBIAS-Derived Component	$12.9		$22.7	
Other (Nonmodeled) Component	$30.0		$39.8	
Lower (Tied to May 2016 Forecast—0.92% per year)	**$100.9**	**-1.4%**	**$131.1**	**-3.4%**
HERS-Derived Component	$58.5	-1.7%	$70.3	-4.0%
NBIAS-Derived Component	$12.9	-0.2%	$22.4	-1.4%
Other (Nonmodeled) Component	$29.6	-1.4%	$38.4	-3.4%
Higher (Tied to State Forecasts—HPMS at 1.40% per year; NBI at 1.45% per year)	**$112.1**	**9.5%**	**$148.8**	**9.6%**
HERS-Derived Component	$66.1	11.1%	$81.5	11.3%
NBIAS-Derived Component	$13.1	1.9%	$23.7	4.4%
Other (Nonmodeled) Component	$32.8	9.5%	$43.6	9.6%

[1] The VMT growth rates identified represent the forecasts entered into the HERS and NBIAS models. The travel demand elasticity features in HERS modify these forecasts in response to changes in highway user costs resulting from future highway investment.

[2] The baseline levels shown correspond to the systemwide scenarios presented in Chapter 7. The investment levels shown are average annual values for the period from 2015 through 2034.

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

Replacing the baseline traffic growth assumptions with the high-growth assumptions has much larger effects on the estimated investment requirements, consistent with the change in the annual growth rate (0.33 percent per year) being much larger. The resulting increase in the estimated investment requirement is 9.6 percent in the Improve Conditions and Performance scenarios and virtually the same in the Maintain Conditions and Performance scenario. The percentage effect is again considerably larger for the HERS component of the investment requirement than for the NBIAS component.

Transit Sensitivity Analysis

This section examines the sensitivity of estimated transit investment needs, as produced by the Transit Economic Requirements Model (TERM), to variations in key inputs, including:

- asset replacement timing (condition threshold),
- capital costs,
- value of time, and
- discount rate.

The alternative projections presented in this chapter assess how the estimates of baseline investment needs for the State of Good Repair (SGR) benchmark and the Low-Growth and High-Growth scenarios discussed in Chapter 7 vary in response to changes in the assumed values of the input variables listed above. Note that, by definition, funding under the Sustain 2014 Expenditure scenario does not vary with changes in any input variable, and thus this scenario is not considered in this sensitivity analysis.

Key Takeaways

- Changes in Replacement Thresholds: TERM is very sensitive to changes in replacement thresholds. A 0.5 point change in the condition scale results in roughly ± 30 percent in replacement needs.
- Change in Capital Costs:
  - SGR (no benefit-cost analysis test): The change in capital costs for preservation costs is comparable to the change in replacement investment costs.
  - High- and Low-Growth scenarios (applies BCA test): a 25% increase in capital cost results in 18-25% increase in investment costs.
- Value of Time for Preservation Needs: Low sensitivity to variations in value of time. Doubling the value of time cost (from $12.80 to $25.60) increases investment costs by 5-6%.
- Discount Rate: Changes in the discount rate from 7% to 3% leads to an increase of 4% in investment levels.

Changes in Asset Replacement Timing (Condition Threshold)

Each of the four investment scenarios examined in Chapter 7 assumes that assets are replaced at condition rating 2.50 as determined by TERM's asset condition decay curves (in this context, 2.50 is referred to as the "replacement condition threshold"). TERM's condition rating scale runs from 5.0 for assets in "excellent" condition through 1.0 for assets in "poor" condition. In practice, this assumption implies replacement of assets within a short period (e.g., roughly 1 to 5 years, depending on asset type) of their having attained their expected useful lives. Replacement at condition 2.50 can therefore be thought of as providing a replacement schedule that is both realistic and potentially conservative. This replacement schedule is realistic because, in practice, few assets are replaced exactly at their expected useful life value due to many factors, including the time to plan, fund, and procure asset replacement, and whether the assets are replaceable or not. A nonreplaceable asset is subjected only to maintenance activities, which generally accounts for a small share of its total replacement cost (see Box "How does TERM Handle Non-Replaceable Assets?" in Chapter 6). Its decay continues past the 2.50 replacement threshold. Examples of nonreplaceable assets include assets with long useful lives such as bridges, stations, tunnels, and other long-lived assets. It is a potentially conservative schedule because the needs estimates would be higher if all assets were to be replaced at precisely the end of their expected useful lives, and if nonreplaceable assets were replaceable.

Exhibit 9-7 shows the effect of varying the replacement condition threshold by increments of 0.25 on TERM's projected asset preservation needs for the SGR benchmark and the Low-Growth and High-Growth scenarios. Note that selection of a higher replacement condition threshold results in assets being replaced while in better condition (i.e., at an earlier age). This, in turn, reduces the length of each asset's service life, thus increasing the number of replacements over any given period of analysis and driving up scenario costs. Reducing the replacement condition threshold would have the opposite effect. As shown in *Exhibit 9-7*, each of these three scenarios shows significant changes to total estimated preservation needs from quarter-point changes in the replacement condition threshold. Relatively small changes in the replacement condition threshold frequently translate into significant changes in the expected useful life of some asset types; hence, small changes can also drive significant changes in replacement timing and replacement costs.

Exhibit 9-7: Impact of Alternative Replacement Condition Thresholds on Transit Preservation Investment Needs by Scenario (Excludes Expansion Impacts)

	SGR Benchmark		Low Growth Scenario		High Growth Scenario	
Replacement Condition Thresholds	**Billions of 2014 Dollars**	**Percent Change From Baseline**	**Billions of 2014 Dollars**	**Percent Change From Baseline**	**Billions of 2014 Dollars**	**Percent Change From Baseline**
Very Late Asset Replacement (2.00)	$12.1	-29%	$11.5	-34%	$11.5	-34%
Replace Assets Later (2.25)	$14.8	-13%	$14.0	-19%	$14.1	-19%
Baseline (2.50)	$17.0		$17.4		$17.5	
Replace Assets Earlier (2.75)	$21.7	27%	$20.4	18%	$20.6	18%
Very Early Asset Replacement (3.00)	$23.8	40%	$22.3	28%	$22.6	29%

Source: Transit Economic Requirements Model.

Changes in Capital Costs

The asset costs used in TERM are based on actual prices paid by agencies for capital purchases as reported to the Federal Transit Administration (FTA) in the Transit Award Management System and in special surveys. Asset prices in the current version of TERM have been converted from the dollar-year replacement costs in which assets were reported to FTA by local agencies (which vary by agency and asset) to 2014 dollars using the RSMeans construction cost index. Given the uncertain nature of capital costs, a sensitivity analysis has been performed to examine the effect that higher capital costs would have on the dollar value of TERM's baseline projected transit investment.

As *Exhibit 9-8* shows, TERM projects that a 25-percent increase in capital costs (i.e., beyond the 2014 level used for this C&P Report) would be fully reflected in the SGR benchmark, but only partially realized under the Low-Growth or High-Growth scenarios. This difference in sensitivity results is driven by the fact that investments are not subject to TERM's benefit-cost test in computing the SGR benchmark (i.e., increasing costs have no consequences), whereas the two cost-constrained scenarios do employ this test. Hence, for the Low-Growth or High-Growth scenarios, any increase in capital costs (without a similar increase in the value of transit benefits) results in lower benefit-cost ratios and the failure of some investments to pass this test. Therefore, for these latter two scenarios, a 25-percent increase in capital costs would yield a roughly 18- to 20-percent increase in needs that pass TERM's benefit-cost test.

Exhibit 9-8: Impact of an Increase in Capital Costs on Transit Investment Estimates by Scenario

Capital Cost Increases	SGR Benchmark		Low Growth Scenario		High Growth Scenario	
	Billions of 2014 Dollars	Percent Change From Baseline	Billions of 2014 Dollars	Percent Change From Baseline	Billions of 2014 Dollars	Percent Change From Baseline
Baseline (No Change)	$17.1		$23.4		$25.5	
Increase Costs by 25%	$21.2	24%	$28.1	20%	$30.3	18%

Source: Transit Economic Requirements Model.

Changes in the Value of Time

The most significant source of transit investment benefits, as assessed by TERM's benefit-cost analysis, is the net cost savings to users of transit services, a key component of which is the value of travel time savings. Therefore, the per-hour value of travel time for transit riders is a key model input and a key driver of total investment benefits for those scenarios that use TERM's benefit-cost test. Readers interested in learning more about the measurement and use of the value of time for the BCAs performed by TERM, the Highway Economic Requirements System (HERS), and the National Bridge Investment Analysis System (NBIAS) should refer to the related discussion presented earlier in the highway section of this chapter.

For this C&P Report, the Low-Growth and High-Growth scenarios are the only scenarios with investment needs estimates that are sensitive to changes in the benefit-cost ratio. (Note that the Sustain 2014 Spending scenario uses TERM's estimated benefit-cost ratios to allocate fixed levels of funding to preferred investments, while the computation of the SGR benchmark does not.)

Exhibit 9-9 shows the effect of varying the value of time on the needs estimates of the Low-Growth and High-Growth scenarios. The baseline value of time for transit users in 2014 was $12.80 per hour, based on DOT guidance. TERM applies this amount to all in-vehicle travel, but then doubles it to $25.60 per hour when accounting for out-of-vehicle travel time, including time spent waiting at transit stops and stations (also consistent with DOT guidance).

Exhibit 9-9: Impact of Alternative Value of Time Rates on Transit Investment Estimates by Scenario

Changes in Value of Time	Low Growth Scenario		High Growth Scenario	
	Billions of 2014 Dollars	Percent Change From Baseline	Billions of 2014 Dollars	Percent Change From Baseline
Reduce by 50% ($6.4)	$21.0	-10%	$22.2	-13%
Baseline ($12.8)	$23.4		$25.5	
Increase by 100% ($25.6)	$24.5	5%	$27.1	6%

Source: Transit Economic Requirements Model.

Given that value of time is a key driver of total investment benefits, doubling or halving this variable leads to changes in investment ranging from an increase of roughly 5 percent to a decrease of nearly 10 percent. The High-Growth scenario appears to be more sensitive to the value of time than the Low-Growth scenario. This is because the High-Growth scenario is associated with higher investment levels than is the Low-Growth scenario, so any changes in the value of time will be magnified accordingly.

Changes to the Discount Rate

TERM's benefit-cost module uses a discount rate of 7.0 percent, in accordance with guidance provided in OMB Circular A-94. Readers interested in learning more about the selection and use of discount rates for the BCAs performed by TERM, HERS, and NBIAS should refer to the related discussion presented earlier in the highway section of this chapter. For this sensitivity analysis, and for consistency with the discussion above on HERS and NBIAS discount rate sensitivity, TERM's needs estimates for the Low-Growth and High-Growth scenarios were re-estimated using a 3-percent discount rate. The results of this analysis, presented in *Exhibit 9-10*, show that this lower discount rate leads to a range in total investment needs (or changes in the proportion of needs passing TERM's benefit-cost test) amounting to between a 4- and 5.6-percent increase.

Exhibit 9-10: Impact of Alternative Discount Rates on Transit Investment Estimates by Scenario

Discount Rates	Low Growth Scenario		High Growth Scenario	
	Billions of 2014 Dollars	Percent Change From Baseline	Billions of 2014 Dollars	Percent Change From Baseline
7.0% (Baseline)	$23.4		$25.5	
3.0%	$24.3	4%	$27.0	6%

Source: Transit Economic Requirements Model.

Under this sensitivity test, investment needs are usually higher for the lower (3 percent) discount rate compared with the higher base rate (7 percent). This means that use of the lower rate allows more investments to pass TERM's benefit-cost test. This situation is primarily the result of differences in the timing of the flows of benefits versus costs for the underlying scenario. Specifically, this test uses a fully (financially) unconstrained scenario that completely eliminates the large investment backlog at the start of the period of analysis and then invests incrementally as needed at a much lower rate to maintain this "state of good repair" for the remaining 20 years of analysis. In contrast, investment benefits tend to be more evenly distributed throughout the 20-year period of analysis. So, with a high proportion of costs concentrated very early in the period of analysis and evenly distributed benefits, the ratio of discounted benefits to discounted costs tends to decline as the discount rate increases.

CHAPTER 10

Impacts of Investment

Impacts of Highway Investments

The analyses presented in this section use a common set of assumptions to derive relationships between alternative levels of future highway capital investment and various measures of future highway and bridge conditions and performance. A subsequent section in this chapter provides comparable information for different types and levels of potential future transit investments.

This section examines the types of investment within the scopes of the Highway Economic Requirements System (HERS) and the National Bridge Investment Analysis System (NBIAS) and provides more context for the capital investment scenarios for highways presented in Chapter 7. The accuracy of projections for highway investments in this chapter depends on the validity of the technical assumptions underlying the analysis, some of which are explored in the sensitivity analysis in Chapter 9. The analyses presented in this section make no explicit assumptions regarding how future investment in highways could be funded.

Key Takeaways

- Due to the impact of travel demand elasticity procedures, the HERS model predicts an annual percentage change in VMT on Federal-aid Highways of 1.13 to 1.22 percent for the range of investment levels analyzed compared with the 1.07 percent assumed if user costs remain unchanged in the future.
- HERS finds it to be cost-beneficial to reduce the percentage of travel on pavements with poor ride quality, but not necessarily to reduce average pavement roughness. For the NHS and Interstate highways, average IRI would get worse even at the Improve Conditions and Performance scenario level.
- Unlike for bridges overall, or bridges on Federal-aid highways, NBIAS finds that sustaining spending at 2014 levels for NHS bridges and Interstate bridges would be insufficient to keep the deck area-weighted share of bridges in poor conditions from rising over time.

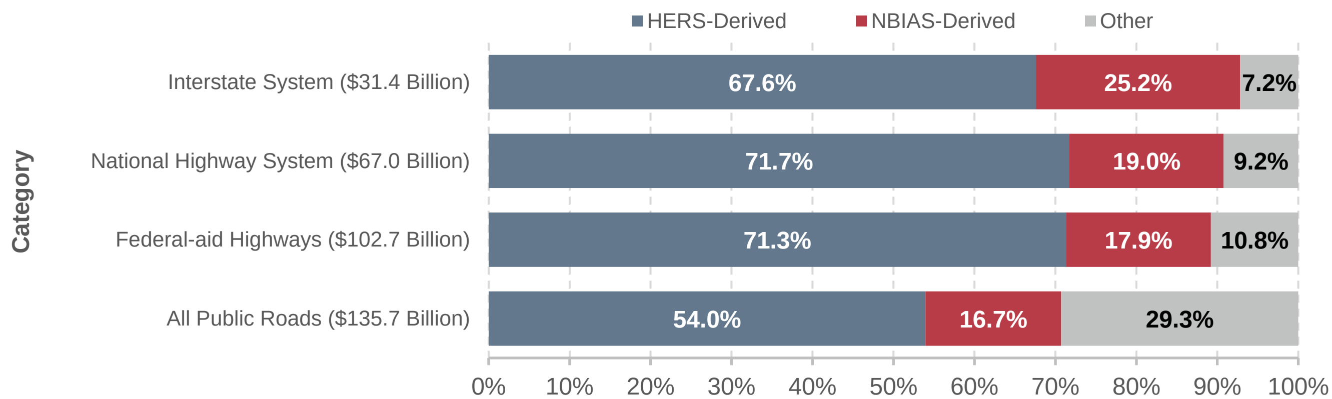
HERS, NBIAS, and Nonmodeled Inputs to the Improve Conditions and Performance Scenario

Exhibit 10-1 illustrates the derivation of the Improve Conditions and Performance scenario presented in Chapter 7. Of the $135.7 billion average annual investment level for all public roads under this scenario, 16.7 percent was derived from NBIAS (corresponding to the $22.7 billion identified as "System Rehabilitation – Bridge" in the "All Public Roads" row) and 54.0 percent was derived from HERS (corresponding to the $49.0 billion and $24.2 billion identified as "System Rehabilitation – Highways" and "System Expansion," respectively, in the "Federal-aid Highways" row). The remaining 29.3 percent was nonmodeled; this corresponds to the $18.3 billion identified as "System Enhancement" in the "All Public Roads" row plus the difference between the amounts shown in the "All Public Roads" and the "Federal-aid Highway" rows for "System Rehabilitation – Highways" ($16.7 billion, computed as $65.7 billion minus $49.0 billion) and "System Expansion" ($4.9 billion, computed as $29.1 billion minus $24.2 billion). Each of the nonmodeled input values was computed using scaling procedures so that its share of the total scenario investment level would match its share of actual 2014 spending.

Exhibit 10-1 also identifies the average annual investment levels resulting from applying the Improve Conditions and Performance scenario criteria to various system subsets including the Interstate Highway System ($31.4 billion), the National Highway System (NHS) ($67.0 billion, including the amount directed to Interstate highways), and Federal-aid Highways ($102.7 billion, including the amount directed to the NHS). The modeled share of investment on these systems is higher than for all public roads because HERS and NBIAS fully cover system rehabilitation and system expansion investments on these types of highways, and only system enhancement investment is outside the scope of the two models.

The average annual investment level for the Federal-aid highways is 71.3 percent HERS-derived, 17.9 percent NBIAS-derived, and 10.8 percent nonmodeled. The average annual investment level for the Federal-aid highways is 71.3 percent HERS-derived, 17.9 percent NBIAS-derived, and 10.8 percent nonmodeled. The share of spending by source of estimate for the NHS is similar to that for Federal-aid highways, but the Interstate distribution is somewhat different with 67.6 percent HERS-derived, 25.2 percent NBIAS-derived, and 7.2 percent nonmodeled.

Exhibit 10-1: Improve Conditions and Performance Scenario for 2015 Through 2034: Distribution by System, by Source of Estimate, and by Capital Improvement Type



System Component	System Rehabilitation			System Expansion	System Enhancement	Total	Percent of Total
	Highway	Bridge	Total				
Average Annual Investment in Billions of 2014 Dollars							
Interstate Highway System	$11.9	$7.9	$19.9	$9.3	$2.3	$31.4	23.2%
National Highway System	$29.6	$12.8	$42.3	$18.5	$6.2	$67.0	49.4%
Federal-aid Highways	$49.0	$18.4	$67.4	$24.2	$11.1	$102.7	75.7%
All Public Roads	$65.7	$22.7	$88.4	$29.1	$18.3	$135.7	100.0%

Note: The "NBIAS-Derived" share includes all outlays (values shown as red in the table) classified as "System Rehabilitation: Bridge." The "HERS-Derived" share includes most outlays (values shown as blue in the table) classified as "System Rehabilitation: Highway" and "System Expansion" except for the portions spent off of Federal-aid Highways, which are classified as "Other." The "Other" category also includes all outlays classified as "System Enhancement."

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

The top row in each table in *Exhibits 10-2* through *10-18* corresponds to values presented in *Exhibit 10-1* as HERS-derived or NBIAS-derived inputs to the Improve Conditions and Performance scenario presented in Chapter 7.

How were the investment levels presented in Exhibits 10-2 to 10-18 selected?

The particular investment levels shown in each exhibit were selected from the results of a much larger number of model simulations. All are meant to be illustrative; some were chosen to align with the scenarios presented in Chapter 7, but others were simply chosen to show a relatively even distribution of data points for the charts. There is no special significance to the lowest investment level shown in each table.

Most of the HERS and NBIAS analyses presented in this chapter assume a fixed amount of spending in constant dollars in each of the 20 years of the analysis period. However, the highest levels shown (the one or more shown above the bold horizontal line in the tables) are based on model runs constrained by a benefit-cost ratio.

Impacts of Federal-aid Highway Investments Modeled by HERS

The HERS analysis for this edition of the C&P Report starts with an evaluation of the state of Federal-aid highways in 2014—the base year. In the Introduction to Part II, *Exhibit II-1* shows that capital spending on the types of improvements modeled in HERS for these highways in the base year was $60.2 billion (total highway capital spending was $105.4 billion). The analysis continues by considering the potential impacts on system performance of raising or lowering the amount of investment within the scope of HERS over 20 years. Spending in any year is measured in constant 2014 (real) dollars, rather than nominal dollars.

Selection of Investment Levels for Analysis

Exhibit 10-2 introduces the nine investment levels presented in the next several exhibits to illuminate the relationship between the levels of investment modeled in HERS and the future conditions and performance of Federal-aid highways. The "Improve C&P" reference in the top row of *Exhibit 10-2* signifies that this level of investment feeds into the Improve Conditions and Performance scenario in Chapter 7, which is defined by attaining a minimum benefit-cost ratio (BCR) of 1.0 in each year over the 20-year analysis period. The remaining eight runs are funding-constrained, for which HERS ranks potential projects in order of BCR and implements them until the funding constraint is reached.

One funding level shown in *Exhibit 10-2* represents the spending level designed to match a specific level of performance in 2034; a spending level of $59.5 billion is projected to be adequate to allow average pavement roughness as measured by the International Roughness Index (IRI) in 2034 to match the level in 2014 (see discussion of IRI in Chapter 6) and for average delay to be at least as low in 2034 as it was in 2014. The "Maintain C&P" reference in *Exhibit 10-2* signifies that this level of investment feeds into the Maintain Conditions and Performance scenario presented in Chapter 7.

The "2014 Spending" reference in *Exhibit 10-2* signifies that this level of spending feeds into the Sustain 2014 Spending scenario presented in Chapter 7. The remaining six of the nine funding levels shown in *Exhibit 10-2* represent roughly $4.0 billion increases from $49.0 billion to $73.2 billion (Improve C&P).

The portion of each investment level that HERS directs to system rehabilitation versus system expansion is important, as these types of investments have varying degrees of influence on different performance measures. Investment in system rehabilitation (ranging from $34.3 billion to $49.0 billion across reported investment levels) tends to have a stronger influence on physical condition measures such as pavement ride quality.

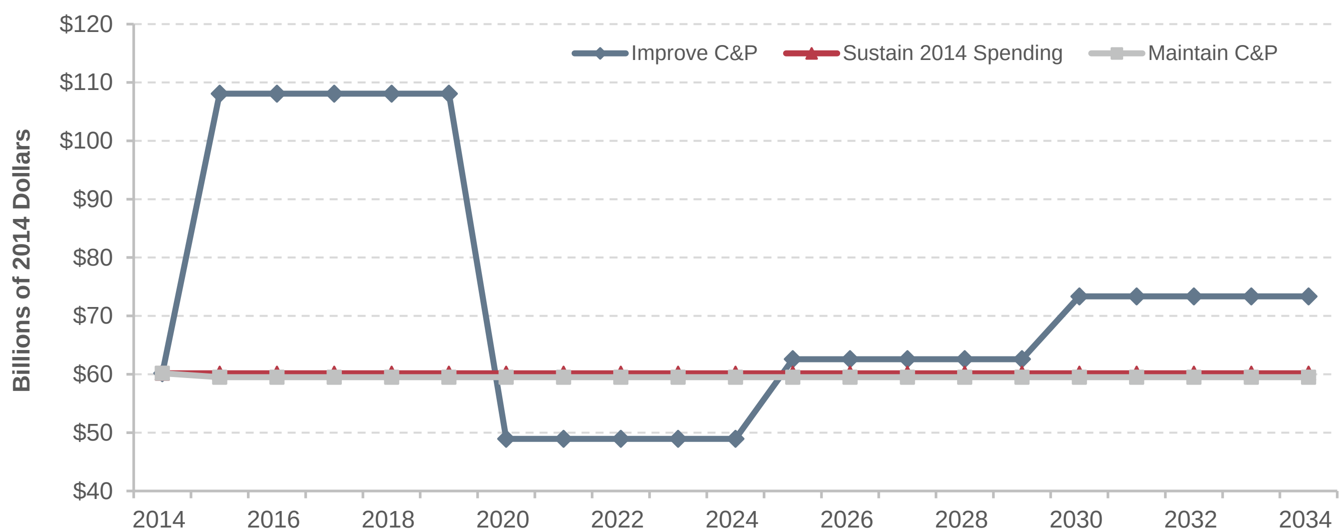
Investment in system expansion (ranging from $14.7 billion to $24.2 billion across reported investment levels) has a more pronounced impact on operational performance measures such as delay.

Investment Levels and BCRs by Funding Period

Exhibit 10-2 illustrates how the nine alternative funding levels for Federal-aid highways that were selected for further analysis in this chapter would translate into cumulative spending in 5-year intervals (corresponding to 5-year analysis periods used in HERS).

As shown in *Exhibit 10-2*, achieving a minimum BCR of 1.0 is estimated to require $1.465 trillion over the 20-year analysis period. This would necessitate an increase in spending of $262 billion over the analysis period relative to the $1.203 trillion 20-year cost of a scenario in which 2014 spending levels were sustained from 2014 through 2034.

Exhibit 10-2: HERS Annual Investment Levels Analyzed for Federal-aid Highways



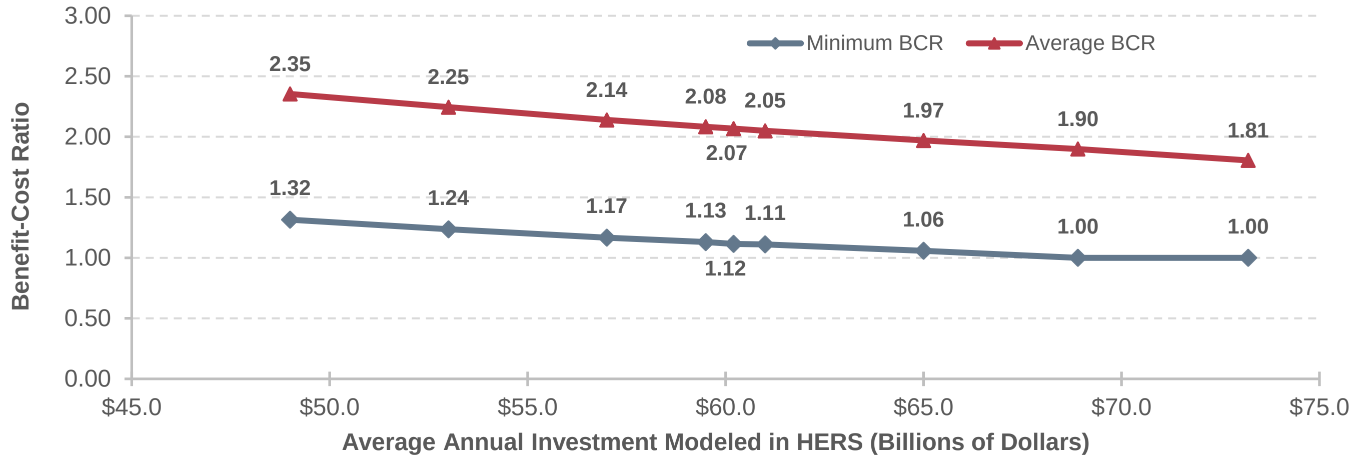
Spending Modeled in HERS (Billions of 2014 Dollars)								Link to Chapter 7 Scenario
Average Annual Over 20 Years			Cumulative					
Total HERS Spending	System Rehabilitation Spending[1]	System Expansions Spending[1]	5-Year 2013 Through 2017	5-Year 2018 Through 2022	5-Year 2023 Through 2027	5-Year 2028 Through 2032	20-Year 2013 Through 2032	
$73.2	$49.0	$24.2	$540	$245	$313	$367	$1,465	Improve C&P
$68.9	$46.4	$22.5	$344	$345	$344	$345	$1,378	
$65.0	$44.1	$20.9	$325	$325	$325	$325	$1,300	
$61.0	$41.9	$19.1	$305	$305	$305	$305	$1,220	
$60.2	$41.5	$18.7	$301	$301	$301	$301	$1,203	2014 Spending
$59.5	$41.0	$18.5	$297	$297	$297	$297	$1,190	Maintain C&P
$57.0	$39.4	$17.6	$285	$285	$285	$285	$1,140	
$53.0	$37.0	$16.0	$265	$265	$265	$265	$1,060	
$49.0	$34.3	$14.7	$245	$245	$245	$245	$980	

[1] HERS splits its available budget between system rehabilitation and system expansion based on the mix of spending it finds to be most cost-beneficial, which varies by funding level.

Source: Highway Economic Requirements System.

Exhibit 10-3 illustrates the marginal BCRs (i.e., the lowest BCR among the improvements selected within a funding period) associated with the nine alternative funding levels. *Exhibit 10-3* also provides the minimum BCRs across all funding periods (which is identical to the lowest marginal BCR) and the average BCRs across all funding periods (i.e., the total level of benefits of all improvements divided by the total cost of all improvements). The marginal BCRs for the top row are all 1.00, as this analysis allowed spending levels to vary by funding period specifically to result in this outcome.

Exhibit 10-3: Minimum and Average Benefit-Cost Ratios (BCRs) for Different Possible Funding Levels on Federal-aid Highways



HERS-Modeled Investment on Federal-Aid Highways Average Annual Investment (Billions of 2014 Dollars)	Benefit-Cost Ratios[1]						Link to Chapter 7 Scenario
		Marginal BCR[2]					
	Average BCR 20-Year 2015 Through 2034	5-Year 2015 Through 2019	5-Year 2020 Through 2024	5-Year 2025 Through 2029	5-Year 2030 Through 2034	Minimum BCR 20-Year 2015 Through 2034	
$73.2	1.81	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**Improve C&P**
$68.9	1.90	1.36	1.08	**1.00**	1.01	**1.00**	
$65.0	1.97	1.41	1.13	**1.06**	1.06	**1.06**	
$61.0	2.05	1.46	1.18	**1.11**	1.11	**1.11**	
$60.2	2.07	1.47	1.19	**1.12**	1.12	**1.12**	2014 Spending
$59.5	2.08	1.48	1.20	**1.13**	1.13	**1.13**	Maintain C&P
$57.0	2.14	1.52	1.24	**1.17**	1.18	**1.17**	
$53.0	2.25	1.59	1.31	**1.24**	1.25	**1.24**	
$49.0	2.35	1.68	1.38	**1.32**	1.33	**1.32**	

[1] As HERS ranks potential improvements by their estimated BCRs and assumes that the improvements with the highest BCRs will be implemented first (up until the point where the available budget specified is exhausted), the minimum and average BCRs will naturally tend to decline as the level of investment analyzed rises.

[2] The marginal BCR represents the lowest benefit-cost ratio for any project implemented during the period identified at the level of funding shown. The minimum BCRs, indicated by bold font, are the smallest of the marginal BCRs across the funding periods.

Source: Highway Economic Requirements System.

For the analyses assuming fixed levels of spending each year, the marginal BCR is highest in the first funding period and then declines over time, reflecting the tendency in HERS to implement the most worthwhile improvements first. However, by the fourth funding period the marginal BCRs begin to creep back up slightly (not evident in all rows due to rounding), so that the minimum BCR over the entire 20-year analysis period equals the marginal BCR in the third 5-year period. This pattern reflects the impacts of funding constraints; the relative scarcity of funding toward the end of the analysis period is inadequate to keep pace with newly emerging needs, limiting the range of needs that can be addressed.

Further evident in *Exhibit 10-3* is the inverse relationship between the minimum BCR and the level of investment. At any given level of average annual investment, the average BCR always exceeds the marginal BCR. For example, at the highest level of investment considered, an average annual investment level of $73.2 billion, the average BCR of 1.81 exceeds the minimum BCR of 1.00.

Impact of Future Investment on Highway Pavement Ride Quality

For all investment levels above Maintain C&P presented in *Exhibit 10-4*, pavements on Federal-aid highways are projected to be smoother on average in 2034 than in 2014. For the $59.5 billion average annual HERS investment level associated with the Maintain C&P scenario, pavements on Federal-aid highways are projected to be as smooth on average in 2034 as they were in 2014, while for the lower investment levels ($57.0 billion and lower) Federal-aid highways are projected to have higher average IRI in 2034 than in 2014. VMT-weighted average IRI decreases by up to 13.2 percent across alternatives (from 124.0 to 110.8), from an investment level that increases average IRI by 5.6 percent to the top-line investment level that reduces average IRI by 5.6 percent.

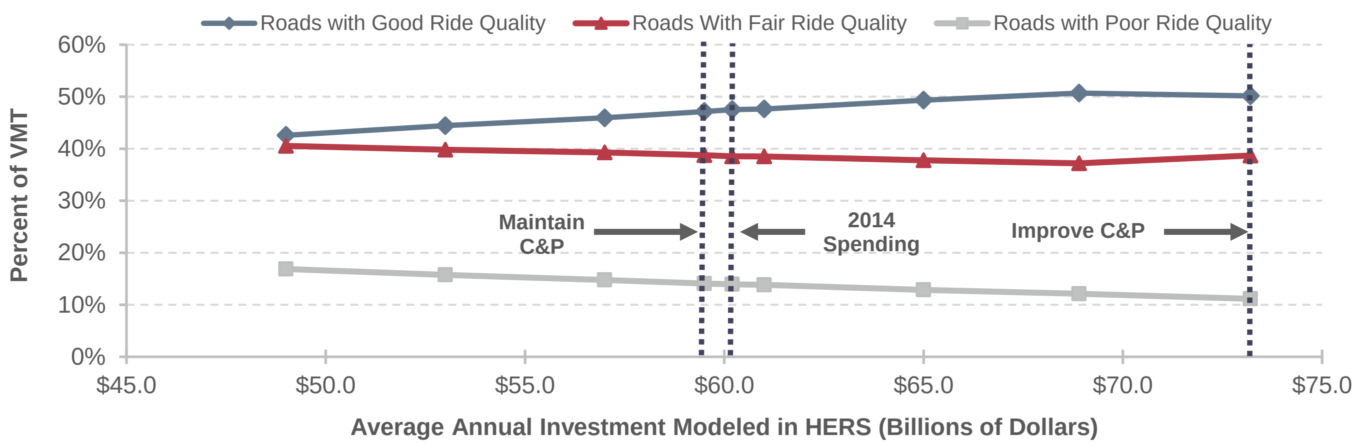
Exhibit 10-4 also shows the HERS projections for the percentage of travel occurring on pavements with ride quality that would be rated “good,” “fair,” and “poor” based on the IRI thresholds described in Chapter 6. Under all circumstances represented in the exhibit, the 2034 projection for the percentage of travel occurring on pavements with “poor” ride quality is lower than the 17.3 percent that occurred in 2014, as the model identifies significant user benefits that can be obtained by addressing pavement deficiencies. Among the rows depicting analyses with fixed annual investment levels, the improvement in the share of travel on pavements with “good” ride quality increases roughly linearly with spending, while the share of travel on roads with “fair” ride quality decrease roughly linearly with spending.

The projections for the percentage of VMT with “good” ride quality for 2034 range from 50.7 percent at the second-highest level of average annual investment modeled (an average annual investment for system rehabilitation of $46.4 billion) to 42.6 percent at the lowest level of investment (an average annual investment for system rehabilitation of $34.3 billion).

Relative to the second row, the top row of *Exhibit 10-4* shows a slightly lower percentage of VMT on pavements with good ride quality (50.2 percent versus 50.7 percent) and a slightly higher share of VMT on pavements with fair ride quality (38.7 percent versus 37.2 percent). This result is an artifact of the relatively front-loaded investment pattern associated with the minimum-BCR-driven analysis reflected in the top row: some of the pavements improved in the surge of investment in the first funding period would have declined to fair condition by 2034, but would not yet warrant additional corrective actions. Looking over the full 20-year analysis period rather than just a single point in time (2034), the average percentage of pavements with good ride quality would be highest for the average annual investment level for system rehabilitation of $49.0 billion identified in the top row.

As noted in Chapter 6, the IRI threshold of 170 used to identify fair ride quality was originally set to measure performance on the NHS and may not be fully applicable to non-NHS routes, which tend to have lower travel volumes and speeds. This helps to explain why the percentage of VMT on roads with poor ride quality falls no lower than 11.2 percent, even when all cost-beneficial improvements are implemented. In some cases, the benefits of potential pavement improvements may not exceed their costs until the IRI has increased to a level well higher than the threshold of 170.

Exhibit 10-4: Projected Impact of Alternative Investment Levels on 2034 Pavement Ride Quality Indicators for Federal-aid Highways



HERS-Modeled Capital Investment Average Annual Spending (Billions of 2014 Dollars)		Projected 2034 Condition Measures on Federal-aid Highways[1,2]					Link to Chapter 7 Scenario
		Percent of VMT on Roads With Ride Quality of:			Average IRI (VMT-Weighted)		
Total	System Rehabilitation[2]	Good (IRI<95)[3]	Fair (IRI 95 to 170)	Poor (IRI>170)[3]	Inches Per Mile	Change Relative to Base Year	
$73.2	$49.0	50.2%	38.7%	11.2%	110.8	-5.6%	Improve C&P
$68.9	$46.4	50.7%	37.2%	12.1%	112.4	-4.3%	
$65.0	$44.1	49.3%	37.8%	12.9%	114.3	-2.6%	
$61.0	$41.9	47.6%	38.5%	13.8%	116.6	-0.7%	
$60.2	$41.5	47.5%	38.5%	13.9%	117.0	-0.3%	2014 Spending
$59.5	$41.0	47.2%	38.8%	14.1%	117.4	**0.0%**	**Maintain C&P**
$57.0	$39.4	45.9%	39.3%	14.8%	119.0	1.4%	
$53.0	$37.0	44.4%	39.8%	15.8%	121.4	3.4%	
$49.0	$34.3	42.6%	40.5%	16.9%	124.0	5.6%	
Base Year Values:		**47.0%**	**35.7%**	**17.3%**	**117.4**		

[1] The HERS model relies on information from the HPMS sample section database, which is limited to those portions of the road network that are generally eligible for Federal funding (i.e., “Federal-aid highways”) and excludes roads classified as rural minor collectors, rural local, and urban local.

[2] The system rehabilitation component of HERS-modeled spending would likely have a greater impact on the performance indicators in this exhibit than would the system expansion component that is also reflected in the total.

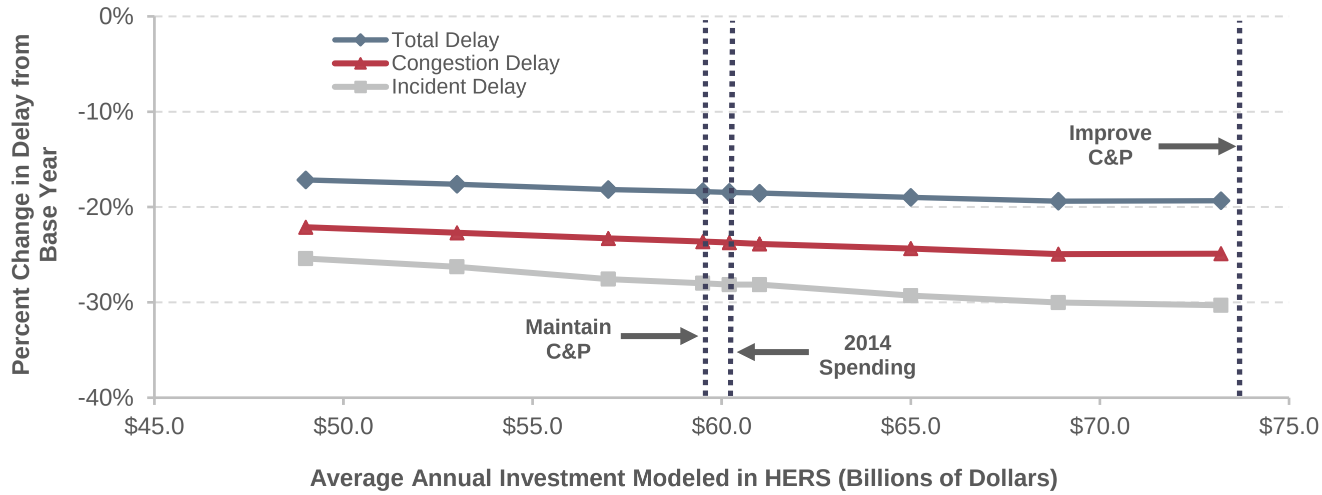
[3] As discussed in Chapter 6, IRI values of 95 through 170 inches per mile are classified as “fair,” lower IRI values are classified as “good,” and higher IRI values are classified as “poor.”

Source: Highway Economic Requirements System.

Impact of Future Investment on Highway Operational Performance

Exhibit 10-5 shows the HERS projections for the impact of investment levels on average speed and traveler delay. *Exhibit 10-5* splits out the portion of the investment that HERS allocates for system expansion (such as widening existing highways or building new routes in existing corridors), which tends to reduce congestion delay more than spending on system rehabilitation. The tabular portion of the exhibit shows that the levels of system expansion analyzed range from an average annual investment of $14.7 billion (which feeds the Maintain Conditions and Performance scenario in Chapter 7) to an average annual investment of $24.2 billion (which feeds the Improve Conditions and Performance scenario in Chapter 7). The graph is plotted based on total average annual investment modeled in HERS, including spending on both system rehabilitation and system expansion.

Exhibit 10-5: Projected Impact of Alternative Investment Levels on 2034 Highway Travel Delay and Speed on Federal-aid Highways



HERS-Modeled Capital Investment Average Annual Spending (Billions of 2014 Dollars)		Projected 2034 Performance Measures on Federal-aid Highways					Link to Chapter 7 Scenario
		Average Speed in 2034 (mph)	Annual Hours of Delay per Vehicle[2]	Percent Change Relative to Baseline			
Total	System Expansion[1]			Total Delay per VMT	Congestion Delay per VMT	Incident Delay per VMT	
$73.2	$24.2	45.2	37.8	-19.3%	-24.9%	-30.3%	Improve C&P
$68.9	$22.5	45.2	37.8	-19.4%	-24.9%	-30.0%	
$65.0	$20.9	45.2	38.0	-19.0%	-24.4%	-29.3%	
$61.0	$19.1	45.1	38.2	-18.5%	-23.9%	-28.1%	
$60.2	$18.7	45.1	38.2	-18.5%	-23.7%	-28.1%	2014 Spending
$59.5	$18.5	45.1	38.3	-18.4%	-23.6%	-28.0%	Maintain C&P
$57.0	$17.6	45.1	38.4	-18.2%	-23.3%	-27.6%	
$53.0	$16.0	45.0	38.6	-17.6%	-22.7%	-26.3%	
$49.0	$14.7	45.0	38.8	-17.2%	-22.1%	-25.4%	
Base Year Values:		**43.1**	**46.9**				

[1] The system expansion component of HERS-modeled spending would likely have a greater impact on the performance indicators in this exhibit than would the system rehabilitation component that is also reflected in the total.

[2] The values shown were computed by multiplying HERS estimates of average delay per VMT by 11,742, the average VMT per registered vehicle in 2014. HERS does not forecast changes in VMT per vehicle over time. The HERS delay figures include delay attributable to stop signs and signals as well as delay resulting from congestion and incidents.

Source: Highway Economic Requirements System; Highway Statistics 2015, Table VM-1.

The results in *Exhibit 10-5* reveal investment within the scope of HERS to be a potent instrument for reducing congestion delay. HERS projects congestion delay to decrease by between 22.1 percent and 24.9 percent between 2014 and 2034.

Across all scenarios presented in *Exhibit 10-5*, annual delay per vehicle in 2034 is lower than the 2014 level (46.9 hours), with reductions in delay ranging narrowly from 8.1 hours in the lowest level of investment analyzed to 9.1 hours in the highest. The projected increases in average vehicle speed are similarly narrow, ranging from 45.0 miles per hour to 45.2 miles per hour, compared with the 2014 level of 43.1 miles per hour.

Some traffic basics are important to keep in mind when interpreting these results. In addition to congestion and incident delay, some delay inevitably results from traffic control devices. For this reason, and because traffic congestion occurs only at certain places and times, *Exhibit 10-5* shows the variation in investment levels as having less impact on projections for total delay and average speed than on the projections for congestion and incident delay. In addition, although the impacts of additional investment on average speed are proportionally small, these impacts apply to a vast amount of travel; hence, the associated savings in user cost are not necessarily small relative to the cost of the investment.

Impact of Future Investment on Highway User Costs

In HERS, the benefits from highway improvements are measured as reductions in highway user costs, agency costs, and societal costs of vehicle emissions. In measuring the highway user costs, the model includes the costs of travel time, vehicle operation, and crashes.

Exhibit 10-6 shows the projected changes from 2014 in average user cost of travel on Federal-aid highways by cost component. For Federal-aid highways, HERS estimates that user costs—the costs of travel time, vehicle operation, and crashes—averaged $1.262 per mile traveled in 2014.

Average user cost per VMT is projected to increase from the 2014 values by 3.7 percent at the lowest level of spending ($49.0 billion) to 2.7 percent at the highest level of spending ($73.2 billion, which feeds the Improve Conditions and Performance scenario in Chapter 7). The cost of crashes is the user cost component with the lowest absolute sensitivity to the assumed level of highway investment. Crash costs in 2034 are projected to be between 0.7 percent and 1.0 percent lower than in 2014.

What are the monetized national-level impacts implied by the changes in average user costs projected by HERS?

Exhibit 10-6 presents measures of average user costs per VMT, rather than projections of aggregate, national-level user costs. User costs comprise the costs of travel time, vehicle operation (fuel, maintenance & repairs, etc.), and crashes for all vehicle occupants (highway “users”). To identify monetized impacts of changes in investment levels on national-level user costs, national VMT in 2034 can be multiplied by differences in average user costs across investment levels. At the highest level of investment (an annual average of $73.2 billion), average total user costs are projected to be $1.296 per VMT. Average total user costs at the highest level of investment represent decreases in average total user costs of $0.006 per VMT when spending is held at the base-year level ($60.2 billion per year) and $0.013 per VMT at the lowest level of investment (an annual average of $49.0 billion).

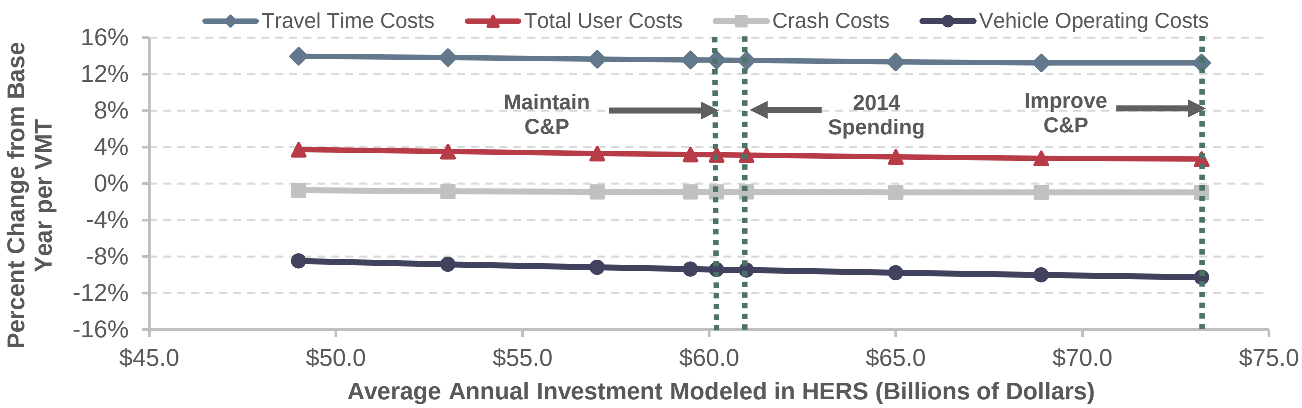
Investing at the highest level is projected to result in a decrease in total user costs in 2034 of $44.2 billion relative to the lowest level of investment ($49.0 billion per year) analyzed. Investing at the highest level is projected to result in a decrease in total user costs in 2034 of $20.4 billion relative to investing at the base-year level.

Approximately half the projected national-level impacts on average user costs can be attributed to impacts on vehicle operating costs. At the highest investment level, average vehicle operating costs per VMT in 2034 are projected to be $0.008 lower than under the lowest investment level and $0.004 lower than when spending is held at the base-year level. Investing at the highest level is projected to result in a decrease in total vehicle operating costs in 2034 of $25.3 billion relative to the lowest level of investment, based on projected VMT for the lowest investment level in 2034. Investing at the highest level is projected to result in a decrease in total vehicle operating costs in 2034 of $12.7 billion relative to investing at the base-year level, based on projected VMT for the lowest investment level in 2034.

The levels of spending in each scenario are limited to the types of improvements that HERS evaluates, which are basically system rehabilitation and expansion. Because HPMS lacks detailed information on the current location and characteristics of safety-related features (e.g., guardrail, rumble strips, roundabouts, yellow change intervals at signals), safety-focused investments are not evaluated. Thus, the findings presented in *Exhibit 10-6* establish nothing about how such investments affect highway safety.

Crash costs also form the smallest of the three components of highway user costs. For 2014 travel on Federal-aid highways, HERS estimates the breakdown by cost component for each spending level. The average across spending levels for each share of user costs are crash cost, 12.7 percent; travel time cost, 54.7 percent, and vehicle operating cost, 32.4 percent. Research underway to update the vehicle operating cost equations in HERS (see Appendix A) could somewhat alter the split among these costs in future reports, but crash costs will likely remain a relatively small component. Although highway trips always consume traveler time and resources for vehicle operation, only a small fraction involve crashes. In addition, many crashes involve only damage to property with no injuries, particularly on urban highways.

Exhibit 10-6: Projected Impact of Alternative Investment Levels on 2034 Average Total User Costs on Federal-aid Highways



HERS-Modeled Investment On Federal-aid Highways Average Annual Investment (Billions of 2014 Dollars)	Projected 2034 Performance Measures on Federal-aid Highways					Link to Chapter 7 Scenario
	Average Total User Costs ($/VMT)	Percent Change Relative to Baseline Average per VMT				
		Total User Costs	Travel Time Costs	Vehicle Operating Costs	Crash Costs	
$73.2	$1.296	2.7%	13.2%	-10.3%	-1.0%	Improve C&P
$68.9	$1.297	2.8%	13.2%	-10.0%	-1.0%	
$65.0	$1.299	2.9%	13.3%	-9.8%	-1.0%	
$61.0	$1.301	3.1%	13.5%	-9.5%	-0.9%	
$60.2	$1.302	3.2%	13.5%	-9.4%	-0.9%	2014 Spending
$59.5	$1.302	3.2%	13.6%	-9.4%	-0.9%	Maintain C&P
$57.0	$1.303	3.3%	13.6%	-9.2%	-0.9%	
$53.0	$1.306	3.5%	13.8%	-8.9%	-0.8%	
$49.0	$1.309	3.7%	14.0%	-8.5%	-0.7%	
Base Year Values:	**$1.262**					

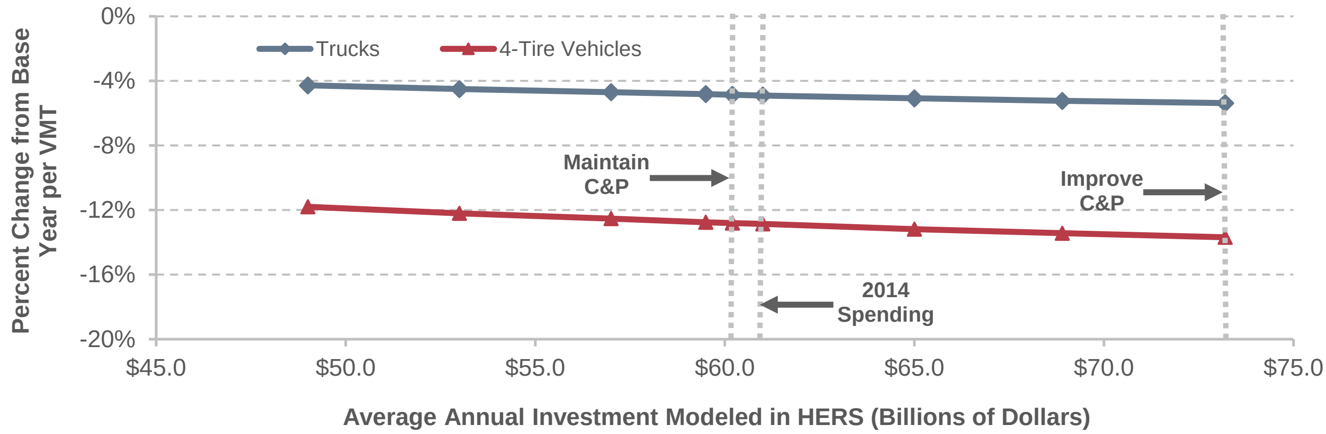
Source: Highway Economic Requirements System.

The projections for travel time costs are less sensitive to the assumed level of investment than are the projections for vehicle operating costs. The projected 2014–2034 change in travel time cost per VMT ranges from an increase of 13.2 percent at the highest level of assumed investment to an increase of 14.0 percent at the lowest. The increase in cost despite the reduction in total delay (as shown in *Exhibit 10-5*) is due in part to the fact that the value of time used for this report assumes a 1.0 percent real increase per year. These projections indicate that investing at the highest level rather than the lowest level would reduce the time cost of travel per VMT in 2034 by 0.8 percentage points, saving travelers hundreds of millions of hours per year in aggregate.

Impact on Vehicle Operating Costs

Exhibit 10-7 presents projections for vehicle operating costs per VMT, including separate values for four-tire vehicles (light-duty vehicles) and trucks (heavy-duty vehicles). The projected impacts on vehicle operating costs are larger for four-tire vehicles than for trucks when compared with both the 2014 values and the adjusted baseline. When comparing the vehicle operating cost projections with the adjusted baseline, the magnitudes of the impacts are much larger; isolating the effects of future highway investment reveals that vehicle operating costs per mile are projected to decline by between 11.8 percent and 13.7 percent for four-tire vehicles, and by between 4.3 percent and 5.4 percent for trucks from 2014 to 2034.

Exhibit 10-7: Projected Impact of Alternative Investment Levels on 2034 Vehicle Operating Costs on Federal-aid Highways



HERS-Modeled Investment on Federal-aid Highways Average Annual Investment (Billions of 2014 Dollars)	Projected 2032 Performance Measures on Federal-Aid Highways					Link to Chapter 7 Scenario
	Average Vehicle Operating Costs			Percent Change Relative to Baseline		
	All Vehicles ($/VMT)	4-Tire Vehicles ($/VMT)	Trucks ($/VMT)	4-Tire Vehicles	Trucks	
$73.2	$0.418	$0.342	$1.034	-13.7%	-5.4%	Improve C&P
$68.9	$0.419	$0.343	$1.035	-13.4%	-5.2%	
$65.0	$0.420	$0.344	$1.037	-13.2%	-5.1%	
$61.0	$0.421	$0.346	$1.039	-12.9%	-4.9%	
$60.2	$0.422	$0.346	$1.039	-12.8%	-4.9%	2014
$59.5	$0.422	$0.346	$1.040	-12.8%	-4.8%	Maintain C&P
$57.0	$0.423	$0.347	$1.041	-12.5%	-4.7%	
$53.0	$0.424	$0.348	$1.043	-12.2%	-4.5%	
$49.0	$0.426	$0.350	$1.046	-11.8%	-4.3%	
Base Year Values:	**$0.466**					

Source: Highway Economic Requirements System.

The projected reductions in vehicle operating costs per VMT are driven by projected increases in fuel efficiency across the analysis horizon. The assumed paths of fuel efficiency are based on projections from the Energy Information Administration's Annual Energy Outlook 2016. The average price of gasoline is assumed to increase between 2014 and 2034 by 0.7 percent relative to 2014, while the average price of diesel fuel is assumed to increase by 4.8 percent relative to 2014. The projected changes in fuel prices are added to the fuel cost savings that would result from the improvements in vehicle energy efficiency that the Energy Information Administration projects for this same period; these changes are represented in HERS as increases in average miles per gallon of 55.4 percent for light-duty vehicles, 47.0 percent for six-tire trucks, and 13.9 percent for other trucks.

Impact of Future Investment on Future VMT

As discussed above, the travel demand elasticity features in HERS modify future VMT growth for each HPMS sample section based on changes to highway user costs. In the absence of information to the contrary, most previous C&P Reports assumed that the HPMS forecasts represented the level of travel that would occur if user costs did not change. This assumption was changed beginning with the 2015 C&P Report because the baseline VMT forecasts used in this report are now tied to a specific VMT forecasting model with known inputs. HERS is now programmed to assume that the baseline projections of future VMT already account for anticipated independent changes in user cost component values.

In computing the impact of user cost changes on future VMT growth on an HPMS sample section, HERS compares projected highway user costs against assumed user costs that would have occurred had the physical conditions or operating performance on that highway section remained unchanged. This concept is illustrated in *Exhibit 10-8*. Based on the 2014 values assigned to various user cost components (e.g., value of travel time per hour, fuel prices, fuel efficiency, truck travel as a percentage of total travel), HERS computes baseline 2014 user costs at $1.262 per mile. If the 2034 values assigned to those same user cost components were applied in 2014, however, HERS would compute 2014 user costs to be $1.344 per mile. This "adjusted baseline" is the relevant point of comparison when examining the impact of user cost changes on VMT.

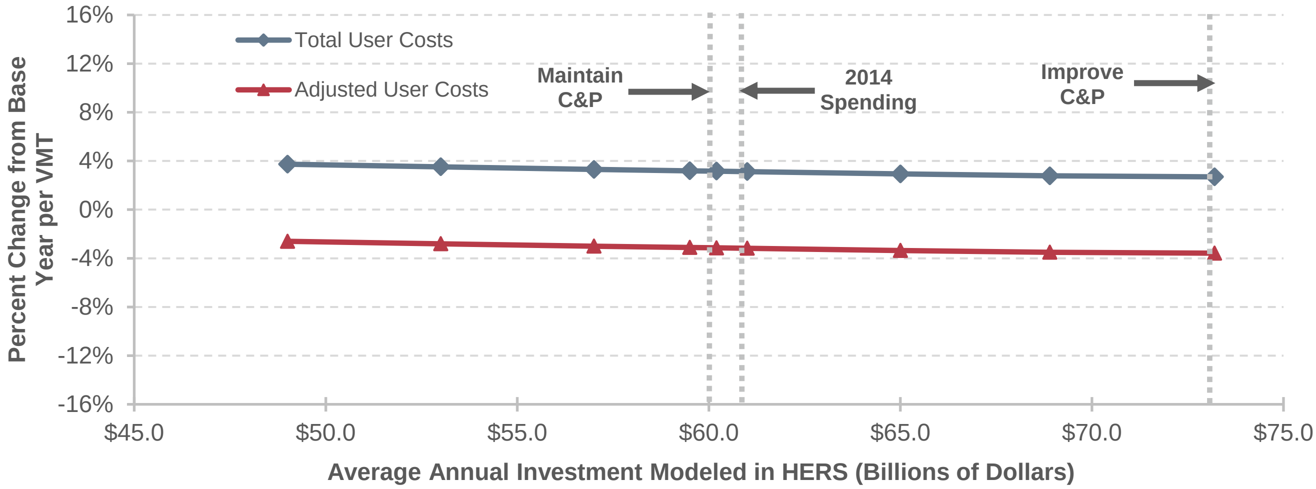
Although user costs are projected to increase in absolute terms from 2014 to 2034, they are projected to decline relative to the adjusted baseline by between 2.6 percent (at the lowest level of investment analyzed) and 3.6 percent (at the highest level of investment analyzed in 2034). Because the percentage change in adjusted total user costs declined for each investment level identified, the effective annual projected VMT growth associated with each investment level was higher than the 1.07 percent baseline projection in all cases, ranging from 1.13 percent to 1.22 percent.

Impacts of NHS Investments Modeled by HERS

As described in Chapter 1, the NHS includes the Interstate System and other routes most critical to national defense, mobility, and commerce. As noted earlier, the NHS analyses presented in this section are based on the NHS after its expansion pursuant to MAP-21.

This section examines the impacts that investment on NHS roads could have on future NHS conditions and performance, independent of spending on other Federal-aid highways. The analysis presented in this section centers on special HERS runs that used a database consisting only of NHS roads. The highest two investment levels shown in the three exhibits presented in this section are based on model runs constrained by a BCR. The top row in each table represents a run within which all potential improvements with a BCR of 1.0 or higher are implemented; this corresponds to the definition of the Improve Conditions and Performance scenario presented in Chapter 7. The second row in each table represents a run at which the average annual investment level over 20 years matches actual 2014 highway capital spending by all levels of government combined. (HERS was unable to identify $44.0 billion of cost-beneficial investment annually assuming spending remained at this fixed amount in each year, so the analysis was redone as a BCR-constrained run under which spending varies by year.) The remaining investment levels presented in this section reflect analyses in which a fixed amount of investment occurred in each year; these were arbitrarily selected as increments of $4.0 billion per year simply to show a wide range of alternatives.

Exhibit 10-8: Projected Impact of Alternative Investment Levels on 2034 User Costs and VMT on Federal-aid Highways



HERS-Modeled Investment on Federal-aid Highways Average Annual Investment (Billions of 2014 Dollars)	Projected 2034 Indicators on Federal-aid Highways					Link to Chapter 7 Scenario
	Average Total User Costs[1]			Projected VMT[2]		
		Percent Change				
	($/VMT)	vs. Actual 2014	vs. Adjusted Baseline	Trillions of VMT	Annual Percent Change vs. 2014	
$73.2	$1.296	2.7%	-3.6%	3.227	1.22%	Improve C&P
$68.9	$1.297	2.8%	-3.5%	3.212	1.19%	
$65.0	$1.299	2.9%	-3.4%	3.205	1.18%	
$61.0	$1.301	3.1%	-3.2%	3.197	1.17%	
$60.2	$1.302	3.2%	-3.1%	3.195	1.17%	2014 Spending
$59.5	$1.302	3.2%	-3.1%	3.194	1.16%	Maintain C&P
$57.0	$1.303	3.3%	-3.0%	3.189	1.16%	
$53.0	$1.306	3.5%	-2.8%	3.181	1.14%	
$49.0	$1.309	3.7%	-2.6%	3.172	1.13%	
Base Year Values:	**$1.262**			**2.534**	**1.07%**	
Adjusted Baseline:	**$1.344**					

[1] The computation of user costs includes several components (value of travel time per hour, fuel prices, fuel efficiency, truck travel as a percentage of total travel, etc.) that are assumed to change over time independently of future highway investment. The adjusted baseline applies the parameter values for 2034 to the data for 2014 so that changes in user costs attributable to future highway investment can be identified.

[2] The operation of the travel demand elasticity features in HERS cause future VMT growth to be influenced by future changes in average user costs per VMT. For this report, the model was set to assume that the baseline projections of future VMT already take into account anticipated independent future changes in user cost component values; hence, it is the changes versus the adjusted baseline user costs that are relevant. Since the percentage change in adjusted total user costs declined for each of the investment levels identified, the annual projected VMT growth was higher than the 0.92-percent baseline projection in all cases.

Source: Highway Economic Requirements System.

Impact of Future Investment on NHS User Costs and VMT

Exhibit 10-9 presents the projected impacts of NHS investment on VMT and total average user costs on NHS roads in 2034. Average user costs are projected to be lower in 2034 than for the adjusted baseline ($1.262 per VMT) for all investment levels presented. When implementing all cost-beneficial projects (the highest level of investment, an annual average of $48.1 billion), average total user costs are projected to be 3.48 percent lower ($1.218 per VMT) than adjusted baseline user costs in 2014 ($1.262 per VMT). At the lowest level of investment presented (an annual average of $28.0 billion), average total user costs are projected to be 1.97 percent lower ($1.237 per VMT) than adjusted baseline user costs in 2014.

Projected VMT growth on NHS roads is relatively insensitive to the range of investment levels presented in *Exhibit 10-9*. At the highest level of investment presented in *Exhibit 10-9* (an annual average of $48.1 billion), VMT is projected to grow at an average annual rate of 1.20 percent from 2014 to 2034 (2.086 trillion VMT in 2034 versus 1.644 trillion VMT in 2014). At the lowest level of investment presented in *Exhibit 10-9* (an annual average of $28.0 billion), VMT is projected to grow at an average annual rate of 1.10 percent from 2014 to 2034 (2.046 trillion VMT in 2034 versus 1.644 trillion VMT in 2014).

Across the investment levels presented in *Exhibit 10-9*, HERS allocates between $18.0 billion and 29.6 billion in average annual spending on NHS roads to system rehabilitation and between $10.0 billion and $18.5 billion in average annual spending on NHS roads to system expansion.

Exhibit 10-9: HERS Investment Levels Analyzed for the National Highway System and Projected Minimum Benefit-Cost Ratios, User Costs, and Vehicle Miles Traveled

HERS-Modeled Investment On the NHS (Average Annual Over 20 Years)			Projected NHS Indicators			
Total HERS Spending[1]	System Rehabilitation Spending	System Expansion Spending	Minimum BCR 20-Year 2015 through 2034[2]	Average 2034 Total User Costs ($/VMT)[3]	Projected 2034 VMT (Trillions)[4]	Description
$48.1	$29.6	$18.5	**1.00**	$1.218	2.086	BCR>=1.0
$44.0	$27.4	$16.6	1.07	$1.221	2.079	2014 Spending
$40.0	$25.1	$14.9	1.08	$1.224	2.072	
$36.0	$22.9	$13.1	1.16	$1.228	2.064	
$32.0	$20.5	$11.5	1.28	$1.232	2.056	
$28.0	$18.0	$10.0	1.42	$1.237	2.046	
			Base Year Values:	**$1.195**	**1.644**	
			Adjusted Baseline:	**$1.262**		

[1] HERS splits its available budget between system rehabilitation and system expansion based on the mix of spending it finds to be most cost-beneficial, which varies by funding level.

[2] As HERS ranks potential improvements by their estimated BCRs and assumes that the improvements with the highest BCRs will be implemented first (up until the point where the available budget specified is exhausted), the minimum BCR will naturally tend to decline as the level of investment analyzed rises.

[3] The computation of user costs includes several components (value of travel time per hour, fuel prices, fuel efficiency, truck travel as a percentage of total travel, etc.) that are assumed to change over time independently of future highway investment. The adjusted baseline applies the parameter values for 2034 to the data for 2014, so that changes in user costs attributable to future highway investment can be identified.

[4] The operation of the travel demand elasticity features in HERS cause future VMT growth to be influenced by future changes in average user costs per VMT. For this report, the model was set to assume that the baseline projections of future VMT already take into account anticipated independent future changes in user cost component values; hence, it is the changes versus the adjusted baseline user costs that are relevant. "

Source: Highway Economic Requirements System.

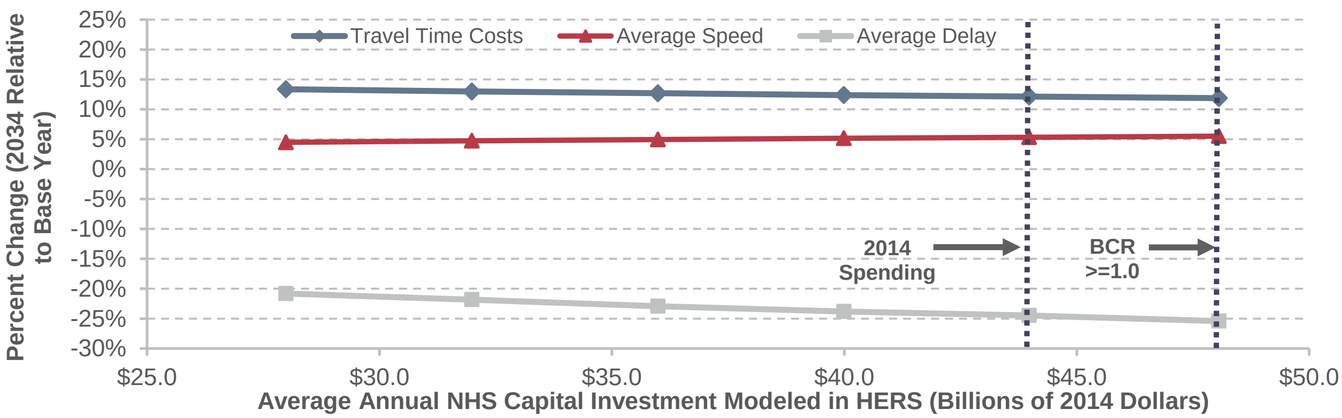
Impact of Future Investment on NHS Travel Times and Travel Time Costs

The tabular portion of *Exhibit 10-10* presents the projections of NHS averages for time-related indicators of performance, along with the spending amount that HERS allocates for NHS expansion projects (which have stronger effects on time-related indicators of performance than preservation projects have).

The graph is plotted based on total average annual NHS investment modeled in HERS, including spending on both system rehabilitation and system expansion. For all investment levels presented in *Exhibit 10-10*, average travel speed in 2034 exceeds average travel speed in 2014 (49.6 miles per hour). The range of average travel speeds is narrow across the investment levels. At the lowest level of investment in system expansion presented in Exhibit 10-10 (an annual average of $11.5 billion), the average travel speed in 2034 is projected to be 52.0 miles per hour. At the highest level of investment in system expansion presented in *Exhibit 10-10* (an annual average of $18.5 billion), the average travel speed in 2034 is projected to be 52.4 miles per hour.

The global increase in average travel speed across investment levels corresponds to large decreases in average delay per VMT across investment levels. At the highest level of investment in system expansion presented in *Exhibit 10-10*, average delay per VMT in 2034 is projected to be 25.4 percent lower than in 2014. At the lowest level of investment in system expansion presented in *Exhibit 10-10*, average delay per VMT in 2034 is projected to be 21.8 percent lower than in 2014.

Exhibit 10-10: Projected Impact of Alternative Investment Levels on 2034 Highway Speed, Travel Delay, and Travel Time Costs on the National Highway System



HERS-Modeled Investment on the NHS Average Annual Spending (Billions of 2014 Dollars)		Projected 2034 Performance Measures on the NHS				
			Percent Change Relative to Baseline			
Total	System Expansion[1]	Average Speed (mph)	Average Speed	Average Delay per VMT	Travel Time Costs per VMT[2]	Description
$48.1	$18.5	52.4	5.5%	-25.4%	11.9%	BCR>=1.0
$44.0	$16.6	52.3	5.3%	-24.5%	12.1%	2014 Spending
$40.0	$14.9	52.2	5.2%	-23.8%	12.4%	
$36.0	$13.1	52.1	5.0%	-22.9%	12.7%	
$32.0	$11.5	52.0	4.7%	-21.8%	13.0%	
$27.0	$9.6	51.8	4.4%	-20.4%	13.5%	
	Base Year Values:	**49.6**				

[1] The amounts shown represent only the portion of HERS-modeled spending directed toward system expansion, rather than system rehabilitation. Other types of spending can affect these indicators as well.

[2] Travel time costs are affected by an assumption that the value of time will increase by 1.0 percent in real terms each year. Hence, costs would rise even if travel time remained constant.

Source: Highway Economic Requirements System; Highway Statistics 2015, Table VM-1.

Travel time costs per VMT in 2034 are projected to increase across the investment levels presented. Travel time costs per VMT in 2034 are projected to increase by 11.9 percent relative to 2014 at the highest investment level and to increase by 13.0 percent at the lowest level of investment.

Impact of Future Investment on NHS Pavement Ride Quality

The tabular portion of *Exhibit 10-11* shows the portion of modeled NHS spending that HERS allocates to rehabilitation projects (which influence average pavement quality more than expansion projects do). The graph is plotted based on total average annual NHS investment modeled in HERS, including spending on both system rehabilitation and system expansion. At the highest level of investment presented in *Exhibit 10-11* (an annual average of 29.6 billion allocated to system rehabilitation), the model projects that pavements with an IRI above 170 (the criterion presented in Chapter 6 for rating ride quality as "poor") will carry 8.2 percent of the VMT on the NHS, down from the 11.4 percent estimated for 2014.

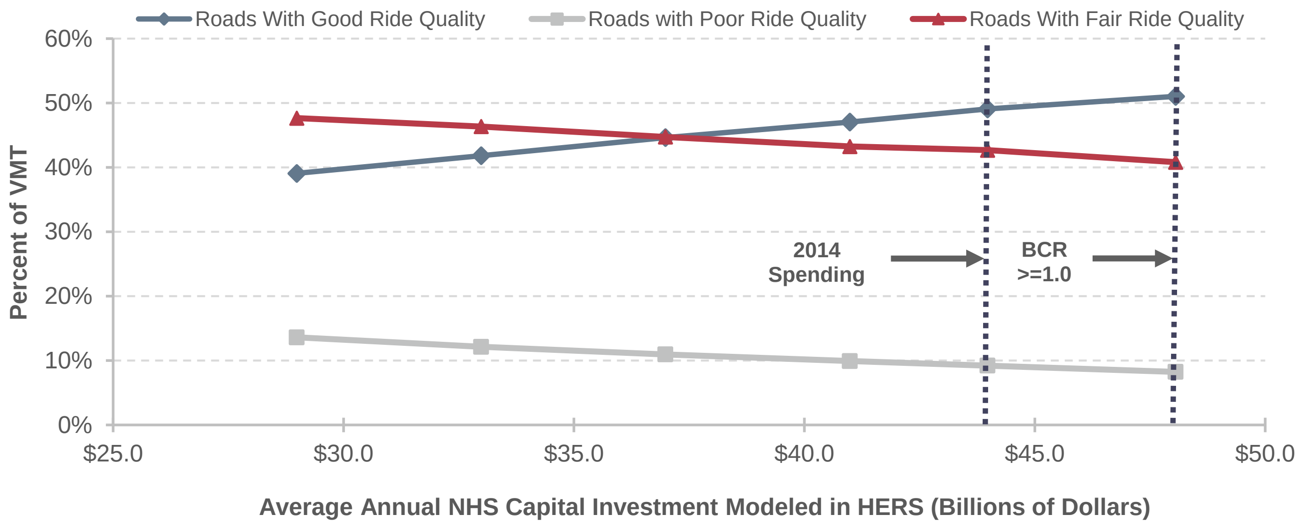
HERS also projects the share of travel on pavements with an IRI below 95 (the criterion presented in Chapter 6 for rating ride quality as "good") will carry 51.0 percent of the VMT on the NHS, down from the 58.7 percent estimated for 2014. The model projects a large increase in the share of NHS travel on pavements with "fair" ride quality (rising from 30.0 percent in 2014 to projects in 2034), and projects the average IRI of the system would rise 3.6 percent to 105.6, remaining within the classification of providing "fair" ride quality at the aggregate level.

Based on these modeling results, additional investment to bring the percentage of NHS VMT on roads with "good" ride quality closer to 100 percent would be economically inefficient, as the costs would exceed the benefits. As discussed in Chapter 6, while the percentage of VMT on pavements with good ride quality has improved significantly over the past decade, other measures of pavement performance have shown declines. The HERS results suggest that some degree of shifting of pavement investment (toward lower-volume NHS routes, or non-NHS routes) may be warranted.

The model does find it to be cost-beneficial to reduce the share of pavements with poor ride quality, but not all the way down to zero percent. A key factor leading to this result is that some improvements are not cost-beneficial until IRI rises above the threshold for "fair" ride quality by a sufficient margin. Thus, for some roads with an IRI above 170, improvements would not generate benefits exceeding costs. Also, at any given point, some pavements will be under construction, which will negatively affect their ride quality.

At the lowest level of investment presented in *Exhibit 10-11* (an annual average of $18.7 billion allocated to system rehabilitation), the model projects that the share of NHS travel carried by pavements with an IRI above 170 would rise from 11.4 percent in 2014 to 13.6 percent in 2034. At this investment level, average IRI would increase to 121.3, and the share of NHS travel on pavements with an IRI below 95 would decline to 39.1 percent.

Exhibit 10-11: Projected Impact of Alternative Investment Levels on 2034 Pavement Ride Quality Indicators for the National Highway System



HERS-Modeled Investment on the NHS Average Annual Spending (Billions of 2014 Dollars)		Projected 2034 Condition Measures on the NHS[1]					
		Percent of VMT on Roads With Ride Quality of:			Average IRI (VMT-Weighted)		
Total	System Rehabilitation[2]	Good (IRI<95)	Fair (IRI 95 to 170)	Poor (IRI>170)	Inches Per Mile	Change Relative to Base Year	Description
$48.1	29.6	51.0%	40.7%	8.2%	105.6	3.6%	BCR>=1.0
$44.0	$27.4	49.1%	41.7%	9.2%	107.9	5.9%	2014 Spending
$41.0	$25.7	47.0%	43.0%	9.9%	110.9	8.8%	
$37.0	$23.5	44.6%	44.4%	11.0%	113.8	11.7%	
$33.0	$21.2	41.8%	46.0%	12.1%	117.3	15.1%	
$29.0	$18.7	39.1%	47.3%	13.6%	121.3	19.0%	
Base Year Values:		**58.7%**	**30.0%**	**11.4%**	**101.9**		

[1] As discussed in Chapter 6, IRI values of 95 through 170 inches per mile are classified as "fair," lower IRI values are classified as "good," and higher IRI values are classified as "poor."

[2] The amounts shown represent only the portion of HERS-modeled spending directed toward system rehabilitation, rather than system expansion. Other types of spending can affect these indicators as well.

Source: Highway Economic Requirements System.

Impacts of Interstate System Investments Modeled by HERS

The Interstate System, unlike the broader NHS of which it is a part, has standard design and signage requirements, making it the most recognizable subset of the highway network. This section examines the impacts that investment in the Interstate System could have on future Interstate System conditions and performance, independently of spending on other Federal-aid highways. The analysis presented in this section centers on special HERS runs that used a database consisting only of Interstate System roads.

As was the case for the NHS analyses presented above, the highest two investment levels shown in the three exhibits presented in this section are based on model runs constrained by a BCR. The top row in each table represents a run with in which all potential improvements with a BCR of 1.0 or higher are implemented; this corresponds to the definition of the Improve Conditions and Performance scenario presented in Chapter 7. The second row in each table represents a run at which the average annual investment level over 20 years matches actual 2014 highway capital spending by all levels of government combined. (HERS was unable to identify $20.3 billion of cost-beneficial investment annually assuming spending remained at this fixed amount in each year, so the analysis was redone as a BCR-constrained run under which spending varies by year.) The remaining investment levels presented in this section reflect analyses in which a fixed amount of investment occurred in each year; these were arbitrarily selected simply to show a wide range of alternatives.

Impact of Future Investment on Interstate User Costs and VMT

Exhibit 10-12 presents the projected impacts of highway investment on VMT and total average user costs on Interstate roads in 2034, along with the amount that HERS allocates to Interstate projects. Average user costs are projected to be lower in 2034 than the adjusted baseline ($1.162 per VMT) for all investment levels presented. At the highest level of investment presented in *Exhibit 10-12* (an annual average of $21.3 billion), average total user costs are projected to be 2.5 percent lower ($1.133 per VMT) than in 2014. At the lowest level of investment presented (an annual average of $11.5 billion), average total user costs are projected to be 0.03 percent lower ($1.159 per VMT) than in 2014.

Exhibit 10-12: HERS Investment Levels Analyzed for the Interstate System and Projected Minimum Benefit-Cost Ratios, User Costs, and Vehicle Miles Traveled

HERS-Modeled Investment On the Interstate System			Projected Interstate Indicators			
Average Annual Over 20 Years						
Total HERS Spending[1]	System Rehabilitation Spending	System Expansion Spending	Minimum BCR 20-Year 2015 through 2034[2]	Average 2034 Total User Costs ($/VMT)[3]	Projected 2034 VMT (Trillions)[4]	Description
$21.3	$11.9	$9.3	**1.00**	$1.133	0.940	BCR>=1.0
$20.3	$11.7	$8.6	1.06	$1.136	0.938	2014 Spending
$15.5	$9.4	$6.1	1.10	$1.149	0.930	
$14.5	$8.8	$5.7	1.15	$1.151	0.928	
$13.5	$8.3	$5.2	1.23	$1.154	0.926	
$12.5	$7.7	$4.8	1.32	$1.157	0.924	
$11.5	$7.1	$4.4	1.43	$1.159	0.921	
Base Year Values:				**$1.115**	**0.738**	
Adjusted Baseline:				**$1.162**		

[1] HERS splits its available budget between system rehabilitation and system expansion based on the mix of spending it finds to be most cost-beneficial, which varies by funding level.

[2] As HERS ranks potential improvements by their estimated BCRs, and assumes that the improvements with the highest BCRs will be implemented first (up until the point where the available budget specified is exhausted), the minimum BCR will naturally tend to decline as the level of investment analyzed rises.

[3] The computation of user costs includes several components (value of travel time per hour, fuel prices, fuel efficiency, truck travel as a percent of total travel, etc.) that are assumed to change over time independent of future highway investment. The adjusted baseline applies the parameter values for 2034 to the data for 2014 so that changes in user costs attributable to future highway investment can be identified.

[4] The operation of the travel demand elasticity features in HERS cause future VMT growth to be influenced by future changes in average user costs per VMT. For this report, the model was set to assume that the baseline projections of future VMT already take into account anticipated independent future changes in user cost component values; hence, it is the changes versus the adjusted baseline user costs that are relevant.

Source: Highway Economic Requirements System.

Projected VMT growth on Interstate highways is relatively insensitive to the range of investment levels presented in *Exhibit 10-12*. At the highest level of investment presented in *Exhibit 10-12* (an annual average of $23.7 billion), VMT is projected to grow at an average annual rate of 1.22 percent from 2014 to 2034 (940 billion VMT in 2034 versus 738 billion VMT in 2014). At the lowest level of investment presented in

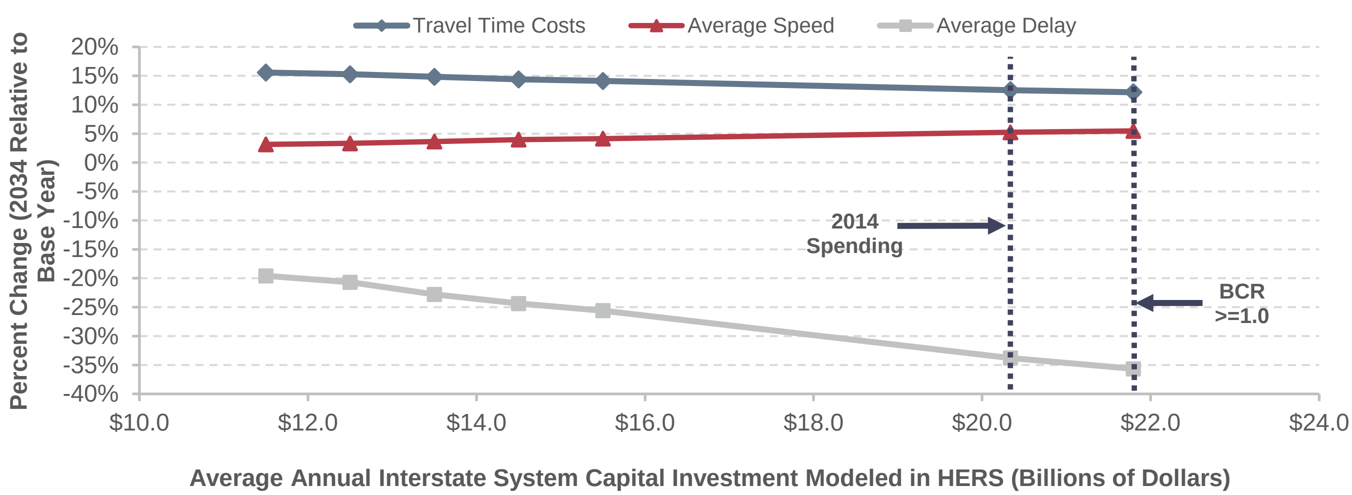
Exhibit 10-12 (an annual average of $11.2 billion), VMT is projected to grow at an average annual rate of 1.11 percent from 2014 to 2034 (921 billion VMT in 2034 versus 738 billion VMT in 2014).

Across the investment levels presented in *Exhibit 10-12*, HERS allocates between $7.1 billion and $11.9 billion in average annual spending on Interstate roads to system rehabilitation, and between $4.4 billion and $9.3 billion in average annual spending on Interstate roads to system expansion.

Impact of Future Investment on Interstate System Travel Times and Travel Costs

The tabular portion of *Exhibit 10-13* presents the projections of Interstate System averages for time-related indicators of performance, along with the amount that HERS allocates for Interstate System expansion projects (which have a relatively large impact on travel time). The graph is plotted based on total average annual Interstate investment modeled in HERS, including spending on both system rehabilitation and system expansion.

Exhibit 10-13: Projected Impact of Alternative Investment Levels on 2034 Highway Speed, Travel Delay, and Travel Time Costs on the Interstate System



HERS-Modeled Investment on Interstate Highways		Projected 2034 Performance Measures on Interstate Highways				
Average Annual Spending (Billions of 2014 Dollars)			Percent Change Relative to Baseline			
Total	System Expansion[1]	Average Speed (mph)	Average Speed	Average Delay per VMT	Travel Time Costs per VMT[2]	Description
$21.3	$9.3	65.6	5.5%	-35.7%	12.2%	BCR>=1.0
$20.3	$8.6	65.4	5.2%	-33.8%	12.5%	2014 Spending
$15.5	$6.1	64.7	4.1%	-25.6%	14.1%	
$14.5	$5.7	64.6	4.0%	-24.4%	14.4%	
$13.5	$5.2	64.4	3.6%	-22.8%	14.8%	
$12.5	$4.8	64.2	3.3%	-20.7%	15.3%	
$11.5	$4.4	64.1	3.1%	-19.6%	15.6%	
Base Year Values:		**62.2**				

[1] The amounts shown represent only the portion of HERS-modeled spending directed toward system expansion, rather than system rehabilitation. Other types of spending can affect these indicators as well.

[2] Travel time costs are affected by an assumption that the value of time will increase by 1.0 percent in real terms each year; hence, costs would rise even if travel time remained constant.

Source: Highway Economic Requirements System; Highway Statistics 2015, Table VM-1.

Across all investment levels presented in *Exhibit 10-13*, average speed on the Interstate System is projected to be higher than its 2014 level (62.2 miles per hour) in 2034. At the highest level of investment presented in *Exhibit 10-13* (average annual investment in system expansion of $9.3 billion), average Interstate highway travel speed is projected to be 5.5 percent higher (65.6 miles per hour) in 2034 than in 2014. At the lowest level of investment presented in *Exhibit 10-13* (average annual investment in system expansion of $4.4 billion), average Interstate highway travel speed is projected to be 3.1 percent higher (64.1 miles per hour) in 2034 than in 2014.

The global increase in average travel speed across investment levels corresponds with large decreases in average delay per VMT across investment levels. At the highest level of investment presented in *Exhibit 10-13*, average delay per VMT in 2034 is projected to be 35.7 percent lower than in 2014. At the lowest level of investment presented in *Exhibit 10-13*, average delay per VMT in 2034 is projected to be 19.6 percent lower than in 2014.

The projected impacts on travel delay across investment levels are much greater for Interstates than for other portions of Federal-aid highways. This result suggests the presence of a large scope of congestion-related benefits that could be achieved through investments in Interstate highway improvements.

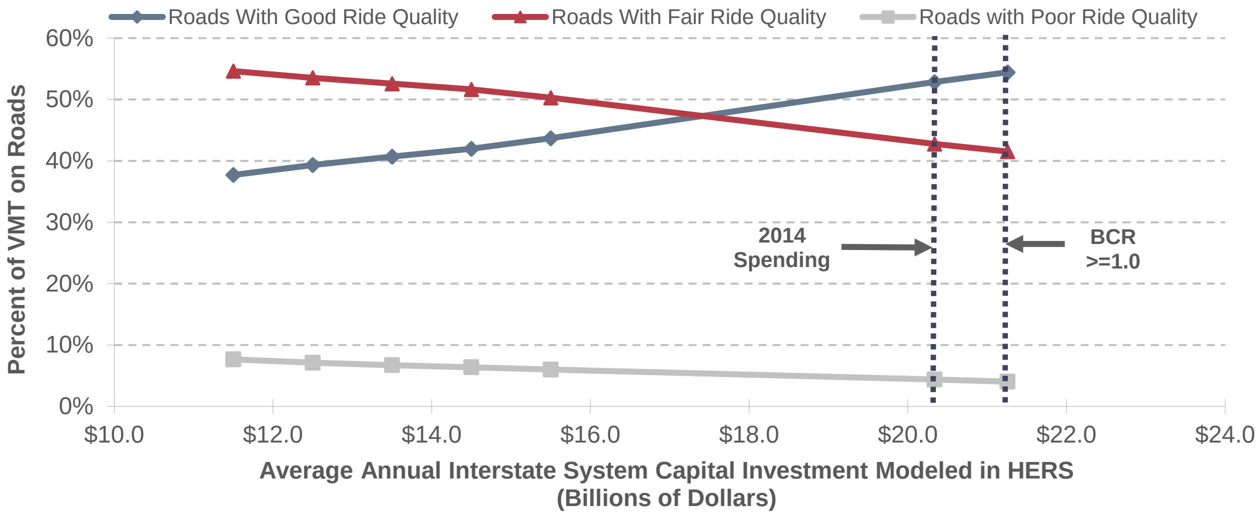
Due to increases in the assumed value of time from 2014 to 2034 as discussed earlier under Impact of Future Investment on Highway Pavement Ride Quality, the projected increases in average travel speed do not correspond to decreases in travel time costs per VMT. Travel time costs per VMT in 2034 are projected to increase across all investment levels. Travel time costs per VMT in 2034 are projected to increase by 12.2 percent relative to 2014 at the highest level of investment presented in *Exhibit 10-13* and by 15.6 percent at the lowest level of investment.

Impact of Future Investment on Interstate Pavement Ride Quality

The tabular portion of *Exhibit 10-14* shows the portions of modeled Interstate System spending that HERS allocates to rehabilitation projects (which influence average pavement quality more than expansion projects do). The graph is plotted based on total average annual Interstate investment modeled in HERS, including spending on both system rehabilitation and system expansion. Across all investment levels presented in *Exhibit 10-14*, the model projects that the share of pavements with an IRI below 95 (the criterion described in Chapter 6 for rating ride quality as "good") would be below the corresponding share in 2014 (72.2 percent). These results suggest that placing more emphasis on reducing the percentage of VMT on Interstate highways with "poor" ride quality would be more economically efficient than focusing on further increasing the share with "good" ride quality. A key factor leading to this result is that HERS assumes that the effects of increasing pavement roughness on free-flow speed and vehicle operating costs are modest until after IRI rises to a relatively high level.

At the highest level of investment presented in *Exhibit 10-14* (an annual average of $11.9 billion allocated to system rehabilitation), the model projects average pavement roughness on the Interstate System to be 11.5 percent higher in 2034 than in 2014. These results suggest that it would not be cost-effective to keep the average VMT-weighted IRI of the Interstate System at its 2014 level of 85.9 (well into the "good" range), and that allowing it to move just across the threshold into the "fair" range (to 95.8) would be economically advantageous. The HERS results also suggest it would not be cost-beneficial to reduce the percent of Interstate VMT on pavements with "good" ride quality below its 2014 level of 4.0 percent.

Exhibit 10-14: Projected Impact of Alternative Investment Levels on 2034 Pavement Ride Quality Indicators for the Interstate System



HERS-Modeled Investment on Interstate Highways		Projected 2034 Condition Measures Interstate Highways[1]					
Average Annual Spending (Billions of 2014 Dollars)		Percent of VMT on Roads with Ride Quality of:			Average IRI (VMT-Weighted)		
Total	System Rehabilitation[2]	Good (IRI<95)	Fair (IRI 95 to 170)	Poor (IRI>170)	Inches Per Mile	Change Relative to Base Year	Description
$21.3	$11.9	54.4%	41.5%	4.0%	95.8	11.5%	BCR>=1.0
$20.3	$11.7	52.8%	42.8%	4.4%	97.2	13.2%	2014 Spending
$15.5	$9.4	43.7%	50.3%	6.0%	105.6	22.9%	
$14.5	$8.8	42.0%	51.6%	6.4%	107.1	24.7%	
$13.5	$8.3	40.7%	52.6%	6.7%	108.4	26.2%	
$12.5	$7.7	39.3%	53.5%	7.1%	109.7	27.7%	
$11.5	$7.1	37.7%	54.6%	7.7%	111.6	29.9%	
Base Year Values:		**72.2%**	**23.8%**	**4.0%**	**85.9**		

[1] As discussed in Chapter 6, IRI values of 95 through 170 inches per mile are classified as "fair," lower IRI values are classified as "good," and higher IRI values are classified as "poor."

[2] The amounts shown represent only the portion of HERS-modeled spending directed toward system rehabilitation, rather than system expansion. Other types of spending can affect these indicators as well.

Source: Highway Economic Requirements System.

Impacts of Systemwide Investments Modeled by NBIAS

In using NBIAS to project conditions and performance of the Nation's bridges over 20 years, this section considers the alternatives of continuing to invest in bridge rehabilitation at the 2014 level (in constant dollars) and at higher or lower levels. The expenditures modeled pertain only to bridge system rehabilitation; expenditures associated with bridge system expansion are modeled separately as part of the capacity expansion analysis in HERS. The NBIAS-modeled investments presented here should be considered as additive to the HERS-modeled investments presented above; each capital investment scenario presented in Chapter 7 combines one HERS analysis with one NBIAS analysis and makes adjustments to account for nonmodeled spending.

As referenced in Chapter 2, of the $105.4 billion invested in highways in 2014, $14.4 billion was used for bridge system rehabilitation. For investments of the types modeled by NBIAS, *Exhibit 10-15* shows how the total amount invested over the 20-year analysis period influences the bridge performance levels projected for the final year, 2034. If spending were sustained at its 2014 level in constant dollar terms ($14.4 billion, the investment level feeding the 2014 Spending scenario presented in Chapter 7), projected performance for 2034 would improve relative to 2014 for each performance measure considered. The share of bridges classified as in “poor” condition would decrease from 6.8 percent to 4.7 percent, while the share of bridges classified as in “good” condition would increase from 44.3 percent in 2014 to 52.8 percent in 2034. The average Health Index would rise from 92.1 to 94.3. The Economic Investment Backlog would decrease to $49.5 billion (60.5 percent below its 2014 level of $125.4 billion).

The highest level of spending shown in *Exhibit 10-15* averages $22.7 billion per year (this feeds the Improve Conditions and Performance scenario in Chapter 7). This level of investment is projected to reduce the deck-area-weighted share of bridges in poor condition to 0.6 percent and to eliminate the Economic Investment Backlog for bridges by 2034. This indicates that the model does not find that completely eliminating all deficiencies would be cost-beneficial at any single point in time. In some cases, the model recommends that corrective actions be deferred; in other cases it estimates that the benefits of replacing a bridge would be outweighed by its costs (suggesting that it should eventually be closed, diverting traffic to other available crossings).

Bridge Performance Measures in *Exhibits 10-15* to *10-18*

Exhibits 10-15 to *10-18* provide three metrics of bridge performance:

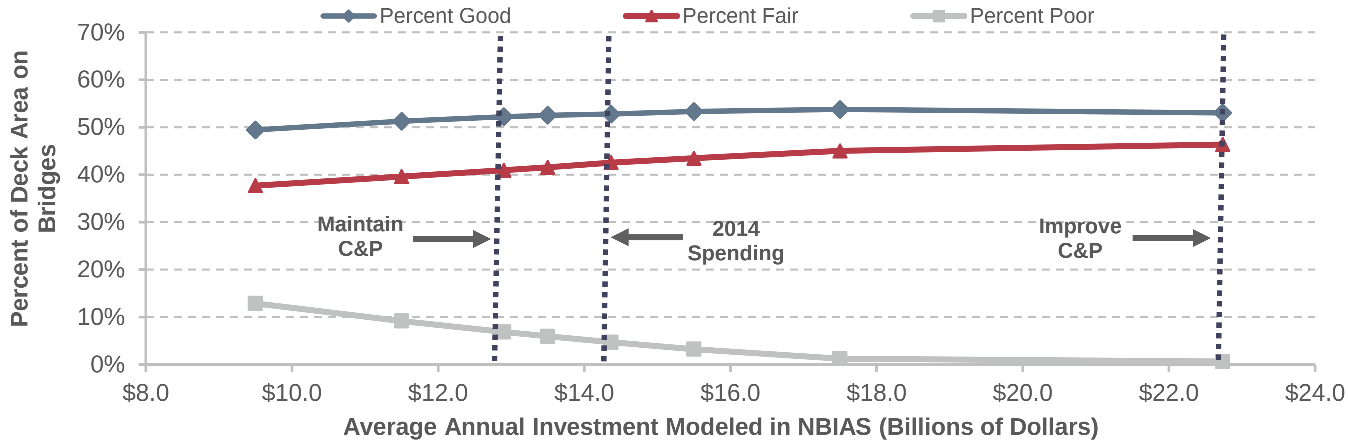
- Percentage of bridges (weighted by deck area) in “good,” “fair,” and “poor” condition (the percentage in poor condition is used in computing the Maintain Conditions and Performance scenario in Chapter 7)
- Average Health Index
- Economic Investment Backlog (used in computing the Improve Conditions and Performance scenario in Chapter 7)

As described in Chapter 6, bridges in “good,” “fair,” and “poor” condition are defined by the degree of deterioration of the three major bridge components: deck, superstructure, and substructure. For a bridge to be classified as in “good” condition, all three major bridge components must be rated “good.” For a bridge to be classified as in “poor” condition, at least one bridge element must be rated “poor.” All other bridges are classified as in “fair” condition.

The average Health Index metric is a ranking system (0–100) for bridge elements typically used in the context of decisionmaking for bridge preventive maintenance, with 0 being the worst and 100 being the best. To aggregate the element-level result to the bridge level (i.e., assign a value for the Health Index), a weight is assigned to each bridge element according to the economic consequences of its failure, and then an average of all the weighted elements is calculated. Thus, an element for which a failure has relatively little economic effect would receive less weight than an element for which a failure could result in closing the bridge. In general, the lower the Health Index, the higher the priority for rehabilitation or maintenance of the structure, although other factors also are instrumental in determining priority of work on bridges.

The Economic Investment Backlog metric represents the combined cost of all corrective actions for which NBIAS estimates implementation would be cost-beneficial. Consistent with the HERS analysis, implementing all cost-beneficial corrective actions in NBIAS would not necessarily mean that no bridges would remain in poor condition; rather, implementing all cost-beneficial corrective actions in NBIAS would indicate that it would not be cost-beneficial to take any further corrective actions.

Exhibit 10-15: Projected Impact of Alternative Investment Levels on 2034 Bridge Condition Indicators for All Bridges



NBIAS-Modeled Investment on All Bridges	Projected 2034 Condition Indicators—All Bridges					Link to Chapter 7 Scenario
	Weighted by Deck Area					
Average Annual Investment (Billions of 2014 Dollars)[1]	Percent Good	Percent Fair	Percent Poor	Health Index	Economic Investment Backlog (Billions of 2014 Dollars)[1]	
$22.7	53.0%	46.3%	0.6%	95.2	**$0.0**	Improve C&P
$17.5	53.8%	45.0%	1.2%	95.2	**$4.3**	
$15.5	53.3%	43.5%	3.2%	94.9	**$30.7**	
$14.4	52.8%	42.5%	4.7%	94.3	**$49.5**	2014 Spending
$13.5	52.5%	41.5%	5.9%	93.7	**$64.7**	
$12.9	52.2%	40.9%	**6.8%**	93.3	**$75.6**	Maintain C&P
$11.5	51.3%	39.6%	9.2%	92.2	**$101.3**	
$9.5	49.4%	37.7%	12.9%	90.3	**$141.6**	
Base Year Values:	**44.3%**	**48.9%**	**6.8%**	**92.1**	**$125.4**	

[1] The amounts shown do not reflect system expansion needs; the bridge components of such needs are addressed as part of the HERS model analysis.

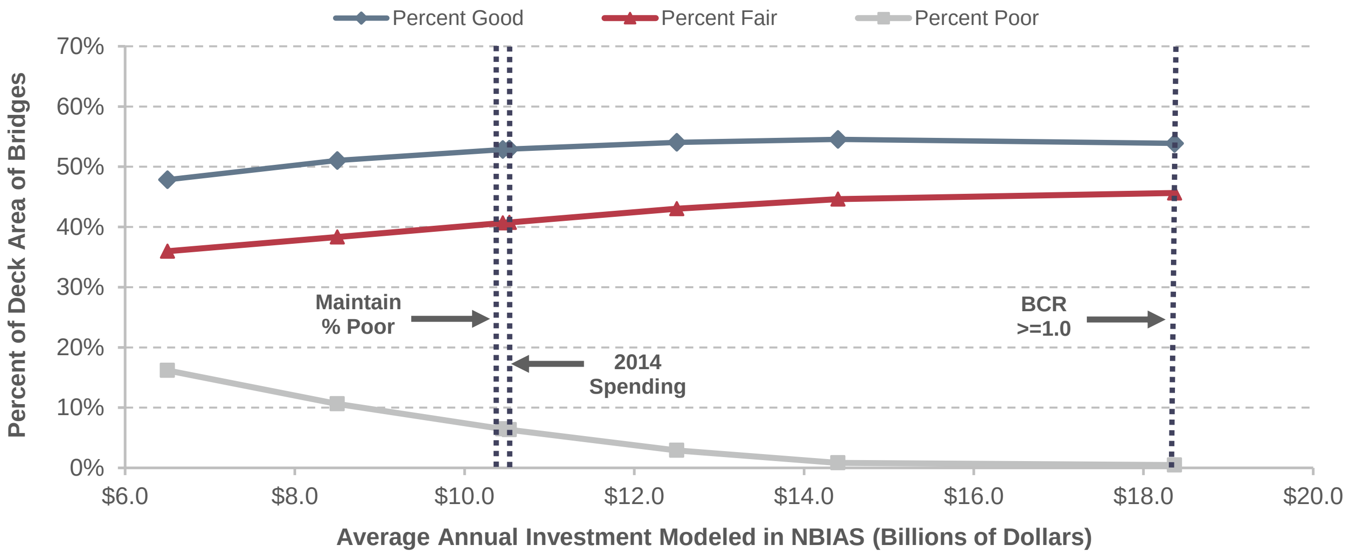
Source: National Bridge Investment Analysis System.

Exhibit 10-15 also indicates that the average annual bridge investment could be reduced from the 2014 level while maintaining bridge performance. The Maintain C&P scenario (an average annual spending of $12.9 billion) would still be sufficient to maintain the share of bridges in poor condition, weighted by deck area, at 6.8 percent (its 2014 level) through 2034. At this level of investment, the average Health Index is projected to rise 1.2 percentage points (improve), and the Economic Investment Backlog is projected to shrink (improve) from $125.4 billion to $75.6 billion.

Impacts of Federal-aid Highway Investments Modeled by NBIAS

For bridges on Federal-aid highways, *Exhibit 10-16* compares performance projections for 2034 at various levels of investment with measured performance in 2014. If spending on the types of improvements modeled in NBIAS were sustained at the 2014 level of $10.5 billion (in constant dollars), performance is projected to improve slightly. The percent of bridges in “poor” condition would decrease from 6.5 percent to 6.3 percent weighted by deck area, and the average Health Index would rise from 92.1 to 93.4. The Economic Investment Backlog would decrease by 59.3 percent (to $60.6 billion) from its 2014 level of $102.2 billion.

Exhibit 10-16: Projected Impact of Alternative Investment Levels on 2034 Bridge Condition Indicators for Federal-aid Highway Bridges



NBIAS-Modeled Investment on Federal-aid Bridges	Projected 2034 Condition Indicators—Federal-aid Bridges					Link to Chapter 7 Scenario
	Weighted by Deck Area					
Average Annual Investment (Billions of 2014 Dollars)[1]	Percent Good	Percent Fair	Percent Poor	Health Index	Economic Investment Backlog (Billions of 2014 Dollars)[1]	
$18.4	53.9%	45.6%	0.5%	95.2	**$0.0**	BCR>=1.0
$14.4	54.5%	44.6%	0.8%	95.3	**$0.6**	
$12.5	54.0%	43.0%	2.9%	94.9	**$25.0**	
$10.5	52.9%	40.8%	6.3%	93.4	**$60.6**	2014 Spending
$10.4	52.9%	40.7%	**6.5%**	93.3	**$62.0**	Maintain % Poor
$8.5	51.0%	38.3%	10.6%	91.3	**$100.3**	
$6.5	47.8%	36.0%	16.2%	88.4	**$146.9**	
Base Year Values:	**43.3%**	**50.2%**	**6.5%**	**92.1**	**$102.2**	

[1] The amounts shown do not reflect system expansion needs; the bridge components of such needs are addressed as part of the HERS model analysis.

Source: National Bridge Investment Analysis System.

At the $18.4 billion average annual investment level feeding the Improve Conditions and Performance scenario, NBIAS projects the percent of bridges in "poor" condition weighted by deck area would decrease to 0.5 percent on Federal-aid highways. The Economic Investment Backlog would be reduced to zero by 2034, and the Average Health Index would increase from 92.1 to 95.2.

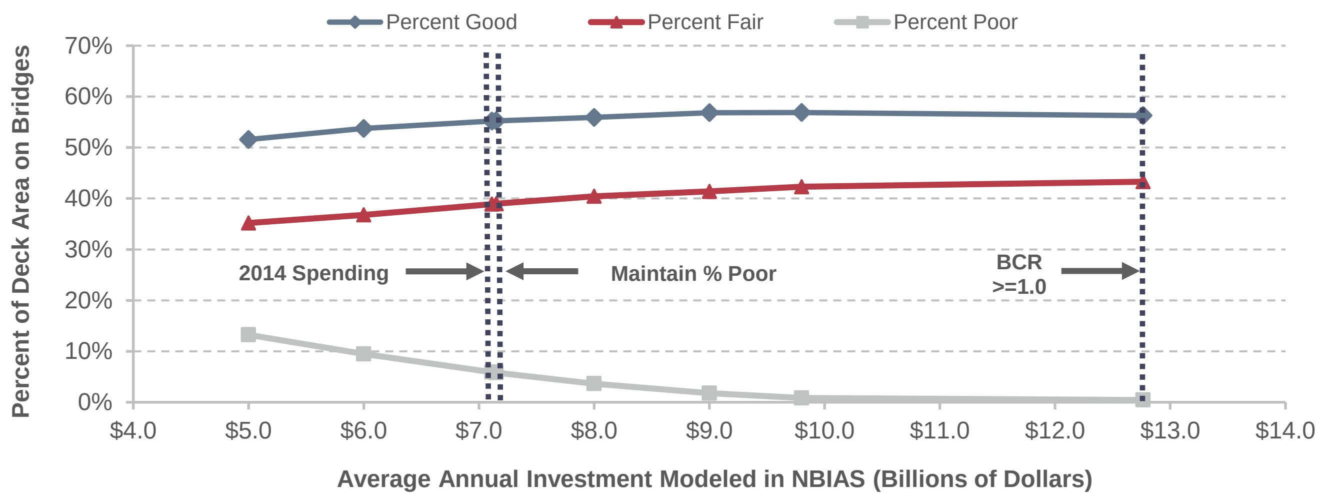
Impacts of NHS Investments Modeled by NBIAS

The impact of various funding levels on the performance of the bridges on the NHS is shown in *Exhibit 10-17*.

If spending on types of improvements modeled in NBIAS on NHS bridges were sustained at the 2014 level of $10.5 billion ($7.1 billion in constant dollar terms), the deck-area-weighted share of bridges in "poor" condition would increase slightly from 5.8 percent in 2014 to 5.8 percent in 2034. The average annual investment needed to maintain this indicator at its 2014 level is slightly higher (also rounding to $7.1 billion per year). This finding deviates from those identified above for all bridges and bridges on Federal-aid highways, for which spending in

2014 was estimated to be above the level needed to maintain this metric at base year levels. For the Improve C&P scenario, the average annual investment level of $7.1 billion would reduce the Economic Investment Backlog to zero by 2034. The percentage of bridges in "poor" condition would decrease from 5.8 in 2014 to 0.4 percent in 2034. The average Health Index would increase from 92.1 to 95.3 during the same period.

Exhibit 10-17: Projected Impact of Alternative Investment Levels on 2034 Bridge Condition Indicators for Bridges on the National Highway System



NBIAS-Modeled Investment on NHS Bridges	Projected 2034 Condition Indicators—NHS Bridges					Link to Chapter 7 Scenario
	Weighted by Deck Area					
Average Annual Investment (Billions of 2014 Dollars)[1]	Percent Good	Percent Fair	Percent Poor	Health Index	Economic Investment Backlog (Billions of 2014 Dollars)[1]	
$12.8	56.3%	43.3%	0.4%	95.3	**$0.0**	BCR>=1.0
$9.8	56.9%	42.3%	0.8%	95.3	**$0.7**	
$9.0	56.8%	41.4%	1.8%	95.3	**$8.3**	
$8.0	55.9%	40.4%	3.7%	94.6	**$24.4**	
$7.1	55.2%	39.0%	**5.8%**	93.6	**$40.3**	Maintain % Poor
$7.1	55.2%	38.9%	5.9%	93.5	**$41.2**	2014 Spending
$6.0	53.7%	36.8%	9.5%	92.0	**$63.9**	
$5.0	51.6%	35.2%	13.2%	90.0	**$87.2**	
Base Year Values:	**42.4%**	**51.8%**	**5.8%**	**92.1**	**$67.1**	

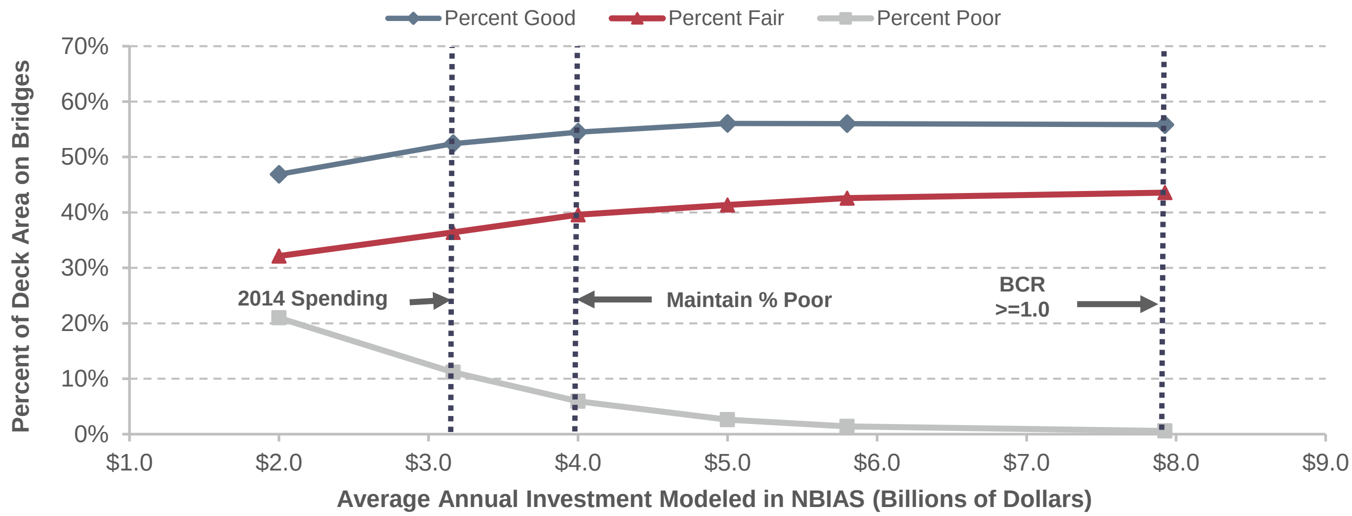
[1] The amounts shown do not reflect system expansion needs; the bridge components of such needs are addressed as part of the HERS model analysis.

Source: National Bridge Investment Analysis System.

Impacts of Interstate System Investments Modeled by NBIAS

Exhibit 10-18 shows the impact of varying funding levels on the performance of bridges on the Interstate System. If spending on types of improvements modeled in NBIAS on Interstate bridges were sustained at the 2014 level of $3.2 billion in constant dollar terms, the share of bridges in "poor" condition would increase from 5.9 percent in 2014 to 11.2 percent in 2034, weighted by deck area. In 2034, the average Health Index would fall from 91.7 to 91.3, and the Economic Investment Backlog would increase slightly to $36.8 billion from the 2014 level of $36.6 billion. An average annual investment of $4.0 billion would be needed to keep the deck area-weighted share of bridges in poor condition from rising above its 2014 level in 2034. For the Improve C&P scenario, the average annual investment level of $7.9 billion is estimated to be sufficient to reduce the Economic Investment Backlog to zero by 2034, decrease the deck area-weighted share of bridges rated as poor to 0.6 percent, and increase the average Health Index to 95.3.

Exhibit 10-18: Projected Impact of Alternative Investment Levels on 2034 Bridge Condition Indicators for Interstate Bridges



NBIAS-Modeled Investment on Interstate Bridges	Projected 2034 Condition Indicators—Interstate Bridges					Link to Chapter 7 Scenario
	Weighted by Deck Area					
Average Annual Investment (Billions of 2014 Dollars)[1]	Percent Good	Percent Fair	Percent Poor	Health Index	Economic Investment Backlog (Billions of 2014 Dollars)[1]	
$7.9	55.8%	43.6%	0.6%	95.3	**$0.0**	BCR >= 1.0
$5.8	56.0%	42.6%	1.4%	95.3	**$0.7**	
$5.0	56.1%	41.3%	2.6%	95.1	**$5.9**	
$4.0	54.5%	39.6%	**5.9%**	93.7	**$20.4**	Maintain % Poor
$3.2	52.4%	36.4%	11.2%	91.3	**$36.8**	2014 Spending
$2.0	46.9%	32.1%	21.0%	86.2	**$66.6**	
Base Year Values:	**36.5%**	**57.5%**	**5.9%**	**91.7**	**$36.6**	

[1] The amounts shown do not reflect system expansion needs; the bridge components of such needs are addressed as part of the HERS model analysis.

Source: National Bridge Investment Analysis System.

Impacts of Transit Investment

This section examines how different types and levels of annual capital investments would likely affect transit system condition and performance by 2034. It begins with an overview of the types of capital spending projected by the Federal Transit Administration's (FTA's) Transit Economic Requirements Model (TERM), the primary analysis tool used to assess transit investment needs and impacts in Part II of this report. The section then examines how variations in the level of annual capital spending are likely to affect future transit conditions and performance.

Key Takeaways

- The 2014 level of investment in service expansion ($6.4 billion) is sufficient to accommodate an average annual ridership increase of 1.3 percent, smaller than the 15-year historical rate of 1.5 percent. This might result in more crowded conditions in stations, trains, and buses, and reduced operating speeds.
- However, the 2014 investment levels are sufficient to accommodate the low ridership growth scenario (1.3 percent). If ridership grows at the 1.3–1.8-percent range (± 0.3 percent around the 15-year historical growth rate), investment in expansion in the $6.0 billion–$8.0 billion range would be needed to avoid deterioration of service quality.

Impacts of Systemwide Investments Modeled by TERM

This section uses TERM analyses to assess how various levels of investment in the preservation and expansion of the Nation's transit asset base can be expected to influence transit conditions and performance over the next 20 years. A key objective here is to place a broad range of potential future investment levels—and the consequences of those levels of investment—within the context of both the current expenditures on transit preservation and expansion and some potential investment goals (e.g., attainment of an SGR within 20 years). More specifically, these analyses consider the impact of different levels of transit capital expenditures on the following:

- Preservation Investments—Average condition rating of U.S. transit assets and SGR backlog
- Expansion Investments—Additional ridership (boardings) capacity

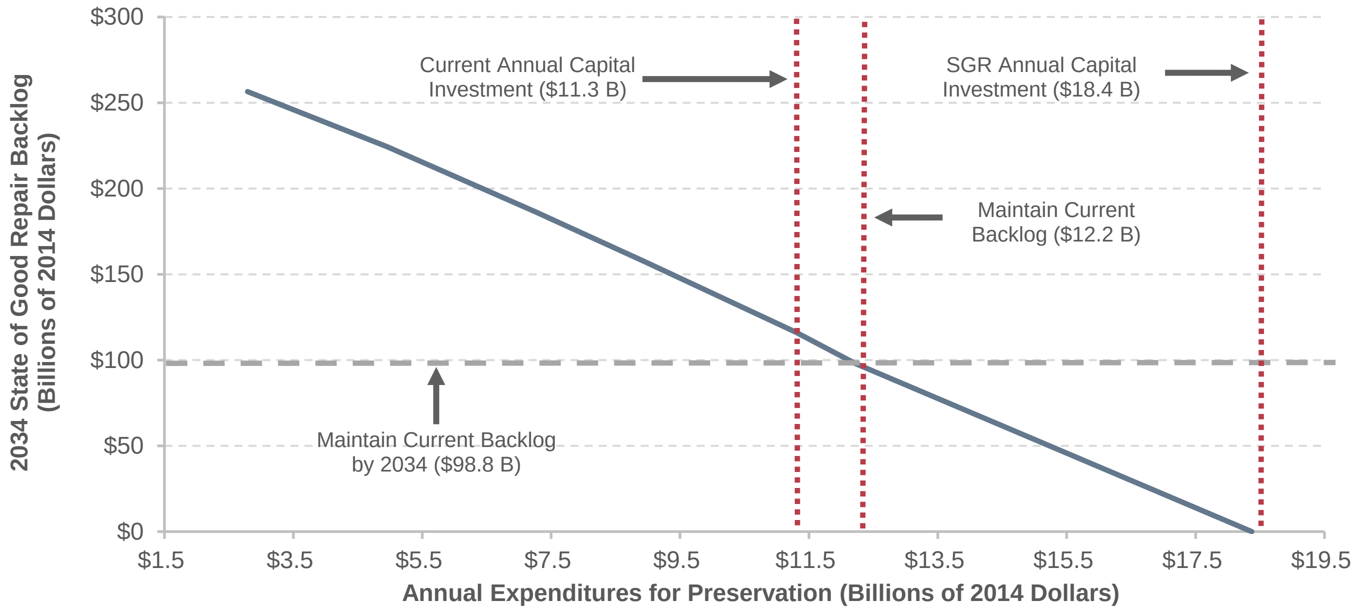
Impact of Preservation Investments on Transit Backlog and Conditions

This subsection considers the expected impact of varying levels of aggregate capital reinvestment by all levels of government on the future investment backlog and physical condition (as of 2034) for the Nation's existing stock of transit assets.

Transit Backlog

The 2010 Conditions and Performance Report introduced the concept of reinvestment backlog as an indication of the amount of near-term investment that would be needed to replace assets that are beyond their expected useful lifetime. Reinvestment backlog focuses attention on assets that are in the worst condition rather than on the average condition of all assets, which is reported in *Exhibit 10-19* and had been the primary measure in previous editions. This additional perspective is needed because average condition has become less meaningful in the current environment as an indicator of the health of the current system, with high levels of investment in new assets for transit system expansion raising the systemwide averages independent of the state of existing transit assets. Reinvestment backlog is a measure of the potential need for investment in infrastructure preservation. TERM estimates that reinvestment backlog is $98.0 billion (see Chapter 7).

Exhibit 10-19: Impact of Preservation Investment on 2034 Transit State of Good Repair Backlog in All Urbanized and Rural Areas[1]



Average Annual Investment (Billions of 2014 Dollars)	Average Annual Percent Change vs. 2014	Average Condition Rating in 2034	Backlog in 2034 (Billions of 2014 Dollars)	Percent Change From Current Backlog	Funding Level Description
$18.4	4.6%	3.01	$0.0	-100%	SGR (Unconstrained, Replace at 2.50)
$12.2	0.8%	2.85	$98.0	0%	Maintain Current Backlog
$11.3	0.0%	2.81	$116.2	19%	2014 Capital Expenditures (Sustain 2014 Spending)
$9.0	-2.4%	2.72	$157.1	60%	
$7.2	-4.8%	2.63	$186.6	90%	
$5.0	-9.4%	2.51	$224.3	129%	
$2.8	-19.0%	2.43	$256.5	162%	

[1] Note that for this report, assets are considered past their useful lives once their estimated condition in TERM falls below condition 2.50.

Source: Transit Economic Requirements Model.

Exhibit 10-19 focuses on the impact of future spending levels on this reinvestment backlog. Specifically, *Exhibit 10-19* presents the estimated impact of differing levels of annual capital reinvestment on the expected size of the reinvestment backlog in 2034. Here the reinvestment backlog is defined as the level of investment required to bring all of the Nation's assets to an SGR. This includes replacing those assets that currently exceed their useful lives (the $98.0 billion) and completing all major rehabilitation activities and replacing assets that will exceed their useful lives during the analysis period. If future reinvestment rates are insufficient to address these ongoing reinvestment needs as they arise, the size of the backlog will increase over time. Reinvestment at a rate above that required to address new needs as they arise will ultimately result in elimination of the existing backlog.

As shown in *Exhibit 10-19*, TERM analysis suggests that the current rate of capital reinvestment of $11.3 billion is insufficient to keep pace with ongoing rehabilitation and replacement needs and, if maintained over the next 20 years, would result in a reinvestment backlog of roughly $116.2 billion by 2034. In contrast, increasing the annual rate of reinvestment to an average of $18.4 billion would eliminate the backlog by 2034. The annual level of reinvestment would need to be increased to roughly $12.2 billion just to maintain the backlog at roughly its current size.

Transit Conditions

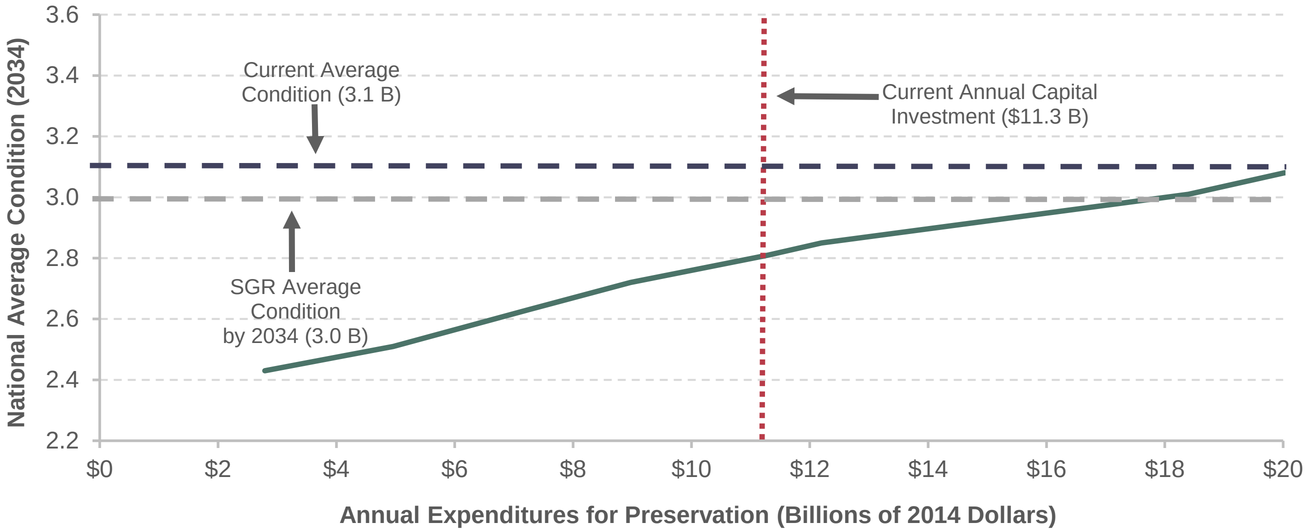
Exhibit 10-20 presents the estimated impact of various levels of annual rehabilitation and replacement investments on the average physical condition of all existing assets nationwide as of 2034. The exhibit shows ongoing improvements to the overall condition of the Nation's existing transit asset base from increasing levels of transit capital reinvestment. Of special note is that average condition provides a measure of asset conditions taken together. Hence, despite the fact that overall conditions improve with additional expenditures, the condition of some individual assets is expected to continue to deteriorate (given the length of asset lives and the timing of their replacement cycles) while the condition of other assets improves. The value of the aggregate measure lies in providing an overall, single measure of asset conditions. Moreover, given the relationship between asset condition and asset reliability, any general improvement in overall asset conditions also can be associated with related improvements to service quality and reliability.

The table portion of *Exhibit 10-20* presents the same investment and average condition information as in the chart. This table also presents the impact of reinvestment on asset conditions for five key transit asset categories (i.e., guideway and track, facilities, systems, stations, and vehicles) and the average annual percentage change in constant dollar funding from 2014 levels to achieve each projected condition level.

Further review of *Exhibit 10-20* reveals several observations: First, almost none of the selected reinvestment rates presented (including the 2014 level of reinvestment, which was $11.3 billion) is sufficient to maintain aggregate conditions at or near the current national average condition rating of 3.1. Only the highest reinvestment rate presented here of $21.8 billion annually (replacement at condition rating 3.0), which is an aggressive reinvestment rate, is sufficient to maintain aggregate conditions at current levels. A primary factor driving this result is the ongoing expansion investment in new rail systems over the past several decades. Although this expansion investment has tended to maintain or even increase the average condition rating of assets nationwide (despite the ongoing deterioration of older assets), it also has resulted in an average condition rating that is not sustainable in the long term (i.e., without including the influence of further expansion investments or replacing assets at an unreasonably early age).

Second, reinvestment at roughly $18.4 billion annually is required to attain an SGR condition by 2034, and this level of reinvestment is estimated to yield an average condition value of roughly 3.01 by that year. Given the definition of the SGR benchmark (described in more detail in Chapter 7), which seeks to eliminate the existing investment backlog and then address all subsequent rehabilitation and replacement activities "on time" thereafter, the 3.01 value could be considered representative of the expected long-term average condition of a well-maintained and financially and economically unconstrained national transit system. Hence, an average condition rating of roughly 3.01 represents a more reasonable long-term condition target for existing transit infrastructure than the current aggregate rating of 3.1.

Exhibit 10-20: Impact of Preservation Investment on 2034 Transit Conditions in All Urbanized and Rural Areas



Average Annual Investment (Billions of 2014 Dollars) Total Capital Outlay	Average Annual Percent Change vs. 2014	Average Transit Conditions in 2034						Notes
		Asset Categories					All Transit Assets	
		Guideway	Facilities	Systems	Stations	Vehicles		
$21.8	6.1%	2.75	3.33	3.83	2.99	3.53	3.12	Unconstrained, Replace at 3.00
$20.0	5.4%	2.73	3.33	3.70	2.99	3.47	3.08	Unconstrained, Replace at 2.75
$18.4	4.6%	2.69	3.28	3.58	2.97	3.33	3.01	SGR (Unconstrained, Replace at 2.50)
$12.2	0.8%	2.63	2.68	3.52	2.46	3.25	2.85	Maintain Current Backlog
$11.3	0.0%	2.61	2.68	3.40	2.33	3.25	2.81	2014 Capital Expenditures
$9.0	-2.4%	2.47	2.68	3.30	2.31	3.25	2.72	
$7.2	-4.8%	2.43	2.68	3.00	2.24	3.21	2.63	
$5.0	-9.4%	2.36	2.68	2.64	2.22	3.03	2.51	
$2.8	-19.0%	2.32	2.68	2.56	2.21	2.70	2.43	

[1] Note that the conditions of individual transit assets are estimated using TERM's asset decay curves, which estimate asset conditions on a scale of 5 (excellent) through 1 (poor), as described earlier in this chapter and in Appendix C of this report. The average national condition is the weighted average of the condition of all assets nationwide, weighted by the estimated replacement cost of each asset.

[2] Note that this preservation analysis is intended to consider reinvestment needs only for existing transit assets (as of 2014), not for expansion assets to be added to the existing capital stock in future years.

Source: Transit Economic Requirements Model.

Another observation is that a significant level of reinvestment is required to alter the estimated 2034 average condition measure by a point or more. This result is also driven in part by a large proportion of transit assets with expected useful lives of 80 years or more that will not require significant reinvestment over the 20-year period of this analysis (regardless of the level of reinvestment). These assets tend to contribute a high weighting in the average condition measure, making the measure somewhat insensitive to the rate of reinvestment (note that a high proportion of reinvestment activity is focused on the replacement of those assets with relatively shorter useful lives, such as vehicles).

Finally, TERM prioritizes asset needs based on five criteria (condition, reliability, safety, riders impacted, and operations and maintenance cost impacts) with condition having the highest weighting. Replacement and rehabilitation investments are both subject to this same prioritization scoring. Replacement needs tend to score higher, however, as they tend to reflect the needs of assets that are in poorer condition than those assets requiring rehabilitation. Therefore, rehabilitation needs tend not to be addressed until most (but far from all) replacement needs are addressed. TERM currently predicts improvement in asset condition only following a replacement. Thus, expenditures beyond approximately $11.8 billion on the chart increase total cost as rehabilitation projects are added, but these projects do not contribute to an increase in condition.

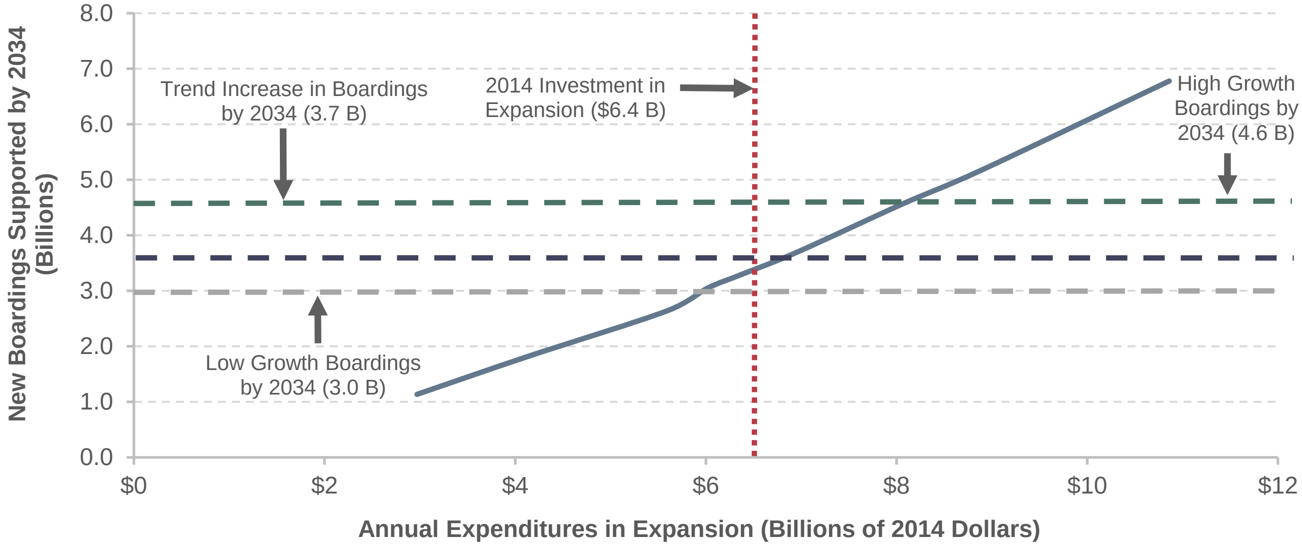
Impact of Expansion Investments on Transit Ridership

Although capital spending on preservation primarily benefits the physical condition of existing transit assets, expansion investments are typically undertaken to expand the asset base to accommodate projected growth in ridership and potentially to improve service performance for existing transit system users.

Exhibit 10-21 shows the relationship between aggregated annual capital spending by all levels of government on expansion investments and the additional number of annual passenger boardings that transit systems would be able to support by 2034. More precisely, this chart presents the level of expansion investment required to ensure that transit vehicle occupancy rates are maintained at current levels over the next two decades for a broad range of the potential rates of growth in transit passenger miles traveled. As the upward sloping curve of the chart indicates, higher levels of investment are required to support greater numbers of additional riders at a constant level of service. If investment levels are insufficient to support the projected growth in ridership fully, vehicle occupancy rates will tend to increase, leading to increased crowding on high-utilization systems and potentially leading to increased dwell times at stops, reduced average operating speeds, and increased rates of vehicle wear. Conversely, if the rate of transit capacity expansion exceeds the actual rate of ridership growth, occupancy rates will tend to decline, but cost-effectiveness (operating expenses per PMT) and other financial indicators will worsen, increasing the operating deficit which might require fare increases and/or additional State, local, or Federal assistance.

The findings presented in *Exhibit 10-21* suggest the following trends. First, the 2014 rate of investment in asset expansion ($6.4 billion in 2014 dollars) could support roughly 3.3 billion additional boardings by 2034 (approximately a 1.3-percent annual growth in ridership). If the actual rate of future ridership growth is close to the trend rate of growth for the past 15 years, an average capital investment of $7.0 billion annually in transit expansion would be required over the next 20 years to support an additional 3.7 billion annual boardings—again after excluding expansion investments that do not pass TERM's benefit-cost test. Thus, the 2014 level of transit capital expansion investment is close to—but somewhat less than—that required to support future rider growth, assuming future growth aligns with the 15-year historical trend. The end result would be increased crowding on some bus and rail systems, increased rates of asset wear, and the potential for increased service delays due to crowding, dwell time increases, and breakdowns.

Exhibit 10-21: New Ridership Supported in 2034 by Expansion Investments in All Urbanized and Rural Areas



Total New Boardings by 2034				
Average Annual Investment (Billions of 2014 Dollars)	**Average Annual Percent Change vs. 2010-2014 Average**	**New Riders Supported (Billions of Annual Boardings)**	**Average Annual Growth in Boardings[1]**	**Funding Level Description**
$10.9	5.0%	6.8	2.5%	Highest Growth Scenario (+1.0%)
$8.9	3.2%	5.2	2.0%	Higher Growth Scenario (+0.5%)
$8.1	2.3%	4.6	1.8%	High Growth Scenario (+0.3%)
$7.0	0.9%	3.7	1.5%	15 Year Historic Growth Rate Trend
$6.4	0.0%	3.3	1.3%	2014 Capital Expenditures
$6.0	-0.6%	3.0	1.3%	Low Growth Scenario (-0.3%)
$5.6	-1.3%	2.6	1.1%	Lower Growth Scenario (-0.5%)
$4.1	-4.6%	1.8	0.8%	Lower Growth Scenario (-1.0%)
$3.0	-8.7%	1.1	0.5%	Lowest Growth Scenario (-1.5%)

[1] As compared with total urban ridership in 2014; only includes increases covered by investments passing TERM's benefit-cost test.

Note: TERM assesses expansion needs at the agency-mode level subject to (1) current vehicle occupancy rates at the agency-mode level and (2) expected transit PMT growth at the UZA level (hence, all agency modes within a given UZA are subject to the same transit PMT growth rate). However, TERM does not generate expansion needs estimates for agency modes that have occupancy rates that are well below the national average for that mode.

Source: Transit Economic Requirements Model.

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PART III

Highway Freight Transportation Conditions and Performance

Introduction

The Moving Ahead for Progress in the 21st Century Act (MAP-21), enacted in 2012, included provisions to reduce traffic congestion and improve the efficiency of freight movement. MAP-21 called for freight-specific initiatives, including the development of a National Freight Strategic Plan, the designation of data-driven highway networks relevant to freight, and the establishment of a freight performance measure for the Interstate System. These initiatives subsequently formed the basis for freight provisions in the Fixing America's Surface Transportation (FAST) Act of 2015 (P.L. 114-94). The FAST Act directed FHWA to establish a National Highway Freight Program (NHFP) and a National Highway Freight Network (NHFN) under Title 23 to improve the efficient movement of freight. The law also created a multimodal freight program under Title 49 that requires the establishment of the National Multimodal Freight Network (NMFN). In addition, the FAST Act required the Federal Highway Administration (FHWA) Administrator to submit to Congress a report describing the conditions and performance of the NHFN.

As stated in the Fixing America's Surface Transportation Act:

"…the goals for the National Highway Freight Program are established in Section 167 of Title 23, subsection (b), and are as follows:

- To invest in infrastructure improvements and to implement operational improvements on the highways of the United States that –
  - Strengthen the contribution of the NHFN to the economic competitiveness of the United States;
  - Reduce congestion and bottlenecks on the NHFN;
  - Reduce the cost of freight transportation;
  - Improve the year-round reliability of freight transportation; and
  - Increase productivity, particularly for domestic industries and businesses that create high-value jobs;
- To improve the safety, security, efficiency, and resiliency of freight transportation in rural and urban areas;
- To improve the state of good repair of the NHFN;
- To use innovation and advanced technology to improve the safety, efficiency, and reliability of the NHFN;
- To improve the efficiency and productivity of the NHFN;
- To improve the flexibility of States to support multi-State corridor planning and the creation of multi-State organizations to increase the ability of States to address highway freight connectivity; and
- To reduce the environmental impacts of freight movement on the NHFN…"

Chapter 11 of this report addresses freight transportation on systems (including the National Network and National Highway System) covered in previous versions of the biennial *Status of the Nation's Highways, Bridges, and Transit: Conditions and Performance* Report to Congress (C&P Report).

Chapter 12 addresses the statutory requirement of a report on the conditions and performance of the NHFN. Based on the goals of the NHFP, Chapter 12 discusses metrics used to analyze the current conditions and performance of the NHFN and provides information on freight movement on this network.

CHAPTER 11

Freight Transportation

Freight is generally understood to be merchandise or commodities that are moved by a mode of transportation, such as a truck, ship, aircraft, pipeline, or train. Freight transportation is the physical process of transporting commodities or merchandise from one place to another for a fee.

Freight transportation affects every business and household in some way. The economy of the United States depends on freight transportation to connect businesses to markets throughout the world. Domestic manufacturers rely on the timely delivery of freight to meet production schedules. Wholesalers and retailers depend on a fast, reliable, and cost-effective transportation system. In the expanding world of e-commerce, households and small businesses depend on transportation to deliver freight directly to them. Service providers, public utilities, construction companies, and Government agencies rely on freight transportation to obtain needed equipment and supplies.

Key Takeaways

Freight transportation affects everyone.

By the year 2045, the total value of freight in the United States is expected nearly to double that of 2012.

Trucks move 64 percent of freight by ton and 69 percent of freight by value—by far the single largest mode.

Intermodal Connectors provide the "last mile" linkage between freight facilities and the NHS.

Since the year 2000, States have designated approximately 182 new freight intermodal connectors.

The lack of safe truck parking in all States, and especially in and around large metropolitan areas, is a growing concern to truckers.

As the economy continues to grow in the coming decades, freight transportation demand is expected to increase. Projections released in March 2016 by the U.S. Department of Transportation's (DOT's) Bureau of Transportation Statistics (BTS) and FHWA show that freight tons moving on the Nation's transportation system will grow by 40 percent in the next three decades, and the value of the freight will almost double.[ii]

Freight System

The freight transportation system in the United States includes an extensive network of highways, railroads, waterways, pipelines, and airways: 958,000 miles of Federal-aid highways, 141,000 miles of railroads, 11,000 miles of inland waterways, and 1.6 million miles of pipelines. The United States has more than 19,000 airports and more than 5,000 coastal, Great Lakes, and inland waterway facilities. Freight moves to, from, and within the United States via this extensive network, sometimes using two or more modes along the supply chain, with trucks moving the largest share of freight by tonnage and value. By 2045, the total weight of freight on all modes of transportation is projected to reach 25 billion tons, whereas the value of freight is expected to grow to $37 trillion.[iii]

Exhibit 11-1 identifies the share of total tonnage and value moved by each freight transportation mode in the United States in 2015, broken out by origin and destination (import and export). The domestic movement of freight makes up 89 percent of the total weight of goods transported and 78 percent of the total value of goods transported.

Exhibit 11-1: Mode Share by Tonnage and Value, 2015

Domestic Mode	Millions of Tons				Billions of 2015 USD[1]			
	Domestic Only	Export	Import	Total	Domestic Only	Export	Import	Total
Air (includes truck-air)	0%	0%	0%	0%	1%	17%	14%	4%
Multiple Modes & Mail	2%	5%	3%	2%	12%	6%	6%	11%
Other Modes and Unknown	0%	0%	0%	0%	0%	1%	2%	0%
Pipeline	19%	13%	16%	18%	9%	4%	4%	8%
Rail	9%	15%	9%	9%	3%	5%	5%	3%
Truck	66%	52%	35%	64%	73%	57%	53%	69%
Water	4%	15%	11%	5%	3%	10%	9%	4%
No Domestic Mode	0%	0%	25%	2%	0%	0%	7%	1%
Total	**16,045**	**912**	**1,099**	**18,056**	**15,558**	**1,745**	**2,567**	**19,871**

[1] USD = U.S. dollars.

Source: Bureau of Transportation Statistics and FHWA, Freight Analysis Framework, version 4, 2016.

Freight transportation movements are expected to increase over the next few decades, as global populations grow and consumer spending power increases. *Exhibit 11-2* shows historical and forecasted mode share in ton-miles from 1990–2040. The data reveal that most freight transportation modes are expected to experience increased volumes, although the amount of expected growth will vary by mode, with pipelines projected to have negative growth to year 2040.

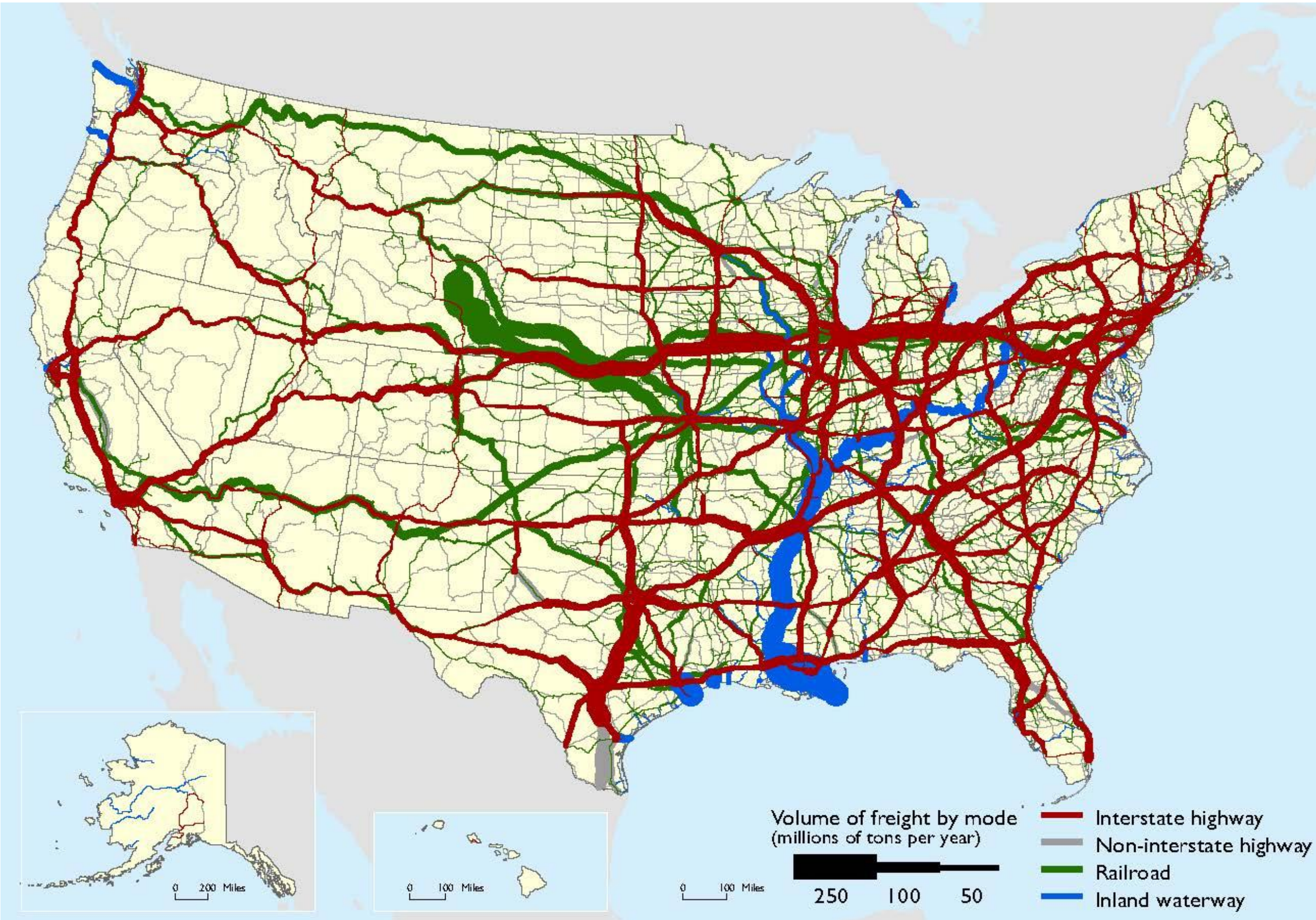
Exhibit 11-2: Historical and Forecasted Mode Share of Ton-miles, 1990–2040

Domestic Mode	Ton-miles Mode Share					Average Annual Growth Rate (percent)			
						Historical		Forecast	
	1990	2000	2010	2015	2040	1990 to 2000	2000 to 2010	2010 to 2015	2015 to 2040
Truck	36.4%	42.3%	44.0%	46.5%	54.4%	3.2	1.0	3.0	1.6
Railroad	22.9%	28.1%	29.4%	28.7%	25.9%	3.8	1.1	1.4	0.6
Pipeline	22.0%	17.3%	17.0%	16.7%	12.1%	-0.8	0.5	1.5	-0.3
Domestic Water Transportation	17.9%	11.5%	8.8%	7.4%	6.8%	-2.8	-2.0	-1.8	0.6
Air	0.8%	0.7%	0.8%	0.7%	0.7%	1.1	1.0	0.9	0.8
Total Ton-miles (trillions)	**4.8**	**5.6**	**6.0**	**6.6**	**8.4**	**1.6**	**0.6**	**1.9**	**1.0**

Source: 2016 Freight Quick Facts Report, DOT, Draft National Freight Strategic Plan, BTS Special Tabulation, Figure 4.

Exhibit 11-3 illustrates freight tonnage in 2014 by mode on the National Highway System (NHS), Class I railroads, and inland waterways.

Exhibit 11-3: Tonnage on Highways, Railroads, and Waterways, 2014



Sources: Highways—Federal Highway Administration, Freight Analysis Framework, Version 4; Rail—Surface Transportation Board, Annual Carload Waybill Sample, Federal Railroad Administration, Rail Freight Flow Assignments (2012); Waterways—U.S. Army Corps of Engineers (USACE), Annual Vessel Operating Activity, Tennessee Valley Authority, Lock Performance Monitoring System data for USACE, USACE Institute for Water Resources, Waterborne Foreign Trade Data, USACE Water Flow Assignments (2012).

Freight Transportation Demand

The BTS publication *Freight Facts and Figures 2015* indicates that the U.S. freight transportation system handled a record amount of freight in 2014. A daily average of approximately 55 million tons of freight valued at $49.3 billion moved across the transportation system in 2014 to meet the needs of the Nation's 122.5 million households, 7.5 million business establishments, and 90,056 Government units.[iv]

Freight transportation is important to the overall economy. In 2014, freight transportation establishments serving for-hire transportation and warehousing operations employed nearly 4.6 million workers and comprised 9.5 percent of the Nation's economic activity as measured by gross domestic product (GDP). Truck driving is by far the largest freight transportation occupation, with approximately 2.83 million truck drivers.[v] About 57.5 percent of these professional truck drivers operate heavy or tractor-trailer trucks and 28.2 percent drive light or delivery service trucks.[vi]

The BTS Freight Transportation Services Index (TSI) measures the output of services provided by for-hire transportation industries. This freight index correlates strongly with U.S. economic activity and helps illustrate the relationship between freight transportation and long-term changes in the U.S. economy.

Exhibit 11-4 shows the annual Freight TSI figures for the years 2000 and 2005–2016. The TSI declined steadily from 2005 through 2009. However, since 2010, the TSI has steadily increased, reaching its highest level in 2016.

The highway system is the most-used mode of transport for freight by tonnage and by the value of goods moved. The highway system is composed of all Federal, State, local, and private roads that move freight by commercial vehicles. The total tonnage for trucking is forecasted to grow by almost 45 percent by 2045, and the value of freight is forecasted to increase by 84 percent.[vii] The major highway systems that support the movement of freight are described in the following sections.

Exhibit 11-4: Annual Freight Transportation Services Index, 2000–2016[1]

Year	Freight TSI
2000	100.0
2005	112.4
2006	111.5
2007	110.1
2008	108.8
2009	98.3
2010	106.4
2011	110.9
2012	112.1
2013	116.2
2014	120.4
2015	122.1
2016	122.3

[1] The TSI is indexed such that the Year 2000 TSI equals 100.0.

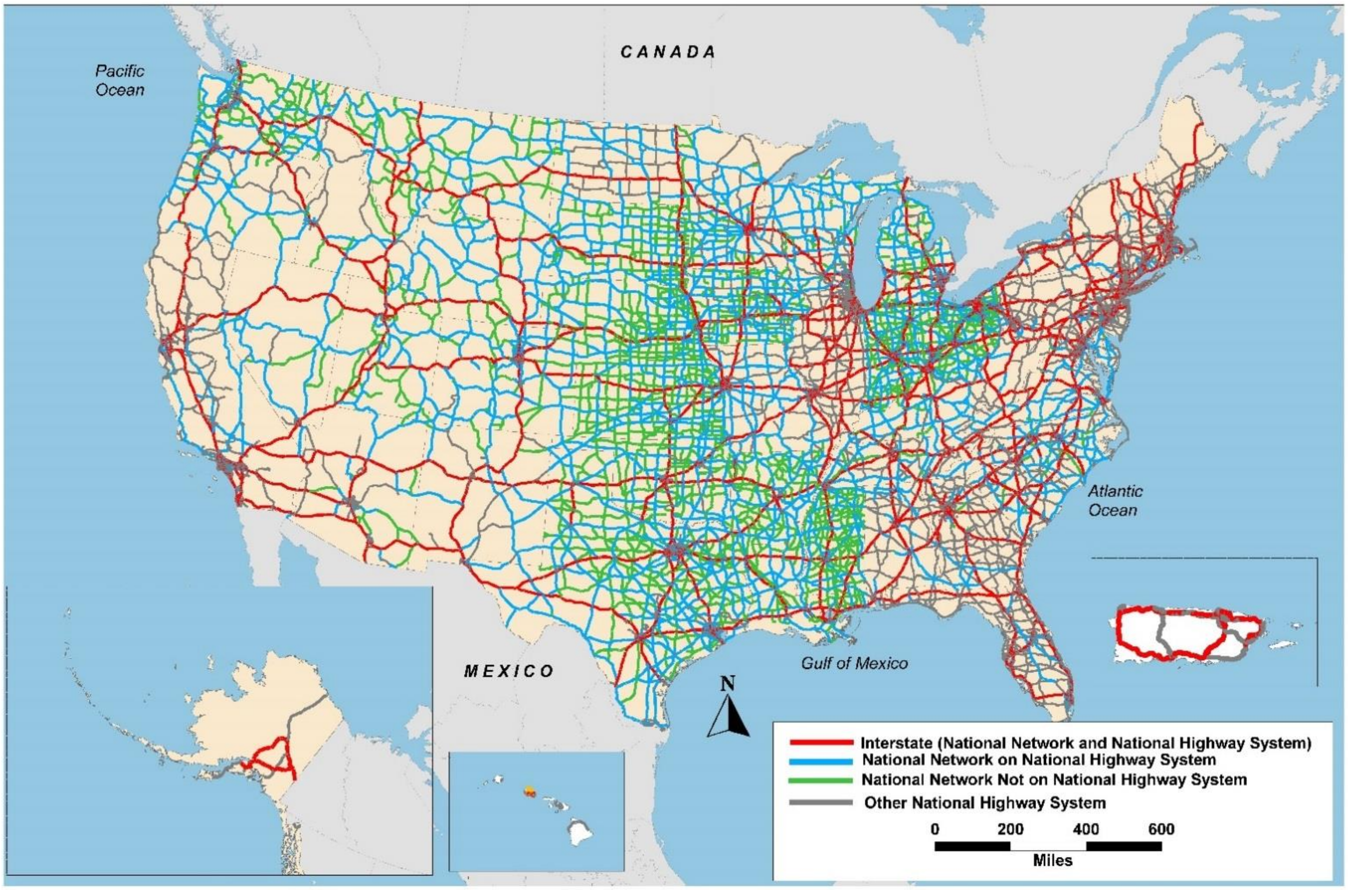
Source: U.S. Department of Transportation, Office of the Assistant Secretary for Research and Technology, Bureau of Transportation Statistics.

Freight Highway Systems

National Network

The National Network is the system of roadways officially designated to accommodate commercial freight-hauling vehicles authorized by the Surface Transportation Assistance Act (STAA) of 1982 (P.L. 97-424) and specified in the U.S. Code of Federal Regulations (23 CFR 658). The STAA requires States to allow conventional truck-trailer combinations on the Interstate System and certain portions of the Federal-aid Primary System. Conventional combinations are tractors with one semitrailer up to 48 feet in length or with one 28-foot semitrailer and one 28-foot trailer, and can be up to 102 inches wide. Currently, most States allow conventional combination trucks with single trailers up to 53 feet in length to operate without permits on their portions of the National Network. These National Network routes for conventional combination trucks as of 2014 are illustrated in *Exhibit 11-5*.

Exhibit 11-5: National Network for Conventional Combination Trucks, 2014[1,2]



[1] This map should not be interpreted as the official National Network and should not be used for truck size and weight enforcement purposes. The National Network and the National Highway System (NHS) are approximately 200,000 miles in length, but the National Network includes 65,000 miles of highways beyond the NHS, and the NHS encompasses about 50,000 miles that are not part of the National Network.

[2] "Other NHS" refers to NHS mileage that is not included on the National Network. Conventional combination trucks are tractors with one semitrailer up to 48 feet in length or with one 28-foot semitrailer and one 28-foot trailer. Conventional combination trucks can be up to 102 inches wide.

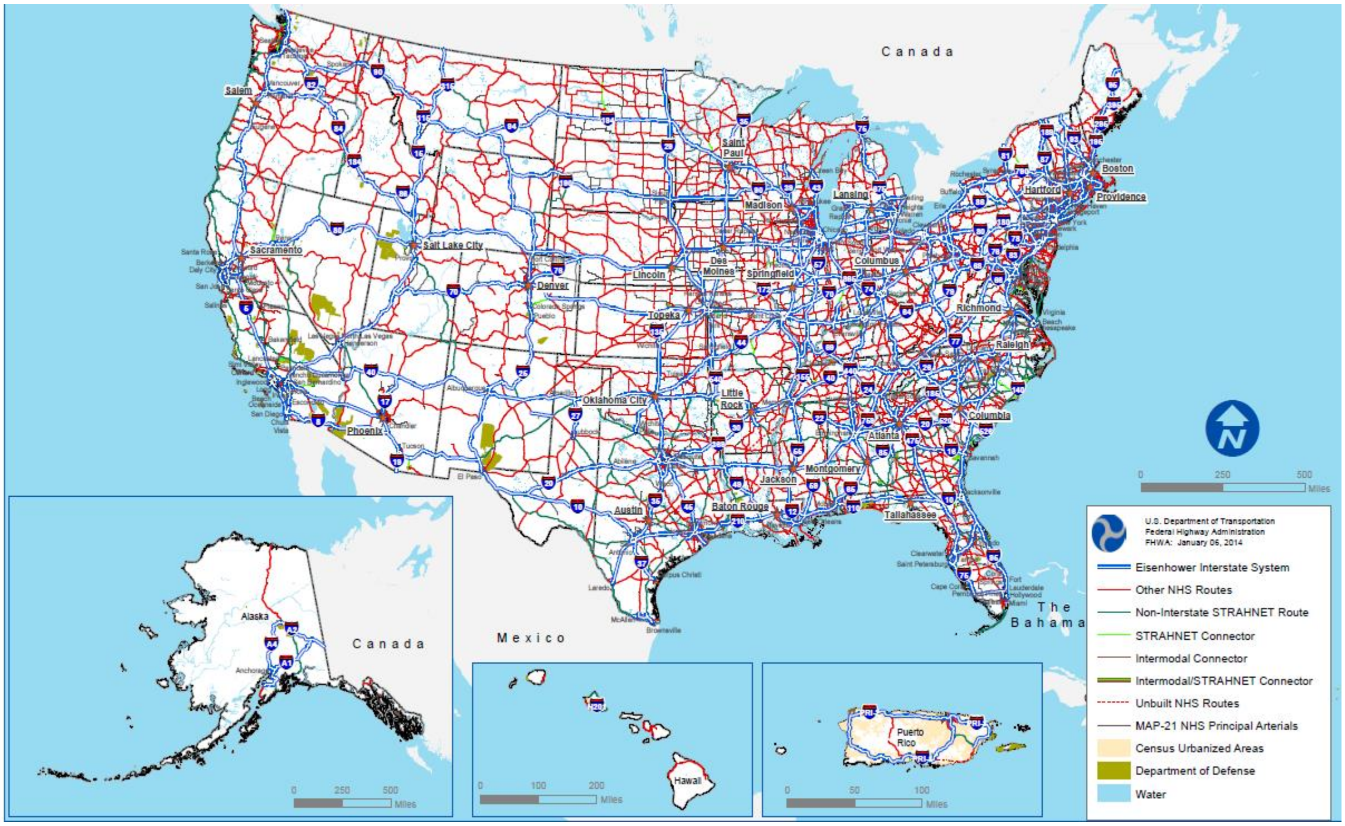
Source: DOT, FHWA, Office of Freight Management and Operations, Freight Analysis Framework, version 3.4, 2013.

National Highway System

The National Highway System (NHS) consists of roadways important to the Nation's economy, defense, and mobility. The NHS was developed by DOT in cooperation with the States, local officials, and metropolitan planning organizations (MPOs).

As discussed in Chapter 1, the NHS includes the Interstate System of Highways, other principal arterials, the Strategic Highway Network (STRAHNET), major strategic highway network connectors, and intermodal connectors. *Exhibit 11-6* shows the National Highway System as of 2014.

Exhibit 11-6: National Highway System (NHS)



Source: DOT, 2014.

Intermodal Connectors

Freight intermodal connectors are the roads that provide the "last mile" connection between major intermodal freight facilities and the NHS. They are critical components of our transportation system and can affect the timely and reliable delivery of goods. Public roads leading to major intermodal terminals are designated as NHS connectors by the DOT, in cooperation with State departments of transportation and MPOs. When considering changes to the intermodal connectors, FHWA reviews several factors, including annual freight volumes, daily vehicular traffic, and the importance of an intermodal facility within a specific State.[viii]

Exhibit 11-7 shows the number of new freight intermodal connectors, by mode, added to the NHS and the percentage change between the years 2000 and 2014. In total, 182 connectors were added, representing a 30-percent increase in the designation of intermodal connectors.

Exhibit 11-7: Number of Freight Intermodal Connectors by Mode, 2000–2014

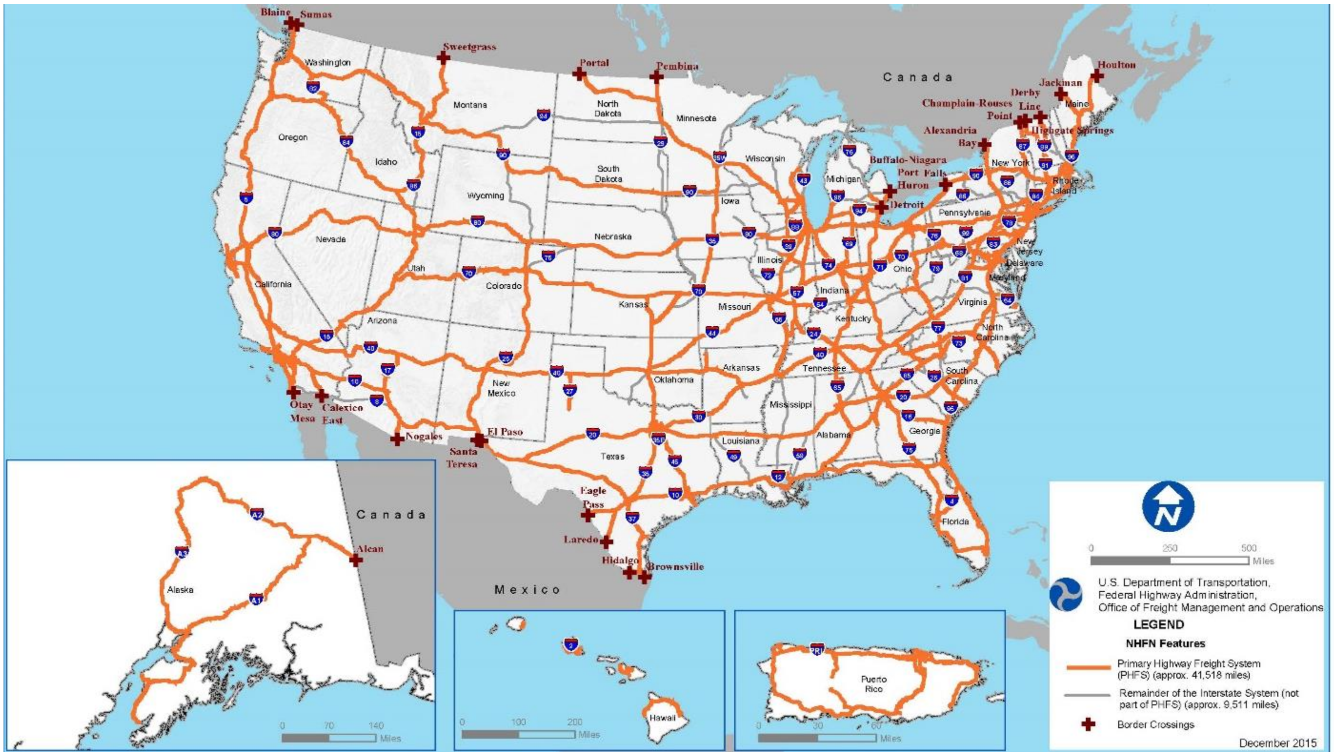
Mode	2000 Connectors	2014 Connectors	Net Change	Percentage Change
Port	252	329	77	31%
Rail	204	269	65	32%
Airport	99	132	33	33%
Pipeline	61	68	7	11%
Total	**616**	**798**	**182**	**30%**

Source: *Final Report, FHWA Freight Intermodal Connectors Study*, April 2017, Table 1.

National Highway Freight Network

The Fixing America's Surface Transportation (FAST) Act directed the FHWA Administrator to establish a National Highway Freight Network (NHFN) to strategically direct Federal resources and policies toward improved performance of highway portions of the U.S. freight transportation system. (See *Exhibit 11-8.*)

Exhibit 11-8: National Highway Freight Network (NHFN)



Source: DOT, FHWA Office of Freight Management and Operations, 2015.

The NHFN includes the following subsystems of roadways:

- **Primary Highway Freight System (PHFS):** This is a network of highways identified as the most critical highway portions of the U.S. freight transportation system, determined by measurable and objective national data. The network consists of 41,518 centerline miles, including 37,436 centerline miles of Interstate and 4,082 centerline miles of non-Interstate roads.
- **Other Interstate portions not on the PHFS:** These highways consist of the remaining portion of Interstate roads not included in the PHFS. These routes provide important continuity and access to freight transportation facilities. These portions amount to an estimated 9,511 centerline miles of Interstate nationwide, and will fluctuate with additions and deletions to the Interstate Highway System.
- **Critical Rural Freight Corridors (CRFCs):** These are public roads not in an urbanized area that provide access and connection to the PHFS and the Interstate System with ports, public transportation facilities, or other intermodal freight facilities.
- **Critical Urban Freight Corridors (CUFCs):** These are public roads in urbanized areas that provide access and connection to the PHFS and the Interstate System with ports, public transportation facilities, or other intermodal transportation facilities.

The NHFN consists of an estimated total of 51,029 centerline miles, not including CRFCs and CUFCs. Congress granted States, and in certain cases, MPOs, the ability to designate additional public roads as CRFCs and CUFCs in accordance with Section 1116 of the FAST Act. Designation is subject to mileage limitations. FHWA must re-designate the PHFS every 5 years, subject to a cap of up to 3 percent growth in total mileage with each re-designation.

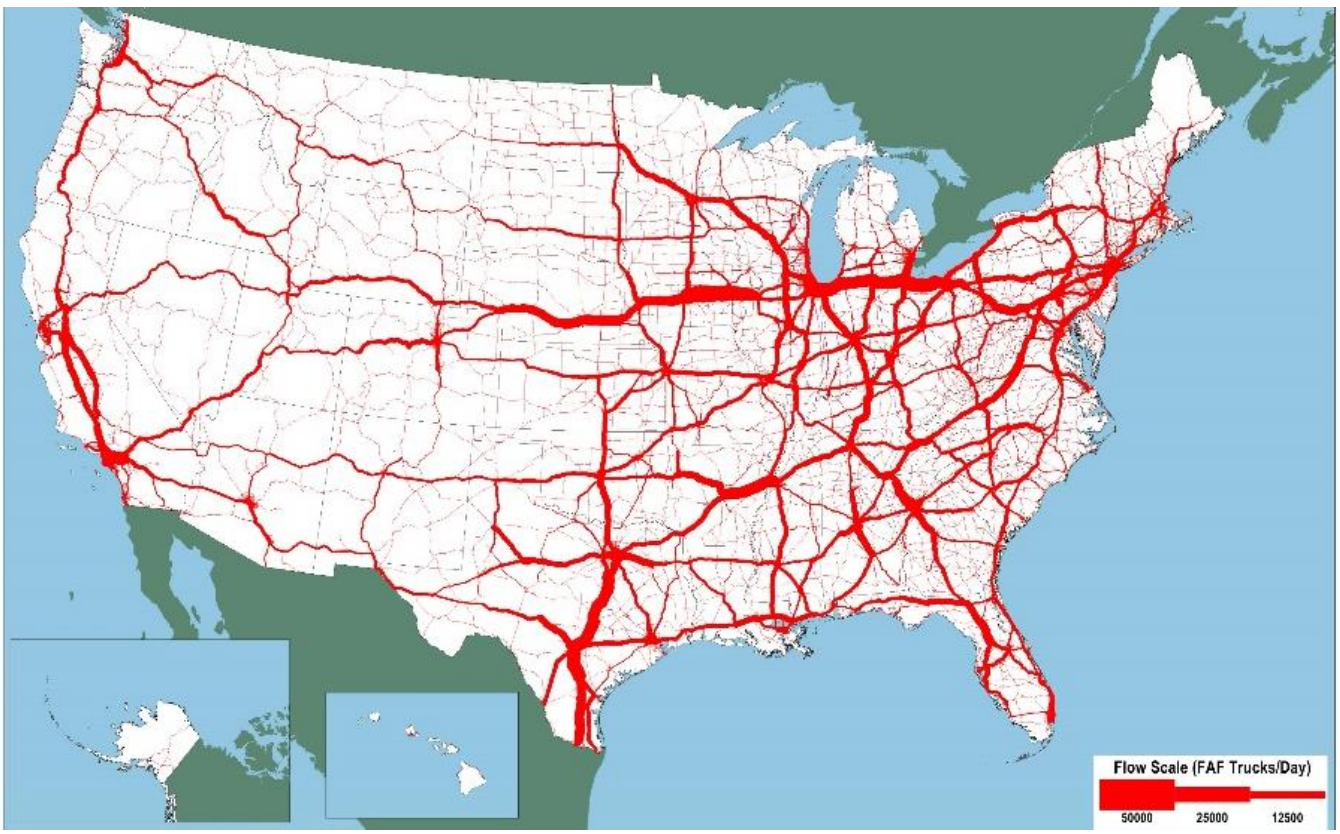
Freight on the NHS

As stated earlier, freight transportation is expected to increase over the next 30 years.

Approximately 50 percent of large freight trucks (trucks with a gross vehicle weight of over 10,000 pounds) operate within 50 miles of their origination and account for about 30 percent of truck vehicle miles traveled (VMT). By contrast, only 10 percent of large trucks operate more than 200 miles away from their origin, but these large trucks account for more than 30 percent of overall truck VMT. Long-distance truck travel also accounts for nearly all freight ton-miles and a large share of truck VMT.[ix]

The map in *Exhibit 11-9* illustrates the average daily long haul freight truck volumes on the NHS in 2012, and the map in *Exhibit 11-10* illustrates the forecasted average daily long haul truck freight volumes in 2045 on the NHS.

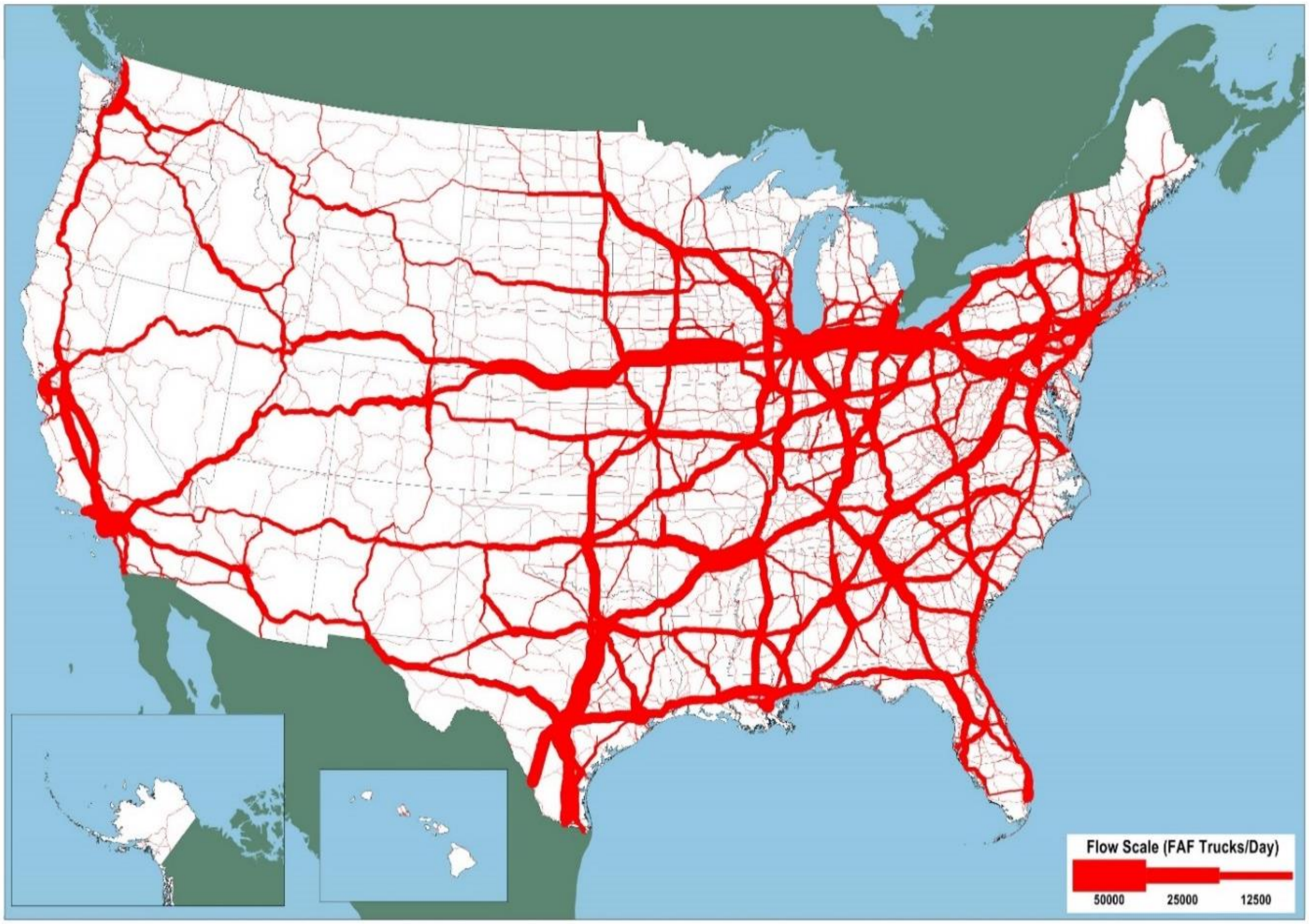
Exhibit 11-9: Average Daily Long Haul Freight Truck Traffic on the NHS, 2012



Note: Major flows include domestic and international freight moving by truck on highway segments with more than 25 FAF trucks per day and between places typically more than 50 miles apart.

Source: DOT, FHWA Office of Freight Management and Operations, Freight Analysis Framework, version 4.3, 2017.

Exhibit 11-10: Forecasted Average Daily Long Haul Freight Truck Traffic on the NHS, 2045



Note: Major flows include domestic and international freight moving by truck on highway segments with more than 25 FAF trucks per day and between places typically more than 50 miles apart.

Source: DOT, FHWA Office of Freight Management and Operations, Freight Analysis Framework, version 4.3, 2017.

These maps illustrate the projected increase in tonnage flows across the NHS (*Exhibit 11-10*) compared with the current tonnage flows shown in *Exhibit 11-9*. Truck volumes on many key routes of the NHS are expected to increase significantly between 2014 and 2045. These projected increases can have major implications for highway congestion and freight movement efficiency, especially near large urban areas along major truck corridors.

Trucks carry high-value, time-sensitive freight, as well as lower-value, bulk tonnage such as agricultural products, gasoline for local distribution, and municipal solid waste. *Exhibit 11-11* shows truck VMT and registrations for 2014. In this table, data reveal that combination trucks and single-unit trucks account for 9.2 percent of total miles driven in 2014. On average, combination trucks drove approximately five times more miles per year than did single-unit trucks.

Exhibit 11-11: Truck Vehicle Miles Traveled and Registrations, 2014[1]

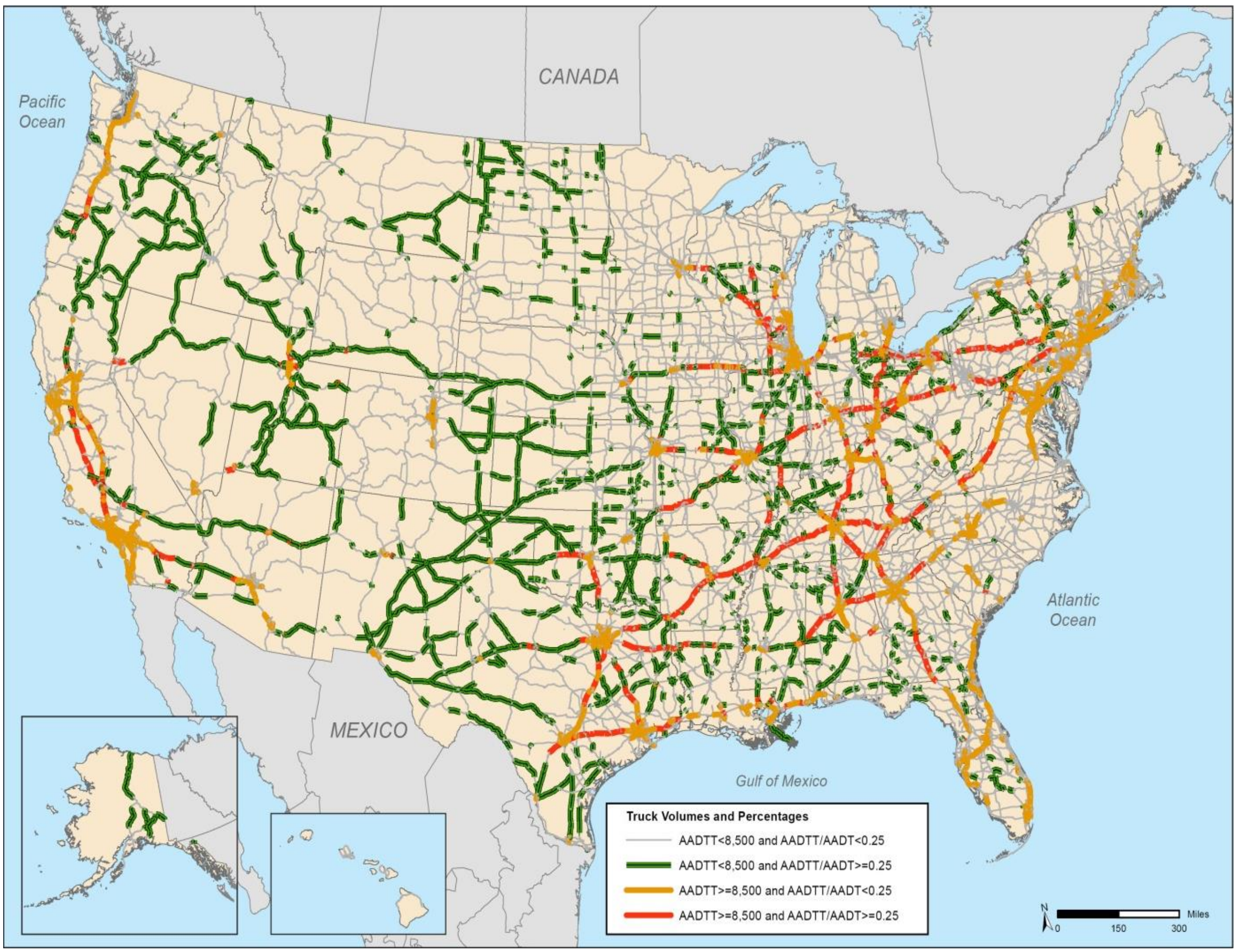
Vehicle Type	Urban and Rural Miles		Registered Vehicles		Average VMT per Year
	Billion VMT	Percent	Billion VMT	Percent	
Single-unit Trucks	109.3	3.6	8.3	3.2	13,123
Combination Trucks	169.8	5.6	2.6	1.0	65,897
All Vehicles	3,025.7	100.0	260.4	100.0	11,621

[1] VMT = vehicle miles traveled.

Source: FHWA Highway Statistics 2014, Table VM-1. (https://www.fhwa.dot.gov/policyinformation/statistics/2014/vm1.cfm)

The map in *Exhibit 11-12* identifies the major truck routes on the NHS. These routes handle more than 8,500 trucks per day or are routes where trucks comprise at least 25 percent of the traffic.

Exhibit 11-12: Major Truck Routes on the NHS[1]



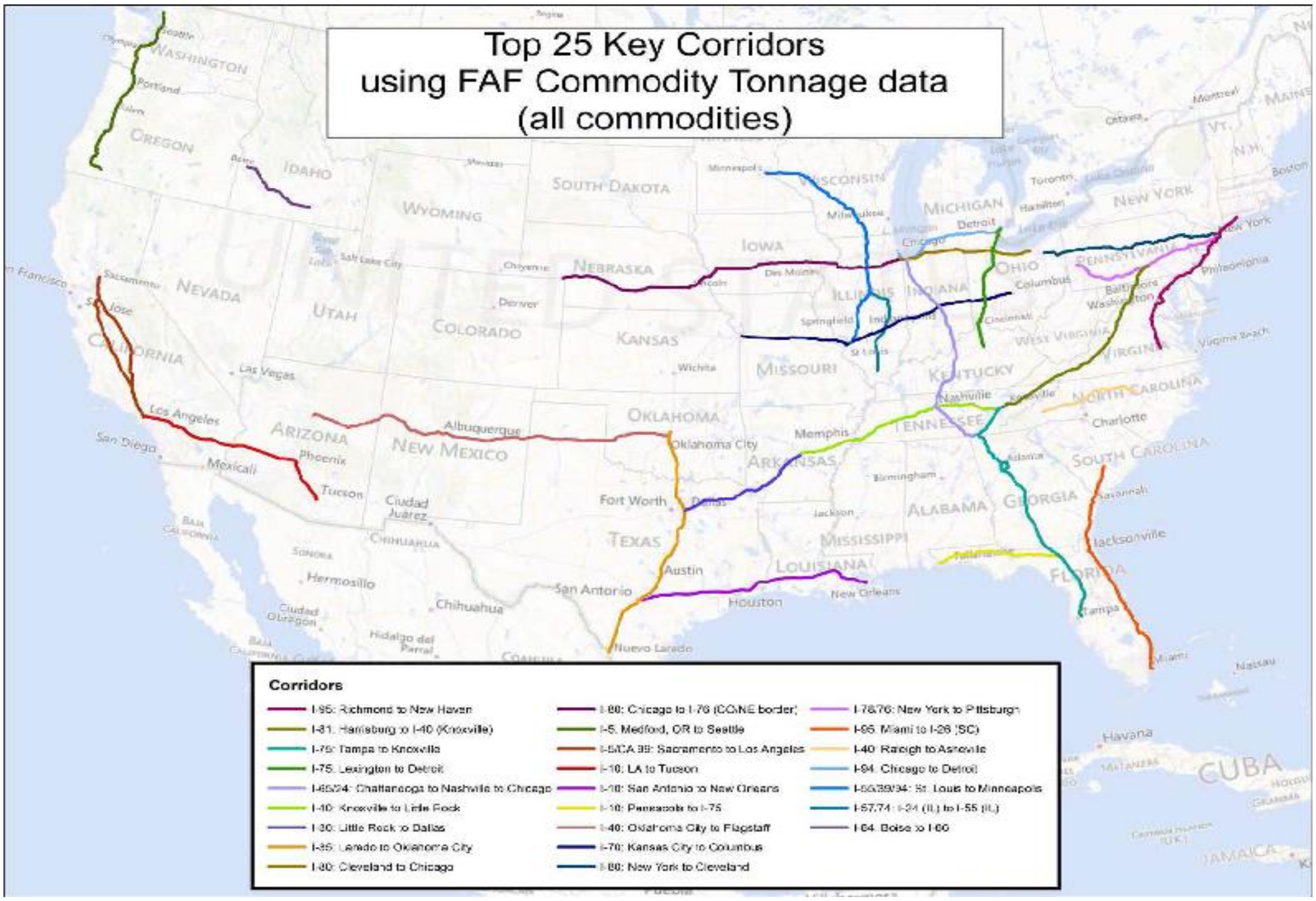
[1] AADTT is average annual daily truck traffic and includes all freight-hauling and other trucks with six or more tires. AADT is average annual daily traffic and includes all motor vehicles. NHS mileage as of 2011, prior to MAP-21 system expansion.

Source: DOT, FHWA Office of Freight Management and Operations, Freight Analysis Framework, Version 3.4, 2013.

Top 25 Domestic Freight Corridors

To determine the top 25 domestic freight corridors, FHWA used Freight Analysis Framework (FAF), version 3 data to identify the top 10 percent of the FAF highway segments by tonnage. FHWA connected segments with the highest tonnage and known freight generators (land uses or groups of land uses that generate high freight transportation volumes, such as truck terminals, intermodal rail yards, water ports, airports, warehouses and distribution centers, or large manufacturing facilities) or population centers (origins and destinations). *Exhibit 11-13* shows the top 25 key corridors with the greatest network commodity tonnage of freight movement, based on FAF data for 2015.

Exhibit 11-13: Top 25 Corridors by Freight Tonnage, 2015



Source: DOT, FHWA Office of Freight Management and Operations, Freight Analysis Framework, FAF version 3.

Freight Challenges

There are substantial challenges to moving freight on a highway network that is projected to see continued increases in freight volume but may be difficult to expand in places to provide additional capacity. To address the challenges and ensure that the U.S. freight system and its highway network are prepared to support U.S. economic growth and competitiveness, freight stakeholders will need to understand and address the impact of increased freight movement on such areas as safety, reliability, efficiency, and the environment. A few of those challenges are described in this section.

Truck Parking

One of the major challenges to the effective movement of freight is that of safe and available truck parking. An inadequate supply of truck parking spaces can have negative consequences. Tired truck drivers may continue to drive because they have difficulty finding a place to park for rest. Truck drivers may choose to park at unsafe locations, such as on the shoulder of the road, exit ramps, or vacant lots, if they are unable to locate official, available parking. With the projected growth of truck traffic, the demand for truck parking will continue to outpace the supply of public and private parking facilities and could exacerbate truck parking problems experienced in many regions.

To address this concern, the *Jason's Law Truck Parking Survey Results and Comparative Analysis* report evaluated the adequacy of truck parking capacity across the Nation. FHWA worked with the American Association of State Highway and Transportation Officials (AASHTO) and other industry stakeholders to develop a truck parking survey that was responsive to a requirement in MAP-21. The survey was administered to every State in 2014. In addition, survey responses were provided by truck drivers, State motor carrier safety enforcement officials, travel plaza and truck stop owners and operators, trucking firm managers, and logistics personnel.

The survey results provided insight into issues associated with providing and maintaining commercial vehicle parking facilities and services, including shortages in geographic regions and a lack of truck parking information. The survey found that more than 75 percent of truck drivers responding said they regularly experienced problems with finding "safe parking locations when rest was needed." Ninety percent reported struggling to find safe parking at night. The report also documented the location of more than 308,000 truck parking spaces, including 36,000 at public rest areas and nearly 273,000 at private truck stops.[x]

The *Jason's Law* report identified several key findings, including the following:

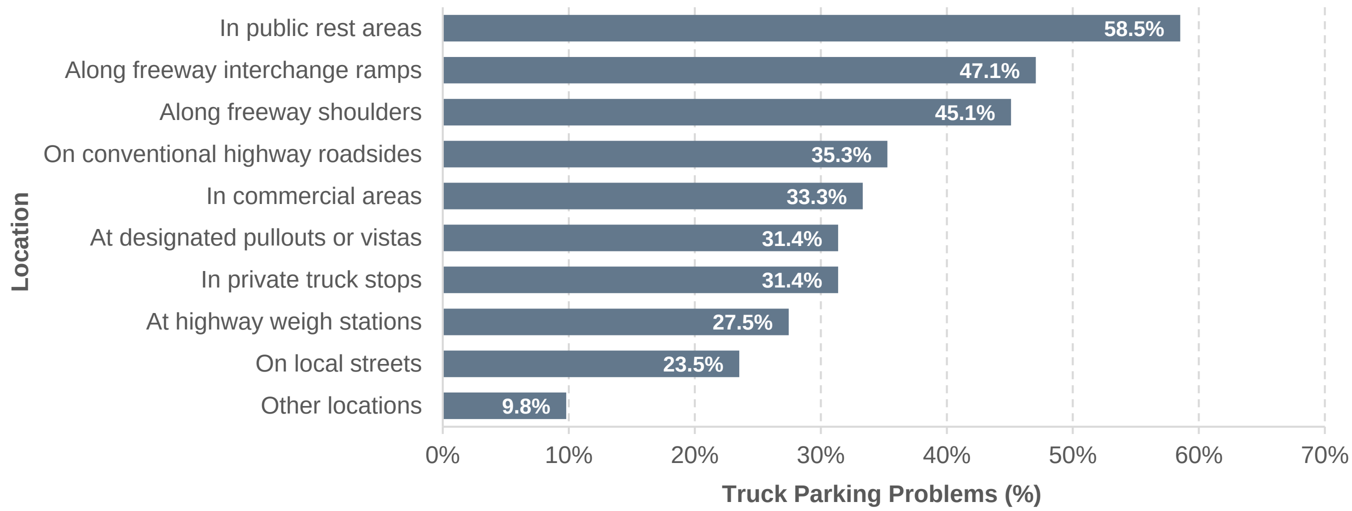
- Truck parking capacity is a problem in all States. The greatest problems were found on major freight corridors and in large metropolitan areas.
- Consistent, continued measurement and data are important to understanding dynamic truck parking needs and whether the situation is changing.
- Truck parking analysis is an important component of State and MPO freight plans, as well as regional and corridor-based freight planning.
- There is a need to understand the supply chains of key industries and major commodities.
- There is a need to understand the movement of freight, within and through a State, to better anticipate and plan for parking needs.
- Local regulations and zoning requirements often create challenges for the development of truck parking facilities.
- Public- and private-sector coordination is critical to address long-term truck parking needs.

The *Jason's Law* survey found that 38 States reported having truck parking problems in 2014. Truck drivers, however, reported truck parking problems in all States.

Most States provided information on observed problems, including shortages and the existence of unofficial parking (parking in areas not designated for parking). Only limited information was reported on actual use of the parking facilities, maintenance, and future parking capacity plans.

The *Jason's Law* survey responses indicated that truck drivers were observed using other, unofficial parking places due to parking shortages. This is indicated in *Exhibit 11-14*, a chart showing the types of truck parking locations in which parking problems were reported by States in 2014.

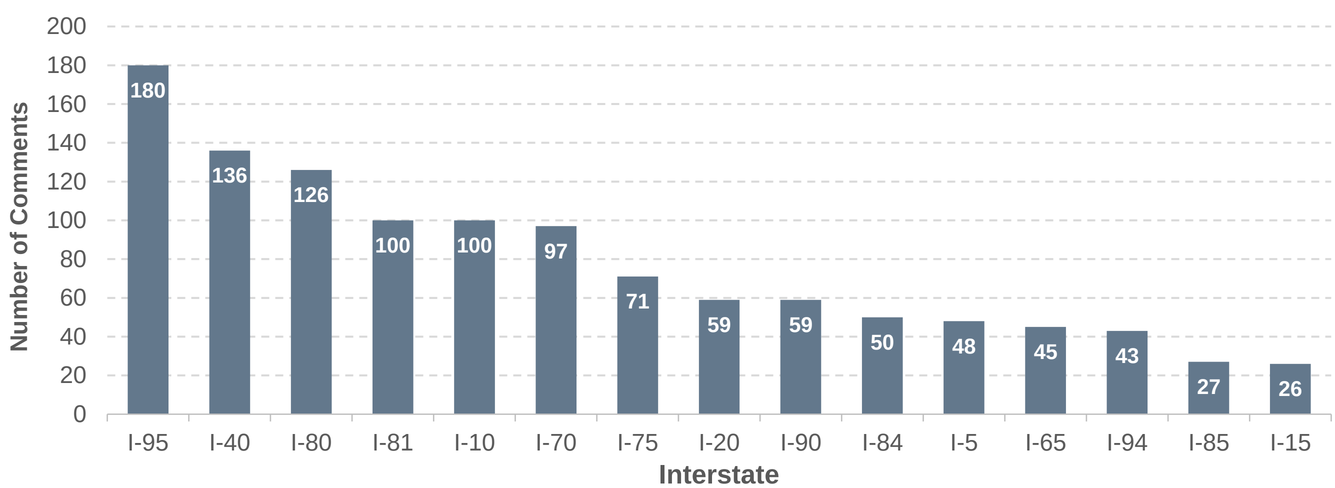
Exhibit 11-14: Locations of Truck Parking Problems Reported by States, 2014



Source: DOT, *Jason's Law Truck Parking Survey Results and Comparative Analysis: Survey of State Departments of Transportation*, Figure 9.

Exhibit 11-15 shows the 15 Interstate corridors most identified with parking shortages, according to a survey of truck drivers by the trucking industry.

Exhibit 11-15: Top 15 Interstates with Truck Parking Shortages Cited by OOIDA/ATA Truck Drivers and Professionals, 2014



Source: American Trucking Associations and Owner Operator Independent Drivers Association Survey.

Additional analysis would be necessary to understand fully truck parking issues, including a comparison of parking utilization across origins and destinations; and near freight generators (such as distribution centers), intermodal facilities, and ports.

[ii] DOT Releases 30-Year Freight Projections, BTS 13-16, 3/3/16. (https://www.bts.gov/statistical-releases)
[iii] BTS, 2016. *Freight Facts and Figures 2015*.
[iv] BTS, 2016. *Freight Facts and Figures 2015*, pg. 3.
[v] BTS, 2017. *Transportation Economic Trends*, Chapter 4: Transportation Employment. (https://cms.bts.dot.gov/archive/publications/transportation_economic_trends/ch4/index)
[vi] DOT, FHWA, 2016. *Freight Quick Facts Report*, September 2016, pp. 3, 9.
[vii] BTS, 2016. *Freight Facts and Figures 2015*, pg. 3.
[viii] DOT, FHWA, 2017. *Freight Intermodal Connectors Study,* Final Report, April 2017.
[ix] BTS, 2016. *Freight Facts and Figures 2015,* pg. 4
[x] (https://ops.fhwa.dot.gov/freight/infrastructure/truck_parking/jason_law/truckparkingsurvey/jasons_law.pdf)

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CHAPTER 12

Conditions and Performance of the National Highway Freight Network

Introduction

The Fixing America's Surface Transportation (FAST) Act designated a freight network and established a national policy of maintaining and improving the conditions and performance of the new National Highway Freight Network (NHFN). The law also required the development of a regular report on the conditions and performance of the NHFN. This chapter serves as the first of these reports.

Using the definitions associated with the longstanding Congressional reporting requirement that produces the *Conditions and Performance Report on the Status of the Nation's Highways, Bridges, and Transit* as a model, the terms "conditions" and "performance" may be defined as follows:

- "Conditions" refers to the physical state of the infrastructure, and therefore shows a snapshot in time of infrastructure quality.
- "Performance" reflects how the system is performing relative to a program goal, the direct products and services delivered by a program, and/or the results of those products and services.

It is generally acknowledged that "conditions" and "performance" measures are related to each other, as the condition of an infrastructure asset typically affects its performance. The structural integrity of a bridge or the ride quality of a roadway are examples of conditions metrics. Examples of performance metrics include congestion or travel time on a roadway, changes in that roadway's congestion statistics over time, safety metrics, and how the conditions on the roadway affect the overall movement of goods through a region. The goal areas of the FAST Act have been used in this chapter as a guide to reporting on conditions and performance of the NHFN. *Exhibit 12-1* shows how the goal areas for the NHFN in the FAST Act relate to conditions and performance measures included in this report.

Key Takeaways

- The FAST Act established the National Highway Freight Network (NHFN) and required a conditions and performance report.
- Pavement IRI was acceptable on 96 percent of the NHFN roadways, based on 2014 data.
- Nearly one-third of the bridges on the NHFN are 51 years or older, based on 2014 data.
- The number of crashes and fatalities on the NHFN increased from 2014 to 2015, by 5.7 percent and 6.1 percent respectively, based on 2015 data.
- Travel time has become less predictable over the last 5 years, with the Travel Time Reliability Planning Time Index increasing in 14 of the top 25 intercity truck corridors, based on 2011–2014 data.
- Average travel speed has decreased in 13 of the top 25 freight-significant corridors, based on 2011–2015 data.

Exhibit 12-1: Conditions and Performance by Goal Area

Goal Area	Measure
State of Good Repair	▪ International Roughness Index for Pavement ▪ Percentages of Structurally Deficient Bridges ▪ Age of Structurally Deficient Bridges ▪ Percent Good, Fair, and Poor for Bridge Deck Elements
Safety, Security, and Resilience	▪ Number of Crashes and Number of Fatalities
Congestion, Economic Efficiency, Productivity, and Competitiveness	▪ Planning Time Index ▪ Truck Tonnage ▪ Truck Volumes ▪ Average Speeds

The goals addressed in this report reflect areas where measures were defined and datasets were available at the time of the writing of this report. In keeping with the focus of this report, the goals used were specific to measures obtainable for the NHFN roadways. It is possible that, in future iterations of this report, additional metrics for NHFN goal areas will be developed and new datasets may become available to improve the range of measures available to understand the conditions and performance of this highway freight network.

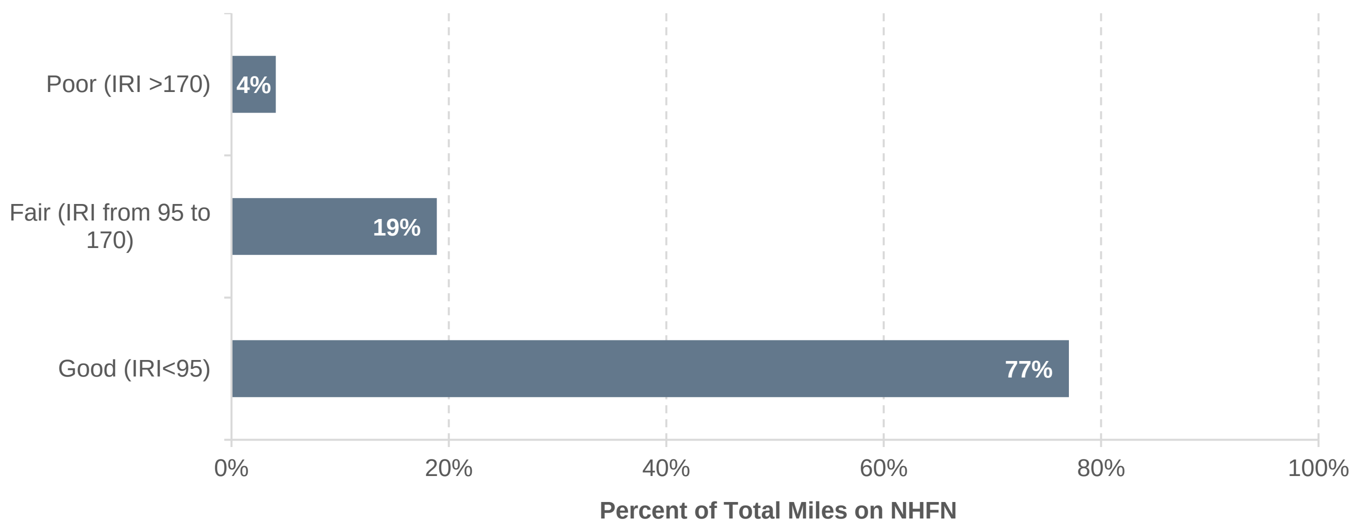
Conditions

Pavement Quality on the NHFN

Designated in 2015 based on 2012 data, the original NHFN consisted of 51,029 centerline miles, including 46,947 centerline miles of Interstate and 4,082 centerline miles of non-Interstate roads, using the Highway Performance Monitoring System (HPMS) dataset. The routes comprising the total miles include the underlying Primary Highway Freight System (PHFS) of 41,518 centerline miles, of which 37,436 miles were Interstate and 4,082 miles were non-Interstate roads, combined with the remaining 9,511 miles of Interstate roads not included in the PHFS. The overall centerline mileage will fluctuate with additions and deletions (rare) to the Interstate Highway System, as well as when States elect to designate Critical Rural Freight Corridors (CRFCs) and Critical Urban Freight Corridors (CUFCs). *Exhibit 11-8* shows the original NHFN as established by Congress.

Pavement conditions are reported to FHWA by States through the HPMS for Federal-aid highways. The reporting agency uses the International Roughness Index (IRI) to measure the smoothness of pavement and ride quality. The IRI measures smoothness using an algorithm based on the longitudinal profile of a section of the road. Lower IRI values indicate better pavement conditions (i.e., smoother), whereas higher values indicate worse conditions. The IRI represents pavement ride quality in terms of the cumulative deviation from a smooth surface in inches per mile, as shown in the categories in *Exhibit 12-2*.

Exhibit 12-2: Pavement Ride Quality (IRI) on the NHFN (Based on Mileage)



Source: HPMS data from 2014.

Using more recent Interstate mileage data from the HPMS in 2014, the NHFN now comprises 52,020 centerline miles of roadway. Seventy-seven percent of pavement miles on the NHFN were rated as having good ride quality per 2015 HPMS data, 19 percent had fair ride quality, and 4 percent had poor ride quality.

Approximately 96 percent of roadways on the NHFN had an acceptable IRI, as measured by the combined number of good and fair roadways. The data showed that 15 percent of the non-Interstate portion of the NHFN had a poor IRI, whereas only approximately 3 percent of the Interstate roadways on the NHFN had a poor IRI.

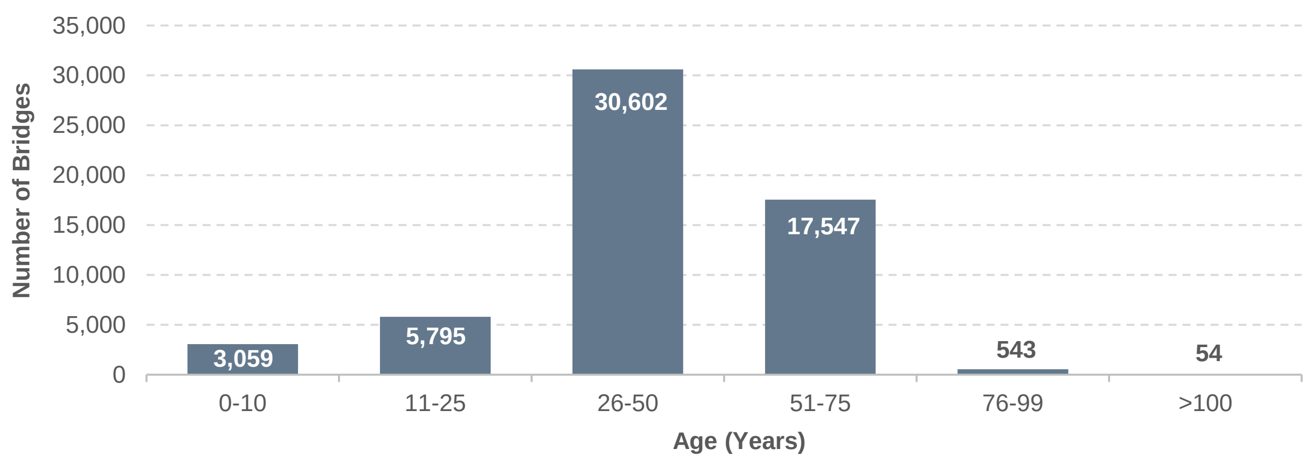
Bridges on the NHFN

Structural status and bridge age are two commonly used metrics to determine the condition of bridges. The classification of a bridge as structurally deficient does not imply that a bridge is unsafe; rather, it indicates the extent to which a bridge has deteriorated from its original condition. Structurally deficient bridges are characterized by the deteriorated condition of bridge elements and reduced load-bearing capacity. In some cases, weight restrictions are placed on structurally deficient bridges. Such load limitations may affect freight routing and efficiency. The age of a bridge is also relevant to freight routing and efficiency, as most bridges were designed for a 50-year life span and would be expected to be replaced or need major rehabilitation efforts after they have been in service for 50 years. Construction projects can increase freight delays, create workzone areas for increased safety consideration, and in some cases necessitate rerouting for a period of time.

To inventory the bridges on the NHFN, the National Bridge Inventory (NBI) was analyzed using ArcGIS software to determine which bridges are on the NHFN and to identify current bridge ratings. This analysis showed that there are approximately 57,600 bridges on the NHFN, 4.3 percent of which were rated as structurally deficient.

The age of a bridge structure is an important indicator of its serviceability; that is, the condition under which a bridge is still considered useful. Nearly 31.5 percent of bridges on the NHFN are 51 years old or older. More than 53 percent of the bridges are 26 to 50 years old. A breakdown of the age of bridges on the NHFN, grouped into six unequal but meaningful segments, is shown in *Exhibit 12-3*.

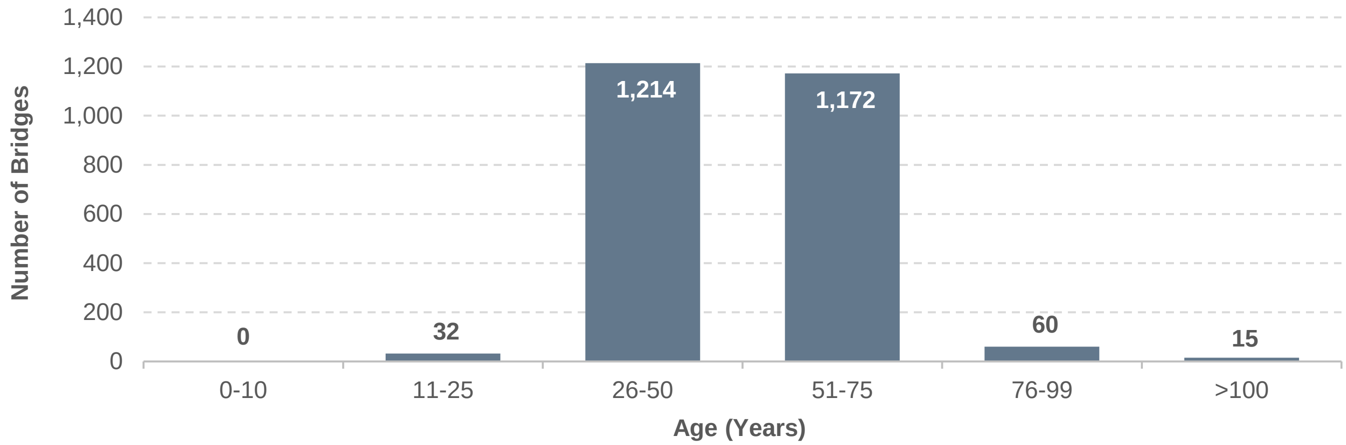
Exhibit 12-3: Age of Bridges on the NHFN



Source: NBI data from 2014.

More than half of the structurally deficient bridges on the NHFN are over 50 years old, as shown by the bar graph of structurally deficient NHFN bridges by age in *Exhibit 12-4*. This result has funding and operations implications, as these bridges will need significant rehabilitation and replacement now or in the near future.

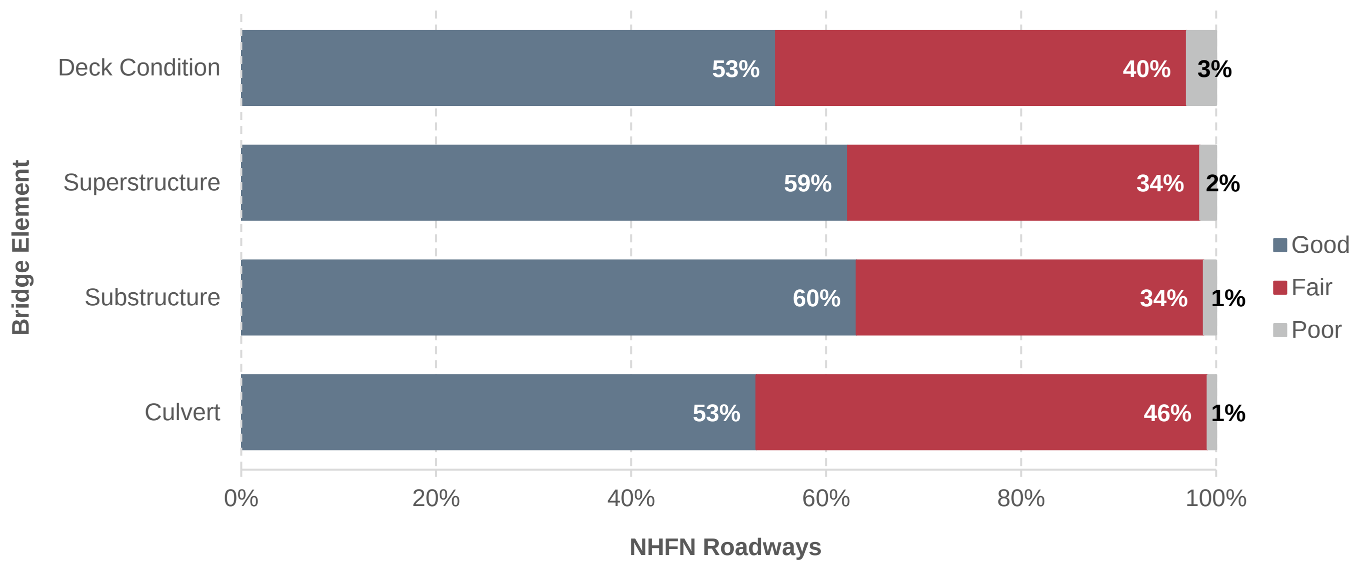
Exhibit 12-4: Age of Structurally Deficient Bridges on the NHFN



Source: NBI data from 2014.

Exhibit 12-5 summarizes the bridge element conditions on the NHFN as of 2014, including the condition rating for individual culverts and for the deck, superstructure, and substructure of bridges. The results show that greater than 96 percent of each of the individual elements of NHFN bridges and culverts on the NHFN are in good or fair condition.

Exhibit 12-5: Bridge Element Conditions on the NHFN, 2014



Source: NBI data from 2014.

Performance

Safety Data on the NHFN

Safety performance measures are indicators that enable decision makers and other stakeholders to monitor changes in system conditions and performance against established visions, goals, and objectives. Typical safety performance measures relate to the number and rate of fatalities and or crashes. The crash statistics discussed in this section were extracted from the Fatality Analysis Reporting System (FARS) for rural and urban Interstate highways, which make up the bulk of the NHFN.

The table in *Exhibit 12-6* shows the number of fatal motor vehicle crashes and fatalities on the NHFN in 2014 and 2015, along with a breakdown of crash locations between urban and rural areas. There were 3,633 fatal crashes reported on the Interstate System portion of the NHFN in 2014, resulting in 4,094 fatalities. In 2015, the number of crashes and the number of fatalities increased by 5.7 percent and 6.1 percent, respectively.

Crashes involving trucks on the Interstate System portion of the NHFN have increased in recent years, rising from 942 crashes and 1,104 fatalities in 2015 to 1,053 crashes and 1,194 fatalities in 2016.

Exhibit 12-6: Fatal Motor Vehicle Crashes and Fatalities on the Interstate System portion of the NHFN, 2014 and 2015

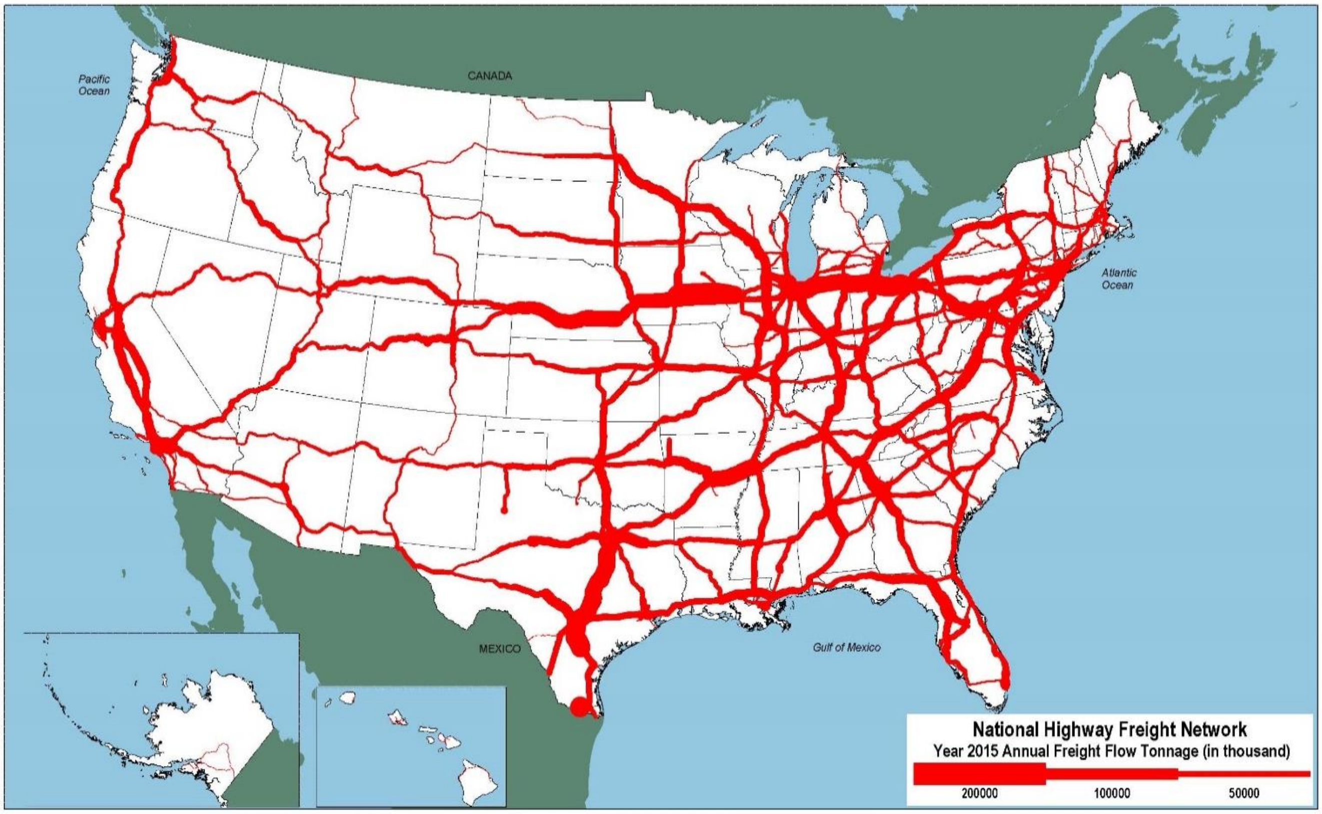
Year	Rural/Urban						Total	
	Rural		Urban		Unknown			
	Crashes	Fatalities	Crashes	Fatalities	Crashes	Fatalities	Crashes	Fatalities
2014	1,521	1,762	2,112	2,332	0	0	3,633	4,094
2015	1,647	1,918	2,190	2,424	4	4	3,841	4,346

Source: Information obtained from crash data contained in Fatality Analysis Reporting System (FARS) files.

Freight Volumes

The map in *Exhibit 12-7* shows the 2015 volume of freight moved by trucks on the NHFN, in millions of tons.

Exhibit 12-7: Tonnage on the NHFN, 2015

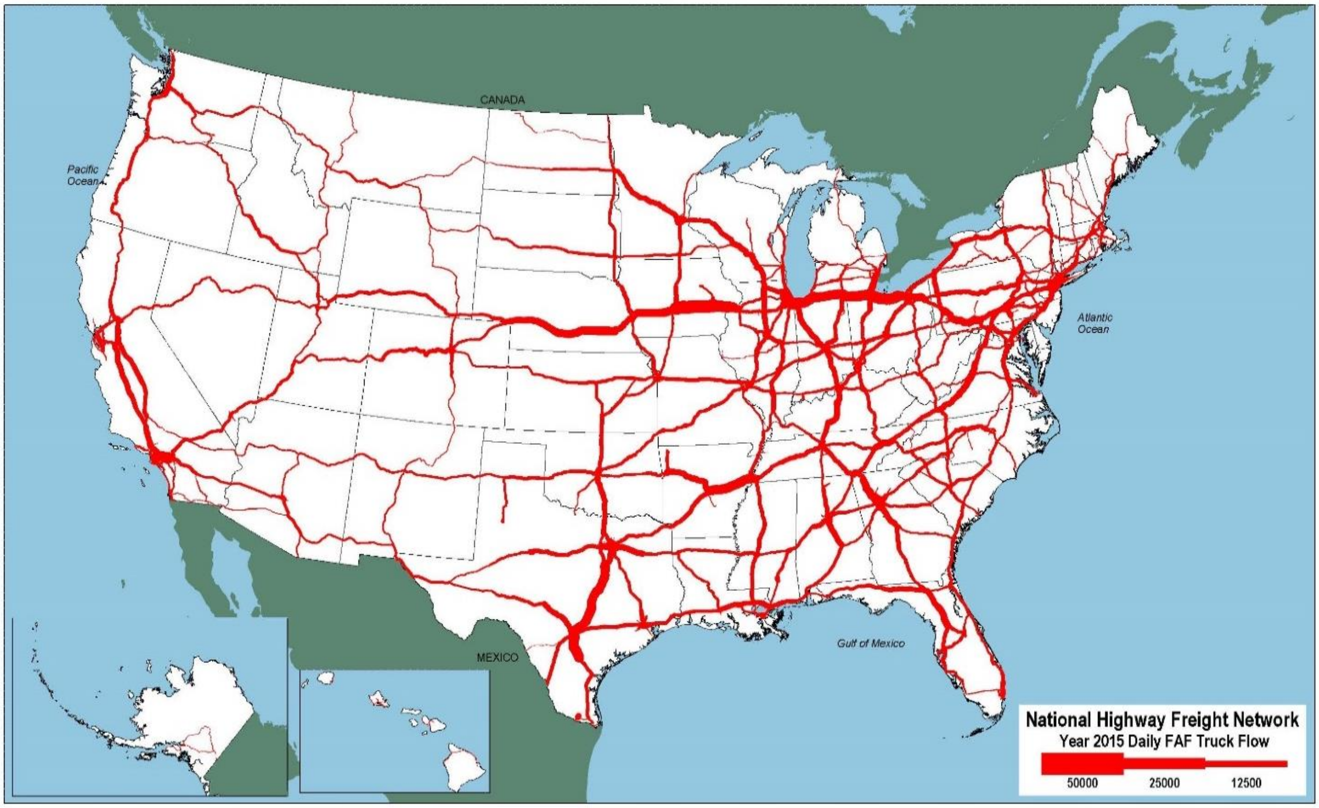


Note: Long haul freight typically serves locations at least 50 miles apart, excluding trucks that are used in movements by multiple modes and mail.

Source: Information obtained from FAF data, version 4.

Truck traffic on the NHFN is expected to increase significantly between 2015 and 2045. The current average daily long haul truck traffic on the NHFN is shown for 2015 in *Exhibit 12-8* and the forecasted growth in average daily long haul truck traffic on the NHFN for 2045 is shown *Exhibit 12-9*.

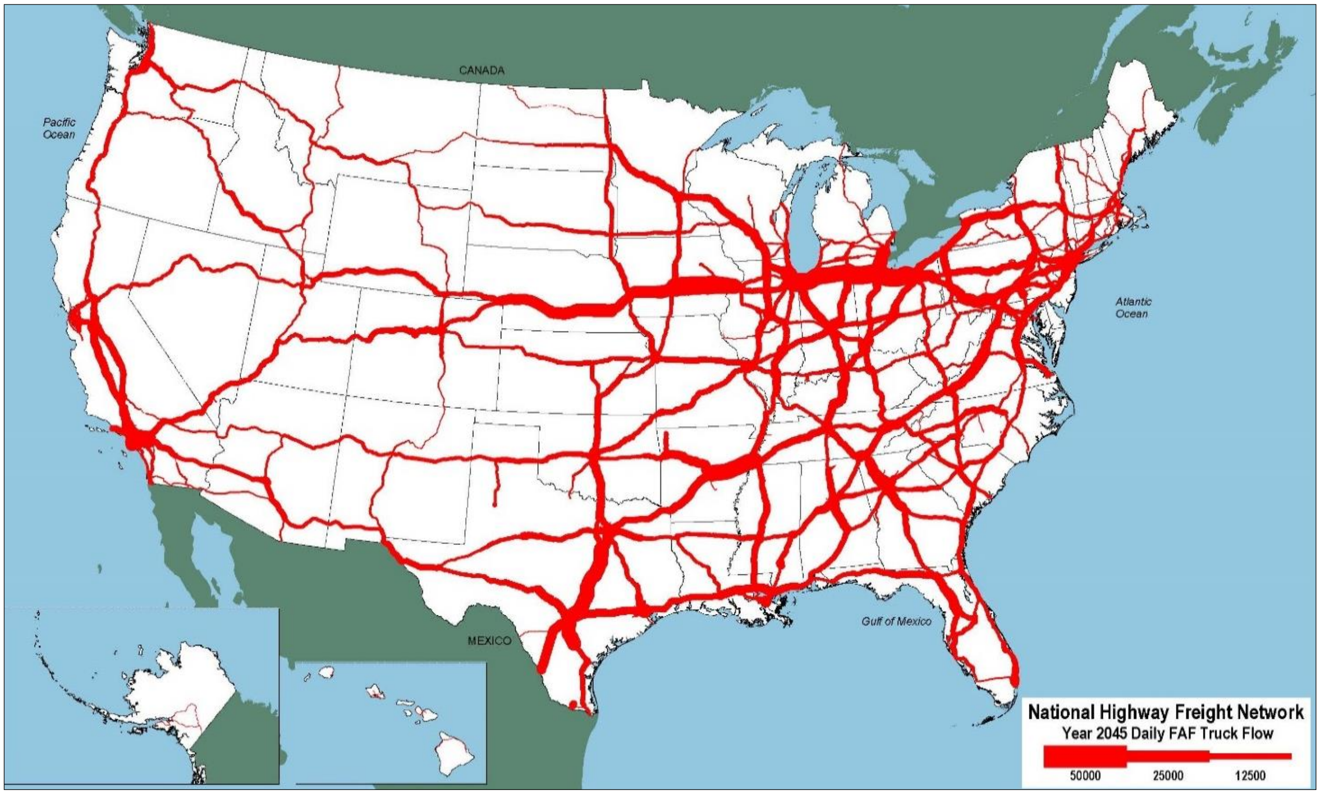
Exhibit 12-8: Average Daily Long Haul Truck Traffic on the NHFN, 2015



Note: Major flows include domestic and international freight moving by truck on highway segments with more than 25 FAF trucks per day and between places typically more than 50 miles apart.

Source: Information obtained from FAF data, version 4.

Exhibit 12-9: Forecasted Average Daily Long Haul Truck Traffic on the NHFN, 2045



Note: Major flows include domestic and international freight moving by truck on highway segments with more than 25 FAF trucks per day and between places typically more than 50 miles apart.

Source: Information obtained from FAF data, version 4.

Congestion

Congestion on highways and bridges occurs when traffic demand approaches or exceeds the available capacity of the system. "Recurring" congestion refers to congestion taking place at roughly the same place and time every day, usually during peak traffic periods due to insufficient infrastructure or physical capacity, such as roadways that are too narrow to accommodate the demand. "Nonrecurring" congestion is caused by temporary disruptions that render part of the roadway unusable. Factors that trigger nonrecurring congestion include traffic incidents, bad weather, construction work, poor traffic signal timing, and special events. About half the total congestion occurrence on roadways is recurring, with the other half nonrecurring.

FHWA monitors performance for the freight system as part of its Freight Performance Measurement (FPM) program to analyze the impacts of congestion and determine the operational capacity and efficiency of key freight routes in the United States. Freight highway congestion is measured using truck probe data from more than 600,000 trucks equipped with GPS. These trucks provide billions of position signals that FHWA analyzes to determine truck freight performance, both for routine monitoring and for ad hoc analysis to understand truck movements and impacts, such as when an incident affects highway network reliability. Over time, the number of vehicle probes will need to increase to improve the comprehensiveness of the data. FHWA estimates that the current number of probes represents approximately 30 percent of the truck population for Classes 6, 7, and

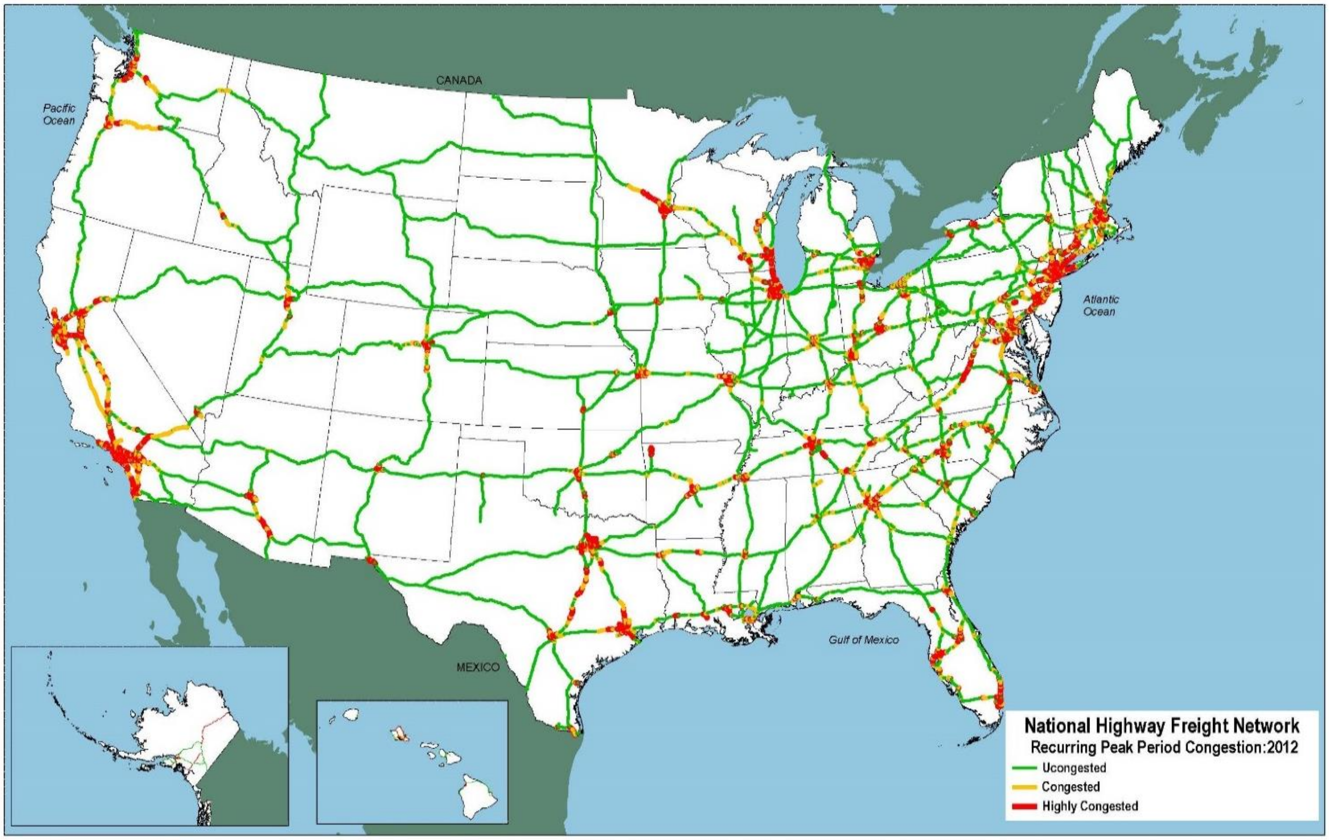
8 (i.e., trucks with gross vehicle weight exceeding 19,500 pounds). In addition to the FPM truck probe data, FHWA uses information from the FAF tool for tonnage and volume flows.

FPM's routine monitoring of truck freight performance is principally used to monitor congestion, using measures of travel time reliability and speed for corridors, border crossings, urban areas, freight intermodal connections, and freight bottlenecks. FHWA produces quarterly performance monitoring reports that provide insight into these areas. More information is available on FHWA's Website at (http://ops.fhwa.dot.gov/freight/freight_analysis/perform_meas/).

FHWA produces a Freight Movement Efficiency Index that combines measures of speeds and travel times for intermodal locations, urban areas, bottlenecks, and border crossings. FHWA monitors travel times for the top 25 freight corridors in the United States. All of these freight corridors are designated on the NHFN. The measures indicate that the current congestion negatively influencing truck carrier operations occurs on a recurring basis during peak periods, particularly in and near major metropolitan areas.

The two maps in *Exhibits 12-10* and *12-11* show the locations of peak-period congestion on the NHFN and for the high-volume truck portions of the NHFN. High-volume truck portions of the NHFN carry more than 8,500 trucks per day, including freight-hauling long-distance trucks, freight-hauling local trucks, and other trucks with six or more tires. Highly congested segments are stop-and-go conditions with volume/service flow ratios greater than 0.95. The volume/service flow ratio is calculated as an indicator of peak hour congestion. Congested segments have reduced traffic speeds with volume/service flow ratios between 0.75 and 0.95. Although the NHFN was designated in 2015, the peak-period congestion depicted in the exhibits below were developed using 2012 data.

Exhibit 12-10: Peak-period Congestion on the NHFN, 2012



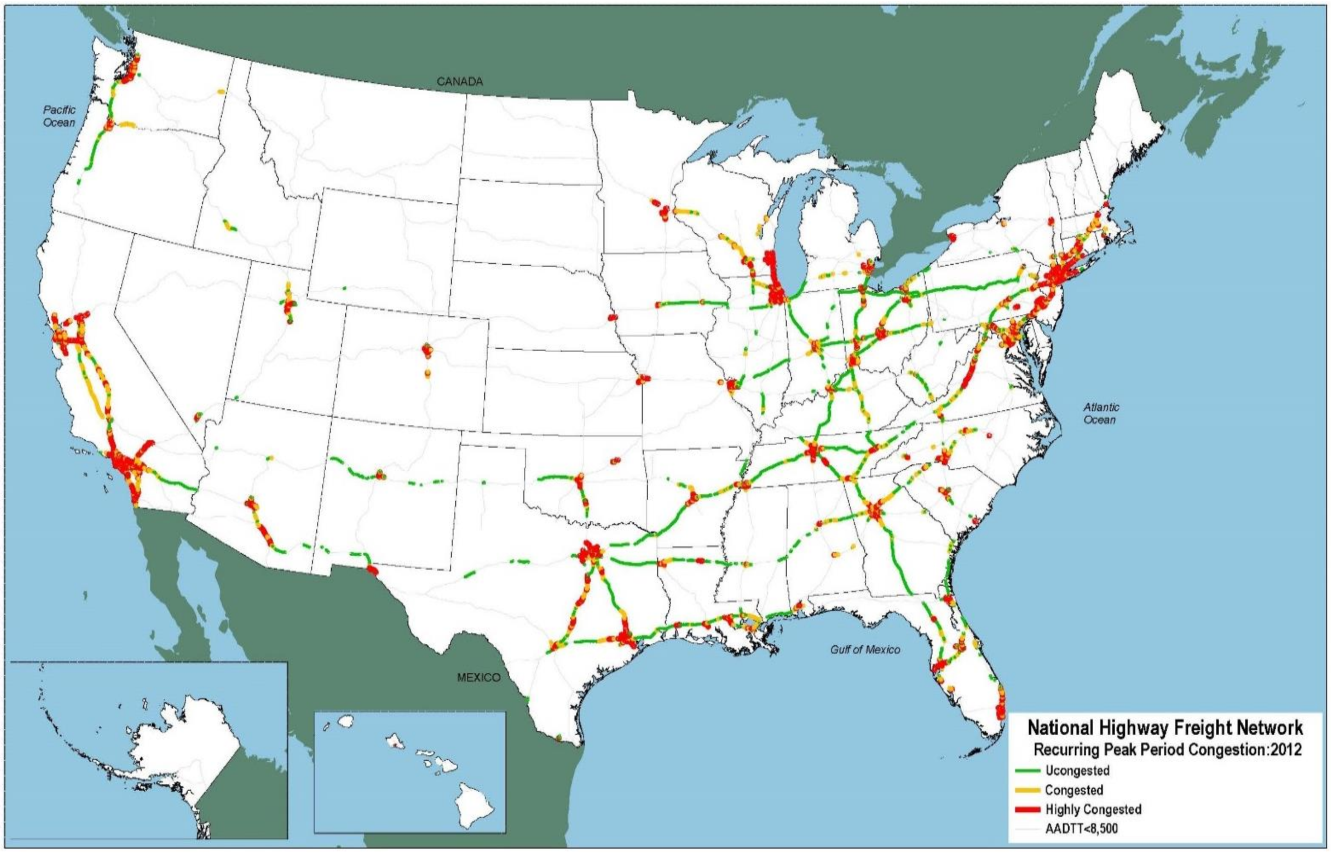
Note: The volume/service flow ratio is estimated using the procedures outlined in the HPMS Field Manual, Appendix N.

Note: Highly congested segments are stop-and-go conditions with volume/service flow ratios greater than 0.95. Congested segments have reduced traffic speeds with volume/service flow ratios between 0.75 and 0.95.

Note: Long haul freight trucks typically serve locations at least 50 miles apart, excluding trucks that are used in movements by multiple modes and mail.

Source: Information obtained from FAF data, version 4.

Exhibit 12-11: Peak-period Congestion on the High-volume Truck Portions of NHFN, 2012



Note: The volume/service flow ratio is estimated using the procedures outlined in the HPMS Field Manual, Appendix N.

Note: Highly congested segments are stop-and-go conditions with volume/service flow ratios greater than 0.95. Congested segments have reduced traffic speeds with volume/service flow ratios between 0.75 and 0.95.

Note: Long haul freight trucks typically serve locations at least 50 miles apart, excluding trucks that are used in movements by multiple modes and mail.

Source: Information obtained from FAF data, version 4.

The table in *Exhibit 12-12* shows the speeds experienced on the top 25 congested freight-significant locations within a pre-selected sample of freight facilities (predominantly interchanges), all of which are on the NHFN. The rankings are based on a volume-weighted calculation of congestion that considers the volume of truck traffic, which is captured through truck probe sample data. Note: Variations in the concentration of truck probes reporting by facility compared to actual truck traffic may affect the ranking of these facilities.

Exhibit 12-12: Top 25 Congested Freight-significant Locations on the NHFN, 2014[1]

Congestion Ranking[2]	Location Description[3]	State	Average Speed[4]	Peak Average Speed	Nonpeak Average Speed	Nonpeak/Peak Ratio
1	Atlanta, GA: I-285 at I-85 (North)	GA	40	28	47	1.68
2	Chicago, IL: I-290 at I-90/I-94	IL	27	21	29	1.38
3	Fort Lee, NJ: I-95 at SR 4	NJ	36	29	39	1.33
4	Louisville, KY: I-65 at I-64/I-71	KY	44	38	47	1.24
5	Houston, TX: I-610 at US 290	TX	38	29	43	1.51
6	Houston, TX: I-10 at I-45	TX	42	32	47	1.48
7	Cincinnati, OH: I-71 at I-75	OH	47	40	50	1.23
8	Houston, TX: I-45 at US 59	TX	39	28	44	1.54
9	Los Angeles, CA: SR 60 at SR 57	CA	45	38	48	1.28
10	Houston, TX: I-10 at US 59	TX	43	32	50	1.57
11	Dallas, TX: I-45 at I-30	TX	39	28	44	1.55
12	Atlanta, GA: I-75 at I-285 (North)	GA	46	35	51	1.46
13	St. Louis, MO: I-70 at I-64 (West)	MO	42	38	44	1.15
14	Seattle, WA: I-5 at I-90	WA	35	26	40	1.54
15	Chicago, IL: I-90 at I-94 (North)	IL	32	18	40	2.25
16	Austin, TX: I-35	TX	33	21	40	1.90
17	Auburn, WA: SR 18 at SR 167	WA	46	39	50	1.29
18	Los Angeles, CA: I-710 at I-105	CA	44	34	49	1.42
19	Baton Rouge, LA: I-10 at I-110	LA	42	35	46	1.34
20	Hartford, CT: I-84 at I-91	CT	46	37	50	1.36
21	Houston, TX: I-45 at I-610 (North)	TX	46	36	51	1.43
22	Seattle, WA: I-90 at I-405	WA	39	29	45	1.58
23	Cincinnati, OH: I-75 at I-74	OH	45	40	48	1.20
24	Indianapolis, IN: I-65 at I-70 (North)	IN	50	45	52	1.16
25	Denver, CO: I-70 at I-25	CO	45	39	49	1.26

[1] Using data associated with the FHWA-sponsored Freight Performance Measures (FPM) initiative, the American Transportation Research Institute provides a yearly analysis to quantify the impact of traffic congestion on truck-borne freight at 250 specific locations throughout the United States.

[2] The ranking analysis factors in the number of trucks using a particular highway facility and the impact that congestion has on average commercial vehicle speed in each of the 250 study areas. These data represent truck travel during weekdays at all hours of the day in 2014.

[3] These locations were identified over several years through reviews of past research, available highway speed and volume data sets, and surveys of private- and public-sector stakeholders.

[4] Average speeds below a free flow of 55 miles per hour indicate congestion.

Source: American Transportation Research Institute (ATRI), Congestion Impact Analysis of Freight Significant Highway Locations.

The National Performance Management Research Data Set (NPMRDS) truck probe data also measure corridor-level travel time reliability. Travel time reliability is derived from measured average speeds of commercial vehicles for the top 25 domestic freight corridors annually. Compared with simple average measures of congestion, measures of travel time reliability—the certainty (or variability) of travel conditions from day to day—provide a different perspective of improved travel beyond a simple average travel time. From an economic perspective, low reliability can cause drivers to budget extra time in planning trips or to suffer the consequences of being delayed. This extra time usually carries higher value beyond the typical travel time. Unpredictable travel times are problematic for truck drivers and freight receivers because they can cause unwanted schedule changes that can add cost and delay to their operations.

Exhibit 12-13 shows the Travel Reliability Planning Time Index for the 25 freight-significant corridors on the NHFN. Values greater than 1.00 illustrate travel time variability. Higher numbers indicate greater variability, and the numbers after the decimal points can be treated as percentages. For example, the 2014 Travel Reliability Planning Time Index for Corridor 25 was 1.85. This means travel times were 85 percent longer on heavy travel days, compared with normal days, for drivers traveling the I-95 corridor from Richmond, VA to New Haven, CT.

Exhibit 12-13: Travel Reliability Planning Time Index for the Top 25 Freight-significant Corridors on the NHFN, 2011–2014

Planning Time Index (95th Percentile/50th Percentile)						
Corridor		**2011**	**2012**	**2013**	**2014**	**2015**
1	I-5: Medford, OR to Seattle	1.31	1.34	1.37	1.41	1.48
2	I-5/CA 99: Sacramento to Los Angeles	1.28	1.33	1.34	1.33	1.35
3	I-10: Los Angeles to Tucson	1.24	1.21	1.26	1.27	1.34
4	I-10: San Antonio to New Orleans	1.23	1.28	1.30	1.31	1.31
5	I-10: Pensacola to I-75	1.06	1.06	1.06	1.07	1.06
6	I-30: Little Rock to Dallas	1.21	1.15	1.14	1.17	1.18
7	I-35: Laredo to Oklahoma City	1.24	1.24	1.28	1.30	1.39
8	I-40: Oklahoma City to Flagstaff	1.10	1.12	1.11	1.11	1.12
9	I-40: Knoxville to Little Rock	1.17	1.18	1.20	1.24	1.16
10	I-40: Raleigh to Asheville	1.11	1.12	1.14	1.15	1.15
11	I-55/I-39/I-94: St. Louis to Minneapolis	1.15	1.13	1.14	1.14	1.15
12	I-57/I-74: I-24 (IL) to I-55 (IL)	1.09	1.12	1.15	1.14	1.10
13	I-70: Kansas City to Columbus	1.21	1.18	1.20	1.20	1.21
14	I-65/I-24: Chattanooga to Nashville to Chicago	1.26	1.26	1.29	1.34	1.34
15	I-75: Tampa to Knoxville	1.16	1.16	1.20	1.21	1.22
16	I-75: Lexington to Detroit	1.26	1.24	1.29	1.30	1.34
17	I-78/I-76: New York to Pittsburgh	1.16	1.20	1.20	1.21	1.22
18	I-80: New York to Cleveland	1.26	1.19	1.19	1.20	1.22
19	I-80: Cleveland to Chicago	1.18	1.14	1.17	1.21	1.17
20	I-80: Chicago to I-76 (CO/NE border)	1.13	1.12	1.12	1.12	1.12
21	I-81: Harrisburg to I-40 (Knoxville)	1.11	1.12	1.11	1.11	1.10
22	I-84: Boise to I-86	1.14	1.08	1.09	1.14	1.14
23	I-94: Chicago to Detroit	1.09	1.08	1.10	1.15	1.11
24	I-95: Miami to I-26 (SC)	1.17	1.18	1.21	1.23	1.26
25	I-95: Richmond to New Haven	1.62	1.59	1.69	1.85	1.76

Source: NPMRDS truck probe data.

Finally, as shown below in *Exhibit 12-14*, the NPMRDS truck probe data indicate the average travel speed for the top 25 freight-significant corridors on the NHFN from 2011 to 2015. The average travel speeds shown serve as an indicator of congestion for each corridor.

The efficient and reliable movement of goods is important to the U.S. economy. Truck travel time and speed are two indicators of transportation system performance. Slower speeds and unreliable travel times caused by congestion and inclement weather conditions increase fuel costs and affect efficiency and productivity.

Exhibit 12-14: Average Weekday Travel Speeds for the Top 25 Freight-significant Corridors on the NHFN, 2011–2015[1]

Corridor		2011	2012	2013	2014	2015
1	I-5: Medford, OR to Seattle	56.64	56.33	56.12	54.94	56.15
2	I-5/CA 99: Sacramento to Los Angeles	56.19	56.05	56.11	55.99	56.11
3	I-10: Los Angeles to Tucson	59.53	59.42	59.42	58.60	59.54
4	I-10: San Antonio to New Orleans	61.79	61.45	61.77	60.82	61.78
5	I-10: Pensacola to I-75	64.69	63.90	64.03	63.99	64.27
6	I-30: Little Rock to Dallas	61.78	62.64	62.82	62.13	62.70
7	I-35: Laredo to Oklahoma City	61.06	61.45	61.05	59.76	60.29
8	I-40: Oklahoma City to Flagstaff	63.99	63.86	64.15	64.31	64.18
9	I-40: Knoxville to Little Rock	62.34	62.24	62.14	61.53	62.30
10	I-40: Raleigh to Asheville	62.42	62.36	62.32	61.62	61.90
11	I-55/I-39/I-94: St. Louis to Minneapolis	62.00	62.37	62.16	62.10	62.57
12	I-57/I-74: I-24 (IL) to I-55 (IL)	62.86	62.71	62.56	62.76	63.59
13	I-70: Kansas City to Columbus	61.51	61.94	61.81	61.50	61.98
14	I-65/I-24: Chattanooga to Nashville to Chicago	60.97	61.04	60.85	59.57	59.95
15	I-75: Tampa to Knoxville	62.74	62.47	62.39	61.67	62.13
16	I-75: Lexington to Detroit	60.18	60.76	60.66	59.30	59.43
17	I-78/I-76: New York to Pittsburgh	59.59	59.94	59.88	59.34	59.70
18	I-80: New York to Cleveland	60.78	61.12	61.13	60.68	61.14
19	I-80: Cleveland to Chicago	61.86	62.26	61.99	61.57	62.09
20	I-80: Chicago to I-76 (CO/NE border)	62.96	63.16	63.36	63.39	63.64
21	I-81: Harrisburg to I-40 (Knoxville)	62.38	62.42	62.60	62.60	62.53
22	I-84: Boise to I-86	61.81	62.53	62.53	62.43	62.91
23	I-94: Chicago to Detroit	59.89	60.54	59.95	58.74	59.24
24	I-95: Miami to I-26 (SC)	63.07	62.63	62.48	61.77	62.27
25	I-95: Richmond to New Haven	55.36	55.52	54.70	51.72	54.33

[1] Weekdays (24/7).

Source: NPMRDS truck probe data.

Data Needs

FHWA prepared this first baseline report on the conditions and performance of the NHFN with available data to be responsive to the statutory reporting requirements of the FAST Act. Although conditions and performance data are available for most of the roadways on the NHFN, actions would be needed to report such data comprehensively for all four subsystems of roadways that make up the NHFN. Specifically, improving the database relationship between NHFN geography and HPMS and NBI data will greatly assist in the preparation of future NHFN conditions and performance reports and allow for a better understanding of the system and its needs.

The HPMS is a critical data set, containing information on pavement characteristics, conditions, and truck volumes. More than 85 percent of the NHFN consists of Interstate mileage for which the HPMS collects comprehensive conditions and performance data including pavement condition information and truck volume data. The remaining 15 percent of the NHFN is made up of 4,082 non-Interstate miles that are part of the PHFS portion of the NHFN and the estimated total possible CUFC and CRFC mileage that States and MPOs may elect to designate as part of the NHFN. For this 15 percent of roadways, less comprehensive conditions and performance data are available through the HPMS. These data may include sampled data rather than roadway-specific data or the data may not be readily available for States to report in the HPMS.

Similar limitations exist with respect to the NHFN data from the NBI. Condition data for all bridges on the Nation's roadways are reported to FHWA through the NBI. However, at the time of the drafting of this report, there was no specific identifier in the NBI data set indicating whether a bridge is on the NHFN. Future versions of the NBI will include the NHFN as a specific identifier in its coding guide. This identifier will allow for more accurate reporting on the condition of bridges on all four roadway subsystems that make up the NHFN.

In summary, this 2017 report provides a baseline description of the current conditions and performance of the NHFN. Future reports are expected to offer more detailed analysis of the trends and patterns in freight conditions and performance.

Furthermore, the NHFN is an evolving network based on changes to the Interstate System. The network will also change in size and coverage as States and MPOs elect to designate, de-designate, or re-designate CRFCs and CUFCs, and when DOT makes subsequent re-designations of the NHFN.

Finally, the measures summarized and graphed in this report, and their utility and comprehensiveness, are a function of data quality and availability. Because the FAST Act requires an assessment report of the NHFN every 2 years, subsequent versions of this report will provide the opportunity, subject to the availability of new, improved data, to replace some exhibits and improve others to reflect the evolving quality of the data and the performance measures.

PART IV

Changes to the Highway Performance Monitoring System

The Highway Performance Monitoring System (HPMS) has recently undergone a reassessment to evaluate the HPMS dataset against the Federal Highway Administration's (FHWA) mission and goals. The results and details of this effort are documented in a report titled HPMS 9.0: Modernization Study. It can be found on the FHWA Office of Highway Policy Information website (https://www.fhwa.dot.gov/policyinformation/).

Although HPMS is not specifically mandated by Congress, many of the data applications that HPMS supports—such as this C&P Report and Transportation Performance Management (TPM) discussed in detail in the Introduction to Part I—are mandated. As part of TPM, State departments of transportation are required to establish performance targets for safety, road condition, and congestion in support of the National Highway Performance Program (23 U.S.C. 119). The Fixing America's Surface Transportation (FAST) Act requires additional data from HPMS for and greater transparency of highway project information at the state level, and monitoring freight operations.

In addition to identifying potential changes to the attributes in HPMS, an overarching goal of the reassessment was to implement strategies to ease the reporting burden on State Departments of Transportation, which provide critical data to FHWA.

Potential Strategies to Relieve the Burden on the States

- **Transactional approach to data reporting**: States would only report changes to existing data. For example, lane widths are used to calculate capacity. These data are static until a road is reconstructed, so there is no reason for a State to report the lane width annually unless it has changed.
- **Reliance on alternative sources of data:** Commercially available and open data sources may be effectively used to satisfy some of FHWA data needs.

The Moving Ahead for Progress in the 21st Century (MAP-21) and FAST Acts created the need for reassessment of the HPMS. MAP-21 established a new performance-based planning regime with national goals and accountability. Through rulemaking with input from stakeholders, FHWA developed the performance measures that will be used to measure progress in meeting those goals. States and metropolitan planning organizations (MPOs) are setting targets to address the goals. States will report on their success in achieving their targets and will be accountable for shortcomings.

Beginning in May 2017, several Transportation Performance Measures identified in MAP-21 rely on data from the HPMS. VMT calculated from HPMS will continue to be used to calculate Fatality and Serious Injury Rates as part of the Transportation Safety Measures. VMT will be determined through existing methods and will not require any HPMS modification. Pavement and Condition data from the HPMS will be used to calculate highway condition measures. There will be no additional pavement condition attributes; however, the extent of the collection parameters will be broadened to include the full extent of the National Highway System (including the Interstate System) and the National Highway Freight Network. Calculations needed to implement the Final Rule for System Performance Measures (PM-3) (see Introduction to Part I) will require HPMS to include 20 additional attributes, with data to be provided by State departments of transportation. Most of these attributes will capture travel time reliability information.

The FAST Act establishes the National Highway Freight Network (NHFN). HPMS will provide a module to support identification and maintenance of the location of the designated NHFN routes. This will provide a better linkage to attributes that are stored in HPMS to support the freight program.

Federal Land Management Agencies and the Certified Road Public Miles

Each governor or designated official is required to certify annually the public road mileage in their respective State (23 CFR 460). This information is used in the formula for apportioning NHTSA's State and Community Highway Safety Grants. The current practice is for State Departments of Transportation to calculate this mileage based on the inventory within their data systems. It has always been a challenge for many States to account for mileage that is owned by Federal Land Management Agencies. The reporting burden is on the States, yet there is no regulatory requirement for Federal agencies to report public road mileage in National Parks, National Forests, or lands managed by the Bureau of Land Management, Bureau of Indian Affairs, Fish and Wildlife Service, Army Corps of Engineers, Bureau of Land Reclamation, and the Department of Defense. FHWA staff in HPMS and Federal Lands Highways programs have been working actively with the Federal Land Management Agencies to resolve this situation.

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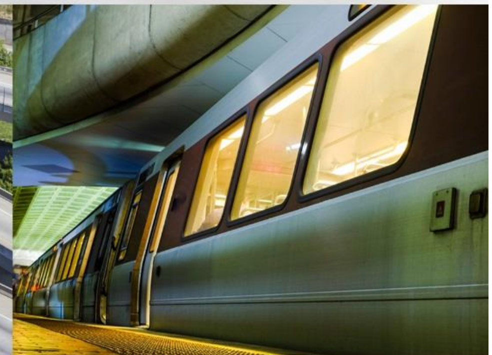
PART V
Appendices



Introduction

Appendices A, B, and C describe the modeling techniques used to generate the investment/performance analyses and capital investment scenarios highlighted in Chapters 7 through 10. Appendix D discusses an ongoing initiative, "Reimagining the C&P Report in a Performance Management-Based World."

Appendix A describes selected technical aspects of the **Highway Economic Requirements System** (HERS), which is used to analyze potential future investments for highway resurfacing and reconstruction and highway and bridge capacity expansion.

Appendix B details the **National Bridge Investment Analysis System** (NBIAS), which is used to examine potential future bridge rehabilitation and replacement investments.

Appendix C presents technical information on the **Transit Economic Requirements Model** (TERM), which is used to explore potential future transit investments in urbanized areas. This appendix also describes the data and methods used to estimate the size of the current state of good repair backlog, and how the backlog has changed over time.

Appendix D discusses the current status of two FHWA-sponsored research efforts aimed at identifying opportunities to enhance the analytical approaches used for assessing future investment needs and to improve the communication of information in the print and Web versions of the C&P Report.

APPENDIX A
Highway Investment Analysis Methodology

Highway Investment Analysis Methodology

Investments in highway resurfacing and reconstruction and in highway and bridge capacity expansion are modeled using the Highway Economic Requirements System (HERS), which has been used since the publication of the 1995 C&P Report. This appendix describes the basic HERS methodology and approach, and details the model features that have changed significantly from those used for the 2015 C&P Report.

Highway Economic Requirements System

HERS begins the investment analysis process by evaluating the current state of the highway system using information on pavements, geometry, traffic volumes, vehicle mix, and other characteristics from the Highway Performance Monitoring System (HPMS) sample dataset. Using section-specific traffic growth projections, HERS forecasts future conditions and performance across several funding periods. As used in this report, the future analysis covers four consecutive 5-year periods. At the end of each period, the model checks for deficiencies in eight highway section characteristics: pavement condition, surface type, volume/service flow (V/SF) ratio (a measure of congestion), lane width, right shoulder width, shoulder type, horizontal alignment (curves), and vertical alignment (grades).

After HERS determines that a section’s pavement or capacity is deficient, it identifies potential improvements to correct some or all of the section’s deficient characteristics. The HERS model evaluates seven kinds of improvements: resurfacing, resurfacing with shoulder improvements, resurfacing with widened lanes (i.e., minor widening), resurfacing with added lanes (i.e., major widening), reconstruction, reconstruction with widened lanes, and reconstruction with added lanes. For reconstruction projects, the model allows for upgrades of low-grade surface types when warranted by sufficient traffic volumes. For improvements that add travel lanes, HERS further distinguishes between two capacity additions: those that can be made at “normal cost” and those on sections where obstacles to widening are present, making capacity additions feasible only at “high cost.” HERS might also evaluate alignment adjustments to improve curves, grades, or both.

When evaluating which potential improvement, if any, should be implemented on a particular highway section, HERS employs incremental benefit-cost analysis. This analysis compares the benefits and costs of a candidate improvement with those of a less aggressive alternative—for example, reconstructing and adding lanes to a section could be compared with reconstruction alone. HERS defines benefits as reductions in direct highway user costs, agency costs, and societal costs. Highway user benefits include reductions in travel time costs, crash costs, and vehicle operating costs (e.g., fuel, oil, and maintenance costs); agency benefits include reduced routine maintenance costs (plus the residual value of projects with longer expected service lives than the alternative); societal benefits include reduced vehicle emissions. Increases in any of these costs resulting from a highway improvement (such as higher emissions rates at high speeds or the increased delay associated with a work zone) would be factored into the analysis as a negative benefit (“disbenefit”).

Dividing these improvement benefits by the capital costs associated with implementing the improvement results in a benefit-cost ratio (BCR) that is used to rank potential projects on different highway sections. HERS implements improvements in order of BCR, with the improvement having the highest BCR implemented first. Thus, as each additional project is implemented, the marginal BCR declines, resulting in a decline in the average BCR for all implemented projects. However, total net benefits continue to increase as additional projects are implemented, until the point at which the marginal BCR falls below 1.0 (i.e., costs exceed benefits). Investment beyond this point is not economically justified because a decline in total net benefits would result.

Because HERS analyzes each highway section independently rather than the entire transportation system, it cannot fully evaluate the network effects of individual highway improvements. Although efforts have been made to account indirectly for some network effects, HERS is fundamentally reliant on its primary data source—the national sample of independent highway sections contained in HPMS. Fully recognizing all network effects would require developing significant new data sources and analytical techniques.

HERS Improvement Costs

For the 2004 C&P Report, significant changes were made to the structure of the HERS improvement cost matrix, the assumed unit costs in that matrix, and the manner in which those values were applied. The improved cost updates reflected in the 2004 C&P Report were based on highway project data from six States. The 2004 update disaggregated the improvement cost values in urban areas by functional class and by urbanized area size. Three population groupings were used: small urban (populations of 5,000 to 49,999), small urbanized (populations of 50,000 to 200,000), and large urbanized (populations of more than 200,000).

For the 2006 C&P Report, additional project cost data were collected for large urbanized areas, rural mountainous regions, and high-cost capacity improvements. These data were used to update the HERS improvement cost matrix, which was also modified to include a new category for major urbanized areas with populations of more than 1 million. The HERS improvement cost matrix was adjusted further for the 2008 C&P Report based on additional analysis of the data previously collected.

Exhibit A-1 identifies the costs per lane mile assumed by HERS for different types of capital improvements. For rural areas, separate cost values are applied by terrain type and functional class, while costs are broken down for urban areas by population area size and type of highway. These costs are intended to reflect the typical values for these types of projects in 2014, and thus do not reflect the large variation in cost among projects of the same type, even in a given year. Such variation, which is evident in the project-level data on which these typical values are based, is attributable to several location-specific factors. For example, the costs assumed for highway widening projects are predicated on each section’s having several bridges typical for the section’s length, but in reality some sections will have more bridges than other sections of equal length, which adds to costs. Among other factors that could make costs unusually high are complicated interchanges, major environmental issues, and other extreme engineering issues.

The values shown in *Exhibit A-1* for adding a lane at “normal cost” reflect costs of projects for which sufficient right-of-way is available or readily obtained to accommodate additional lanes. The values for adding lane equivalents at “high cost” are intended to reflect situations in which conventional widening is infeasible and alternative approaches are required to add capacity to a given corridor. Such alternatives include the construction of parallel facilities, double decking, tunneling, or the purchase of extremely expensive right-of-way. HERS models these lane equivalents as though they are part of existing highways, but some of this capacity could be from new highways or other modes of transportation.

Exhibit A-1: Typical Costs per Lane Mile Assumed in HERS by Type of Improvement

Category	Typical Costs (Thousands of 2014 Dollars per Lane Mile)								
	Re-construct and Widen Lane	Re-construct Existing Lane	Resurface and Widen Lane	Resurface Existing Lane	Improve Shoulder	Add Lane, Normal Cost	Add Lane, Equivalent High Cost	New Alignment, Normal	New Alignment, High
Rural									
Interstate									
Flat	$1,993	$1,302	$1,128	$462	$86	$2,561	$3,551	$3,551	$3,551
Rolling	$2,234	$1,335	$1,298	$492	$142	$2,777	$4,493	$4,493	$4,493
Mountainous	$4,235	$2,924	$2,151	$728	$297	$8,646	$10,121	$10,121	$10,121
Other Principal Arterial									
Flat	$1,556	$1,042	$941	$371	$57	$2,052	$2,937	$2,937	$2,937
Rolling	$1,757	$1,071	$1,069	$413	$96	$2,197	$3,546	$3,546	$3,546
Mountainous	$3,412	$2,411	$2,072	$583	$126	$7,756	$8,931	$8,931	$8,931
Minor Arterial									
Flat	$1,423	$915	$877	$329	$54	$1,865	$2,618	$2,618	$2,618
Rolling	$1,718	$1,013	$1,091	$354	$99	$2,138	$3,372	$3,372	$3,372
Mountainous	$2,854	$1,871	$2,072	$486	$224	$6,547	$7,857	$7,857	$7,857
Major Collector									
Flat	$1,499	$969	$905	$336	$69	$1,937	$2,617	$2,617	$2,617
Rolling	$1,640	$985	$1,018	$356	$93	$1,979	$3,220	$3,220	$3,220
Mountainous	$2,489	$1,541	$1,482	$486	$143	$4,191	$5,474	$5,474	$5,474
Urban									
Freeway/Expressway/Interstate									
Small Urban	$3,356	$2,324	$2,645	$564	$103	$4,211	$13,784	$5,675	$19,373
Small Urbanized	$3,608	$2,344	$2,736	$667	$137	$4,601	$15,117	$7,649	$26,114
Large Urbanized	$5,754	$3,837	$4,238	$895	$517	$7,700	$25,826	$11,220	$38,303
Major Urbanized	$11,509	$7,675	$8,224	$1,483	$1,034	$15,400	$64,219	$22,440	$85,845
Other Principal Arterial									
Small Urban	$2,925	$1,974	$2,420	$473	$105	$3,579	$11,691	$4,474	$15,270
Small Urbanized	$3,130	$1,998	$2,530	$559	$140	$3,878	$12,715	$5,520	$18,841
Large Urbanized	$4,471	$2,929	$3,702	$703	$451	$5,675	$18,961	$7,577	$25,864
Major Urbanized	$8,942	$5,857	$7,405	$1,135	$902	$11,350	$43,997	$15,154	$65,597
Minor Arterial/Collector									
Small Urban	$2,155	$1,491	$1,831	$346	$76	$2,643	$8,562	$3,228	$11,019
Small Urbanized	$2,258	$1,508	$1,848	$394	$93	$2,785	$9,050	$3,961	$13,520
Large Urbanized	$3,040	$2,017	$2,527	$483	$253	$3,861	$12,820	$5,155	$17,594
Major Urbanized	$6,080	$4,033	$3,822	$804	$507	$7,722	$43,997	$10,310	$54,445

Source: Highway Economic Requirements System.

Pavement Condition Modeling

The version of HERS used for this report incorporates a revision to the modeled relationship between pavement roughness and average speed. In the previous model, pavement roughness causes drivers to slow down only when it reaches a level of roughness found extremely rarely on U.S. highways (International Roughness Index (IRI) > ~380 in./mi.). This relationship, taken from the World Bank's HDM-4 model, was based mainly on studies from low-income countries that are dated and for which documentation is unavailable in some cases. Yu and Lu (2014) observed that relevant data on the roughness-speed relationship that could be generalized to the

United States is scant.[10] In their own study using data from California highways, they found that the average free-flow speed decreases 0.0083 mph with every 1 in/mi increase in roughness. In incorporating this finding into HERS, it has been assumed that pavement roughness has no impact on speed at roughness levels below IRI values of 157 in./mi. This threshold value is taken from the economic evaluation manual of the New Zealand Transport Agency, which advises users to assume zero impacts of pavement roughness on vehicle running costs and rider comfort for roughness levels below 2.5 m/km (=157 in./mi.).[11]

Valuation of Travel Time Savings

As indicated in Appendix A of the 2015 C&P Report, the values of travel time used in HERS were comprehensively updated to support the economic analyses of alternative highway investment levels presented in the main chapters of that report. The primary objectives of that update were to:

- Identify reliable, recent sources of information on major components of the values of travel time, including hourly values of vehicle drivers' and other occupants' time, vehicle occupancy, and the distribution of vehicle use by travel purpose.
- Expand HERS' previous estimates of the hourly value and amount of work-related business travel using light-duty passenger vehicles (automobiles and light trucks), which previously included only work-related travel in household vehicles, including corporate and government fleets, rental vehicles, emergency vehicles (police and fire), and taxi service.
- Distinguish between hourly values of travel time for buses and those for three- or four-axle single-unit trucks, which were previously combined into a single vehicle class in HERS.
- Ensure that the values of travel time for vehicle occupants used in HERS were consistent with DOT's official guidance on valuing travel time savings.

No important sources of new information on these issues since the previous C&P Report could be identified, so the adjustments to the values of travel time reported in this edition were limited to minor changes and technical corrections to the previous values. In addition, the values used in the current (23rd) edition of the C&P Report were converted from constant 2012 dollars, which were used in the previous report, to constant 2014 dollars, to make them consistent with other economic values used in the analyses described previously in this report.

Changes to key inputs used to construct the values of time reported in *Exhibit A-2*, corrections to the calculations used to construct the table entries, and their effects on the entries in the table include the following:

- A small fraction of use of rental cars (HERS VT1 and VT2) and light-duty trucks (VT3) was reassigned from personal to business travel to reflect households' use of rental vehicles. Previously, all household use of rental vehicles was assumed to be for personal travel; this revision assumes instead that household use of rental vehicles is divided between business and personal travel in the same proportion as is use of household-owned vehicles. Because business travel is assumed to be valued at a higher hourly rate than personal travel, this change slightly increases the average values of travel time per vehicle hour for HERS VT1, VT2, and VT3.
- Travel using light-duty trucks—including vans, pickups, and SUVs—owned by businesses but stored at the private residences of business owners or employees, as reported in the 2002 Vehicle Inventory and Use

[10] Yu, B, and Lu, Q. 2014, Empirical model of roughness effect on speed. International Journal of Pavement Engineering, vol. 15, no. 4, pp. 345-351.
[11] New Zealand Transport Agency 2016, Economic Evaluation Manual, First Edition, Amendment 1. Available at: http://www.nzta.govt.nz/assets/resources/economic-evaluation-manual/economic-evaluation-manual/docs/eem-manual-2016.pdf.

Survey, was accounted for separately. Use of these vehicles was previously assumed to be included in travel by household members reported in 2009 National Household Travel Survey (NHTS), but the extent to which this assumption was correct was unknown. The model has been updated to allow for the presence of additional passengers when these vehicles are used for business travel. This change increases the estimated average occupancy of HERS VT3 (4-tire trucks) slightly, which increases the value of travel time per vehicle hour for HERS VT3 slightly.

- Business travel using urban public transit and intercity bus services, as reported in the 2009 NHTS, was accounted for and valued separately. Previously, all passengers traveling on public transit and intercity buses were assumed to be engaged in personal travel. Because business travel is assumed to be valued at a higher hourly rate than personal travel, this change slightly increases the average values of travel time per vehicle hour for HERS VT5a (3-4 Axle Single-Unit Trucks) and 5b (Buses).

Exhibit A-2 shows components of the hourly value of travel time for each HERS vehicle type, reports the overall average values of time per vehicle hour in 2014 dollars, and compares these with the 2012 values used in the 2015 C&P Report.

Exhibit A-2: Estimated 2014 Values of Travel Time by Vehicle Type

2014 Travel Time Cost Element	VT1 Small Auto	VT2 Medium Auto	VT3 4-Tire Truck	VT4 6-Tire Truck	VT5a 3–4 Axle Truck	VT5b Bus	VT6 4-Axle Combination	VT7 5+-Axle Combination
Business Travel								
Value of Time per Person Hour	$32.30	$31.74	$30.90	$27.40	$28.13	$25.73	$28.53	$28.53
Average Vehicle Occupancy	1.33	1.33	1.36	1.38	1.14	1.50	1.02	1.02
Total Hourly Value of Occupants' Time	$42.98	$42.11	$42.17	$37.79	$32.18	$38.59	$28.99	$28.99
Vehicle Capital Cost per Vehicle	N/A	N/A	N/A	$12.38	$19.71	$7.80	$15.62	$12.95
Inventory Value of Cargo	N/A	N/A	N/A	N/A	N/A	N/A	$0.10	$0.17
Value of Time per Vehicle Hour	$42.98	$42.11	$42.17	$50.17	$51.89	$46.40	$44.72	$42.11
Personal Travel								
Value of Time per Person Hour	$12.53	$12.53	$12.53	N/A	N/A	$12.53	N/A	N/A
Average Vehicle Occupancy	1.57	1.76	1.64	N/A	N/A	12.64	N/A	N/A
Value of Time per Vehicle Hour	$19.74	$22.00	$20.55	N/A	N/A	$158.44	N/A	N/A
Share of Vehicle Use for Personal Travel	88.96%	90.32%	78.14%	N/A	N/A	89.90%	N/A	N/A
Average Values per Vehicle Hour								
2014	$22.31	$23.95	$25.27	$50.17	$51.89	$204.84	$44.72	$42.11
2012 (from 2015 C&P Report)	$21.43	$23.06	$24.58	$53.15	$54.34	$180.51	$44.37	$41.75

Source: DOT Revised Guidance on the Value of Travel Time in Economic Analysis (Revision 2 – 2015 Update) and internal DOT estimates.

Highway Operational Strategies

One of the key modifications to HERS, introduced in the 2004 C&P Report, was the ability to consider the impact of highway management and operational strategies, including Intelligent Transportation Systems (ITS), on highway system performance. This feature has been substantially updated in this report following review of literature on ITS impacts. Current and future investments in operations are modeled outside of HERS, but the impacts of these deployments affect the model's internal calculations, and thus also affect the capital improvements considered and implemented in HERS.

Among the many operational strategies available to highway agencies, HERS considers only certain types based on the availability of suitable data and empirical impact relationships. These strategies have been revised from the 2015 C&P Report after a literature review to update the impacts of operations strategies and to remove others. The 2015 C&P Report operations strategies that have changes in the method of application are:

- Ramp Metering is now modeled as an 8-percent increase in freeway base capacity; this value feeds directly into the freeway delay function. Compared to the previous method, the positive impact of ramp meters is now more modest.
- Integrated Corridor Management is now modeled as a 25-percent decrease in freeway base delay. This delay decrease is higher than the factor previously used, resulting in larger delay decrease.
- Traveler information and emergency vehicle signal preemption were removed from consideration due to questionable impact relationships from the literature.

The impacts of all other operations strategies remain the same. *Exhibit A-3* details the operational strategies deployed and the estimates of their impacts, which are based primarily on a review of the DOT ITS Benefits Database (https://www.itsbenefits.its.dot.gov/its/benecost.nsf/ByLink/BenefitsAbout).

Exhibit A-3: Impacts of Operations Strategies in HERS

Operations Strategy	Impact Category	Impact
Arterial Management		
Adaptive Signal Control	Delay	-25%
	Travel time	-12%
Automated Enforcement; Speed and Red Light Cameras	Total Crashes	-15%
Signal Timing Coordination	Delay	-20%
	Travel time	-10%
Freeway Management		
Ramp Metering	Mainline Capacity	6%
	Total Crashes	-30%
Road Weather Systems		
Anti-icing Technology	Total Crashes	-70%
RWIS and Other Weather Information	Total Crashes	-15%
Incident Management (Freeways Only)		
Incident Detection with Service Patrols	Incident Duration	-55%
Active Transportation and Demand Management Systems		
Dynamic Ramp Metering	Capacity	8%
Integrated Corridor Management Systems		
Smart Corridors Solutions (ASC, TSP, HOT/HOV Lanes, Ramp Metering)	Travel Time	-15%
	Total Crashes	-20%
	Total Delay	-25%

Source: Highway Economic Requirements System.

Examples of HERS Impact Estimates

HERS calculates the impacts of investments on speeds, operating costs, crash costs, and emissions. These calculations use a set of lookup tables and equations that vary by vehicle type and other variables, and are generally drawn from other published sources such as the Highway Capacity Manual and Highway Safety

Manual. More detailed information is available in the HERS Technical Report, which is currently being updated and will be made available online at (https://www.fhwa.dot.gov/policy/otps/).

Vehicle Operating Costs

Exhibit A-4 demonstrates the effects of pavement roughness on vehicle operating costs in the HERS model. Vehicle operating costs include fuel, oil, tires, maintenance and repair, and vehicle depreciation. For simplicity, figures are shown for only two vehicle types (small automobile and combination truck) over a range of speeds (20–70 mph), for three different pavement conditions (IRI 50, 95, 170) on level, straight pavement. As discussed in Chapter 6, ride quality changes from "good" to "fair" as IRI rises above 95 and then to "poor" for IRI above 170. HERS currently resets the IRI to 50 following a full reconstruction project.)

As *Exhibit A-4* shows, improvements to pavement condition reduce vehicle operating costs but the size of the impact varies. For example, for a small automobile traveling at 50 miles per hour on a level, straight road, estimated operating cost is 17 percent lower at an IRI of 50 rather than 170 (per-VMT cost of $0.291 vs. $0.351). For a combination truck under the same conditions, the estimated reduction in operating costs would be 16 percent. (Note that these results would differ for roads with curves or grades.)

Exhibit A-4: Example of Vehicle Operating Costs per VMT

International Roughness Index (IRI)	Vehicle Speed (miles per hour)					
	20	30	40	50	60	70
Small Automobiles						
50	$0.366	$0.305	$0.284	$0.291	$0.320	$0.365
95	$0.383	$0.322	$0.302	$0.311	$0.341	$0.390
170	$0.417	$0.357	$0.339	$0.351	$0.387	$0.442
Combination Trucks						
50	$1.220	$0.989	$0.884	$0.888	$0.990	$1.175
95	$1.258	$1.029	$0.929	$0.940	$1.050	$1.244
170	$1.341	$1.119	$1.030	$1.055	$1.184	$1.401

Source: Highway Economic Requirements System.

Emissions

Emissions are estimated using emission rates per VMT for three vehicle classes (four-tire autos and trucks; single-unit trucks; and combination trucks) and four highway types (rural highway with unrestricted access, rural highway with restricted access, urban highway with unrestricted access, and urban highway with restricted access). Highway improvement projects are modeled as affecting emissions through their influence on travel volumes and speeds. Emission costs are then monetized using data from EPA's MOVES model.

Exhibit A-5 provides an example of HERS' estimates of air pollution damage costs. It shows average air pollution costs per VMT at 5 mph intervals for each of HERS' three vehicle classes operating on rural highway sections with restricted access. The figures are an overall total for four types of emissions: CO, SOx, NOx, and PM. As shown, emission costs per VMT vary by vehicle type and speed but are substantially higher when vehicles are traveling at low speeds, such as during extreme congestion. For example, for four-tire vehicles, a decrease in speed from the 13–17 mph range to 3–7 mph increases the estimated emission cost by 91 percent (per VMT, from $0.0167 to $0.0319). For a combination truck making the same change in operating speeds, the increase in emission cost would be 70 percent. At any speed, the emissions cost per VMT is substantially higher for single-unit trucks than for four-tire vehicles, and still higher for combination trucks.

Exhibit A-5: Example of Emission Damage Costs ($ per Vehicle-Mile)

Speed	Four-Tire Vehicles	Single-Unit Trucks	Combination Trucks
< 3	$0.0515	$1.0493	$2.4214
3—7	$0.0319	$0.5331	$1.2262
8—12	$0.0214	$0.2958	$0.7699
13—17	$0.0167	$0.2271	$0.7215
18—22	$0.0140	$0.1924	$0.6659
23—27	$0.0135	$0.1693	$0.6262
28—32	$0.0139	$0.1605	$0.6098
33—37	$0.0156	$0.1437	$0.4813
38—42	$0.0169	$0.1372	$0.4603
43—47	$0.0177	$0.1316	$0.4438
48—52	$0.0177	$0.1257	$0.4045
53—57	$0.0169	$0.1201	$0.3580
58—62	$0.0164	$0.1119	$0.3385
63—67	$0.0166	$0.1086	$0.3528
68—72	$0.0172	$0.1060	$0.3640
>= 73	$0.0183	$0.1020	$0.3527

Source: Highway Economic Requirements System.

Safety

Crash rates are estimated in HERS using a set of empirically derived equations for six different types of roads: urban/rural freeways, urban/rural multi-lane roads, and urban/rural two-lane roads. Improvement projects modeled in HERS can affect estimated crashes through their influence on traffic volumes and other crash model parameters, such as grade, curvature, and the presence and dimensions of shoulders and medians.

Exhibit A-6 shows the calculations for rural multi-lane roads, which are based on a modified version of an equation developed by Wang, Hughes, and Stewart. (Jun Wang, Warren Hughes and Richard Stewart, *Safety Effects of Cross-Section Design of Rural Four-Lane Highways*, FHWA Report FHWA-RD-98-071, May 1998, Equation 6.)

Exhibit A-6: Safety Equation for Rural Multi-Lane Roads

$$\boldsymbol{CRASH = CRC \times AADT^{0.073} \times exp(0.131 \times RHRRML - 0.151 \times AC + 0.034 \times DDRML + 0.078 \times INTSPM - 0.572 \times RPA - 0.094 \times SHLDW - 0.003 \times MEDW + 0.429 \times PDEVEL)}$$

where:

CRASH	crash rate per 100 million VMT
AADT	annual average daily traffic
CRC	crash rate coefficient for rural multilane roads (=165.5 in this case)
RHRRML	roadside hazard rating for rural multilane roads (=2.45)
AC	1 for sections with (full or partial) access control, 0 for other sections
DDRML	driveway density (per mile) for rural multilane roads (0.94 used for the 23rd C&P Report)
INTSPM	intersections per mile (maximum =10)
RPA	1 for rural principal arterials and rural Interstate, 0 for lower functional systems
SHLDW	right shoulder width, in feet (maximum = 12 feet)
MEDW	50 if positive barrier median, median width, in feet, otherwise (maximum = 50)
PDEVEL	probability that road is in area of dense development (=31% for undivided multi-lane and 9% for divided multi-lane)

Source: Highway Economic Requirements System.

Unquantified Costs and Benefits

Planning and Miscellaneous Agency Costs

The HERS model omits the costs that highway projects entail in public consultation and outreach. Also omitted are possible effects of highway projects on certain types of agency costs, such as those for overhead and highway law enforcement and safety; these effects defy quantitative generalizations, being quite context-specific. Even the direction of these effects could vary. For example, adding capacity to some highway corridors could reduce the incidence of aggressive driving, which can be engendered by frustration with stop-and-go traffic, which in turn could reduce the need for highway patrol presence. On other highway corridors, however, adding capacity could *increase* the need for highway patrol presence by making speeding more possible. For many items of overhead expense, one would expect the types of projects that HERS models to have only marginal impact if any: for example, simple resurfacing of pavement would generally not affect materially the costs of traffic control center operations.

Environmental Effects

Apart from changes to emissions of pollutants, HERS does not capture the environmental impacts of highway projects such as changes in noise levels, ecosystem disruption, or water runoff. The HPMS database on which HERS relies lacks the information that would be needed to model these effects, which do not readily lend themselves to quantitative, or even qualitative, generalizations. Projects often include elements to mitigate or remediate harm to the environment, such as noise walls; these are reflected in the HERS estimates of typical improvement costs. Although negative effects can remain, positive effects are also possible. For example, while increases in freeway traffic volume and speed may increase traffic noise levels, adding capacity to a severely congested urban arterial might reduce noise levels from congestion-related horn honking. Moreover, even with reasonable estimates of environmental impacts, translating these measures into impacts on well-being and monetary costs or benefits is generally quite challenging. How would an analyst value, for example, the loss of aesthetics from a row of trees being cut down to carve out additional lanes? The contingent valuation approach is standard for addressing such questions, but its validity is widely debated. For these various reasons, HERS limits its modeling of environmental impacts to the changes in pollution emissions.

Economic Effects

The savings in transportation costs that result from highways improvements produce a variety of economic adaptations that entail increased highway use ("induced travel"). Popular examples include changes to freight logistics, such as more frequent shipments to economize on inventory. As a generic allowance for the net benefits from such adaptations, HERS measures an "incremental consumer surplus," which could also be termed an induced travel benefit. Relative to the other user benefits that HERS measures—the savings in time and vehicle operating costs for existing travel—the induced travel benefit is quite small. However, it does not capture all the benefits from economic adaptations to highway improvements. Potential additional benefits can result from market catchment areas expanding after highways improve; this can increase both productivity (by facilitating competition) and the variety of goods and services that are available. FHWA continues to monitor and evaluate the growing body of research on these hard-to-measure benefits for possible future treatment within HERS.

Other Effects

HERS evaluates projects independently for a geographically scattered national sample of highway sections. Its assessment of national needs for highway investment will thus not capture benefits for which a network model would be required, such as the option value of additional alternative routes or travel routes becoming less circuitous. HERS also does not consider the effects of modeled highway improvements on non-motorized transportation. For motor vehicles, a possibly significant effect it does not capture is the increase in traveler comfort resulting from pavement improvements. Although research into how much travelers value this benefit is scant, this value could conceivably be significant compared to savings in vehicle operating costs from pavement improvements, which HERS does measure.

Future HERS Enhancements Currently Underway

As part of an ongoing program of model revisions and improvements, the matrix of typical costs per mile for the various types of highway capital improvements modeled in HERS, as reflected in *Exhibit A-1*, is currently being updated. As part of this effort, the matrix will be expanded to capture differences in costs associated with "typical reconstruction" versus "total reconstruction," which would involve complete reconstruction of the roadway starting at the subgrade. The current distinction between "normal cost" capacity expansion and "high cost" capacity expansion will be broadened to consider the impact on expansion costs resulting from different types of obstacles to widening that are now coded by the States in HPMS. Other aspects of this research effort include developing procedures for adjusting the cost matrix to remove costs associated with culverts and bridge replacements in conjunction with highway widening projects, in anticipation that future enhancements to the National Bridge Investment Analysis System will allow it to compute such needs more accurately than HERS can. Procedures also will be developed to facilitate analysis of the variable costs associated with different overlay depths.

Work is also underway to refine and update the new pavement performance equations recently introduced into HERS. These equations were based on an early version of the American Association of State Highway and Transportation Officials (AASHTO) Mechanistic-Empirical Pavement Design Guide algorithms, some of which have subsequently been revised. This research is also intended to address certain anomalies encountered in translating the simplified mechanistic-empirical equations into the HERS framework.

FHWA has initiated a major effort to update the equations for predicting vehicle fuel economy and other vehicle operating costs currently included in HERS and in several other public and private-sector tools for highway benefit-cost analysis. The current HERS procedures are based on a 1982 study and are not considered adequately reflective of current vehicle technology and driving patterns. The new study builds on the Strategic Highway Research Program 2 Naturalistic Driving Study and the Road Information Database to develop driving cycles that will be used to model the relationship between vehicle speed and fuel consumption. The impacts of road curvature and pavement roughness on fuel consumption also will be explored. This project includes modeling the relationships among pavement roughness, speed, roadway characteristics, and vehicle operating costs such as repair and maintenance, tire wear, mileage-related vehicle depreciation, and oil consumption.

FHWA is engaged in research to update and refine the HERS valuation of travel time savings. The proliferation of tolled express lanes on U.S. highways has provided valuable new data for studies of motorist willingness to pay for travel time savings, and the evidence from these and other studies is being examined.

APPENDIX B
Bridge Investment Analysis Methodology

Bridge Investment Analysis Methodology

The National Bridge Investment Analysis System (NBIAS) was developed to assess national bridge investment needs and the tradeoff between funding and performance. NBIAS, first introduced in the 1999 C&P Report, is used to model investments in bridge repair, rehabilitation, and functional improvements. Over time, the system has been used increasingly as an essential decision-support tool for analyzing policy and providing information to the U.S. Congress.

NBIAS is based on an analytical framework similar to that used in the Pontis bridge management system developed by the Federal Highway Administration (FHWA) in 1992 and subsequently adopted by the American Association of State Highway and Transportation Officials (AASHTO). The system incorporates economic forecasting tools to project the multiyear funding needs required to meet user-selected performance objectives over the length of a user-specified performance period. NBIAS differs from Pontis in that it works with bridge condition data as reported by the States, Federal agencies, and Tribal governments for the National Bridge Inventory (NBI) in addition to the element/condition state inspection regime used in Pontis. NBIAS combines statistical models with engineering principles and heuristic rules to synthesize representative elements so they can be defined and manipulated using the same structure of condition states, actions, deterioration, costs, and effectiveness probabilities used in Pontis, which makes them compatible with the predictive models and analytical routines in Pontis. NBIAS extends the Pontis element model by introducing the climate zone dimension into the stratification scheme and adding user cost components to the cost model. Effective in version 4.0 (2011), NBIAS also features an enhanced element optimization model that integrates selected maintenance policies. *Exhibit B-1* illustrates the general NBIAS decision-making approach.

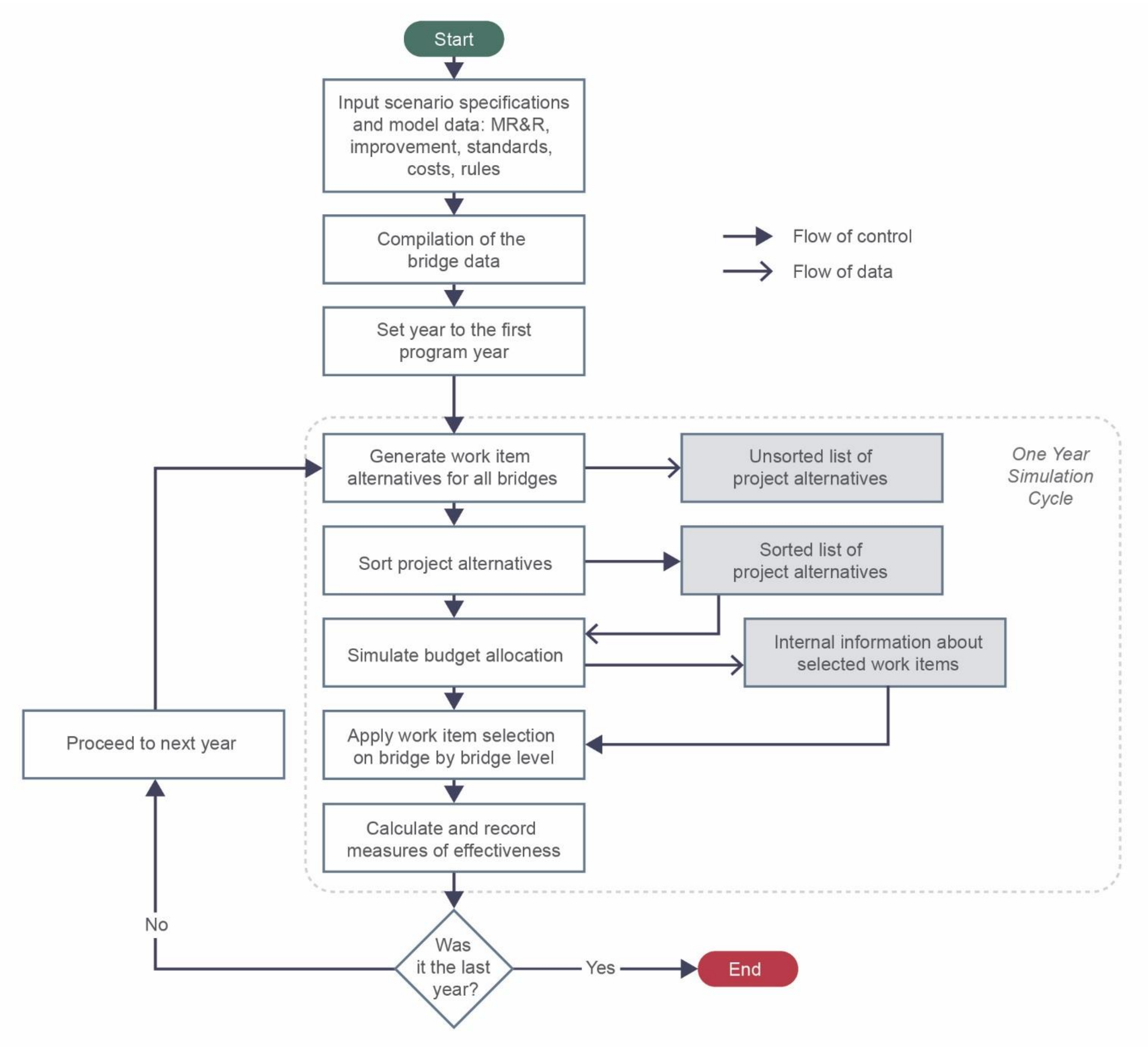
General Methodology

Using linear programming optimization, NBIAS generates a set of prototype maintenance policies for defined subsets of the NBI. Models of element deterioration, feasible actions, and the cost and effectiveness of those actions are incorporated as major inputs for each subset of the inventory. For functional deficiencies and improvements, NBIAS uses a model similar to the bridge level-of-service standards and user cost models of Pontis, augmented by a bridge improvement model developed by the Florida Department of Transportation.

With a set of synthesized projects developed from the maintenance and functional improvement models, NBIAS calculates a tradeoff structure showing the effect of hypothetical funding levels on each of more than 200 performance measures, including FHWA's recently adopted measures of the percentage of bridge deck area in good, fair, and poor condition. For this analysis, the system uses an adaptation of an incremental benefit-cost model with graphical output showing the tradeoff between funding and performance. To estimate functional improvement needs, NBIAS applies a set of improvement standards and costs, which the user can modify, to each bridge in the NBI. The system uses the available NBI data to predict detailed structural element data for each bridge. It measures repair and rehabilitation needs at the bridge-element level using a Markov decision model and then applies the obtained maintenance strategy, along with the improvement model, to each bridge.

Replacement costs for structures are determined based on State-reported values gathered by FHWA. Improvement costs are consistent with those in Pontis and are adjusted to account for inflation. In evaluating functional improvement needs and repair and rehabilitation needs, the system uses a set of unit costs for various improvement and preservation actions. State-specific cost-adjustment factors are applied to the unit costs.

Exhibit B-1: NBIAS Flow Chart



The NBIAS user can specify hypothetical budget constraints in several ways, by setting (1) a range of constant budgets, which directs the software to find the performance levels achievable with each budget level within the range; (2) a range of budget growth rates; or (3) a minimum benefit-cost ratio, in which case, the software determines the funding level corresponding to that benefit-cost ratio. All of these options have applications in the preparation of the C&P Report and could be useful for specific owner agencies that might want to use NBIAS to analyze the funding vs. performance tradeoff for their transportation asset management plans or other planning purposes.

Determining Functional Improvement Needs

The standards for functional improvement address lane width, shoulder width, load rating, and clearances (vertical and horizontal). NBIAS includes a set of standards by functional class, additional standards derived from sufficiency rating calculations, and those standards prescribed by the Florida Department of Transportation models.

The standards used in NBIAS initially were set to be the same as the default standards specified in Pontis, which were established as an early effort to define level-of-service standards for AASHTO. The standards used in the previous editions of the C&P Report were reviewed and compared with design standards in the AASHTO Green Book, and adjustments were made where warranted. A revised set of standards was subsequently added that triggers consideration of a functional improvement whenever a deduction in sufficiency rating occurs due to road width, load rating, or clearances. Adopting the Florida improvement model enabled further fine-tuning of the analysis logic of functional needs.

NBIAS estimates needs for the following types of bridge functional improvements: widening existing bridge lanes, raising bridges to increase vertical clearances, and strengthening bridges to increase load-carrying capacity. Functional improvement needs are determined by applying user-specified standards to the existing bridge inventory, subject to benefit-cost considerations. For example, a need to raise a bridge will be identified if the vertical clearance under the bridge fails to meet the specified standard and if the stream of discounted excess cost of diverting commercial vehicles around the bridge exceeds the cost of improving the bridge.

If functional improvement is infeasible due to the bridge design or impractical because of deteriorated structural condition, a replacement need is generated. Replacement need might also be identified if a user-specified replacement rule is triggered. For example, one or more replacement rules can be introduced in NBIAS based on the threshold values for age, sufficiency rating, and health index.

Because the benefit predicted for a functional improvement increases proportionally with the amount of traffic, whether a functional improvement is justified, and how much benefit is derived from that improvement, greatly depends on predicted traffic. In the current version of NBIAS, traffic predictions are made for each year in an analysis period based on NBI data. NBIAS allows the user to apply either linear or exponential traffic growth projections. Linear growth was selected for this edition of the C&P report, consistent with the assumption used in the Highway Economic Requirements System (HERS). When NBIAS selects a structure for replacement, the cost of the replacement is based on the number of lanes on the existing bridge. The cost of adding lanes to satisfy increased capacity demands is not included in the cost to construct the replacement structure. Additional costs for expanding bridges to meet increased capacity demands are included in the cost to construct a lane mile of highway used in HERS.

Determining Repair and Rehabilitation Needs

To determine repair and rehabilitation needs, NBIAS estimates the type, quantity, and condition of elements that exist for each bridge in the NBI by statistical means and applies a set of deterioration and cost models to the estimated elements. This allows NBIAS to determine the optimal preservation actions for maintaining the bridge inventory in a state of good repair while minimizing user and agency costs.

Predicting Bridge Element Composition

The NBIAS analytical approach relies on structural element data not available in the NBI. To develop such data, NBIAS uses a set of Synthesis, Quantity, and Condition (SQC) models to predict the elements that exist on each bridge in the NBI and the condition of those elements.

The synthesis part of the SQC model is implemented as a decision tree, in which the choice of the elements for a bridge is dictated by its design, material, and several other characteristics available in the NBI. Element quantities are estimated based on the geometric dimensions of the bridge, its design, and material. The condition of the synthesized elements is modeled in the form of a percentage-based distribution of element quantities across condition states. Such distributions are evaluated based on the structural ratings (superstructure, substructure, and deck) of the bridge to which statistically tabulated lookup data and Monte Carlo simulation are applied.

The current version of NBIAS can accept the direct import of structural element data when such data are available, but this capability was not used for the development of this report. States are now required to collect and report such data for bridges on the National Highway System (NHS). Many collect such data for other State-owned bridges, as well, as part of their bridge inspection process.

Calculating Deterioration Rates

NBIAS models bridge deterioration probabilistically, based on techniques first developed for Pontis. In the system, deterioration rates are specified for each bridge element through a set of transition probabilities that specify the likelihood of progression from one condition state to another over time. For each element, deterioration probability rates vary across nine climate zones.

Forming the Optimal Preservation Policy

The policy of maintenance, repair, and rehabilitation (MR&R) in NBIAS is generated with the help of two optimization models: long-term and short-term. The long-term model is formulated as a linear program with the objective of keeping the element population in a steady-state condition that requires the minimum cost to maintain. The short-term model, not being concerned with the steady state, seeks to find a policy of remedial actions that minimize the cost of moving the inventory to conditions the long-term solution recommends. The short-term MR&R model is implemented as the Markov decision model solved as a linear programming problem.

In the earlier versions of NBIAS, only one MR&R strategy was available. While developing NBIAS version 4.0, a study was conducted to develop alternative MR&R models. The result was three additional MR&R strategies reflecting approaches for maintaining a bridge network that are more diverse, as discussed in the following sections.

Minimize MR&R Costs

This strategy involves identifying and implementing a pattern of MR&R improvements that minimizes long-term MR&R spending. This strategy is intended to prevent a catastrophic decrease in bridge network performance rather than to maintain or improve the overall condition of the bridge network. Some Pontis users and participants on expert peer-review panels for NBIAS had raised concerns that this strategy was not consistent with typical bridge management strategies, and that following such a strategy could call for a bridge to be replaced sooner than might be the case if a more aggressive MR&R approach were used.

One consequence of having initially developed this strategy as the only MR&R option in NBIAS was that most measures of bridge performance (such as the health index or percentage of deficient bridges) would always worsen over the 20-year analysis period, even if all the potential bridge improvements identified in NBIAS as cost-beneficial were implemented. The exception was the estimated backlog of bridge needs, which is why this report has focused on that metric in the past. The MR&R strategy influences the estimated backlog; assuming a less aggressive MR&R strategy reduces the estimated MR&R backlog but also increases the estimated bridge replacement backlog, generally resulting in a higher combined backlog estimate.

Maximize Average Returns

This strategy seeks to maximize the degree of bridge system performance improved per dollar of MR&R expenditure. Following this strategy results in more MR&R spending than under the Minimize MR&R strategy, but still generally results in an increase in the number of deficient bridges over time.

Sustain Steady State

This strategy was used for the analyses presented in the 2013 C&P Report. It involves identifying and implementing a pattern of MR&R improvements that would achieve an improved steady state in terms of overall bridge system conditions, without frontloading MR&R investment. Following this strategy results in more MR&R spending than under the Maximize Average Returns strategy, but still generally results in increases in deficient bridges over time.

State of Good Repair

This strategy seeks to bring all bridges to a good condition that can be sustained via ongoing investment. MR&R investment is frontloaded under this strategy, as large MR&R investments would be required in the early years of the forecast period to improve bridge conditions, while smaller MR&R investments would be needed in the later years to sustain bridge conditions.

The selection of MR&R policy can significantly influence the results of an NBIAS analysis. Based on the results of the comparison of life-cycle costs for MR&R relative to replacement, the system might simulate more or fewer bridge replacements. Given the MR&R and replacement costs developed for this C&P Report, the State of Good Repair strategy, although the most aggressive, generates results more consistent with agency practices and recent trends in bridge condition than the other three strategies evaluated. It was used for the 2015 C&P Report and has been adopted for use in the baseline analyses presented in Chapter 7 of this report. (Please note that, despite the similarity in names, the correspondence is not one-to-one between the NBIAS State of Good Repair strategy and the state of good repair benchmark presented in Chapter 7. The state of good repair benchmark includes all investments identified as cost-beneficial by NBIAS and includes both MR&R investments and functional improvements.)

Applying the Preservation Policy

Using transition probability data, and information on preservation action costs and user costs for operating on deteriorated bridge decks, NBIAS applies the Markov decision model to determine the optimal set of repair and rehabilitation actions for each bridge element based on the element's condition. During the simulation process, the preservation policy is applied to each bridge in the NBI to determine bridge preservation work needed to minimize user and agency costs over time.

In analyzing potential improvement options, NBIAS compares the cost of performing preservation work with the cost of completely replacing a bridge, to identify situations in which replacement would be more cost-effective. If the physical condition of the bridge has deteriorated to the point of being considered unsafe (the system user specifies the threshold for such a determination), the system might consider bridge replacement to be the only feasible alternative.

Future NBIAS Enhancements Currently Underway

Several enhancements are being introduced for future versions of NBIAS. One such enhancement is to enable the user to assign individual budgets for specific work categories, such as maintenance, rehabilitation, and replacement of structurally deficient bridges, instead of providing a single budget for all actions. This capability will enable the user to consider a broader array of potential alternative future investment strategies. NBIAS also will be modified to improve its ability to determine budget levels required to meet user-defined performance measures. This feature will enable the user to quickly determine the annual level of funding required over a specified period to change the current value of a performance measure to a user-specified target value.

Another important enhancement is to update the element specifications used in the system. NBIAS was developed using the AASHTO Commonly Recognized Elements specification. This standard was recently superseded by the AASHTO Manual for Bridge Element Inspection. FHWA has incorporated this specification in its requirements for submission for bridge element data for NHS bridges detailed in the Specification for National Bridge Inventory Bridge Elements (SNBIBE), and States are in the process of changing their bridge inspection practices to use the new element specifications. NBIAS is being updated to use data reported according to the SNBIBE, allowing for better incorporation of available State data and to support future use of the system. At the same time, the NBIAS element performance algorithms are being recalibrated to improve the model's prediction of various bridge condition measures. These algorithms, which were last fully recalibrated in 2006, are no longer fully consistent with current bridge management practices.

Currently, data for approximately 125,000 culverts are included in NBI. The NBIAS model does not contain the algorithms needed to conduct a full analysis of culverts because, unlike typical bridges, culverts do not have a deck, superstructure, or substructure. Instead, they are self-contained units located under roadway fill and typically are constructed of concrete or corrugated steel pipes. When multiple pipes or box culverts placed side by side below a public roadway span a total length greater than 20 feet, they are considered structures and are subject to the NBI reporting requirements. Functionality is being added to NBIAS to enable analysis of culvert deterioration, projection of future overall culvert conditions, and estimation of the costs of culvert maintenance and replacement.

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APPENDIX C
Transit Investment Analysis Methodology

Transit Investment Analysis Methodology

The Transit Economic Requirements Model (TERM), an analytical tool developed by the Federal Transit Administration (FTA), forecasts transit capital investment needs over a 20-year period. Using a broad array of transit-related data and research, including data on transit capital assets, current service levels and performance, projections of future travel demand, and a set of transit asset-specific condition decay relationships, the model generates the forecasts that appear in the C&P Report.

This appendix provides a brief technical overview of TERM and describes the various methodologies used to generate the estimates for the current (23rd) edition of the C&P Report.

Transit Economic Requirements Model

TERM forecasts the level of annual capital expenditures required to attain specific physical condition and performance targets within a 20-year period. These annual expenditure estimates cover the following types of investment needs: (1) asset preservation (rehabilitation and replacement); and (2) asset expansion to support projected ridership growth.

TERM Database

The capital needs forecasted by TERM rely on a broad range of input data and user-defined parameters. Gathered from local transit agencies and the National Transit Database (NTD), the input data are the foundation of the model's investment needs analysis, and include information on the quantity and value of the Nation's transit capital stock. The input data in TERM are used to draw an overall picture of the Nation's transit landscape; the most salient data tables that form the backbone of the TERM database are described below.

Asset Inventory Data Table

The asset inventory data table documents the asset holdings of the Nation's transit operators. Specifically, these records contain information on each asset's type, transit mode, age, and expected replacement cost. As the FTA does not directly measure the condition of transit assets, asset condition data are not maintained in this table. Instead, TERM uses asset decay relationships to estimate current and future physical condition as required for each model run. These condition forecasts are then used to determine when each type of asset identified in the asset inventory table is due for either rehabilitation or replacement. The decay relationships are statistical equations that relate asset condition to asset age, maintenance, and utilization. The decay relations and how TERM estimates asset conditions are further explained later in this appendix.

The asset inventory data are derived from a variety of sources, including the NTD, responses by local transit agencies to FTA data requests, and special FTA studies. The asset inventory data table is the primary data source for the information used in TERM's forecast of preservation needs.

Urban Area Demographics Data Table

This data table stores demographic information on 486 urbanized areas as well as for 10 regional groupings of rural operators. Fundamental data, such as current and anticipated population, in addition to more transportation-oriented information, such as current levels of vehicle miles traveled (VMT) and transit passenger miles, are used by TERM to predict future transit asset expansion needs.

Agency-Mode Statistics Data Table

The agency-mode statistics table contains operations and maintenance (O&M) data on each of the individual modes operated by 845 urbanized area transit agencies and 1,684 rural operators. Specifically, the agency-mode data on annual ridership, passenger miles, operating and maintenance costs, mode speed, and average fare data are used by TERM to help assess current transit performance, future expansion needs, and the expected benefits from future capital investments in each agency-mode (both for preservation and expansion). All the data in this portion of the TERM database come from the most recently published NTD reporting year. Where reported separately, directly operated and contracted services are both merged into a single agency-mode within this table.

Asset Type Data Table

The asset type data table identifies approximately 500 different asset types utilized by the Nation's public transit systems in support of transit service delivery (either directly or indirectly). Each record in this table documents each asset's type, unit replacement costs, and the expected timing and cost of all life-cycle rehabilitation events. Some of the asset decay relationships used to estimate asset conditions are also included in this data table. The decay relationships—statistically estimated equations relating asset condition to asset age, maintenance, and utilization—are discussed more in the next section of this appendix.

Benefit-Cost Parameters Data Table

The benefit-cost parameters data table contains values used to evaluate the merit of different types of transit investments forecasted by TERM. Measures in the data table include transit rider values (e.g., value of time and links per trip), auto costs per VMT (e.g., congestion delay, emissions costs, and roadway wear), and auto user costs (e.g., automobile depreciation, insurance, fuel, maintenance, and daily parking costs).

Mode Types Data Table

The mode types data table provides generic data on all of the mode types used to support U.S. transit operations—including their average speed, average headway, and average fare—and estimates of transit riders' responsiveness to changes in fare levels. Similar data are included for nontransit modes, such as private automobile and taxi costs. The data in this table are used to support TERM's benefit-cost analysis.

The input tables described above form the foundation of TERM, but are not the sole source of information used when modeling investment forecasts. In combination with the input data, which are static—meaning that the model user does not manipulate them from one model run to the next—TERM contains user-defined parameters to facilitate its capital expenditure forecasts.

Investment Policy Parameters

As part of its investment needs analysis, TERM predicts the current and expected future physical condition of U.S. transit assets over a 20-year period. These condition forecasts are then used to determine when each of the individual assets identified in the asset inventory table are due for either rehabilitation or replacement. The investment policy parameters data table allows the user to set the physical condition ratings at which rehabilitation or replacement investments are scheduled to take place (though the actual timing of rehabilitation and replacement events may be deferred if the analysis is budget-constrained). Unique replacement condition thresholds may be chosen for the following asset categories: guideway elements, facilities, systems, stations, and vehicles. For the current (23rd) edition of the C&P Report, all of TERM's replacement condition thresholds have been set to trigger asset replacement at condition 2.5. (Under the **Sustain 2014 Spending scenario**, many of these replacements would be deferred due to insufficient funding capacity.)

In addition to varying the replacement condition, users can vary other key input assumptions intended to better reflect the circumstances under which existing assets are replaced and the varying cost impacts of those circumstances. For example, users can assume that existing assets are replaced under full service, partial service, or a service shutdown. Users can also assume assets are replaced either by agency (force-account) or by contracted labor. Each of these affects the cost of asset replacement for rail assets.

Financial Parameters

TERM also includes two key financial parameters. First, the model allows the user to establish the rate of inflation used to escalate the cost of asset replacements for TERM's needs forecasts. Note that this feature is not used for the C&P Report, which reports all needs in current dollars. Second, users can adjust the discount rate used for TERM's benefit-cost analysis.

Investment Categories

The data tables described above allow TERM to estimate different types of capital investments, including rehabilitation and replacement expenditures, expansion investments, and capital projects aimed at performance improvements. These three different investment categories are described below.

Asset Rehabilitation and Replacement Investments

TERM's asset rehabilitation and replacement forecasts are designed to estimate annual investments for the ongoing rehabilitation and replacement of the Nation's existing transit assets. Specifically, these needs include the normal replacement of assets reaching the end of their useful life, mid-life rehabilitations, and annual "capital expenditures" to cover the cost of smaller capital reinvestment amounts not included as part of asset replacement or rehabilitation activities.

To estimate continuing replacement and rehabilitation investments, TERM estimates the current and expected future physical condition of each transit asset identified in TERM's asset inventory for each year of the 20-year forecast. These projected condition values are then used to determine when individual assets will require rehabilitation or replacement. TERM also maintains an output record of this condition forecast to assess the impacts of alternate levels of capital reinvestment on asset conditions (both for individual assets and in aggregate). In TERM, the physical conditions of all assets are measured using a numeric scale of 5 through 1; see *Exhibit C-1* for a description of the scale.

Exhibit C-1: Definitions of Transit Asset Conditions

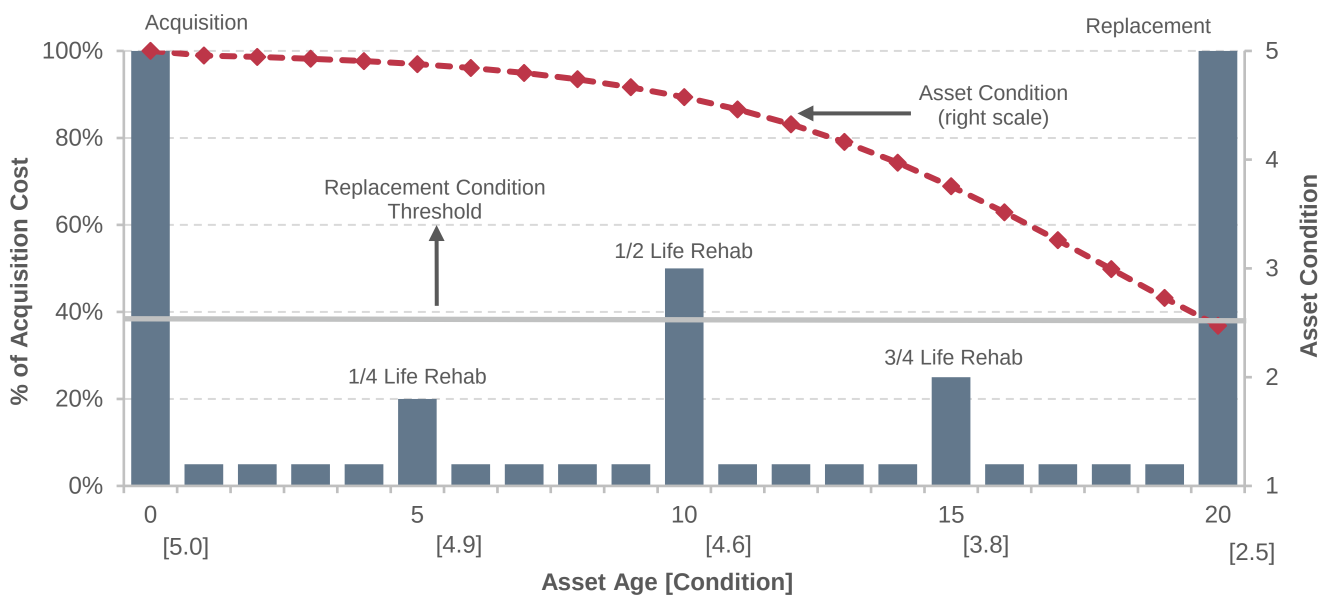
Rating	Condition	Description
Excellent	4.8–5.0	No visible defects, near new condition.
Good	4.0–4.7	Some slightly defective or deteriorated components.
Adequate	3.0–3.9	Moderately defective or deteriorated components.
Marginal	2.0–2.9	Defective or deteriorated components in need of replacement.
Poor	1.0–1.9	Seriously damaged components in need of immediate repair.

Source: Transit Economic Requirements Model.

TERM currently allows an asset to be rehabilitated up to five times throughout its life cycle before being replaced. During a life-cycle simulation, TERM records the cost and timing of each reinvestment event as a model output and adds it to the tally of national investment needs (provided they pass a benefit-cost test, if applied).

TERM's process of estimating rehabilitation and replacement needs is represented conceptually for a generic asset in *Exhibit C-2*. In this theoretical example, asset age is shown on the horizontal axis, the cost of life-cycle capital investments is shown on the left vertical axis (as a percentage of acquisition cost), and asset conditions are shown on the right vertical axis. At the acquisition date, each asset is assigned an initial condition rating of 5, or "excellent," and the asset's initial purchase cost is represented by the tall vertical bar at the left of the chart. Over time, the asset's condition begins to decline in response to age and use, represented by the dotted line, requiring periodic life-cycle improvements including annual capital maintenance and periodic rehabilitation projects. Finally, the asset reaches the end of its useful life, defined in this example as a physical condition rating of 2.5, at which point the asset is retired and replaced.

Exhibit C-2: Scale for Determining Asset Condition Over Time, From Acquisition to Replacement



Asset Expansion Investments

In addition to devoting capital to the preservation of existing assets, most transit agencies invest in expansion assets to support ongoing growth in transit ridership. To simulate these expansion needs, TERM continually invests in new transit fleet capacity as required to maintain at current levels the ratio of peak vehicles to transit passenger miles. The rate of expansion is projected individually for each of the Nation's 487 urbanized areas (e.g., based on the urbanized area's specific growth rate projections or historical rates of transit passenger mile growth), while the expansion needs are determined at the individual agency-mode level. TERM will not invest in expansion assets for agency-modes with current ridership per peak vehicle levels that are well below the national average (these agency-modes can become eligible for expansion during a 20-year model run if there is sufficient projected growth in ridership for them to rise above the expansion investment threshold).

In addition to forecasting fleet expansion requirements to support the projected ridership increases, the model also forecasts expansion investments in other assets needed to support that fleet expansion. This includes investment in maintenance facilities and, in the case of rail systems, additional guideway miles including guideway structure, trackwork, stations, train control, and traction power systems. Like other investments forecast by the model, TERM can subject all asset expansion investments to a benefit-cost analysis. Finally, as TERM adds the cost of newly acquired vehicles and supporting infrastructure to its tally of investment needs, it also ensures that the cost of rehabilitating and replacing the new assets is accounted for during the 20-year period of analysis.

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

Use of the 10 FTA regions captures regional differences in PMT growth, while use of population strata (over 1 million population, 1 million to 500,000, 500,000 to 250,000 and under 250,000) captures differences in urban area size.

The approach recognizes differences in PMT growth trends by mode. Over the past decade, the rate of PMT growth has differed significantly across transit modes, being highest for heavy rail, vanpool, and demand-response, and low to flat for motor bus. These differences are recognized in the Low and High Growth scenario expansion needs projections.

Asset Decay Curves

TERM asset decay curves were developed expressly for use within TERM and are comparable to asset decay curves used in other modes of transportation and bridge and pavement deterioration models. While the collection of asset condition data is not uncommon within the transit industry, TERM asset decay curves are believed to be the only such curves developed at a national level for transit assets. Most of the TERM key decay curves were developed using data collected by FTA at multiple U.S. transit properties specifically for this purpose.

TERM decay curves serve two primary functions: (1) to estimate the physical conditions of groups of transit assets and (2) to determine the timing of rehabilitation and replacement reinvestment.

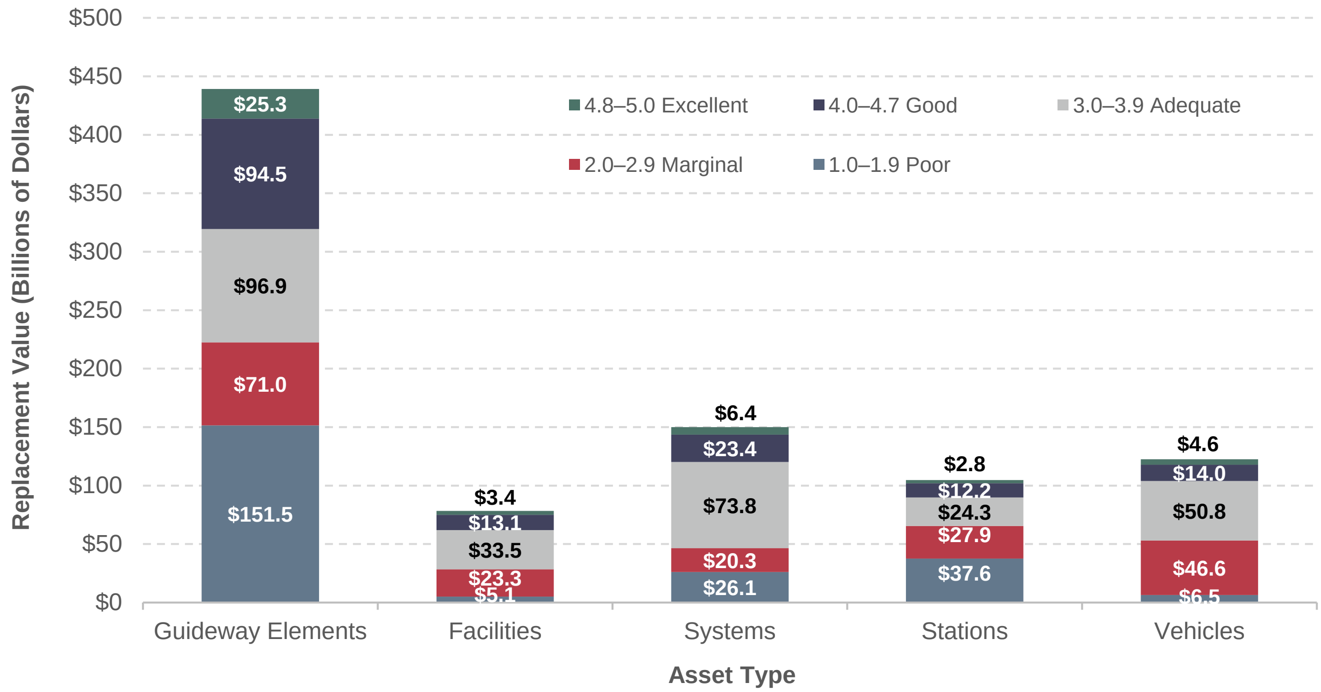
Estimating Physical Conditions

One use of the decay curves is to estimate the current and future physical conditions of groups of transit assets. The groups can reflect all of the national transit assets or specific subsets, such as all assets for a specific mode. For example, *Exhibit C-3* presents a TERM analysis of the distribution of transit asset conditions at the national level as of 2014.

This exhibit shows the proportion and replacement value of assets in each condition category (excellent, good, etc.) segmented by asset category. TERM produced this analysis by first using the decay curves to estimate the condition of individual assets identified in the inventory of the national transit assets, and then grouping these individual asset condition results by asset type.

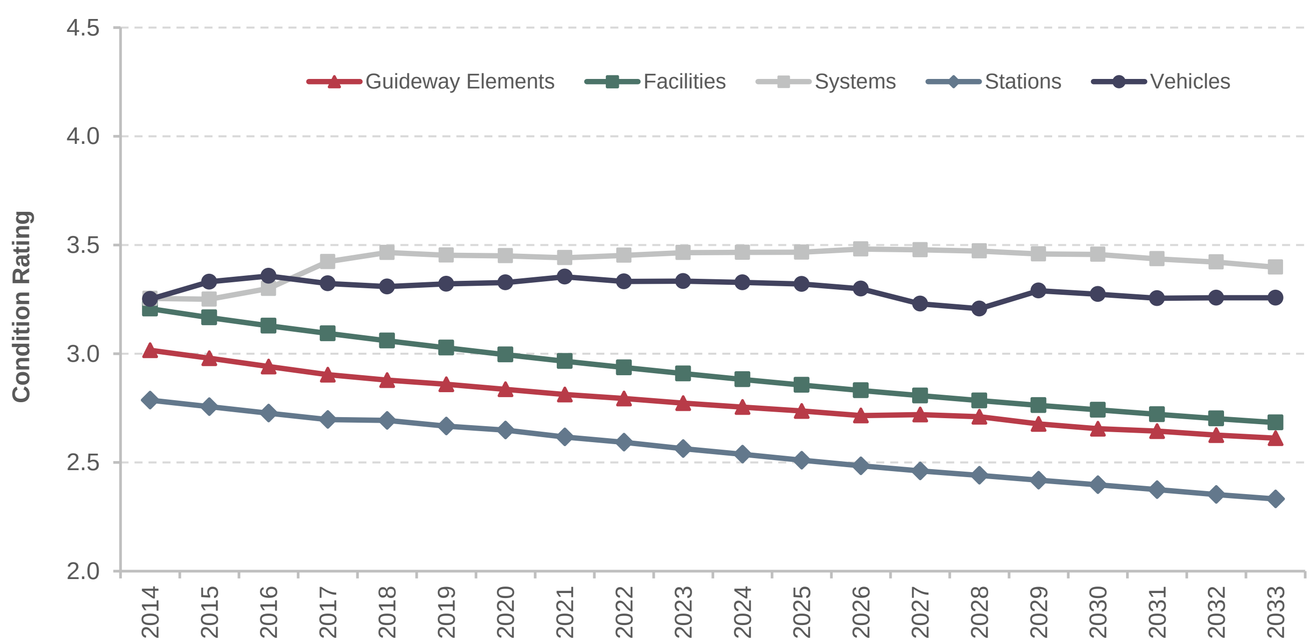
TERM also uses the decay curves to predict expected future asset conditions under differing capital reinvestment funding scenarios. An example of this type of analysis is presented in *Exhibits C-4* and *C-5*, which present TERM forecasts of the future condition of the national transit assets assuming the national level of reinvestment remains unchanged. *Exhibit C-4* shows the future condition values estimated for each of the individual assets identified in the asset inventory (weighted by replacement value) to generate annual point estimates of average future conditions at the national level by asset category. *Exhibit C-5* presents a forecast of the proportion of assets in either marginal or poor condition, assuming limited reinvestment funding for a subset of the national transit assets.

Exhibit C-3: Distribution of Asset Physical Condition by Asset Type for All Modes, 2014



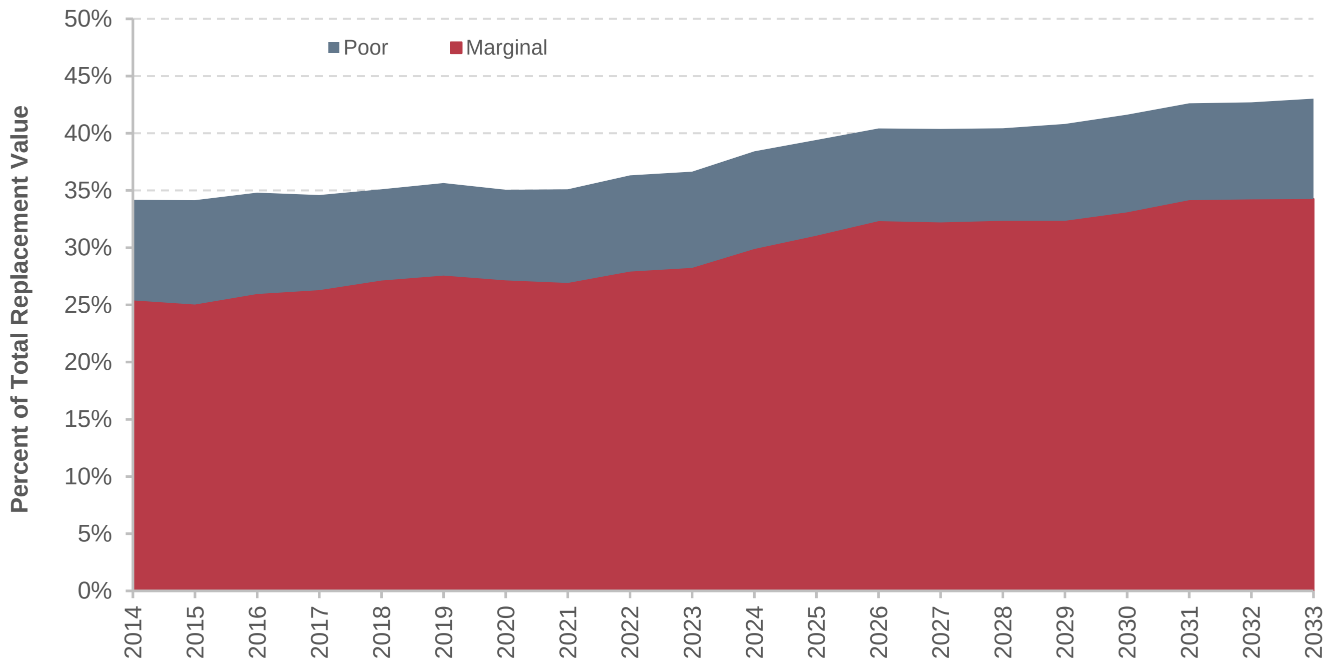
Source: Transit Economics Requirements Model.

Exhibit C-4: Weighted Average by Asset Category, 2014–2033



Source: TERM, Sustain 2014 Spending.

Exhibit C-5: Assets in Marginal or Poor Condition, 2014–2033



Source: TERM, Sustain 2014 Spending (Excludes Unreplaceable Assets).

Determine the Timing of Reinvestment

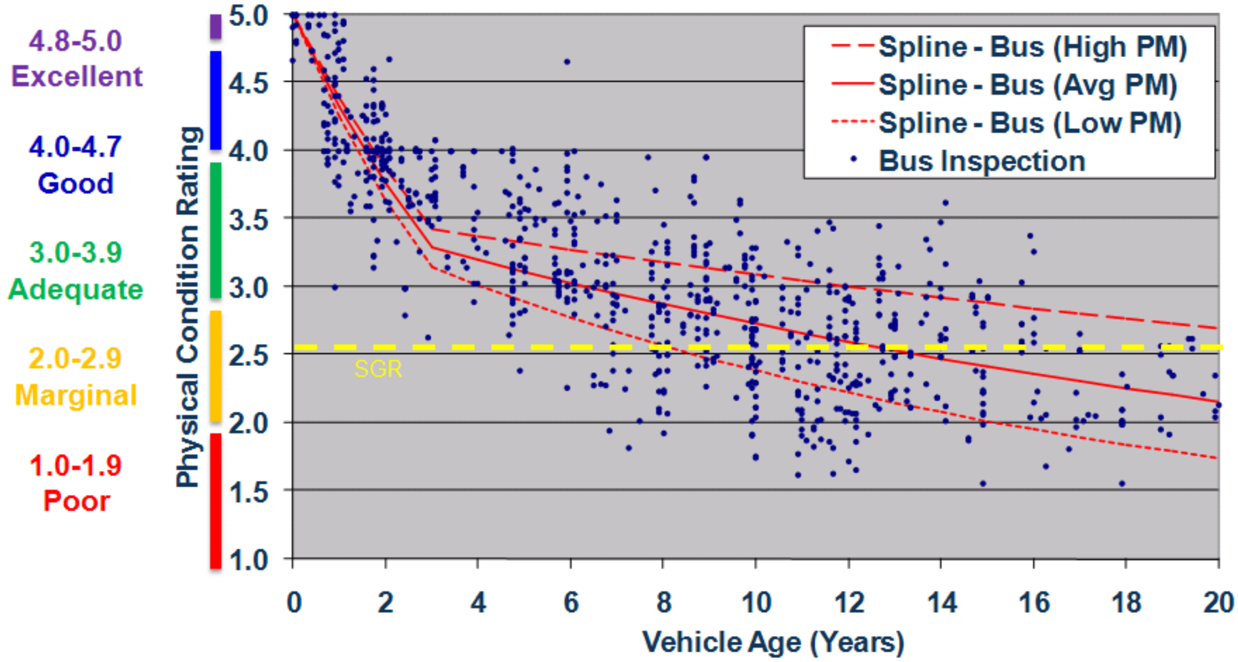
Another key use of the TERM asset decay curves is to determine when the individual assets identified in the asset inventory will require either rehabilitation or replacement, with the ultimate objective of estimating replacement needs and the size of the state of good repair (SGR) backlog. Over the 20-year period of analysis covered by a typical TERM simulation, the model uses the decay curves to continually monitor the declining condition of individual transit assets as they age. As an asset's estimated condition value falls below predefined threshold levels (known as "rehabilitation condition threshold" and "replacement condition threshold"), TERM will seek to rehabilitate or replace that asset accordingly. If sufficient funding is available to address the need, TERM will record this investment action as a need for the specific period in which it occurs. If insufficient funding remains to address a need, that need will be added to the SGR backlog. These rehabilitation and replacement condition thresholds are controlled by asset type and can be changed by the user. Some asset types, such as maintenance facilities, undergo periodic rehabilitation while others, such as radios, do not.

Development of Asset Decay Curves

Asset decay curves are statistically estimated mathematical formulas that rate the physical condition of transit assets on a numeric scale of 5 (excellent) to 1 (poor).

The majority of TERM decay curves are based on empirical condition data obtained from a broad sample of U.S. transit operators; hence, they are considered to be representative of transit asset decay processes at the national level. An example decay curve showing bus asset condition as a function of age and preventive maintenance based on observations of roughly 900 buses at 43 different transit operators is presented in *Exhibit C-6*.

Exhibit C-6: TERM Asset Decay Curve for 40-Foot Buses



Source: FTA; empirical condition data obtained from a broad sample of U.S. transit operators.

Benefit-Cost Calculations

TERM uses a benefit-cost (B/C) module to assess which of a scenario's capital investments are cost-effective and which are not. The purpose of this module is to identify and filter investments that are not cost-effective from the tally of national transit capital needs. Specifically, TERM can filter all investments where the present value of investment costs exceeds investment benefits (BCR<1).

The TERM B/C module is a business case assessment of each agency-mode (e.g., "Metroville Bus" or "Urban City Rail") identified in the NTD. Rather than assessing the BCR for each individual investment need for each agency-mode (e.g., replacing a worn segment of track for Urban City Rail), the module compares the stream of future benefits arising from continued future operation for an entire agency-mode against all capital (rehab-replace and expansion) and operating costs required to keep that agency-mode in service. If the discounted stream of benefits exceeds the costs, then TERM includes that agency-mode's capital needs in the tally of national investment needs. If the net present value of that agency-mode investment is less than zero (BCR<1), then TERM scales back these agency-mode needs until the benefits are equal to costs as discussed below.

In effect, the TERM B/C module conducts a systemwide business case analysis to determine if the value generated by an existing agency-mode is sufficient to warrant the projected cost to operate, maintain, and potentially expand that agency-mode. If an agency-mode does not pass this systemwide business case assessment, then TERM will not include some or all of that agency-mode's identified reinvestment needs in the tally of national investment needs. The benefits assessed in this analysis include user, agency, and social benefits of continued agency operations.

Why Use a Systemwide Business Case Approach?

TERM considers the cost-benefit of the entire agency rail investment versus simply considering the replacement of a single rail car. Costs and benefits are grouped into an aggregated investment evaluation and not evaluated at the level of individual asset investment actions (e.g., replacement of a segment of track) for two primary reasons: (1) lack of empirical benefits data, and (2) transit asset interrelationships.

Lack of Empirical Benefits Data: The marginal benefits of transit asset reinvestment are very poorly understood for some asset types (e.g., vehicles) and nonexistent for others. Consider this example: replacement of an aging motor bus will generate benefits in the form of reduced maintenance costs, improved reliability (fewer in-service failures and delays) and improved rider comfort, and potentially increased ridership in response to these benefits. The magnitude of each of these benefits will be dependent on the age of the vehicle retired (with benefits increasing with increasing age of the vehicle being replaced). But what is the dollar value of these benefits? Despite the fact that transit buses are the most numerous of all transit assets and a primary component of most transit operations, the relationship between bus vehicle age and O&M cost, reliability, and the value of rider comfort is poorly understood (there are no industry standard metrics tying bus age to reliability and related agency costs). The availability of reinvestment benefits for other transit asset types is even more limited (perhaps with the exception of rail cars, where the understanding is comparable to that of bus vehicles).

Transit Asset Interrelationships: The absence of empirical data on the benefits of transit asset replacement is further compounded by both the large number of transit assets that must work together to support transit service and the high level of interrelatedness between many of these assets. Consider the example of a (1) rail car operating on (2) trackwork equipped with (3) train control circuits and (4) power supply (running through the track), all supported by (4) a central train control system and located on (5) a foundation such as elevated structure, subway, retained embankment, etc. This situation represents a system that is dependent on the ongoing operation of multiple assets, each with differing costs, life cycles, and reinvestment needs and yet totally interdependent on one another. Now consider the benefits of replacing a segment of track that has failed. The cost of replacement (thousands of dollars) is insignificant compared with the benefits derived from all the riders that depend on that rail line for transit service of maintaining system operations. The fallacy in making this comparison is that the rail line benefits are dependent on ongoing reinvestment in all components of that rail line (track, structures, control systems, electrification, vehicles, and stations) and not just from reinvestment in specific components.

Incremental Benefit-Cost Assessment

TERM's B/C module is designed to assess the benefits of incremental levels of reinvestment in each agency-mode in a three-step approach:

- Step 1: TERM begins its benefit-cost assessment by considering the benefits derived from all of TERM's proposed capital investment actions for a given agency-mode—including all identified rehabilitation, replacement, and expansion investments. If the total stream of benefits from these investments exceeds the costs, then all assets for this agency-mode are assigned the same (passing) benefit-cost ratio. If not, then the B/C module proceeds to Step 2.
- Step 2: Having "failed" the Step 1 B/C test, TERM repeats this B/C evaluation, but this time excludes all expansion investments. In effect, this test suggests that this agency-mode does not generate sufficient benefits to warrant expansion but may generate enough benefits to warrant full reinvestment. If the agency-mode passes this test, then all reinvestment actions are assigned the same, passing benefit-cost

ratio. Similarly, all expansion investments are assigned the same failing benefit-cost ratio (as calculated in Step 1). If the agency-mode fails the Step 2 B/C test, the B/C module proceeds to Step 3.

- Step 3: The Step 3 B/C test provides a more realistic assessment of agency-mode benefits. Under this test, it is assumed that agency-mode benefits exceed costs for at least some portion of that agency-mode's operations; hence, this portion of services is worth maintaining.

Investment Benefits

TERM's B/C module segments investment benefits into three groups of beneficiaries:

- transit riders (user benefits),
- transit operators, and
- society.

Rider Benefits: By far the largest individual source of investment benefits (roughly 86 percent of total benefits) accrue to transit riders. Moreover, as assessed by TERM, these benefits are measured as the difference in total trip cost between a trip made via the agency-mode under analysis versus the agency-mode user's next best alternative. The total trip cost includes both out-of-pocket costs (e.g., transit fare, station parking fee) and value of time costs (including access time, wait time, and in-vehicle travel time).

Transit Agency Benefits: In general, the primary benefit to transit agencies of reinvestment in existing assets comes from the reduction in asset O&M costs. In addition to fewer asset repair requirements, this benefit includes reductions of in-service failures (technically also a benefit to riders) and the associated in-service failures response costs (e.g., bus vehicle towing and substitution, bus for rail vehicle failures).

At present, none of these agency benefits is considered by TERM's B/C model. As noted above, there are little to no data to measure these cost savings. That said, there are some data on which to evaluate these benefits, mostly related to fleet reinvestment and not available at the time the B/C module was developed. FTA could move to incorporate some of these benefits in future versions of TERM.

Societal Benefits: TERM assumes that investment in transit provides benefits to society by maintaining or expanding an alternative to travel by car. More specifically, reductions in VMT made possible by the existence or expansion of transit assets are assumed to generate benefits to society. Some of these benefits may include reductions in highway congestion, air and noise pollution, energy consumption, and automobile accidents. TERM's B/C module does not consider any societal benefits beyond those related to reducing VMT (hence, benefits such as improved access to work are not considered).

Backlog Trends

The analysis of the SGR backlog—a measure of the total value of deferred transit capital investment at the national level—is motivated by two main concerns:

1) the high backlog value relative to existing funding capacity, and
2) projections suggesting the backlog will continue to grow if funding levels are maintained for the foreseeable future.

The text that follows provides a brief overview of the SGR backlog measure, including the measure's definition and the data and methods used to estimate its size. It also describes limiting factors that affect the accuracy and comparability of the backlog size published in different editions of the C&P Report.

What Does the SGR Backlog Estimate Measure?

The SGR backlog provides an estimate of the total level of capital reinvestment required to eliminate all outstanding reinvestment needs and thus bring the nation's transit assets to a full state of good repair. This should in principle include investment to replace all assets that currently exceed their service life and to repair all assets with outstanding rehabilitation needs.

However, estimates for this and previous editions of the C&P Report are subjected to four main limitations:

- The estimate of current backlog size is focused solely on deferred replacement needs, and thus does not include an assessment of deferred rehabilitation needs. As such, the current backlog estimate is necessarily a lower-bound estimate of the actual SGR backlog.
- The asset inventory data provide only information on asset age or overall condition. These data are sufficient to estimate replacement needs, but not rehabilitation needs.
- TERM provides estimates of future rehabilitation needs based on the typical life-cycle reinvestment needs of transit assets. However, as the underlying asset inventory data sources are not designed to report the extent to which an asset's expected rehabilitation actions have been performed, TERM has no basis on which to estimate the current level of deferred rehabilitation needs.
- TERM's backlog estimates are limited primarily to those assets owned by FTA grantees. Hence, the estimates tend to exclude the reinvestment needs of some assets that are used for transit service but not owned by a grantee. For example, it excludes some assets that are leased by the grantee, provided for service by a municipality, or provided through track access agreements. This resulting level of backlog underestimation is thought to be minor.

What Data Are Used to Support Backlog Estimation?

Backlog is estimated from two different sources:

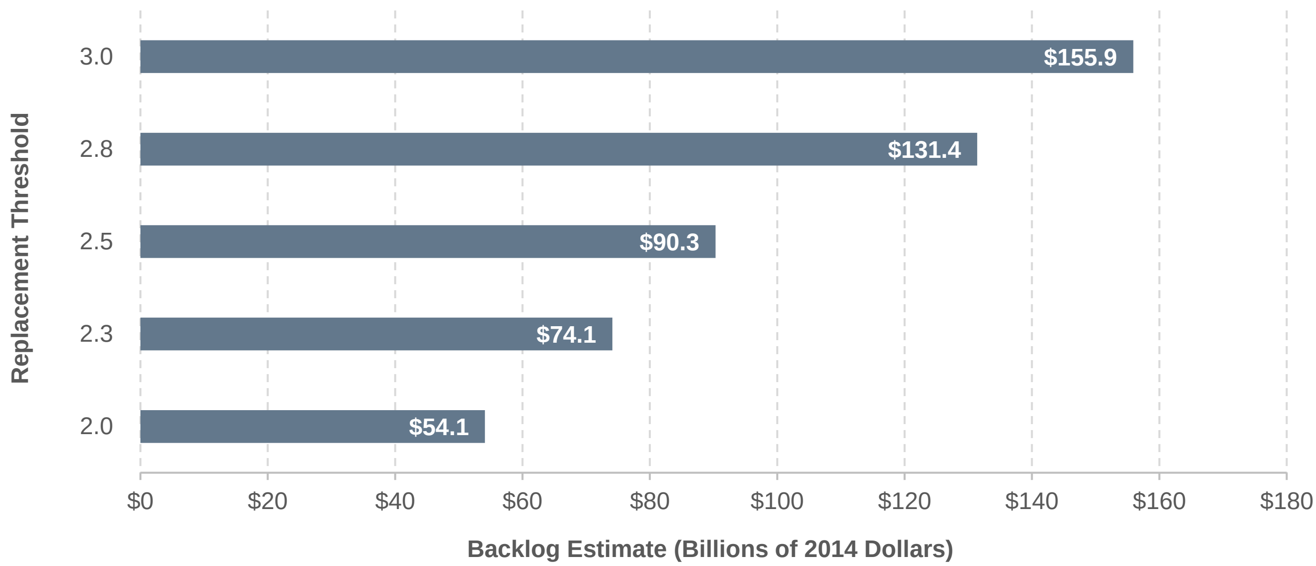
1) NTD data on vehicle assets, including vehicle types, quantities, and ages of all rail cars, buses, vans, and other revenue vehicles used by grantees to provide transit service.
2) Data requests to a sample of the nation's largest (primarily rail) operators and special studies for all other asset categories.

Data requests were obtained at a time when data collection, recording, and classification were not standardized. Therefore, data provided to FTA vary significantly in level of detail, content, and quality from one operator to the next. Moreover, in response to the transit industry's movement toward improved asset management practices, the level of reported inventory detail, format, and data quality obtained through direct grantee requests has been and continues to undergo significant change. The nature and magnitude of these ongoing changes in local agency inventory quality and level of detail has similarly resulted in significant changes to the national inventory dataset on which TERM relies. Consequently, these changes result in inventory datasets and backlog estimates that are not strictly comparable from one C&P Report to the next.

What Drives the Backlog Estimate Level and Accuracy?

In addition to data standardization and quality, the accuracy of the SGR backlog estimate and investment needs is affected by TERM's methodology and assumptions. Specifically, the shape of the decay curves used to model asset condition and the condition threshold selected for asset replacement (currently condition level 2.5) have a significant impact on the size of the backlog estimate, as shown in *Exhibit C-7.*

Exhibit C-7: Backlog Estimate vs Replacement Threshold



Source: Transit Economic Requirements Model.

Future Improvements to the Modeling

Many of issues addressed in this appendix will be significantly mitigated or eliminated following the implementation of the expanded and standardized Asset Inventory Module (AIM), implemented over 2018–2020. Under the new reporting requirements, all grantees will report the age and quantities of their asset holdings in AIM, after which inventory data requests will no longer be required.

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APPENDIX D
Reimagining the C&P Report

Reimagining the C&P Report

Over the past 50 years, the C&P Report series has provided an objective assessment of current system conditions and future investment needs. Its target audience includes the U.S. Congress, all levels of government, policy makers and analysts, academia, transportation associations, industry, news media, and the public. It raises public awareness of the physical conditions, operational performance, and financing mechanisms of highways, bridges, and transit systems, and promotes an understanding of the importance of these transportation investments.

The C&P Report is a dynamic and evolving product, which has periodically undergone substantial overhauls and enhancements. A good example is the introduction of benefit-cost analysis (BCA) to the process for estimating future investment needs through application of the Highway Economic Requirements System (HERS), introduced in the 1995 C&P Report; the Transit Economic Requirements Model (TERM), introduced in the 1997 C&P Report; and the National Bridge Investment Analysis System (NBIAS), introduced in the 2002 C&P Report. These models are presented and described in Appendices A, B, and C, respectively.

MAP-21 (the Moving Ahead for Progress in the 21st Century Act) incorporated performance management principles into its requirements. States will set targets for several key performance measures and report on their progress in meeting these targets. This shift toward more performance-driven and outcome-based programs has direct and indirect implications for the C&P Reports. At the most basic level, the introduction of other performance reporting requirements in MAP-21 might necessitate some content changes to the C&P Reports, both to take advantage of newly available data and to avoid unnecessary duplication of information presented elsewhere. The shift in the processes that States and metropolitan planning organizations (MPOs) use for planning and performance management also has implications for assessing future transportation investment needs. State and local agencies are adopting more outcome-based approaches to investment decision-making, which has significant implications for the potential impacts of future investment on system performance and how these impacts are simulated. In addition, the data, analytical tools, and techniques developed to support the implementation of performance management could yield new approaches that can be adapted to refine or replace HERS, NBIAS, and TERM.

With these issues in mind, the Federal Highway Administration (FHWA) initiated the *Reimagining the C&P Report in a Performance Management-Based World* effort in late 2012. Preliminary scoping work was conducted in 2013 to document who uses the C&P Report, to assess the utility of the report to FHWA program offices, and to identify options for presenting information more effectively. This effort identified two areas of potential improvement to align better with performance measures: methodology and communication. Two major research projects were initiated in 2014, with the objectives of improving estimation methodologies to compute investment needs and enhancing communication approaches, respectively.

Methodology Improvement

Simulation modeling inherently involves compromises, as the desire for detailed, reliable predictions must be balanced against data collection burdens and computational tractability. The tools and methodologies currently used in the C&P Reports reflect several analytical simplifications introduced to accomplish the desired analysis with the available data and resources. Since the initial introduction of these tools, a new generation of analytical tools and models has been developed that provides advanced methodologies in asset management and performance management.

HERS, NBIAS, and TERM have been constantly revised and updated to incorporate newly developed data and tools. Building on this ongoing improvement effort, a research project is currently underway to scan and compare methods for assessing investment needs and to propose new and improved methods for more precise and comprehensive needs estimation in the C&P Reports. Several analytical frameworks are being explored to identify potential alternative methodologies and upgrades to the current BCA approach. This project, initiated by FHWA, includes a systematic review of performance management tools that States and local governments currently use and potential new approaches to be incorporated in the analytical framework. The goal is to identify practical approaches for improving the C&P Report methodology in the future.

Evaluation of Alternative Methodologies

The first stage of this research effort involved evaluating alternative methodologies that could be used to replace or supplement the BCA-driven tools currently used in the C&P Report. Two specific decision methodologies were reviewed: the multi-criteria decision method (MCDM) and value for money.

MCDM allows for consideration of performance objectives that are difficult to monetize. Therefore, MCDM frequently includes some performance measures that are not limited to monetary terms or condition matrices. It is a flexible tool, enabling the evaluation of projects based on multiple performance measures such as environmental sustainability, livability, and safety. Its application, however, hinges on the selection of appropriate performance measures and assignment of weight to each performance measure, which could be challenging for national investment analysis, as well as being incompatible with the principles underlying the economic approach to investment modeling.

As defined in the Eddington Transport Study of the United Kingdom,[xi] value for money is another methodology that measures wider economic and reliability benefits. It assesses the economic, environmental, social, distributional, and fiscal impacts of an investment based on both quantitative, monetized information and qualitative information at the project level. Although this approach helps guide the modeling of reliability and economic impacts, scaling the findings from individual projects to the national system and obtaining a strategic allocation of resources for infrastructure investment could be challenging.

Other assessed methodologies and tools that may be used to incorporate additional performance measures into the C&P Reports include broader economic impacts models, life cycle cost analysis models, highway operations and congestion cost measurement models, work zone models, bridge and pavement management models, and BCA models. Three modeling tools—Transportation Project Impact Case Studies (T-PICS, now called EconWorks Case Studies), the Transportation Economic Development Impact System (TREDIS), and the Prioritization Scenario Model (PRISM)—were examined closely for their potential contributions to C&P analytical framework improvement.

Although these alternative methodologies could provide a new framework for the C&P evaluation of a national investment program, it would be challenging to generalize them from individual projects to the entirety of the highway system at the national level. The BCA technique currently used in HERS remains an appropriate approach for examining traffic condition, capacity, and current and future traffic load.

Identification of Alternatives for Refining BCA

The second stage in this research effort involved identifying alternatives for refining the current BCA approach. After reviewing many options, four possible alternatives were picked for in-depth study to evaluate their feasibility and relevance to be integrated into the HERS framework: performance measures, trade-off analysis, freight analysis, and connected and automated vehicles (C/AV).

MAP-21 established national performance goals for Federal highway programs in safety, infrastructure condition, congestion reduction, system reliability, freight movement, environmental sustainability, and reduced delays in project delivery. After careful study, the research team selected performance measures related to pavement, safety, congestion and reliability, and bridge performance. These performance measures, which are similar to values already used in BCA methods, can be integrated into HERS predictive models in C&P analysis and reporting without substantial coding efforts.

Currently, project selection in HERS is based on the type of deficiency and the improvement's benefit-cost ratio (BCR). The trade-off analysis allows the user to intervene in this process by changing project selection priorities other than HERS's current economic analysis. Once HERS develops the ability to report costs and budgets by performance categories (safety, congestion and pavement), trade-off analysis can be performed by the priority order of performance categories based on BCR. In each funding period, projects are selected in the priority category until the category's budget is exhausted. Alternatively, projects could be selected based on the priority category with the highest BCR. For example, if both congestion and pavement projects are being evaluated by HERS and the priority category is pavement, then the pavement project is selected even if its BCR is lower than that of the congestion project.

Section 1116(h) of the Fixing America's Surface Transportation (FAST) Act requires a biennial report describing the conditions and performance of the National Highway Freight Network, which is included as Chapter 12 in this report. Options for enhancing freight analysis capabilities for the C&P Report are being explored as part of the reimagining the C&P effort. One option is to create a freight corridor sketch tool to display the freight performance measures on a national network based on the Freight Analysis Framework. The process will enable reporting of annual freight flows by region and easy extraction of routing data through existing travel demand models.

The aggressive and increasing deployment of connected and automated vehicles will have significant impacts on national highway conditions and performance. Many experts have indicated that this will represent the most significant discontinuity in the relationship between highway demand and supply since the development of the Interstate System. Although estimating the C/AV market penetration is highly uncertain at this point, it can affect highway system traffic patterns, VMT, safety, pavement, and infrastructure needs. Hence, C/AV merits consideration in C&P methodologies and reporting. A potential approach to incorporating C/AV analysis is to develop sensitivity testing of key C&P parameters that are presumed to be affected by increasing market penetration of C/AV, under different partial and full automation scenarios.

FHWA also considered the feasibility of integrating needs analysis of pedestrian and cycling infrastructure and integrating network analysis into the C&P highway needs assessment. However, these two options can be implemented only after the establishment of data standards and appropriate modeling approaches. For current research efforts, only the four alternatives would be further explored for the feasibility of being integrated into the HERS framework.

Integration of Performance Management and Needs Estimation

The systematic review of tools and potential new improvements is completed. The project has now moved to the next stage, which will involve integrating the findings identified in the assessments of BCA refinements and alternative decision methodologies with HERS modeling. This combination will enable a detailed evaluation and comparison of several comprehensive approaches to upgrading the current national needs estimation process. Once appropriate analytical frameworks are identified, new components could be added to HERS and NBIAS, or a new generation of analytical tools could replace these models.

Enhanced Communication

Currently, the C&P Report is issued in print form and the entire report is posted online using standard Adobe Acrobat and HTML formats. Several features were introduced in recent editions of the C&P Report to improve its visual appeal. These improvements include a shift from black and white to color, addition of several infographics, new maps and photos, and changes to the writing style and structure of the report. It is anticipated that the demand for improved visualizations will lead to additional changes to the C&P Report.

Although the C&P Report contains useful information and serves as a valuable reference document, its sheer size creates some problems for users. Because writing and reviewing the document is a lengthy process, the report is often transmitted to Congress after newer data have been published elsewhere. Even when this is not the case, many of the data series in the biennial report are updated annually, which means that readers must often look elsewhere to find the latest available data.

One option under consideration is to develop an interactive website to complement the print report. An interactive website may improve the readability, accessibility, and usability of the information in the report by:

- Incorporating enhanced visualization of the graphs and tables;
- Adding interactivity in the report website that will enable readers to drill down to various subsets or create desired views of information of interest;
- Migrating some detailed, supplementary analyses to the website, allowing the print version to focus on key findings;
- Enabling readers to view and access the underlying raw data tables with added capability to export charts and graphs as images;
- Facilitating more frequent data updates than are currently possible for the C&P Report.

A multiyear research effort is underway to explore alternatives for enhancing the current report, focusing on data visualization and an interactive Web-based design. The underlying goal is to facilitate ease of use by a wider audience of readers and enable the alignment of performance-based information in the C&P Report with the information obtained from State and MPO performance management processes.

Data Visualization

Data visualization is the representation of data in a pictorial or graphical format. It is the easiest way for the brain to receive and process large amounts of information quickly and intuitively. As part of this research effort, alternatives are being explored to improve the communication of data in print and on the Web through advanced data visualization tools and infographics. For the print version of the C&P Report, new static graphics are developed to help readers visualize complex information on highways, bridges, and transit, making the details easier to understand at a glance. Contents of each chapter could be condensed into a format that is more accessible to the public, such as bullet points, at-a-glance boxes, and content optimization for print layout.

For the online version, selected contents could be presented through interactive data visualization to convey information from in-depth and complex analytics. For example, an online platform might support the use of more dynamic and interactive graphics, such as customized dashboards and charts filtered per the user’s unique needs. Through their intuitive interfaces, data visualization tools enable customized analytical views with flexibility and ease by multiple users with diverse demands.

Web-Based User Interface

As part of this research effort, a demonstration C&P website was developed. An immediate goal is to explore and evaluate visualization techniques and tools that could be used online. Another goal is to gather feedback from users regarding their preferences about the balance between the print and Web version of the report and the best ways to inform, attract, and retain users. Ultimately, a new digital publishing platform could integrate traditional formats such as PDF with many interactive elements such as embedded video and audio, and interactive graphs. To attract and maintain the attention of an increasingly mobile audience, an upgraded website could use a responsive Web design to accommodate data exploration and communication across all common types of devices, including touchscreen and mobile devices.

A critical part of developing an enhanced future C&P Report website is ensuring that it complements existing online resources and potential new resources coming online in response to the MAP-21 State and MPO performance reporting requirements. In many cases, providing links to information posted in other locations might be sufficient, allowing the C&P website to focus mainly on elements unique and central to the C&P Report.

Moving Forward

Although FHWA began the research initiatives described in this appendix, the Federal Transit Administration (FTA) is a full partner in the development of the C&P Report and is closely involved in these efforts. FTA has initiated its own reviews regarding future analytical approaches and report presentation and content. As potential enhancements become more fully refined through current research efforts, external outreach will be conducted to ensure that any changes to the report content and structure will improve its usefulness to Congress and other stakeholders. Although the objectives of the report will remain unchanged, the goal of this effort ultimately is to provide a multimodal product with cutting-edge analytics that improve users' experience.

[xi] The Eddington Transport Study (2006). The case for action: Sir Rod Eddington's advice to Government. Available at http://webarchive.nationalarchives.gov.uk/20090104005813/http:/www.dft.gov.uk/about/strategy/transportstrategy/eddingtonstudy/.

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