24th EDITION

STATUS OF THE NATION'S Highways, Bridges, and Transit

Conditions and Performance

REPORT TO CONGRESS

U.S. Department of Transportation

Federal Highway Administration

Federal Transit Administration

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Abbreviations

AADTT	Annual average daily truck traffic
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACS	American Community Survey
ADA	Americans with Disabilities Act
ADS	Automated Driving System
ADT	Average Daily Traffic
AIM	Accelerating Innovative Mobility
APTL	Average passenger trip length
ARF	Annual Report File
ARNOLD	All Road Network of Linear Data
ATCMTD	Advanced Transportation and Congestion Management Technologies Deployment
AV	Automated vehicle
AVO	Average vehicle occupancy
AWZSE	Automated Work Zone Speed Enforcement
BART	Bay Area Rapid Transit
BCA	Benefit-cost analysis
BCR	Benefit-cost ratio
BEPS	Bus Exportable Power Supply
BLS	Bureau of Labor Statistics
BOS	Bus-on-Shoulder
BPI	Bid-Price Index
C&P	Conditions and performance
CARMA	Cooperative Automation Research Mobility Applications
CDA	Cooperative driving automation
CFR	Code of Federal Regulations
CMAQ	Congestion Mitigation and Air Quality
CMP	Congestion Management Process
COG	Councils of governments
CPI	Consumer Price Index
CRFC	Critical Rural Freight Corridor

CRSS	Crash Report Sampling System
CUFC	Critical Urban Freight Corridor
CV	Connected vehicle
DAS	Driver Assist System
DDSA	Data Driven Safety Analysis
DOT	Department of Transportation
DR	Demand response
EMP	Express Mobility Partners
ERS	Economic Research Service
FAA	Federal Aviation Administration
FAF	Freight Analysis Framework
FARS	Fatality Analysis Reporting System
FAST	Fixing America's Surface Transportation
FCC	Federal Communications Commission
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
GARVEE	Grant Anticipation Revenue Vehicle
GDP	Gross domestic product
GNP	Gross national product
GPS	Global positioning system
GTFS	General Transit Feeds Specification
HEPA	High-efficiency particulate air
HERS	Highway Economic Requirements System
HOV	High-occupancy vehicle
HSIP	Highway Safety Improvement Program
HSM	Highway Safety Manual
HTF	Highway Trust Fund
HVAC	Heating, ventilation, and air conditioning
IBCR	Incremental benefit-cost ratio
IMI	Integrated Mobility Innovation
INFRA	Infrastructure for Rebuilding America
IoT	Internet of Things

IRI	International Roughness Index
ITS	Intelligent transportation system
LIDAR	Light detection and ranging
LPI	Leading pedestrian interval
LRSP	Local road safety plan
LRV	Light rail vehicle
MaaS	Mobility as a Service
MCDM	Multi-criteria decision method
MIRE	Model Inventory of Roadway Elements
MOD	Mobility on Demand
MOE	Margin of Error
MOVES	Motor Vehicle Emissions Simulator
MPO	Metropolitan planning organization
MR&R	Maintenance, repair, and rehabilitation
MTA	Mass Transit Account
NAPCOM	National Pavement Cost Model
NBI	National Bridge Inventory
NBIAS	National Bridge Investment Analysis
NCSL	National Conference of State Legislatures
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
NN	National Network
NOACA	Northeast Ohio Areawide Coordinating Agency
NPMRDS	National Performance Management Research Data Set
NSC	National Safety Council
NTD	National Transit Database
O&M	Operations and maintenance
OMB	Office of Management and Budget
PBE	Prefabricated bridge element

PHED	Peak hour excessive delay
PHFS	Primary Highway Freight System
PMT	Passenger miles traveled
POV	Privately owned vehicle
PSR	Present Serviceability Rating
PT	Purchased transportation
PTI	Planning Time Index
PTIDS	Platform Track Intrusion Detection System
RAIRS	Rail Accident/Incident Reporting System
ROUTES	Rural Opportunities to Use Transportation for Economic Success
RPCGB	Regional Planning Commission of Greater Birmingham
RTP	Recreational Trails Program
RTZ	Road to Zero
SBIR	Small Business Innovative Research
SGR	State of good repair
SHSP	Strategic Highway Safety Plan
SIB	State Infrastructure Bank
SNBIBE	Specification for National Bridge Inventory Bridge Elements
SOV	Single occupancy-vehicle
SPaT	Signal Phase and Timing
SQC	Synthesis, Quantity, and Condition
STBG	Surface Transportation Block Grant
STEP	Safe Transportation for Every Pedestrian
STIC	Small Transit Intensive Cities
STIP	Statewide Transportation Improvement Program
SUV	Sport utility vehicle
TAM	Transit asset management
TAMP	Transportation Asset Management Plan
TERM	Transit Economic Requirements Model
TIF	Tax increment financing
TIFIA	Transportation Infrastructure Finance and Innovation Act
TIP	Transportation Improvement Program
TMCC	Travel Management Coordination Center
TNC	Transportation network company

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
UAS	Unmanned Aircraft Systems
UHPC	Ultra-high performance concrete
UPDAPS	Unified Pavement Distress Analysis and Prediction System
UPT	Unlinked Passenger Trips
U.S.C.	United States Code
USDA	U.S. Department of Agriculture
UZA	Urbanized areas
VDOT	Virginia Department of Transportation
VMT	Vehicle miles traveled
VRM	Vehicle revenue mile

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Introduction

The U.S. Department of Transportation (DOT) has prepared this report—the 24th in a series of reports dating back to 1968—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 and bridge 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 24th edition is intended to address the requirements for reports due:

- July 31, 2019, under 23 U.S.C. §503(b)(8);
- December 4, 2019, under 23 U.S.C. §167(h); and
- March 31, 2020, under 49 U.S.C. §308(e).

This edition of the *Status of the Nation's Highways, Bridges, and Transit: Conditions and Performance Report to Congress* (C&P Report) draws primarily on 2016 data. In assessing recent trends, many of the exhibits presented in this report provide statistics for the 10 years from 2006 to 2016. 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 2036.

This 24th C&P Report is the 50th anniversary edition in the report series. To mark the occasion, this edition includes a special look back to the findings and projections of the inaugural edition of this report series, the *1968 National Highway Needs Report*.

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. This edition includes a discussion noting changes in funding patterns attributable to the Fixing America's Surface Transportation (FAST) Act.
- 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. Each of these chapters includes separate sections focusing on highways and transit.

- The Introduction to Part II provides critical background information 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. This includes a discussion of the findings and projections from the *1968 National Highway Needs Report.*
- Chapter 9 discusses how changing some of the underlying technical assumptions would affect the future highway and transit investment scenarios.
- Chapter 10 provides additional detail on the methodology used to develop the future highway and transit investment scenarios and 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 Conditions and Performance*, explores issues pertaining specifically to freight movement, including an examination of the conditions and performance of the National Highway Freight Network.

Part IV, Additional Information, explores related issues not fully covered in the core analyses.

- Chapter 11 discusses emerging transportation technologies.
- Chapter 12 examines issues relating to rural transportation.

Part V, *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 called *Reimagining the C&P Report in a Performance Management-Based World*. Two additional appendices provide supporting material for the freight analysis presented in Part III.

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 back to the late 1970s that involves the Federal Highway Administration (FHWA) and State and local governments. HPMS includes a random sample of roughly 133,000 sections of Federal-aid highways selected by each State using instructions provided by FHWA. 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 primarily 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 data set 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, some historical time series data are also 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 C&P Reports beginning in 2021.

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 grant recipients 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 grant recipients and are subject to no reporting requirements.

In recent practice, data requests have been made primarily 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 grant recipients' 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 beginning with the 25th edition.

Multimodal Data Sources

Freight data are derived primarily from the Freight Analysis Framework version 4.3, which includes all freight flows to, from, and within the United States (https://ops.fhwa.dot.gov/freight/freight_analysis/faf/). The framework is a joint product of FHWA and the Bureau of Transportation Statistics, built from a variety of data sets such as the 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, as well as 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

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.

Changes to C&P Report Scenarios from the 23rd Edition

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

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

Key Information for Properly Interpreting C&P Report Scenarios

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 object intent. Analysts outside DOT 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.

HERS, NBIAS, and TERM are not able to be used for direct multimodal analysis. 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. Although the three models use benefit-cost analysis, their methods for implementing this analysis are very different. 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.

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.

COVID-19

Since this report draws primarily on 2016 data, the effects of the coronavirus disease 2019 (COVID-19) pandemic are not reflected in the analyses presented in Part I or Part II. However, the discussions of emerging transportation technologies and issues relating to rural transportation presented in Part IV rely in part on more recent data, and do include some references to COVID-19.

This report does not take into account reductions in transit service, etc. due to the COVID-19 pandemic. Even though the virus has had a big impact on recent ridership trends and operating revenues, the long-term implications are still unknown.

Similarly, Part I of this report does not reflect the impacts of the COVID-19 pandemic on highway passenger or freight travel and the resulting implications for highway funding, mobility, safety, or infrastructure conditions. The 20-year highway travel forecasts that feed the investment scenarios presented in Part II of the report have not been modified to reflect the COVID-19 pandemic, as its long-term implications (if any) are still unknown. The report provides sensitivity analyses that estimate investment needs under different assumptions of vehicle miles traveled, but those assumptions were not built to specifically model the effects of the COVID-19 pandemic.

Highlights

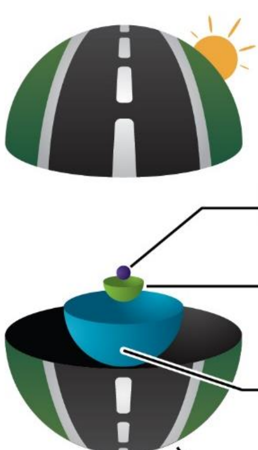
This edition of the C&P Report is based primarily on data through 2016. In assessing recent trends, it generally focuses on the 10-year period from 2006 to 2016. The prospective analyses generally cover the 20-year period from 2016 to 2036; the investment levels associated with these scenarios are stated in constant 2016 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 4,157,292 miles of public roadways and 614,387 bridges in 2016. This network carried 3.189 trillion vehicle miles traveled (VMT) and 5.458 trillion person miles traveled, up from 3.034 trillion VMT and up from 4.961 trillion person miles traveled in 2006.
- The 1,026,319 miles of Federal-aid highways (25 percent of total mileage) carried 2.710 trillion VMT (85 percent of total travel) in 2016.
- Although the 222,331 miles on the National Highway System (NHS) comprise only 5 percent of total mileage, the NHS carried 1.749 trillion VMT in 2016, approximately 55 percent of total travel.
- The 48,474 miles on the Interstate System carried 0.811 trillion VMT in 2016, slightly more than 1 percent of total mileage and close to 25 percent of total VMT. The Interstate System has grown since 2006, when it consisted of 46,836 miles that carried 0.727 trillion VMT.

2016 Highway System Statistics



United States Road System	EXTENT (Miles per System)	VMT (Vehicle Miles Traveled)	CAPITAL SPENDING ($ Billions)
Interstate System	1% 48,474 miles	25% 0.811 trillion VMT	23% $26.4 billion
National Highway System	5% 222,331 miles	55% 1.749 trillion VMT	52% $59.2 billion
Federal-aid Highways	25% 1,026,319 miles	85% 2.710 trillion VMT	74% $84.1 billion
Systemwide (All Roads)	100% 4,157,292 miles	100% 3.189 trillion VMT	100% $112.9 billion

The Interstate System accounts for 1% of road mileage, but carries 25% of highway travel.

Highway Funding – 2016

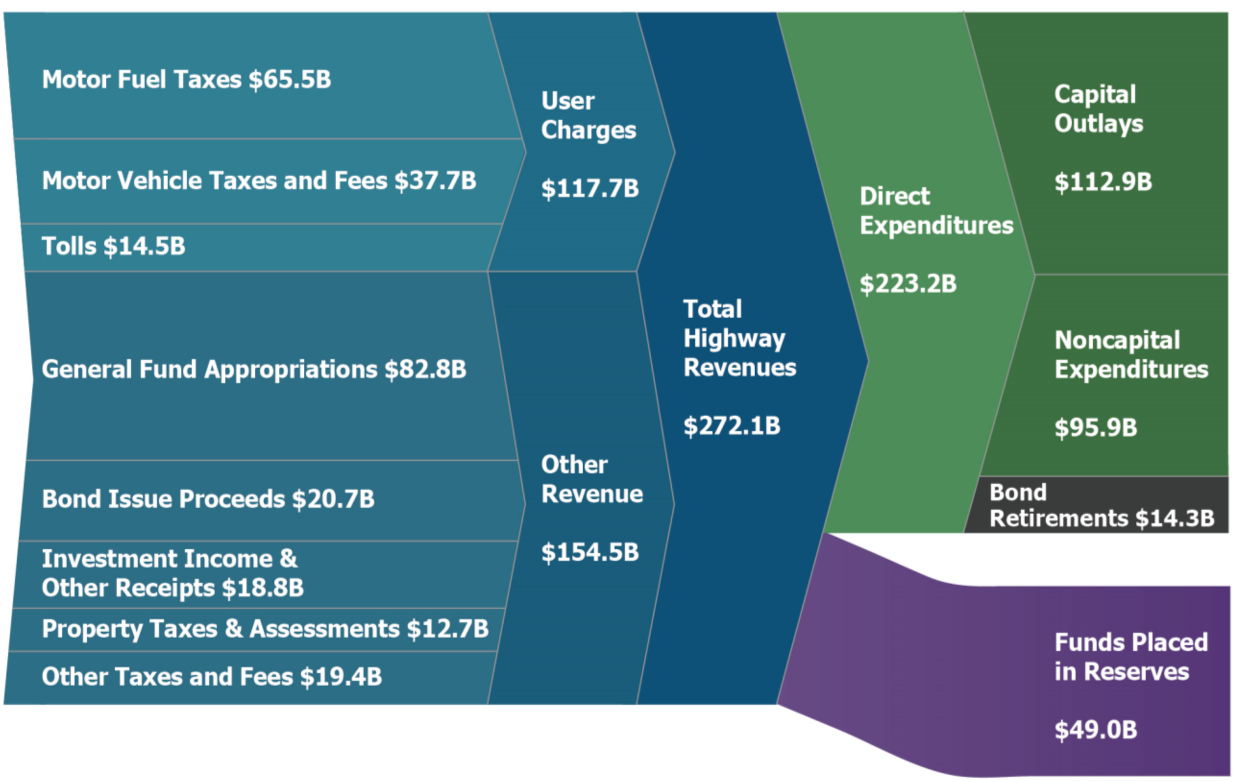
- All levels of government spent a combined $223.2 billion for highway-related purposes in 2016. More than half (50.6 percent) of total highway spending ($112.9 billion) was for capital improvements to highways and bridges; the remainder included expenditures for physical maintenance, highway and traffic services, administration, highway safety, bond interest, and bond retirement.
- Of the $112.9 billion spent on highway capital improvements in 2016, $26.4 billion (23 percent) was spent on the Interstate System, $59.2 billion (52 percent) was spent on the NHS, and $84.1 billion (74 percent) was spent on Federal-aid highways (including the NHS).

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 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 the Moving Ahead for Progress in the 21st Century Act (MAP-21).

2016 Highway Revenues and Expenditures



- Revenues raised for use on highways, by all levels of government combined, totaled $272.1 billion in 2016. The $49.0 billion difference between highway revenues and highway expenditures ($223.2 billion) identified as "funds placed in reserves" represents the net increase during 2016 of the cash balances of the Federal Highway Trust Fund and comparable dedicated accounts at the State and local level. This single-year increase in cash balances is by far the largest ever recorded, and is due entirely to a $51.9 billion one-time transfer of general funds to the Federal Highway Trust Fund required under the Fixing America's Surface Transportation Act (FAST Act).

- Of the total $272.1 billion of revenues raised in 2016 for use on highways, $117.7 billion (43 percent) was collected from various forms of user charges, including fuel taxes ($65.5 billion), tolls ($14.5 billion), and vehicle taxes and fees ($37.7 billion).
- During 2016, $154.5 billion was raised from nonuser sources for use on highways, including general fund appropriations ($82.8 billion), bond issue proceeds ($20.7 billion), investment income and other receipts ($18.8 billion), property taxes ($12.7 billion), and other taxes and fees ($19.4 billion). The amount of general funds directed toward highway purposes in 2016 was nearly double the highest amount recorded in any previous year due to a $51.9-billion transfer of general funds to the Federal Highway Trust Fund in 2016.

Highway Spending Trends

- In nominal dollar terms, highway spending increased by 36.5 percent (3.2 percent per year) from 2006 to 2016; after adjusting for inflation this equates to a 20.0-percent increase (1.8 percent per year).
- Highway capital expenditures rose from $80.2 billion in 2006 to $112.9 billion in 2016, a 40.7-percent increase (3.5 percent per year) in nominal dollar terms; after adjusting for inflation this equates to a 30.1-percent (2.7 percent per year) increase.

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.

- The portion of total highway capital spending funded by the Federal government decreased from 43.1 percent in 2006 to 39.7 percent in 2016. Federally funded highway capital outlay grew by 2.6 percent per year over this period, compared with a 4.1-percent annual increase in capital spending funded by State and local governments.
- The composition of highway capital spending shifted during the 2006–2016 period. The percentage of highway capital spending directed toward system rehabilitation rose from 51.5 percent in 2006 to 62.0 percent in 2016. Over the same period, the percentage of spending directed toward system enhancement rose from 10.6 percent to 13.6 percent, whereas the percentage of spending directed toward system expansion fell from 37.9 percent to 24.4 percent.

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 operation improvements such as the installation of intelligent transportation systems, environmental enhancements, and other enhancements such as construction of bicycle and pedestrian facilities.

Conditions and Performance of the System

Bridge Conditions Have Improved

- Based directly on bridge counts the share of bridges classified as poor has improved, dropping from 10.4 percent in 2006 to 7.9 percent in 2016. The share of NHS bridges classified as poor also improved over this period, dropping from 5.4 percent to 3.5 percent. (More recent data show that from 2017 to 2020, the number of bridges in poor condition decreased by 5 percent, from 47,619 to 45,031.)
- Weighted by deck area the share of bridges classified as poor also improved, declining from 9.0 percent in 2006 to 5.9 percent in 2016. The deck area-weighted share of poor NHS bridges dropped from 8.3 percent to 5.2 percent over this period.
- The decline over the past decade in the percentage of bridges classified as poor was accompanied by an increase in the share of bridges classified as good. Weighted by deck area, the share of bridges classified as good improved slightly, increasing from 46.1 percent in 2006 to 46.5 percent in 2016. The deck area-weighted share of good NHS bridges improved from 43.9 percent to 44.5 percent over this period.

Bridge Condition Terminology

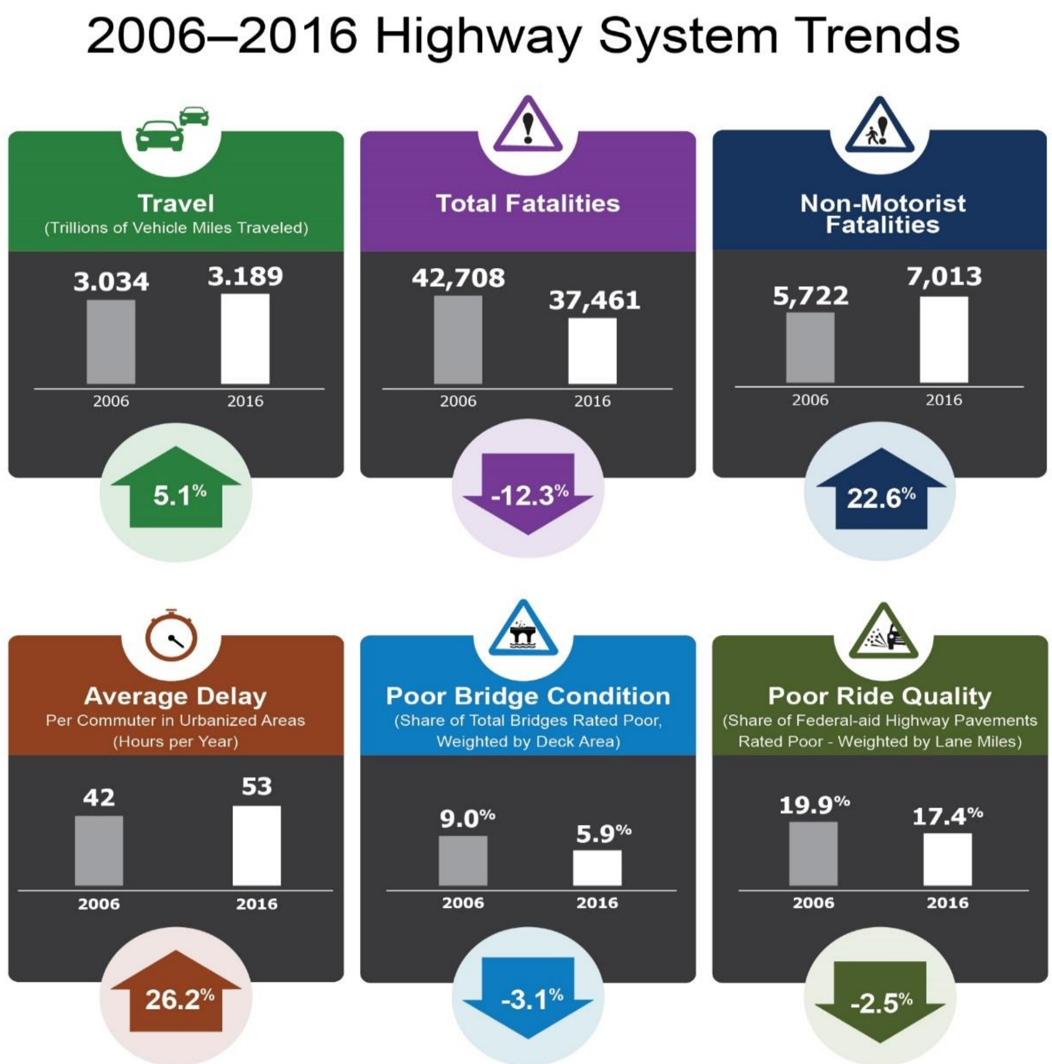
Bridges are given an overall rating of "good" if the deck, substructure, and superstructure are all found to be in good condition. Bridges receive a rating of "poor" if any of these three bridge components is found to be in poor condition. All other bridges are classified as "fair."

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

The classification of a bridge as poor does not mean it is unsafe; bridges that are considered to be unsafe are closed to traffic.

Highway Safety Improved Overall, but Pedestrian and Bicyclist Fatalities Rose

- The annual number of highway fatalities decreased by 12.3 percent from 2006 to 2016, dropping from 42,708 to 37,461. However, fatalities increased after 2014, by 8.4 percent from 2014 to 2015, and by 5.6 percent from 2015 to 2016. (More recent data show a 3.3-percent decrease in fatalities between 2016 and 2018).
- From 2006 to 2016 the number of nonmotorists (pedestrians, bicyclists, etc.) killed by motor vehicles increased by 22.6 percent, from 5,722 to 7,013 (18.7 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 44.2-percent increase up to 2016. (More recent data show that from 2017 to 2018, fatalities involving pedestrians increased by 3.4 percent and bicyclist fatalities increased by 6.3 percent.)
- Fatalities related to roadway departure decreased by 20.2 percent from 2006 to 2016, but roadway departure remains a factor in close to half (48.3 percent) of all highway fatalities. Intersection-related fatalities remained virtually flat from 2006 to 2016, but more than one-fourth (27.4 percent) of highway fatalities in 2016 occurred at intersections. (More recent data show that roadway departure and intersection fatalities accounted for 51 percent and 27 percent, respectively, of total fatalities.)
- The fatality rate per 100 million VMT declined from 1.42 in 2006 to 1.18 in 2016, but has increased since reaching a low of 1.08 in 2014. (More recent data show that the fatality rate per 100 million VMT declined to 1.13 in 2018.)



Poor ride quality data are affected by changes in reporting instructions beginning in 2010.

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 25 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 47.0 percent in 2006 to 48.9 percent in 2016. Over this same period, the trend based on highway mileage was different, with the share of mileage that had good ride quality declining from 41.5 percent to 40.2 percent and the lane mile-weighted share declining from 41.1 percent to 38.2 percent. This divergence may be due to States focusing improvements on those roads that are most heavily traveled.

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 during the 2006–2016 period, as measured on both a VMT-weighted basis (rising from 14.0 percent to 17.1 percent) and a mileage basis (rising from 15.8 percent to 22.0 percent). However, weighted by lane miles, the share of pavements with poor ride quality decreased from 19.9 to 17.4 over this period.
- The share of VMT on NHS pavements with good ride quality rose from 57.0 percent in 2006 to 59.6 percent in 2016. This gain is especially impressive considering MAP-21 expanded the NHS by 60,292 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 57.0 percent in 2006 to 60 percent in 2010 based on the pre-expansion NHS, and from an estimated 54.7 percent in 2010 to 59.6 percent in 2016 based on the post-expansion NHS.
- The share of VMT on NHS pavements with poor ride quality stayed the same at 7 percent from 2006 to 2010; since the expansion of the NHS under MAP-21 this share has remained relatively constant at approximately 11 percent.

Pavement Data Reporting Change

A change in data reporting instructions beginning in 2010 led States to split roadways into shorter segments for purposes of evaluating pavement conditions. This more refined approach captured more of the variation in pavement conditions, which tended to increase the share of sections considered "good" or "poor" and to reduce the share considered "fair." For example, the share of mileage rated "poor" rose from 15.8 percent in 2008 to 20.0 percent in 2010.

Operational Performance Has Worsened

- Based on the National Performance Management Research Data Set (NPMRDS), the Travel Time Index (TTI) for Interstate highways averaged 1.34 in 2016 in the Nation's 52 largest metropolitan areas. This means that the average peak-period trip took 34 percent longer than did the same trip under free-flow traffic conditions. The comparable TTI value for 2012 was 1.24.
- For the same 52 metropolitan areas, the Planning Time Index (PTI) averaged 2.49 for Interstate highways in 2016, meaning that ensuring on-time arrival 95 percent of the time required planning for 2.49 times the travel time under free-flow traffic conditions. The comparable PTI value for 2012 was 2.17. On average, urban Interstate highways in these areas were congested for 4.4 hours per day in 2016, up from 3.6 hours in 2012.
- The Texas Transportation Institute 2019 Urban Mobility Report estimates that the average commuter in 494 urbanized areas experienced a total of 53 hours of delay resulting from congestion in 2016, up from 43 hours in 2006. Total delay reached 8.6 billion hours and fuel waste reached 3.3 billion gallons in 2016, leading to a total cost of $171

Operational Performance Terminology

The TTI measures the average intensity of congestion, calculated as the ratio of the peak-period travel time to the free-flow travel time for the peak period on weekdays. The value of the 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 typically take 78 minutes (30 percent longer) during the period of peak congestion.

The PTI measures travel time reliability and the severity of delay, defined as the ratio of the 95th percentile of travel time during the peak periods to 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).

billion. (More recent data show that in 2017, these commuters experienced an estimated average of 54 hours of congestion delay.)

Future Capital Investment Scenarios

The scenarios that follow pertain to spending by all levels of government combined for the 20-year period from 2016 to 2036 (reflecting the impacts of spending from 2017 through 2036); the funding levels associated with these analyses are stated in constant 2016 dollars. The results discussed in this section 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.

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 $165.9 billion, 55.2 percent higher than the level of the Sustain Recent Spending scenario.
- Approximately 30.5 percent of the capital investment under the Improve Conditions and Performance scenario would go toward addressing an existing backlog of cost-beneficial investments of $1.01 trillion. The rest would address new needs arising from 2017 through 2036. The backlog includes $556 billion related to the pavement component of system rehabilitation investments, $132 billion related to the bridge component of system rehabilitation investments, $181 billion related to system expansion, and $143 billion related to system enhancement.
- 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 $104.7 billion, 63.1 percent of the $165.9 billion cost of the overall scenario.
- The Improve Conditions and Performance scenario also includes average annual spending of $37.8 billion (22.8 percent) directed toward system expansion, and $23.5 billion (14.1 percent) directed toward system enhancement.

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 Recent 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). These scenarios also assume that spending would be directed toward projects with the largest benefit-cost ratios.

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 an existing backlog of cost-beneficial investments has 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.

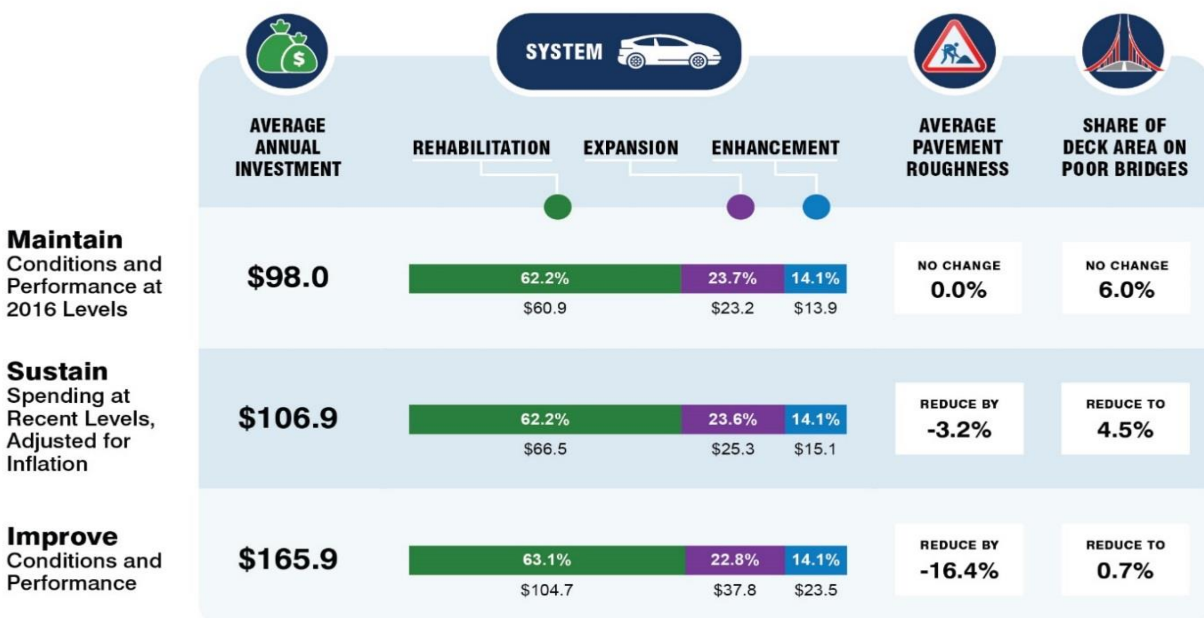
- Under the Improve Conditions and Performance scenario, average pavement roughness on Federal-aid highways is projected to improve by 16.4 percent. The share of bridges classified as poor is also projected to improve, declining from 6.0 percent in 2016 to 0.7 percent in 2036. This scenario would not eliminate all poor pavements and bridges because in some cases it only becomes cost-beneficial to improve assets after they have declined into poor condition, and in others it is cost-beneficial to proactively improve assets before they become poor. Therefore, at the end of any given year, some portion of the pavement and bridge population would remain in poor condition.

Scenario Impacts on Delay

Congestion-related delay is projected to decrease sharply under all three of the highway scenarios presented in this report. For example, average delay per VMT is projected to improve by 24.8 percent over 20 years under the Maintain Conditions and Performance scenario.

These results can be explained in part by assumptions regarding a slowdown in future travel growth and the future adoption rate for various highway management and operational strategies. However, it also appears that there are issues with the State-supplied data for some highway sections that are skewing upward the national-level estimates of base-year delay. This issue will be addressed in future editions of this report.

2016–2036 Future Highway Capital Investment Scenarios



Billions of 2016 dollars. Includes all public and private investment.

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 the 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. Of recent (2012 to 2016) average annual capital spending on all U.S. roads, 14.1 percent was used for system enhancements (safety enhancements, traffic control facilities, and environmental enhancements) that neither model analyzes directly. An additional 15.5 percent was used 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 approximately 29.6 percent; each scenario for the overall road system was scaled up so that nonmodeled investment would comprise this share of its total investment level. For example, of the $165.9 billion average annual investment level under the Improve Conditions and Performance scenario, $49.2 billion represents nonmodeled investment.

Sustain Recent Spending Scenario

- The Sustain Recent Spending scenario assumes that capital spending by all levels of government is sustained through 2036 at the average annual level from 2012 to 2016 ($106.9 billion), and that all spending supports only cost-beneficial projects. Under these assumptions, average pavement roughness on Federal-aid highways would be projected to improve (i.e., be reduced) by 3.2 percent, and the share of bridges classified as poor would also be projected to improve, declining from 6.0 percent in 2016 to 4.5 percent in 2036.

Maintain Conditions and Performance Scenario

- The Maintain Conditions and Performance scenario seeks to identify a level of capital investment at which, if only cost-beneficial projects are chosen, selected measures of future conditions and performance in 2036 are maintained at 2016 levels. The average annual level of investment associated with this scenario is $98.0 billion, 8.3 percent lower than the level of the Sustain Recent Spending scenario.

Changes in Improve Scenario and Backlog Estimates

The average annual investment level for the Improve Conditions and Performance scenario increased from $135.7 billion (in 2014 dollars) in the 23rd C&P to $165.9 billion (in 2016 dollars) between the 23rd and 24th C&P reports. (The subset of this scenario that represents the existing investment backlog similarly increased from $786.4 billion to $1.01 trillion.)

As explained in the "Comparison with the 23rd C&P Report" section in Chapter 8, the estimates in the 23rd C&P were likely an underestimate, mostly because the data available data for processing in HERS were less comprehensive, causing some existing deficiencies to go undetected, but also because of other factors such as improved HERS analysis procedures.

- Under this scenario, $60.9 billion per year would be directed to system rehabilitation, $23.2 billion to system expansion, and $13.9 billion to system enhancement. Average pavement roughness on Federal-aid highways and the share of bridges classified as poor in 2036 would match their 2016 levels.

Highlights: Transit

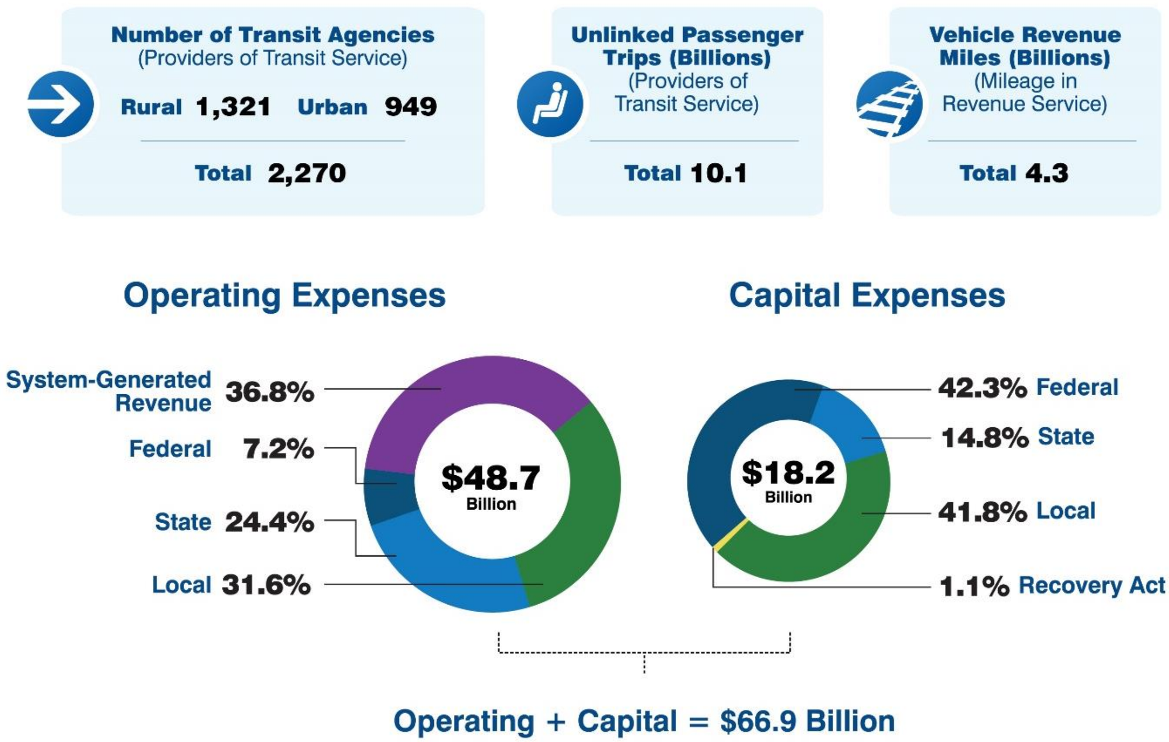
Operating and Capital Funds

- All levels of government spent a combined $66.9 billion to provide public transportation and to maintain and expand transit infrastructure in 2016.
- Operating funding totaled $48.7 billion in 2016, a 36.8-percent increase from 2006. Of this total, 36.8 percent was system-generated revenue, of which most came from passenger fares. Federal funding comprised 7.2 percent of revenues for operations; the remaining funds (54.0 percent) came from State and local sources.
- Capital funding totaled $18.2 billion in 2016, a 29.7-percent increase from 2006. Federal funding made up 42.3 percent of revenues for capital spending. Remaining funds from the Federal American Recovery and Reinvestment Act provided another 1.1 percent, and the rest (56.6 percent) came from State and local sources.
- In 2016, $14.4 billion, or 72.4 percent of total transit capital expenditures, was invested in rail modes and $5.3 billion, or 27.1 percent, was invested in non-rail modes. Guideway investments, including at-grade rail, elevated structures, tunnels, bridges, track, and power systems, totaled $7.7 billion or 53.7 percent of the total capital expenditure in 2016. Investments in vehicles, stations, and maintenance facilities totaled $8.5 billion.
- Between 2006 and 2016, public funding for transit increased at an average annual rate of 2.7 percent, Federal funding increased at an average annual rate of 1.7 percent, and State and local funding increased at an average annual rate of 3.1 percent after adjusting for inflation (constant dollars).
- Farebox recovery ratios, representing the share of operating expenses that come from passenger fares, were about 31.7 percent for the top 10 transit agencies. The 2016 average recovery ratio reflects a total 5.8-percent decrease and an average annual 0.6-percent decrease since 2006.

Transit Agencies, Service Supply, and Ridership

- Of the 2,270 transit systems in the United States that report to FTA's National Transit Database (NTD), 949 provided service primarily to urbanized areas and 1,321 provided service primarily to rural areas in 2016.
- Transit ridership was 10.1 billion unlinked passenger trips on 4.3 billion vehicle revenue miles (VRM) supplied in 2016.

2016 Transit System Extent and Spending



Service Supply and Consumption by Mode

- Urban and rural agencies operated 1,138 bus systems (including regular local bus service, commuter service, trolleybus, bus rapid transit, and the Puerto Rico público) and 1,894 demand-response systems. There were also 15 heavy rail systems, 23 light rail systems, 18 streetcar systems, 27 commuter rail systems, and six hybrid rail systems that mixed the characteristics of light rail and commuter rail. Also, there were 13 smaller rail systems including monorail, automated guideway, inclined planes, aerial tramways, and the San Francisco Cable Car, along with 104 transit vanpool systems and 30 ferryboat systems.
- Fixed-route bus is the most common mode of public transportation in the United States. It accounts for nearly 50 percent of all vehicle revenue miles and unlinked passenger trips, and is provided by transit agencies of all sizes in virtually all urbanized areas and in many rural areas of the country.
- Heavy rail, by contrast, is provided solely in the largest, most densely populated areas of the country by 15 agencies in cities such as New York City, Chicago, Philadelphia, Boston, Miami, and others. Heavy rail accounts for 38 percent of all public transportation trips, but only 16 percent of all miles and hours of service.
- Light rail (including streetcars), like heavy rail, exhibits a relatively higher share of passenger trips than vehicle revenue miles but accounts for a smaller share of the overall transit market. Of all modes, light rail has increased the most in the last 10 years; the number of agencies operating light rail grew from 28 in 2006 to 39 in 2016 (39 percent).

- Commuter rail, like light rail, has also expanded significantly as suburban areas have continued to grow in population. Commuter rail trips have a small share of total transit passenger trips but have long average passenger trip lengths (APTL) of approximately 30 miles.
- The demand-response mode specifically targets the needs of persons with disabilities and persons in special conditions; its provision is required by the Americans with Disabilities Act (ADA) of 1990. A large share of the demand-response market consists of people living below the poverty level and who lack other options for transportation. Demand-response service usually generates large operating deficits and requires higher public subsidies due to both the nature of the service (on-demand, limited capacity, and commonly serving areas of low population density) and to its generally serving a market with transportation needs that often cannot be met by fixed-route transit service.

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. Each UZA has a designated recipient—a metropolitan planning organization or large transit agency—that sub-allocates FTA funds according to local policy. 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 (i.e., awarded in a grant), all funds then become available on a reimbursement basis and cash payments are disbursed.

Transit Service Supplied and Consumed

	No. of Transit Systems	% of Vehicle Revenue Miles **(Supply)**	% of Unlinked Passenger Trips **(Consumption)**
Fixed-route Bus Systems	1,659	47.0%	48.5%
Heavy Rail Systems	15	15.7%	37.6%
Light Rail Systems (includes street cars)	45	2.7%	5.4%
Commuter Rail Systems	29	8.0%	4.9%
Demand-response Systems (includes taxi cabs)	2,240	20.1%	1.1%
Other Systems (Rail)	19	0.2%	0.4%
Other Systems (Nonrail)	167	6.3%	2.2%

- Fixed-route Bus Systems includes local service bus, commuter bus, and Bus Rapid Transit (BRT)
- Other Systems (Rail) includes inclined plane, cable car, hybrid rail, automated guideway/monorail
- Other Systems (Nonrail) includes vanpools, tramway, jitney, públicos, trolleybus, ferryboat

Fatalities, VRM, Cost, and Average Fleet Age

- Transit fatalities rose from 220 in 2006 to 354 in 2016, an increase of 61 percent. This sharp increase was driven mainly by an increased rate of suicides. In 2006, suicides accounted for 7 percent of all fatalities; in 2016, the share was 31 percent.
- Two measures of service supplied by transit agencies are vehicle revenue miles (VRM) and fleet (vehicles available for maximum service). Light rail and commuter rail had the largest number of new systems installed between 2006 and 2016 relative to all modes. From a fleet perspective, commuter rail and light rail increased at an average rate lower than that of VRM. This is explained by the fact that a marginal increase of one passenger car results in a higher marginal increase in VRM.

Some Aspects of System Performance Have Improved

- Between 2006 and 2016, the service offered by transit agencies grew substantially. The annual rate of growth in VRM 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.
- In 2016, agencies reported 212,668 transit vehicles serving urban and rural areas, 3,449 rail passenger stations, and 2,424 maintenance facilities. Rail systems operated on 13,094 miles of track and fixed-route buses operated on over 233,000 mixed traffic route miles.
- 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.

- The average age and condition of the Nation's bus fleet remained unchanged between 2006 and 2016; however, the percentage of vehicles below the replacement threshold increased from 13.2 percent in 2006 to 21.4 percent in 2016.
- Between 2006 and 2016, the number of annual service miles per vehicle (vehicle productivity) remained unchanged and the average number of miles between breakdowns (mean distance between failures) increased by 11 percent.
- Growth in service offered was nearly equal to growth in service consumed. Despite steady growth in route miles and revenue miles, average vehicle occupancy levels did not decrease. Passenger Miles Traveled (PMT) grew at a 2.0-percent annual pace, whereas 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 outcome.

Transit Modes

Public transportation is provided by several different types of vehicles that are used in different operational *modes*.

Fixed-route bus service uses rubber-tired buses that run on scheduled routes.

Commuter bus service is similar, but runs longer distances between stops.

Bus rapid transit is high-frequency bus service similar to 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), characterized primarily by third-rail electric power and exclusive dedicated guideway.
- *Commuter rail*, which often shares track with freight trains and usually uses overhead electric power (but may also use diesel power or third rail); typically found in extended urban areas.
- *Light rail* systems, which are common in large- and medium-sized urban areas, feature overhead electric power and run on track that is generally or in part on city streets 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 and 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 station density 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 on request. This mode is mostly used to provide *paratransit* service as required by the ADA, but in some cases is used to provide service to the general public in low ridership areas or at off-peak service times. These vehicles do not follow a fixed schedule or route.

2006–2016 Transit Trends in Urban Area

Fatalities
(Including suicides and commuter rail)

2006	2016
230	353

53.5%

Vehicle Revenue Miles

2006	2016
3,670,700	4,267,700

16.3%

Average Annual Growth

Bus	Heavy Rail	Commuter Rail	Light Rail
0.5%	0.7%	1.8%	4.9%

Operating Expenditures
(Per Capacity-equivalent Vehicle Revenue Mile)

2006	2016
$7.20	$8.25

14.6%

Average Annual Growth

Bus	Heavy Rail	Commuter Rail	Light Rail
0.8%	4.0%	0.2%	-0.4%

Fleet Count, Average Fleet Age, and Condition

2006	2016
125,647	134,308

6.9%

Average Annual Growth

Bus	Heavy Rail	Commuter Rail	Light Rail
-0.1%	-0.3%	1.4%	3.3%

Average Fleet Age (weighted)

	All Rail	All Buses
2006	19.3	6.0
2016	20.8	6.3

Average Fleet Condition (weighted)

	All Rail	All Buses
2006	3.6	3.2
2016	3.4	3.2

Future Transit Capital Investment Scenarios and the State of Good Repair Benchmark

As in the highway discussion, the transit investment scenarios discussed in this section pertain to spending by all levels of government combined for the 20-year period from 2016 to 2036; the funding levels associated with all of these analyses are stated in constant 2016 dollars. Unlike the highway scenarios, these transit scenarios 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. All other capital investment scenarios are subjected to cost-benefit constraints.

State of Good Repair – Expansion vs. Preservation

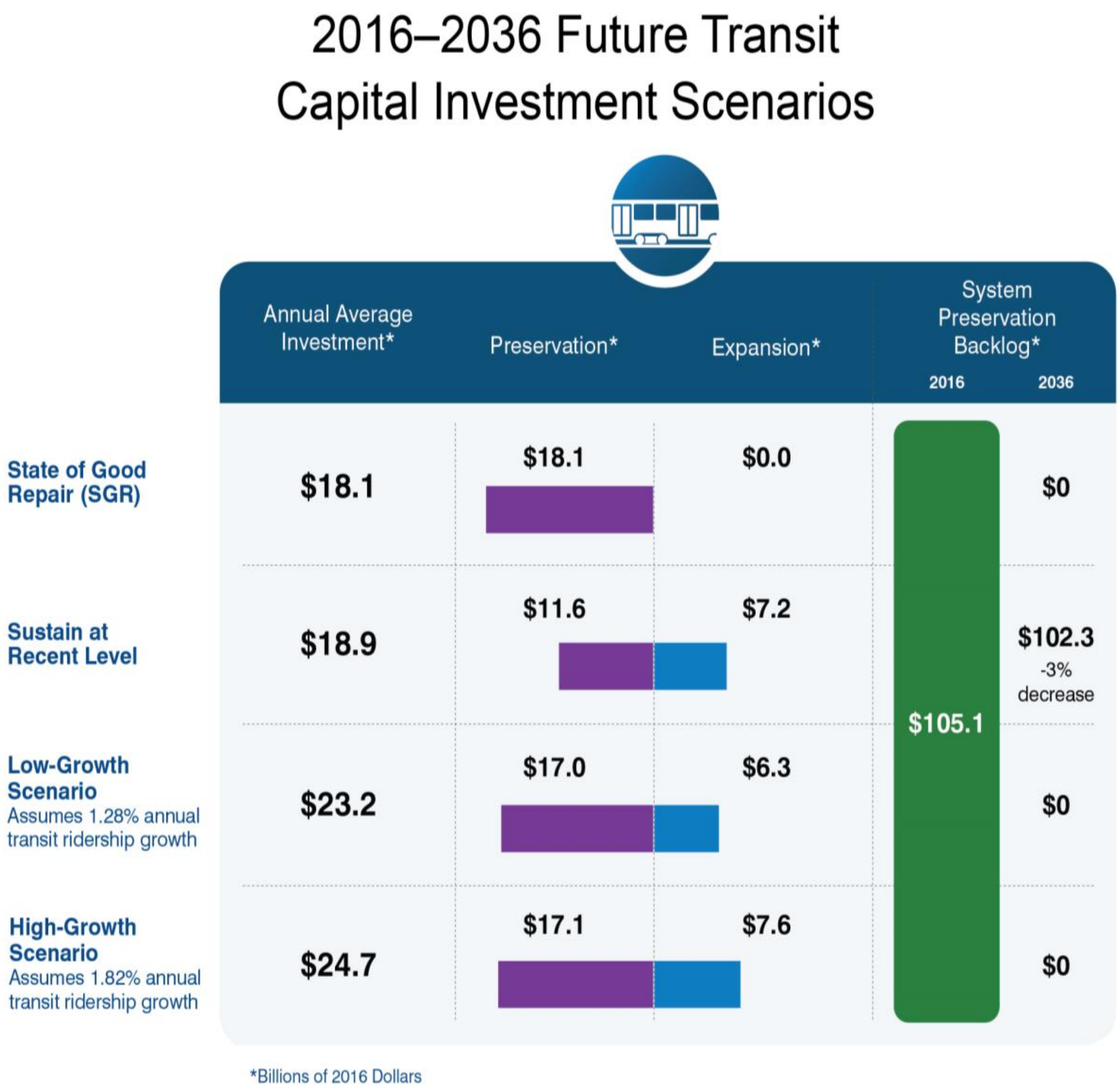
State of Good Repair (SGR) is defined in this report as all transit capital assets being within their average service life. This is a general construct that allows FTA to estimate *system preservation* needs. The analysis looks at the age of all transit assets and adds the value of those that are past 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 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. Estimates of future demand are, by their nature, speculative. 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.

Sustain Recent Spending Scenario

- The **Sustain Recent Spending** scenario assumes that capital spending by all levels of government is sustained in constant-dollar terms at recent levels (average from 2012–2016) through 2036. Unlike the growth scenarios, which estimate the levels of investment required to meet ridership growth and eliminate the backlog at year 20, the Sustain Recent Spending scenario assumes continued spending at the actual average investment levels for rehabilitation/replacement and expansion during 2012–2016. It then estimates the size of the backlog at year 20 and the ridership level supported by the average recent expansion investment.
- The average recent (2012–2016) capital invested stood at $18.9 billion, of which $11.6 billion was devoted to rehabilitation/replacement and $7.2 billion to expansion. At this level, this scenario results in a backlog of $102.3 billion in 2036, 3 percent less than the $105.1 billion in 2016. It is the first time in the last three editions of the C&P Report that the backlog did not grow over the 20-year timeframe.
- The Sustain Recent Spending scenario addresses 61 percent of the required level to eliminate the backlog in 2036.

- It supports a ridership level increase of 4.1 million trips on average per year, which is higher than that of the Low-Growth scenario (3 million per year), but lower than that of the High-Growth (4.5 million per year).



Growth Scenarios

The growth scenarios estimate capital investment levels required to meet two primary objectives: (1) eliminate the backlog at year 20 (2036) by investing in preservation and replacement of legacy and new assets past their useful lives subjected to a cost-benefit test, and (2) invest in the acquisition of new assets to meet a forecasted ridership growth based on 15-year historical trends analysis at the UZA and mode levels.

- The **Low-Growth scenario** assumes that transit ridership will grow at an average rate of 3 billion trips per year, corresponding to an average annual rate of 1.28 percent. It also eliminates the backlog of legacy assets, estimated at $105.1 billion, plus the backlog of new assets past their useful lives. Only new assets with relatively short useful lives, such as buses (12-year average) and smaller vehicles, affect the size of the backlog. The average annualized cost of this scenario is $23.2 billion, of which $17.0 billion is to eliminate the backlog in 2036 and $6.3 billion is for service expansion.
- The Low-Growth scenario requires a level of investment in system expansion of $6.3 billion, which is less than the recent spending on expansion at $7.2 billion.

- The **High-Growth scenario** is similar to the Low-Growth scenario but assumes that transit ridership will grow at an average rate of 4.5 billion trips per year, corresponding to an annual rate of 1.82 percent between 2016 and 2036. The annualized cost of this scenario is $24.7 billion, of which $17.1 billion is to eliminate the backlog in 2036 and $7.6 billion is for service expansion.

The small difference in average annual preservation investment between the High-Growth and Low-Growth scenarios ($100 million per year) is proportional to the actual difference in ridership growth forecasted for the two scenarios. A higher rate requires more assets, which require more rehabilitation and replacement investment.

State of Good Repair Benchmark

- The State of Good Repair (SGR) benchmark estimates, on an unconstrained basis, the annual investment in preservation of existing assets at year 1 (2016) that are required to eliminate the backlog in year 20 (2036). FTA estimates that $18.1 billion annually will reduce the backlog of $105.1 billion to zero in 2036.

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, **System Assets**, describes the existing extent of the highways, bridges, and transit systems.
- Chapter 2, **Funding**, provides data on the revenue collected and expended by different levels of governments and transit operators to fund transportation construction and operations.
- Chapter 3, **Travel Behavior**, explores the 2017 National Household Travel Survey (NHTS), including data on internet-based and phone-based mobility solutions.
- Chapter 4, **Mobility and Access,** covers highway congestion and reliability in the Nation's urban areas. The transit section explores ridership, average speed, vehicle utilization, and maintenance reliability.
- Chapter 5, **Safety**, presents statistics on highway safety performance, focusing on the most common roadway factors that contribute to 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

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 to national performance goals. FHWA has finalized six related rulemakings to implement the TPM framework established by the Moving Ahead for Progress in the 21st Century (MAP-21) Act and the Fixing America's Surface Transportation (FAST) Act:

- Statewide and Metropolitan / Nonmetropolitan Planning Rule (implements a performance-based planning process at the State and metropolitan levels; defines coordination in the selection of targets, linking planning and programming to performance targets).
- Safety Performance Measures Rule (PM-1) (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).
- 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 target establishment, progress assessment, and reporting requirements).
- Asset Management Plan Rule (defines the contents and development process for an asset management plan; also defines minimum standards for pavement and bridge management systems).
- System Performance Measures Rule (PM-3) (defines performance measures to assess performance of the Interstate System, non-Interstate National Highway System, freight movement on the Interstate System, Congestion Mitigation and Air Quality Improvement Program traffic congestion, and on-road mobile emissions).

All 50 State DOTs, the District of Columbia, and Puerto Rico reported performance data and targets for each of 17 performance measures. These data are available at https://www.fhwa.dot.gov/tpm/reporting/state/index.cfm

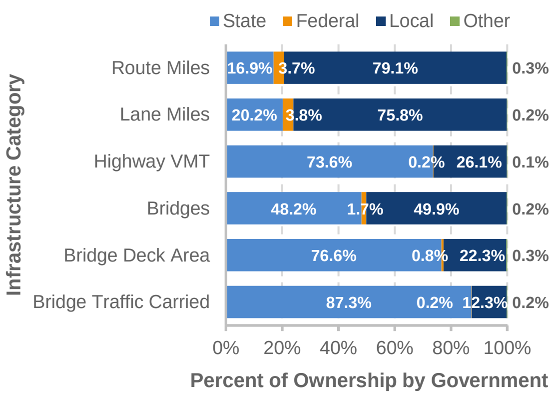
CHAPTER 1: System Assets – Highways

Based on data collected from States through the Highway Performance Monitoring System (HPMS), in 2016 local governments owned 79.1 percent of the Nation's 4,157,292 public road route miles and 75.8 percent of its lane miles (computed as roadway length times number of lanes). However, State-owned roads carried a disproportionate share of the Nation's travel in motorized vehicles, accounting for 73.6 percent of the 3.189 trillion vehicle miles traveled (VMT) in 2016.

Based on 2016 data collected from States through the National Bridge Inventory (NBI), ownership of bridges is more evenly split, as local governments owned slightly more (49.9 percent) of the Nation's 614,387 bridges in 2016 than did State governments (48.2 percent). State-owned bridges made up 76.6 percent of the Nation's bridge deck area, and carried 87.3 percent of total bridge traffic.

Although the Federal government provides significant financial support for the Nation's highways and bridges, it owns only 3.7 percent of public road route miles and 1.7 percent of bridges.

Highway and Bridge Ownership by Level of Government, 2016



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 adjacent land. Collectors funnel traffic from local roads to arterials.

Nearly half the Nation's route mileage was classified as rural local in 2016, part of the 70.7 percent of route mileage located in rural areas. Almost one-third of the Nation's bridges were classified as rural local.

Highway Mileage and Bridges, by Functional System, 2016

Functional System	Route Miles	Bridges
Rural Areas (less than 5,000 in population)		
Interstate	0.7%	4.1%
Other Principal Arterial	2.3%	6.1%
Minor Arterial	3.2%	6.2%
Collector	16.1%	22.8%
Local	48.4%	33.1%
Subtotal Rural Areas	**70.7%**	**72.2%**
Urban Areas (5,000 or more in population)		
Interstate	0.5%	5.2%
Other Principal Arterial	1.9%	8.2%
Minor Arterial	2.7%	5.1%
Collector	3.5%	3.7%
Local	20.7%	5.5%
Subtotal Urban Areas	**29.3%**	**27.8%**
Total	**100.0%**	**100.0%**

Note: Other Freeway and Expressway is shown within Other Principal Arterial. Collector includes Major Collector and Minor Collector.

Source: HPMS and NBI.

In general, the 1,026,319 route miles of public roads that were functionally classified as arterials, urban collectors, or rural major collectors in 2016 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 connects principal arterials to other transportation modes and defense installations. The total length of the NHS was 222,331 miles in 2016, including 48,474 miles on the Interstate Highway System. State highway agencies own 89.2 percent of the NHS and 94.4 percent of Interstate highways. A combination of local governments and other State agencies own most of the remaining NHS mileage.

CHAPTER 1: System Assets – Transit

Most transit systems in the United States report to the National Transit Database (NTD). In 2016, 949 systems served 486 urbanized areas that have populations greater than 50,000. In rural areas, about 1,301 systems were operating, of which 718 were located in urban clusters (urban areas with population of less than 50,000 and over 2,500), 395 were located in Census-designated rural areas, and the remaining 188 were tribes and agencies that could not be geocoded.

Modes. Transit is provided through 18 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, trolleybus, commuter bus, bus rapid transit, demand response, vanpools, other less common rubber-tire modes such as jitney and público, ferryboats, and aerial tramways.

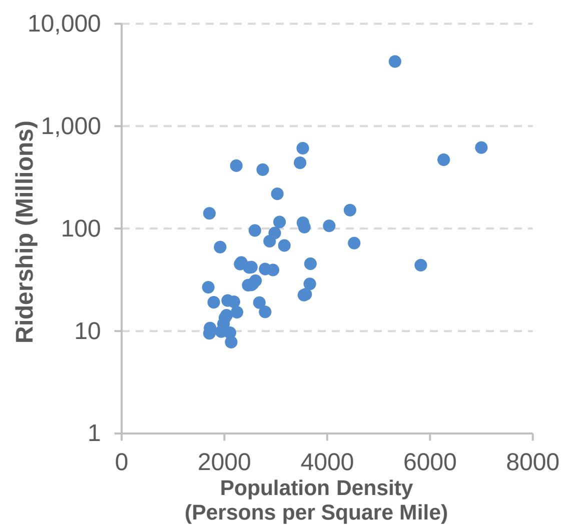
Urbanized Areas, Population Density, and Demand. Based on the 2010 census, the average population density of the United States is 82.4 people per square mile. The average population density of all 497 urbanized areas combined is 2,548 people per square mile. The exhibit shows the relationship between ridership and urbanized area density for the top 50 areas in 2016. Areas with higher population density are able to attract more discretionary transit riders.

Organizational Structure of Urban and Rural Agencies. Approximately 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 21 percent; 19 percent are private operators and the remaining 9 percent are other organizational structures such as State governments, area agencies on aging, municipal planning organizations, planning agencies, Tribes, and universities.

National Transit Assets

- Of the 212,668 vehicles in urban and rural areas, 191,064 are nonrail vehicles (buses, demand response, and vanpool), whereas 21,604 rail vehicles are rail passenger cars.
- Demand response is the most common mode in rural areas, with over 79 percent of the 21,331 vehicles in the rural fleet.
- Rail systems operate on 13,094 miles of track and bus systems operate over 233,000 directional route miles.
- Urban and rural areas have 3,449 stations and 2,424 maintenance facilities, of which 70 are heavy facilities.

Urbanized Area Density vs. Ridership, 2016 (Top 50 Areas in Population)



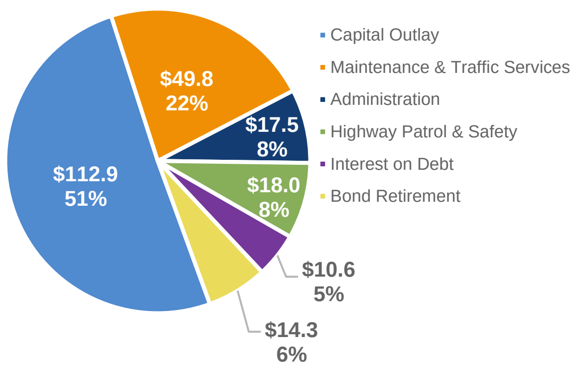
Source: U.S. Census and National Transit Database.

ADA Compliance. The Americans with Disabilities Act of 1990 (ADA) ensures equal opportunity and access for persons with disabilities. The ADA requires transit agencies to provide accessible vehicles (e.g., with lifts) and accessibility enhancements to key rail stations, such as barriers on platforms, ramps, elevators, and other elements. Nearly 95 percent of vehicles are ADA-compliant. Most key rail stations are compliant, but many non-key rail stations are not fully accessible.

CHAPTER 2: Funding – Highways

Total expenditures for highways and bridges by all levels of government combined reached $223.2 billion in 2016. Slightly more than half of that amount (50.6 percent or $112.9 billion) was for capital outlays. Noncapital expenditures such as maintenance and traffic services, administration, and highway patrol and safety totaled $95.9 billion (43.0 percent) and another $14.3 billion (6.4 percent) was used for bond retirement.

Highway Expenditures by Type, 2016



Source: FHWA Bulletin: Highway Funding 2013–2016.

Of the $112.9 billion in capital outlays, $70.0 billion was used for system rehabilitation, $27.6 billion for system expansion, and $15.3 billion for system enhancement.

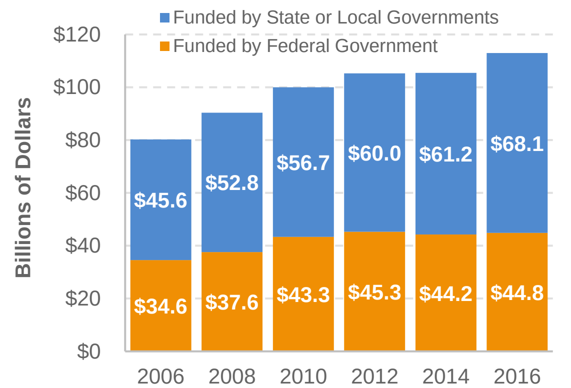
All levels of government raised a combined $272.1 billion for highways and bridges in 2016, of which $49.0 billion was put in reserves for future use.

State governments raised $122.4 billion for highways in 2016, and directly spent $144.6 billion on highways. Local governments raised $60.1 billion for highways and directly spent $75.6 billion.

The Federal government raised $89.6 billion for highways in 2016, including a one-time transfer of $51.9 billion from the general fund to the Highway Trust Fund required under the FAST Act. These revenues supported a large $42.4 billion increase in the cash balance of the Federal Highway Trust Fund to support highway spending over the duration of the FAST Act; the Federal government funded $47.2 billion of highway expenditures in 2016. Most of this ($44.2 billion) took the form of transfers to State and local governments; direct spending by Federal agencies on roads and bridges totaled $3.0 billion in 2016.

Although federally funded highway capital outlay grew nominally from 2006 to 2016, the federally funded share of highway capital decreased from 43.1 percent to 39.7 percent, as capital outlay funded by non-Federal sources grew even faster.

Highway Capital Outlay Funded by Level of Government, 2006–2016



Sources: FHWA Bulletin: Highway Funding 2013–2016, Table HF-10B; Highway Statistics, various years, Table HF-10A.

User charges (tolls, vehicle and fuel taxes) accounted for 43.2 percent ($117.7 billion of the $272.1 billion raised). General fund appropriations accounted for another 30.4 percent ($82.8 billion), bolstered by the large one-time Federal general fund transfer. The rest came from property taxes, other taxes and fees, investment income and other receipts, and bond issue proceeds.

Alternative Funding Mechanisms

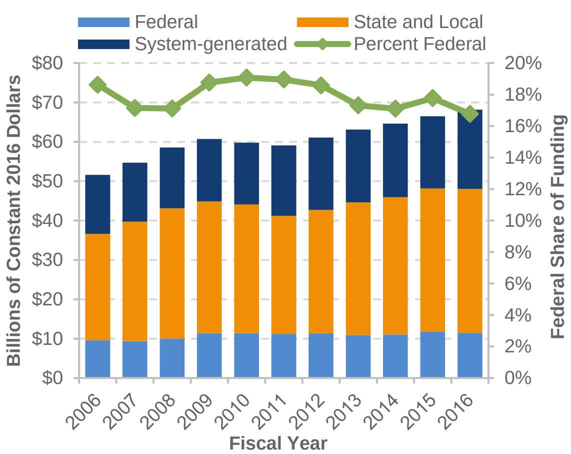
Many jurisdictions are using alternative methods to raise additional transportation funds, including public-private partnerships (P3), value capture techniques, Federal credit assistance, and other debt-financing tools. Of the 74 loans issued through FY 2017 under the Transportation Infrastructure Finance and Innovation Act (TIFIA) program, 16 were for Design-Build-Finance-Operate-Maintain highway projects where the financing responsibility was given to private partners.

Funding Sources

In 2016, $68.4 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 2016, 70 percent came from public sources and 30 percent came from system-generated funds (passenger fares and other system-generated revenue sources). The Federal share was $12.0 billion (25 percent of total public funding and 17.5 percent of all funding).

Between 2006 and 2016, all sources of public funding for transit increased by 3.6 percent per year. The Federal share remained relatively stable, varying in the range of 17 to 20 percent.

Funding for Urban Transit by Government Jurisdiction, 2006–2016



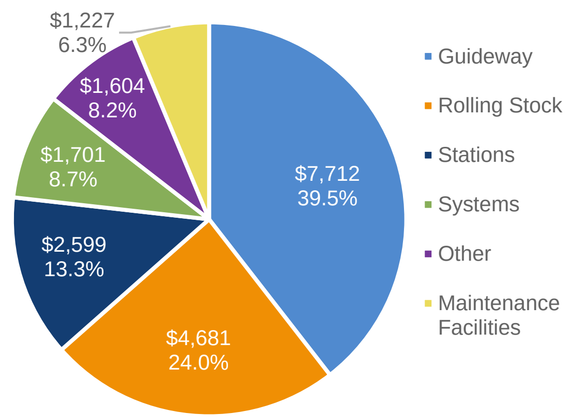
Source: NTD.

Expenditures

In 2016, operating expenses consumed $48.7 billion of all funding while capital expenditures consumed $18.2 billion of all funding devoted to transit ($68.4 billion).

Capital investment consumed $18.1 billion. The largest share of capital expenditures—39.5 percent ($7.7 billion)—was used for expansion or rehabilitation of guideway assets.

Urban Capital Expenditures by Asset Type, 2016

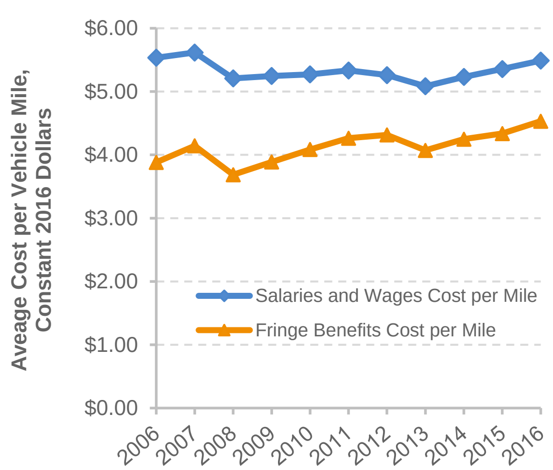


Source: NTD.

Salaries and Fringe Benefits

From 2006 to 2016, 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, the cost of fringe benefits increased at an annual compound average rate of 1.6 percent with a total accumulated increase of 16.8 percent. Fringe benefits can include many components, but the cost of medical insurance is usually a key element. Meanwhile, salaries and wages decreased by nearly 1 percent over the 10-year period.

Salaries/Wages and Fringe Benefits, Average Cost per Mile, Top 10 Transit Agencies, 2006–2016



Sources: NTD and Bureau of Labor Statistics Consumer Price Index.

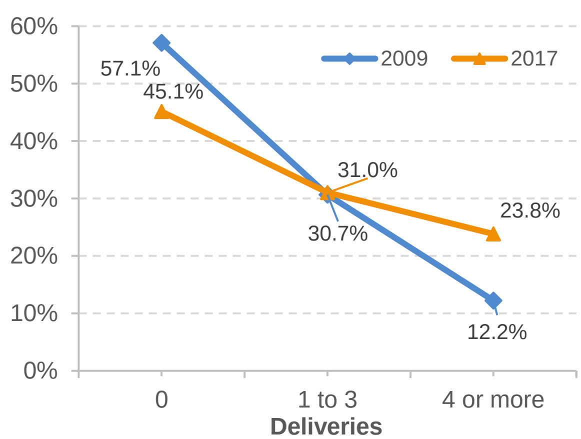
CHAPTER 3: Travel Behavior

Household travel behavior depends heavily on demographic distribution and geographic location. Many of these characteristics can be found in the National Household Travel Survey (NHTS) data.

The 2017 NHTS also captures information on household technology use. New technologies and internet access have opened the door to a growing number of mobility options for many Americans. The most recent NHTS has revealed the ubiquity of internet use—more than 80 percent of households use the internet on a daily basis and more than 90 percent use it at least a few times a month. Wireless connectivity is more prevalent in urban households with 81 percent of urban and 73 percent of rural households using the internet via smartphone at least a few times a week. Despite these high levels of connectivity, only 9 percent of Americans at or above 16 years old indicated that they hailed a ride with a ridehail smartphone app in the last 30 days.

The share of households reporting having received a delivery from an online purchase in the last 30 days grew from 42.9 percent in 2009 to 54.9 percent in 2017. The share of households with frequent deliveries has increased considerably; households receiving four or more monthly deliveries almost doubled from 12.2 percent in 2009 to 23.8 percent nationally in 2017.

Online Monthly Purchase Deliveries, 2009–2017



Source: NHTS.

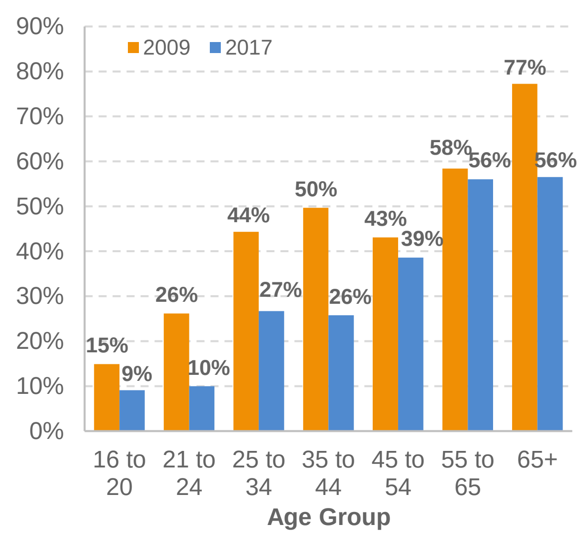
Telework has also seen growth with eligibility increasing from 11 percent in 2001 to 14 percent in 2017. Ineligibility to telework is more pronounced in rural areas where 90 percent of workers are not eligible to work from home compared with their urban counterparts at 85 percent.

Travel Patterns Associated with Household Characteristics

Vehicle miles traveled (VMT) has consistently shown a strong relationship with labor force participation over time. The most recent NHTS data show that an average worker drove 13,733 miles annually, almost double the miles driven by nonworkers at 7,600 miles. Workers travel more regardless of whether it is in a vehicle with almost 60 percent more passenger miles traveled than those of nonworkers in 2017.

Baby boomers are working longer, and they are driving more miles than their cohorts of the past with women moving closer to parity and closing the VMT gap. Although men 65+ drove 56 percent more annual average miles than did their female counterparts in 2017, women have lessened the gap by 21 percentage points from 2009 when men 65+ drove 77 percent more annual average miles than did women 65+.

Percent Difference in Average Annual VMT Between Male and Female Drivers, by Age

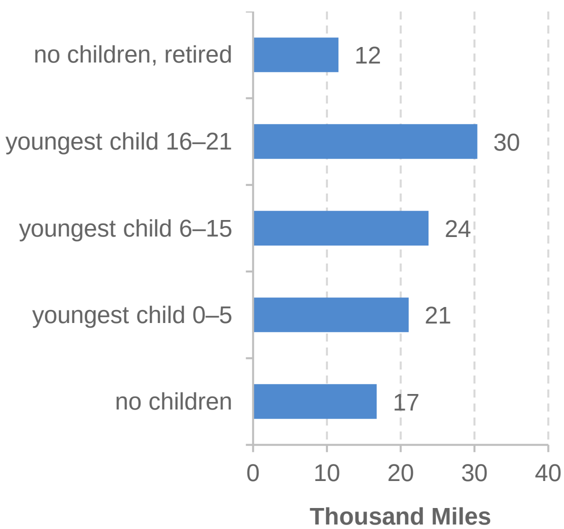


Source: NHTS.

Households with children have higher than average annual household VMT whereas retirees and households with no children have lower than average household VMT. More than 80 percent of households without a car have no children present.

Household minors create many additional drop-off and pick-up trips with school and extracurricular activities, adding more miles to the household log that likely already contains regular work trips.

2017 Average Household Annual VMT



Source: NHTS.

According to the Centers for Disease Control and Prevention, U.S. women are waiting longer to have their first child. In 1970, the mean age of a first-time mother was 24.6 years compared with 28 years in 2016. This growing delay in parenthood may also result in pushing back the need for vehicle purchases and higher VMT levels for older age groups.

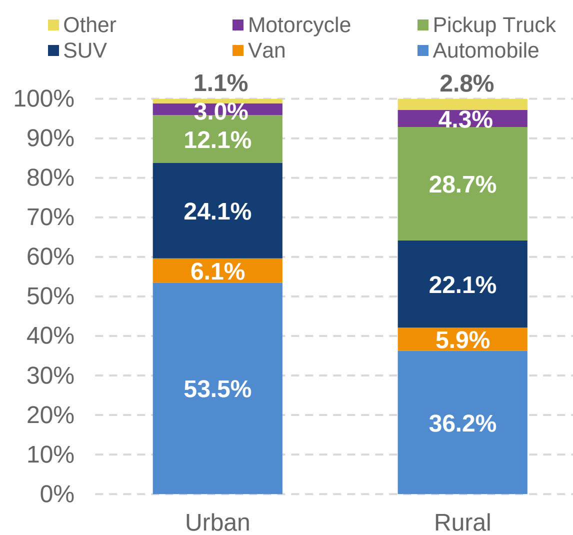
Travel Behavior Characteristics

Since 2009, the United States has seen an uptick in both vehicle and nonmotorized trips. Households living in areas with a population density greater than 10,000 people per square mile consistently have higher household person trips across all vehicle ownership levels, likely due to higher average income levels and the larger variety of mobility options.

When NHTS respondents were asked how many walking or bicycling trips taken in the past seven days, the data showed a 7.7 percentage point increase (from 65.4 percent in 2001 to 73.1 percent in 2017) in individuals who took at least one walking trip, and a 5.1 percentage point increase in individuals who took at least one bicycling trip in the 2017 survey compared with the 2001 survey.

The number and type of vehicles in U.S. households vary by region. Pickup trucks and motorcycles are more prevalent in rural areas (28.7 percent vs. 12.1 percent and 4.3 percent vs. 3.0 percent, respectively) whereas automobiles and sport utility vehicles (SUV) are more common in urban areas (53.5 percent vs. 36.2 percent and 24.1 percent vs. 22.1 percent, respectively).

2017 Vehicle Types, Rural vs. Urban



Source: NHTS.

The total mileage-weighted average vehicle occupancy is 1.67. This varies by mode with vans at the top at 2.44 and motorcycles and pickup trucks at the bottom with 1.20 and 1.49, respectively.

The median age of the household vehicle fleet has been growing over the last 40 years. The average U.S. vehicle is almost 4 years older than in 1977 with rural households holding their vehicles longer than urban households. This pattern of vehicle ownership leads to a slower turnover of the U.S. vehicle fleet and delays in the penetration of safety and fuel-efficient technologies.

CHAPTER 4: Mobility and Access – Highways

The Texas Transportation Institute's 2019 Urban Mobility Study indicates that congestion grew worse from 2006 to 2016. The average delay experienced by an individual commuter rose from 42 hours in 2006 to 53 hours in 2016. Total delay rose from 6.7 billion hours to 8.6 billion hours during this 10-year period, while fuel wasted rose from 3.1 billion gallons to 3.3 billion gallons. Expressed in constant 2017 dollars, the estimated total cost of congestion rose from $115 billion in 2006 to $171 billion in 2016.

NPMRDS

The National Performance Management Research Data Set (NPMRDS) is a compilation of vehicle probe-based data in both rural and urban areas on the National Highway System, as well as over 25 key Canadian and Mexican border crossings. It includes observed travel times, date/time, direction, and location for freight, passenger, and other traffic.

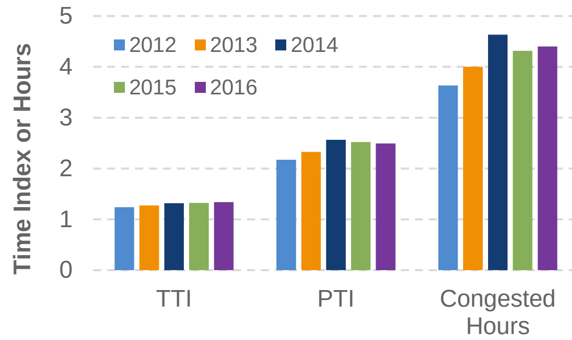
Based on the NPMRDS, the Travel Time Index (TTI) was 1.34 in 2016 for Interstate highways in the 52 largest metropolitan areas, meaning that the average peak-period trip took 34 percent longer than the same trip under free-flow traffic conditions.

The Planning Time Index (PTI) is a measure of travel time reliability. In 2016, the PTI of Interstate highways in the NPMRDS was 2.49 in the 52 largest metropolitan areas, meaning that drivers making a trip would need to leave early enough each day to account for it taking 2.49 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.

On average, Interstate highways were congested 4.4 hours per weekday in 2016.

Average travel time delays represented by the TTI increased from 2012 (the first year that data are available) to 2016. However, travel reliability and the length of road congestion have improved since 2014 when the values of PTI (2.56) and congested hours (4.6) peaked and then tapered off. A similar congestion trend is also observed on the limited-access non-Interstate highways.

Mobility on Interstate Highways in 52 Urban Areas, 2012–2016



Source: FHWA staff calculation from the NPMRDS.

Congestion occurs in urban areas of all sizes. Residents in large metropolitan areas tend to experience more severe congestion. Average values of TTI, PTI, and congested hours were consistently higher in larger urban areas than in medium and small ones.

In 2016, the average TTI was 1.47, 1.27, and 1.19 on Interstate Highways in metropolitan areas with populations over 5 million, between 2 and 5 million, and between 1 and 2 million, respectively. For the same sized areas, the average PTI was 2.89, 2.28, and 2.02 respectively in 2016.

Interstate Mobility

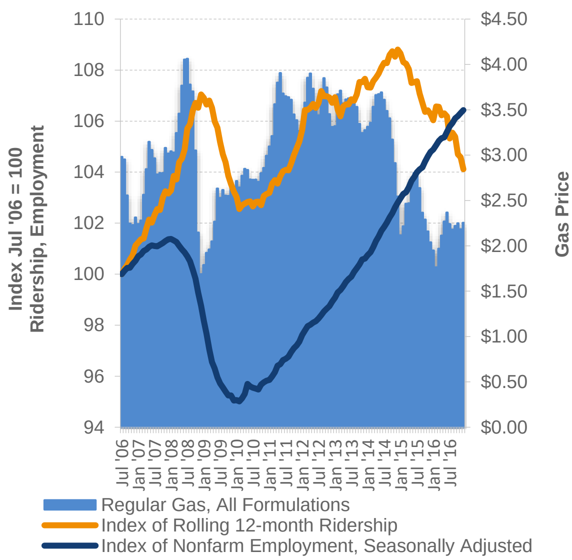
Combined with a detailed geospatial network, FHWA uses NPMRDS to examine speeds on Interstate highways for the entire Nation. The average observed vehicle speed on the entire Interstate Highway System in 2016 was 56.8 mph including peak and off-peak travel, compared to an average speed limit of 67.0 mph. The average observed speed was 60.3 mph on rural Interstates, and 53.8 mph on urban Interstates.

On rural Interstates, average speeds were relatively uniform and constant during the weekday morning and afternoon peak hours, varying within a small range between 59 and 62 mph. Average urban Interstate speed dropped substantially during weekday morning and afternoon peak hours, with the most noticeable reductions during the p.m. peak hours. Average speed fell to 47 mph between 5:00 and 6:00 p.m.

Transit Ridership and Employment

Transit ridership increased significantly from July 2006 to January 2009, then plummeted following the economic crisis in 2009. Between 2010 and 2015, growth in ridership tracked employment levels. Ridership declined roughly 5 percent between January 2015 and the end of 2016. This decline coincided with a drop in gas prices, despite ongoing growth in employment.

Transit Ridership vs. Employment, 2006–2016

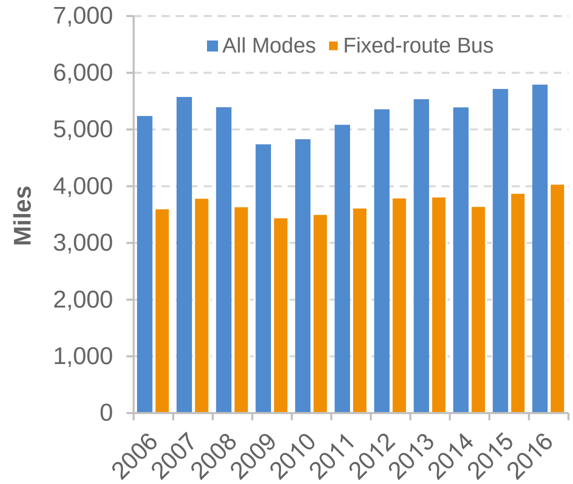


Source: NTD, EIA Gas Pump Data History, and BLS Employment Data.

Maintenance Reliability

The mean distance between failures is an important performance measure for analysis of replacement and rehabilitation needs of the national transit fleet. Between 2006 and 2016, the number of miles between failures increased by an average of 1.0 percent annually. Miles between failures for all modes combined increased in 2007, decreased until 2009, then increased steadily until 2016. The overall increase between 2006 and 2016 was 10.5 percent. The trend for fixed-route bus is nearly identical to that of all modes combined, with miles between failures increasing by 12 percent between 2006 and 2016. Bus replacement was an important factor for the increase.

Mean Distance Between Urban Vehicle Failures, 2006–2016



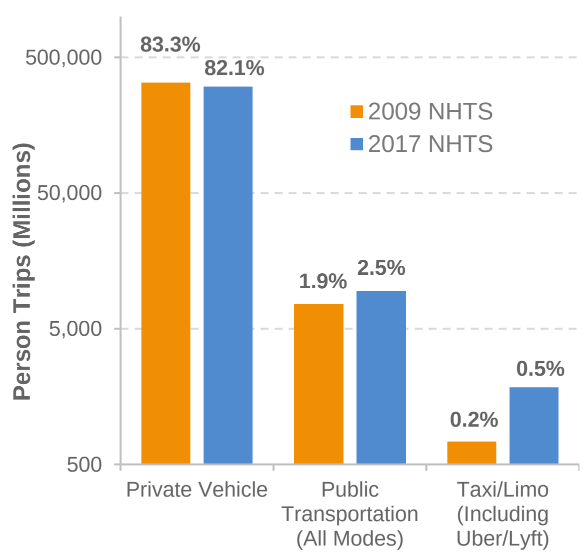
Notes: Only directly operated vehicle data were used to calculate mean distance between failures. Data from 2014 to 2016 do not include agencies that qualified for and opted to use the small systems waiver of the National Transit Database.

Source: NTD.

Market Share of Public Transportation

The share of public transportation users increased from 1.9 percent of person trips in 2009 to 2.5 percent in 2017.

Market Share Change of Public Transportation, Private Vehicles, and Taxi Trips, 2009 and 2017



Note: NHTS is National Household Travel Survey. Vertical axis is portrayed using a logarithmic scale.

Source: NHTS, FHWA, 2017.

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 DOT—FHWA, the National Highway Traffic Safety Administration (NHTSA), and the Federal Motor Carrier Safety Administration (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 and responsibility while working toward the Nation's safety goal.

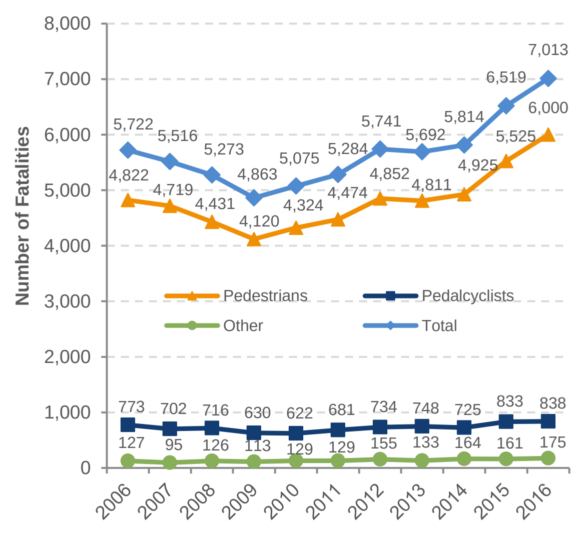
Great progress has been made in reducing overall roadway-related fatalities and injuries over time despite increases in population, travel, and some types of crashes. The figures below come from NHTSA's Fatality Analysis Reporting System (FARS).

- From 2006 to 2016, highway fatalities decreased by nearly 12 percent.
- In 2006, 42,708 motor vehicle fatalities occurred. By 2011, that count declined by 24 percent, to 32,479. Fatalities changed little from 2011 through 2014, but increased in 2015 and 2016. The 2016 fatality count of 37,461 was more than 14 percent higher than the 32,744 fatalities in 2014.
- From 2006 to 2016, fatality rates per 100 million vehicle miles traveled decreased by 17 percent.
- From 2006 to 2010, the fatality rate per 100 million VMT dropped significantly from 1.42 down to 1.11 and varied little from 2010 through 2014. The rate rose in 2015 and 2016, from 1.08 in 2014 up to 1.15 in 2015 and 1.18 in 2016.

FHWA has established three focus areas based on the most common crash types relating to roadway characteristics. In 2016, roadway departure, intersection, and pedestrian/pedalcyclist fatalities accounted for 48 percent, 27 percent, and 19 percent, respectively, of the 37,461 fatalities. Note that these three categories overlap, and 11 percent of fatalities involve more than one of these three focus areas; 13 percent do not involve a focus area.

- From 2006 to 2016, roadway departure fatalities decreased by 20.2 percent.
- From 2006 to 2016, intersection-related fatalities increased by 0.5 percent. Estimates indicate that the United States has more than 3 million intersections, most of which are nonsignalized (controlled by stop signs or yield signs, or without any traffic control devices), and a small portion of which are signalized (controlled by traffic signals). In 2016, 34.8 percent of fatalities related to intersections occurred in rural areas and 65.2 percent occurred in urban areas.
- From 2006 to 2016, pedestrian/bicyclist fatalities increased by 22.6 percent.
- 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 44.2-percent increase by 2016. Pedestrian fatalities rose from 4,120 in 2009 to 6,000 in 2016, an increase of 45.6 percent. Pedalcyclist (primarily bicyclist) fatalities rose from 630 in 2009 to 838 in 2016, an increase of 33 percent.

Pedestrian, Pedalcyclist, and Other Nonmotorist Traffic Fatalities, 2006–2016



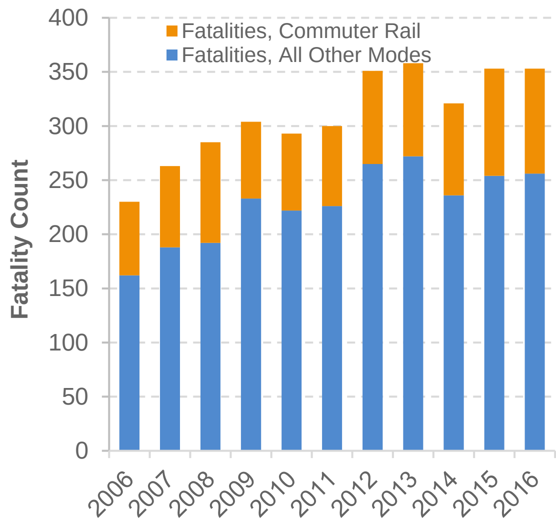
Source: FARS Final File for 2006 to 2015; FARS Annual Report File (ARF) for 2016.

Rates of injuries and fatalities on public transportation generally are lower than for other types of 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 but are members of the general public such as pedestrians, automobile drivers, bicyclists, or trespassers. Patrons are individuals in stations who are waiting to board or just got off transit vehicles. Passengers are individuals boarding, traveling, or alighting a transit vehicle.

Fatality measures exhibited a general increasing trend between 2006 and 2016 (rising from 230 in 2006 to 353 in 2016), but were essentially flat between 2012 and 2016. One significant contributor to the 10-year increase was growth in the number of suicides in transit, from 12 in 2006 to 81 in 2016.

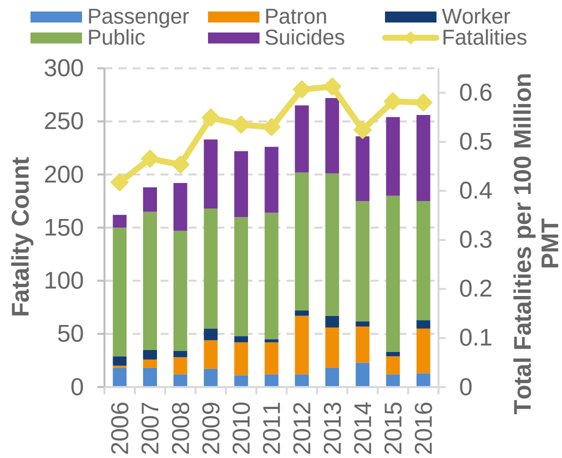
Annual Fatalities, for All Modes, 2006–2016 (Including Commuter Rail)



Source: NTD, Transit Safety and Security Statistics and Analysis Reporting.

Of the 256 transit-related fatalities in 2016 (excluding commuter rail), 13 were passengers, 42 were patrons, 8 were workers, and 112 (44 percent) were members of the public. The remaining 81 were suicides. The number of fatalities per 100 million passenger miles travelled increased from 0.4 in 2006 to 0.6 in 2016.

Annual Transit Fatalities, by Victim Type, 2006–2016 (Excluding Commuter Rail)

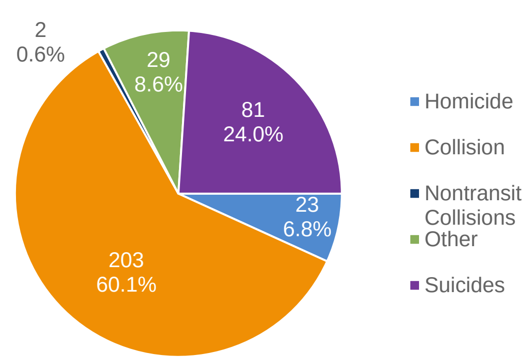


Notes: The right Y-axis displays total fatalities per 100 million passenger miles traveled (PMT), including suicides. Fatality totals include both directly operated (DO) and purchased transportation (PT) service types.

Source: NTD, Transit Safety and Security Statistics and Analysis Reporting.

Collisions are the most common type of fatal incident in rail transit. In 2016, 203 people, or 60 percent of all fatalities (excluding commuter rail), died in collision incidents. Most victims were not passengers or patrons but individuals in the general public. Suicides were the second most common type with 81 fatalities in 2016, down from 74 in 2015.

Transit Fatality Event Types, 2016 (Excluding Commuter Rail)



Notes: Exhibit includes data for both rail and nonrail transit modes, excluding commuter rail. Two NTD event type categories were updated in 2016.

Source: NTD.

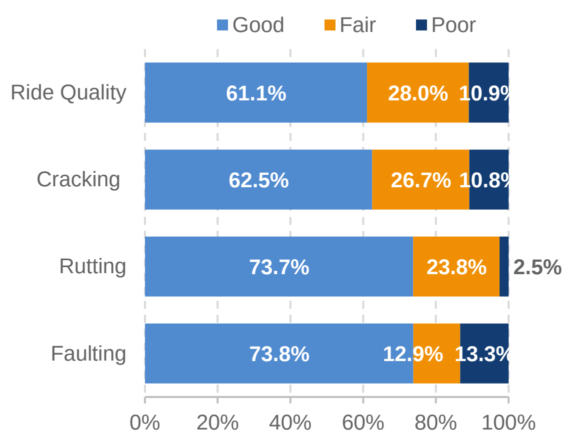
Commuter rail fatalities have risen by 42 percent since 2006, from 68 fatalities to 97 in 2016.

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, including pavement roughness (used to assess the quality of the ride that highway users experience), pavement cracking, pavement rutting (surface depressions in the vehicle wheel path, generally relevant only to asphalt surface pavements), and pavement faulting (the vertical displacement between adjacent jointed sections on concrete surface pavements).

Weighted by lane miles, 10.9 percent of pavements on Federal-aid highways for which data were available had poor ride quality in 2016; the comparable shares for cracking, rutting, and faulting were 10.8 percent, 2.5 percent, and 13.3 percent, respectively.

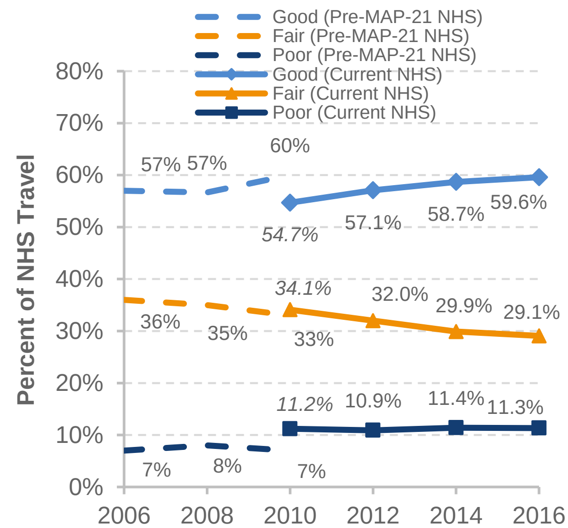
Federal-aid Highway Pavement Condition, Weighted by Lane Miles, 2016



Source: HPMS.

FHWA currently uses the share of VMT on NHS pavements with good ride quality as a metric for performance planning purposes; this metric was affected by the 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. The share of pavements with good ride quality rose from 57 percent in 2006 to 60 percent in 2010 on the pre-expansion NHS, and from an estimated (italicized in chart) 54.7 percent in 2010 to 59.6 percent in 2016 on the expanded NHS.

NHS Pavement Ride Quality, Weighted by VMT, 2006–2016



Notes: Data for odd-numbered years are omitted.

Source: HPMS.

The NBI contains data on bridge decks, superstructures, substructures, and culverts that can be combined to form an overall bridge condition rating. The share of bridges rated poor was reduced from 10.4 percent in 2006 to 7.9 percent in 2016. Larger bridges carrying more traffic fared even better, with the deck-area weighted share rated poor reduced from 9.0 percent to 5.9 percent and the traffic-weighted share reduced from 7.1 percent to 3.9 percent over this period. It should be noted that a poor condition rating does not mean that a bridge is unsafe.

Systemwide Bridge Conditions, 2006–2016

	2006	2016
Percent Good		
By Bridge Count	48.2%	47.4%
Weighted by Deck Area	46.1%	46.5%
Weighted by Traffic	45.6%	48.1%
Percent Fair		
By Bridge Count	41.2%	44.6%
Weighted by Deck Area	44.7%	47.6%
Weighted by Traffic	47.1%	47.9%
Percent Poor		
By Bridge Count	10.4%	7.9%
Weighted by Deck Area	9.0%	5.9%
Weighted by Traffic	7.1%	3.9%
Percent Structurally Deficient		

Source: NBI.

CHAPTER 6: Infrastructure Conditions – Transit

Transit asset infrastructure in the C&P Report includes five major asset groups: guideway elements, maintenance facilities, stations, systems, and vehicles.

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: TERM.

Assets belong to two other categories: replaceable and non-replaceable assets. Non-replaceable assets are assets such as tunnels, bridges, and certain stations and facilities.

Condition Rating

FTA uses a capital investment needs tool, the Transit Economic Requirements Model (TERM), to measure the condition of transit assets. The model uses a numeric scale that ranges from 1 to 5.

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: TERM.

The replacement value of the Nation's transit assets was $850 billion in 2016. Nonreplaceable assets accounted for 39 percent of this total.

The relatively substantial proportion of facilities elements and systems assets that are rated below 2.5, or a state of good repair (SGR), and the magnitude of the $174-billion investment required to replace them, represent major challenges to the rail transit industry.

Asset Categories Rated Below SGR, 2016

Asset Category	Percentage Below SGR
Guideway Elements	43.2
Systems	23.8
Facilities	14.7
Stations	53.7
Vehicles	19.7

Source: TERM.

SGR. An asset is deemed in SGR 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.

Average Age and Trends in Urban Bus and Rail Transit

The average condition rating for bus and rail fleets did not change much between 2006 and 2016, ranging between 3.3 and 3.5 for buses and remaining relatively constant for rail, ranging between 3.5 and 3.7. The percentage of the bus fleet not in SGR rose from a value of 13.2 percent in 2006 to 21.4 percent in 2016. For rail, the percentage not in SGR increased from 3.6 percent to 9.9 percent. Heavy rail contributed the most, with an increase from 5.5 percent in 2006 to 16 percent in 2016. However, for modes such as light rail, the share decreased from 6.4 percent in 2006 to 2 percent in 2016.

The average age of rail assets varies by category. For instance, for rail facilities the average age is 39 years, for stations it is 61, and for guideway elements it is 73.

PART II: Investing for the Future

Within this report, the term "investment" refers to capital spending, which includes the construction or acquisition of new assets and the rehabilitation of existing pavement, bridge, and transit assets, but does not include routine maintenance expenditures. Chapters 7 through 10 present and analyze general 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 level of infrastructure performance. **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 system conditions 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 analytical models used to develop the projections 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 quantifying them and valuing them monetarily, and these other benefits and costs can and do affect project selection. In addition, actual project selection can be guided by other considerations outside benefit-cost analysis (BCA).

The 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. 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.

Sustain Recent Spending Scenario

Although some earlier C&P editions included analyses showing the impacts of sustaining spending at base-year levels, the 2008 C&P Report was the first to include a full-fledged scenario projecting the impact of sustaining investment at base-year levels in constant-dollar terms over 20 years. This approach was retained in subsequent editions; most recently, the 23rd C&P Report included a Sustain 2014 Spending scenario. Although this scenario has proven useful in providing a frame of reference to readers, one issue with this approach was that spending levels in a single base year could be influenced by one-time events, and might not be representative of typical annual spending. This edition replaces this scenario with a Sustain Recent Spending scenario based on average annual spending over 5 years (2012–2016) converted to base-year (2016) constant dollars. This approach is expected to smooth out annual variations and make the scenarios more consistent between editions of this report.

Constant-dollar conversions for the Highway Sustain Recent Spending scenario were performed using the National Highway Construction Cost Index (NHCCI), resulting in an average annual capital spending level from 2012 to 2016 of $106.9 billion.

Derivation of Highway Sustain Recent Spending Scenario

Year	National Highway Construction Cost Index	Total Highway Capital Spending (Billions of Dollars)	
		Current Dollars	Constant 2016 Dollars
2012	1.6016	$105.3	$109.2
2013	1.6130	$98.7	$101.6
2014	1.6816	$105.4	$104.1
2015	1.6984	$109.3	$106.9
2016	1.6606	$112.9	$112.9
5-Year Average		$106.3	$106.9

Sources: FHWA Bulletin: Highway Funding 2013–2016, Table HF-10B; Highway Statistics, Various Years, Tables HF-10A and PT-1.

Constant-dollar conversions for the Transit Sustain Recent Spending scenario were performed using the RS Means Construction Index, resulting in an average annual capital spending level from 2012 to 2016 of $18.9 billion.

Derivation of Transit Sustain Recent Spending Scenario

Year	RS Means Construction Index (2016 = 100)	Total Transit Capital Spending (Billions of Dollars)	
		Current Dollars	Constant 2016 Dollars
2012	92.73	$16.8	$18.4
2013	94.37	$17.1	$18.4
2014	97.58	$17.4	$18.1
2015	99.37	$19.3	$19.7
2016	100.00	$19.4	$19.4
5-Year Average		$18.0	$18.9

Sources: National Transit Database; Bureau of Labor Statistics.

Part II Chapters

The four investment-related chapters in Part II measure investment levels in constant 2016 dollars, except where noted otherwise. The chapters consider scenarios for investment from 2017 through 2036 that are geared toward maintaining some indicator of physical condition or operational performance at its 2016 level, sustaining investment at recent levels, or achieving some objective linked to benefits vs. costs. The average annual investment level over the 20 years from 2017 through 2036 is presented for each scenario.

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 address the potential contributions of different public or private revenue sources.

Chapter 7, 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.

Chapter 8, Supplemental Analysis, explores some implications of the scenarios presented in Chapter 7 and discusses potential alternative methodologies. It includes a comparison of highway projections from previous editions of the C&P Report with current findings. This edition includes a special section that looks back at the 1968 Highway Needs report, in recognition of the 50th anniversary of the report series.

Chapter 9, Sensitivity Analysis, explores the impacts on scenario projections of changes to several key assumptions that are relatively arguable, 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.

Analytical Tools

Applying an economic approach to transportation investment modeling 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." The Highway Economic Requirements System (HERS) was first used in the production of the 1995 C&P Report. The Transit Economic Requirements Model (TERM) was introduced in the 1997 C&P Report, and the National Bridge Investment Analysis System (NBIAS) was first used in the 2002 C&P Report. Each of these tools has subsequently undergone several rounds of updates and refinements to expand its accuracy and coverage.

As in any modeling process, simplifying assumptions have been used to make analysis practical and to report within the limitations of available data. Each of the models used in this report—HERS, NBIAS, and TERM—omits various types of investment impacts from its BCAs. To some extent, these omissions reflect the national coverage of the models' primary databases. Although consistent with this report's national focus, such broad geographic coverage requires some sacrifice of detail to stay within feasible budgets for data collection.

CHAPTER 7: Capital Investment Scenarios – Highways

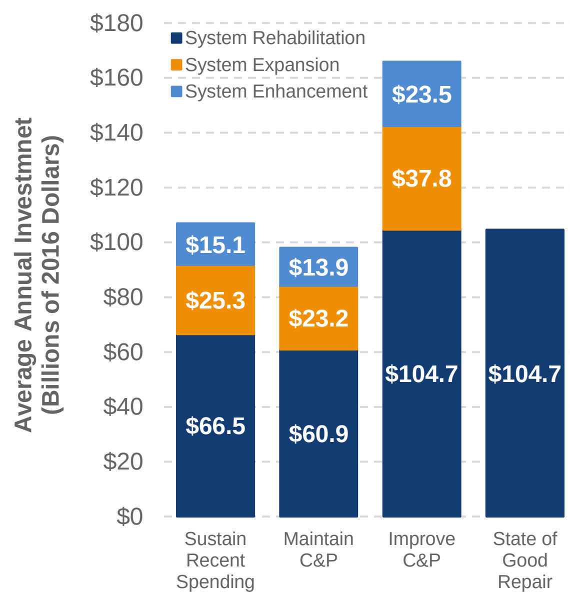
This report presents a set of illustrative 20-year highway capital investment scenarios based on simulations developed using HERS and NBIAS, with scaling factors applied to account for types of capital spending that are not currently modeled. All scenario investment levels are stated in constant 2016 dollars.

The Sustain Recent Spending scenario assumes that annual capital spending is sustained over the next 20 years at the average level from 2012–2016 ($106.9 billion), in constant-dollar terms. 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 recent (2012–2016) 60.8 percent average to 62.2 percent ($66.5 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 $98.0 billion; this suggests that sustaining spending at the 2012–2016 average level of $106.9 billion should result in improved overall conditions and performance in 2036 relative to 2016.

The Improve Conditions and Performance scenario seeks to identify the level of investment needed to implement all potential investments estimated to be cost-beneficial. The investment estimate includes projects off the Federal-aid highway system and enhancement projects regardless of whether they are cost-beneficial, due to data limitations. This scenario can be viewed as an "investment ceiling," above which it would not be cost-beneficial to invest. Of the $165.9 billion average annual investment level under the Improve Conditions and Performance scenario, $104.7 billion would be directed toward system rehabilitation; this portion is identified as the State of Good Repair benchmark. This scenario also includes $37.8 billion directed toward system expansion and $23.5 billion for system enhancement.

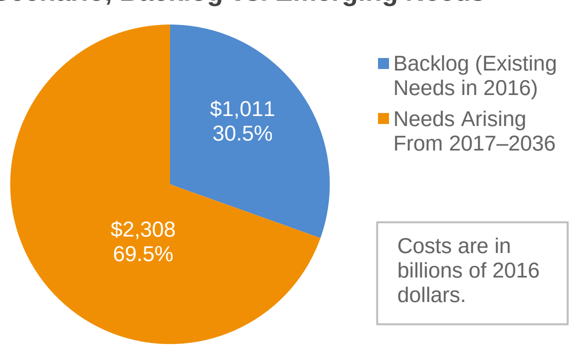
Highway Capital Investment Scenarios



Sources: HERS and NBIAS.

Cumulative 20-year investment under the Improve Conditions and Performance scenario would total more than $3.3 trillion. This includes an estimated $1.0 trillion (30.5 percent), as of 2016, needed to address an existing backlog of cost-beneficial highway and bridge investments. The remainder would address future highway and bridge needs as they arise over the next 20 years.

Composition of 20-year Spending under the Improve Conditions and Performance Scenario, Backlog vs. Emerging Needs



Source: HERS and NBIAS.

CHAPTER 7: Capital Investment Scenarios – Transit

Chapter 7 presents a reference benchmark focused solely on preservation spending and three transit investment scenarios covering both preservation and expansion capital spending, along with the impact of these expenditures on asset conditions and future ridership capacity.

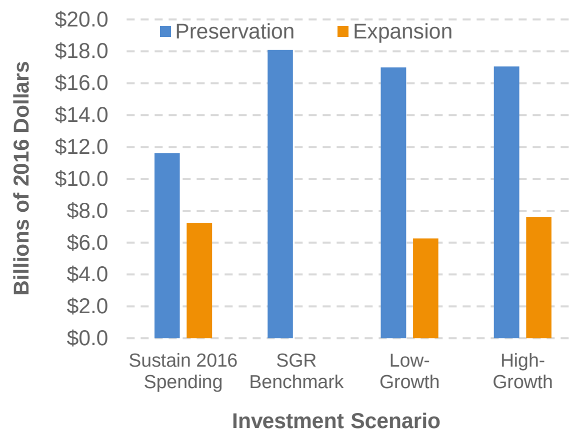
SGR Benchmark: This benchmark depicts the level of preservation expenditures required to eliminate the SGR backlog over 20 years (by 2036). The benchmark does not include investment in expansion assets. Unlike the three scenarios, the benchmark is not subject to a benefit-cost screen.

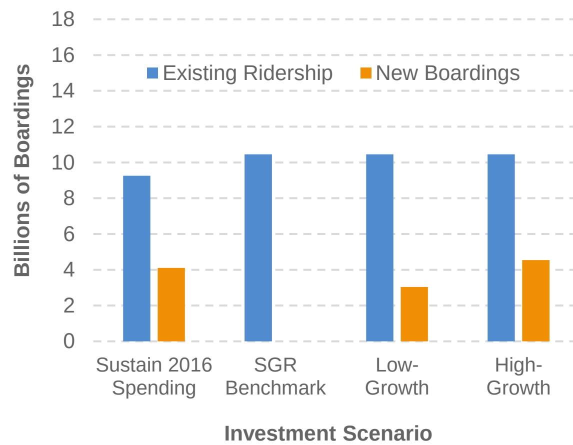
- Expenditures: An estimated $18.1 billion in annual reinvestment is required to fully eliminate the SGR backlog by 2036. This is 42 percent higher than the actual 2016 reinvestment of $11.6 billion.
- Asset Conditions: Despite elimination of the backlog, average asset conditions are projected to decrease slightly from a 2016 rating of 3.0 to 2.9 in 2036.

Sustain 2016 Spending Scenario: Under this scenario, 2016 spending on transit asset preservation and expansion ($11.6 billion and $7.2 billion, respectively) is sustained for the next 20 years.

- Backlog: Given that the current rate of capital reinvestment is insufficient to fully address the replacement needs of the existing stock of transit assets, the size of that backlog is projected to decrease only marginally from the current estimated level of $105.1 billion to roughly $102.3 billion by 2036.
- Asset Conditions: Under this scenario, the average condition rating of physical assets is expected to decline from 3.0 in 2016 to 2.7 in 2036 due in part to the ongoing aging of rail systems built since 1980.
- Ridership: The $7.2 billion annual rate of investment in expansion assets is estimated to support a 1.7-percent annual increase in ridership, or 0.2 percent above the annual 1.5-percent rate of growth experienced since 2001—potentially resulting in decreased vehicle crowding.

Scenario Investment Summary





Source: TERM.

Low-Growth and High-Growth Scenarios: These scenarios model the level of investment required both to eliminate the backlog by 2036 and to support ridership growth within ±0.3 percent of the 1.5-percent average annual rate experienced since 2001.

- Preservation Expenditures: The reinvestment need of the Low-Growth scenario is $17.0 billion; the reinvestment need of the High-Growth scenario is not significantly higher, at $17.1 billion
- Ridership: The estimated annual rate of expansion investment ranges from $6.3 billion to $7.6 billion under the Low-Growth and High-Growth scenarios respectively. This range encompasses the $6.7 billion expended on expansion in 2016. These investments support an additional 2.9 to 4.5 billion annual boardings by 2036.

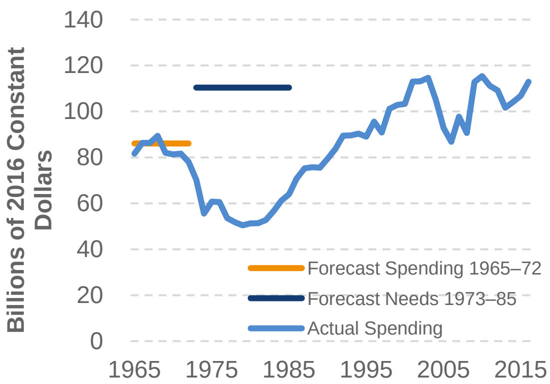
1968 C&P Report

The C&P Report series dates back to the 1968 *National Highway Needs Report*. Looking back to that report on the occasion of the 50th anniversary of the series sheds light on what has changed over time and what perennial challenges remain.

The 1968 edition was written during a period of high travel growth and it underestimated future growth for the 1965 to 1985 period. It forecast that highway travel would grow by 2.7 percent annually to reach 1.5 trillion VMT in 1985. The actual average annual growth rate over this period was 3.5 percent, resulting in 1.7 trillion VMT in 1985. The 1968 edition similarly underestimated the wide adoption of motor vehicle ownership. National motor vehicle registrations reached 172 million in 1985, higher than the forecast 144 million.

The 1968 edition projected capital spending by all levels of government for the 1965 to 1972 period and estimated annual capital investment needs for 1973 to 1985.

1968 C&P Forecasts Compared to Actual Highway Capital Spending



Sources: 1968 C&P Report; FHWA Construction Bid Price Index and National Highway Construction Cost Index 2.0; FHWA Bulletin: Highway Funding 2013–2016; Highway Statistics, various years, Table HF-10A.

Converted to constant 2016 dollars, actual spending averaged $83.3 billion per year from 1965 to 1972, aligning well with the forecast ($86.1 billion). During the 1973 to 1985 period, highway spending did not keep pace with inflation, averaging only $56.9 billion in constant 2016 dollars, well short of the estimated investment needs for this period ($110.4 billion).

Although the investment needs presented in the 1968 edition were determined by engineering criteria alone, the report referenced the importance of a broader assessment of costs and benefits (foreshadowing the benefit-cost modeling approach used in more recent reports). Needs in the 1968 edition were based on an aggregation of State estimates of capital investment needed to raise the highway system to predetermined design standards (such as lane width and number, maximum grades, minimum curvature, and a capacity adequate to accommodate the level of traffic forecast for 20 years ahead). The 1968 Report notes that States were given only a few months to prepare their needs estimates, and they did not provide any measure of monetized benefits derived from reduction in accidents, gains in travel time and pavement quality, or vehicle operation savings; these factors are all considered in current C&P reports.

24th Edition vs. Recent Editions

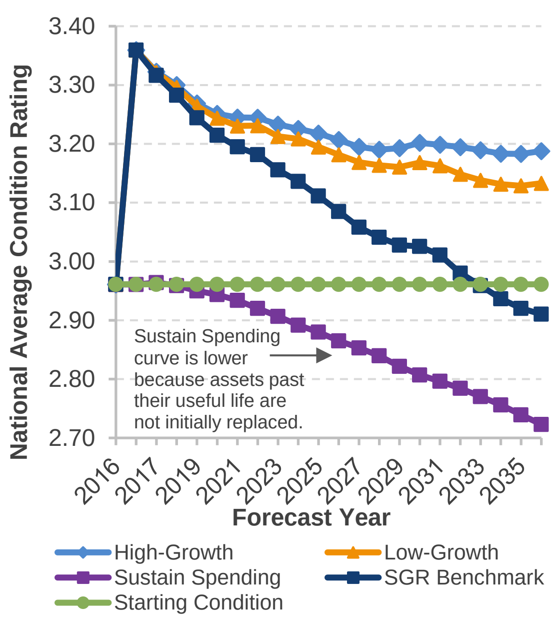
The 23rd C&P report estimated scenario investment levels in 2014 dollars. Converting these amounts to 2016 dollars facilitates more direct comparisons to results from this 24th C&P report. The annual investment level for the Maintain Conditions and Performance scenario and the Improve Conditions and Performance scenario were 3.0 percent lower and 23.8 percent higher, respectively, in this 24th C&P Report relative to inflation-adjusted values based on the 23rd C&P Report. Among the last 11 C&P reports, the gap between base-year spending and the average annual investment level for the primary "Improve" and "Maintain" scenarios has varied, reaching the highest level in the 2008 C&P Report (121.9 percent and 34.2 percent, respectively). The gap between the Improve Conditions and Performance scenario and base-year spending was 55.2 percent in this 24th edition. Base-year spending has been higher than the Maintain Conditions and Performance scenario since the 2013 edition.

CHAPTER 8: Supplemental Analysis – Transit

Chapter 8 analyzes assumptions underlying the scenarios presented in Chapter 7, along with implications of their outcomes.

Impact of scenario assumptions on asset conditions. The Chapter 7 scenarios use differing assumptions regarding the rate at which assets are replaced, and that result in different impacts on asset conditions. Specifically, the Sustain Spending scenario assumes a constant annual reinvestment rate resulting in a steady change in asset conditions from the current 2.96 average. In contrast, the State of Good Repair (SGR) benchmark and the Low-Growth and High-Growth scenarios are fully unconstrained. Here, all backlog needs are fully addressed in the first year of the model run, resulting in a spike in asset conditions. For the growth scenarios, investment in expansion assets ultimately results in average conditions above the current level.

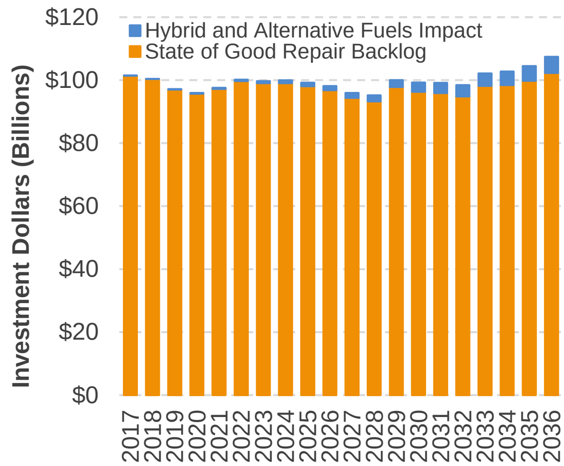
Scenario Impacts on Conditions



Source: TERM.

Effect of new technologies on transit investment needs. TERM does not consider the impact of technological improvements on reinvestment needs. These improvements typically come at a higher cost, driving up the cost of replacement and, in the absence of additional funding, the size of the SGR backlog. As an example, alternative fuel propulsion buses add an additional cost, as depicted in the following figure. This is just one of many technological trends that could affect transit reinvestment needs through 2036.

Impact of Technological Change on Backlog

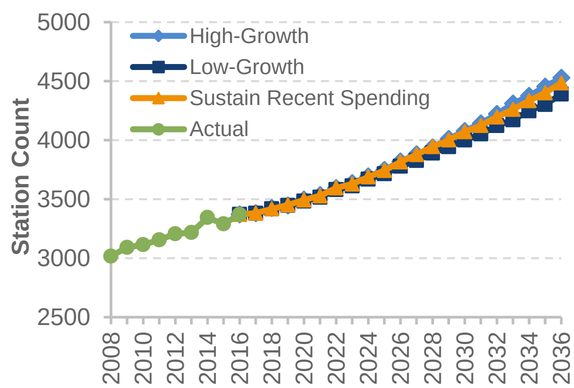


Source: TERM.

Investment in expansion assets. Chapter 8 assesses the increase in transit assets required to support the additional 2.8 to 4.0 billion annual boardings by 2036 projected by the Low-Growth and High-Growth scenarios. This increase includes:

- Fleet: 51,800 to 72,900 additional vehicles (29- to 40-percent increase from 2016)
- Rail Guideway: 1,700 to 1,900 additional route miles (12- to 14-percent increase)
- Stations: 2,600 to 4,000 additional stations (76- to 120-percent increase)

Growth Scenario Investment in Stations



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

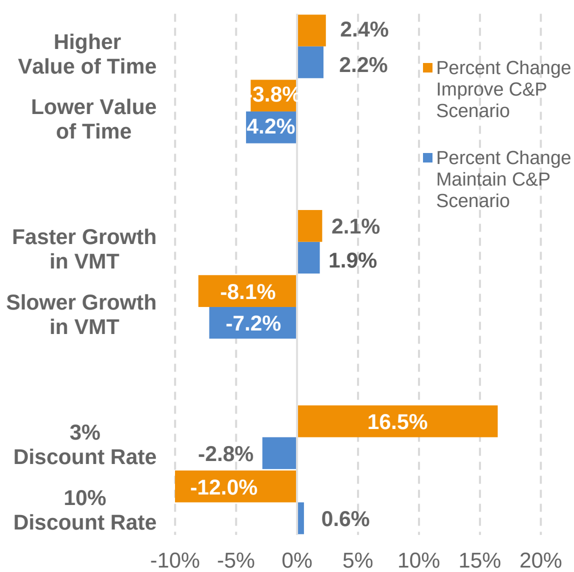
Source: TERM.

CHAPTER 9: Sensitivity Analysis – Highways

Sound practice in modeling includes analyzing the sensitivity of key results to changes in assumptions. This section analyzes how changing key assumptions regarding the value of travel time savings, the discount rate, and traffic growth projections would affect the investment levels for two of the future capital investment scenarios presented in Chapter 7.

The Improve Conditions and Performance scenario is highly sensitive to the real 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. Substituting a 3-percent discount rate for the 7-percent discount rate assumed in the baseline would increase its average annual investment requirements by 16.5 percent (from $165.9 billion to $193.2 billion). The Maintain Conditions and Performance scenario would be reduced by 2.8 percent assuming a 3-percent discount rate. Substituting in a 10-percent discount rate would reduce the Improve scenario by 12.0 percent and increase the Maintain scenario by 0.6 percent.

Sensitivity of Highway Scenarios to Alternative Assumptions, Percent Change in Investment Levels from Baseline

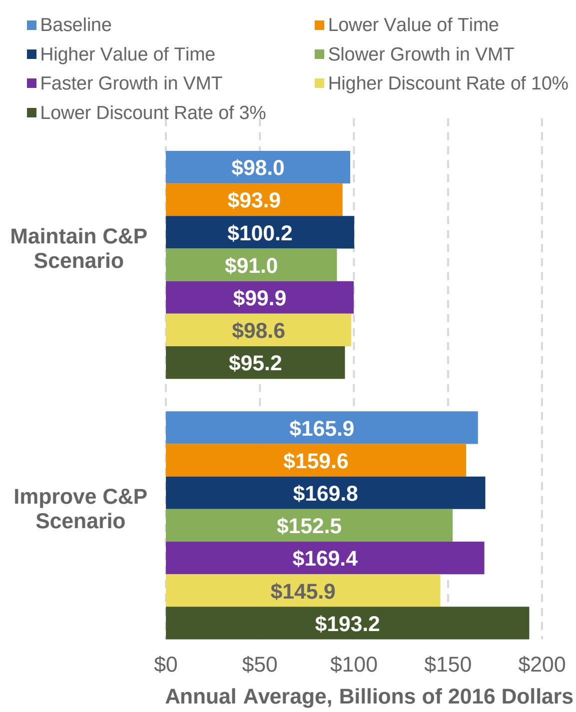


Sources: Highway Economic Requirements System; National Bridge Investment Analysis System.

The overall impact of different estimates of growth in VMT was similar for both scenarios. Applying a forecast of 1.3-percent growth per year (linked to an optimistic economic growth forecast), instead of 1.2 percent, increases the Improve Conditions and Performance scenario funding level by 2.1 percent and the Maintain Conditions and Performance scenario by 1.9 percent. Applying a forecast of 0.9-percent growth in VMT per year (linked to a pessimistic economic growth forecast) reduces the Improve scenario by 8.1 percent and the Maintain scenario by 7.2 percent.

Different assumptions about the value of time have similar effects on both the Improve Conditions and Performance scenario and the Maintain Conditions and Performance scenario. Assuming lower values of time for personal travel (35 percent of median hourly household income instead of 50 percent) reduces the average annual investment level for the Improve scenario by 3.8 percent and for the Maintain scenario by 4.2 percent. Conversely, assuming higher values of time for personal travel (60 percent of median hourly household income) increases the average annual investment level for the Improve scenario by 2.4 percent and for the Maintain scenario by 2.2 percent.

Impact of Alternative Assumptions on Highway Scenario Investment Levels



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

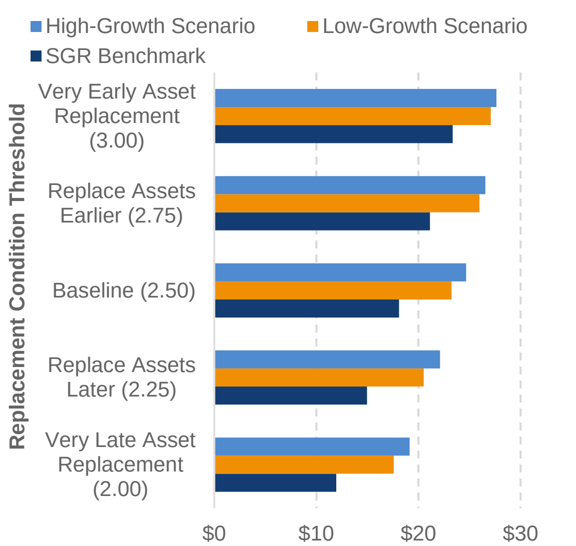
CHAPTER 9: Sensitivity Analysis – Transit

TERM relies on several key input parameters, variations of which can significantly influence the model's projected investment needs and backlog estimates.

Alternative Replacement Thresholds

TERM uses a "replacement threshold" to specify the condition at which aging assets are replaced. The benchmark threshold value is 2.5 on a scale of 1 to 5. A 0.5-point change in the threshold yields a roughly ±30-percent change in replacement investment needs for the SGR benchmark. The same change in threshold results in approximately ±18-percent change in replacement investment needs for the Low-Growth and High-Growth scenarios.

Sensitivity to Replacement Threshold



Source: TERM.

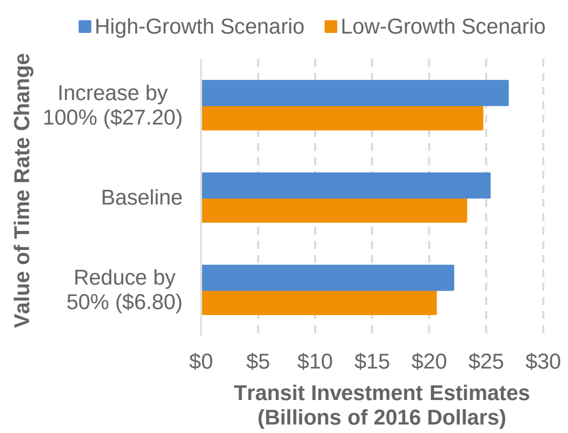
Increase in Capital Costs Impact

The sensitivity of estimated scenario investment needs to changes in capital costs is dependent on whether TERM's benefit-cost test is applied for that scenario. Under the Low-Growth and High-Growth scenarios, both of which 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 forces some reinvestment actions to fail the benefit-cost test.

Value of Time

The per-hour value of travel time for transit riders is a key model input, and a key driver of total investment benefits. The current hourly rate based on U.S. Department of Transportation guidance is $13.60.[1] 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 (to $27.20) results in increases of 6.0 percent in needs for both the Low-Growth and High-Growth scenarios. Reducing the rate by half (to $6.80) results in decreases of 12 percent and 13 percent, respectively.

Sensitivity to Value of Time



Source: TERM.

Impact of Discount Rate

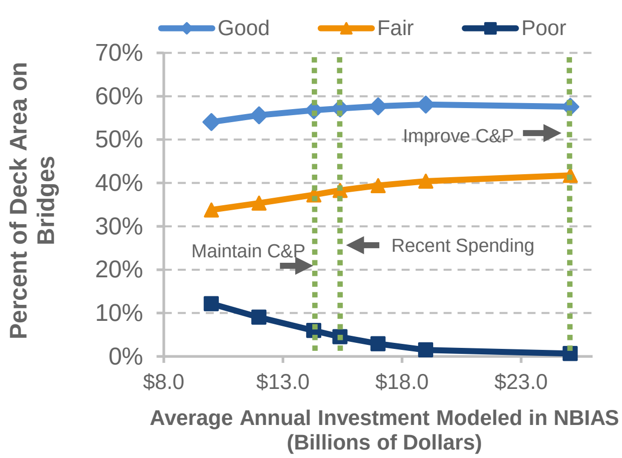
TERM's benefit-cost test is sensitive to the discount rate used to calculate the present value of investment costs and benefits. TERM's analysis uses a rate of 7.0 percent in accordance with Office of Management and Budget guidance. The analysis using a rate of 3 percent (57 percent smaller) leads to an increase of 1.2 percent in investment needs in the High-Growth scenario, and a 0.9-percent increase in the Low-Growth scenario.

[1] Although the analyses performed elsewhere in this report used a value of time of $12.80, the most recent value of time as stated by DOT is $13.60. This discrepancy in time valuation translates to a less than 1-percent difference in TERM's estimates of 20-year transit reinvestment needs for those scenarios that employ TERM's benefit-cost analysis.
Source: DOT, Revised Departmental Guidance on Valuation of Travel Time in Economic Analysis.

Of the $165.9 billion average annual investment level for all public roads under the Improve Conditions and Performance scenario presented in Chapter 7, 15.1 percent ($25.1 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; 55.2 percent ($91.7 billion) of this scenario was derived from HERS. The remaining 29.7 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 recent (2012 to 2016) spending.

Sustaining NBIAS-modeled investment at $15.4 billion (the portion of recent spending directed toward implementation types modeled in NBIAS) in constant-dollar terms over 20 years is projected to result in deck area-weighted bridge conditions of 57.2 percent good, 38.3 percent fair, and 4.5 percent poor. Increasing annual investment to $25.1 billion would increase the deck area-weighted share rated as good to 57.6 percent and reduce the share rated as poor to 0.7 percent.

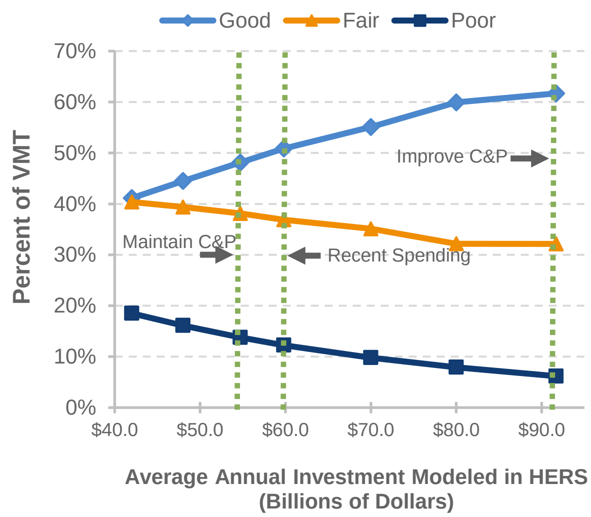
Projected Impact of Future Investment Levels on 2036 Bridge Condition Indicators for All Bridges



Source: NBIAS.

Sustaining HERS-modeled investment at $59.8 billion (the portion of recent spending directed toward improvement types modeled in HERS) in constant-dollar terms over 20 years is projected to result in 50.9 percent of VMT in 2036 occurring on Federal-aid highway pavements with good ride quality, 36.9 percent on pavements with fair ride quality, and 12.3 percent on pavements with poor ride quality. Increasing annual investment to $91.7 billion would increase the VMT-weighted share rated as good to 61.7 percent and reduce the share rated as poor to 6.2 percent.

Projected Impact of Alternative Investment Levels on 2036 Pavement Ride Quality Indicators for Federal-aid Highways



Source: HERS.

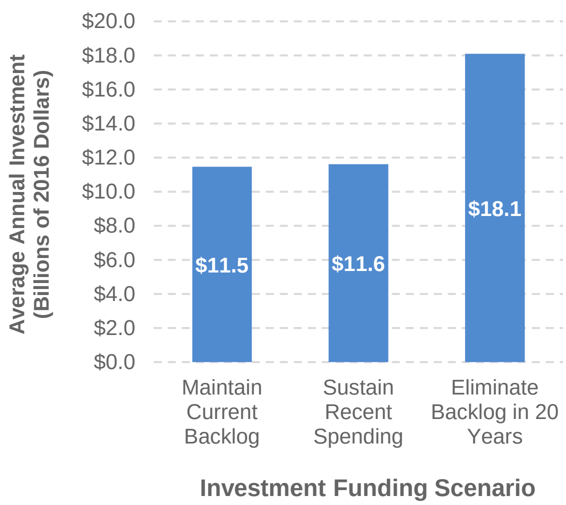
Other projected impacts of investing at the Improve scenario level include reducing VMT-weighted average pavement roughness on Federal-aid highways by 15.4 percent in 2036 relative to 2016 and reducing average delay per VMT by 28.8 percent. Average total user costs (including travel time costs, vehicle operating costs, and crash costs) are projected to decrease by 4.8 percent, from $1.355 per VMT in 2016 to $1.289 per VMT in 2036.

HERS computes the average benefit-cost ratio over 20 years for the HERS-modeled portion of the Improve scenario to be 2.15, suggesting that total benefits would be more than double the total capital costs associated with this scenario.

CHAPTER 10: Impacts of Investment – Transit

The current level of investment in transit asset preservation is insufficient to materially reduce the size of the SGR backlog. Assuming preservation expenditures are sustained at the 2016 level ($11.6 billion annually), the State of Good Repair (SGR) backlog is projected to decline marginally from $105.1 billion to $102.3 billion by 2036. Based on current estimates, $18.9 billion in annual investment is required to fully eliminate the SGR backlog in 20 years (by 2036).

Investment Funding Scenarios



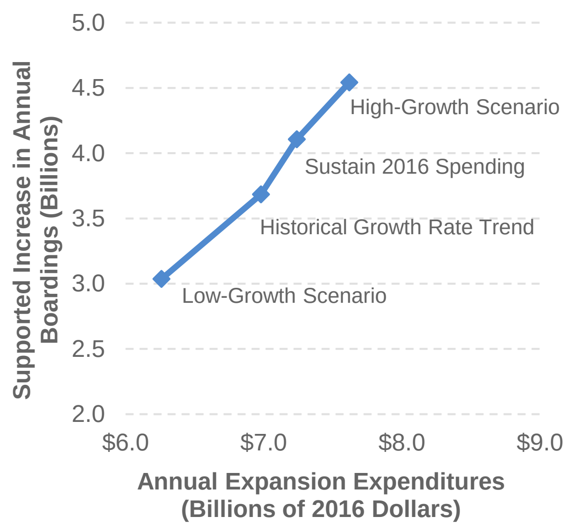
Source: TERM.

A much higher rate of reinvestment 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 recent 5-year average ($11.6 billion), overall average asset conditions are projected to decline from a condition rating of 3.0 in 2016 to 2.7 by 2036 (near the upper bound of the "marginal" range). Much of this decline is due to the ongoing aging of newer rail systems developed within the last 20- to 30-year period. In contrast, annual preservation expenditures of $18.9 billion are required to sustain an overall average condition rating of 2.9, with higher rates of annual investment required to attain significant improvements in overall asset conditions.

The 2016 level of expansion investment supports ridership growth that is marginally above the historical rate. Investment in transit expansion investments was $7.2 billion in 2016. If maintained into the future, this annual investment amount is estimated to support roughly 1.7 percent in annual ridership growth, which is above the 1.5 percent average rate experienced since 2001.

Assuming this trend continues, the limited overinvestment could result in a decrease in vehicle occupancy rates through 2036, with reduced vehicle crowding and dwell times. Expenditures in 2016 are within the $6.2 billion to $7.6 billion range covered by the Low-Growth and High-Growth scenarios (supporting ridership growth rates of 1.3 to 1.8 percent).

Growth Scenarios: Expansion Expenditures vs. Increase in Annual Boardings



Source: TERM.

Introducing a cost-effectiveness prioritization criterion reduces the projected size of the backlog in model run year 20. Introduction of the cost-effectiveness criterion, defined as an asset's reinvestment cost divided by the number of riders benefiting from the investment, results in a more cost-efficient selection of investments that reduces the rate of backlog growth.

PART III: Freight

Pursuant to the Fixing America's Surface Transportation (FAST) Act of 2015, the Federal Highway Administration (FHWA) prepared this section to serve as the second edition of the biennial report on the conditions and performance of the National Highway Freight Network (NHFN), referred to hereafter as the *Highway Freight C&P* Report to Congress.

The FAST Act required FHWA to establish an NHFN to strategically direct Federal resources and policies toward improved performance of that network. The NHFN is composed of four component subsystems: the Primary Highway Freight System (PHFS), other Interstate portions not on the PHFS, Critical Rural Freight Corridors (CRFCs), and Critical Urban Freight Corridors (CUFCs).

The Nation's freight transportation system—a complex network of millions of miles of public roads, railways, navigable waterways, pipelines, and airways—is an extraordinary asset to our wellbeing and our country's economic health. Significant investments, however, are required to sustain the conditions and performance of that system and accommodate expected growing demand. In analyzing the NHFN conditions and performance, this section supports improved freight decision-making.

This edition includes many of the same NHFN conditions and performance indicators reported in the previous edition. It also updates the analysis to 2016 (primary data sources are the Highway Performance Monitoring System and the National Bridge Inventory, although additional sources with dates other than 2016 are used).

This edition includes several new conditions and performance indicators and analyses:

- NHFN pavement condition: overall ride quality, individual pavement distresses, and overall ride quality by roadway functional class; and
- NHFN bridges: overall condition rating and condition rating by roadway functional class.

Notably, this edition includes CRFCs/CUFCs (submitted as of May 1, 2018) as part of the NHFN conditions and performance analysis. The CRFCs/CUFCs had not yet been designated when the first edition was developed.

As of May 1, 2018, the NHFN consists of an estimated 54,310 miles, including 41,308 miles of Interstate and 9,541 miles of non-Interstate roads. The CRFCs and CUFCs represent a total of 3,461 miles (about six percent) of this total NHFN mileage. More recent data show that, as of April 2021, the NHFN had grown to 57,943 miles, of which CRFCs/CUFCs represented 6,720 miles (about 12 percent of the total).

This edition provides:

- An overview of the freight transportation network;
- An examination of trends that characterize freight movement on the NHFN;
- An analysis for NHFN conditions and performance indicators; and
- A series of "spotlight topics," which are initiatives or issues that affect freight transportation management and provide context for understanding NHFN conditions and performance analysis.

Between 2014 and 2016, NHFN pavement and bridge condition largely stayed the same. Many portions of the NHFN experience congestion. Between 2011 and 2016, travel reliability decreased for the majority (72 percent) of the Nation's top 25 domestic freight corridors. Average travel speeds slightly increased or remained the same for just over half (52 percent) of these corridors.

The first edition of the *Highway Freight C&P* Report to Congress (included as Part III of the 23rd C&P Report) provided a baseline understanding of NHFN conditions and performance. This edition improves this baseline by including additional indicators and examining new data not previously available. Furthermore, this edition benefitted from the implementation of data improvements identified in the previous edition.

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CHAPTER 11: Rural America – Highways

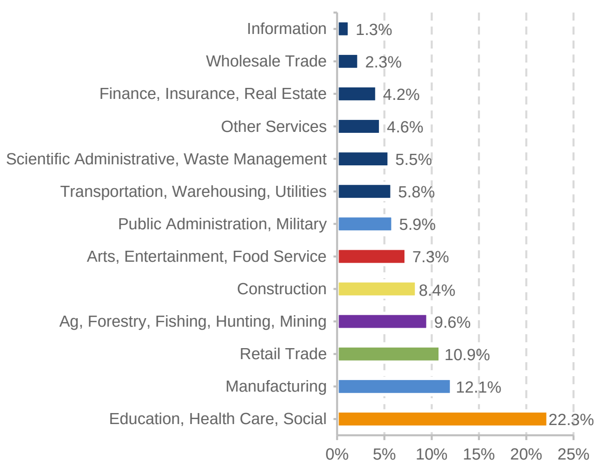
Rural communities provide most of the Nation's food and energy and encompass more than 70 percent of the Nation's roadways. Although the rural population has declined overall during the last quarter century, rural areas have experienced rising net population growth since 2011.

Rural America is diverse: some areas are commuting sheds for large metropolitan areas, others are remote communities with limited access to major cities; some thrive on agriculture or mining, others rely on tourism or manufacturing. Rural area transportation must provide the means to access employment, education, and goods and services while also providing connections to other communities and commerce.

Rural Economics

The economy in rural counties is not entirely dependent on agriculture or manufacturing: in fact, the largest segment of the workforce is employed in professional, managerial, or technical occupations.

Rural Employment by Type of Industry



Source: U.S. Census Bureau, American Community Survey, 2011–2015, 5-year estimates (http://www.census.gov/programs-surveys/acs/).

Due to the longer distances traveled in rural areas, rural households on average spend more on transportation than their urban counterparts.

Transportation is the second largest household expenditure category after housing, and in 2017 rural households devoted almost 20 percent of their total budget to transport, four percentage points more than urban households.

Modal Availability and Travel Behavior

Travel patterns for urban and rural households are distinctly different, with options varying by geography, population size, and density. Households in high-density areas typically have fewer vehicles and are more likely to use public transit, rideshare, bikeshare, and pedestrian facilities, which are costly to operate in less-dense areas such as suburbs, small towns, and rural communities, resulting in a dependency on personal vehicles.

According to the 2017 National Household Travel Survey, rural households account for 24 percent of all passenger vehicle miles traveled (VMT), with an average annual household VMT of 24,465—about 50 percent higher than that of urban households.

The proportion of Americans with access to broadband internet continues to increase, creating an alternative to travel for employment, education, entertainment, and the purchase of goods and services.

Freight Movement in Rural Areas

Although rural transportation is an important resource for people living in rural areas, it is also an important asset for the movement of goods. Trucks continue to move the bulk of freight in the United States, and over half of all truck VMT occurs on rural roads. In 2018, combination trucks on rural roads logged 95.13 billion VMT for goods movement, significantly more than the 89.04 billion VMT by combination trucks in urban areas. Maintaining the condition of rural roadways and bridges is critical to the safe, secure, and efficient transport of freight by trucks.

CHAPTER 11: Rural America – Transit

In 2018, rural transit in the United States accounted for 55 percent of transit agencies, 14 percent of the National fleet, 10 percent of revenue vehicle miles, and 1.3 percent of unlinked trips.

Bus and demand response are the most common modes of rural transit and account for more than 95 percent of total service supply and consumed.

There were 1,301 rural transit systems that reported to the NTD in 2018, of which 1,167 were rural agencies and 134 were Tribes. In addition, X systems in urbanized areas also served rural areas.

Of the 1,167 rural agencies reporting to NTD, 718 were located in urban clusters and 395 were in Census-designated rural areas; the remaining 54 could not be geocoded.

The State with the largest number of systems in 2018 was Georgia, with 79 systems, followed by Kansas with 77. The number of systems by State is not necessarily driven only by demand, but also by local decisions.

Number of Systems by State

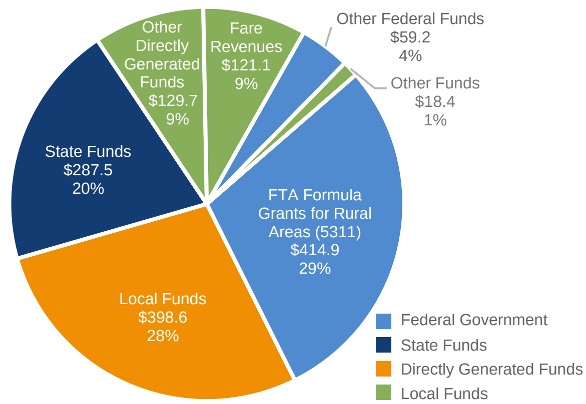
Bus and demand response systems serve distinct markets. Bus ridership is driven by the demand for recreational destinations during winter and summer months, such as ski resorts, National and state parks, beaches, and others. Service is seasonal and concentrated around destinations.

Demand response systems, which provide service to persons with disabilities and other conditions, are offered in all urban and rural areas of the country.

Operating Funding

In 2018, public funds of $1.4 billion were spent in rural transit operations. Of this amount, Federal funding provided $474.0 million or 33 percent of total funding.

Operating Funding Sources, 2018

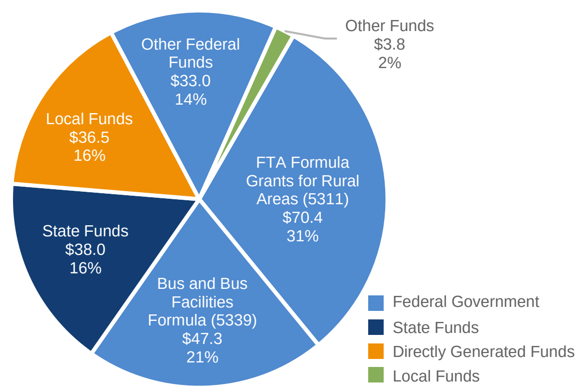


Source: National Transit Database, 2018.

Capital Funding

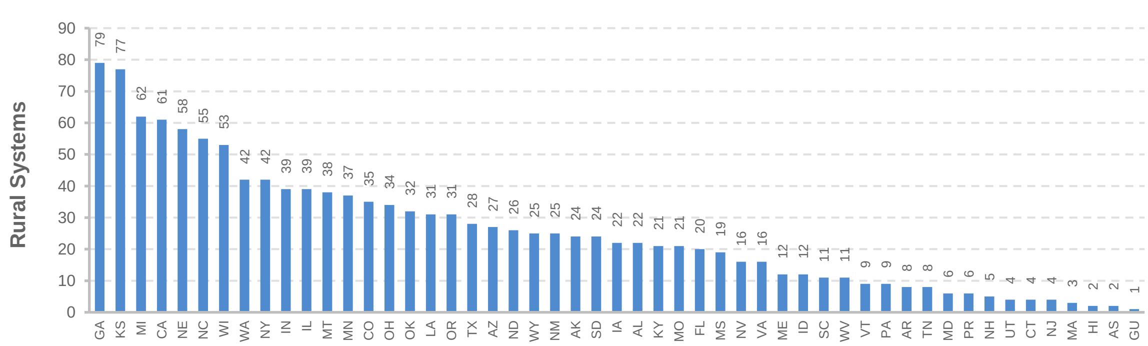
Capital funding in 2018 was $229.0 million, of which Federal sources accounted for 66 percent.

Capital Funding Sources, 2018



Source: National Transit Database, 2018.

Rural Systems by State/Territory, 2018



CHAPTER 12: Transformative Technologies – Highways

Trends of the past decade in technology and innovation are reshaping our options in surface transportation.

Information Technology

Smartphone technology has spurred the creation of countless "on-the-go" traveler mobile apps that offer travelers and service providers key information such as work zone, traffic incident, and inclement road weather locations, as well as predicted travel times, cost of travel, alternative routes, and parking availability.

Traveler information has evolved at a rapid rate over the past decade and is expected to continue evolving as the public becomes increasingly dependent on real-time, easily accessible information.

Innovation in Transportation Services

Recent technology innovations have expanded beyond traditional transportation and ownership models of personal vehicles, transit, walking, biking, and taxis. Through innovations in transportation, service travelers can request a ride (ride hailing); access a shared car, bicycle, or scooter for a short trip (micromobility); ride a private shuttle on demand; and have groceries, packages, or take-out food delivered, all using internet-enabled smartphones and tablets.

Since 2010, the proportion of Americans with access to broadband internet has increased from about 74.5 percent to 93.5 percent, and one-third of workers now say they can work from home, making broadband an emerging trend as a travel alternative.

Emerging Trends

In addition to the deployment of micromobility and the widespread use of broadband, testing of vehicle automation and the use of drones have become commonplace in the transportation sector, providing new opportunities and challenges for improved transportation safety, accessibility, and mobility.

Supported by advances in artificial intelligence, rapid progress is being made in automated vehicle development and deployment. Automation is categorized in six levels: from Level 0, which has no automation, to Level 5, which is fully automated. Levels 1 and 2 control some aspects of steering, braking, or acceleration (e.g., adaptive cruise control or parallel parking assist), and currently operate on public roadways. Level 3, 4, and 5 technologies are still in development and are being tested on public roads.

Infrastructure and Technology

Infrastructure and technology, often via intelligent transportation systems, improve transportation safety and mobility through the integration of advanced communications technologies for payment systems (user fees and tolls), connected vehicles, construction work zones, and traffic incident response.

Modern communication technology is becoming more embedded within vehicles or roadway infrastructure, allowing for continuous communication and data exchange between individual vehicles or between vehicles and infrastructure. Connected vehicle applications include safety, navigation, and diagnostics, which could reduce crash rates, increase transportation options, and reduce travel times.

Work zones play a key role in maintaining and upgrading the Nation's roadways, but often create a combination of factors resulting in crashes, injuries, and fatalities. Transportation agencies across the country are using technology to keep transportation workers safe and make travel through and around work zones safer and more efficient. This includes efforts toward creating universal access to data on work zone activity.

CHAPTER 12: Transformative Technologies – Transit

FTA's research mission is to advance public transportation by accelerating innovation that improves peoples' mobility, enhances public transportation operations, and ensures everyone's safety.

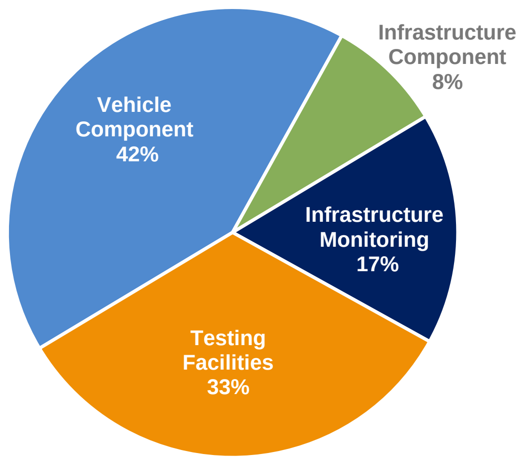
In recent years, FTA has invested more than $40 million in grants for programs such as Mobility on Demand, Integrated Mobility Innovation, and Accelerating Innovative Mobility. Through these grants, transit agencies across the United States are experimenting and demonstrating new technologies and approaches that integrate public and private mobility services to increase service hours, geographic coverage, and accessibility.

Public transportation is one of the safest modes of travel. However, certain types of safety events continue to pose challenges, such as bus collisions at intersections with vehicles and pedestrians, track worker injuries and fatalities, and suicides at rail stations. FTA is addressing these issues by investing in new technologies to enhance vehicle components, collision avoidance, and worker communication and alerts.

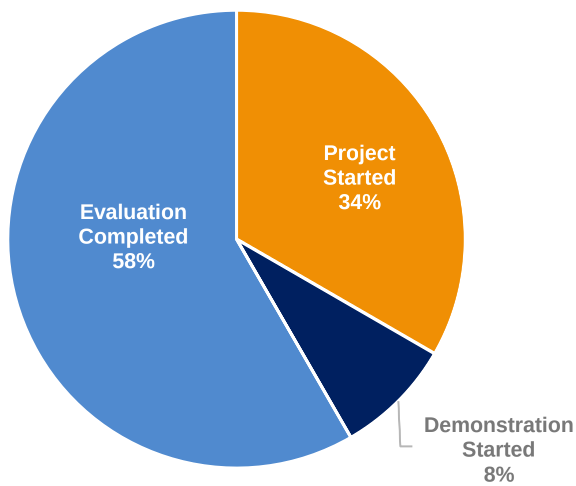
FTA's research and demonstration projects use technology to enhance public transportation operations across all aspects of system services, from the design of buses to the maintenance and management of important transit assets and ensuring a state of good repair. Key areas of focus include enhancing public transit operational effectiveness and efficiency through new technologies such as unmanned aerial systems, artificial intelligence, and robotics. FTA is also exploring new energy technologies and innovative bus designs in partnership with the Department of Energy.

Over the next decade, emergent technologies such as artificial intelligence, machine learning, and autonomous vehicles will continue to provide transit agencies with opportunities to improve their infrastructure and operations. As more data become available and accessible through applications, travelers can make informed decisions about ride sources and agencies can optimize travel through transit routing and scheduling. Strategies to improve data governance, standardization, and interoperability are increasingly important as the transit industry operates in a more data-driven environment.

Infrastructure Technology Categories



Infrastructure Technology Deployment Status, March 2020



Tomorrow's public transportation may look very different from today's, as transit agencies transform themselves and their operations to meet the changing needs and expectations of their customers. Emerging technologies provide the fuel for this transformation. Whether disruptive or complementary, technology is the yin to new transportation modes' yang.

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PART I: Moving a Nation

Introduction

Part I of this 24th C&P Report includes six chapters, each of which describes the current system from a different perspective:

- Chapter 1, **System 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, whereas 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 Behavior**, analyzes travel patterns associated with various household characteristics. The chapter also discusses internet- or phone- based mobility solutions.
- Chapter 4, **Mobility and Access,** covers highway congestion and reliability in the Nation's urban areas, the economic costs of congestion, and active transportation and access to destinations for all users. The transit section explores ridership, average speed, vehicle utilization, and maintenance reliability.
- Chapter 5, **Safety**, presents national-level 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 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 (TPM).

What Is Transportation Performance Management?

The Federal Highway Administration (FHWA) defines TPM as a strategic approach that uses system information to make investment and policy decisions that contribute to 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 integrate 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 Highway 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 the Federal-aid Highway Program 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 Highway Freight Network, strengthen the ability of rural communities to access national and international trade markets, and support regional economic development;
- **Environmental Sustainability** – To enhance the performance of the transportation system while protecting and enhancing the natural environment; and
- **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 more effectively communicate the efforts made to implement these requirements. These six TPM elements are listed below. Additional details are available at https://www.fhwa.dot.gov/tpm/about/how.cfm

National Goals	Congressionally established goals or program purpose to focus the Federal-aid Highway Program into specific areas of performance
Measures	FHWA-established measures to assess performance/condition in carrying out performance-based Federal-aid highway programs
Targets	Targets established by Federal-aid highway funding recipients for the measures to document future performance expectations
Plans	Development of strategic and tactical plans by Federal funding recipients to identify strategies and investments that address performance needs
Reports	Development of reports by Federal funding recipients that document progress toward target achievement, including the effectiveness of Federal-aid highway investments
Accountability and Transparency	FHWA-developed requirements for Federal funding recipients to use to achieve or make significant progress toward targets

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** 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)** 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)** 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)** defines pavement and bridge condition performance measures and minimum condition standards, along with target establishment, progress assessment, and reporting requirements.
- A Final Rule for an **Asset Management Plan** 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)** defines 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.

The Safety PM Final Rule (PM-1) has been implemented where States set their first round of safety performance targets in their 2017 HSIP Reports. The State Safety Performance Targets microsite (https://safety.fhwa.dot.gov/hsip/spm/state_safety_targets/) provides a glimpse into each State's safety performance targets by displaying historical data alongside its safety performance targets and includes information on how States set their targets. States set their first round of PM-2 and PM-3 targets in their 2018 State Biennial Performance Report on October 1, 2018.

Beginning with the 2018 reporting year, all 50 State DOTs, the District of Columbia, and Puerto Rico reported performance data and targets for each of the 17 performance measures. The first full set of performance data submitted to the FHWA is available online at the State Performance Dashboard and Reports website.[2] The States' performance targets represent an important step in the integration of performance management in transportation investment decisions. State DOTs and MPOs worked together to set data-informed targets, and are accountable for managing performance to make progress toward the targets they set. Now, State DOTs can benchmark their performance among peer agencies because they have access to consistent data. Also, FHWA can uniformly track performance data and tell a national story. This is a critical step in a long-term effort to better manage the performance of the Nation's highways.

[2] https://www.fhwa.dot.gov/tpm/reporting/state/index.cfm

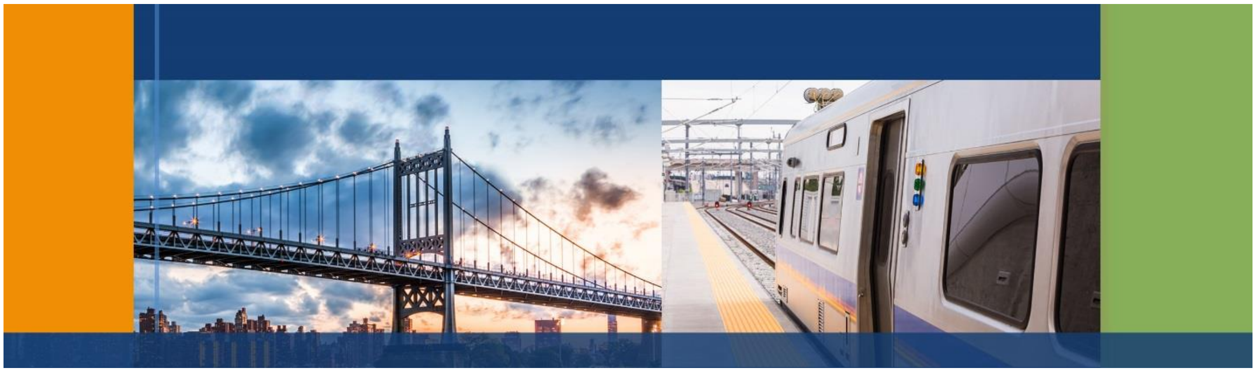
Summary of MAP-21/FAST Act Performance Measures

Measure Area	Performance Measures
Safety[1]	
National Performance Management Measures to Assess Highway Safety *Rule Effective Date: April 14, 2016* *Regulatory Part: 23 CFR 490 (Subparts A, B)*	▪ Number of fatalities ▪ Rate of fatalities per 100 million vehicle miles traveled (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 *Rule Effective Date: May 20, 2017* *Regulatory Part: 23 CFR 490 (Subparts A, C)*	▪ 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 *Rule Effective Date: May 20, 2017* *Regulatory Part: 23 CFR 490 (Subparts A, D)*	▪ 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 (NHS) *Rule Effective Date: May 20, 2017* *Regulatory Part: 23 CFR 490 (Subparts A, E)*	▪ **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 *Rule Effective Date: May 20, 2017* *Regulatory Part: 23 CFR 490 (Subparts A, F)*	▪ **Freight Reliability Measure:** Truck Travel Time Reliability Index
CMAQ Program[4]	
Measures for Assessing the CMAQ Program – Traffic Congestion *Rule Effective Date: May 20, 2017* *Regulatory Part: 23 CFR 490 (Subparts A, G)*	▪ **PHED Measure**: Annual hours of peak hour excessive delay (PHED) per capita ▪ **Non-SOV Travel Measure**: Percentage of non-single occupancy vehicle (SOV) travel
Measures for Assessing the CMAQ Program – On-road Mobile Source Emissions *Rule Effective Date: May 20, 2017* *Regulatory Part: 23 CFR 490 (Subparts A, H)*	▪ **Emissions Measure:** Total Emission Reductions

[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 CMAQ Improvement Program.

Additional Performance Management-related Rules

TPM-related Rules	Rule Effective Date	Regulatory Part	Requirements
Highway Safety Improvement Program (HSIP)	April 14, 2016	23 CFR 924	Integrates performance measures, targets, and reporting into HSIP
Statewide and Non-metropolitan Planning; Metropolitan Planning	June 27, 2016	23 CFR 450 and 49 CFR 613	Defines coordination for target selection and performance-based planning and programming
Highway Asset Management Plans for National Highway System (NHS)	October 2, 2017	23 CFR 515	Defines the Asset Management Plan, as well as minimum standards



CHAPTER 1: System Assets

System Assets – Highways

The Nation's extensive network of roadways and bridges 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.

A public road is defined as a road or street under the jurisdiction of and maintained by a public authority and open to public travel. Although most public roads carry a mix of vehicular users and non-vehicular uses, this section focuses on vehicular use. Chapter 3 includes information on a broader range of transportation modes. (See Chapter 11 of the 23rd C&P Report for more detailed information on pedestrian and bicycle transportation.)

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. The mileage data presented in this section do not reflect turn lanes, bike paths, pedestrian walkways, and alleys.

Route mileage measures road distances from one point to another, whereas lane mileage accounts for the number of lanes in operation—thus accounting for travel in both directions. VMT measures the distance traveled by motorized vehicles of all kinds on the Nation's road network over the course of a year. Person miles traveled weights travel by the number of occupants in a vehicle. (Note that data on passenger miles traveled presented in the transit sections of this report do not include the drivers of transit vehicles; data on person miles traveled presented in this section include both drivers and passengers for all motorized vehicles).

Bridge 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 longer than 20 feet. As of December 2016, the NBI contained records for 614,387 bridges. Data for input to NBI are collected regularly from the States as set forth in the National Bridge Inspection Standards.

KEY TAKEAWAYS

- The nation's highway assets included 4.1 million miles of public roadways (route miles) and 8.7 million lane miles in 2016. Considering motorized vehicles only, these roads carried 3.2 trillion miles of vehicular travel and 4.8 trillion miles of person travel in 2016.
- Federal-aid highways are a subset of public roads eligible for Federal-aid highway assistance. These include 24.7 percent of route miles, which carried 84.9 percent of vehicle miles traveled (VMT) in 2016.
- The National Highway System (NHS), a subset of Federal-aid highways, included 5.3 percent of the nation's route miles and carried 54.8 percent of VMT in 2016. The NHS carried 73.6 percent of VMT by combination trucks.
- The Interstate System, a subset of the NHS, constituted just 1.2 percent of route miles but carried 25.4 percent of the Nation's VMT in 2016.
- Local governmental agencies own 79.1 percent of the Nation's route miles, which carry 26.1 percent of VMT. State governments own 16.9 percent of route miles, which carry 73.6 percent of VMT.
- Local governments own 49.9 percent of the Nation's bridges, but these include only 22.3 percent of total bridge deck area and carry only 12.3 percent of bridge traffic. State governments own 48.2 percent of bridges, which include 76.6 percent of total bridge deck area and carry 87.3 percent of bridge traffic.
- The number of lane miles on the Nation's roadways increased by almost 3.0 percent between 2006 and 2016.
- Total bridge deck area increased by approximately 10.1 percent between 2006 and 2016.

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.

As shown in *Exhibit 1-1*, highway mileage and its accompanying lane mileage have each increased between 2006 and 2016, at an average annual rate of 0.3 percent. Highway VMT grew at an average annual rate of 0.5 percent between 2006 and 2016. Person miles traveled grew at average annual rate of 1.0 percent during this period, due in part to the increase in VMT and in part due to an increase in estimated average vehicle occupancy.

Exhibit 1-1 ■ Highway and Bridge Extent and Travel, 2006–2016

	2006	2008	2010	2012	2014	2016	Average Annual Rate of Change 2016/2006
Route Miles	4,033,011	4,059,352	4,083,768	4,109,421	4,194,257	4,157,292	0.3%
Lane Miles	8,454,762	8,518,776	8,616,206	8,641,051	8,830,511	8,775,538	0.4%
VMT (trillions)	3.034	2.993	2.986	2.988	3.040	3.189	0.5%
Person Miles Traveled (trillions)[1]	4.961	4.931	5.063	5.100	5.205	5.458	1.0%
Bridges	597,561	601,506	604,493	607,380	610,749	614,387	0.3%
Bridge Deck Area (millions of square meters)	333.9	343.5	351.5	358.5	365.5	371.5	1.1%
Bridge Average Daily Traffic (billions)	4.277	4.432	4.439	4.485	4.504	4.627	0.8%

[1] Values for 2006 and 2008 were based on a vehicle occupancy rate of approximately 1.63 based on data from the 2001 NHTS. Values for 2010, 2012, 2014, and 2016 were based on a vehicle occupancy rate of approximately 1.70, based on data from the 2009 NHTS. Data include Puerto Rico.

[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.

Exhibit 1-1 also shows that the number of bridges cataloged in NBI increased at an annual rate of 0.3 percent between 2006 and 2016, from 594,101 to 614,387. Total bridge deck area grew at an average annual rate of 1.1 percent, while bridge crossings (measured as annual daily traffic) increased at an average annual rate of 0.8 percent.

Roads and Bridges by Ownership

State and local governments own the vast majority of public roads and the bridges located on these roads. As shown in *Exhibit 1-2*, local governments own 79.1 percent of the Nation's public route mileage and 49.9 percent of all bridges. State governments own 16.9 percent of public route mileage and 48.2 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. The Federal government owns a relatively small share of the Nation's route miles (3.7 percent) which are located primarily in military installations, tribal lands, National Forests and National Parks. These roads carry only 0.2 percent of total VMT.

VMT Trends Since 2016

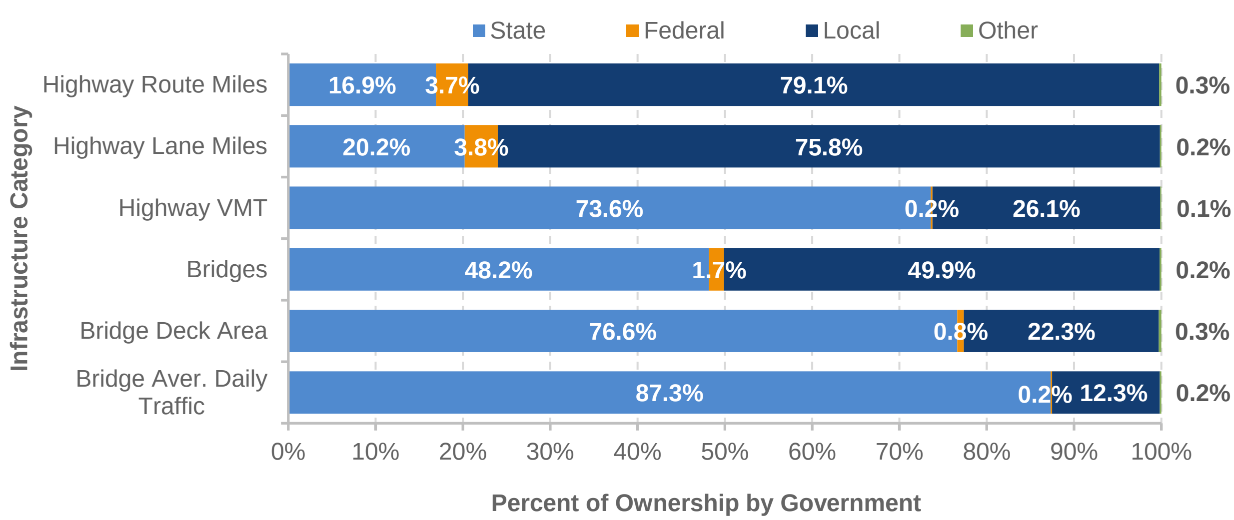
Based on data from Table VM-2 of the annual Highway Statistics publication, VMT grew by 1.2 **percent** in 2017 and by 0.9 percent in 2018.

The December 2019 Traffic Volume Trends (TVT) report estimated a 0.9-percent increase in VMT from 2018 to 2019, to a level of 3.269 trillion.

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 1-2 ■ Highway and Bridge Ownership by Level of Government, 2016



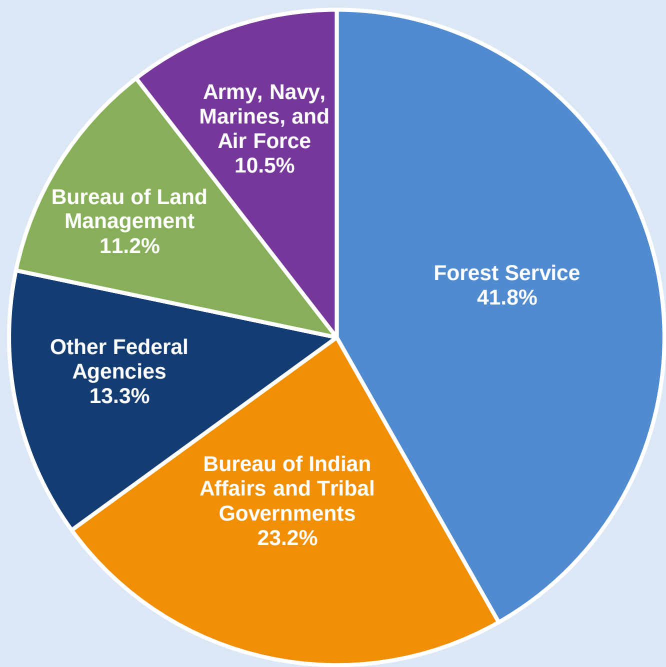
Note: Highways/bridges owned by Tribal governments are included within the "Federal" category. The "Other" category contains highways/bridges owned by Private, Railroad, and Other Public Entity and highways/bridges where ownership code is not available.

Sources: Highway Performance Monitoring System, National Bridge Inventory.

Roads Owned by the Federal Government

As shown in *Exhibit 1-2*, the Federal government and Tribal governments owned a combined 3.7 percent of the Nation's route miles of publicly owned roads in 2016. *Exhibit 1-3* shows that of these route miles, the U.S. Forest Service owns the largest share, approximately 41.8 percent. The Bureau of Indian Affairs and Tribal governments own a combined 23.2 percent of Federally owned route miles; approximately 11.2 percent is owned by the Bureau of Land Management. Roads on military installations (owned by the Army, Navy, Marines, and Air Force) comprise 10.5 percent. The remaining 13.3 percent of Federally owned route miles is divided among multiple agencies including the National Park Service, the U.S. Army Corps of Engineers, the Fish and Wildlife Service, the Bureau of Reclamation, the Tennessee Valley Authority, and other Federal agencies.

Exhibit 1-3 ■ Distribution of Route Miles Owned by Federal Agencies, 2016



Source: Highway Performance Monitoring System.

Roads and Bridges by System Subset

Federal-aid highways are a subset of all public roads. The term Federal-aid highway is defined in 23 U.S.C. 101(a)(6) as "a public highway eligible for assistance under this chapter other than a highway functionally classified as a local road or rural minor collector." (Functional classification is discussed later in this section.)

The NHS is a subset of Federal-aid highways, containing the most critical routes for movement of passengers and goods. The Interstate System is a subset of the NHS. The NHS and Interstate System are discussed in more detail below.

Exhibit 1-4 compares the relative magnitudes of these subsets to the total extent of the Nation's highways and bridges. Relative to the average public road, Federal-aid highways consist of longer routes and facilitate higher traffic volumes at increased speeds. The same is true for NHS routes relative to the average Federal-aid highway, and the average Interstate highway relative to the average NHS route.

Exhibit 1-4 ■ Interstate, NHS, and Federal-aid Highway Extent, Bridge Count, and Travel, 2016

	Interstate	NHS	FAH	All Public Roads	Share of Total Interstate	Share of Total NHS	Share of Total FAH
Highway Route Miles	48,474	222,331	1,026,319	4,157,292	1.2%	5.3%	24.7%
Lane Miles	225,481	769,508	2,485,190	8,775,538	2.6%	8.8%	28.3%
VMT (trillions)	0.811	1.749	2.710	3.189	25.4%	54.8%	85.0%
Bridges	57,309	144,610	329,324	614,387	9.3%	23.5%	53.6%
Bridge Deck Area (millions of sq. meters)	98.393	215.604	313.277	371.464	26.5%	58.0%	84.3%
Bridge Average Daily Traffic (billions)	2.094	3.670	4.436	4.627	45.3%	79.3%	95.9%

Sources: Highway Performance Monitoring System; National Bridge Inventory.

Although Federal-aid highways constitute just 24.7 percent of the Nation's route mileage, they carry 85.0 percent of the Nation's VMT. The NHS includes 5.3 percent of the Nation's route mileage, but carries 54.8 percent of highway traffic. The Interstate System makes up only 1.2 percent of the Nation's roads, but carries 25.4 percent of VMT.

Federal-aid highways include 53.6 percent of the nation's bridges, compared with 23.5 percent for the NHS and 9.3 percent for Interstate highways. The Interstate System and the NHS have a larger share of multilane roadways (four lanes or more) and tend to include larger bridges than does the average Federal-aid highway.

Ownership of Federal-aid Highway Components

Only 0.6 percent of Federal-aid highway route miles are owned by the Federal government. State governments own 55.6 percent of Federal-aid highway route miles, whereas local governments own 43.8 percent.

State governments owned 60.2 percent of Federal-aid highway lane-miles in 2016, whereas 39.3 percent was owned by local governments. The remaining 0.5 percent of lane-miles was owned by the Federal government.

Based on mileage, State governments own more than 90.7 percent of the NHS. In contrast, the Federal government owns less than 0.1 percent of the 222,331 NHS route mileage, and local governments own 9.2 percent. State governments own more than 99.9 percent of the 48,192 miles in the Interstate System; the Federal government owns none of the Interstate System.

Federal-aid Highways

Federal-aid highways comprised approximately 1.03 million route miles in 2016 and facilitated approximately 2.71 trillion VMT. As shown in *Exhibit 1-5*, highway route mileage on Federal-aid highways increased by 42,226 miles between 2006 and 2016, to approximately 1.03 million miles in 2016. Lane mileage increased by 126,676 miles to almost 2.49 million lane miles in 2016 and VMT increased from 2.57 trillion in 2006 to 2.71 trillion VMT in 2016, an increase of more than 136 billion VMT. The number of bridges on Federal-aid highways increased from 312,062 in 2006 to 329,324 in 2016. This is an annual rate of change of approximately 0.5 percent.

Exhibit 1-5 ■ Federal-aid Highways Extent and Travel, 2006–2016

	2006	2008	2010	2012	2014	2016	Average Annual Rate of Change 2016/2006
Highway Route Miles	984,093	994,358	1,007,777	1,005,378	1,020,461	1,026,319	0.4%
Lane Miles	2,364,514	2,388,809	2,451,140	2,433,012	2,445,667	2,485,190	0.5%
VMT (trillions)	2.574	2.534	2.525	2.527	2.572	2.710	0.5%
Bridges	312,062	316,012	319,108	321,724	325,467	329,324	0.5%

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, a subset of the Federal-aid highways, 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 route mileage not previously designated as part of the NHS. This modification increased the size of the NHS by approximately 36 percent, bringing it from 164,154 miles in 2011 up to 224,446 miles.[3]

The NHS was designed to be a dynamic system capable of changing in response to future travel and trade demands. States may propose modifications to the NHS provided they meet the criteria established for the NHS and enhance the characteristics of the NHS, as specified in 23 U.S.C. 103 and 23 CFR 470. States must cooperate with local and regional officials in proposing such modifications. FHWA has approval authority for modifications to the NHS. Each year, FHWA receives requests to modify hundreds of NHS segments. FHWA processes these requests and updates the official map record of the NHS on its website (see https://www.fhwa.dot.gov/planning/national_highway_system/nhs_maps/) throughout the year.

The modifications approved by the FHWA from 2014 to 2016 resulted in decreases in highway miles and lane miles on the NHS to 222,331, and 769,508, respectively. However, VMT and the number of bridges on the NHS increased during the same period. *Exhibit 1-6* shows the changes in the NHS from 2006 to 2016. Route miles and lane miles increased at an average annual rate change of 3.1 percent while VMT on the NHS increased at an annual average rate change of 2.6 percent. The number of bridges increased at average annual rate of 2.3 percent.

Exhibit 1-6 ■ NHS Extent and Travel, 2006–2016

	Year						Average Annual Rate of Change 2016/2006
	2006	2008	2010	2012	2014	2016	
Route Miles	163,472	164,108	159,326	223,357	226,767	222,331	3.1%
Lane Miles	568,074	574,011	575,546	771,184	771,245	769,508	3.1%
VMT (trillions)	1.354	1.327	1.311	1.644	1.661	1.749	2.6%
Bridges	115,202	116,523	116,669	117,485	143,165	144,610	2.3%

Sources: Highway Performance Monitoring System; National Bridge Inventory.

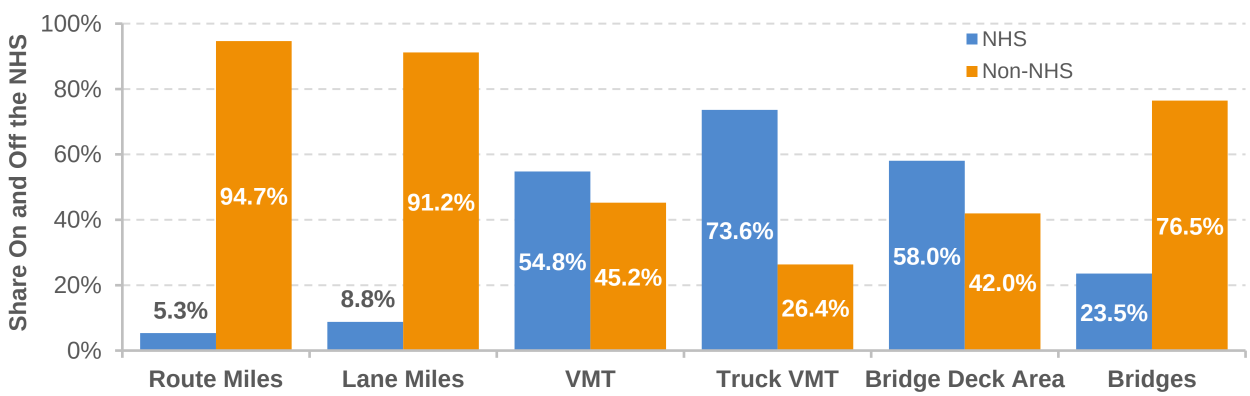
[3] See https://www.fhwa.dot.gov/planning/national_highway_system/nhs_maps/map21estmileage.cfm. Figures adjusted to include Puerto Rico based on data from Highway Statistics 2011, Tables HM-41 and HM-20.

The 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 components that comprise the NHS.

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, which include a power unit (truck tractor) and one or more trailing units (a semitrailer or trailer).

As shown in *Exhibit 1-7*, only 5.3 percent of the Nation's highway route mileage and 8.8 percent of the Nation's lane mileage were located on the NHS in 2016. Of the total number of the Nation's bridges, 23.5 percent are located on the NHS. However, these bridges account for 58.0 percent of the total bridge deck area in the Nation. Approximately 54.8 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 73.6 percent of combination truck VMT occurred on the NHS in 2016. Freight transportation is discussed in more detail in Part III of this report.

Exhibit 1-7 ■ Highway and Bridge Extent and Travel, Shares on and off the National Highway System, 2016



Source: Highway Performance Monitoring System, National Bridge Inventory.

Interstate System

The Federal-aid Highway Act of 1956 declared that completion of the originally planned 41,000 route miles of the "National System of Interstate and Defense Highways" as 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 by the American Association of State Highway Officials (AASHO), the forerunner of the American Association of State Highway and Transportation Officials (AASHTO). The Act also addressed the challenging issue of how to pay for construction by establishing the Highway Trust Fund to dedicate revenue from highway user taxes, such as the motor fuels tax, to the Interstate System and other Federal-aid highway and bridge projects.

As shown in *Exhibit 1-8,* there were small increases in the size of the Interstate System from 2006 to 2016. The total number of route miles increased from 46,836 route miles in 2006 to 48,474 route miles in 2016. Lane miles increased from 212,029 lane miles in 2006 to 225,481 lane miles in 2016. The number of bridges increased from 55,270 bridges in 2006 to 57,309 bridges in 2016.

Exhibit 1-8 ■ Interstate System Extent and Travel, 2006–2016

	2006	2008	2010	2012	2014	2016	Annual Rate of Change 2016/2006
Route Miles	46,836	46,892	47,019	47,182	47,714	48,474	0.3%
Lane Miles	212,029	213,542	214,880	217,165	220,124	225,481	0.6%
VMT (trillions)	0.727	0.741	0.725	0.731	0.736	0.811	1.1%
Bridges	55,270	55,626	55,339	55,959	56,553	57,309	0.4%

Sources: Highway Performance Monitoring System; National Bridge Inventory.

Roads and Bridges by Purpose

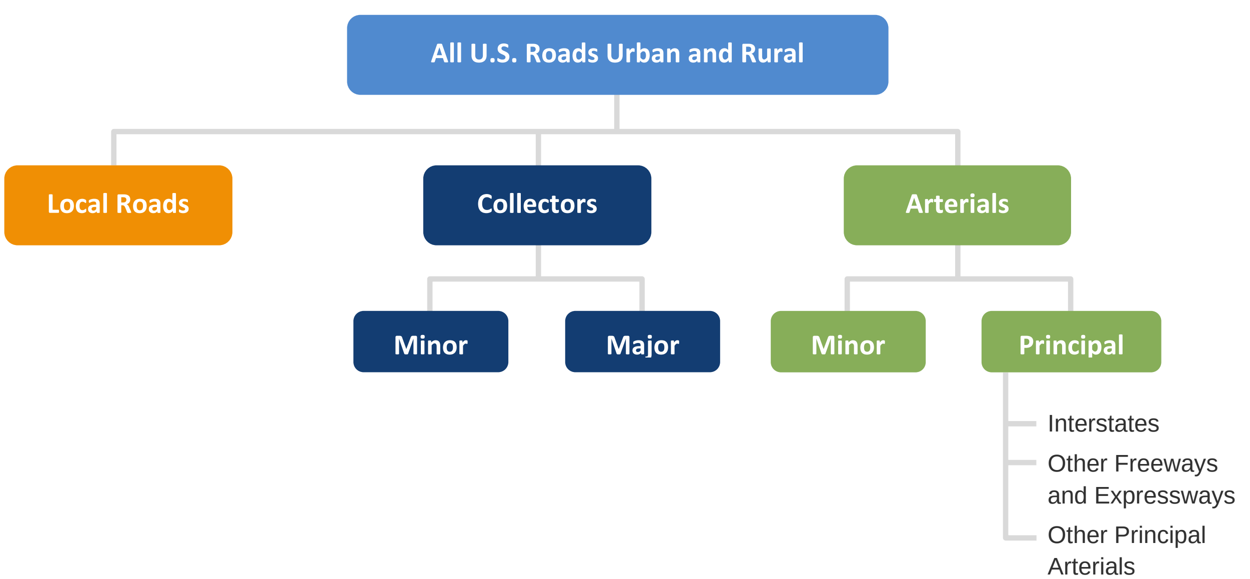
The Nation's roadway system serves movements from long-distance freight needs to neighborhood travel. Because of the diverse needs for vehicular travel, the network is categorized under the Highway Functional Classification System. Each functional classification defines the role an element of the network plays in serving motorized/vehicular travel needs.

Exhibit 1-9 presents a formal FHWA hierarchy of road functional classifications. Although the functional classification definitions do not change for each setting, roads are divided also into rural and urban classifications.

Classification of Roadways as Rural vs. Urban

Roadways in a census tract with a population of 5,000 or more are classified as urban; all other roadways are classified as rural. Census Tracts are small, relatively permanent statistical subdivisions of a county or equivalent entity that are updated by local participants prior to each decennial census as part of the Census Bureau's Participant Statistical Areas Program. The Census Bureau delineates census tracts in situations where no local participant existed or where state, local, or tribal governments declined to participate. The primary purpose of census tracts is to provide a stable set of geographic units for the presentation of statistical data.

Exhibit 1-9 ■ Highway Functional Classification System Hierarchy



Source: Highway Functional Classification Concepts, Criteria and Procedures–2013 Edition.

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 support long-distance travel at higher speeds with minimal conflict from traffic entering or leaving the roadway. Interstates are relatively easy to locate due to their official designation by the Secretary of Transportation and distinct signage.
- **Other Freeways and Expressways** are very 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 providing access to adjacent properties than on mobility.

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. They are intended to grant access at the maximum level to adjacent properties. 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.)

Extent and Vehicular Travel by Functional System

The Nation's network of public roads is diversely constructed to fit the needs of its surrounding environment. Roads in an urban setting will often have multiple lanes on a facility to support high levels of demand for vehicular traffic, whereas a rural setting will have fewer lanes supporting lower traffic levels.

As shown in *Exhibit 1-10,* almost half (49.1 percent) of the Nation's highway mileage was classified as rural local in 2016. Urban local roads comprised an additional 19.7 percent of total highway miles.

Exhibit 1-10 also details the breakdown of travel occurring in rural and urban settings. Urban areas have a higher share of VMT and lower

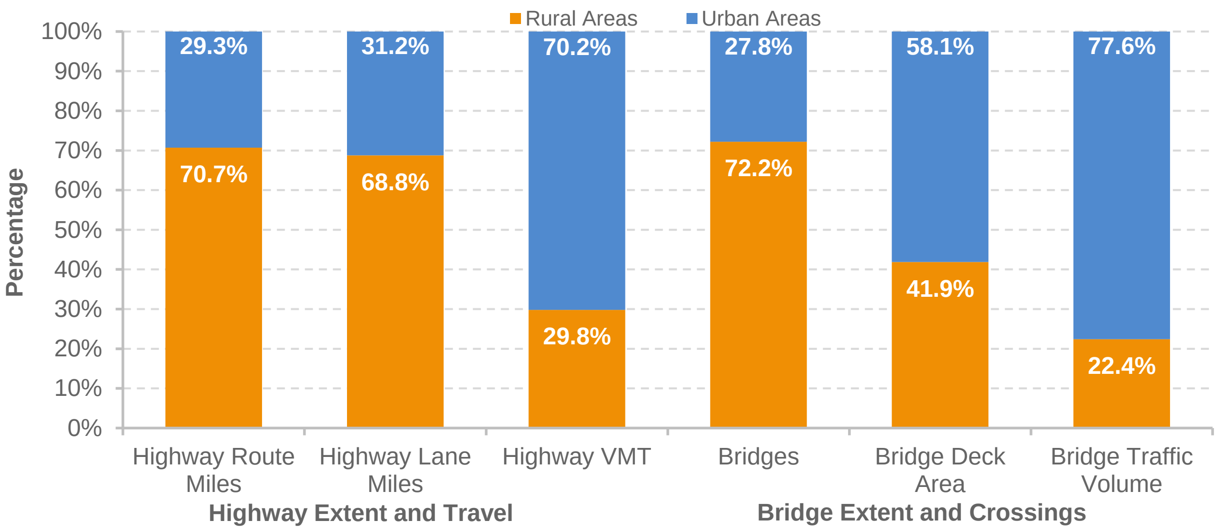
Relationship of Federal-aid Highways to Functional Classes

Public roads that are functionally classified higher than rural minor collector, rural local, or urban local are called Federal-aid highways and 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.

There are exceptions to the general rules limiting Federal-aid funding to Federal-aid highways. For example, States may use funding from their Surface Transportation Block Grant (STBG) Program apportionments to fund projects on existing bridges and tunnels not on Federal-aid highways. Highway Safety Improvement Program (HSIP) funds may be used on safety projects on any public road.

highway route mileage because urban settings tend to be more consolidated environments. With higher population concentrations, more vehicles use the highway route 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 1-10 ■ Highway and Bridge Extent and Travel by Functional System and Area, 2016



Functional System	Highway Route 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%	7.8%	4.1%	6.8%	9.0%
Other Freeway and Expressway	0.2%	0.3%	1.1%			
Other Principal Arterial	2.2%	2.7%	6.0%			
Other Principal Arterial[1]				6.1%	8.8%	5.7%
Minor Arterial	3.2%	3.2%	4.5%	6.2%	5.7%	2.8%
Major Collector	9.8%	9.4%	5.0%	15.0%	8.7%	2.8%
Minor Collector	6.2%	5.9%	1.5%	7.8%	3.1%	0.7%
Local	48.4%	46.0%	4.0%	33.1%	8.9%	1.3%
Subtotal Rural Areas	**70.7%**	**68.8%**	**29.8%**	**72.2%**	**41.9%**	**22.4%**
Urban Areas (5,000 or more in population)						
Interstate	0.5%	1.2%	17.7%	5.2%	19.7%	36.2%
Other Freeway and Expressway	0.3%	0.7%	7.8%	3.4%	11.0%	16.6%
Other Principal Arterial	1.6%	2.7%	15.1%	4.8%	11.8%	12.3%
Minor Arterial	2.7%	3.4%	12.9%	5.1%	8.2%	7.6%
Collector[1]				3.7%	3.7%	2.8%
Major Collector	3.1%	3.2%	6.5%			
Minor Collector	0.4%	0.4%	0.5%			
Local	20.7%	19.7%	9.6%	5.5%	3.7%	2.2%
Subtotal Urban Areas	**29.3%**	**31.2%**	**70.2%**	**27.8%**	**58.1%**	**77.6%**
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 urban Interstate highway route mileage comprised only 0.5 percent of the Nation's highway route mileage, these highways carried the Nation's highest share of VMT by classification at 17.7 percent. Urban Interstate bridges also received the highest share of bridge traffic volume by classification with 36.2 percent in 2016.

Approximately 70.7 percent of the Nation's highway route mileage was located in rural areas, as was 68.8 percent of lane mileage. Local roads in urban and rural settings had the highest share of the Nation's lane mileage. Approximately 77.6 percent of bridge traffic volume was on the 27.8 percent of bridges in urban areas. Urban areas accounted for 58.1 percent of bridge deck area, compared with 41.9 percent for rural areas. The percentage of highway VMT occurring in urban areas (70.2 percent) was more than double that of rural areas (29.8 percent).

The difference seen in *Exhibit 1-10* between the functional classes reported under the highway portion of the exhibit and the bridge portion is due to the NBI not having been updated to use the new functional classifications instituted in the HPMS in 2013 and described in *Highway Functional Classification: Concepts, Criteria and Procedures, 2013 Edition*.

Exhibit 1-11 shows the highway route miles in the Nation based on functional system. The Nation's public highways comprised approximately 4.16 million route miles in 2016, up from the more than 4.0 million route miles in 2006. Total route mileage in urban areas grew from 1,041,747 route miles in 2006 to 1,226,171 route miles in 2016. Highway route miles in rural areas, however, decreased from approximately 3.0 million route miles in 2006 to slightly more than 2.93 million route miles in 2016. The largest decrease in route 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 route 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 route 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 route mileage.

Impact of Census Redesignations on Rural and Urban Data Trends

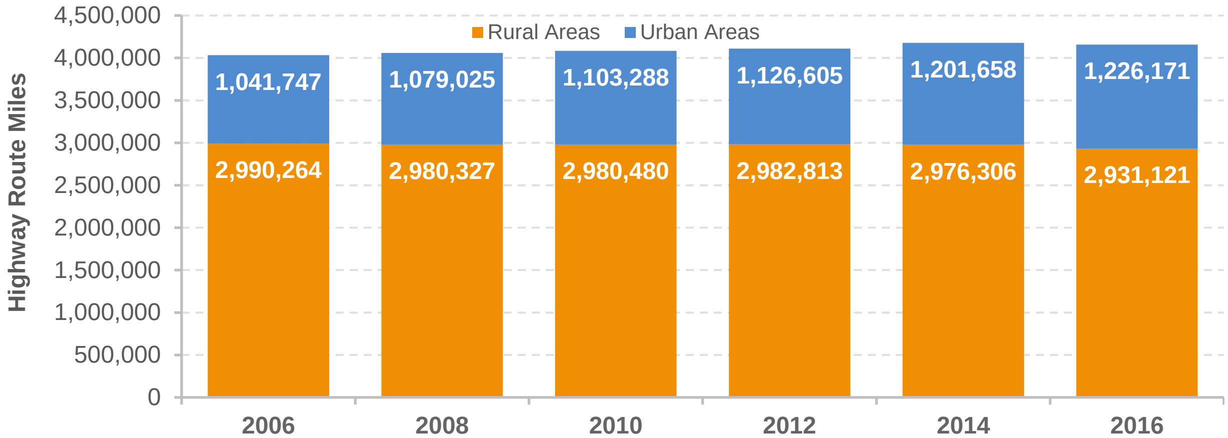
The declines in rural route mileage and rural lane mileage shown in *Exhibits 1-11* and *1-12*, respectively, are primarily a function of the expansion of urban boundaries following the 2010 Census.

While data are not available to quantify the magnitude of this effect for all functional classes, an analysis comparing the lengths of individual Interstate routes in each State between 2006 and 2016 suggests that at least 76 percent of the growth in urban Interstate route miles and 51 percent of the growth in urban Interstate lane miles was attributable to boundary changes rather than new construction or widening.

Although *Exhibits 1-11* and *1-12* show average annual decreases from 2006 to 2016 in rural Interstate route mileage and rural Interstate lane mileage of 0.5 percent and 0.4 percent, respectively, after removing apparent urban reclassifications each of these measures appears to have grown at an average annual rate of at least 0.2 percent per year.

These estimated impacts of urban boundary changes may be conservative, as the approach used to develop the analysis did not capture potential boundary changes involving Interstate routes that were renumbered between 2006 and 2016.
Source: FHWA staff analysis of HPMS data.

Exhibit 1-11 ■ Highway Route Miles by Functional System and Area, 2006–2016



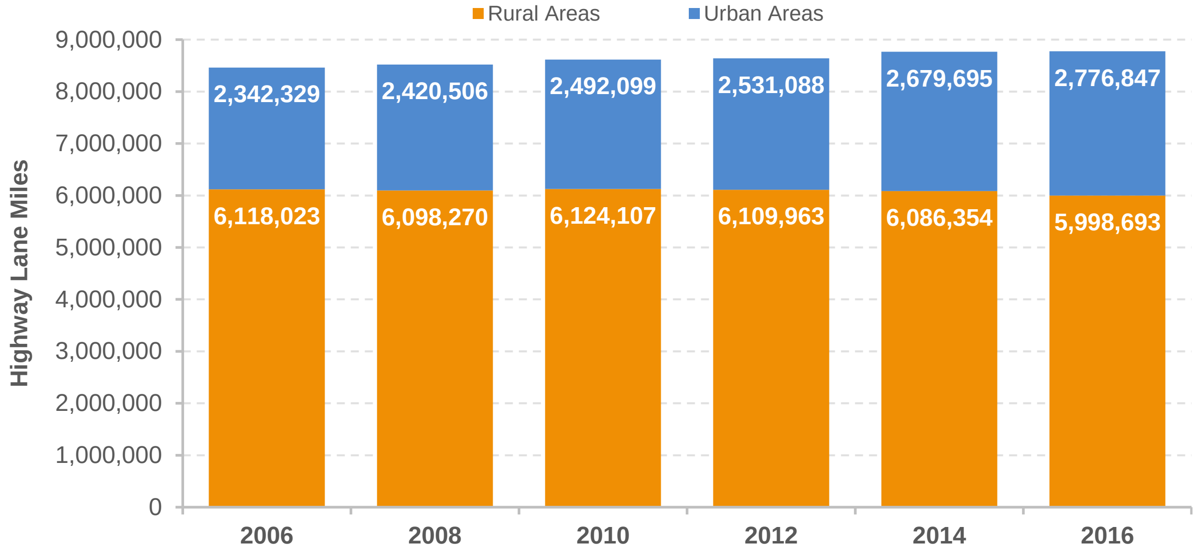
Functional System	2006	2008	2010	2012	2014	2016	Annual Rate of Change 2016/2006
Rural Areas (less than 5,000 in population)							
Interstate	30,615	30,227	30,260	30,564	29,095	29,177	-0.5%
Other Freeway & Expressway[1]			3,299	4,395	3,299	6,378	
Other Principal Arterial[1]			92,131	91,462	92,131	89,772	
Other Principal Arterial[1]	95,009	95,002					0.1%
Minor Arterial	135,589	135,256	135,681	135,328	132,672	134,034	-0.1%
Major Collector	419,289	418,473	418,848	419,353	418,848	407,870	-0.3%
Minor Collector	262,966	262,852	263,271	262,435	263,271	258,719	-0.2%
Local	2,046,796	2,038,517	2,036,990	2,039,276	2,036,990	2,005,171	-0.2%
Subtotal Rural Areas	**2,990,264**	**2,980,327**	**2,980,480**	**2,982,813**	**2,976,306**	**2,931,121**	**-0.2%**
Urban Areas (5,000 or more in population)							
Interstate	16,277	16,789	16,922	17,150	18,567	19,312	1.7%
Other Freeway and Expressway	10,817	11,401	11,371	11,521	11,784	12,302	1.3%
Other Principal Arterial	63,180	64,948	65,505	65,593	66,761	66,517	0.5%
Minor Arterial	103,678	107,182	108,375	109,337	112,228	113,316	0.9%
Collector[1]	109,639	115,087					3.0%
Major Collector[1]			115,538	116,943	127,809	130,294	
Minor Collector[1]			3,303	3,588	11,754	16,961	
Local	738,156	763,618	782,273	802,473	852,755	867,469	0.7%
Subtotal Urban Areas	**1,041,747**	**1,079,025**	**1,103,288**	**1,126,605**	**1,201,658**	**1,226,171**	0.6%
Total Highway Route Miles	**4,032,011**	**4,059,352**	**4,083,768**	**4,109,418**	**4,177,964**	**4,157,292**	**0.3%**

[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 the change in highway lane miles from 2006 to 2016 by functional class and shows the changes in rural areas vs. urban areas of the Nation. Urban areas have seen an increase in lane miles from more than 2.34 million in 2006 to slightly less than 2.78 million in 2016. The largest decrease in lane miles occurred on rural local roadways, a loss of 83,250 lane miles of roadway, whereas urban local roadways experienced the largest increase in lane miles, at 265,551 lane miles.

Exhibit 1-12 ■ Highway Lane Miles by Functional System and Area, 2006–2016



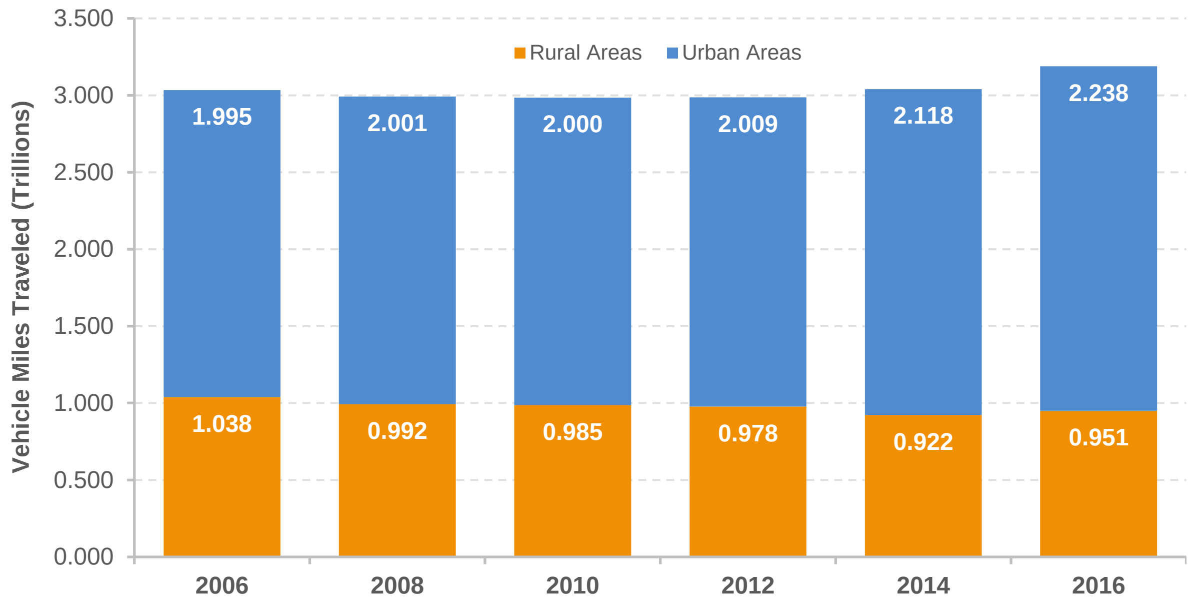
Functional System	Highway Lane Miles 2006	2008	2010	2012	2014	2016	Annual Rate of Change 2016/2006
Rural Areas (less than 5,000 in population)							
Interstate	124,506	122,956	123,762	124,927	118,688	119,159	-0.4%
Other Freeway and Expressway[1]			11,907	16,593	20,677	24,542	
Other Principal Arterial[1]			243,065	240,639	233,985	231,532	
Other Principal Arterial[1]	248,334	250,153					0.3%
Minor Arterial	282,397	281,071	287,761	281,660	274,271	276,685	-0.2%
Major Collector	843,262	841,353	857,091	842,722	823,609	818,994	-0.3%
Minor Collector	525,932	525,705	526,540	524,870	517,026	517,439	-0.2%
Local	4,093,592	4,077,032	4,073,980	4,078,552	4,098,098	4,010,342	-0.2%
Subtotal Rural Areas	**6,118,023**	**6,098,270**	**6,124,107**	**6,109,963**	**6,086,354**	**5,998,693**	**-0.2%**
Urban Areas (5,000 or more in population)							
Interstate	89,036	91,924	93,403	95,197	102,541	105,457	1.7%
Other Freeway and Expressway	50,205	53,073	53,231	54,160	55,385	58,943	1.6%
Other Principal Arterial	221,622	228,792	235,127	234,469	231,099	237,381	0.7%
Minor Arterial	269,912	274,225	285,954	283,608	287,061	296,203	0.9%
Collector[1]	235,240	245,262					3.7%
Major Collector[1]			252,435	250,760	272,931	278,414	
Minor Collector[1]			7,404	7,948	25,168	58,584	
Local	1,476,314	1,527,230	1,564,546	1,604,946	1,705,510	1,741,865	1.7%
Subtotal Urban Areas	**2,342,329**	**2,420,506**	**2,492,099**	**2,531,088**	**2,679,695**	**2,776,847**	**1.7%**
Total Highway Lane Miles	**8,460,352**	**8,518,776**	**8,616,206**	**8,641,051**	**8,766,049**	**8,775,540**	**0.4%**

[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 VMT in trillions of miles by functional class from 2006 to 2016. VMT in rural areas decreased from 1.04 trillion miles in 2006 to 0.95 trillion miles in 2016. Urban VMT increased from just under 2.0 trillion to slightly less than 2.24 trillion during the same period. *Exhibit 1-13* also shows the largest average annual decrease of 2.0 percent was on rural minor collectors and the largest gain was on the combined functional classifications of urban major and minor collectors, an increase of 2.5 percent. Overall, VMT on rural roadways declined by an average annual rate of 0.9 percent and VMT on urban roadways increased by an average annual rate of 1.2 percent between 2006 and 2016.

Exhibit 1-13 ■ VMT by Functional System and Area, 2006–2016



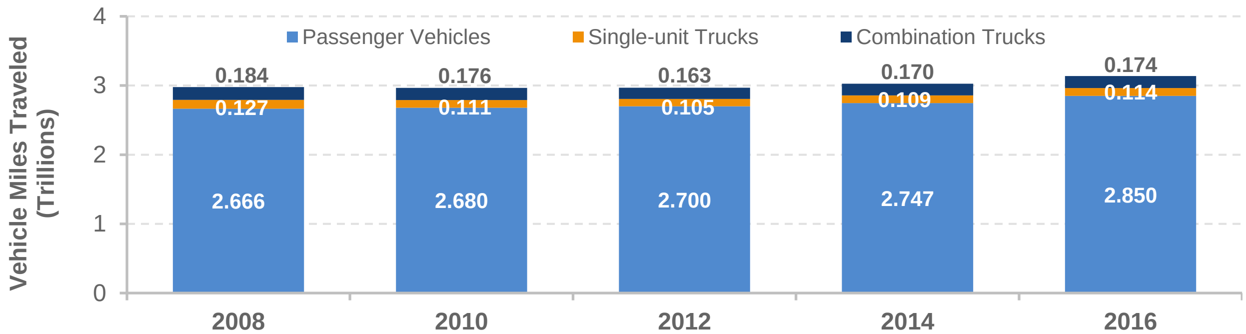
Functional System	Annual Travel Distance (Trillions of Miles)						Annual Rate of Change 2016/2006
	2006	2008	2010	2012	2014	2016	
Rural Areas (less than 5,000 in population)							
Interstate	0.258	0.244	0.246	0.246	0.232	0.247	-0.4%
Other Freeway & Expressway[1]			0.020	0.020	0.026	0.034	
Other Principal Arterial[1]			0.206	0.203	0.188	0.190	
Other Principal Arterial[1]	0.232	0.223					-0.3%
Minor Arterial	0.163	0.152	0.151	0.149	0.141	0.144	-1.3%
Major Collector	0.193	0.186	0.176	0.176	0.159	0.160	-1.9%
Minor Collector	0.058	0.055	0.053	0.053	0.050	0.048	-2.0%
Local	0.133	0.132	0.133	0.130	0.126	0.128	-0.4%
Subtotal Rural Areas	**1.038**	**0.992**	**0.985**	**0.978**	**0.922**	**0.951**	**-0.9%**
Urban Areas (5,000 or more in population)							
Interstate	0.483	0.482	0.483	0.490	0.525	0.563	1.6%
Other Freeway and Expressway	0.218	0.224	0.222	0.225	0.228	0.250	1.4%
Other Principal Arterial	0.470	0.466	0.461	0.460	0.471	0.483	0.3%
Minor Arterial	0.380	0.381	0.378	0.375	0.393	0.412	0.8%
Collector[1]	0.176	0.178					2.5%
Major Collector[1]			0.179	0.177	0.195	0.207	
Minor Collector[1]			0.004	0.004	0.012	0.016	
Local	0.268	0.271	0.273	0.278	0.295	0.306	1.3%
Subtotal Urban Areas	**1.995**	**2.001**	**2.000**	**2.009**	**2.118**	**2.238**	**1.2%**
Total VMT	**3.034**	**2.993**	**2.985**	**2.987**	**3.040**	**3.189**	**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 1-14 shows an analysis of the types of vehicles comprising the Nation's VMT between 2008 and 2016. 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 2016, combination trucks accounted for more than 5.5 percent, and single-unit trucks accounted for 3.6 percent.

Exhibit 1-14 ■ Highway Travel by Functional System and Vehicle Type, 2008–2016



Functional System Vehicle Type	Annual Travel Distance (Trillions of Miles)					Annual Rate of Change 2016/2008
	2008	2010	2012	2014	2016	
Rural						
Interstate						
Passenger Vehicles	0.181	0.185	0.188	0.175	0.184	0.2%
Single-unit Trucks	0.012	0.011	0.009	0.009	0.010	-2.2%
Combination Trucks	0.050	0.049	0.049	0.047	0.050	0.0%
Other Arterial						
Passenger Vehicles	0.322	0.324	0.325	0.309	0.318	-0.2%
Single-unit Trucks	0.020	0.019	0.017	0.016	0.016	-2.9%
Combination Trucks	0.032	0.033	0.030	0.029	0.029	-1.1%
Other Rural						
Passenger Vehicles	0.335	0.328	0.327	0.304	0.302	-1.3%
Single-unit Trucks	0.019	0.018	0.018	0.017	0.016	-2.3%
Combination Trucks	0.016	0.016	0.014	0.013	0.012	-3.7%
Total Rural						
Passenger Vehicles	0.839	0.837	0.840	0.789	0.804	-0.5%
Single-unit Trucks	0.051	0.048	0.044	0.043	0.042	-2.5%
Combination Trucks	0.098	0.099	0.093	0.089	0.091	-0.9%
Urban						
Interstate						
Passenger Vehicles	0.424	0.427	0.434	0.463	0.492	1.9%
Single-unit Trucks	0.017	0.014	0.015	0.016	0.019	1.6%
Combination Trucks	0.036	0.036	0.036	0.041	0.042	2.1%
Other Urban						
Passenger Vehicles	1.403	1.415	1.427	1.495	1.554	1.3%
Single-unit Trucks	0.059	0.048	0.046	0.050	0.053	-1.3%
Combination Trucks	0.050	0.042	0.035	0.039	0.041	-2.5%
Total Urban						
Passenger Vehicles	1.827	1.842	1.861	1.958	2.046	1.4%
Single-unit Trucks	0.075	0.062	0.061	0.067	0.072	-0.6%
Combination Trucks	0.086	0.077	0.071	0.080	0.083	-0.4%
Total Passenger Vehicles	**2.666**	**2.680**	**2.700**	**2.747**	**2.850**	**0.8%**
Total Single-unit Trucks	**0.127**	**0.111**	**0.105**	**0.109**	**0.114**	**-1.3%**
Total Combination Trucks	**0.184**	**0.176**	**0.163**	**0.170**	**0.174**	**-0.7%**

Notes: Data do not include Puerto Rico. 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.

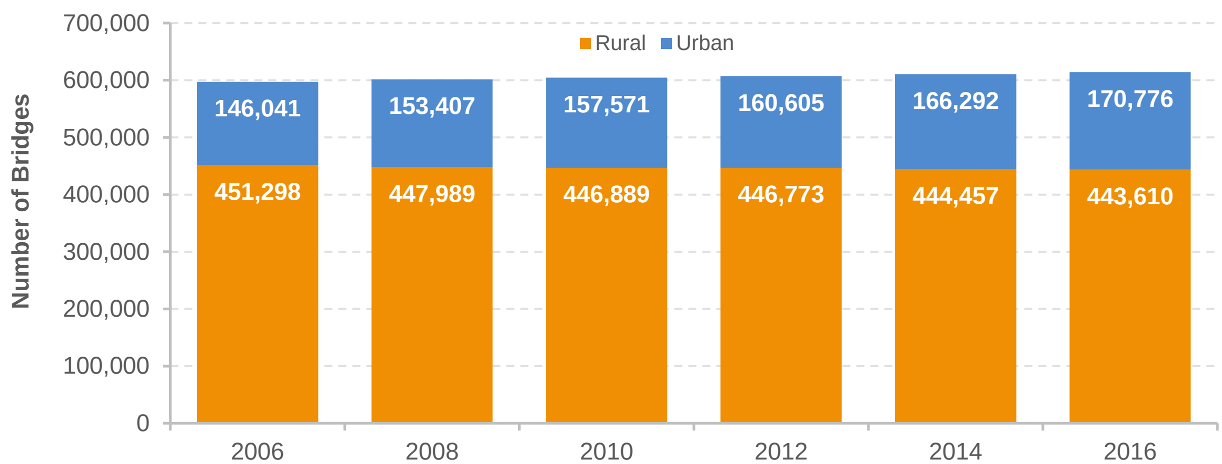
Source: Highway Statistics, various years, Table VM-1.

Passenger vehicle travel grew at an average annual rate of 0.8 percent from 2008 to 2016. During the same period, combination truck traffic declined at an average annual rate of 0.7 percent and single-unit truck traffic declined at an average annual rate of 1.3 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 2006 to 2016 is shown in *Exhibit 1-15.* The number of bridges in the Nation has increased from 597,561 in 2006 to 614,387 in 2016, an annual rate of change of approximately 0.3 percent. Rural interstate bridges decreased at an annual rate of 0.6 percent from 2006 to 2016, whereas the number of bridges on urban collectors had the largest average annual increase at 2.7 percent.

The number of bridges on rural local roadways decreased by the largest amount, from 207,130 bridges in 2006 to 203,393 in 2016. During the same period the number of bridges increased by the largest amount—5,389 bridges—on urban collector roadways.

Exhibit 1-15 ■ Number of Bridges by Functional System and Area, 2006–2016



Functional System	Bridges 2006	2008	2010	2012	2014	2016	Annual Rate of Change 2016/2006
Rural							
Interstate	26,633	25,997	25,223	25,201	25,057	25,176	-0.6%
Other Principal Arterial	35,766	35,594	36,084	36,460	36,711	37,236	0.4%
Minor Arterial	39,521	39,079	39,048	39,123	38,159	37,942	-0.4%
Major Collector	93,609	93,118	93,059	92,875	92,777	92,142	-0.2%
Minor Collector	48,639	48,242	47,866	47,922	47,758	47,721	-0.2%
Local	207,130	205,959	205,609	205,192	203,995	203,393	-0.2%
Subtotal Rural	**451,298**	**447,989**	**446,889**	**446,773**	**444,457**	**443,610**	**-0.2%**
Urban							
Interstate	28,637	29,629	30,116	30,758	31,496	32,133	1.2%
Other Freeway and Expressway	17,988	19,168	19,791	20,139	20,821	20,695	1.4%
Other Principal Arterial	26,051	26,934	27,373	28,141	28,669	29,478	1.2%
Minor Arterial	26,239	27,561	28,103	28,437	29,943	31,515	1.8%
Collectors	17,618	18,932	20,311	20,590	21,834	23,007	2.7%
Local	29,508	31,183	31,877	32,540	33,529	33,948	1.4%
Subtotal Urban	**146,041**	**153,407**	**157,571**	**160,605**	**166,292**	**170,776**	**1.6%**
Unclassified	**222**	**110**	**33**	**2**	**0**	**1**	**-41.7%**
Total	**597,561**	**601,506**	**604,493**	**607,380**	**610,749**	**614,387**	**0.3%**

Source: National Bridge Inventory.

System Assets – Transit

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 and associated public infrastructure investments 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, which 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 to 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 some 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 with a population of more than 50,000, but did not require the establishment of metropolitan planning organizations (MPOs).

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

KEY TAKEAWAYS

Agencies/Reporters

- Most transit systems in the United States report to the National Transit Database (NTD). In 2016, 949 agencies serving almost all 486 urbanized areas and 1,321 rural agencies reported to the NTD.
- In addition, more than 3,800 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 1,107 regular fixed-route bus systems, 190 commuter bus systems, and 16 bus rapid transit systems in 2016.
- Demand-response service was provided by 1,777 systems.
- Open-to-the-public vanpool service was provided by 105 systems.
- Other modes include ferryboat (30 systems), trolleybus (five systems), and other less common modes.
- Rail modes include heavy rail (18 systems), light rail (23 systems), streetcar (26 systems), hybrid rail (five systems), commuter rail (29 systems), and other less common rail modes that run on fixed tracks.

Assets

- Agencies reported 212,668 vehicles in urban and rural areas.
- Rail systems were operated on 13,094 miles of track.
- Fixed-route bus, commuter bus, and bus rapid transit systems operated in over 233,000 mixed-traffic route miles.
- Agencies reported 3,449 passenger stations and 2,424 maintenance facilities.

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 based on a discretionary project basis. The Act also increased flexibility in shifting 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), a Small Starts project eligibility category was created, with a streamlined review process for lower-cost alternative approaches to transit projects such as bus rapid transit. In the rural (rather than the 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.

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 program into the core formula program and added the number of low-income individuals as a new formula factor. Funds for the rural program were 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 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 expenses.

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 1-16*, approximately 949 transit providers in urbanized areas (UZAs) and 1,321 transit providers in rural areas submitted data to the NTD. *Exhibit 1-17* identifies the population and unlinked transit trips for individual UZAs with a population over 1 million. (Some other exhibits in this report present data on areas over and under 1 million in population.)

Exhibit 1-16 ■ Number of Urban and Rural Agencies by Organizational Structure

Organization Structure	City, County, Local Government Transportation Units	Independent Public Authorities or Agencies	State Government Unit	Private Operators[1]	Other[2]	Total
Urban Agencies	525	263	20	88	53	949
Rural Agencies	643	183	5	302	188	1,321
Total	**1,168**	**446**	**25**	**390**	**241**	**2,270**

[1] Private for-profit corporation, or private nonprofit corporation.

[2] Other includes “Area Agency on Aging;” “Metropolitan Planning Organization, Council of Governments, or Other Planning Agencies;” “Tribe;” and “University.”

Source: National Transit Database.

Of the 949 urban reporters, 263 were independent public authorities or agencies; 525 were city, county, or local government transportation units or departments; 20 were State government units or departments of transportation; and 88 were private operators. The remaining 53 agencies were either private operators or independent agencies, such as MPOs, councils of governments (COGs) or other planning agencies, and universities.

Similarly, of the 1,321 rural reporters, 183 were independent public authorities or agencies; 643 were city, county, or local government transportation units or departments; five were State government units or departments of transportation; and 302 were private operators. The remaining 188 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, with requirements parallel to those of rural providers. This simplified reporting applies 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 to assist 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.

As of 2016, 949 urban agencies reported providing transit service. Of these, 278 agencies, or about 30 percent, operated only one mode. About half (485 agencies) operated two modes, and the remaining 196 operated from three to eight modes. Altogether, there are a total of 1,916 agency-mode combinations. In 2016, an additional 1,321 agencies served rural areas. Roughly 73 percent of rural agencies operated only one transit mode, with the remaining agencies operating anywhere from two to four modes. 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.

Exhibit 1-17 ■ 2016 Ridership in Urbanized areas over 1 Million Population (2010 Census)

UZA Rank	UZA Name	2010 Population (Millions)	2016 Unlinked Transit Trips (in Millions)
1	New York-Newark, NY-NJ-CT	18.4	4,293
2	Los Angeles-Long Beach-Anaheim, CA	12.2	619
3	Chicago, IL-IN	8.6	611
4	Miami, FL	5.5	152
5	Philadelphia, PA-NJ-DE-MD	5.4	377
6	Dallas-Fort Worth-Arlington, TX	5.1	76
7	Houston, TX	4.9	91
8	Washington, DC-VA-MD	4.6	440
9	Atlanta, GA	4.5	141
10	Boston, MA-NH-RI	4.2	412
11	Detroit, MI	3.7	40
12	Phoenix-Mesa, AZ	3.6	69
13	San Francisco-Oakland, CA	3.3	471
14	Seattle, WA	3.1	219
15	San Diego, CA	3.0	107
16	Minneapolis-St. Paul, MN-WI	2.7	96
17	Tampa-St. Petersburg, FL	2.4	29
18	Denver-Aurora, CO	2.4	104
19	Baltimore, MD	2.2	116
20	St. Louis, MO-IL	2.2	47
21	San Juan, PR	2.1	42
22	Riverside-San Bernardino, CA	1.9	22
23	Portland, OR-WA	1.9	72
24	Cleveland, OH	1.8	114
25	San Antonio, TX	1.8	45
26	Pittsburgh, PA	1.8	39
27	Sacramento, CA	1.7	66
28	San Jose, CA	1.7	29
29	Cincinnati, OH-KY-IN	1.7	44
30	Kansas City, MO-KS	1.6	20
31	Orlando, FL	1.5	15
32	Indianapolis, IN	1.5	28
33	Virginia Beach, VA	1.5	10
34	Milwaukee, WI	1.4	15
35	Austin, TX	1.4	42
36	Columbus, OH	1.4	19
37	Austin, TX	1.4	31
38	Charlotte, NC-SC	1.2	27
39	Providence, RI-MA	1.2	19
40	Jacksonville, FL	1.1	13
41	Memphis, TN-MS-AR	1.1	8
42	Salt Lake City-West Valley City, UT	1.0	46
Total		**135.6**	**9,276**

Note: UZA is urbanized area.

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

As summarized in *Exhibit 1-18*, in 2016, 1,138 agencies reported fixed-route bus service, including 1,107 regular bus systems, 191 commuter bus systems, and 12 bus rapid transit systems. In addition, 1,894 agencies reported operating demand response services (including demand-response taxi). Note that some agencies operate more than one type of fixed-route bus mode and many agencies provide service for both fixed-route bus and flexible-route demand response modes. Because of this, the sum of these mode types is greater than the number of agencies operating these modes.

Exhibit 1-18 ■ Number of Systems by Mode

Mode Type	Urban	Rural	Total
Nonrail			
Regular Bus	727	411	1,138
Commuter Bus	126	65	191
Bus Rapid Transit	11	1	12
Demand Response / Taxi	812	1,082	1,894
Vanpool	86	18	104
Ferryboat	25	5	30
Trolleybus	5	0	5
Público	1	0	1
Rail			
Heavy Rail	15	0	15
Light Rail	23	0	23
Streetcar	18	0	18
Commuter Rail	27	0	27
Hybrid Rail	5	0	5
Monorail/Automated Guideway	7	0	7
Inclined Plane	3	0	3
Aerial Tramway	1	1	2
Cable Car	1	0	1

Note: No total row shown to avoid double-counting of systems.

Source: National Transit Database.

On the rail side, agencies reported operating, 18 heavy rail systems, 29 commuter rail systems, five hybrid rail systems, 23 light rail systems, and 26 streetcar systems. 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.

Although every major urbanized area in the United States has fixed-route bus and demand-response systems, 48 urbanized areas were also served by at least one of the rail modes, including 27 by commuter rail, 23 by light rail, 15 by heavy rail, 18 by streetcar vehicles, five by hybrid rail vehicle, and 10 by the other rail modes. *Exhibit 1-19* depicts the number of passenger cars for each rail mode by urbanized area.

In addition to fixed-route bus systems, demand-response systems, and rail modes, transit agencies reported operating 104 vanpool systems, 30 ferryboat systems, five trolleybus systems, eight monorail/automated guideway systems, four inclined plane systems, one cable car system, and one público[4] in 2016.

Finally, the transit statistics presented in this report also include those for several minor modes, including the San Francisco Cable Car, Seattle Monorail, Roosevelt Island Aerial Tramway in New York, and Alaska railroad (a long-distance passenger rail system included as public transportation by statutory exemption).

[4] This is a privately owned, market-driven service using vans and small buses that comprises the largest transit system in Puerto Rico.

Exhibit 1-19 ■ Vehicle Revenue Miles for Rail Modes Serving Urbanized Areas, 2016

UZA Rank	Urbanized Area	Commuter Rail	Heavy Rail	Light Rail	Streetcar	Hybrid Rail	Other[1]	Total Rail
1	New York-Newark, NY-NJ-CT	197,736,871	362,594,955	2,463,517	-	1,299,376	-	564,094,719
2	Los Angeles-Long Beach-Anaheim, CA	13,089,698	6,884,795	13,746,952	-	-	-	33,721,445
3	Chicago, IL-IN	47,754,913	71,811,535	-	-	-	-	119,566,448
4	Miami, FL	3,595,531	8,189,085	-	-	-	1,189,377	12,973,993
5	Philadelphia, PA-NJ-DE-MD	23,563,946	21,721,558	-	3,307,488	-	-	48,592,992
6	Dallas-Fort Worth-Arlington, TX	1,164,706	-	9,829,532	89,237	-	-	11,083,475
7	Houston, TX	-	-	3,420,828	-	-	-	3,420,828
8	Washington, DC-VA-MD	2,289,083	77,967,423	-	58,285	-	-	80,314,791
9	Atlanta, GA	-	22,267,826	-	63,298	-	-	22,331,124
10	Boston, MA-NH-RI	23,532,668	23,247,288	6,499,541	-	-	-	53,279,497
11	Detroit, MI	-	-	-	-	-	543,526	543,526
12	Phoenix-Mesa, AZ	-	-	2,912,029	-	-	-	2,912,029
13	San Francisco-Oakland, CA	7,215,731	71,628,728	5,170,134	521,024	-	672,720	85,208,337
14	Seattle, WA	1,794,741	-	4,114,274	267,455	-	229,784	6,406,254
15	San Diego, CA	1,372,271	-	8,673,789	-	684,576	-	10,730,636
16	Minneapolis-St. Paul, MN-WI	538,172	-	5,228,128	-	-	-	5,766,300
17	Tampa-St. Petersburg, FL	-	-	-	66,163	-	-	66,163
18	Denver-Aurora, CO	1,663,629	-	11,355,973	-	-	-	13,019,602
19	Baltimore, MD	6,386,294	5,003,458	3,138,056	-	-	-	14,527,808
20	St. Louis, MO-IL	-	-	6,250,140	-	-	-	6,250,140
21	San Juan, PR	-	1,910,657	-	-	-	-	1,910,657
23	Las Vegas-Henderson, NV	-	-	-	-	-	1,867,222	1,867,222
24	Portland, OR-WA	-	-	8,856,111	405,109	163,721	-	9,424,941
25	Cleveland, OH	-	2,661,244	776,474	-	-	-	3,437,718
27	Pittsburgh, PA	-	-	2,170,843	-	-	11,580	2,182,423
28	Sacramento, CA	-	-	4,369,542	-	-	-	4,369,542
29	San Jose, CA	-	-	3,470,427	-	-	-	3,470,427
30	Cincinnati, OH-KY-IN	-	-	-	29,053	-	-	29,053
32	Orlando, FL	649,088	-	-	-	-	-	649,088
34	Virginia Beach, VA	-	-	393,524	-	-	-	393,524
37	Austin, TX	-	-	-	-	298,379	-	298,379
38	Charlotte, NC-SC	-	-	990,324	54,901	-	-	1,045,225
40	Jacksonville, FL	-	-	-	-	-	165,218	165,218
41	Memphis, TN-MS-AR	-	-	-	-	-	-	-
42	Salt Lake City-West Valley City, UT	5,401,304	-	6,668,973	-	-	-	12,070,277
44	Nashville-Davidson, TN	201,335	-	-	-	-	-	201,335
46	Buffalo, NY	-	-	947,935	-	-	-	947,935
47	Hartford, CT	1,823,515	-	-	-	-	-	1,823,515
49	New Orleans, LA	-	-	-	1,192,948	-	-	1,192,948
52	Tucson, AZ	-	-	-	193,860	-	-	193,860
56	Albuquerque, NM	1,406,934	-	-	-	-	-	1,406,934
88	Little Rock, AR	-	-	-	52,112	-	-	52,112
100	Chattanooga, TN-GA	-	-	-	-	-	18,121	18,121
102	Stockton, CA	1,078,543	-	-	-	-	-	1,078,543
104	Denton-Lewisville, TX	-	-	-	-	644,711	-	644,711
177	Portland, ME	2,129,947	-	-	-	-	-	2,129,947
256	Kenosha, WI-IL	-	-	-	17,523	-	-	17,523
393	Morgantown, WV	-	-	-	-	-	668,979	668,979
400	Johnstown, PA	-	-	-	-	-	2,415	2,415

[1] Other rail modes include cable car, inclined plane, and monorail.

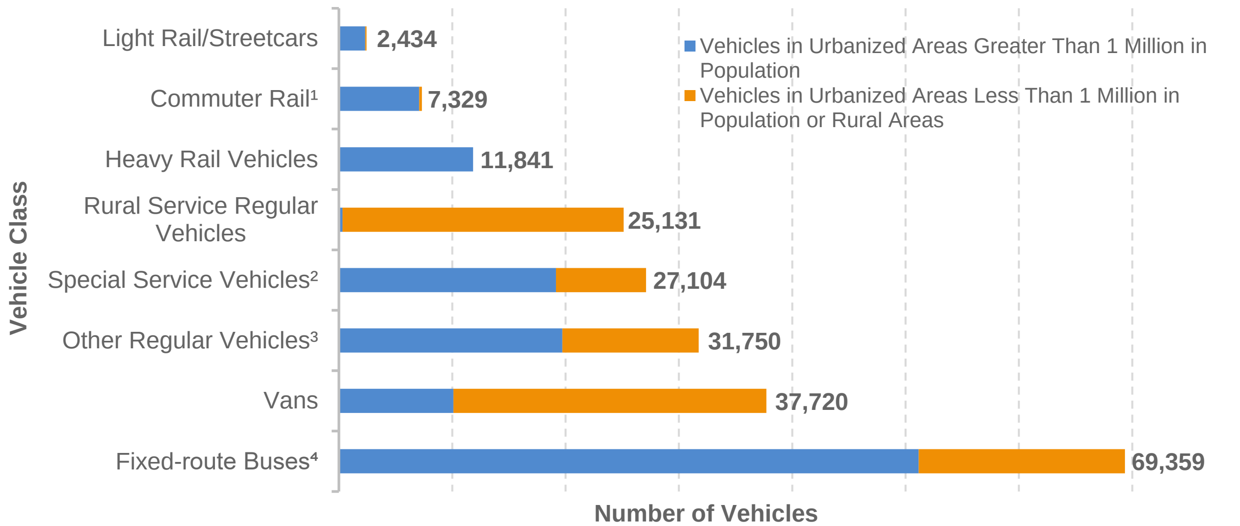
Notes: UZA is urbanized area. Based on primary UZA of the transit system. Some smaller urbanized areas are served by rail that is primary to a larger area. "-" indicates area is not served.

Source: National Transit Database.

Transit Fleet and Stations

Exhibit 1-20 provides an overview of the Nation's fleet of 212,668 transit vehicles as of 2016, segmented by related vehicle type, type of service, and size of urbanized area served. Note here that rail vehicles represent only a small proportion of the nation's total transit fleet (roughly 10 percent) and are almost entirely based in large urban areas. In contrast, rubber-tired, road-based transit vehicles make up close to 90 percent of the national fleet, support a range of service types, and are almost evenly split between service areas that are over and under 1 million population.

Exhibit 1-20 ■ Transit Active Fleet by Vehicle Type, 2016



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

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

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

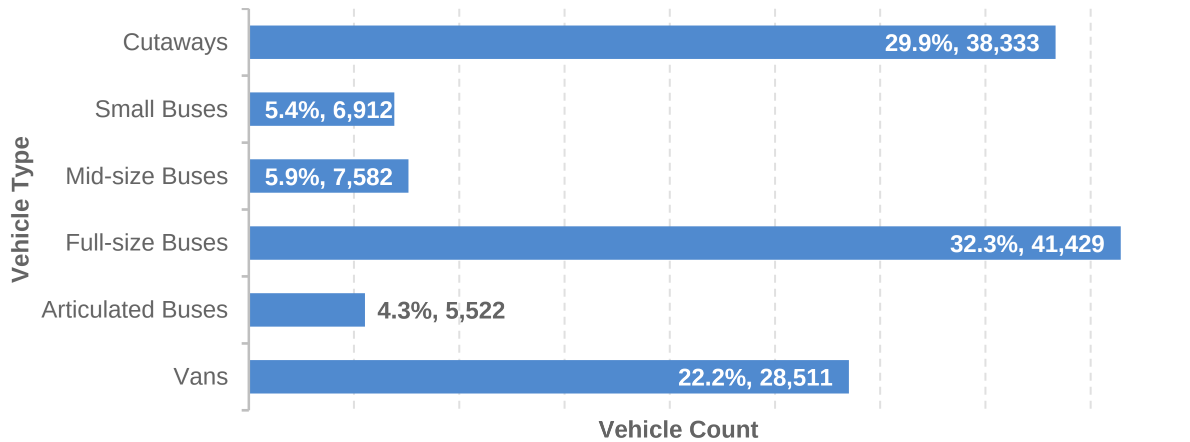
[4] Includes articulated buses, buses, double-decker buses, school buses, and over-the-road-buses.

Source: National Transit Database.

Exhibit 1-21 shows the composition of the Nation's rubber tire transit vehicle fleet as of 2016. These vehicle types serve a mix of urban and rural areas, with urban areas dominated by full-size and articulated buses and rural areas dominated by cutaways, vans, and small buses. Articulated buses are long, 60-foot vehicles that are 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 approximately 25 people. Cutaways are typically built on van chassis, and on average have a seating capacity of 15 seats. Vans, as presented here, are the familiar 10-seat passenger vans. Additional information on trends in the number and condition of these vehicles is included in Chapter 8.

Whereas *Exhibit 1-21* depicts fleet by vehicle type, *Exhibit 1-22* 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 153,000 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.

Exhibit 1-21 ■ Composition of Transit Road Vehicle Fleet, 2016



Note: There is not a one-to-one correspondence between modes and vehicle types. For instance, cutaways are used for both fixed-route bus and demand response. In addition, TERM's classification system for vehicle types differs from that used by NTD.
Sources: Transit Economic Requirements Model (TERM) and National Transit Database.

In addition to fleet counts, *Exhibit 1-22* presents the number of stations by rail and nonrail mode, with heavy rail, commuter rail, light rail and fixed route bus accounting for roughly 90 percent of the total. Despite a brief period of strong investment in the early 2000s, bus rapid transit and commuter bus stations account for only a small share of the station total. The sizes of the ADA fleet and stations are presented in Chapter 4.

Exhibit 1-22 ■ Stations and Fleet by Mode, 2016

Transit Mode	Active Vehicles	Total Stations
Rail		
Heavy Rail	11,841	1,051
Commuter Rail	7,211	1,261
Light Rail	2,129	871
Alaska Railroad	95	11
Monorail/Automated Guideway	163	60
Cable Car	39	0
Inclined Plane	6	6
Hybrid Rail	55	55
Streetcar Rail	361	132
Total Rail	**21,900**	**3,447**
Nonrail		
Bus	68,345	1,514
Demand Response	52,393	0
Vanpool	15,395	0
Ferryboat	183	132
Trolleybus	761	5
Público	2,310	0
Bus Rapid Transit	655	31
Commuter Bus	6,553	235
Demand Response – Taxi	6,534	0
Aerial Tramway	61	2
Total Nonrail	**153,190**	**1,919**
Total All Modes	**175,090**	**5,366**

Source: National Transit Database.

Track and Maintenance Facilities

Exhibit 1-23 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 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 1-24* shows, transit rail providers (including other rail and tramway providers) operated 13,094 miles of track in 2016. 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 1-23 ■ Maintenance Facilities, 2016

Maintenance Facility Type[1]	Over 1 Million	Under 1 Million and Rural Areas	Total
Heavy Rail	61	0	61
Commuter Rail	78	7	85
Light Rail	40	1	41
Hybrid Rail	6	1	7
Other Rail	8	4	12
Streetcar Rail	18	5	23
Fixed-route Bus	459	400	859
Commuter Bus	75	37	111
Bus Rapid Transit	2	1	3
Demand Response	274	281	555
Vanpool	15	8	23
Ferryboat	18	6	24
Trolleybus	4	1	5
Aerial Tramway	1	0	1
Rural Transit	11	604	615
Total Maintenance Facilities	**1,069**	**1,355**	**2,424**

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

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

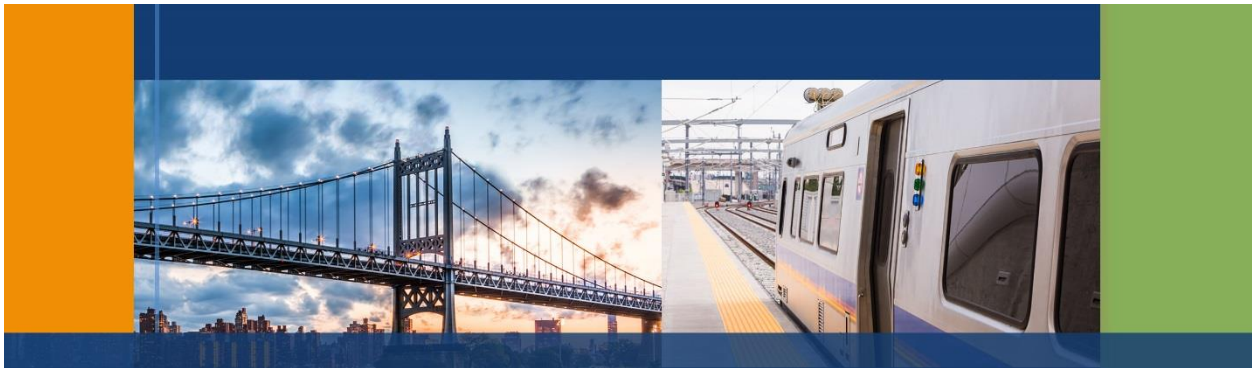
Source: National Transit Database.

Exhibit 1-24 ■ Transit Rail Mileage and Stations, 2016

Urbanized Area Track Mileage	
Heavy Rail	2,272
Commuter Rail	7,907
Light Rail	1,646
Hybrid Rail	202
Streetcar Rail	331
Other Rail and Tramway[1]	736
Total Urbanized Area Track Mileage	**13,094**
Urbanized Area Transit Rail Stations Count	
Heavy Rail	1,051
Commuter Rail	1,261
Light Rail	871
Hybrid Rail	55
Streetcar Rail	132
Other Rail and Tramway[1]	79
Total Urbanized Area Transit Rail Stations	**3,449**

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

Source: National Transit Database.



CHAPTER 2: Funding

Funding – Highways

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 in this section, 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*, which is the instructional manual for States providing financial data for the *Highway Statistics* publication.[5]

Financing for highways comes from both the public and private sectors. Although the private sector's role in the delivery of highway infrastructure has been increasing, the public sector still provides most of the funding. The financial statistics presented in this chapter are drawn predominantly from State reports based on State and local accounting systems. Figures in these accounting systems can include some private-sector investment; in these cases, the 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.

Revenues to fund construction, replacement, rehabilitation, maintenance, and other needed activities for highways and bridges are raised at all three levels of government—Federal, State, and local. Funding and expenditures across the different levels of government are closely intertwined. Most highway revenues raised at the Federal level support the Federal-aid Highway Program (FAHP), a Federally funded, State-administered program through which Federal funds are transferred primarily based on statutory formulas. Some Federal revenues are transferred to States or local governments via other means, such as discretionary grants. Direct Federal expenditures are limited to administrative and research activities plus construction and maintenance of the small share of roads and bridges owned by the Federal government. (See Chapter 1.) States also raise significant amounts of

KEY TAKEAWAYS

- Combined highway expenditures at the Federal, State, and local government levels totaled $223.2 billion in 2016.
- Revenues raised for use on highways by all levels of government totaled $272.1 billion in 2016, including a $51.9 billion one-time transfer of general funds to the Federal Highway Trust Fund (HTF).
- The amount spent on highways at all levels of government reached $223.2 billion in 2016. The largest portion, $144.6 billion (64.8 percent) was spent by States while $75.6 billion (33.9 percent) was spent by local governments.
- The $49.0 billion difference between highway revenues and highway expenditures represents the net increase during 2016 of the cash balances of the HTF plus comparable dedicated accounts at the State and local level. Without the $51.9 billion one-time transfer of general funds to the HTF, cash balances would have decreased in 2016.
- Total highway capital outlays on all systems reached $112.9 billion in 2016. Of this total, $26.4 billion (23 percent) was spent on the Interstate System, $59.2 billion (52 percent) was spent on the National Highway System (NHS), and $84.1 billion (74 percent) was spent on Federal-aid highways.
- The composition of highway capital spending shifted from 2006 to 2016. The share of highway capital spending directed toward system rehabilitation rose from 51.5 percent to 62.0 percent, the share used for system enhancement rose from 10.6 percent to 13.6 percent, and the share used for system expansion fell from 37.9 percent to 24.4 percent.
- Federal funding supported 39.7 percent of highway capital spending and 21.1 percent of total highway spending by all levels of government in 2016.
- Federally funded highway capital outlay grew by 2.6 percent per year from 2006 to 2016, compared with a 4.1-percent annual increase in capital spending funded by State and local governments.
- In recent years, some States have raised their fuel tax rates, adopted variable fuel tax rates, and increasingly explored alternative funding mechanisms.

[5] See http://www.fhwa.dot.gov/policyinformation/hss/guide/guide.pdf and http://www.fhwa.dot.gov/policyinformation/statistics.cfm. Note that both 2014 and 2016 saw transfers from the General Fund to the HTF.

revenue for use on highways, which are combined with Federal dollars to pay directly for highways and bridges, as well as to direct additional resources to local governments.

Highway Revenue and Transfer Terminology

Revenue and transfer terms used in this chapter include:

- Revenue: funds received by a government authority and intended for use on highways, including those from general fund appropriations, user charges, property taxes and assessments, investment income, and bond issue proceeds. Highway-user revenues that are used for non-highway purposes are not included.
- User Charges: taxes and fees imposed on the owners and operators of motor vehicles for their use of public highways, including motor-fuel taxes, tolls, motor-vehicle taxes, certificate-of-title fees, driver-license fees, weight-distance taxes, oversize-overweight permits, and trip permits.
- General Fund: Refers to the basic operating fund of a state, local, or the Federal government and is its chief operating fund. It records all assets and liabilities of the entity that are not assigned to a special purpose fund. Money comes into the general fund from a variety of taxes and fees levied by a governmental entity, some of which could be the same sources cited separately as other categories in the exhibits presented in this chapter. Amounts drawn from the general fund are referred to as General Fund Appropriations.
- Intergovernmental transfers: transfers of funds from one government (e.g., State, local government, or federal unit) to another. Includes Federal aid distributed from the HTF to States and local governments, State funds transferred to local governments, and local funds transferred to State governments.
- Reserves: funds that are received but not expended that same year; usually deposited into government accounts and retained there for future expenditure. This includes any funds that a State may set aside from fees or other receipts for later use and lump-sum transfers to the Highway Trust Fund intended for use over multiple years.

Exhibit 2-1 summarizes revenue and expenditure highlights for highways and bridges in 2016, the first year for which funds were authorized under the Fixing America's Surface Transportation (FAST) Act, enacted December 4, 2015. Total direct expenditures for highways and bridges in 2016 reached $223.2 billion. Total revenues for highways and bridges from all government sources totaled $272.1 billion in 2016. The $49.0 billion difference between total revenues and total expenditures represents amounts placed in reserves for use in future years; this equals the net increase during 2016 in the cash balances of the Highway Account of the HTF plus comparable dedicated accounts at the State and local level.

Total highway revenues included $117.7 billion generated from user charges, including motor fuel taxes, motor vehicle taxes and fees, and tolls. The remaining $154.5 billion was generated from a variety of other sources, or appropriated from general Federal, State, or local general revenues.

Total highway expenditures included $112.9 billion of highway capital expenditures and $95.9 billion of non-capital expenditures such as maintenance and traffic services, administration, highway and safety, and bond interest. The remaining $14.3 billion went for bond retirement.

The Federal government provided $44.2 billion to State and local governments for use on highways during 2016. Net transfers to State governments (transfers from Federal and local governments less transfers to local governments) totaled $28.7 billion, while net transfers to local governments totaled $15.5 billion.

Exhibit 2-1 ■ Summary of Government Revenue Sources and Direct Expenditures for Highways, 2016

Source	Highway Revenue, Billions of Dollars			
	Federal	State	Local	Total
User Charges[1]	$34.8	$77.5	$5.4	$117.7
Other	$54.8	$44.9	$54.8	$154.5
Total Revenues	**$89.6**	**$122.4**	**$60.1**	**$272.1**
Net Intergovernmental Transfers from (or to) Other Levels of Government	($44.2)	$28.7	$15.5	
Funds Drawn From (or Placed in) Reserves	($42.4)	($6.6)	$0.0	($49.0)
Total Transfers and Reserves Deposits/Withdrawals	**($86.6)**	**$22.1**	**$15.5**	**($49.0)**
Capital Outlay	$0.6	$84.0	$28.3	$112.9
Noncapital Expenditures	$2.3	$51.4	$42.1	$95.9
Bond Retirement	$0.0	$9.1	$5.3	$14.3
Total, All Direct Expenditures	**$3.0**	**$144.6**	**$75.6**	**$223.2**

[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 $147.2 billion in 2016.

Sources: FHWA Bulletin: Highway Funding 2013–2016, Table HF-10B, and unpublished FHWA data.

Exhibit 2-2 summarizes expenditures by level of government for 2016. Capital outlay accounted for 50.6 percent of all expenditures, whereas noncapital expenditures accounted for 43.0 percent and bond retirement accounted 6.4 percent. States accounted for 64.8 percent of total direct expenditures in 2016, local governments accounted for 33.9 percent, and the Federal government accounted for 1.3 percent (primarily on Federally owned roads).

Exhibit 2-2 ■ Direct Expenditures for Highways by Expending Agency and Type, 2016

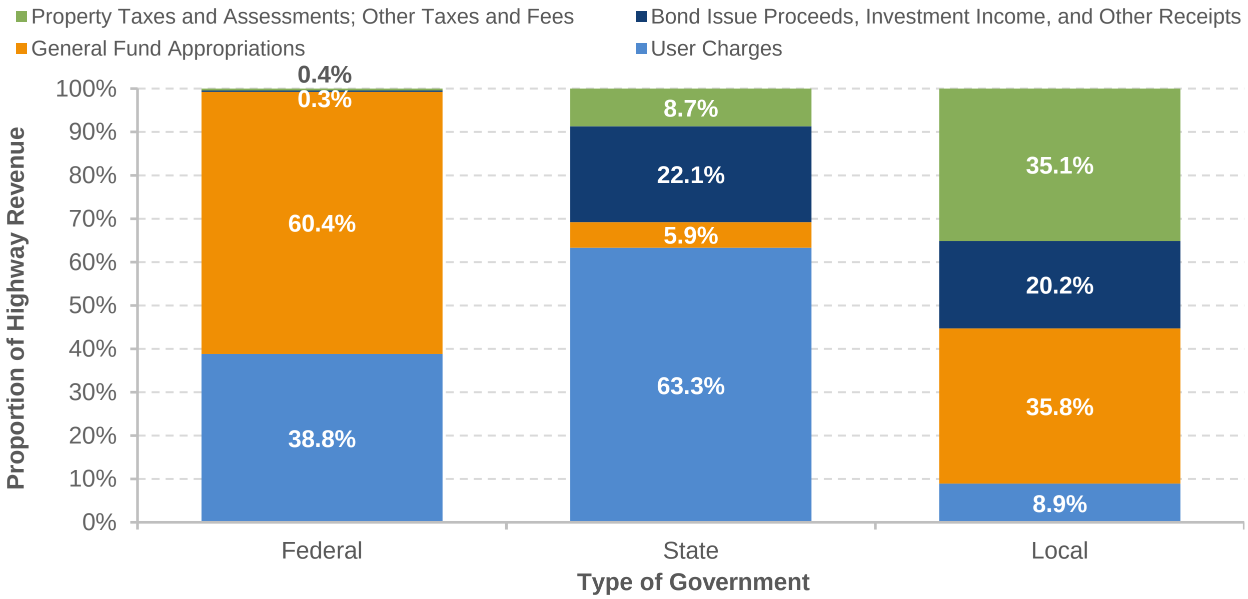
	Highway Expenditures (Billions of Dollars)				
	Federal	State	Local	Total	Percent
Expenditures by Type					
Capital Outlay	$0.6	$84.0	$28.3	$112.9	50.6%
Noncapital Expenditures	$2.3	$51.4	$42.1	$95.9	43.0%
Total, Current Expenditures	**$3.0**	**$135.5**	**$70.4**	**$208.8**	**93.6%**
Bond Retirement	**$0.0**	**$9.1**	**$5.3**	**$14.3**	**6.4%**
Total, All Expenditures	**$3.0**	**$144.6**	**$75.6**	**$223.2**	**100.0%**
Percent of Total	*1.3%*	*64.8%*	*33.9%*	*100.0%*	

Sources: FHWA Bulletin: Highway Funding 2013–2016, Table HF-10B, and unpublished FHWA data.

Revenue Sources for Highways

Revenues intended for highway and bridge construction, operations, and maintenance are raised at the Federal, State, and local levels of government. Revenues come from user charges (motor fuel taxes, motor vehicle taxes and fees, and tolls) and other sources, such as General Fund appropriations, other taxes, investment income, and debt financing (see *Exhibit 2-3*).

Exhibit 2-3 ■ Government Revenue Sources for Highways, 2016



Source	Highway Revenue, Billions of Dollars				
	Federal	**State**	**Local**	**Total**	**Percent**
User Charges[1]					
Motor Fuel Taxes	$29.1	$35.4	$1.0	$65.5	24.1%
Motor Vehicle Taxes and Fees	$5.7	$29.9	$2.0	$37.7	13.8%
Tolls	$0.0	$12.2	$2.3	$14.5	5.3%
Subtotal	**$34.8**	**$77.5**	**$5.4**	**$117.7**	**43.2%**
Other					
General Fund Appropriations[2]	$54.1	$7.2	$21.5	$82.8	30.4%
Property Taxes and Assessments	$0.0	$0.0	$12.7	$12.7	4.7%
Other Taxes and Fees	$0.4	$10.6	$8.4	$19.4	7.1%
Investment Income and Other Receipts[3]	$0.3	$12.2	$6.3	$18.8	6.9%
Bond Issue Proceeds	$0.0	$14.9	$5.8	$20.7	7.6%
Subtotal	**$54.8**	**$44.9**	**$54.8**	**$154.5**	**56.8%**
Total Revenues	**$89.6**	**$122.4**	**$60.1**	**$272.1**	**100.0%**

[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 $147.2 billion in 2016.

[2] The $54.1 billion shown for Federal includes $51.9 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 $0.3 billion figure shown for Federal includes $0.1 billion transferred from the balance of the Leaking Underground Storage Tank Fund to the Highway Account of the Highway Trust Fund.

Sources: FHWA Bulletin: Highway Funding 2013–2016, Table HF-10B, and unpublished FHWA data.

Highway Expenditure Terminology

Definitions for expenditure category types discussed in this chapter are:

- Capital outlay: funds used to purchase a fixed highway asset or to extend its useful life; these highway improvements can include 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).

The $54.1 billion of Federal General Fund appropriations includes $51.9 billion transferred from the General Fund to the Highway Account of the HTF, as per the FAST Act. This one-time General Fund transfer to the HTF represents approximately 95.9 percent of total Federal General Fund appropriations for highways in 2016 and 57.9 percent of total Federal revenue for the year. Although the FAST Act authorized federal highway and public transportation programs through September 30, 2020, the entire $51.9 billion specified for the Highway Account was transferred at one time.

In addition to General Fund appropriations, bond issue proceeds ($20.7 billion) and investment income and other receipts ($18.8 billion) were among the largest sources of revenue, reflecting the use of alternative funding sources in recent years.

In addition to Federal funding from the HTF, States use a variety of revenue sources to support their transportation expenditures—including State fuel taxes, vehicle fees, sales taxes, tolls, mode-specific revenues, road pricing, cigarette taxes, and State lotteries. The investment income and other receipts category in *Exhibit 2-3* 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.

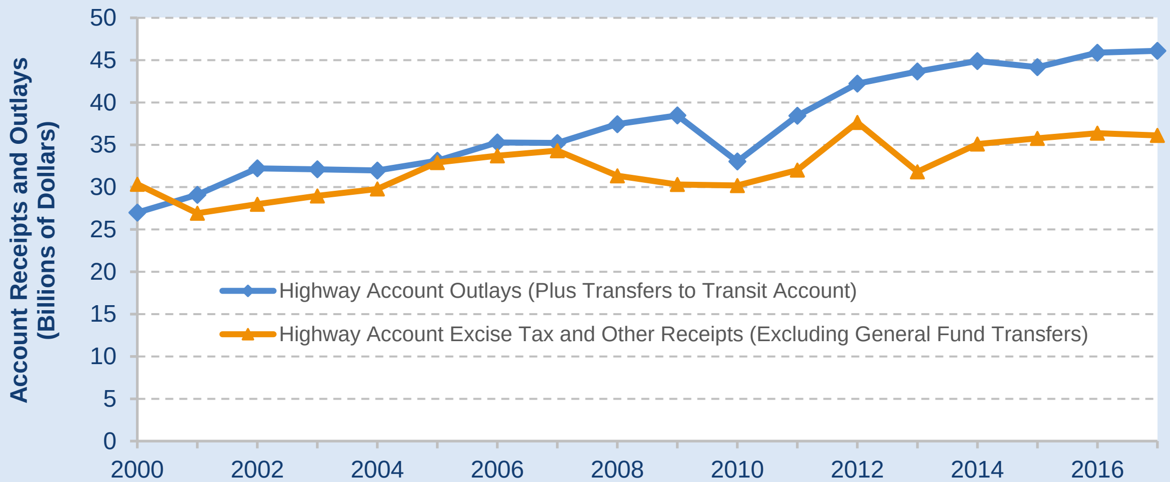
Exhibit 2-3 also shows that the types and relative proportions of revenues used to fund highways vary significantly by level of government, with States generating most of their revenue via dedicated user charges and local governments getting a large portion of their revenues from annual General Fund appropriations. Sixty-three percent of State government revenues ($77.5 billion) for highways and bridges were raised via user charges, mostly from States' motor fuel taxes ($35.4 billion) and motor vehicle taxes and fees ($29.9 billion).

HTF Highway Account Excise Tax Receipts and Expenditures

The last time that annual net highway excise tax and related receipts credited to the Highway Account of the HTF exceeded annual expenditures from the Highway Account was in 2000. As shown in *Exhibit 2-4*, 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 from the Highway Account to the Transit Account). (Note that the HTF Highway Account receipts and outlays shown in *Exhibit 2-4* do not include transfers from the General Fund, such as the $51.9 billion transferred in 2016.) In the years 2005 through 2007, annual net receipts nearly reached the same amount as annual expenditures. The growth of outlays then outpaced increases in revenue, and in 2016 net receipts were equivalent to approximately three-fourths of outlays that year ($36.1 billion vs. $46.1 billion)

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, 2014, and 2016. In Fiscal Years 2012, 2014, and 2016, 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 2-4 ■ Highway Trust Fund Highway Account Receipts and Outlays, Fiscal Years 2000–2017



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

In contrast, the largest portions of local governments' $60.1 billion in revenue came from General Fund appropriations ($21.5 billion; 35.8 percent of the total raised by local governments), followed by property taxes and assessments ($12.7 billion), and other taxes and fees ($8.4 billion). Meanwhile, in 2016 the largest portion of Federal government revenues raised was from General Fund appropriations, which accounted for nearly two-thirds of the total (60.4 percent or $54.1 billion); Federal motor fuel taxes accounted for another $29.1 billion. Of the $89.6 billion raised by the Federal Government, $42.4 billion was placed in reserves. State governments also placed some monies into reserves—$6.6 billion (see *Exhibit 2-1*).

State Fuel Taxes

In recent decades, fuel tax revenues 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 taxes to change over time. Some of these taxes are periodically adjusted based on a measure of inflation, whereas others are calculated as a percentage of wholesale or retail fuel prices, or by some other criterion. In its 2016 report, the American Association of State Highway and Transportation Officials (AASHTO) reported that 19 States used variable-rate fuel taxes, and 10 States used a combination of fixed-rate and variable-rate fuel taxes to fund transportation. According to AASHTO's 2016 report, 42 States used passenger vehicle fees, 42 States used truck registration fees, and 18 used tolls to raise revenues for transportation investment.

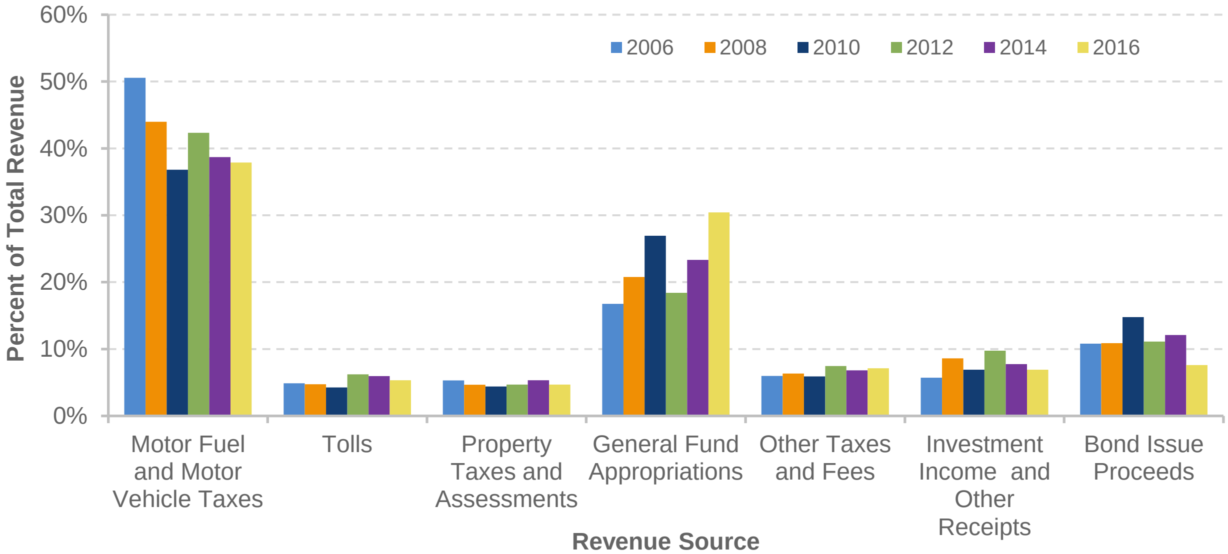
At the same time, State legislative activity with respect to transportation funding has increased. The National Conference of State Legislatures (NCSL) reports that in 2017, seven States (California, Indiana, Montana, South Carolina, Oregon, Tennessee, and West Virginia) had passed legislation to increase fuel taxes. One State (New Jersey) enacted legislation to increase State fuel taxes in 2016, eight States (Georgia, Idaho, Iowa, Michigan, Nebraska, South Dakota, Utah, and Washington) passed legislation to increase fuel taxes in 2015, and 10 more raised their gas tax or adjusted their formula between 2013 and 2015. In contrast, no State legislature approved an increase to fuel taxes in 2010, 2011, or 2012. (See http://www.ncsl.org/research/transportation/2013-and-2014-legislative-actions-likely-to-change-gas-taxes.aspx.)

Revenue Trends

From 2006 to 2016, total revenues for highways across all levels of government increased at an annual rate of 4.9 percent. *Exhibit 2-5* presents the trends in revenues used for highways by source for all levels of government over the past 10 years. The largest rate of increase during that time came from General Fund appropriations, which grew by an annual average rate of 11.3 percent, bolstered by the FAST Act's $51.9 billion one-time transfer recorded in 2016. Meanwhile, user fees overall increased by an annual rate of 2.3 percent, with tolls increasing at a higher rate than motor fuel and motor vehicle taxes (5.8 percent vs. 1.9 percent) but by a lesser dollar amount (from $14.4 billion to $14.5 billion for tolls; from $93.4 billion to $103.1 billion for motor vehicle taxes). Revenues from investment income and other receipts as well as other taxes and fees increased at a greater annual rate than the overall 4.9 percent revenue increase, by 6.9 percent and 6.8 percent, respectively. In contrast, revenues raised from property taxes/assessments and from bond issue proceeds grew comparatively slowly during this period at 3.6 percent and 1.2 percent, respectively.

The graph at the top of *Exhibit 2-5* shows the percentage share of each funding source by year for 2006–2016. It demonstrates that a relatively steady percentage of revenues came from tolls, property taxes/assessments, and other taxes and fees during that time, whereas the portion of revenues coming from General Fund appropriations varied significantly and the portion from motor fuel and motor vehicle taxes generally declined.

Exhibit 2-5 ■ Government Revenue Sources for Highways, 2006–2016



Source	Highway Revenue, Billions of Dollars						Annual Rate of Change 2016/2006
	2006	2008	2010	2012	2014	2016	
Motor Fuel and Motor Vehicle Taxes	$85.4	$84.7	$84.1	$91.5	$93.4	$103.1	1.9%
Tolls	$8.3	$9.1	$9.7	$13.5	$14.4	$14.5	5.8%
Subtotal: User Fees	**$93.7**	**$93.8**	**$93.8**	**$104.9**	**$107.8**	**$117.7**	**2.3%**
Property Taxes and Assessments	$9.0	$9.0	$10.1	$10.1	$12.8	$12.7	3.6%
General Fund Appropriations	$28.3	$40.0	$61.5	$39.8	$56.3	$82.8	11.3%
Other Taxes and Fees	$10.1	$12.2	$13.5	$16.1	$16.4	$19.4	6.8%
Investment Income and Other Receipts	$9.7	$16.6	$15.8	$21.1	$18.7	$18.8	6.9%
Bond Issue Proceeds	$18.3	$20.9	$33.7	$24.0	$29.2	$20.7	1.2%
Total Revenues	**$169.0**	**$192.6**	**$228.3**	**$216.1**	**$241.3**	**$272.1**	**4.9%**

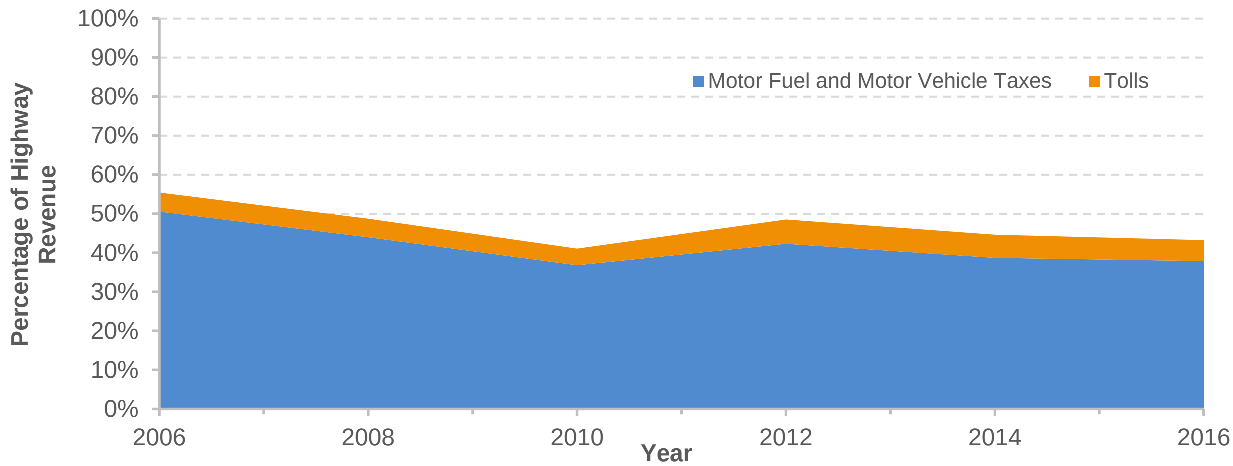
Sources: FHWA Bulletin: Highway Funding 2013–2016, Table HF-10B; Highway Statistics, various years, Table HF-10A.

In the most recent years, between 2014 and 2016, total revenues raised grew from $241.3 billion to $272.1 billion, driven mainly by a jump from $56.3 billion to $82.8 billion in General Fund appropriations and supported by an increase in revenues from motor fuel and motor vehicle taxes from $93.4 billion to $103.1 billion.[6] The amount of revenue raised increased or remained steady in each category except bond issue proceeds, which fell from $29.2 billion to $20.7 billion.

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. The share of revenues from user charges declined from more than 55 percent in 2006 to around 43 percent in 2016. *Exhibit 2-6* shows the share of highway revenue derived from user charges from 2006 to 2016. Revenues from user charges declined steadily from 2006 to 2010, then increased in 2012 before resuming their decline.

[6] Note that both 2014 and 2016 saw transfers from the General Fund to the HTF.

Exhibit 2-6 ■ Percentage of Highway Revenue Derived from User Charges, 2006–2016, All Units of Government



Source: FHWA Bulletin: Highway Funding 2013–2016, Table HF-10B, and unpublished FHWA data.

Highway Expenditures

As noted in *Exhibit 2-2*, highway expenditures by all levels of government totaled $223.2 billion in 2016; $144.6 billion (64.8 percent of the total) was spent by States, $75.6 billion (33.9 percent) was spent by local governments, and $3.0 billion (1.3 percent) was direct Federal spending. Although the Federal government funded $47.2 billion of highway expenditures in 2016 (*Exhibit 2-7*), direct Federal spending (capital outlay, maintenance, administration, and research) was only $3.0 billion. The remaining was transferred to State and local governments.

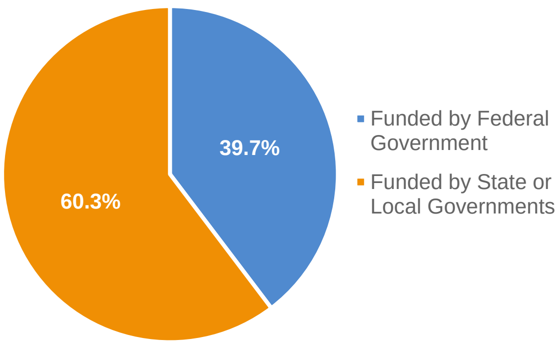
Exhibit 2-7 breaks down the total Federal, State, and local expenditures by type and level of government. The rows "Funding Sources for Capital Outlay" and "Funding Sources for Total Expenditures" in *Exhibit 2-7* indicate the level of government that provided the funding for those expenditures. These expenditures represent cash outlays, not authorizations or obligations of funds. (The terms "expenditures," "spending," and "outlays" are used interchangeably in this report.) Most of the funding for capital outlays came from State or local governments; they provided $68.1 billion of the $112.9 billion total, equivalent to 60.3 percent. Most of the Federal government's $3.0 billion in direct expenditures (i.e., the money spent directly on roads by the Federal government, and not transferred to States or placed in reserves, as presented in *Exhibit 2-1*) were for noncapital expenditures ($2.3 billion; see *Exhibit 2-1*).

State governments combined $42.4 billion in Federal funds, $98.7 billion in State funds, and $3.5 billion in local funding sources to support direct expenditures of $144.6 billion (64.8 percent of all highway expenditures). Local governments directly spent $1.8 billion of Federal funds, $17.2 billion of State funds, and $56.6 billion of local funds on highways, totaling $75.6 billion (33.9 percent of all highway expenditures).

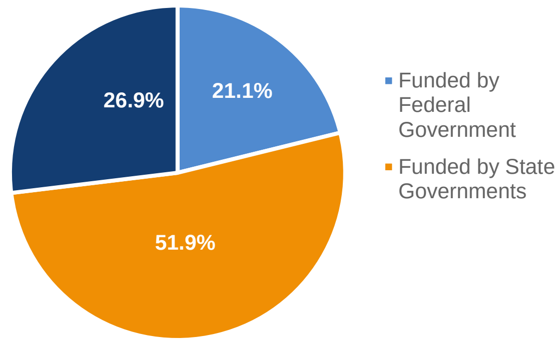
Most Federal funds pay for capital outlays, whereas States direct their highway and bridge funds more broadly. In 2016, $44.8 billion in capital outlays originated from Federal funds, most of which ($42.4 billion) was expended by State governments (*Exhibit 2-7*). Total expenditures (capital outlays plus noncapital expenditures) funded by the Federal government were $47.2 billion, meaning that only $2.4 billion in Federal funding went to noncapital expenditures. In 2016, funds from State or local governments for capital outlays reached $68.1 billion, but total expenditures funded by State or local governments reached $176.0 billion ($115.9 billion and $60.1 billion, respectively). The Federally funded share of highway capital spending was 39.7 percent in 2016, whereas the Federally funded share of total highway spending was 21.1 percent.

Exhibit 2-7 ■ Direct Expenditures for Highways by Expending Agency and Type, 2016

Funding Sources for Capital Outlay



Funding Sources for Total Expenditures



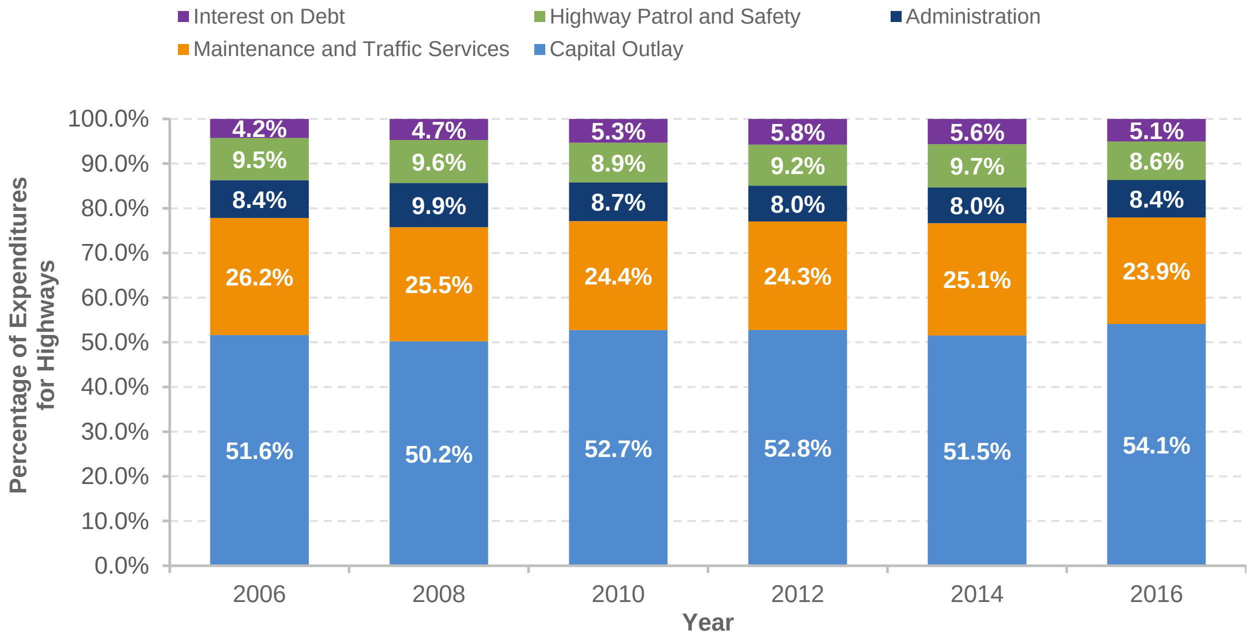
	Highway Expenditures (Billions of Dollars)				
	Federal	**State**	**Local**	**Total**	**Percent**
Funding Sources for Capital Outlay					
Funded by Federal Government	$0.6	$42.4	$1.8	$44.8	39.7%
Funded by State or Local Governments	$0.0	$41.7	$26.4	$68.1	60.3%
Total	**$0.6**	**$84.1**	**$28.2**	**$112.9**	**100.0%**
Funding Sources for Total Expenditures					
Funded by Federal Government	$3.0	$42.4	$1.8	$47.2	21.1%
Funded by State Governments	$0.0	$98.7	$17.2	$115.9	51.9%
Funded by Local Governments	$0.0	$3.5	$56.6	$60.1	26.9%
Total	**$3.0**	**$144.6**	**$75.6**	**$223.2**	**100.0%**

Sources: FHWA Bulletin: Highway Funding 2013–2016, Table HF-10B, and unpublished FHWA data.

Historical Expenditure and Funding Trends

All highway expenditures have grown at an annual rate of 3.2 percent (3.0 percent growth for current expenditures) in the 10-year period from 2006 to 2016 for all levels of government. (Note that this represents growth in nominal dollar terms; see the Constant-dollar Expenditures section below for a discussion of inflation-adjusted expenditure trends). *Exhibit 2-8* breaks out these expenditures since 2006 by type for all levels of government. Total expenditures by major expenditure type have increased at similar rates over the course of that time, with those types related to debt service increasing at slightly higher annual rates. Expenditures directed to bond retirement increased by 5.9 percent annually and payments for interest on debt increased by 4.8 percent annually between 2006 and 2016. The other type categories (maintenance and traffic services, administration, highway patrol and safety) increased at annual rates of between 2.0 and 2.9 percent. Capital outlays have remained near 50 percent of current expenditures since 2006, with a slight increase in 2016, as illustrated in the stacked bar chart at the top of *Exhibit 2-8*, increasing by 3.5 percent per year during the 10-year period.

Exhibit 2-8 ■ Expenditures for Highways by Type, All Units of Government, 2006–2016

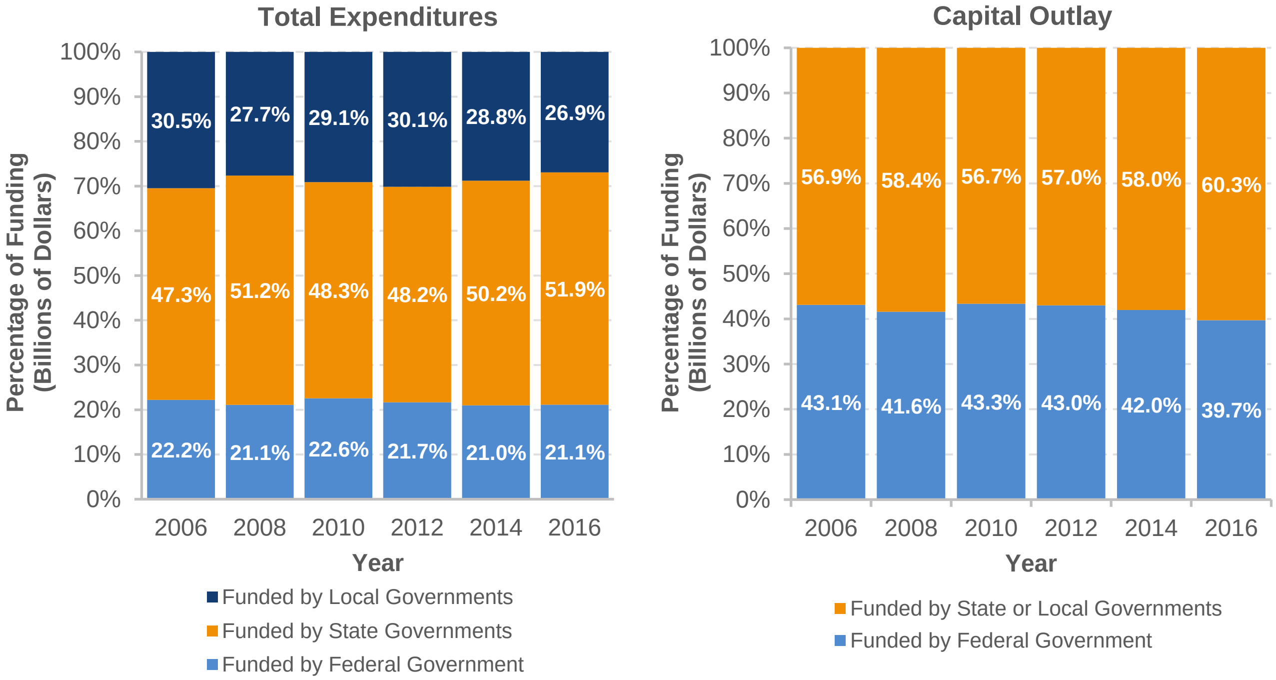


	Highway Expenditures, Billions of Dollars						Annual Rate of Change 2016/2006
	2006	2008	2010	2012	2014	2016	
Expenditure Type							
Capital Outlay	$80.2	$90.4	$100.0	$105.3	$105.4	$112.9	3.5%
Maintenance and Traffic Services	$40.8	$45.9	$46.3	$48.5	$51.4	$49.8	2.0%
Administration	$13.1	$17.8	$16.5	$16.0	$16.4	$17.5	2.9%
Highway Patrol and Safety	$14.7	$17.3	$16.8	$18.3	$19.8	$18.0	2.0%
Interest on Debt	$6.6	$8.5	$10.1	$11.5	$11.5	$10.6	4.8%
Total, Current Expenditures	**$155.5**	**$180.0**	**$189.7**	**$199.5**	**$204.6**	**$208.8**	**3.0%**
Bond Retirement	**$8.1**	**$8.6**	**$14.6**	**$18.9**	**$17.9**	**$14.3**	**5.9%**
Total, All Expenditures	**$163.5**	**$188.5**	**$204.3**	**$218.4**	**$222.6**	**$223.2**	**3.2%**

Sources: FHWA Bulletin: Highway Funding 2013–2016, Table HF-10B; Highway Statistics, various years, Table HF-10A.

The portion of total expenditures and of all capital outlays funded by State and local governments has increased faster than those funded by the Federal government between 2006 and 2016 (see *Exhibit 2-9*). Total expenditures funded by State governments increased at an average annual rate of 4.1 percent since 2006, whereas total federally funded expenditures increased by 2.6 percent and total expenditures funded by local governments increased by 1.9 percent. Growth in capital outlays followed similar patterns, increasing at an annual average rate of 4.1 percent for State and local government expenditures combined, and increasing by 2.6 percent for federally funded expenditures.

Exhibit 2-9 ■ Funding for Highways by Level of Government, 2004–2016



	Highway Funding, Billions of Dollars						Annual Rate of Change 2016/2006
	2006	2008	2010	2012	2014	2016	
Capital Outlay							
Funded by Federal Government	$34.6	$37.6	$43.3	$45.3	$44.2	$44.8	2.6%
Funded by State or Local Governments	$45.6	$52.8	$56.7	$60.0	$61.2	$68.1	4.1%
Total	**$80.2**	**$90.4**	**$100.0**	**$105.3**	**$105.4**	**$112.9**	**3.5%**
Federal Share	*43.1%*	*41.6%*	*43.3%*	*43.0%*	*42.0%*	*39.7%*	
Total Expenditures							
Funded by Federal Government	$36.3	$39.8	$46.1	$47.3	$46.7	$47.2	2.6%
Funded by State Governments	$77.4	$96.6	$98.7	$105.2	$111.8	$115.9	4.1%
Funded by Local Governments	$49.8	$52.2	$59.5	$65.8	$64.1	$60.1	1.9%
Total	**$163.5**	**$188.5**	**$204.3**	**$218.4**	**$222.6**	**$223.2**	**3.2%**
Federal Share	*22.2%*	*21.1%*	*22.6%*	*21.7%*	*21.0%*	*21.1%*	

Sources: FHWA Bulletin: Highway Funding 2013–2016, Table HF-10B; Highway Statistics, various years, Table HF-10A.

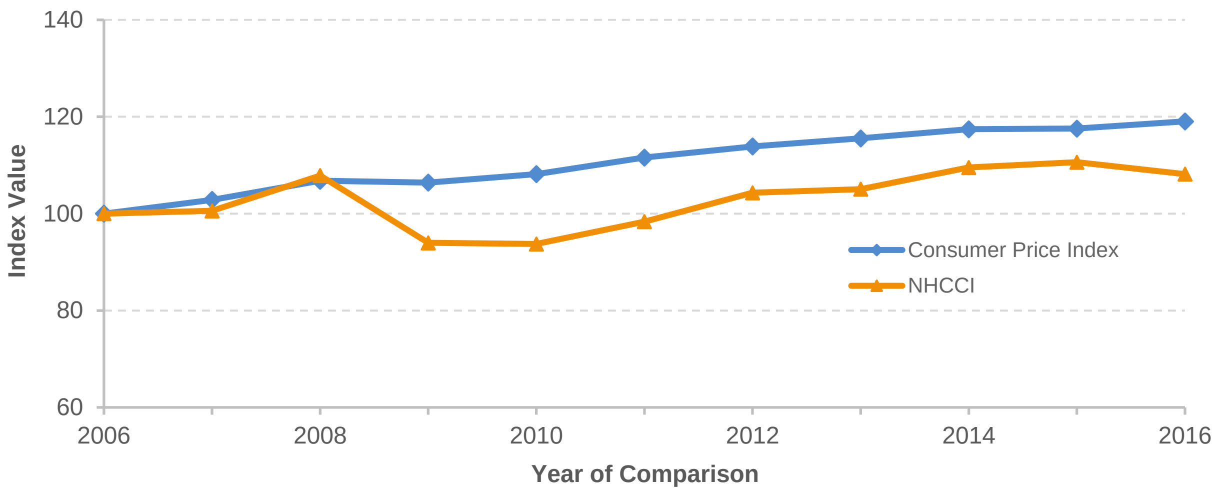
Although the Federal share of funding for capital outlays has decreased slightly (from 43.1 percent in 2006 to 39.7 percent in 2016) it remains nearly double the Federal share of total expenditures (which has fluctuated slightly between 21.0 percent and 22.6 percent). The stacked graphs at the top of *Exhibit 2-9* present funding by level of government between 2006 and 2016.

Constant-dollar Expenditures

When comparing costs and expenditures over time, the general increase in prices and the decrease in the purchasing value of money need to be considered. This report uses different indices for converting nominal-dollar (current year) highway spending to constant dollars for capital and noncapital 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. 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.

Exhibit 2-10 illustrates the trends in cost indices used in the report, converted to a common base year of 2006. Over the 10-year period from 2006 to 2016, the Consumer Price Index increased significantly more than the increase in the NHCCI (119.1 vs. 108.2).

Exhibit 2-10 ■ Comparison of Inflation Indices (Converted to a 2006 Base Year), 2006–2016



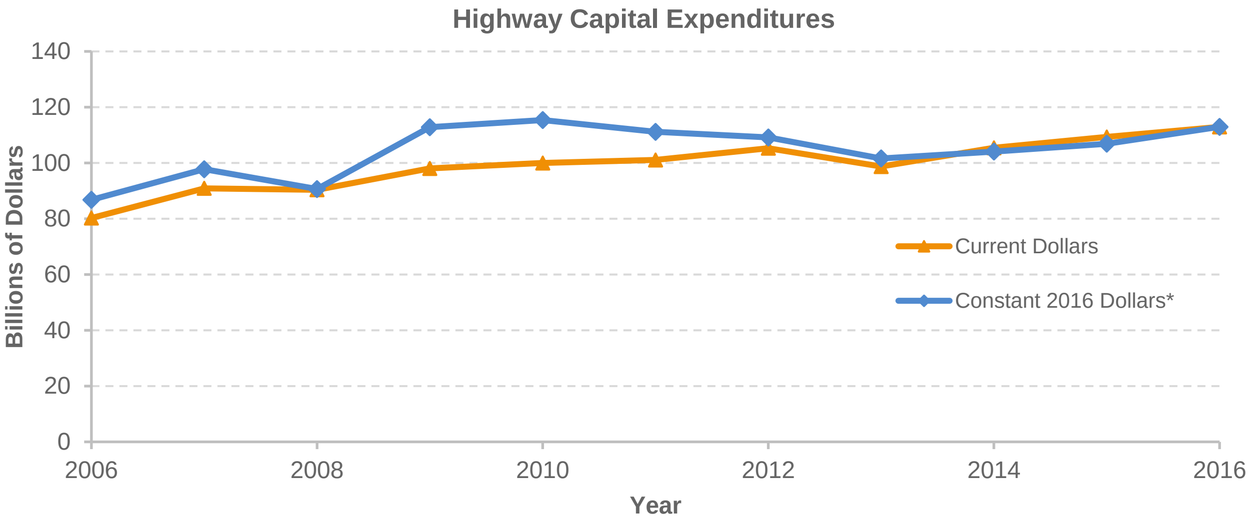
Note: To facilitate comparisons of trends from 2006 to 2016, each index was mathematically converted so that its value for the year 2006 would be equal to 100.

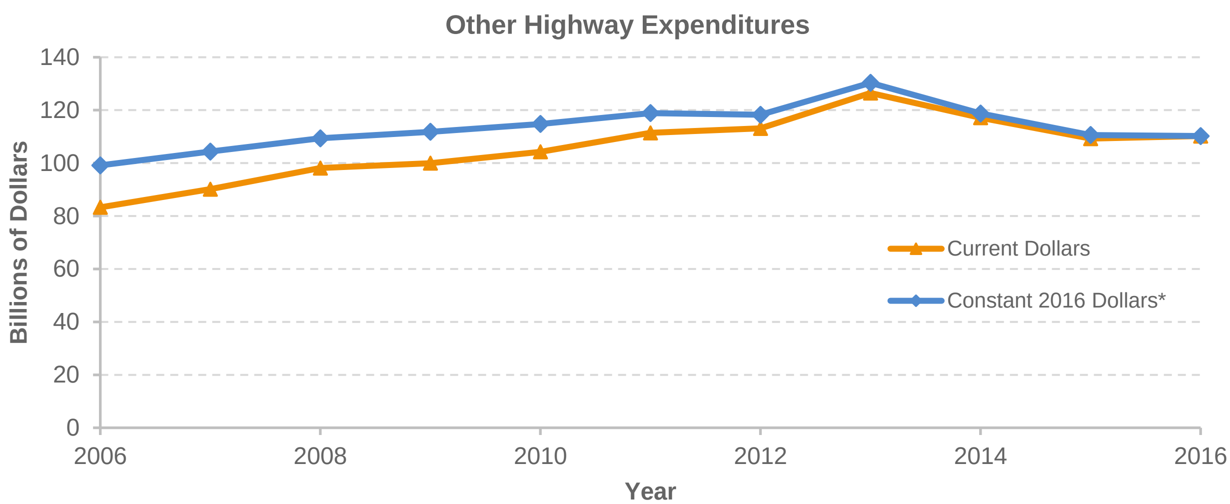
Sources: FHWA Highway Statistics, various years, Table PT-1 (http://www.bls.gov/cpi/).

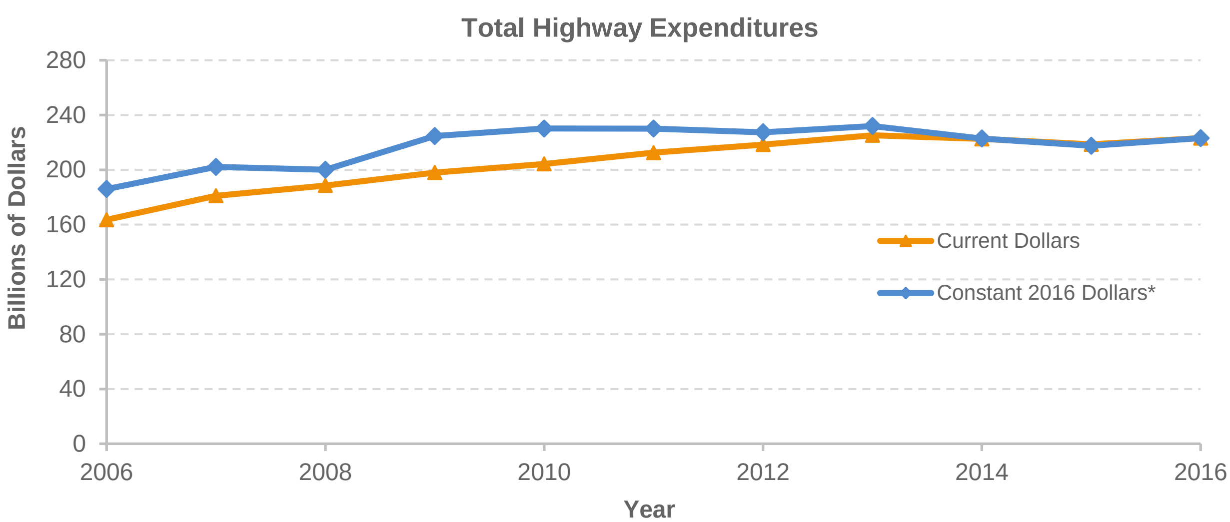
In addition, the indices behaved differently. Whereas the Consumer Price Index rose steadily each year from 2006 to 2016, the NHCCI fluctuated significantly. Sharp increases in the prices of materials such as steel, asphalt, and cement caused NHCCI to increase up through 2008. Highway construction prices as measured by NHCCI then declined dramatically from 2008 to 2009, remained fairly flat in 2010, and then resumed an upward trend. Despite recent increases, the NHCCI has remained below the Consumer Price Index since 2009.

Exhibit 2-11 displays time-series data on highway expenditures in both current (nominal) and constant (real) 2016 dollars. Total highway expenditures in current dollars have generally increased since 2006, reaching $223.2 billion in 2016. However, in constant 2016 dollar terms, total highway expenditures have remained relatively flat since 2009. In current dollars, total highway expenditures increased by more than a third between 2006 and 2016 (from $163.5 billion to $223.2 billion, see *Exhibit 2-8*). Total noncapital (other) expenditures grew similarly by about 32 percent in current dollars (from $83.3 billion to $110.3 billion), and capital expenditures grew by approximately 41 percent during the same period (from $80.2 billion to $112.9 billion).

Exhibit 2-11 ■ Highway Capital, Noncapital, and Total Expenditures in Current and Constant 2016 Dollars, All Units of Government, 2006–2016







Note: 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/).

When expressed in constant 2016 dollars, the growth in total highway expenditures between 2006 and 2016 was 20 percent overall, and the values in constant and current dollars grew steadily and did not vary much as they converged in 2016. Capital expenditures, on the other hand, fluctuated when expressed in constant 2016 dollars from 2006 to 2009, and declined from 2010 to 2016, reflecting the fluctuations in the NHCCI.

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 $71.4 billion in 2016, drawing on a combination of State revenues, transfers from the Federal government, and transfers from local governments. These can be seen in *Exhibit 2-12*.

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). Therefore, *Exhibit 2-13* presents an estimated distribution by broad categories of improvement types for the total $112.9 billion invested in 2016 on all systems, extrapolating from the available detailed data on the $71.4 billion of State expenditures on arterials and collectors. For this estimation, 17 highway capital improvement types have been allocated among three broad categories: system rehabilitation, system expansion, and system enhancement, as shown in *Exhibit 2-12*. 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.

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.

As previously noted, direct State expenditures on arterials and collectors totaled $71.4 billion in 2016. The highway capital improvement type with the largest amount of direct State expenditures on arterials and collectors in 2016 was $21.4 billion for restoration and rehabilitation (30.0 percent of the total); the second largest was engineering ($8.7 billion).

Exhibit 2-12 ■ State Highway Capital Outlay on Arterials and Collectors by Improvement Type, 2016

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[1]					
Right-of-Way		$1.6	$2.1		**$3.8**
Engineering	$5.7	$0.9	$1.2	$0.9	**$8.7**
New Construction		$4.9			**$4.9**
Relocation			$0.8		**$0.8**
Reconstruction—Added Capacity	$1.9		$4.4		**$6.3**
Reconstruction—No Added Capacity	$5.1				**$5.1**
Major Widening			$2.5		**$2.5**
Minor Widening	$0.9				**$0.9**
Restoration and Rehabilitation	$21.4				**$21.4**
Resurfacing	$0.0				**$0.0**
New Bridge		$1.1			**$1.1**
Bridge Replacement	$5.5				**$5.5**
Major Bridge Rehabilitation	$0.5				**$0.5**
Minor Bridge Work	$3.6				**$3.6**
Safety				$2.6	**$2.6**
Traffic Management/Engineering				$1.1	**$1.1**
Environmental and Other				$2.5	**$2.5**
Total, State Arterials and Collectors	**$44.6**	**$8.5**	**$11.1**	**$7.2**	**$71.4**

[1] Improvement type distribution estimated based on 2014 data; 2015 and 2016 data were not available at time of report preparation.
Sources: Highway Statistics 2014, Table SF-12A, and unpublished FHWA data.

Of the $112.9 billion in total highway capital outlay on all systems, an estimated $70.0 billion (62.0 percent) was used for system rehabilitation, $27.6 billion (24.4 percent) was used for system expansion, and $15.3 billion (13.6 percent) was used for system enhancement (see *Exhibit 2-13*). Direct State expenditures on arterials and collectors accounted for more than half of total expenditures ($71.4 billion of $112.9 billion total).

Exhibit 2-13 ■ Estimated Highway Capital Outlay by Improvement Type, 2016

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[1]					
Highways and Other	$35.1	$7.4	$11.1	$7.2	$60.7
Bridges	$9.6	$1.1	$0.0	$0.0	$10.6
Total, Arterials and Collectors	**$44.6**	**$8.5**	**$11.1**	**$7.2**	**$71.4**
Total, Arterials and Collectors, All Jurisdictions (Estimated)[2]					
Highways and Other	$41.4	$9.1	$13.2	$9.5	$73.1
Bridges	$11.7	$1.3			$13.1
Total, Arterials and Collectors	**$53.1**	**$10.4**	**$13.2**	**$9.5**	**$86.2**
Total Capital Outlay on All Systems (Estimated)[1]					
Highways and Other	$54.6	$11.8	$14.0	$15.3	$95.8
Bridges	$15.4	$1.7			$17.2
Total, All Systems	**$70.0**	**$13.6**	**$14.0**	**$15.3**	**$112.9**
Percent of Total	62.0%	12.0%	12.4%	13.6%	100.0%

[1] Improvement type distribution was estimated based on 2014 data; 2015 and 2016 data were not available at time of report preparation.
[2] Improvement type distribution was estimated based on State arterial and collector data.
Sources: Highway Statistics 2014, Table SF-12A, and unpublished FHWA data.

Exhibit 2-13 Estimation Procedures

Exhibit 2-13 reflects three types of estimates, one for 2014 State government capital expenditures on local functional class roads off the National highway system, another for 2014 direct local government and Federal government capital expenditures, and a third for converting 2014 values to 2016 values.

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.

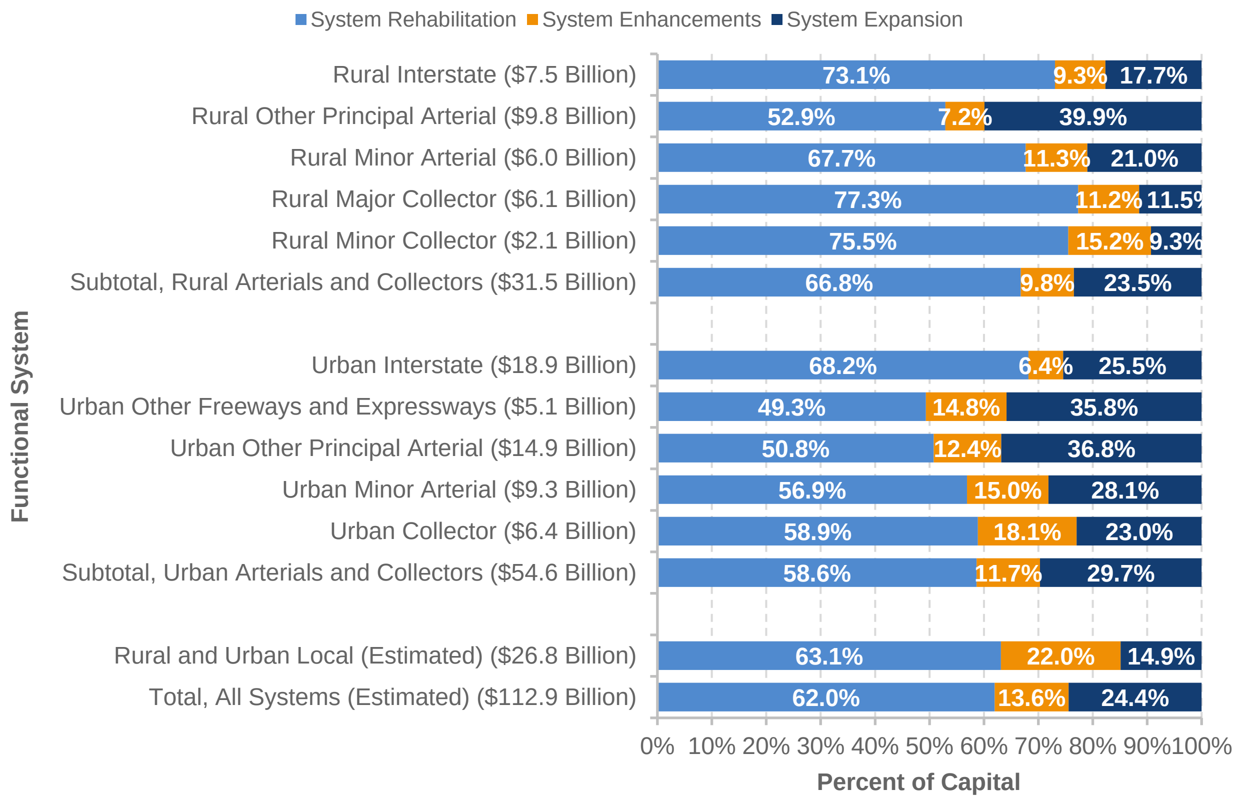
For direct local government expenditures and direct Federal government expenditures, the distribution of capital expenditure by improvement type off the NHS is assumed to be the same as that reported by States for each individual functional class. The share of local and Federal capital expenditures on the NHS and distribution of capital expenditure by improvement type on the NHS are 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.

The conversion from 2014 values to 2016 values was accomplished by multiplying the 2014 percentage distributions described above by estimated values for total 2016 capital outlay at the Federal, State, and local levels. (The same approach was used to convert 2014 values to 2016 values for *Exhibit 2-12,* and for *Exhibits 2-14* through *2-20* as well.)

Highway funds are expended across a range of functional systems. *Exhibit 2-14* shows the distribution of capital expenditures by type and functional system. In 2016, $31.5 billion was invested on rural arterials and collectors, with 66.8 percent of those funds directed to system rehabilitation, and 23.5 percent to expansion; the remainder was directed to system enhancement. Capital outlays on urban arterials and collectors totaled $54.6 billion, of which 58.6 percent was for system rehabilitation and 29.7 percent was for system expansion.

The proportion of funds for system rehabilitation vs. system expansion varied the most among rural arterials and collectors. Among the individual functional systems, rural major collectors had the highest percentage of highway capital outlay directed to system rehabilitation (77.3 percent), whereas urban other freeways and expressways had the lowest percentage directed for that purpose (49.3 percent). The largest portion of capital outlays for expansion occurred on rural other principal arterials; the smallest amount on rural minor collectors.

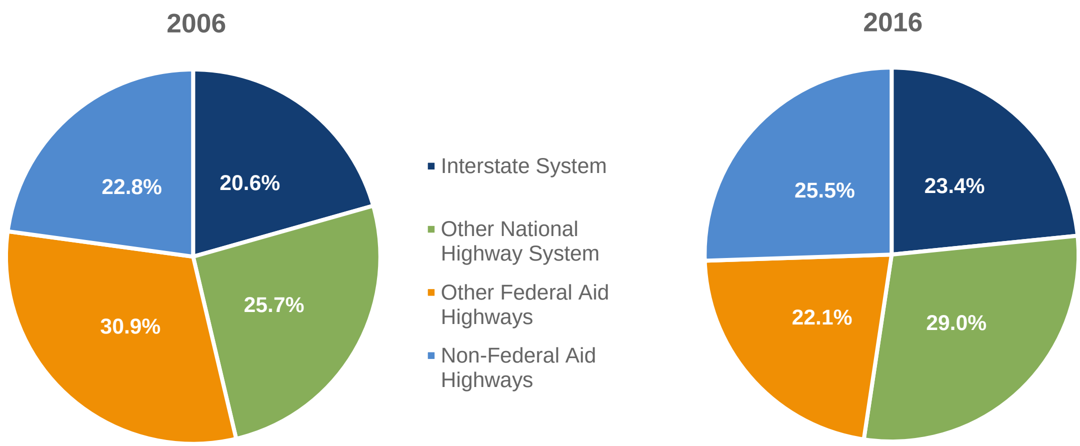
Exhibit 2-14 ■ Distribution of Capital Outlay by Improvement Type and Functional System, 2016



Note: The data for 2016 were estimated based on 2014 data; 2015 and 2016 data were not available at time of report preparation.
Sources: Highway Statistics 2014, Table SF-12A, and unpublished FHWA data.

Most highway capital outlays are made to build, expand, or improve Federal-aid highways ($61.9 billion out of $80.2 billion in 2006, increasing to $84.1 billion out of $112.9 billion in 2016), and the majority of those capital outlays are expended on the NHS ($37.2 billion in 2006, increasing to $59.2 billion in 2016), as shown in *Exhibit 2-15*. About half of capital outlays on the NHS in both 2006 and 2016 were for Interstates. In 2006, Other NHS roads comprised 25.7 percent ($20.6 billion) of total capital outlays, increasing to 29.0 percent ($32.7 billion) in 2016. Non-Federal-aid highways comprised 22.8 percent ($18.3 billion) of total expenditures in 2006 and 25.5 percent ($28.8 billion) in 2016. The only category showing a decrease in the percentage of total capital outlays between 2006 and 2016 was Other Federal-aid highways, which comprised 30.9 percent ($24.8 billion) of total capital outlays in 2006 and 22.1 percent ($25.0 billion) in 2016. This decline was due in part to the expansion of the NHS directed by the Moving Ahead for Progress in the 21st Century Act of 2012 (MAP-21), which reduced the mileage classified as Other Federal-aid highways.

Exhibit 2-15 ■ Distribution of Capital Outlay by System, 2006 vs 2016



<table>
<tr><th colspan="4">2006 Capital Outlays, Billions of Dollars</th><th colspan="4">2016 Capital Outlays, Billions of Dollars</th></tr>
<tr><th colspan="4">All Roads
$80.2</th><th colspan="4">All Roads
$112.9</th></tr>
<tr><td colspan="3">Federal Aid Highways
$61.9</td><td rowspan="3">Non-Federal-aid Highways
$18.3</td><td colspan="3">Federal Aid Highways
$84.1</td><td rowspan="3">Non-Federal-aid Highways
$28.8</td></tr>
<tr><td colspan="2">National Highway System
$37.2</td><td rowspan="2">Other
$24.8</td><td colspan="2">National Highway System
$59.2</td><td rowspan="2">Other
$25.0</td></tr>
<tr><td>Interstate System
$16.5</td><td>Other
$20.6</td><td>Interstate System
$26.4</td><td>Other
$32.7</td></tr>
</table>

Note: Estimated based on 2014 data.

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

Exhibit 2-16 shows trends in capital outlays by improvement categories from 2006 to 2016. Each year, a majority of capital outlays were directed to rehabilitation, reflecting the need to preserve the aging system. Despite already accounting for the majority of outlays, the share of total capital spending for system rehabilitation rose dramatically between 2008 and 2010, from 51.1 percent to 60.5 percent.

Meanwhile, as expenditures on system rehabilitation grew at an annual average rate of 5.4 percent between 2006 and 2016, expenditures on the second-largest of the three categories, system expansion, declined by an annual rate of 1.0 percent, mostly due to a 2.5-percent decline in expenditures for new routes. Expenditures on system enhancements increased by 6.1 percent, but the overall dollar values remain comparatively low (highest at $15.9 billion in 2012). Between 2006 and 2016, the share of capital outlay directed to rehabilitation grew from 51.5 percent to 62.0 percent while the share directed to enhancement rose from 10.6 percent to 13.6 percent; these increases were offset by a reduction in the share directed to expansion from 37.9 percent to 24.4 percent. These trends further illustrate the shifting priorities toward improving and enhancing the existing highway network.

Exhibit 2-16 ■ Capital Outlay on All Roads by Improvement Type, 2006–2016

Improvement Type	Capital Outlay, Billions of Dollars						Annual Rate of Change 2016/2006
	2006	2008	2010	2012	2014	2016	
System Rehabilitation							
Highway	$31.0	$33.5	$43.4	$45.8	$51.0	$54.6	5.8%
Bridge	$10.3	$12.7	$17.0	$16.4	$14.4	$15.4	4.1%
Subtotal	$41.3	$46.2	$60.5	$62.2	$65.4	$70.0	5.4%
System Expansion							
Additions to Existing Roadways	$14.0	$15.7	$15.0	$14.0	$13.2	$14.0	0.0%
New Routes	$15.2	$16.1	$11.4	$12.1	$11.0	$11.8	-2.5%
New Bridges	$1.2	$1.5	$0.9	$1.1	$1.6	$1.7	4.0%
Subtotal	**$30.4**	**$33.3**	**$27.4**	**$27.2**	**$25.9**	**$27.6**	**-1.0%**
System Enhancements	**$8.5**	**$10.9**	**$12.2**	**$15.9**	**$14.2**	**$15.3**	**6.1%**
Total	**$80.2**	**$90.4**	**$100.0**	**$105.3**	**$105.4**	**$112.9**	**3.5%**
Percent of Total Capital Outlay							
System Rehabilitation	52%	51%	60%	59%	62%	62%	
System Expansion	38%	37%	27%	26%	25%	24%	
System Enhancements	11%	12%	12%	15%	13%	14%	

Note: The data for 2016 were estimated based on 2014 data; 2015 and 2016 data were not available at time of report preparation.

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 2-17* shows that total capital outlays on Federal-aid highways increased at an average annual rate of 3.1 percent from 2006 to 2016, slightly below the 3.5 percent annual growth for all roads, and reaching $84.1 billion in 2016. The largest increases in dollar amounts were in the earlier portions of this period, as total capital outlays increased by more than $8 billion between 2006 and 2008 ($61.9 billion to $70.0 billion) and by $5.7 billion from 2008 to 2010 ($70.0 billion to $75.7 billion).

The trends for expenditures on Federal-aid highways generally mirror those for all roads. The share of capital outlay on Federal-aid highways directed to system rehabilitation in 2016 was 61.3 percent, slightly below the comparable percentage for all roads of 62.0 percent (see *Exhibit 2-13*). Expenditures for system rehabilitation grew at an annual rate of 5.4 percent and for system enhancements by 5.3 percent, while declining by 1 percent for system expansion.

Exhibit 2-17 ■ Capital Outlay on Federal-aid Highways by Improvement Type, 2006–2016

Improvement Type	Capital Outlay, Billions of Dollars						Annual Rate of Change 2016/2006
	2006	2008	2010	2012	2014	2016	
System Rehabilitation							
Highway	$22.9	$26.1	$33.1	$34.5	$38.1	$40.4	5.8%
Bridge	$7.7	$9.3	$12.5	$12.0	$10.5	$11.2	3.8%
Subtotal	**$30.6**	**$35.5**	**$45.6**	**$46.5**	**$48.6**	**$51.5**	**5.4%**
System Expansion							
Additions to Existing Roadways	$12.9	$14.3	$13.8	$12.8	$12.3	$13.1	0.1%
New Routes	$12.0	$12.8	$8.8	$9.3	$8.5	$9.0	-2.9%
New Bridges	$0.9	$1.0	$0.7	$0.8	$1.2	$1.3	3.7%
Subtotal	**$25.9**	**$28.1**	**$23.3**	**$22.9**	**$22.1**	**$23.4**	**-1.0%**
System Enhancements	**$5.5**	**$6.4**	**$6.8**	**$9.6**	**$8.6**	**$9.1**	**5.3%**
Total	**$61.9**	**$70.0**	**$75.7**	**$79.0**	**$79.3**	**$84.1**	**3.1%**
Percent of Total Capital Outlay							
System Rehabilitation	49.3%	50.7%	60.3%	58.9%	61.4%	61.3%	
System Expansion	41.9%	40.1%	30.8%	29.0%	27.8%	27.9%	
System Enhancements	8.8%	9.2%	9.0%	12.1%	10.8%	10.9%	

Note: The data for 2016 were estimated based on 2014 data; 2015 and 2016 data were not available at time of report preparation.

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

Capital Outlays on the National Highway System

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 5.3 percent. *Exhibit 2-18* shows that capital outlays for the NHS amounted to $59.2 billion in 2016. System rehabilitation expenditures of $35.8 billion accounted for the greatest share, followed by system expansion at $17.9 billion and system enhancements at $5.5 billion.

Over the 10-year period beginning in 2006, the share of system rehabilitation on the NHS jumped from 44.7 percent to 60.5 percent while the share of system expansion expenditures declined from 47.7 percent to 30.3 percent of total capital outlays. During the same period, the share of system enhancements on the NHS increased slightly from 7.6 percent to 9.2 percent.

Exhibit 2-18 ■ Capital Outlay on the National Highway System by Improvement Type, 2006–2016

Improvement Type	Capital Outlay, Billions of Dollars[1]						Annual Rate of Change 2016/2006
	2006	2008	2010	2012	2014	2016	
System Rehabilitation							
Highway	$12.3	$14.9	$19.9	$19.7	$27.0	$28.3	8.7%
Bridge	$4.3	$5.4	$7.4	$6.7	$7.1	$7.5	5.6%
Subtotal	**$16.6**	**$20.4**	**$27.3**	**$26.4**	**$34.1**	**$35.8**	**8.0%**
System Expansion							
Additions to Existing Roadways	$8.1	$9.2	$8.6	$8.0	$9.2	$9.7	1.8%
New Routes	$8.9	$8.6	$4.7	$5.6	$6.7	$7.1	-2.3%
New Bridges	$0.7	$0.6	$0.3	$0.5	$1.1	$1.1	5.1%
Subtotal	**$17.7**	**$18.3**	**$13.7**	**$14.1**	**$17.0**	**$17.9**	**0.1%**
System Enhancements	**$2.8**	**$3.3**	**$3.4**	**$4.0**	**$5.2**	**$5.5**	**6.8%**
Total	**$37.2**	**$42.0**	**$44.4**	**$44.6**	**$56.3**	**$59.2**	**4.8%**
Percent of Total Capital Outlay							
System Rehabilitation	44.7%	48.5%	61.6%	59.3%	60.6%	60.5%	
System Expansion	47.7%	43.7%	30.8%	31.7%	30.2%	30.3%	
System Enhancements	7.6%	7.8%	7.6%	9.0%	9.2%	9.2%	

[1] The National Highway System 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 National Highway System. The data for 2016 were estimated based on 2014 data; 2015 and 2016 data were not available at time of report preparation.

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

Capital Outlays on the Interstate System

Exhibit 2-19 shows that from 2006 to 2016, capital outlay on the Interstate System increased annually by an average of 4.8 percent, to $26.4 billion in 2016, well above the 3.5 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 3.1 percent observed from 2006 to 2016.

The portion of expenditures going to system rehabilitation on the Interstate System increased from 49.9 percent in 2006 to 69.6 percent in 2016. In contrast, the portion expended on system expansion fell by nearly half, from 42.6 percent in 2006 to 23.2 percent in 2016.

The share of Interstate capital outlay directed to system rehabilitation in 2016 was higher than the comparable percentages for the NHS, Federal-aid highways, and all roads. This pattern is largely consistent with that from 2006 to 2016; the share of Interstate capital outlay directed to system rehabilitation was higher in each year 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 than comparable percentages for all roads, Federal-aid highways, and the NHS.

Exhibit 2-19 ■ Capital Outlay on the Interstate System by Improvement Type, 2006–2016

Improvement Type	Capital Outlay, Billions of Dollars 2006	2008	2010	2012	2014	2016	Annual Rate of Change 2016/2006
System Rehabilitation							
Highway	$5.8	$7.5	$9.4	$8.9	$14.4	$15.1	10.1%
Bridge	$2.5	$3.3	$4.1	$3.8	$3.2	$3.3	2.8%
Subtotal	**$8.3**	**$10.8**	**$13.5**	**$12.7**	**$17.6**	**$18.4**	**8.3%**
System Expansion							
Additions to Existing Roadways	$3.2	$4.5	$3.5	$3.4	$3.8	$3.9	2.0%
New Routes	$3.5	$3.0	$1.7	$2.7	$1.7	$1.8	-6.7%
New Bridges	$0.3	$0.3	$0.1	$0.2	$0.4	$0.5	3.9%
Subtotal	**$7.1**	**$7.8**	**$5.3**	**$6.3**	**$5.9**	**$6.1**	**-1.4%**
System Enhancements	**$1.2**	**$1.4**	**$1.4**	**$1.5**	**$1.8**	**$1.9**	**4.5%**
Total	**$16.5**	**$20.0**	**$20.2**	**$20.5**	**$25.3**	**$26.4**	**4.8%**
Percent of Total Capital Outlay							
System Rehabilitation	49.9%	53.9%	66.7%	62.1%	69.6%	69.6%	
System Expansion	42.6%	38.9%	26.3%	30.5%	23.2%	23.2%	
System Enhancements	7.4%	7.1%	6.9%	7.3%	7.2%	7.2%	

Note: The data for 2016 were estimated based on 2014 data; 2015 and 2016 data were not available at time of report preparation.

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

Project Finance and Alternative Funding Mechanisms

The early portion of this chapter focused on traditional sources of funding for transportation projects, which are primarily from such sources as taxes and other user fees such as tolls, bond issue proceeds, and investment income and other receipts (see *Exhibit 2-5*). In the face of stagnating public revenues and demanding fiscal requirements, transportation policymakers are increasingly interested in alternative funding sources and methods for further leveraging available funds. Many jurisdictions are relying on options such as public-private partnerships, Federal credit assistance, and other debt-financing tools. These project finance strategies could enable public agencies to transfer certain project delivery risks and deliver infrastructure projects earlier than would be possible through traditional mechanisms.

Project finance refers to specially designed techniques and tools that supplement traditional highway financing methods. They typically entail borrowing money, either through bonds, loans, or other financing mechanisms, or by partnering with the private sector. State and local governments rely on a variety of revenue mechanisms to generate revenue for transportation projects and can also make use of several Federal programs to support alternative funding. These funding approaches are introduced below.

Public-Private Partnerships

A growing number of States are using P3s for transportation projects. 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. P3s' 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 up-front 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.

As of early 2018, 35 States and the District of Columbia have enacted statutes that enable the use of various P3 approaches for the development of transportation infrastructure.[7] One private international consulting group, which maintains a public database of public-private partnerships by county and sector, had identified 162 transportation P3s by mid-2018, 20 of which were already in operation.[8]

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.

Innovative Project Financing Profile: *Transform 66—Outside the Beltway*

The Virginia Department of Transportation (VDOT) and I-66 Express Mobility Partners LLC (EMP) are partnering to deliver *Transform 66—Outside the Beltway*, a major Interstate expansion and construction of managed tolled lanes designed to address critical regional transportation needs. The 50-year design-build-finance-operate-maintain public-private partnership concession arrangement between VDOT and EMP will finance the project without direct public investment, relying instead on a significant equity contribution by EMP, a federal Transportation Infrastructure Finance and Innovation Act (TIFIA) loan, and other state credit supports.

Funding Sources	TIFIA loan: $1,229 million Private Activity Bonds: $737 million Virginia State Infrastructure Bank loan: $39.0 million Equity contribution: $1,525 million

Under the agreement, EMP paid a $579 million concession fee upfront to the state transportation fund for use on other improvements in the corridor ($500 million) and for VDOT project oversight and contingency ($79 million). In addition, EMP has committed to provide $800 million for transit services and $350 million for other corridor improvements over the 50-year term of the agreement.

The project area currently experiences peak congestion periods of four to five hours per day, travel speeds that can drop to as low as 10–15 mph, higher than Virginia average crash rates, few alternative single-occupant vehicle routes, and a growing regional population. In one portion, it carries more than 220,000 vehicles per weekday.

Key elements of Transform 66—Outside the Beltway include:

- Two tolled, managed express lanes in each direction;
- The expansion to three general-purpose lanes in each direction for the length of the project;
- 11 miles of new bike and pedestrian trails; and
- The expansion of park and ride facilities, including over 4,000 parking spaces, with direct access to the new express lanes.

The project will also include the design, construction, and/or relocation of certain interchanges, bridges, and utilities, and improvements to auxiliary and bike lanes.
Major construction began in 2018; the express lanes are scheduled to open in 2022.

[7] FHWA, "State P3 Legislation," (https://www.fhwa.dot.gov/ipd/p3/legislation/); accessed June 20, 2018.
[8] Aninver InfraPPP Partners, "PPP PROJECTS IN (USA) UNITED STATES OF AMERICA," (http://www.infrapppworld.com/pipeline-html/projects-in-usa-united-states-of-america); accessed June 22, 2018.

Debt Financing

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.

The bond issuance yields an immediate influx of cash in the form of bond proceeds. The State or local agency then retires its obligation by making principal and interest payments to the investors over time. Although bond financing imposes interest and other debt-related costs, bringing a project to construction more quickly than otherwise possible can sometimes offset these costs.

U.S. DOT's Build America Bureau

The Build America Bureau (the "Bureau") serves as a one-stop shop for project sponsors looking to leverage Federal transportation expertise, apply for Federal transportation credit programs, and explore ways to access private capital in public-private partnerships. The Bureau also provides access to credit and grant programs and technical assistance on innovative best practices in project planning, financing, delivery, and monitoring.

The Bureau is divided into two primary teams: (1) the Public Outreach and Project Development team, which works to educate project sponsors on DOT credits, funding programs, and innovative project delivery approaches such as public-private partnerships; and (2) the Credit Programs team, which underwrites and manages financing associated with credit programs such as TIFIA, including the Rural Projects Initiative, and Private Activity Bonds (PABs).

Technical Assistance and Credit Programs Offered

- Technical Assistance: Offers technical assistance to project sponsors, particularly to those that have not used TIFIA loans in the past.
- TIFIA Loans: Provides credit assistance for qualified projects of regional and national significance. The TIFIA credit program is designed to fill market gaps and leverage substantial private co-investment by providing supplemental and subordinate capital.
- Rural Projects Initiative: Offers assistance to rural areas, including loans up to 49 percent of eligible project costs, reduced interest rates, payment of application fees, and up to 35-year amortizations for qualifying projects.
- Private Activity Bonds: Provides private developers and operators with access to tax-exempt interest rates, significantly lowering the cost of capital and enhancing the investment prospects for transportation infrastructure.

Municipal Bonds

Municipal bonds are issued by State and local governments to raise money for public works projects such as the construction and maintenance of highways, bridges, ports, airports, public transit systems, and other infrastructure. The interest earned on many municipal bonds is tax-exempt, making them attractive to many investors. States and local governments can issue general obligation bonds that are backed by the full faith and credit of the State and are usually repaid from the government's tax receipts, and revenue bonds that are guaranteed by specific State revenue streams such as tolls or fares. In 2015, 32 States and the District of Columbia used bond proceeds for highways.[9]

[9] FHWA, *Highway Statistics 2015, Table SF-1.*

Grant Anticipation Revenue Vehicle

Specific to highways, a Grant Anticipation Revenue Vehicle (GARVEE) is a debt-financing instrument that can generate initial capital for major transportation projects. Section 115 of Title 23, United States Code, authorizes a State to use State revenues (in this instance, bond proceeds) to fund eligible Federal-aid projects and claim reimbursement for eligible expenditures from Federal-aid funds at a later date. The use of advance construction facilitates State issuances of GARVEE bonds. Future Federal-aid funds are used to repay the debt and related financing costs under the provisions of Section 122 of Title 23, United States Code. GARVEE bonds 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. The use of GARVEE bonds expands access to capital markets as an alternative, or in addition, to general obligation or revenue bonds. They are most appropriate for large, long-lived, nonrevenue-generating assets. As of December 2017, 26 States, two U.S. territories, and the District of Columbia had issued approximately $22.5 billion in GARVEEs.[10]

Private Activity Bonds

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. Section 11143 of Title XI of SAFETEA-LU amended Section 142(a) of the Internal Revenue Code to add highway and freight transfer facilities to the types of privately developed and operated projects for which PABs may be issued, allowing private activity on these types of projects while maintaining the tax-exempt status of the bonds. The law limits the total amount of such bonds to $15 billion and directs the Secretary of Transportation to allocate this amount among qualified facilities.[11] As of April 2018, nearly $8.25 billion in PABs had been issued for 23 projects.

Federal Credit Assistance

Federal credit assistance for highway improvements can take one of two forms: (1) loans, which enable project sponsors to borrow Federal funds from a State department of transportation or the Federal government; and (2) credit enhancements, through which 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 Transportation Infrastructure Finance and Innovation Act (TIFIA) credit program, State Infrastructure Bank (SIB) programs, and Section 129 (23 U.S.C. 129 (a)(7)) loans.

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/.

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[10] FHWA, Center for Innovative Finance Support, (https://www.fhwa.dot.gov/ipd/finance/tools_programs/federal_debt_financing/garvees/garvee_state_by_state.aspx #top-banner-wrap).

[11] FHWA, Center for Innovative Finance Support, (https://www.fhwa.dot.gov/ipd/finance/tools_programs/federal_debt_financing/private_activity_bonds/default.aspx). Accessed June 2018.

A Comprehensive Information Source for Major Highway Projects

Transportation practitioners and researchers seek an accessible, searchable, and comprehensive information source with reliable and comparable data on major U.S. highway projects, whether delivered directly by a public agency or via a P3 concession. FHWA is currently engaged in a project to collect and consolidate data on large federally funded transportation projects into a publicly accessible online database. High-level benchmark data regarding project development, procurement, and implementation are being compiled and organized to allow for multiple types of analysis. Users will be able to track discretionary grant amounts, dollars leveraged, project delivery methods, and performance; they will also be able to compare metrics by procurement type, including for various types of P3s. With this information, a public agency could improve its pre-procurement (ex-ante) evaluation of project delivery options, as well as the procurement itself. The first phase of this project—the initial compilation of the benchmark data—has been made available to cooperating stakeholders. FHWA intends to seek a third-party sponsor in 2021 to maintain the data source and extend availability to all interested researchers.

Transportation Infrastructure Finance and Innovation Act

TIFIA is one of the most-used Federal credit assistance programs. Created as part of the 1998 Transportation Equity Act for the 21st Century (TEA-21, Pub. L. 105-178), 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. The program is designed to accelerate project delivery and leverage private co-investment by providing supplemental and subordinate capital. 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.

From FY 1999 through the end of FY 2017, the TIFIA program provided $27.0 billion in 74 loans supporting $105.0 billion in total project costs.[12] The majority of these, 47 loans totaling $17.2 billion, financed road and highway projects (which cost $61.9 billion). By mid-2018, 13 of those loans—totaling $3.5 billion and having helped to finance $15.0 billion worth of transportation infrastructure—had been retired. Of the 74 total loans made from FY 1999 through FY 2017, 16 were for Design-Build-Finance-Operate-Maintain (DBFOM) highway projects where the financing responsibility was given to private partners.

State Infrastructure Banks

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.

[12] FHWA, table "Projects Financed by TIFIA," (https://www.transportation.gov/tifia/projects-financed); accessed June 20, 2018.

State Transportation Funding Actions

According to U.S. DOT Highway Statistics from 2015, all 50 States and the District of Columbia made use of revenues raised from fuel taxes and from vehicle and motor carrier taxes. In addition, 30 States used tolls to raise revenues, 35 used appropriations from their general funds, and 33 made use of bond proceeds for transportation investment.

States have seen increased legislative activity around the other revenue sources used to fund transportation beyond fuel taxes. NCSL reports that in 2017, 145 tolling measures had been introduced and 14 of them enacted; 27 bonding initiatives had been introduced; and nine bills were introduced relating to vehicle miles traveled.[13] As part of a larger shift in focus to leverage private-sector funds and make use of alternative financing mechanisms, many States are issuing bonds or making use of Federal financing tools. More than half of the States issue either general obligation bonds or revenue bonds to finance roads and bridges according to a 2016 AASHTO report. At least half have also used Build America Bonds or GARVEE bonds.

Exhibit 2-20 ■ State Use of Financing Mechanisms for Roads and Bridges

	State Use of Financing Mechanisms for Roads and Bridges					
	State Bonding		Federal Tools			
	General Obligation Bonds	Revenue Bonds	Build America Bonds	GARVEE	Private Activity Bonds	TIFIA Credit Assistance
Number of States Using Finance Mechanism[1]	28	31	31	28	6	15

[1] Including the District of Columbia.

Source: Transportation Governance and Finance: A 50-State Review of State Legislatures and Departments of Transportation (AASHTO, 2016).

Value Capture

Transportation improvements increase accessibility and thereby make surrounding locations more desirable, increasing the value of nearby land and property. Value capture techniques harness a portion of the increased property values to pay for the transportation improvement or for future transportation investment. Although value capture techniques are used more commonly with transit projects, they are also used to fund highway improvements. Several different forms of value capture are used in the United States. The most common are noted below.

Right-of-Way Use Agreements (Air Rights)

Right-of-way use agreements, often referred to as air rights, involve the sale or lease of development rights in urban centers. The amount of built space that can be constructed on an air rights parcel (both above and below the surface) is determined by the site's zoning designation. Highway and transit agencies in the United States have used four models for extracting value from air rights: (1) one-time, up-front lease payments; (2) long- and short-term leases that provide access to land and air space for a specified period of time, usually with renewal options; (3) direct sale to a private developer, who then provides a long-term or perpetual easement to the public agency; and (4) sale of the air rights above the property with a grant of easement where the land owner gives a nonpossessory interest to the developer to use the air rights and have access to the ground for construction.

[13] National Conference of State Legislatures, "Transportation Funding And Finance State Bill Tracking Database," (http://www.ncsl.org/research/transportation/ncsl-transportation-funding-finance-legis-database.aspx#graph). Accessed June 1, 2018.

Development Impact Fees

Development impact fees are one-time charges levied by local governments on new development to help municipalities recover growth-related infrastructure and public service costs. They differ from other forms of value capture in that impact fees can be used to pay for off-site services such as local roads, schools, or parks. Development impact fees are used by local governments throughout the United States to fund transportation improvements.

Joint Development

Joint development involves the development of a transportation project and adjacent complementary private real estate development in which a private developer either implements the real estate improvement directly or gives money to a public-sector sponsor to offset the costs. Joint development is most common at transit stations. The two main forms of joint development are revenue-sharing arrangements and cost-sharing arrangements. When joint development involves private funding of public transportation improvements, it is a form of public-private partnership.

Negotiated Exactions

Negotiated exactions involve payments made by a developer as a condition for receiving municipal approvals. Negotiated exactions are determined on an ad hoc basis for individual projects, usually as part of the development approval process. They often take the form of one-time land transfers or cash payments, but may also involve construction activities or the provision of public services. Exactions have been used to contribute to the financing of transit stations, local roads, sidewalks, streetlights, and local water and sewer lines.

Sales Tax Districts

Sales tax districts levy an incremental sales tax on goods sold within a designated area. The additional tax revenue is then used to support the development of infrastructure improvements. The sales tax service area can be expected to derive benefits from the infrastructure improvements it helps to fund. Sales tax districts may also be implemented on a larger scale, such as a municipality or county. The incremental sales tax rate is established by statute. Sales tax district statutes also identify which types of investments the resulting funds may be used to support. Sales tax districts have been used to support transportation investments in Missouri, Kansas, Illinois, and Georgia, among other locations.

Special Assessments

Special assessments involve assessing incremental property taxes on land and buildings deriving direct benefits due to a transportation improvement. The tax levied typically represents a portion of the estimated benefit to the properties located with a designated zone in close proximity to the improvement. Special assessments are one of the most prominent forms of value capture in the United States and are authorized in all 50 States and the District of Columbia, either under explicit enabling legislation or by State constitutional provisions. In addition to transportation improvements, special assessments may also be used in other sectors, including water and wastewater.

Tax Increment Financing

Tax increment financing (TIF) is a value capture revenue tool that uses taxes on future gains in real estate values to pay for new infrastructure improvements; it creates funding for public or private projects by borrowing against the future increase in these property tax revenues. The intent is for the improvement to enhance the value of existing properties and encourage new development in the district. TIF is authorized by State law in nearly all 50 States and thousands have been established around the United States. TIF begins with the designation of a geographic area as a TIF district, usually established for a period of 20 to 25 years, during which time all incremental real estate tax revenues above the base rate at the time the district is established flow into the TIF district.

Although TIF has not been used extensively to fund transportation infrastructure, some State laws specifically authorize the use of TIF for transport purposes.

Transportation Utility Fees

Transportation utility fees are a financing mechanism that treats the transportation system like a utility in which residents and businesses pay fees based on their use of the transportation system rather than taxes based on the value of property they occupy. Transportation utility fee rates may be determined by the number of parking spaces, square footage, or gross floor area. The fees are paid on an ongoing monthly basis like a utility bill, instead of annual or quarterly installments the way real estate taxes are collected.

Funding – Transit

Transit funding comes from two major sources: public funds allocated by Federal, State, and local governments, and system-generated revenues earned from providing transit services. As shown in *Exhibit 2-21,* $65.1 billion was available for transit funding in 2016. Federal funding for transit includes fuel taxes dedicated to transit from the Mass Transit Account (MTA) of the Highway Trust Fund 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 may be used to fund transit. Most revenues classified as directly generated funds are passenger fares, comprising 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 for transit in 2016 totaled $66.9 billion, including $18.2 billion for capital and $48.7 billion for operating expenses.
- Passenger fares contributed $15.8 billion, or 24 percent of all transit funds. Other directly generated funds such as parking revenues, concessions, and other sources contributed $9.0 billion, or 14 percent.
- Public assistance accounted for 62 percent of all funds, of which Federal funds accounted for 30 percent, State for 32 percent, and local for 38 percent.
- Capital investment grew at an average of 1.0 percent per year, from $15.2 billion in 2006 to $18.2 billion in 2016.
- Capital investments in rehabilitation of existing assets and expansion in 2016 were $12.7 billion and $6.7 billion, respectively, a 65/35-percent split. In 2006, the ratio was 73/27 percent.

Financial Indicators of the Top 10 Transit Agencies

- The average recovery ratio (fare revenues per total operating expenses) of the top 10 transit agencies ranged between 42 percent to 46 percent over the period 2016–2016.
- Average fare revenues per mile increased by 40 percent, from $4.65 per mile in 2006 to $6.20 per mile in 2016 (constant dollars).
- Operating costs per mile increased by 40 percent, from $10.10 per mile in 2006 to $14.10 per mile in 2016. Average labor costs for the top 10 transit agencies increased by 6.4 percent, from $9.40 per mile in 2006 to $10.00 per mile in 2016.

Exhibit 2-21 ■ Revenue Sources for Transit Funding, 2016

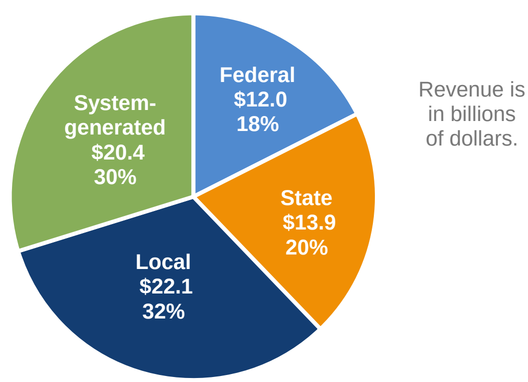
	Revenue Sources (Millions of Dollars)					Percent
	Directly Generated Funds	Federal	State	Local	Total	
Public Funds		**$11,999**	**$12,858**	**$15,473**	**$40,329**	**62%**
General Fund		$11,185	$3,674	$5,282	$20,141	31%
Fuel Tax			$1,121	$180	$1,302	2%
Income Tax			$515	$116	$630	1%
Sales Tax			$4,110	$7,440	$11,550	18%
Property Tax			$48	$615	$663	1%
Other Dedicated Taxes			$2,718	$963	$3,681	6%
Other Public Funds			$272	$252	$524	1%
Reduced Reporter Fed/State/Local		$814	$399	$625	$1,838	3%
System-generated Revenue	**$24,777**				**$24,777**	**38%**
Passenger Fares	**$15,789**				$15,789	24%
Other Revenue	**$8,988**				$8,988	14%
Total All Sources					**$65,107**	**100%**

Source: National Transit Database.

Level and Composition of Transit Funding

Exhibit 2-22 breaks down the sources of total urban and rural transit funding. In 2016, public funds of $40.3 billion were available for transit, accounting for 62 percent of total transit funding. Of this amount, Federal funding was $12.0 billion or 30 percent of total public funding and 20 percent of all funding from both public and nonpublic sources. State funding was $12.9 billion, accounting for 32 percent of total public funds and 18 percent of all funding. Local jurisdictions provided the bulk of transit funds at $15.5 billion in 2016, or 38 percent of total public funds and 24 percent of all funding. System-generated revenues were $24.8 billion or 38 percent of all funding.

Exhibit 2-22 ■ Public Transit Revenue Sources, 2016

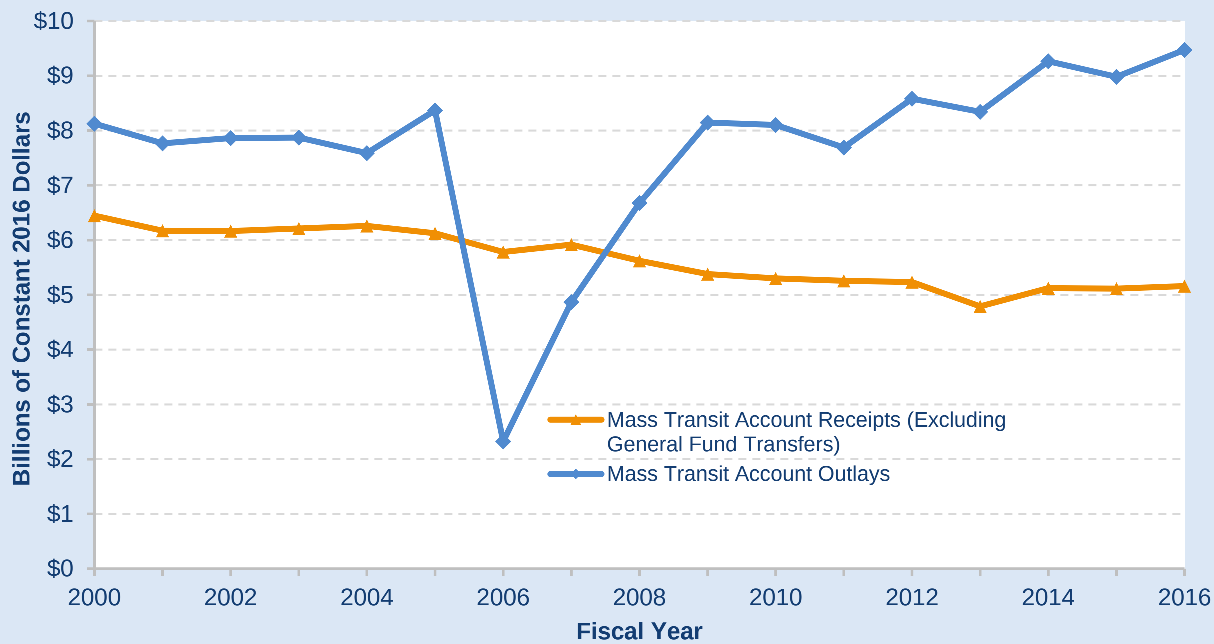


Source: National Transit Database.

How Long Has It Been since Excise Tax Revenue Deposited into the MTA Exceeded Expenditures?

The last time annual net receipts credited to the MTA of the Highway Trust Fund exceeded annual expenditures from the Highway Account was 2007. As shown in *Exhibit 2-23*, for nine of the 10 years since 2006, total annual receipts to the MTA from excise taxes and other income (including amounts transferred from the Highway Account) have been lower than the annual expenditures from the MTA.

Exhibit 2-23 ■ Mass Transit Account Receipts and Outlays, Fiscal Years 2000–2016



Note: As shown in 2016 constant dollars.

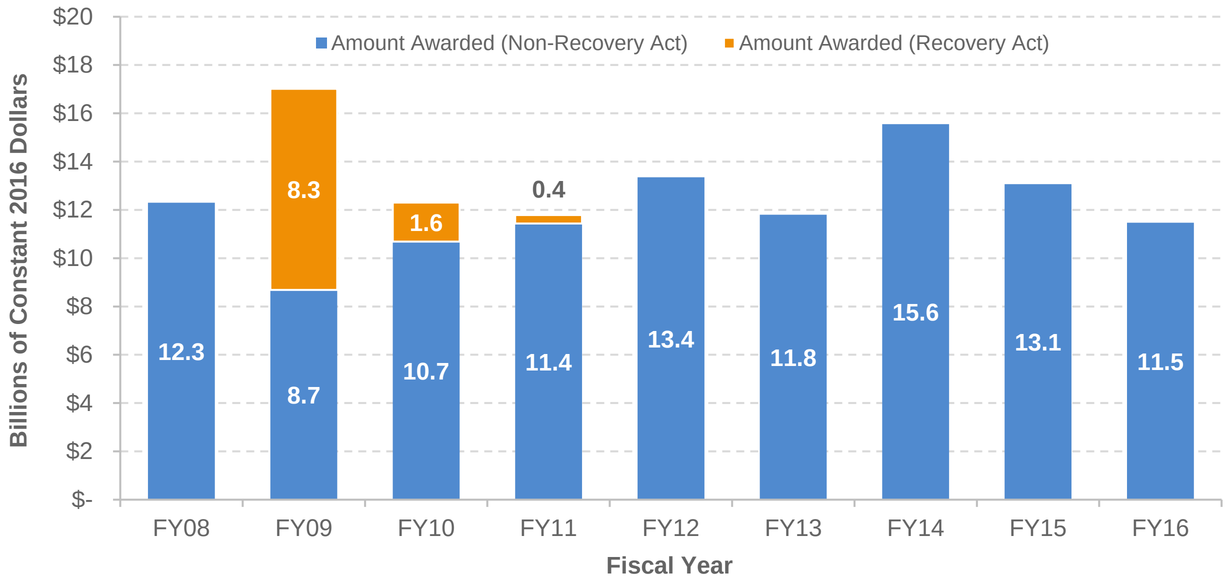
Sources: Highway Statistics, various years, Tables FE-210 (https://www.fhwa.dot.gov/policyinformation/statistics/2015/fe210.cfm) and FE-10 (https://www.fhwa.dot.gov/policyinformation/statistics/2016/fe10.cfm); Bureau of Labor Statistics Consumer Price Index. .

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 Highway Trust Fund's MTA. The largest part of the transit funding from the Highway Trust Fund is distributed to grantees 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 Transit Account is generally the largest source of Federal funding for transit, although in 2009 the Transit Account contribution was surpassed by Recovery Act funds from the General Fund. *Exhibit 2-24* shows how Recovery Act funds were awarded in 2009, 2010, and 2011 compared with other Federal funding from the Transit Account and the General Fund. Of the funds authorized for transit grants in the Federal Transit Administration's (FTA's) 2012 budget, 81 percent were derived from the Transit Account. Funding from the Transit Account in nominal dollars increased from $0.5 billion in 1983 to $12.8 billion in 2012, increasing to $14.0 billion in 2016.

Exhibit 2-24 ■ Recovery Act Funding Awards Compared to Other FTA Fund Awards, 2008–2016



Note: Peak in FY2014 was due to funds awarded in response to Hurricane Sandy.

Sources: Federal Transit Administration, Grants Data; Bureau of Labor Statistics, Consumer Price Index.

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.

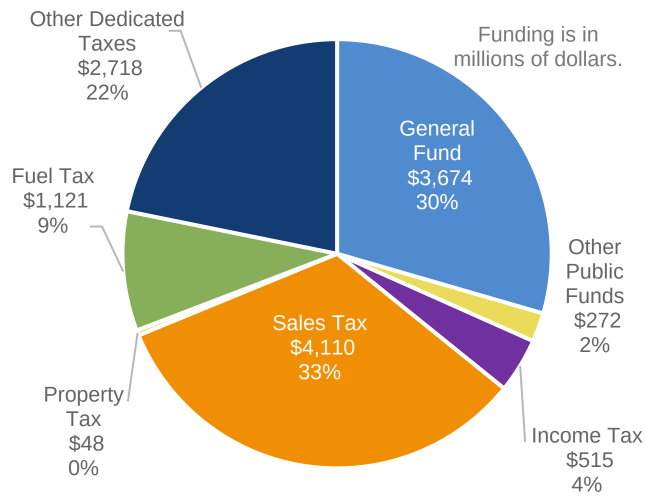
The Surface Transportation Block Grant Program is the primary source of Federal Highway Administration (FHWA) funds that are “flexed” to FTA to pay for transit projects. Funding may be used up to 80 percent of the eligible project costs. All capital and maintenance projects eligible for funds under current FTA programs are eligible for flex funds. 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 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. Capital and maintenance 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 2-25*. Taxes—including fuel, sales, income, property, and other dedicated taxes—provide 65.3 percent of public funds for State and local sources. General funds provide 32.8 percent of transit funding, and other public funds provide the remaining 1.9 percent.

Exhibit 2-25 ■ State and Local Sources of Transit Funding, 2016



Source: National Transit Database.

System-generated Funds

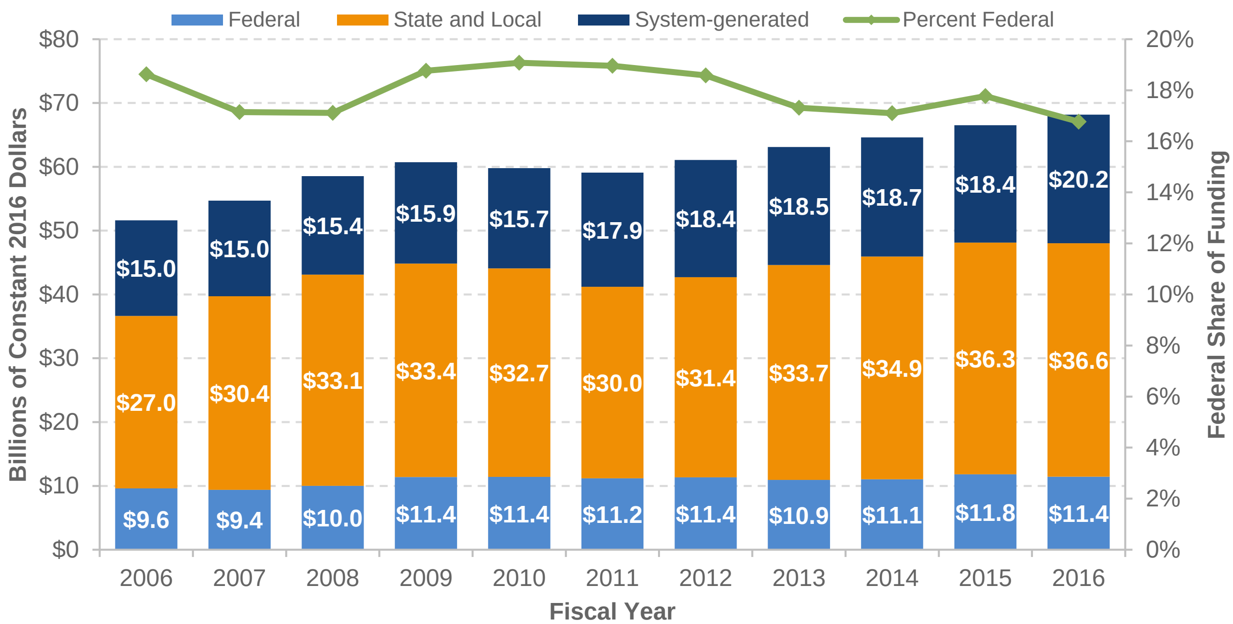
In 2016, system-generated funds were $24.7 billion and provided 38.1 percent of total transit funding. Passenger fares contributed $15.8 billion, accounting for 24.3 percent of total transit funds. These passenger fare figures do not include payments by State entities to transit systems that offset reduced 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 2006 and 2016, public funding for transit increased at an average annual rate of 2.7 percent, Federal funding increased at an average annual rate of 1.7 percent, and State and local funding increased at an average annual rate of 3.1 percent after adjusting for inflation (constant dollars). These trends are suggested in *Exhibit 2-26*.

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 2-26* shows that, since 2006, the Federal government has provided between 17 and 19 percent of total funding for transit (including system-generated funds). In 2016, it provided 17 percent.

Exhibit 2-26 ■ Funding for Urban Transit by Government Jurisdiction, 2006–2016



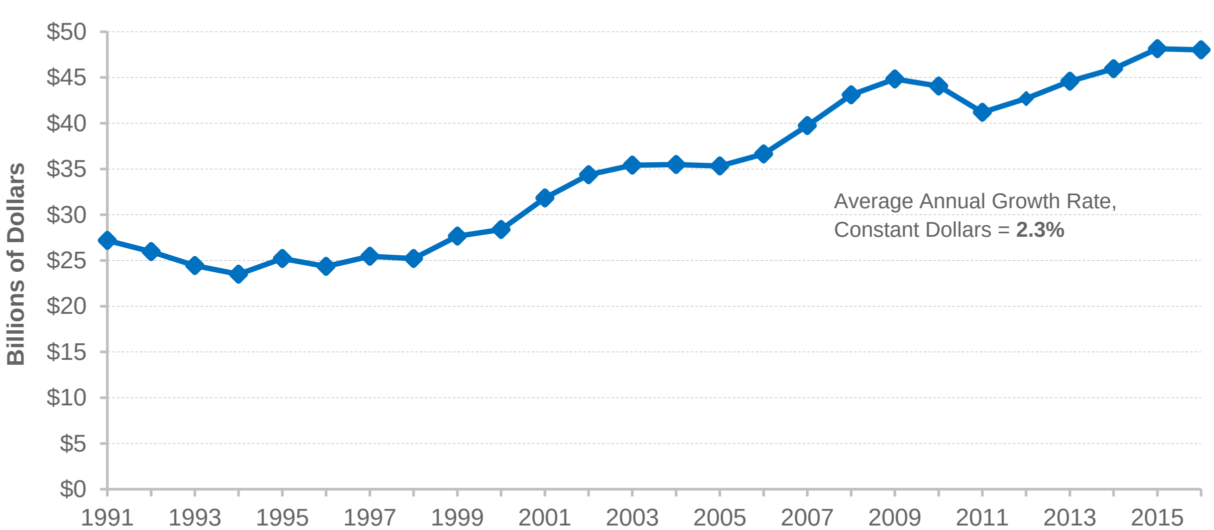
Note: Rural transit not included because the data were not reported to NTD prior to 2007.

Sources: National Transit Database; Bureau of Labor Statistics, Consumer Price Index.

Funding in Constant Dollars

Public funding for transit in constant (adjusted for inflation) dollars since 1991 is presented in *Exhibit 2-27*. Total public funding for transit was $48.0 billion in 2016. The growth in total funding accelerated during the period 2009–2010, slowed, and then turned negative over the 2010–2011 period, coinciding with the increase in Federal funding under the Recovery Act and a decline in State funding during the economic downturn. Funding has since returned to positive growth.

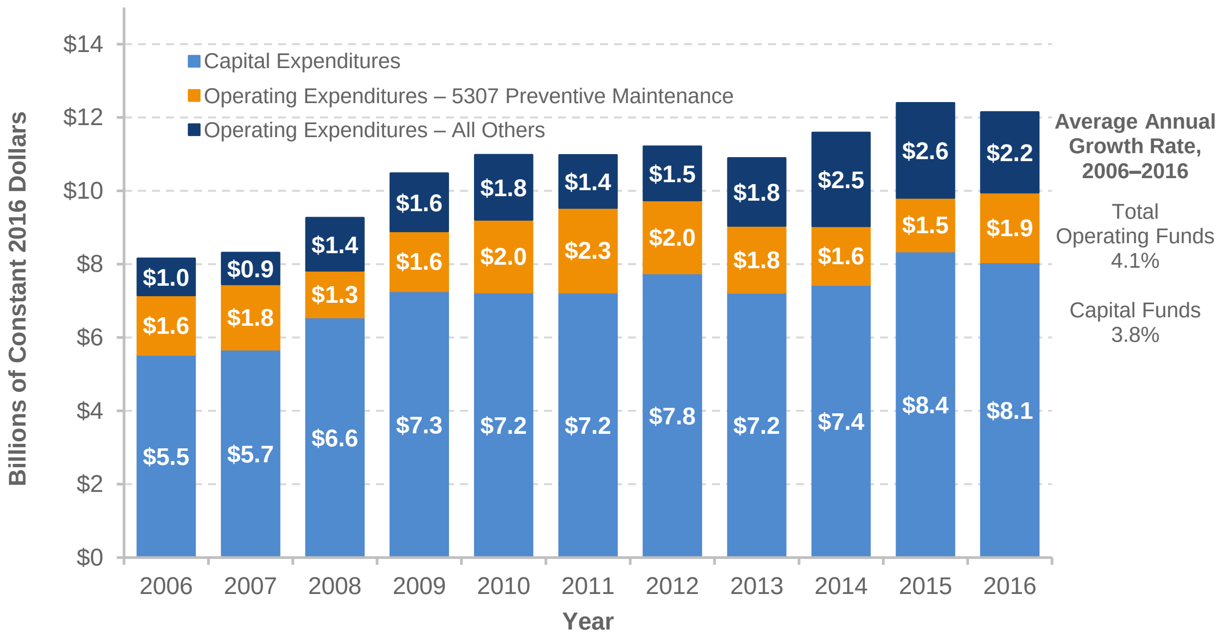
Exhibit 2-27 ■ Constant 2016 Dollar Public Funding for Public Transportation, 1991–2016 (All Sources)



Source: National Transit Database.

Federal funds directed to capital expenditures increased at an average annual rate of 3.8 percent from 2006 to 2016, while capital funds applied to operating expenditures increased by 4.1 percent annually during the same period (constant dollars). As indicated in *Exhibit 2-28*, $2.2 billion was applied to operating expenditures and $8.1 billion was applied to capital expenditures in 2016. Close to half of the operating expenditures were for preventive maintenance, which is reimbursed as a capital expense under FTA's 5307 grant program.

Exhibit 2-28 ■ Applications of Federal Funds for Transit Operating and Capital Expenditures, 2006–2016



Source: National Transit Database.

Capital Funding and Expenditures

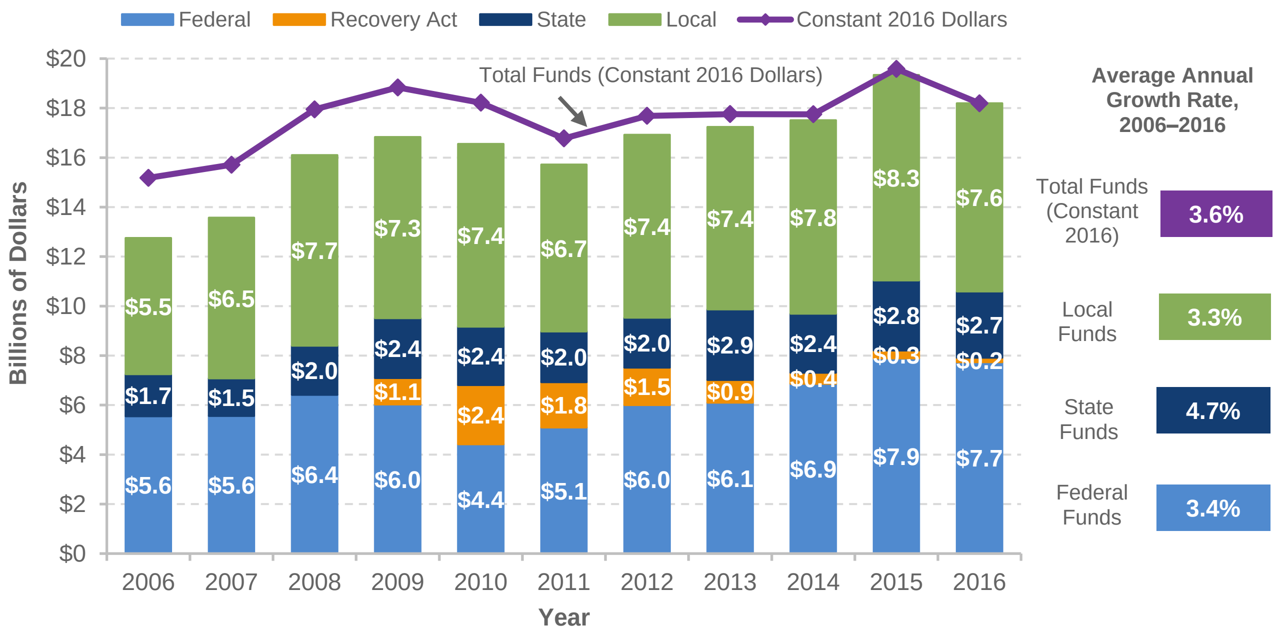
Funding for capital investments by transit operators in the United States comes primarily from public sources. A relatively small amount of private-sector funding for capital investment in transit projects is generated through innovative financing programs.

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 2-29*, total public transit agency expenditures for capital investment were $18.2 billion in 2016. This expenditure accounted for 27.9 percent of total available funds for transit. Federal funds provided $7.7 billion in 2016, accounting for 42.5 percent of total transit agency capital expenditures. State funds provided 14.7 percent and local funds provided 41.7 percent of total transit funding. Recovery Act funds provided the remaining 1.0 percent of revenues for agency capital expenditures in 2016 (constant dollars).

In 2010 and 2011, 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. Over the period 2006 to 2016, State funding for transit capital investments grew at a faster rate (4.7 percent) than did Federal or local funding (3.4 and 3.3 percent, respectively).

Exhibit 2-29 ▪ Sources of Funds for Urban Transit Capital Expenditures, 2006–2016



Note: Rural transit not included because the data were not reported to NTD prior to 2007.
Sources: National Transit Database; Bureau of Labor Statistics, Consumer Price Index.

As shown in *Exhibit 2-30*, rail modes account for approximately three-quarters of transit capital expenditures. This is due to the higher cost of building fixed guideways and rail stations, and because fixed-route bus systems typically do not pay to build or maintain the roads on which they run.

In 2016, $14.1 billion, or 72.4 percent of total transit capital expenditures, was invested in rail modes of transportation, compared with the $5.3 billion, or 27.1 percent of the total, invested in nonrail modes. This investment distribution has been consistent over the past decade.

Fluctuations in the levels of capital investment in different types of transit assets reflect normal rehabilitation and replacement cycles and new investment.

Total guideway investment was $7.7 billion in 2016, 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. Total capital investment in rolling stock, both rail and nonrail, was only 25 percent of total transit capital investment.

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.

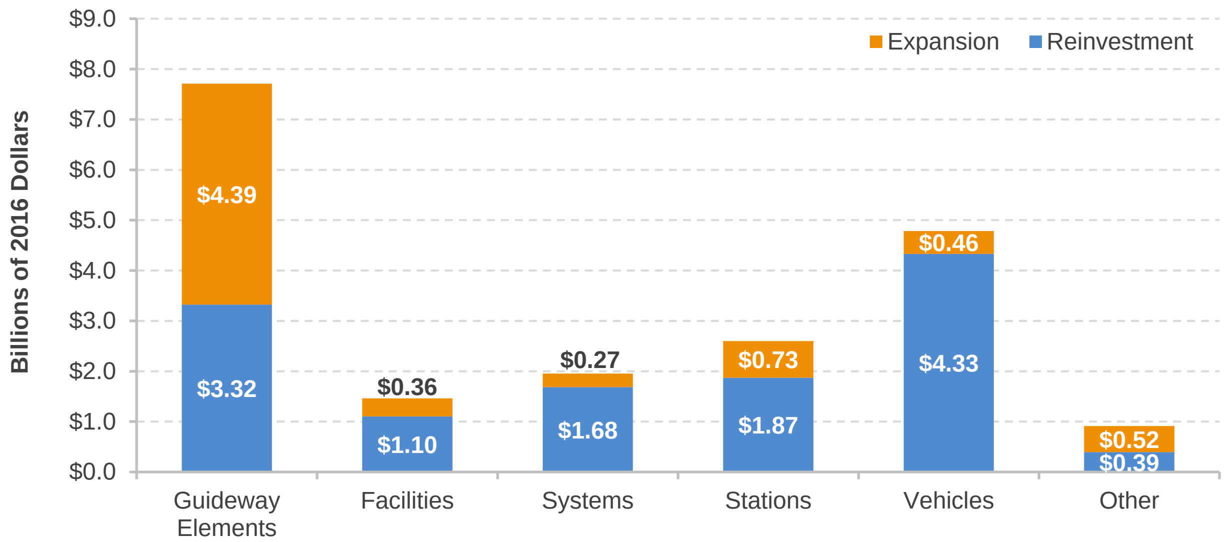
To receive funds from the Capital Investment Grant program, the proposed project must emerge from the metropolitan or statewide planning process and proceed through a multiyear, multistep process outlined in law, which includes a detailed evaluation and rating of the project by FTA. FTA evaluates proposed 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. Generally, however, the Capital Investment Grant program share of such projects averages about 50 percent, 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, but some project sponsors choose to use other sources such as the FTA Urbanized Area Formula funds program. In 2016, total investment in vehicles, stations, and maintenance facilities was $4.7 billion, $2.6 billion, and $1.2 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, which are lumped under "Systems." "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 expenditures" 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 2-30 ■ Urban Transit Capital Expenditures by Type, 2016



Other: 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.

Source: National Transit Database.

Exhibit 2-31 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. Examples of 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 2-31 ■ Urban Capital Expenditures Applied by Rehabilitation or Expansion by Mode, 2006–2016

	Expenditures (Millions of Constant 2016 Dollars)						
	2006	2008	2010	2012	2014	2016	Average Annual Rate of Change 2016/2006
Rail Rehabilitation	$7,272	$8,678	$6,835	$5,776	$6,815	$7,953	0.9%
Rail Expansion	$3,705	$5,025	$6,289	$6,900	$6,137	$6,185	5.3%
Rail Total	**$10,977**	**$13,703**	**$13,124**	**$12,676**	**$12,953**	**$14,138**	**2.6%**
Nonrail Rehabilitation	$3,673	$3,605	$4,548	$4,347	$4,333	$4,756	2.6%
Nonrail Expansion	$423	$627	$554	$569	$350	$531	2.3%
Nonrail Total	**$4,096**	**$4,232**	**$5,103**	**$4,916**	**$4,683**	**$5,287**	**2.6%**
Rehabilitation Total	**$10,945**	**$12,283**	**$11,384**	**$10,123**	**$11,148**	**$12,709**	**1.5%**
Expansion Total	**$4,128**	**$5,652**	**$6,843**	**$7,469**	**$6,487**	**$6,717**	**5.0%**
Grand Total	**$15,073**	**$17,935**	**$18,227**	**$17,592**	**$17,635**	**$19,425**	**2.6%**

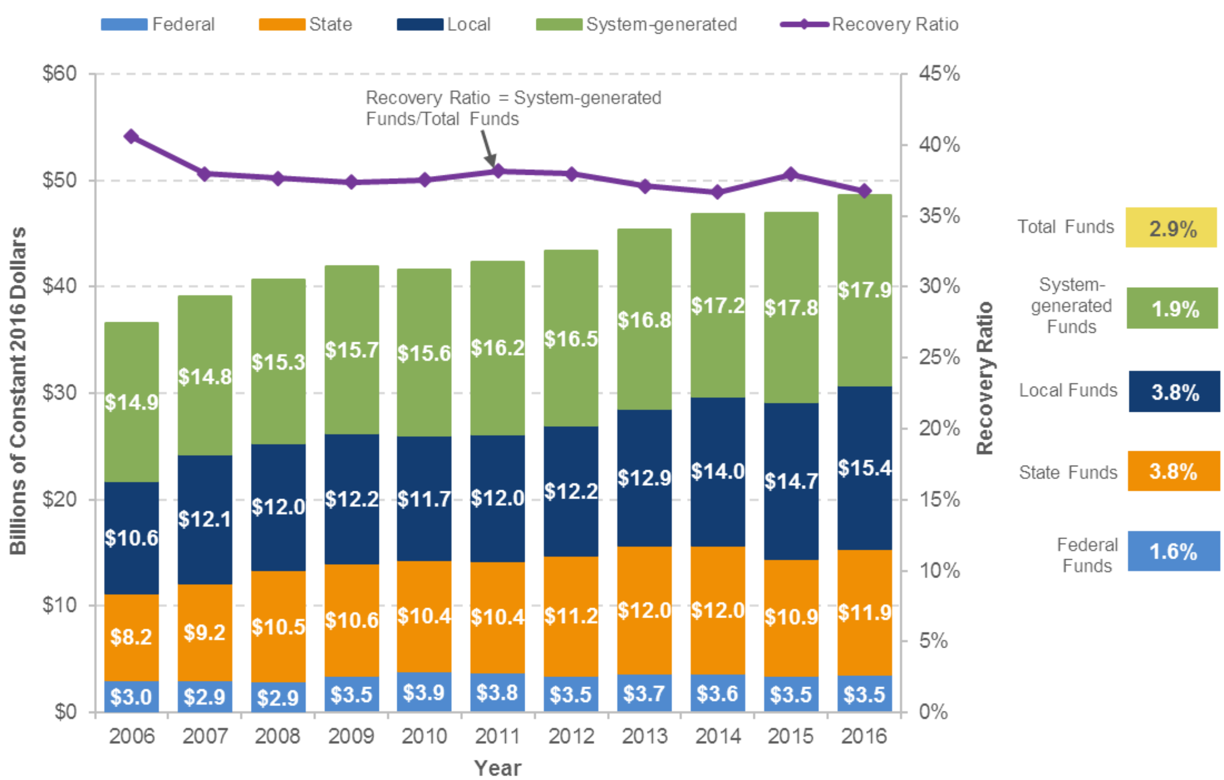
Sources: National Transit Database; Bureau of Labor Statistics Consumer Price Index.

After adjusting for inflation (constant dollars), total capital expenditures from 2006 to 2016 have increased by an annual average of 2.6 percent. Although rehabilitation expenses over this period have decreased slightly, service expansion investment, particularly in rail modes, has increased considerably. Average annual expenses for rail expansion had the largest increase over this time, with an average annual increase in expansion expenses of 5.3 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 2-32*, $48.7 billion was available for operating expenses in 2016. The Federal share of operating expenses decreased from 9.4 percent in 2010 to 7.2 percent in 2016. The Urbanized Area Formula Program (Title 49 U.S.C. Section 5307) contributed 46 percent of all Federal funds for operating assistance. 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 4 percent, and funds from the State of Good Repair Program (Title 49 U.S.C. Section 5337), 34 percent. The remaining 15 percent included FTA, DOT, and other Federal funds. The share generated from system revenues decreased slightly from 38.0 percent in 2012 to 36.8 percent in 2016. The State share remained relatively stable, decreasing from 26.4 percent in 2013 to 24.4 percent in 2016. The local share of operating expenditures increased marginally from 28.1 percent in 2012 to 31.6 percent in 2016.

Exhibit 2-32 ■ Sources of Funds for Transit Operating Expenditures, 2006–2016

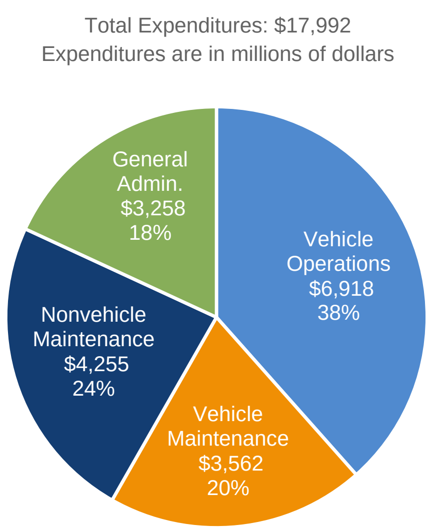


Sources: National Transit Database; Bureau of Labor Statistics Consumer Price Index.

Operating Expenditures by Type of Cost

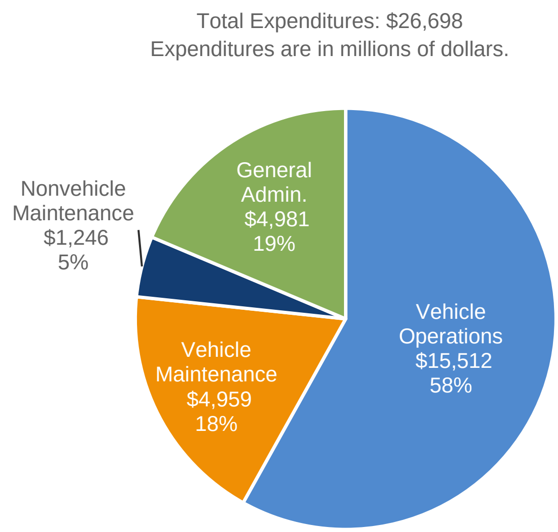
Exhibits 2-33 and *2-34* illustrate how road and rail operations have inherently different cost structures because, in most cases, roads are not maintained by the transit provider, but tracks are. A significantly higher percentage of expenditures for rail modes of transportation is classified as nonvehicle maintenance, corresponding to the repair and maintenance costs of fixed guideway systems.

Exhibit 2-33 ■ Rail Operating Expenditures by Type of Cost, 2016



Source: National Transit Database.

Exhibit 2-34 ■ Nonrail Operating Expenditures by Type of Cost, 2016



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

Source: National Transit Database.

Cost Efficiency, Cost Effectiveness, and Service Effectiveness

Cost Efficiency is the relationship between cost inputs such as labor, fuel, and capital to service outputs such as vehicle miles and hours. Common metrics include labor expenses per hour 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 and passenger miles per revenue mile (load factor).

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 2-35*, operating expenditures per VRM for all transit modes combined were $10.53 in 2016. The average annual increase in operating expenditures per VRM for all modes combined between 2006 and 2016 was 1.0 percent in constant dollars.

Exhibit 2-35 ■ Urban Operating Expenditures per Vehicle Revenue Mile, 2006–2016

Mode	Expenditures (Millions of Constant 2016 Dollars)						
	Heavy Rail	Commuter Rail	Light Rail[1]	Fixed-Route Bus[2]	Demand Response[3]	Other[4]	Total
2006	$9.93	$15.63	$17.45	$9.99	$4.90	$4.76	**$9.50**
2007	$10.68	$15.62	$16.34	$10.14	$4.66	$6.01	**$9.67**
2008	$10.42	$15.50	$16.25	$10.30	$4.64	$5.48	**$9.62**
2009	$10.59	$16.28	$17.68	$10.48	$4.73	$5.12	**$9.76**
2010	$10.83	$16.12	$18.28	$10.62	$4.86	$4.98	**$9.89**
2011	$11.18	$16.06	$17.92	$10.56	$4.63	$4.70	**$9.79**
2012	$11.44	$16.26	$18.09	$10.59	$4.62	$4.80	**$9.85**
2013	$12.86	$16.69	$17.70	$10.65	$4.54	$4.66	**$10.11**
2014	$13.34	$17.00	$18.27	$10.80	$4.55	$4.65	**$10.30**
2015	$13.41	$17.02	$18.64	$10.83	$4.52	$4.94	**$10.35**
2016	$14.02	$17.34	$19.41	$10.91	$4.47	$4.98	**$10.53**
Average Annual Rate of Change 2016/2006	**3.5%**	**1.0%**	**1.1%**	**0.9%**	**-0.9%**	**0.4%**	**1.0%**

[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.

Sources: National Transit Database; Bureau of Labor Statistics, Consumer Price Index.

Exhibit 2-36 provides a range of service efficiency and effectiveness measures for two groups of aggregate data: Top 10 agencies (by ridership) as of 2016, and the national total of all urban and rural agencies in the United States. The table highlights several differences between the top 10 operators and the national average. For example, fare revenue per mile, farebox recovery, and average trips per hour are all higher for the top 10 compared with the national average, reflecting the high population densities (higher vehicle occupancies) and a larger share of riders traveling by rail (higher vehicle capacities) in the urban areas served by the top 10 operators. Similarly, the higher use of rail by the top 10 is also reflected in the operating cost per mile. In contrast, the cost per trip is higher for the national average, reflecting both lower vehicle occupancies and the dominance of bus services (and hence higher labor costs per vehicle) outside of the top 10 markets. Finally, fare revenues and costs have increased by as much as 40 percent over the period 2006 to 2016, whether assessed on a per mile or per trip basis.

As shown in *Exhibit 2-37*, analysis of the NTD reports for the top 10 transit agencies shows that the growth in operating expenses is led by the cost of fringe benefits, which have been increasing at a rate of 1.6 percent per year above inflation (constant dollars) since 2006. By comparison, average salaries at these 10 agencies decreased at an inflation-adjusted rate of 0.1 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. As illustrated in *Exhibit 2-38*, 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. It should be noted that the average capacities for all vehicle types are adjusted separately each year based on reported fleet averages.

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 1.3 percent yearly from 2006 to 2016, whereas the average cost per mile has increased by 1.5 percent yearly. The result is a 0.2 percent yearly decrease in the "fare recovery ratio," which is the percentage of operating costs that passenger fares cover. The 2016 fare recovery ratio for these 10 agencies, which are all rail, was 45.1 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.

Exhibit 2-36 ■ Top 10 Agencies vs All Urban and Rural Agencies in the United States, 2006–2016

	Report Year											Average Annual Percent Increase	Percent Increase 2006–2016
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016		
Top 10 US Transit Operators													
Average Fare per Mile	$5.82	$5.57	$5.54	$5.55	$5.78	$6.25	$6.29	$6.52	$6.54	$6.65	$6.61	1.3%	13.5%
Average Cost per Mile	$12.60	$13.05	$12.73	$12.91	$13.18	$13.36	$13.70	$13.86	$14.18	$14.14	$14.66	1.5%	16.3%
Average Farebox Recovery Ratio	46.2%	42.7%	43.6%	43.0%	43.8%	46.8%	45.9%	47.1%	46.1%	47.0%	45.1%	-0.2%	-2.4%
Average Trips per Hour	60.9	63.9	63.3	60.4	62.4	63.8	66.0	65.3	65.5	63.3	62.3	0.2%	2.3%
Average Cost Per Trip	$3.03	$2.97	$2.94	$3.12	$3.12	$3.07	$3.06	$3.12	$3.19	$3.29	$3.43	1.3%	13.3%
Average Fare Per Trip	$1.40	$1.27	$1.28	$1.34	$1.37	$1.44	$1.40	$1.47	$1.47	$1.55	$1.55	1.0%	10.6%
National (All Urban and Rural Agencies)													
Average Fare per Mile	$3.37	$2.93	$2.92	$2.95	$2.99	$3.16	$3.20	$3.31	$3.32	$3.40	$3.34	-0.1%	-1.1%
Average Cost per Mile	$9.41	$8.62	$8.56	$8.62	$8.61	$8.63	$8.75	$8.84	$9.04	$9.37	$9.54	0.1%	1.4%
Average Farebox Recovery Ratio	35.8%	34.0%	34.2%	34.3%	34.7%	36.7%	36.6%	37.5%	36.8%	36.3%	35.0%	-0.2%	-2.4%
Average Trips per Hour	38.0	36.4	35.8	34.6	34.5	35.0	35.9	35.6	35.6	34.4	33.3	-1.3%	-12.5%
Average Cost Per Trip	$3.68	$3.60	$3.60	$3.78	$3.83	$3.76	$3.75	$3.81	$3.90	$4.17	$4.36	1.7%	18.3%
Average Fare Per Trip	$1.32	$1.23	$1.23	$1.30	$1.33	$1.38	$1.37	$1.43	$1.43	$1.51	$1.52	1.4%	15.4%

Note: Top 10 transit systems are MTA 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 Transportation Agency, Metropolitan Atlanta Rapid Transit Authority, and Maryland Transit Administration.

Sources: National Transit Database; Bureau of Labor Statistics, Consumer Price Index.

Exhibit 2-37 ■ Top 10 Agencies—Urban Growth in Labor Costs, 2006–2016

Cost Component	Average Cost per Vehicle Mile (Constant 2016 Dollars)											% Growth since 2006	Average Annual Rate of Change
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016		
Salaries	$5.5	$5.6	$5.2	$5.2	$5.3	$5.3	$5.3	$5.1	$5.2	$5.4	$5.5	**-0.8%**	**-0.1%**
Fringe Benefits	$3.9	$4.1	$3.7	$3.9	$4.1	$4.3	$4.3	$4.1	$4.2	$4.3	$4.5	**16.8%**	**1.6%**
Total Labor Cost	**$9.4**	**$9.8**	**$8.9**	**$9.1**	**$9.4**	**$9.6**	**$9.6**	**$9.2**	**$9.5**	**$9.7**	**$10.0**	**6.4%**	**0.6%**

Note: Top 10 agencies are MTA 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 Transportation Agency, Metropolitan Atlanta Rapid Transit Authority, and Maryland Transit Administration.

Sources: National Transit Database; Bureau of Labor Statistics, Consumer Price Index.

Exhibit 2-38 ■ Transit Operating Expenditures per Capacity-equivalent Vehicle Revenue Mile by Mode, 2006–2016

Mode	Expenditures (Constant 2016 Dollars)						
	Heavy Rail	Commuter Rail	Light Rail[1]	Fixed-route Bus[2]	Demand Response[3]	Other[4]	Total
2006	$3.95	$5.76	$6.33	$9.85	$24.05	$10.12	**$7.35**
2007	$4.29	$5.68	$5.93	$9.72	$19.61	$11.60	**$7.44**
2008	$4.21	$5.67	$5.97	$9.88	$20.06	$12.67	**$7.51**
2009	$4.27	$5.91	$6.35	$10.04	$20.65	$12.72	**$7.66**
2010	$4.38	$5.88	$6.55	$10.15	$19.78	$12.31	**$7.76**
2011	$4.52	$5.84	$6.07	$10.09	$20.44	$11.45	**$7.75**
2012	$4.62	$5.80	$6.20	$10.20	$19.87	$12.10	**$7.83**
2013	$5.54	$5.86	$5.85	$10.35	$19.79	$12.20	**$8.18**
2014	$5.54	$5.76	$5.80	$10.55	$21.40	$12.05	**$8.31**
2015	$5.53	$5.75	$5.86	$10.55	$21.47	$12.42	**$8.31**
2016	$5.83	$5.85	$6.06	$10.62	$21.38	$12.89	**$8.48**
Average Annual Rate of Change 2016/2006	**4.0%**	**0.1%**	**-0.4%**	**0.8%**	**-1.2%**	**2.4%**	**1.4%**

[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, trolleybus, and vanpool.

Sources: National Transit Database; Bureau of Labor Statistics, Consumer Price Index.

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 1.2 percent between 2006 and 2016 when adjusted for constant dollars (from $0.71 to $0.79). These data are shown in *Exhibit 2-39*.

Exhibit 2-39 ■ Urban Operating Expenditures per Passenger Mile, 2006–2016

Mode	Expenditures (Constant 2016 Dollars)						
	Heavy Rail	Commuter Rail	Light Rail[1]	Fixed-Route Bus[2]	Demand Response[3]	Other[4]	Total
2006	$0.43	$0.43	$0.68	$0.94	$3.95	$0.61	**$0.71**
2007	$0.42	$0.42	$0.70	$0.96	$3.86	$0.70	**$0.70**
2008	$0.41	$0.43	$0.67	$0.95	$3.78	$0.64	**$0.70**
2009	$0.42	$0.46	$0.72	$0.98	$3.88	$0.65	**$0.72**
2010	$0.43	$0.47	$0.77	$0.99	$4.00	$0.63	**$0.74**
2011	$0.41	$0.44	$0.72	$0.97	$3.90	$0.61	**$0.71**
2012	$0.42	$0.46	$0.72	$0.95	$3.96	$0.61	**$0.71**
2013	$0.47	$0.47	$0.74	$0.96	$3.99	$0.60	**$0.72**
2014	$0.48	$0.50	$0.76	$0.97	$3.99	$0.60	**$0.74**
2015	$0.50	$0.50	$0.81	$1.05	$4.03	$0.63	**$0.78**
2016	$0.52	$0.51	$0.85	$1.07	$3.96	$0.64	**$0.79**
Average Annual Rate of Change 2016/2006	**1.9%**	**1.6%**	**2.2%**	**1.3%**	**0.0%**	**0.4%**	**1.2%**

[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.

Note: Includes only urban agencies operating over 30 vehicles in peak service included.

Sources: National Transit Database; Bureau of Labor Statistics, Consumer Price Index.

Farebox Recovery Ratios

The farebox recovery ratio represents farebox revenues as a percentage of total transit operating costs net of reconciling cash expenses. It measures users' contributions to the variable cost of providing transit services and is influenced by the number of riders, fare structure, and rider profile. Low regular fares, high availability and use of discounted fares, and high transfer rates tend to result in lower farebox recovery ratios. Farebox recovery ratios for 2006 to 2016 are provided in *Exhibit 2-40*. The average farebox recovery ratio over this period for all transit modes combined was 34.8 percent in 2016. Heavy rail had the highest average farebox recovery ratio at 57.1 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 2-40 ■ Urban Farebox Recovery Ratio by Mode, 2006–2016

Mode	Heavy Rail	Commuter Rail	Light Rail[1]	Fixed-route Bus[2]	Demand Response[3]	Other[4]	Total
2006	60.9%	49.5%	27.4%	28.6%	10.1%	39.6%	**36.0%**
2007	56.8%	49.5%	26.6%	26.6%	8.6%	35.4%	**34.0%**
2008	59.4%	50.3%	29.3%	26.3%	7.6%	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%	7.9%	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%**
2015	60.3%	52.0%	27.5%	27.1%	7.9%	41.8%	**36.1%**
2016	57.1%	52.1%	26.3%	25.9%	8.0%	40.0%	**34.8%**
Average Annual Rate of Change 2016/2006	**-0.6%**	**0.5%**	**-0.4%**	**-1.0%**	**-2.3%**	**0.1%**	**-0.3%**

[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.

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

Source: National Transit Database.

CHAPTER 3: Travel Behavior

Travel Behavior and the National Household Travel Survey

Household travel behavior depends heavily on the population's demographic distribution and geographic location. These factors historically have significant impacts on the size and distribution of travel demand. The growth of megaregions, changes in marriage and birth rates, and baby boomers entering retirement prompt population shifts that also significantly influence the way people travel. Many of these household characteristics can be found in the National Household Travel Survey (NHTS) data, the primary source of national-level information on travel behavior.

KEY TAKEAWAYS

- Baby boomers are working later in life, and driving more miles than did their cohorts of the past.
- Increased internet use is leading to higher reliance on trip-saving web services as well as growing demand for transportation alternatives such as ridehail, bikeshare, and carshare.
- Although privately owned vehicle (POV) alternatives have risen since 2009, vehicle ownership is still a strong indicator of household mobility with annual household trips increasing with the number of household vehicles.
- One in five American adults are now "smartphone-only" internet users, using their phones to browse the internet without broadband access at home.

The latest 2017 NHTS also captures information on household technology use. Access to the internet represents a fundamental shift in how Americans connect with one another, gather information, and conduct their day-to-day lives. Advancements in information communication technologies, global positioning systems (GPS), sensors, and automation have significantly influenced personal travel patterns. The adoption of new technologies has opened the doors to a growing list of advanced mobility options for many Americans, including teleworking, online shopping, and alternative transportation services.

A growing number of employers and professions offer remote work options, allowing eligible workers to avoid commute trips. The widespread use of online shopping allows households to cut down weekend errands and even grocery shopping. Ridehail, bikeshare, and carshare are all examples of mobility options that did not see significant market penetration as recently as 10 years ago. Myriad apps based on mobility-enabling technologies are now available that can help users perform day-to-day tasks, and are changing travel behavior. A trip that might have been taken in the traveler's personal vehicle now might occur via a variety of transportation alternatives.

Workers continue to drive the demand for vehicle travel. With more baby boomers working past traditional retirement age, the safety of older drivers is a growing concern. Biking and walking have also become more popular modes of travel over the years.

This chapter focuses on issues pertaining to personal travel; freight transportation is addressed separately in Part III of this report. The discussion covers only a subset of the wide array of data available through the 2017 NHTS. Future editions of this report will cover other topics of interest.

National Household Travel Survey

The NHTS, previously called the Nationwide Personal Transportation Survey, is a fundamental intermodal data collection effort conducted periodically and led by the Federal Highway Administration (FHWA) since 1969. The 2017 NHTS is the eighth and most recent survey in this series. The survey documents the demographic characteristics of households and people—and information about household vehicles—for all 129,969 sampled households, collected from April 2016 to April 2017. Unlike previous iterations, the 2017 survey captures additional information on public health, ridehail, carshare, transportation apps, and technology use. The most recent iterations of the survey also capture data on web use, telework, and online shopping, allowing for trend analysis over the last two decades. The 2017 NHTS offers a nationally representative understanding of the adoption of advanced mobility solutions enabled by internet and mobile technologies.

The NHTS collects travel data from a representative sample of U.S. households to characterize personal travel patterns. Details of travel by all modes for all purposes of each household member are collected for a single assigned travel day. In this way, NHTS traces both the movement of household members and the use of each household vehicle on a randomly selected day. The data provide national and State-level estimates of trips and miles by travel mode, trip purpose, time of day, gender and age of traveler, and a wide range of attributes. The NHTS sets itself apart from the American Community Survey by collecting information on all travel purposes as opposed to focusing on only the journey to work. The data presented in this section are from the NHTS data series, unless otherwise noted.

Changes in NHTS Data Collection Methodology

Prior to 1990, NHTS data were collected in face-to-face interviews sampled from respondents to the Census Bureau's Current Population Survey. From 1990 to 2009, NHTS data were collected using a random-digit dial sample of telephone households in the United States. In 2017, address-based sampling was employed due to the decline of households with landline telephones. Most households submitted their responses via the web, although a self-selected group did opt to respond via telephone. Both the 2009 and 2001 surveys were conducted during economic downturns, whereas the 2017 survey, conducted in 2016–2017, occurred during a period of economic growth and a presidential election cycle. All of these factors can affect a household's willingness to participate, the quality of responses, and overall data results.

The 2017 methodology changes are described in the 2017 NHTS Release Notes: (https://nhts.ornl.gov/documentation). Additional information on the NHTS is available at http://nhts.ornl.gov.

Advanced Mobility Solutions

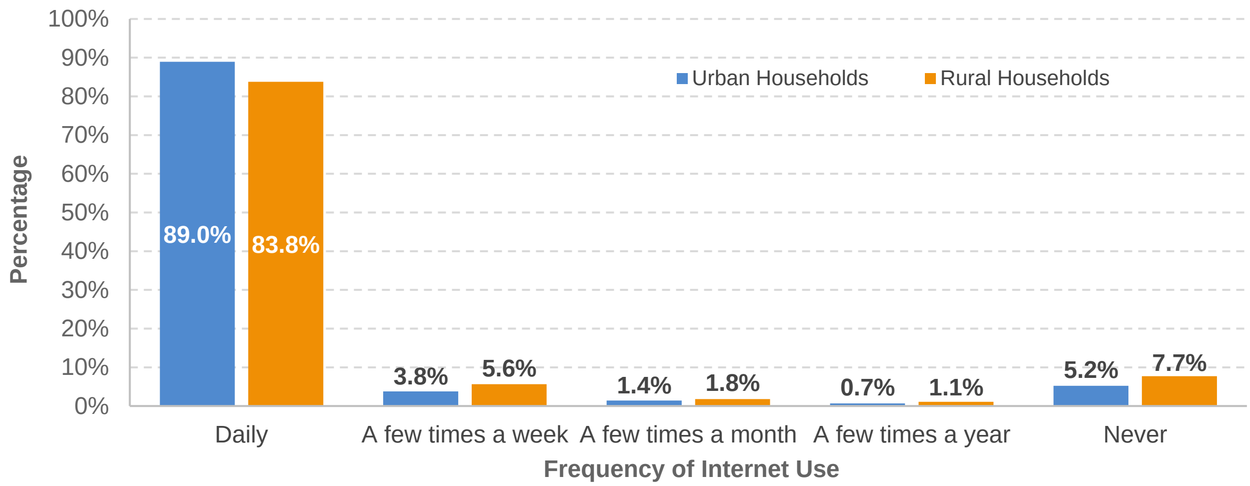
One unique feature of the 2017 NHTS is that it includes questions about advanced mobility technologies that are internet- or mobile phone-based. These trends can be linked to other household characteristics to better describe how mobility patterns are changing. The last decade has seen remarkable changes in internet use, online shopping, and telework.

Internet Use

Access to mobile phones and the internet plays a significant role in enabling these new technologies and often determines the breadth of mobility options available to a household. In some parts of the country, travelers now have the option to avoid enough trips to make car ownership optional. Basic errands such as depositing checks, mailing letters at the post office, purchasing international calling cards, listening to the latest music album, or even watching the latest movie release can all now be accomplished online. Online services, while potentially increasing freight delivery trips, can reduce consumer trips and personal errands, resulting in fewer household road miles traveled, less gasoline consumed, and reduced air pollution. Roughly 90 percent of Americans use the internet today, with 26 percent of American adults reporting that they are online almost constantly according to a 2018 Pew Research Center survey.[14] The 2017 NHTS confirms that more than 80 percent of households use the internet on a daily basis and over 90 percent use it at least a few times a month (see *Exhibit 3-1*).

[14] Pew Research Center. 2018. Internet/Broadband Fact Sheet. http://www.pewinternet.org/fact-sheet/internet-broadband/.

Exhibit 3-1 ■ Household Internet Use, 2017

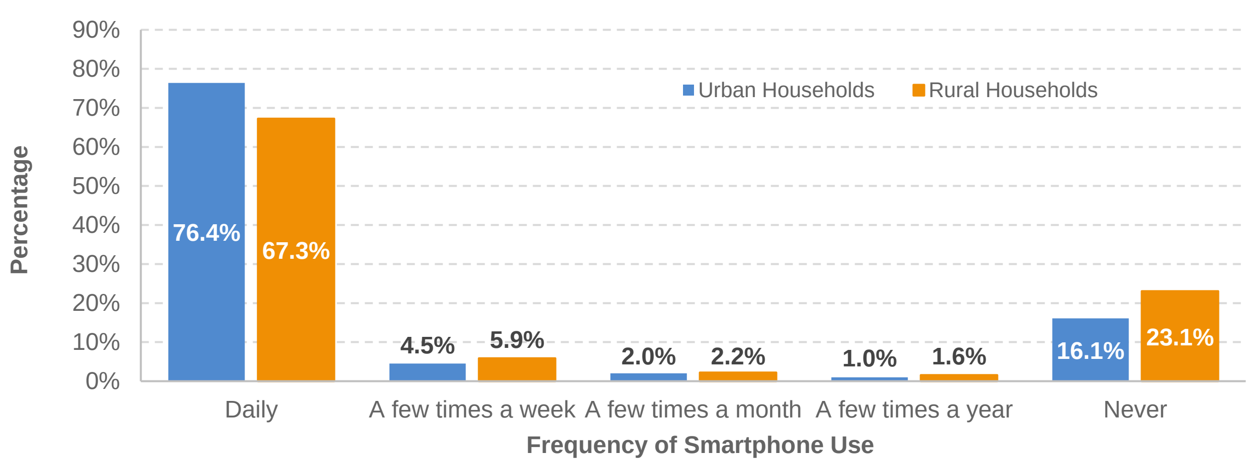


Source: National Household Travel Survey.

Today, about two-thirds of American households have broadband internet access in their homes.[1] Adoption gaps are typically based on factors such as age, income, education, and community type. Older adults and rural residents are less likely to have broadband service at home. Access to the internet is more widespread in urban areas, where 92 percent of residents use the internet at least a few times a week. The proportion of frequent internet use among rural residents is slightly lower at 89 percent. For some demographic groups—such as young adults and college graduates—internet use is nearly ubiquitous.

In early 2000, about half of U.S. adults were already on the Web; today, about nine out of 10 use the internet. Wireless connection is one of the main drivers of widespread internet access across the Nation, particularly in urban areas. The 2017 NHTS found that accessing the internet with a smartphone is more prevalent in urban areas: 81 percent of urban and 73 percent of rural households use the internet via smartphone at least a few times a week (see *Exhibit 3-2*). The share of rural households that have never used a smartphone to access the internet is 7 percentage points higher than that of their urban counterparts. Furthermore, the Pew Research Center found that one in five American adults are now "smartphone-only" internet users, using their phones to browse the internet without broadband access at home. This practice is especially common among younger adults, nonwhites, and lower-income Americans.

Exhibit 3-2 ■ Frequency of Smartphone Use to Access the Internet, 2017



Source: National Household Travel Survey.

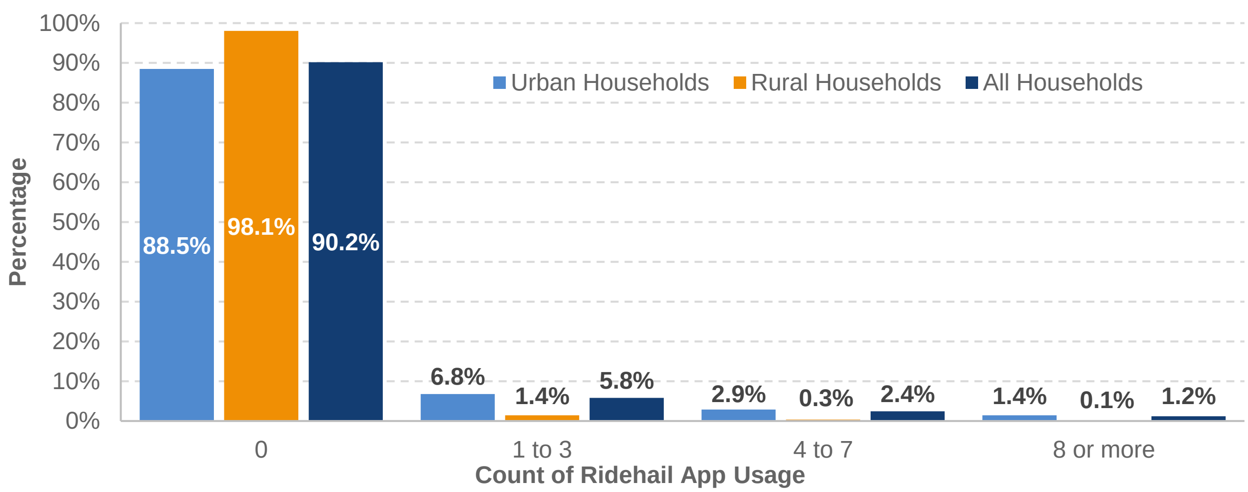
Ridehail and Carshare Use

Ridehailing services like Uber and Lyft are often viewed as alternatives to traditional taxi service, whereas carsharing services like Zipcar and Car2Go are used instead of traditional car rentals. Both of these services rely on the internet to inform customers of real-time vehicle availability.

Although the 2017 NHTS data show that over 80 percent of U.S. households have used their smartphones to access the internet, 91 percent of Americans at or above 16 years old indicated they had not hailed a ride with a ridehail smartphone app in the last 30 days (see *Exhibit 3-3*). The divide was more pronounced in rural areas, where less than 2 percent of respondents had used a ridehail app in the last 30 days, compared with the 11.5 percent of urban residents who had used a ridehail app at least once in the previous 30 days. Ridehail has enabled some users to avoid vehicle ownership altogether, especially in areas with multiple mobility options that support ridehail. Many ridehail companies do not provide service in rural communities due to the lower profit margins. Only a small portion (1.2 percent) of the population are frequent users of ridehail apps (eight or more times a month), and are largely concentrated in urban areas where their popularity among users has seen tremendous growth. Ridehail trips often include late-night trips, weekend trips, and even act as ambulance substitutes for trips to the emergency room. In the NHTS, ridehail trips were catalogued as taxi trips. Taxis' share of overall trips jumped from 0.2 percent in 2009 to 0.5 percent in 2017—an increase of 150 percent.

Carsharing, which also uses mobile app technology to indicate vehicle availability, is virtually negligible in both urban and rural households according to the 2017 NHTS. About 99.8 percent of rural Americans at or above 16 years old had not used a carshare vehicle in the last 30 days. Participation in carsharing was more common in densely populated urban areas, where about 0.7 percent of residents had made at least one carshare trip in the previous month. Although carsharing has not gained significant popularity in the United States, its users can often avoid private car ownership and use sharing services coupled with other transportation alternatives to fulfill their transportation needs.

Exhibit 3-3 ■ Ridehail App Usage in the Last 30 Days, 2017

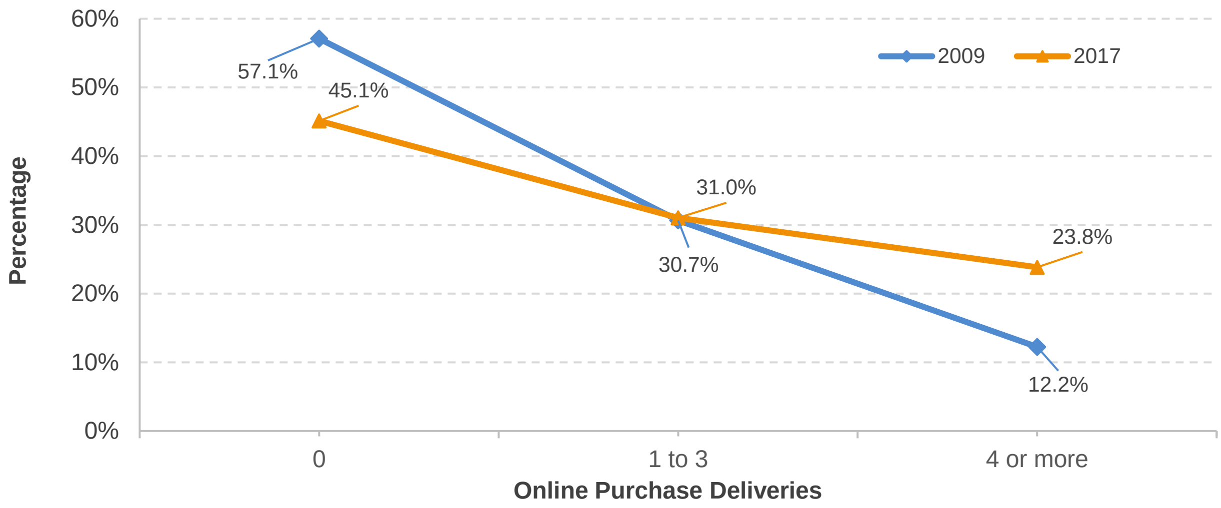


Source: National Household Travel Survey.

Online Shopping

Technology also has the potential to reduce the frequency of household shopping trips, with a growing number of households receiving deliveries from online transactions. 2017 NHTS data show a 2.5 percent and 1.5 percent drop in the distribution of shopping trips and personal errands, respectively, from 2009. This may not necessarily reduce total vehicle miles traveled (VMT) as freight VMT has grown in recent years to meet the needs of American consumers. More than 50 percent of Americans at or above age 16 have had at least one online purchase delivered in the last 30 days according to the 2017 NHTS, a 12 percent increase from 2009 (see *Exhibit 3-4*). The share of households with frequent deliveries has increased considerably, as shoppers making four or more monthly online purchases for delivery almost doubled from 12.2 percent in 2009 to 23.8 percent nationally in 2017. This is complemented by the share of households with zero online purchases, which dropped by 12.0 percentage points over this period.

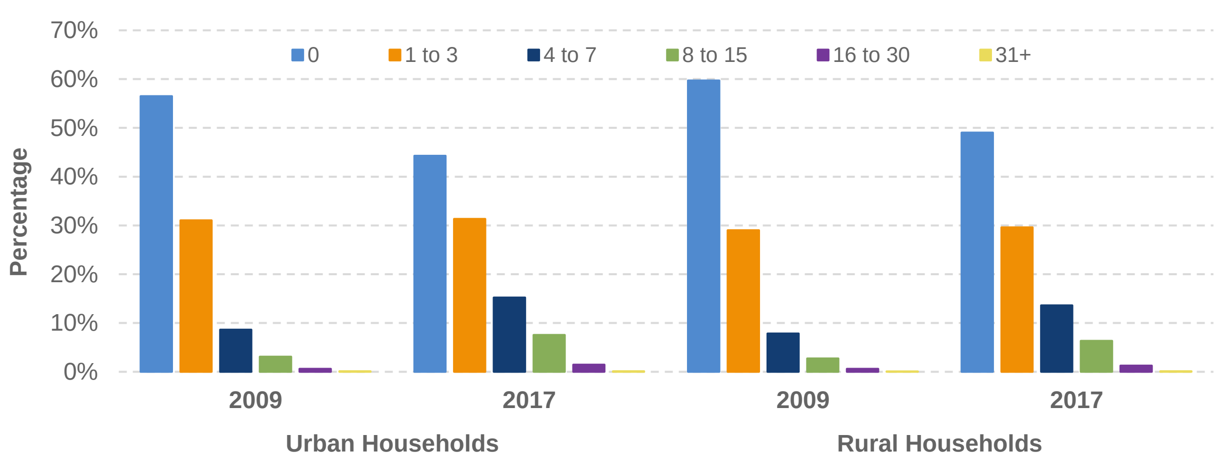
Exhibit 3-4 ■ Frequency of Online Purchase Deliveries in the Last Month, 2009 vs. 2017



Source: National Household Travel Survey.

Just under 60 percent (59.7 percent) of rural households did not receive deliveries of online purchases in 2009; this share decreased to 49.0 percent in 2017. Urban residents saw a slightly larger jump in the delivery of online purchases relative to their rural counterparts from 2009 to 2017: the share of urban households that received no deliveries was 56.5 percent in 2009 and 44.3 percent in 2017. The number of heavy users of online shopping has grown in both rural and urban areas. About 3.8 percent of urban households received more than eight deliveries in 2009, rising to 9.2 percent in 2017. This jump was slightly more pronounced in rural areas, where households relying heavily on online purchases increased from 3.4 percent in 2009 to 7.7 percent in 2017. With access to physical retail stores more limited and farther away in rural areas, online shopping can provide more retail options to rural residents (see *Exhibit 3-5*).

Exhibit 3-5 ■ Online Shopping, Monthly, 2009 vs. 2017



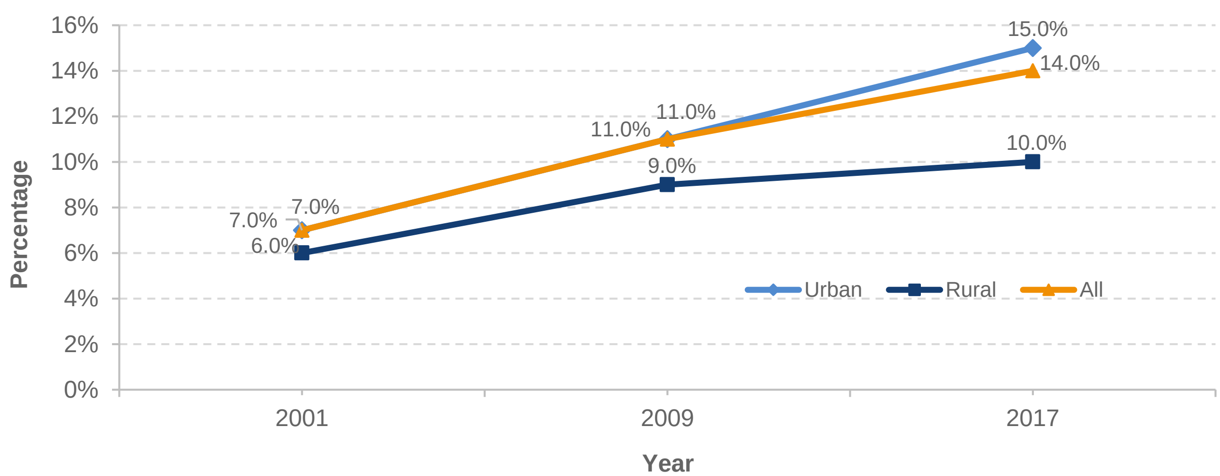
Source: National Household Travel Survey.

Telework

Technology has also enabled telework for some U.S. workers, especially those in careers that do not require a physical presence at all times. In the NHTS, respondents who do not "typically work from home" are asked if they have the option of working from home or an alternate workplace. Although not all who work from home require internet connectivity, many use the Web to check email; advancements in technology have enabled more telework functionality through improved connectivity and security. The share of telework-eligible workers increased from 11 percent in 2001 to 14 percent in 2014 (see *Exhibit 3-6*). The majority of the labor force still does not have the option to telework—especially in rural areas where 90 percent of workers are ineligible, compared with their urban counterparts at 85 percent.

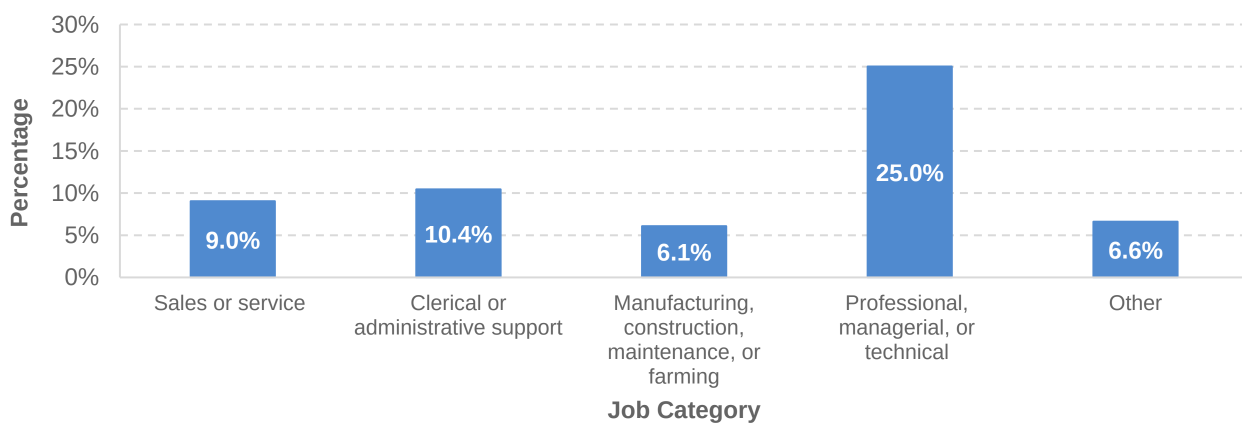
Although most workers do need to travel to their workplace, those in professional, managerial, or technical fields are more than twice as likely to have the option to telework compared with other occupations (see *Exhibit 3-7*). The uptick in telework and the use of advanced information technology has led travel behavior researchers to project that the average number of household trips will decrease, with fewer required commute trips to the office and more video conferencing options supplanting in-person meetings. Increased telework can contribute to reduced peak-hour congestion but may lead to additional discretionary trips or personal errands on non-commuting days/times.

Exhibit 3-6 ■ Telework-eligible U.S. Workers, 2001–2017



Source: National Household Travel Survey.

Exhibit 3-7 ■ Telework Eligibility by Job Category, 2017



Source: National Household Travel Survey.

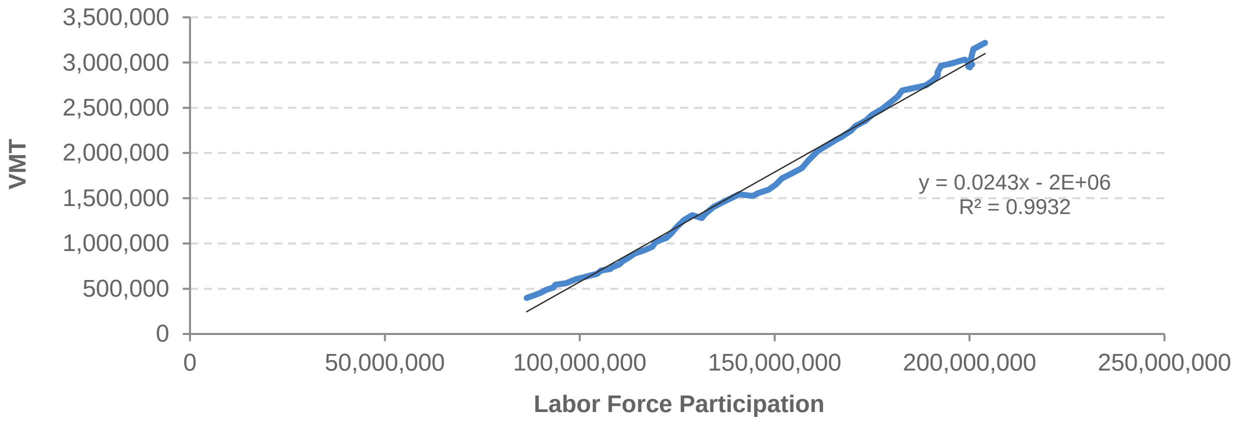
Travel Patterns Associated with Household Characteristics

Work status and household characteristics such as life cycle, age, and gender composition can strongly influence travel patterns.

Work Status

VMT has consistently shown a strong relationship with labor force participation over time. *Exhibit 3-8* shows the Bureau of Labor Statistics' (BLS) Labor Force Participation Population correlation with VMT from 1948 through 2016. Highway travel closely reflects economic conditions as movements of people and goods increase during booming periods. Even through recessions and employment level lows, VMT has remained strongly tied to the activity of the labor force.

Exhibit 3-8 ■ Labor Force Participation Population vs. Vehicle Miles Traveled, 1948–2016

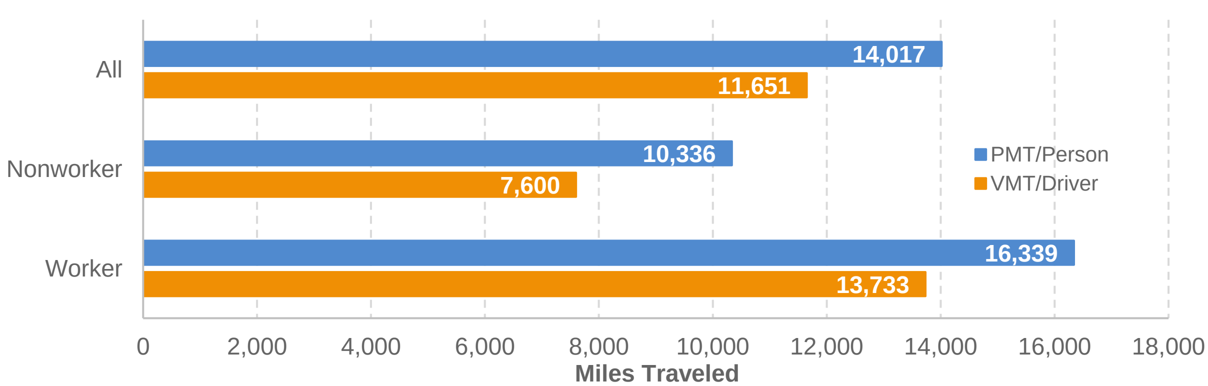


Source: FHWA Highway Statistics, Bureau of Labor Statistics

Travel by Workers vs. Nonworkers

With regular commuting habits and higher incomes, workers tend to have more consistent travel demands, as well as more financial resources, to purchase vehicles and take discretionary trips than do nonworkers. Workers travel more, regardless of whether it is in a vehicle, with almost 60 percent more person miles traveled than nonworkers in 2017 (see *Exhibit 3-9*). NHTS 2017 data show that an average worker drove 13,733 miles annually, almost double the miles driven by an average nonworker at 7,600 miles.

Exhibit 3-9 ■ Annual Miles, Worker vs. Nonworker, 2017

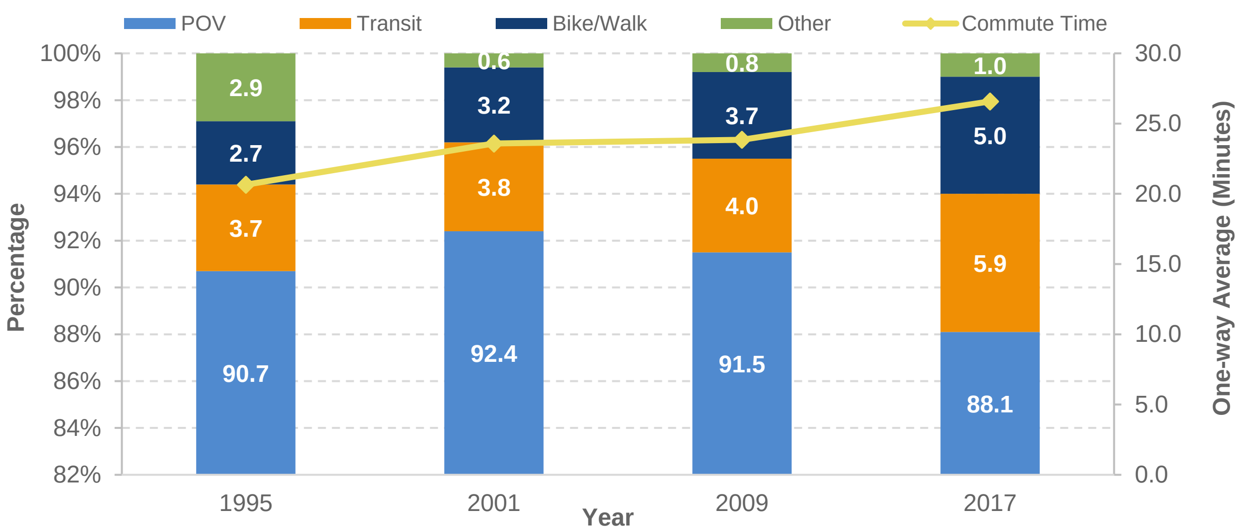


Note: PMT is person miles traveled; VMT is vehicle miles traveled.
Source: National Household Travel Survey.

Commuting Trips

Not only do workers take more daily trips, their time spent commuting has grown over time. *Exhibit 3-10* shows that the average commute in 2017 took 26.6 minutes (one way), compared with 23.9 minutes in 2009, for an average worker who traveled to and from work five days a week. Since 1995, the average commute time has risen by about 29 percent. This translates to an extra 27 minutes per week of commuting time in 2017.

Exhibit 3-10 ■ National Household Travel Survey Commute Trips, 2017



Note: POV is privately owned vehicle.

Source: National Household Travel Survey.

NHTS data on commute trips over time have also shown a small overall decline in the share of POV use though POV still represents the vast majority of commute mode share. From 2009 to 2017, the percentage of commute trips in POVs declined from 91.5 percent to 88.1 percent. Over this same period, the percentage of commute trips using transit rose slightly from 4.0 percent to 5.9 percent; the combined bicycling and walking share rose from 3.7 percent to 5.0 percent.

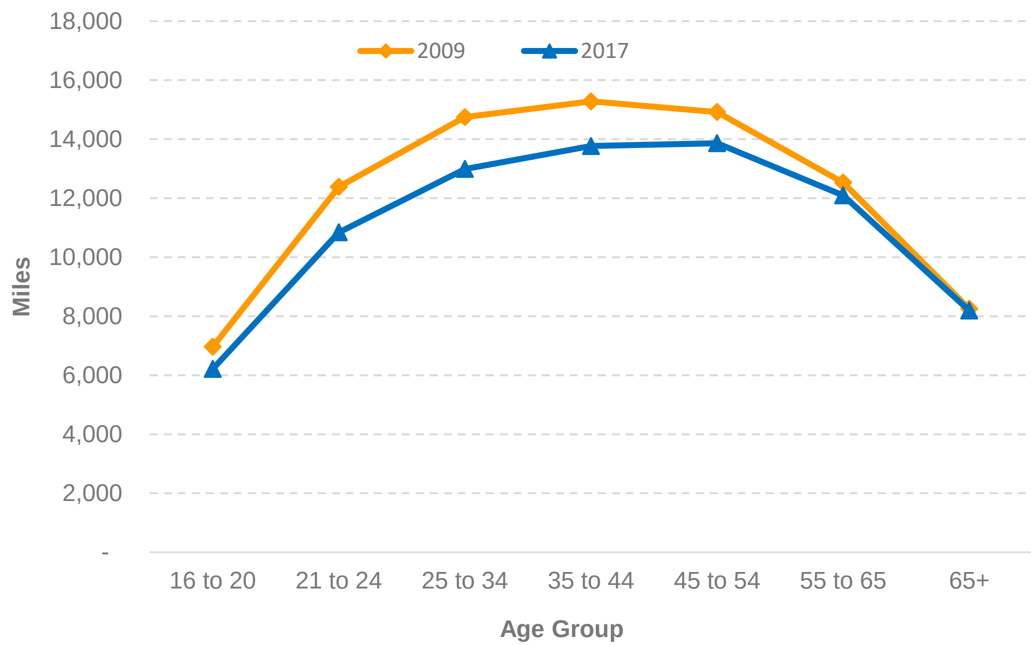
Baby Boomers

Baby boomers are the demographic cohort generally defined as people born from 1946 to 1964. In 2009, this cohort ranged in age from 45 to 63 years old; in 2017, they ranged from 53 to 71 years old.

For baby boomers aged 65 and over, the number of trips per week reported in NHTS showed little change over time, from 22.5 in 2009 to 22.3 in 2017. Older people were the only age group, however, to report an increase in time spent driving: 19 more minutes per week in 2017 compared with the estimate in 2009.

Exhibit 3-11 shows that average annual VMT reported in NHTS by age group. The reported number of miles driven declined between 2009 and 2017 for all age groups; the largest percentage decline was for drivers in the 21 to 24 age group, with progressively smaller declines for each older age group. As shown in *Exhibit 3-12*, those in the 55- to 65-year-old age group drove 4 percent more miles annually than the average U.S. driver in 2017, while in 2009 55- to 65-year-old drivers drove 3 percent fewer miles annually than the average U.S. driver that year. Drivers aged 65+ drove 30 percent fewer miles annually than the average U.S. driver in 2017, while in 2009 those aged 65+ drove 36 percent fewer miles than the average U.S. driver.

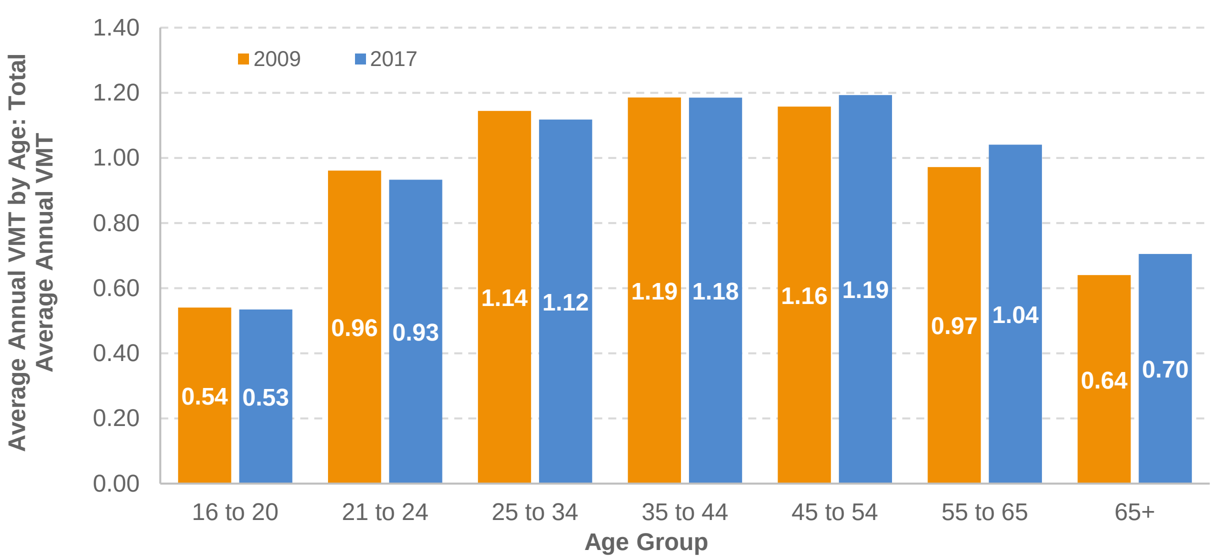
Exhibit 3-11 ■ Average Annual VMT by Age Group, 2009 vs. 2017



Note: VMT is vehicle miles traveled.

Source: National Household Travel Survey.

Exhibit 3-12 ■ Average Annual VMT by Age Indexed to Total Average Annual VMT, 2009 vs. 2017

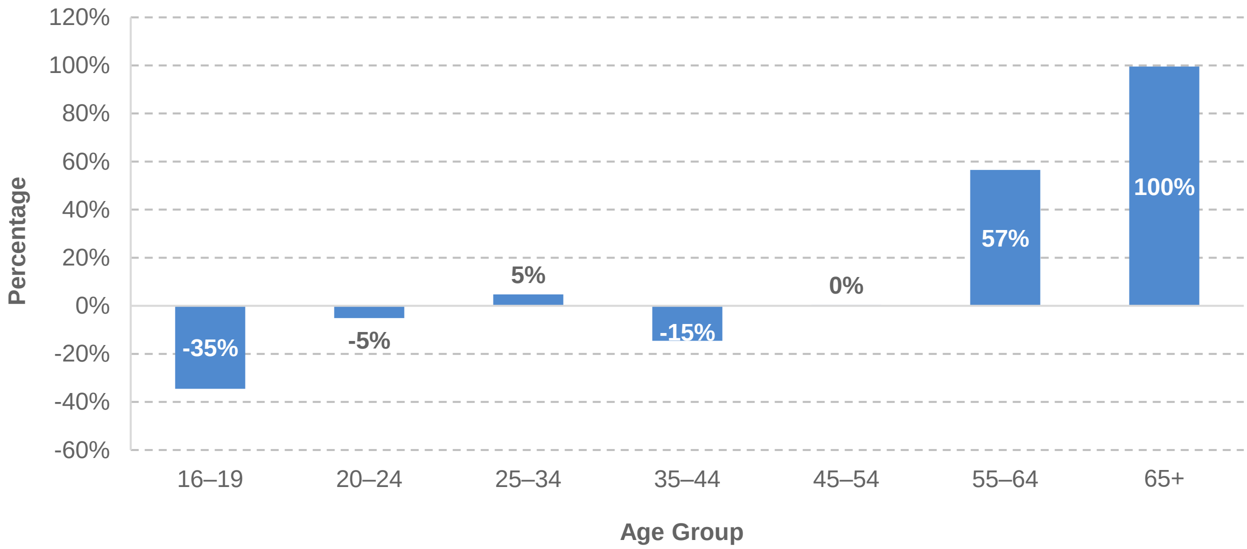


Note: VMT is vehicle miles traveled.

Source: National Household Travel Survey.

As boomers grow older, they are postponing retirement and staying in the workforce longer. From 2002 to 2016, the BLS shows that there was a 100 percent increase in workers over the age of 65 and a 57 percent increase in total employed. Meanwhile those aged 16 to 19 have seen a 35 percent decrease in total employed. Baby boomers are working longer into their traditional retirement years, and they are driving more miles than did their cohorts of the past. This higher demand for driving among age 55+ workers contributes to the growing safety concerns for U.S. road users (see *Exhibit 3-13*)

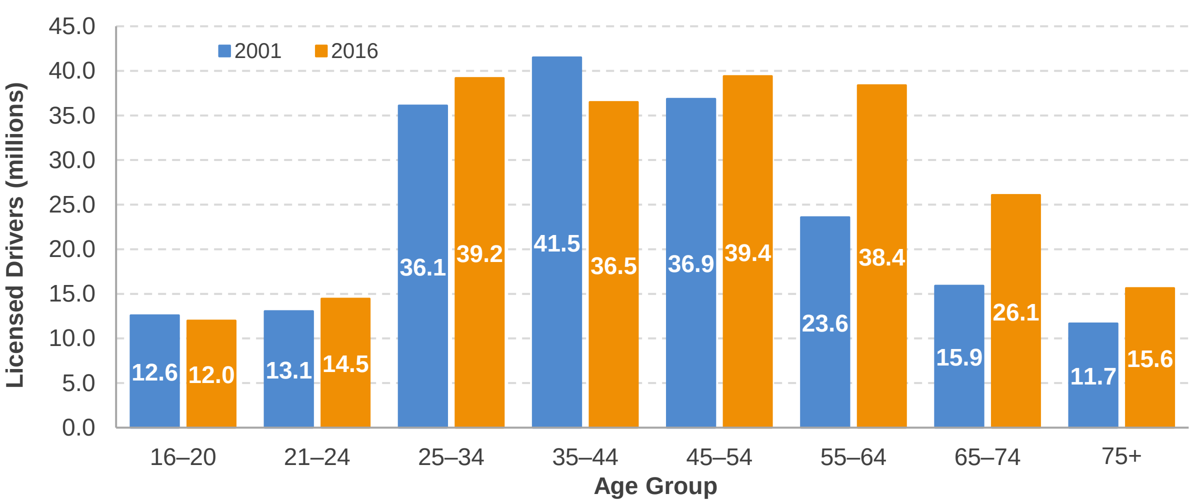
Exhibit 3-13 ■ Change in Employment Numbers, 2002–2016



Source: Bureau of Labor Statistics.

Drivers of the past acquired their licenses at an earlier age. With more States implementing graduated licensing programs, a boom in alternate mobility options, and the large portion of baby boomers entering the 65+ age bracket en masse, a higher percentage of older drivers are on the road compared with previous years. *Exhibit 3-14* shows the composition of licensed drivers by age group. Between 2001 and 2016, the numbers of licensed drivers in younger age groups (below 54 years old) declined or increased modestly. In contrast, the number of licensed drivers aged 55 years or older surged by more than one-third. This is particularly the case for licensed drivers between 55 and 74 years old, whose numbers rose by more than 60 percent. It is possible that the adoption of advanced technology and new mobility options is more prevalent in younger drivers than among aging drivers, but these transportation alternatives could prove quite beneficial to those who choose, or are required, to give up their licenses later in life.

Exhibit 3-14 ■ Licensed Drivers by Age Group, 2001 vs. 2016



Source: FHWA, Office of Highway Policy Information, Highway Statistics (https://www.fhwa.dot.gov/policyinformation/quickfinddata/qfdrivers.cfm).

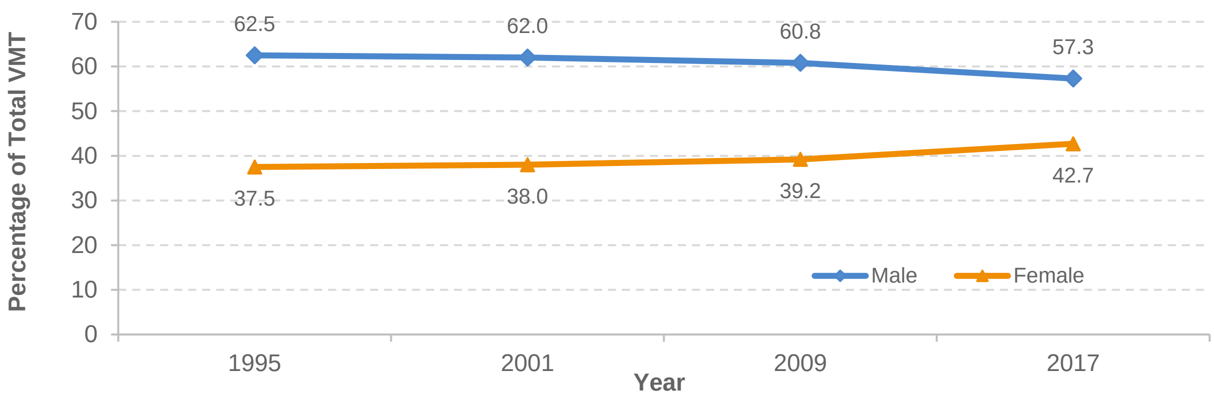
Travel by Gender

Traditionally, the number of male licensed drivers in the United States exceeded the number of female licensed drivers. This gap declined over time, and by 2005 the relationship was reversed: there were more female than male licensed drivers in the United States. The number of female licensed drivers has remained higher ever since.

Women are also closing the VMT gap. Although men drive more average annual miles than do their female counterparts across all age groups, the NHTS data show an increasing trend in VMT among women: they represented 39 percent of driver VMT in 2009, rising to 43 percent in 2017 (see *Exhibit 3-15*).

In 1969, men drove twice as many annual vehicle miles as women drove on average. *Exhibit 3-16* shows how the male-to-female ratio has grown closer to parity over time, with the average annual VMT of men dropping from 110 percent to 36 percent more than women from 1969 to 2017.

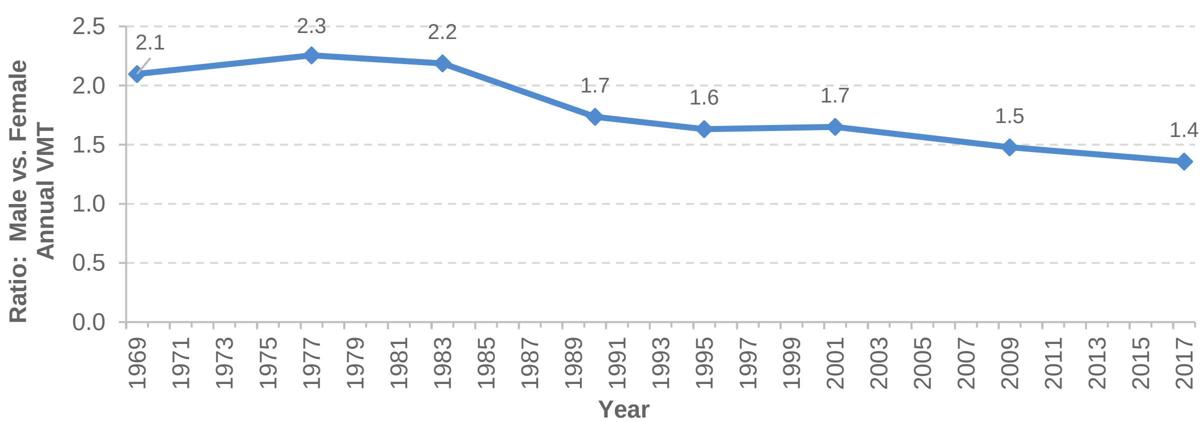
Exhibit 3-15 ■ Share of VMT by Gender, 1995–2017



Note: VMT is vehicle miles traveled.

Source: National Household Travel Survey.

Exhibit 3-16 ■ Male vs. Female NHTS Average Annual VMT per Driver, 1969–2017

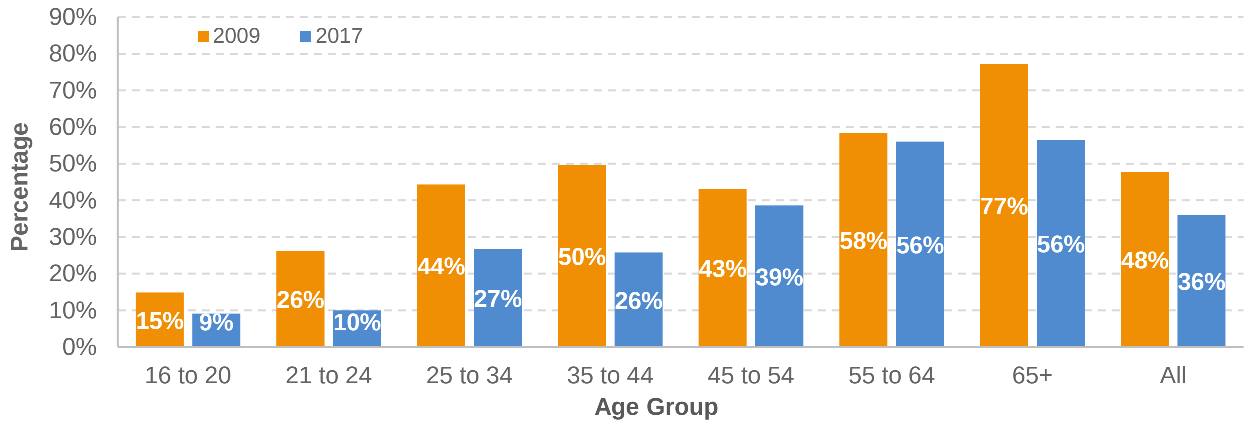


Note: NHTS is National Highway Travel Survey; VMT is vehicle miles traveled.

Source: National Household Travel Survey.

Women over 65 are also driving more and closing the VMT gap, with the male-to-female annual VMT ratio approaching parity across all age groups from 2009 to 2017 in *Exhibit 3-17*. Although men 65+ drove 56 percent more annual average miles than did their female counterparts in 2017, women have closed the gap by 21 percent from 2009 when men 65+ drove 77 percent more annual average miles than did women 65+ (77 percent vs. 56 percent).

Exhibit 3-17 ■ Percentage Difference Between Male Average Annual VMT and Female Average Annual VMT by Age Group, 2009 vs. 2017



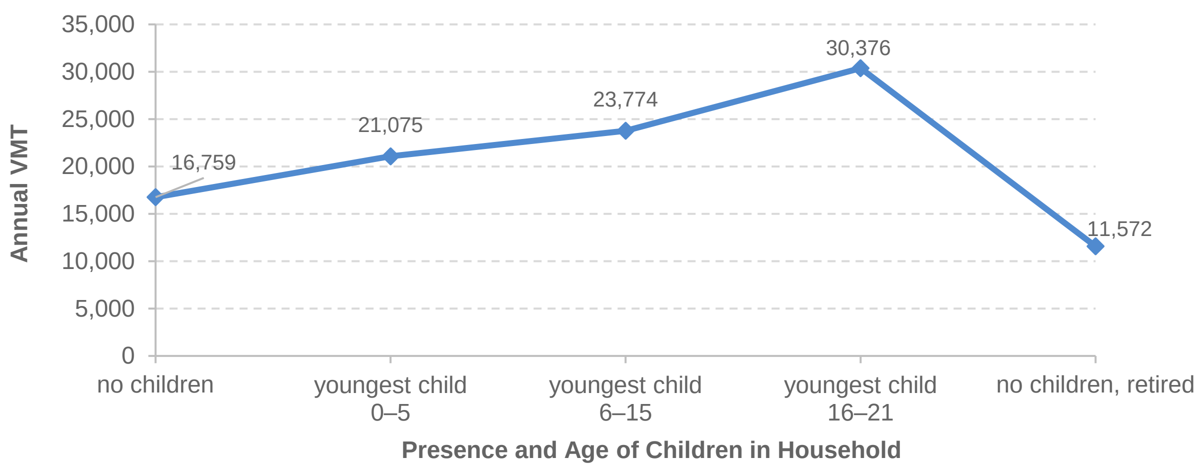
Note: VMT is vehicle miles traveled.

Source: National Household Travel Surveys.

Young Families

Exhibit 3-18 shows that households with children have a higher average annual household VMT whereas retirees and households with no children have the lowest household VMT. Household minors create many additional drop-off and pick-up trips with school and extracurricular activities, adding more miles to the household log that likely already contains regular work trips.

Exhibit 3-18 ■ NHTS Average Household Annual VMT, 2017



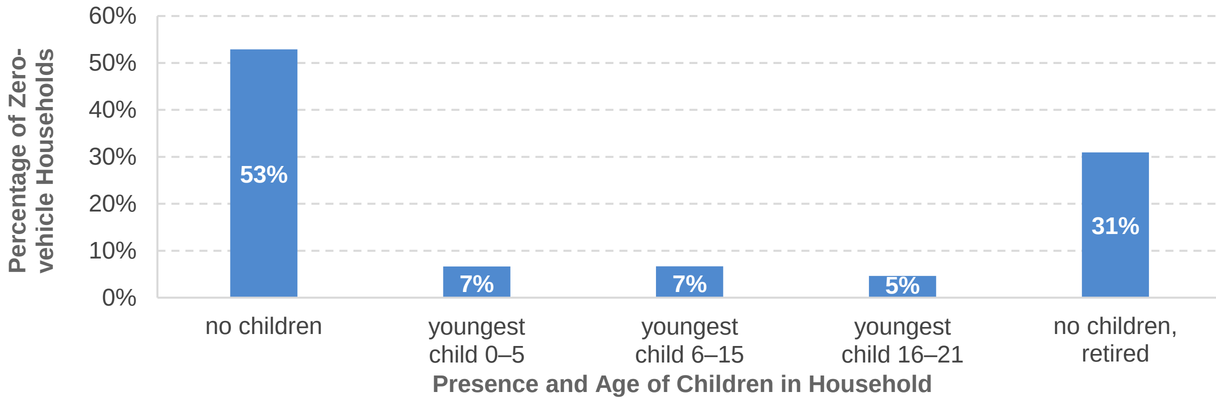
Note: NHTS is National Highway Travel Survey; VMT is vehicle miles traveled.

Source: National Household Travel Survey.

Children also prompt the "call" for vehicle ownership. As shown in *Exhibit 3-19*, households without children are much more likely to be zero-vehicle households. More than 80 percent of households without a car have no children present.

According to the Centers for Disease Control and Prevention, U.S. women are waiting longer to have their first child. In 1970, the mean age of a first-time mother was 24.6 years compared with 28 years in 2016. This growing delay in parenthood may also result in pushing back the need for vehicle purchases and higher VMT levels for older age groups.

Exhibit 3-19 ■ Zero-vehicle Households by Life Cycle, 2017



Source: National Household Travel Survey.

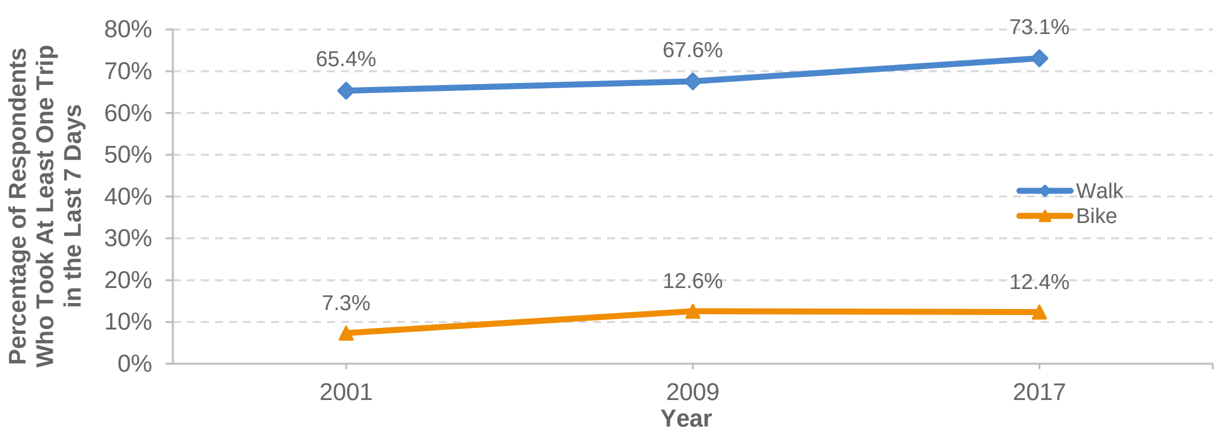
Travel Behavior Characteristics

As the U.S. population continues to grow, urban areas are seeing a disproportionate amount of the growth, with agglomeration effects drawing more jobs and skills to areas with larger population densities. As urban areas expand into their surrounding lands, commuting patterns change and corridors leading to employment centers continue to grow. These major cities have unique needs and hold a significant concentration of economic activity. This evolving distribution of housing and employment leads to unique vehicle ownership patterns and travel behavior trends.

Nonmotorized Trips

The NHTS is the only data source that captures bicycle and pedestrian activity at the national level. Since 2001, the NHTS has asked respondents about their cycling and walking frequency in the last week. The number of people who bike or walk at least once a week increased considerably from 2001 to 2017. Urban areas have seen significant growth in infrastructure to support active transportation, including sidewalks, bike lanes, and bikeshare programs. And although most Americans continue to rely on vehicles as their primary mode of transportation, 21 of the country's 50 most-populated cities saw a significant drop in driving over the last decade. When respondents were asked how many walking or bicycling trips they had taken in the past seven days, the data showed a 7.7 percentage point increase (from 65.4 percent in 2001 to 73.1 percent in 2017) in individuals who took at least one walking trip and a 5.1 percentage point increase in individuals who took at least one biking trip (see *Exhibit 3-20*).

Exhibit 3-20 ■ Bicyclist and Pedestrian Activity, 2001–2017

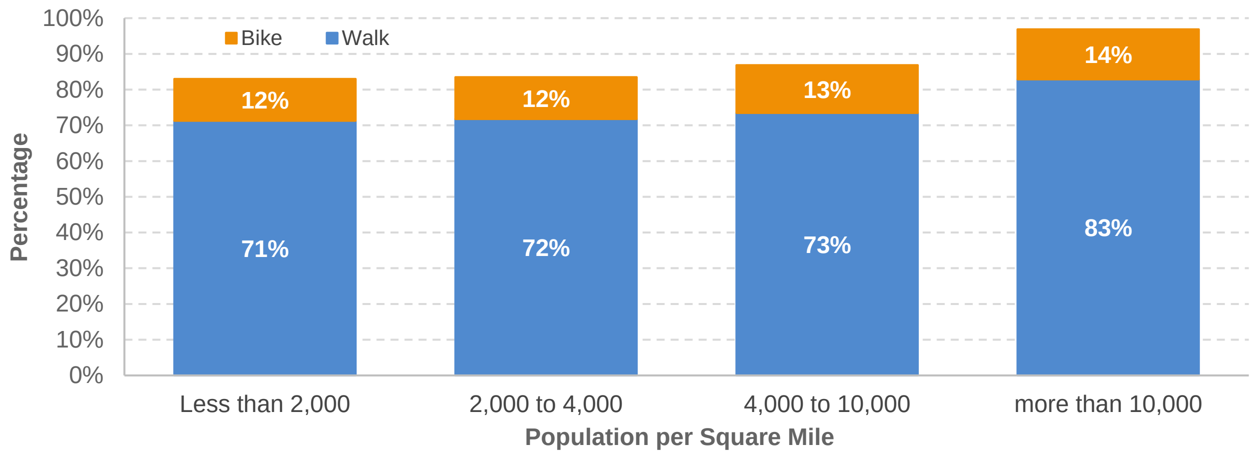


Source: National Household Travel Survey.

Both biking and walking trips were more prevalent in higher population density areas in the 2017 survey, likely due to the more inviting infrastructure, transit connectivity, and the shorter distances between origins and destinations in urban areas (see *Exhibit 3-21*). The likelihood of residents taking biking trips is 2 percent greater in regions with a population density greater than 10,000, compared with those areas with fewer than 2,000 people per square mile, where the likelihood of walking trips is 12 percent greater.

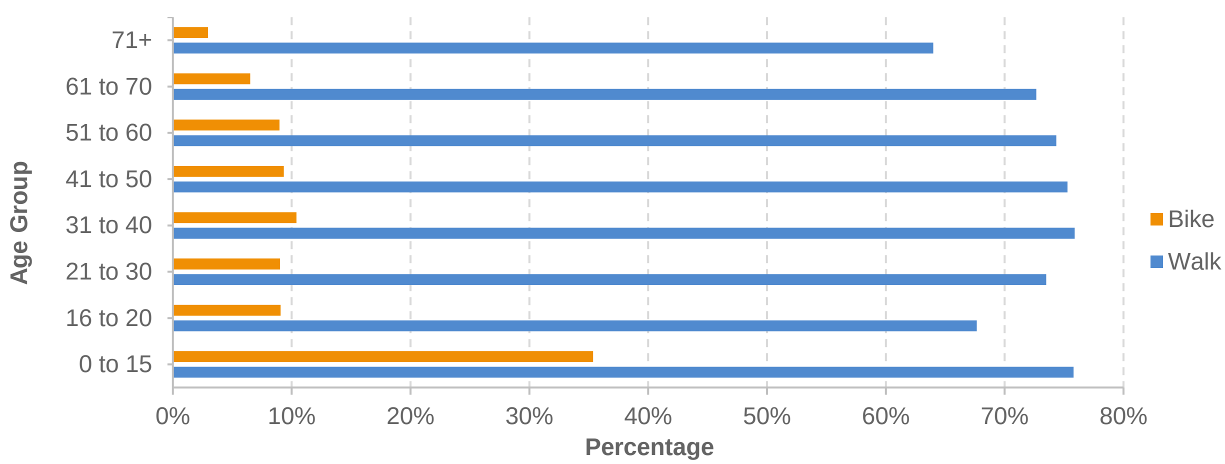
Walking trips are also much more common than biking trips across all age groups. Biking trips taper off considerably once a person reaches driving age, with bicycle use peaking with those 0 to 15 years old (35 percent). A continued decline occurs after age 40. Walking trips, however, remain relatively popular over the years with the lowest popularity in age groups 16 to 20 (68 percent) and 71 and over (64 percent) (see *Exhibit 3-22*).

Exhibit 3-21 ▪ Respondents Who Took a Walk or Bike Trip in the Last Week, by Population Density, 2017



Source: National Household Travel Survey.

Exhibit 3-22 ▪ Respondents Who Took a Bike or Walk Trip in the Last Week, by Age Group, 2017



Source: National Household Travel Survey.

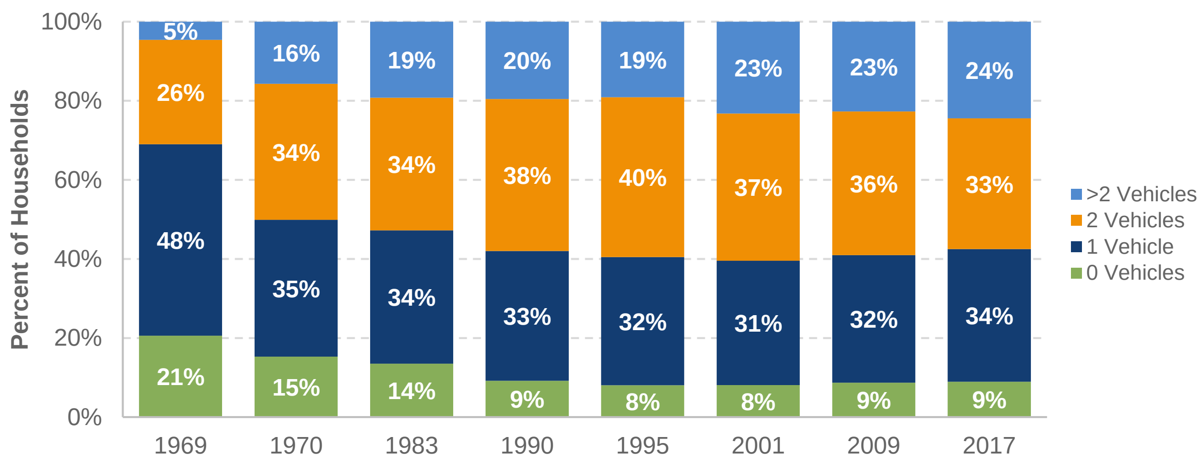
Vehicle Ownership

Household needs often dictate vehicle ownership patterns, and vehicle ownership is often a major indicator of household mobility. The composition of U.S. household vehicles has evolved over time (see *Exhibit 3-23*), which reflects the growing dependency of households on POVs to fulfill transportation needs. With a growing number of transportation alternatives, however, some households now have the option to live car-free and use a combination of transit, ridehail, carshare, and nonmotorized modes. Despite these options, as the number of household vehicles decreases, the number of household person trips also decreases.

Pickup trucks and sport utility vehicles (SUVs) may offer significant utility, vans are helpful for moving large numbers of people, and sedans offer efficiency and fuel economy. Climate, gas prices, regional culture, family size, household hobbies, and income all can play a role in whether and what kind of vehicle is used by a household. *Exhibit 3-24* shows that SUV and motorcycle ownership has increased over the last 20 years, while automobile, van, and pickup truck ownership have declined.

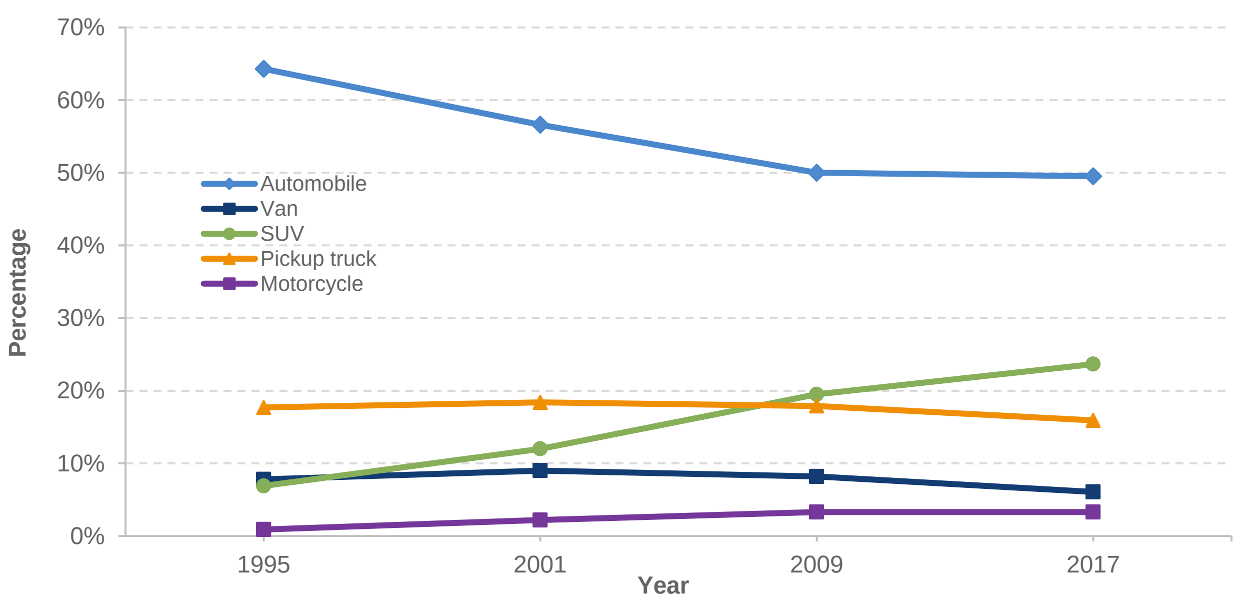
The number and type of vehicles in U.S. households vary by region. Pickup trucks and motorcycles are more prevalent in rural areas (28.7 percent vs. 12.1 percent and 4.3 percent vs. 3.0 percent, respectively), while automobiles and SUVs are more common in urban areas (53.5 percent vs. 36.2 percent and 24.1 percent vs. 22.1 percent, respectively) (see *Exhibit 3-25*).

Exhibit 3-23 ■ Share of U.S. Households by Vehicle Count, 1969–2017



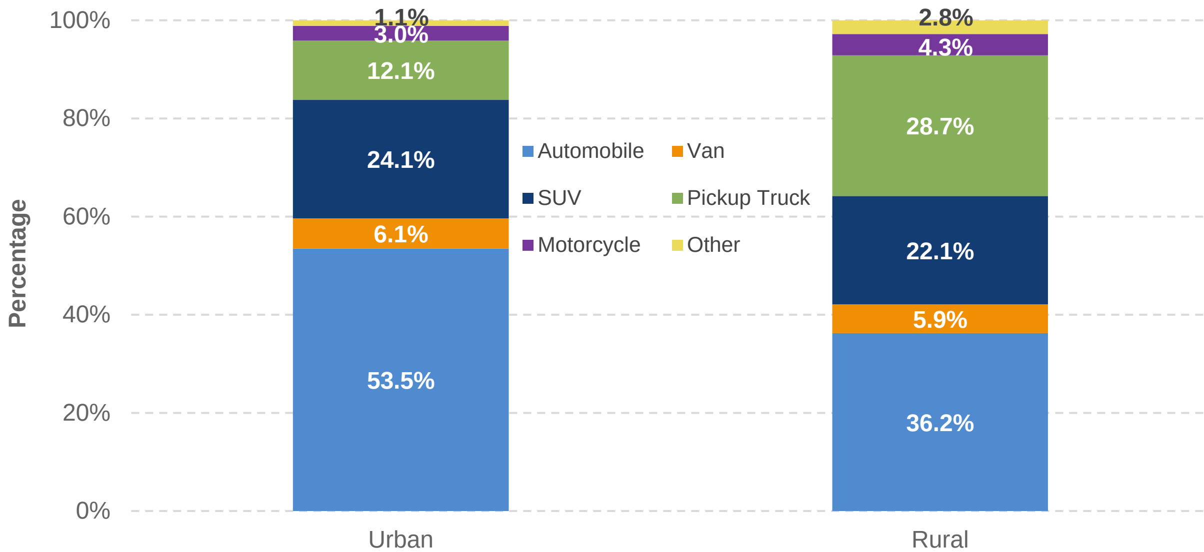
Source: National Household Travel Survey.

Exhibit 3-24 ■ Vehicle Ownership Trends by Vehicle Type, 1995–2017



Source: National Household Travel Survey.

Exhibit 3-25 ■ Vehicle Types, Rural vs. Urban, 2017

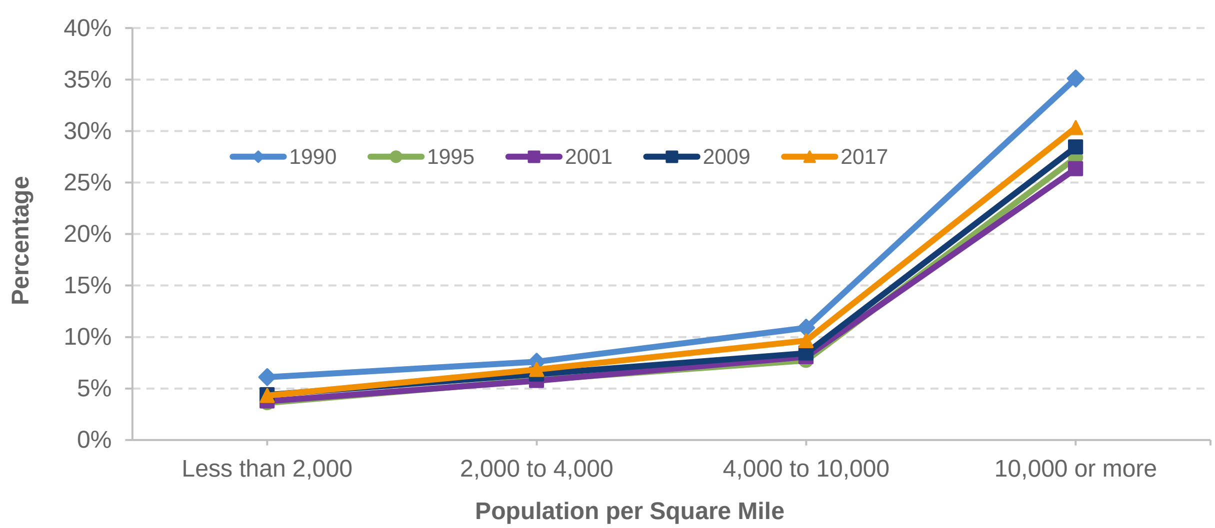


Source: National Household Travel Survey.

Urbanicity

Not only does the distribution of vehicle type change by "urbanicity," but so does the number of household vehicles. Urbanicity is characterized by the Census Bureau based on factors such as population, density, and land use. As population density increases, the percentage of households with more vehicles tends to decrease. This trend has held true for the last five iterations of the NHTS (see *Exhibit 3-26*). The percentage of households without vehicles increases with population density, and then rises sharply in areas with more than 10,000 people per square mile, likely due to higher density non-residential activity and the availability and practicality of more transportation alternatives including walking, biking, and public transit.

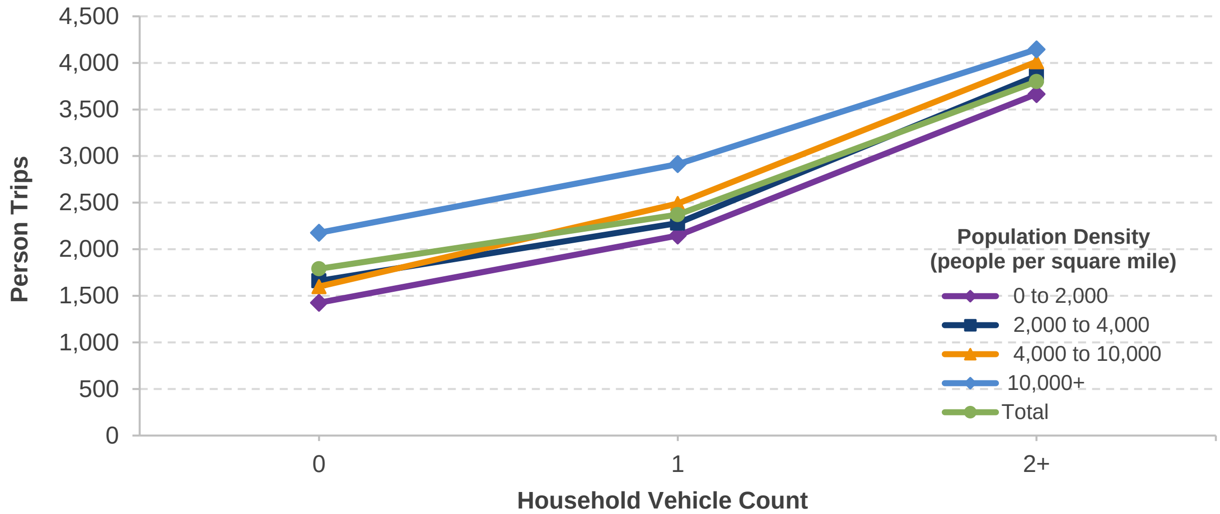
Exhibit 3-26 ■ Households Without a Vehicle, by Population Density, 1990–2017



Source: National Household Travel Survey.

Households living in areas with a population density greater than 10,000 people per square mile consistently have higher household person trips across all vehicle ownership levels, also likely due to the larger variety of mobility options and the close proximity of destinations (see *Exhibit 3-27*).

Exhibit 3-27 ■ Annual Person Trips per Household, 2017



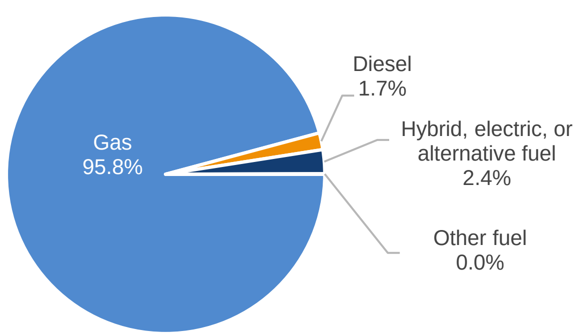
Source: National Household Travel Survey.

Advanced Vehicle Technology Penetration

Despite the post-recession rise in new vehicle sales, vehicle owners are still keeping their vehicles longer. The median age of the household vehicle fleet has been growing over the last 40 years. The average U.S. vehicle is almost 4 years older than in 1977, with rural households holding their vehicles longer than urban households. This pattern of vehicle ownership leads to a slow turnover of the U.S. vehicle fleet and delays in penetration of safety and fuel-efficient technologies.

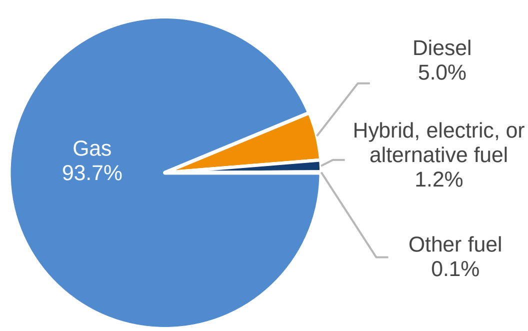
Petroleum-based products remained the predominant energy source for vehicles. About 2.4 percent of the total vehicle fleet in urban households use hybrid, electric, or alternative fuels in 2017, while 95.3 and 2.4 percent used gas and diesel, respectively (see *Exhibit 3-28*). Rural households reported even lower ownership rates of electric vehicles and higher ownership rates of diesel-run vehicles (see *Exhibit 3-29*).

Exhibit 3-28 ■ Urban Household Vehicle Fuel Type, 2017



Source: National Household Travel Survey.

Exhibit 3-29 ■ Rural Household Vehicle Fuel Type, 2017



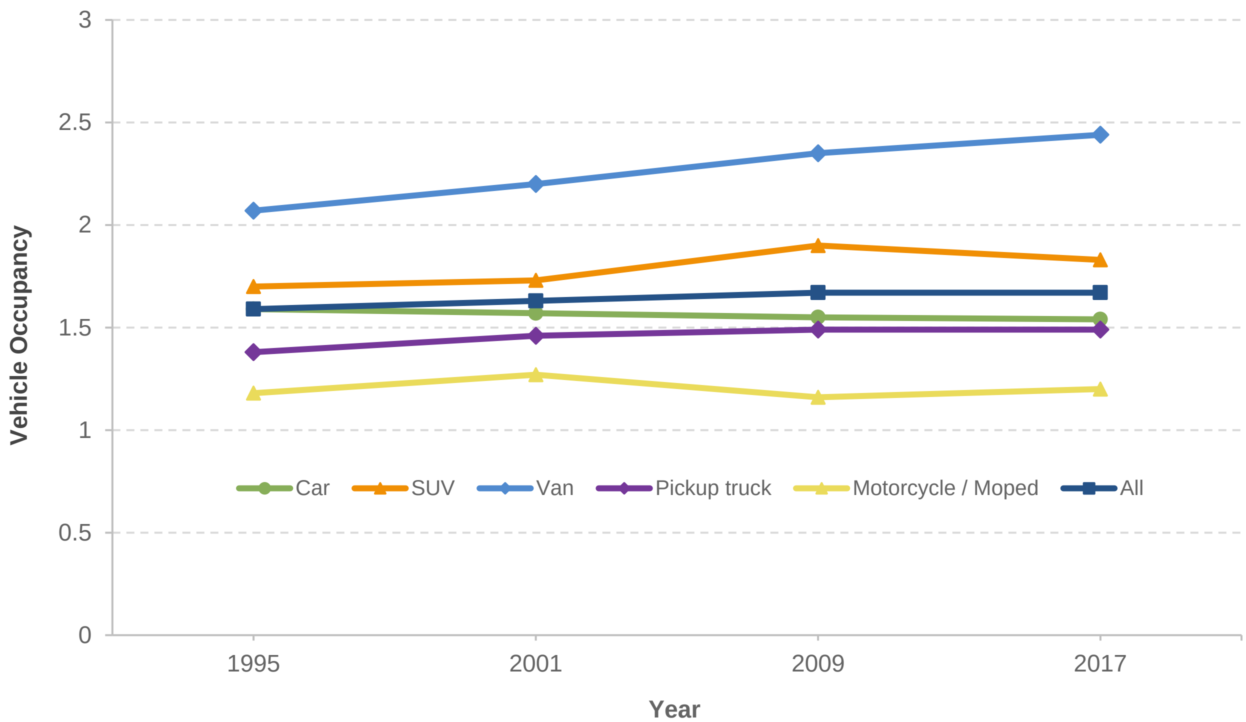
Source: National Household Travel Survey.

Vehicle Occupancy

According to 2017 NHTS data, the total mileage-weighted average vehicle occupancy is 1.67 (see *Exhibit 3-30*). This varies by mode with vans at the top at 2.44 and motorcycles and pickup trucks at the bottom with 1.20 and 1.49, respectively. The 18 percent increase (from 2.07 to 2.44) in the average vehicle occupancy of vans likely reflects their increasing use as family cars and people movers, and the overall 5 percent increase from 1995 to 2017 in average vehicle occupancy (AVO) reflects how slow driving culture changes in the United States.

Examined by trip purpose, work trips are most likely to be single-occupant trips with AVO slightly above 1, whereas social/recreational trips are most likely to have the highest number of passengers (see *Exhibit 3-31*). As with past years, 2017 NHTS mileage-weighted AVOs decreased compared with their 1977 levels for all trip purposes. Within the past decade, AVO showed a decline only for trips related to social/recreational purposes. All other trip-purpose AVOs either remained the same or increased. This may be due to young adults acquiring licenses later in life, increased high-occupancy vehicle/high occupancy toll (HOV/HOT) lanes, or reduced single-occupancy vehicle trips due to online shopping/telework/technology-enabled trip alternatives.

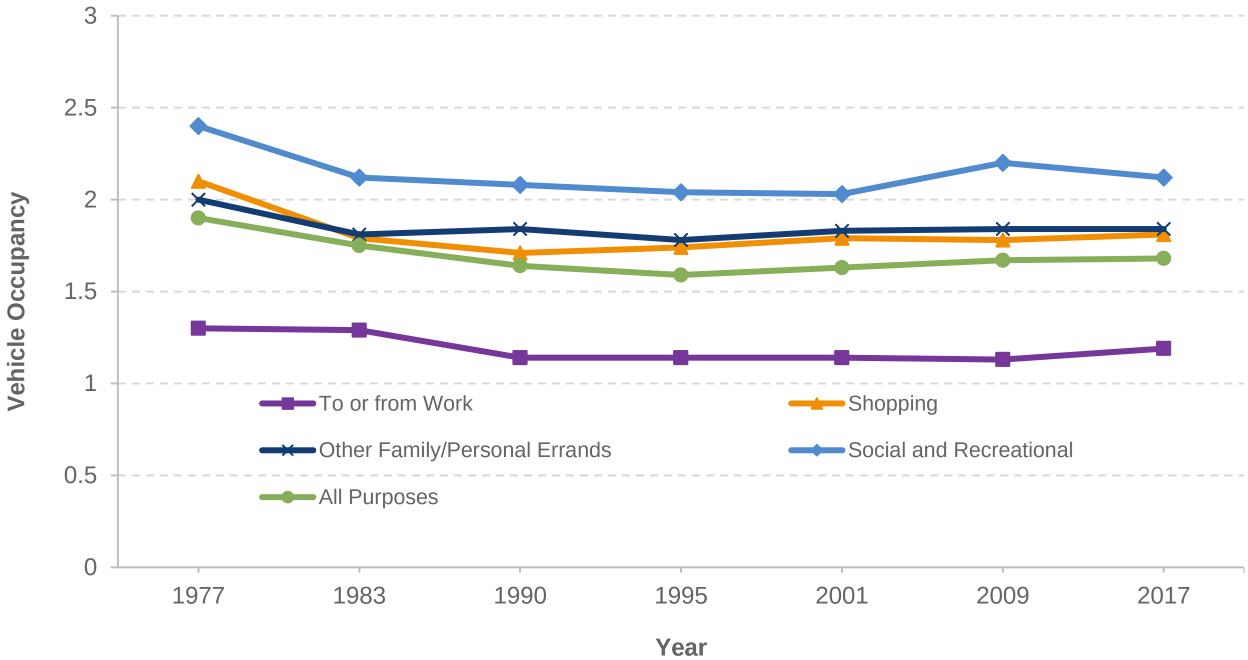
Exhibit 3-30 ■ NPTS/NHTS Vehicle Occupancy by Vehicle Type, 1995–2017



Mileage-weighted Average Vehicle Occupancy				
Vehicle type	**1995**	**2001**	**2009**	**2017**
Car	1.59	1.57	1.55	1.54
SUV	1.70	1.73	1.90	1.83
Van	2.07	2.20	2.35	2.44
Pickup Truck	1.38	1.46	1.49	1.49
Motorcycle/Moped	1.18	1.27	1.16	1.20
All	1.59	1.63	1.67	1.67

Source: National Household Travel Survey.

Exhibit 3-31 ■ NPTS/NHTS Average Vehicle Occupancy by Trip Purpose, 1977–2017



Mileage-weighted Average Vehicle Occupancy							
Trip Purpose	**1977**	**1983**	**1990**	**1995**	**2001**	**2009**	**2017**
To or from Work	1.30	1.29	1.14	1.14	1.14	1.13	1.19
Shopping	2.10	1.79	1.71	1.74	1.79	1.78	1.81
Other Family/ Personal Errands	2.00	1.81	1.84	1.78	1.83	1.84	1.84
Social and Recreational	2.40	2.12	2.08	2.04	2.03	2.20	2.12
All Purposes	1.90	1.75	1.64	1.59	1.63	1.67	1.68

Source: National Household Travel Survey.

CHAPTER 4: Mobility and Access

Mobility and Access – Highways

Transportation infrastructure, such as highways, bridges, bicyclist and pedestrian facilities, 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 the convenience of product delivery.

In urban areas, congestion, along with the lack of congestion-independent alternatives, is often the biggest impediment to maintaining transportation mobility. Despite past capacity expansions on highways, the urban transportation system has had difficulties keeping up with rising mobility demands and thus congestion has worsened over time. This deficiency in transportation capacity and reliability—and underutilization of mechanisms to manage highway demand, such as congestion pricing—has adversely affected the American economy and resulted in loss of time, fuel, and missed opportunities.

Another critical component to mobility is system access. Access to destinations refers to the ability of people to reach employment destinations and essential services, such as health care, education, transit, and recreation, among others, through a diverse transportation network. Accessibility refers to the provision of facilities that are accessible to and usable by individuals with mobility, visual, hearing, and other disabilities.

KEY TAKEAWAYS

- For the 52 largest metropolitan areas with populations over 1 million, the Travel Time Index (TTI) for Interstate highways averaged 1.34 in 2016, meaning that the average peak-period trip took 34 percent longer than the same trip under free-flow traffic conditions.
- For Interstate highways in the same metropolitan areas, the Planning Time Index (PTI) averaged 2.49 for Interstate highways in 2016, meaning that ensuring on-time arrival 95 percent of the time required planning for 2.49 times the travel time under free-flow traffic conditions.
- Congestion is worse in large urban areas with high population than it is in medium and small urban areas.
- The average speed on the Interstate Highway System was 56.8 mph in 2016. The average observed speed was 60.3 mph on rural Interstate highways, and 53.8 mph on urban Interstate highways.
- Speed had the highest variability on urban Interstates during morning peak hours.
- Congestion grew persistently worse from 2006 to 2016. The average delay for an individual commuter rose from 42 hours in 2006 to 53 hours in 2016. Total delay reached 8.6 billion hours and fuel waste reached 3.3 billion gallons in 2016, leading to a total cost of $171 billion.

This section focusses on highway mobility and access issues relating to personal travel. Freight-specific mobility issues are addressed in Part III. Information on operational performance of public transit is presented later in this chapter.

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 places and times. Although typically associated with peak traffic periods, recurring congestion may extend beyond traditional peak traffic windows and create delays at other times of day.

"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 of total highway congestion is recurring, and the other half nonrecurring.

No definition or measurement of exactly what constitutes congestion has been universally accepted. Transportation professionals examine congestion from several perspectives, such as average delays and variability. This report examines congestion through indicators of duration and severity, including travel time indices, congestion hours, and planning time indices.

Congestion Measures

The National Performance Management Research Data Set (NPMRDS) is the Federal Highway Administration's (FHWA's) official data source for measuring congestion, and is provided monthly to States and metropolitan planning organizations (MPOs) for their performance measurement activities. (See the discussion of Transportation Performance Management in the Introduction to Part I of this report.) The NPMRDS is a compilation of vehicle probe-based data on 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, GPS on commercial trucks, 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. Using data from the NPMRDS, FHWA produces quarterly Urban Congestion Reports that estimate mobility, congestion, and reliability on Interstate highways and other limited-access highways in the 52 largest metropolitan areas. (https://ops.fhwa.dot.gov/perf_measurement/ucr/index.htm).

Although the NPMRDS is a rich source of information on congestion, it has not existed long enough to provide a 10-year time series. Data are available starting in 2012 for the Interstate highways and starting in mid-2013 for roads functionally classified as "Other Freeway and Expressway." (See Chapter 1 for a description of functional classes.)

Different Methodologies in The *Urban Congestion Reports and the Urban Mobility Report*

The *Urban Congestion Reports* and the *Urban Mobility Report* both report traffic system performance indicators such as the TTI, congested hours, and the PTI, and use vehicle miles traveled (VMT) as weights to aggregate values. However, these two reports differ in their data coverage, definition of free-flow speed or peak hours, and estimation methodology, resulting in different estimations and interpretations of the same congestion indicators.

In the *Urban Congestion Reports* based on NPMRDS, the peak period includes the a.m. peak period (6 a.m. to 9 a.m.) and p.m. 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. The boundaries of the 52 metropolitan areas used in the *Urban Congestion Reports* are based on metropolitan statistical areas with populations above 1,000,000 in 2010.

The 2019 *Urban Mobility Report* assigned peak hours as 6 a.m. to 10 a.m. and 3 p.m. to 7 p.m. on weekdays. Free-flow travel speed is calculated during a set window of 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 lower value of either the free-flow speed or the speed limit (65 mph on the freeways). The 2019 Urban Mobility Report includes data for 494 urbanized areas (defined by the U.S. Census Bureau as an urban area of 50,000 or more people).

An alternative source of congestion measures is the Urban Mobility Report developed by the Texas Transportation Institute; the most recent edition released in August 2019 included data for 1982 through 2017. The 2019 Urban Mobility Report's estimated congestion trends were based on speed data provided by INRIX®, which contains historical traffic information on freeways and other major roads and streets. Data of traffic speed were collected from more than 1.5 million GPS-enabled vehicles and mobile devices for each section of road for every 15-minute period every day for all major U.S. metropolitan areas.

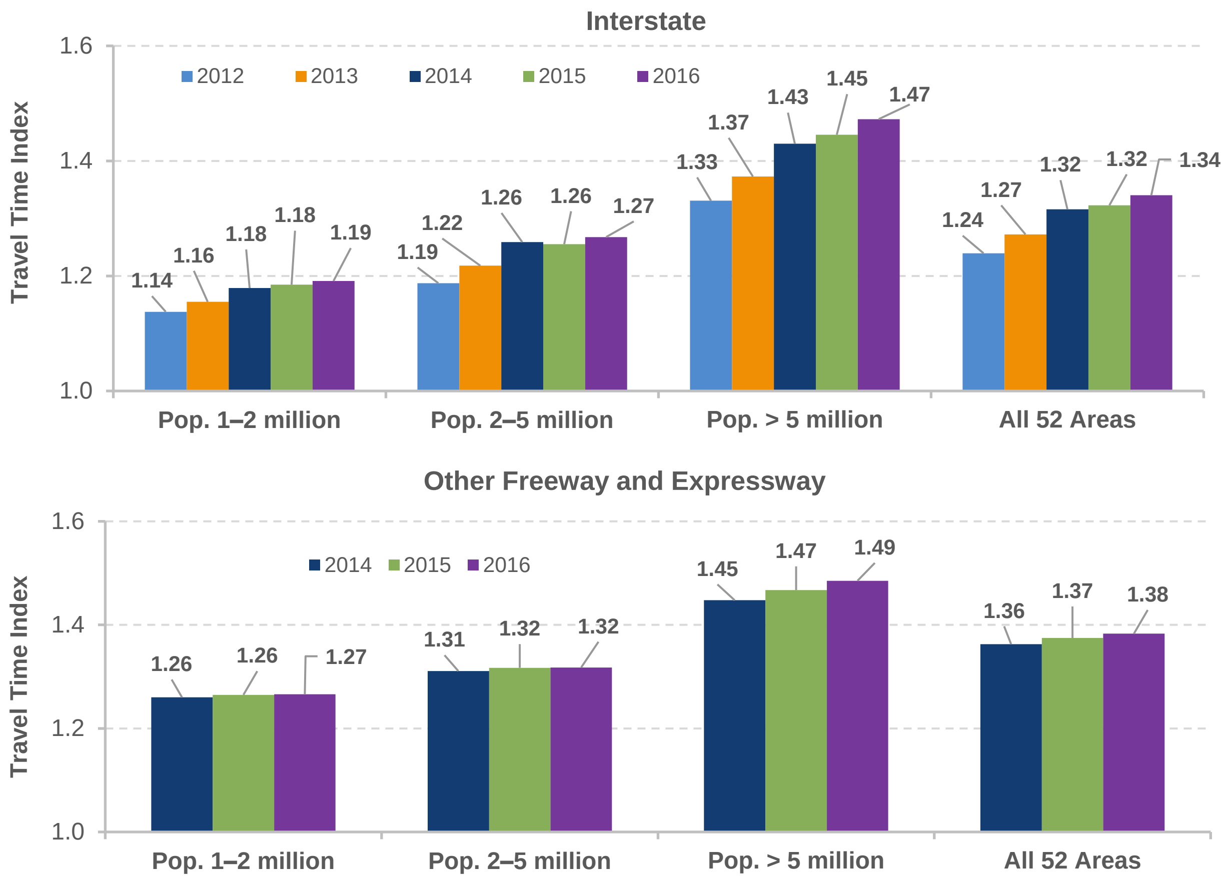
Travel Time Index

The TTI measures the average intensity of congestion. This index is calculated as the ratio of the peak-period travel time to the free-flow travel time for the a.m. and p.m. peak period on weekdays. The value of the 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 typically take 78 minutes (30 percent longer) during the period of peak congestion.

Exhibit 4-1 shows the TTI for the 52 largest metropolitan areas was 1.34 in 2016, which 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 2016. The TTI increased from 1.24 in 2012 to 1.34 in 2016 on Interstate highways, meaning that an average trip on Interstate highways that would have taken 60 minutes during the off-peak period took 74.4 minutes (24 percent longer) during the peak period in 2012, and took 80.4 minutes (34 percent longer) during the peak period in 2016. The TTI rose from 1.36 in 2014 to 1.38 in 2016 for other freeways and expressways, indicating average congestion has become more severe on these types of facilities as well.

Residents in the largest metropolitan areas tend to experience more severe congestion, and those with more moderate populations usually report better mobility. In 2016, the average TTI was 1.47 for Interstate highways in metropolitan areas with populations over 5 million, so that a 60-minute off-peak trip took an average of 88.4 minutes during the peak period (60 minutes times 1.47). The average TTI for Interstate highways in metropolitan areas with populations between 2 and 5 million was 1.27, so that the same length of off-peak trip took 76.1 minutes during the peak. For metropolitan areas with populations between 1 and 2 million the TTI was 1.27 in 2016, so that the same length of off-peak trip took 71.5 minutes during the peak. In 2016, TTI was 1.49, 1.28, and 1.27 on other freeways and expressways in metropolitan areas with populations above 5 million, between 2 and 5 million, and between 1 and 2 million, respectively.

Exhibit 4-1 ■ Travel Time Index for the 52 Largest Metropolitan Areas, 2012–2016



Note: Travel time index is averaged across metropolitan areas, road sections, and periods weighted by VMT using volume estimates derived from FHWA's Highway Performance Monitoring System over the 52 largest metropolitan areas (populations greater than 1 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 2012; full-year data on other freeways and expressways start in 2014. Population is from United States Census Bureau 2014 Metropolitan Statistical Areas Population Estimates for 2010.

Source: FHWA staff calculation from the National Performance Management Research Data Set.

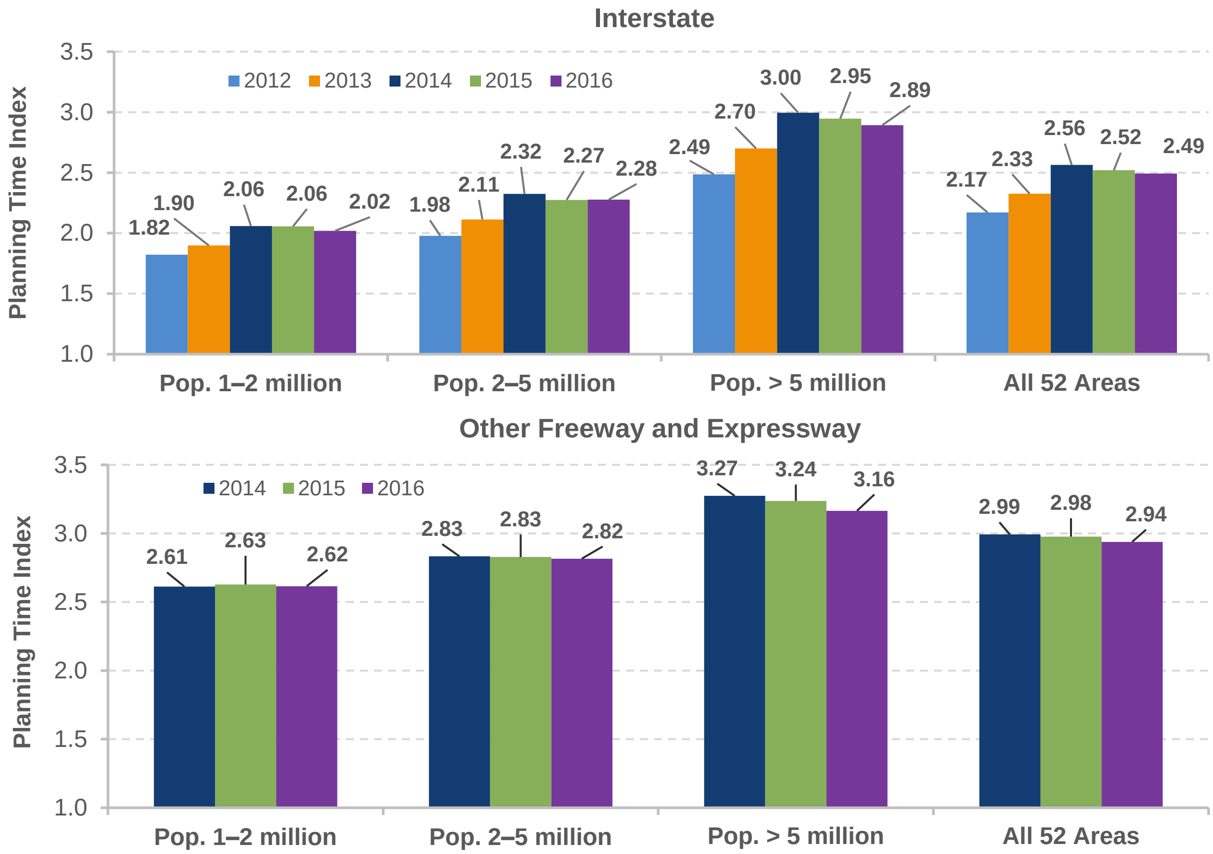
Planning Time Index

Most travelers are less tolerant of unexpected delays than of 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 operation and people's lives. Travelers also tend to better remember spending more time in traffic due to unanticipated disruptions, rather than the average time required for a trip throughout the year. From an economic perspective, low travel time 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 typically compare high-delay days with average-delay days, which provides a different perspective of traffic condition beyond a simple average travel delay. 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 also be concentrated in the same month or week, such as a week with severe weather). The PTI, used to measure travel time reliability in this report, is defined as the ratio of the 95th percentile of travel time during the a.m. and p.m. peak periods to 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 4-2 indicates the average PTI was 2.49 for Interstate highways in the 52 largest metropolitan areas in 2016, meaning that travelers would need to plan on a 60-minute off-peak trip requiring up to 150 minutes (2.49 × 60 minutes) in the peak period to ensure on-time arrival 95 percent of the time. The PTI for other freeways and expressways was 2.94 in 2016, meaning that travelers would need to plan on a trip of the same length taking up to 176 minutes 19 times out of 20 for on-time arrival. The PTI rose in 2012–2014 before tailing back off to lower levels in 2016.

Exhibit 4-2 ■ Planning Time Index for the 52 Largest Metropolitan Areas, 2012–2016



Note: Planning time index is averaged across metropolitan areas, road sections, and periods weighted by VMT using volume estimates derived from FHWA's Highway Performance Monitoring System over the 52 largest metropolitan areas (populations greater than 1 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 2012; full-year data on other freeways and expressways start in 2014. Population is from United States Census Bureau 2014 Metropolitan Statistical Areas Population Estimates for 2010.

Source: FHWA staff calculation from the National Performance Management Research Data Set.

As was the case for the TTI, the PTI was consistently higher in larger metropolitan areas than smaller ones. In 2016, the average PTI was 2.89 on Interstate highways in metropolitan areas with more than 5 million residents, 27 percent higher than the PTI of 2.28 observed in areas with populations between 2 million and 5 million, and 43 percent higher than the PTI of 2.02 in areas with populations between 1 million and 2 million. The PTI in 2016 showed a similar pattern for other freeways and expressways; the average PTI was 3.16 in metropolitan areas over 5 million in population, 2.82 in metropolitan areas with populations between 2 and 5 million, and 2.62 in metropolitan areas with between 1 and 2 million.

Transportation Performance Management (TPM) Reliability Measures

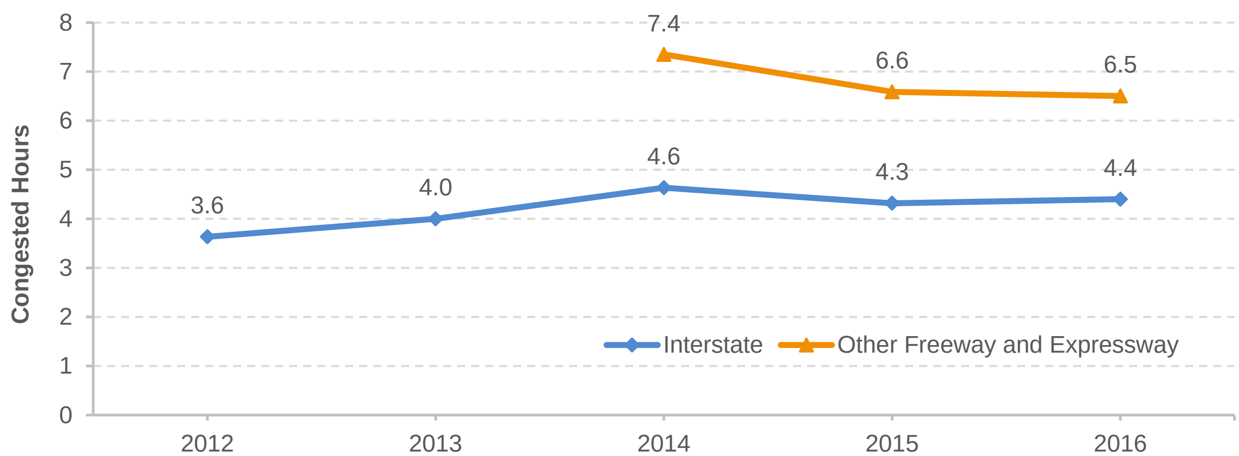
The TPM described in Introduction to Part I establishes specific national performance measures related to travel time reliability, which is defined as the consistency or dependability of travel times from day to day or across different times of the day. These are several travel time based reliability measures, two for carrying out the National Highway Performance Program (NHPP) and one to assess the freight movement:

- Percent of the person-miles traveled on the Interstate that are Reliable;
- Percent of person-miles traveled on the non-Interstate National Highway System (NHS) that are Reliable;
- Truck Travel Time Reliability Index.

Congested Hours

Congested hours is another performance indicator computed from NPMRDS for the 52 largest metropolitan areas in the United States. It is calculated as the average number of hours when road sections are congested from 6 a.m. to 10 p.m. on weekdays. As shown in *Exhibit 4-3*, on average, highways were congested for 4.4 hours per day on Interstate highways in 2016 and 6.5 hours per day on other freeways and expressways.

Exhibit 4-3 ■ Average Congested Hours for the 52 Largest Metropolitan Areas, 2012–2016



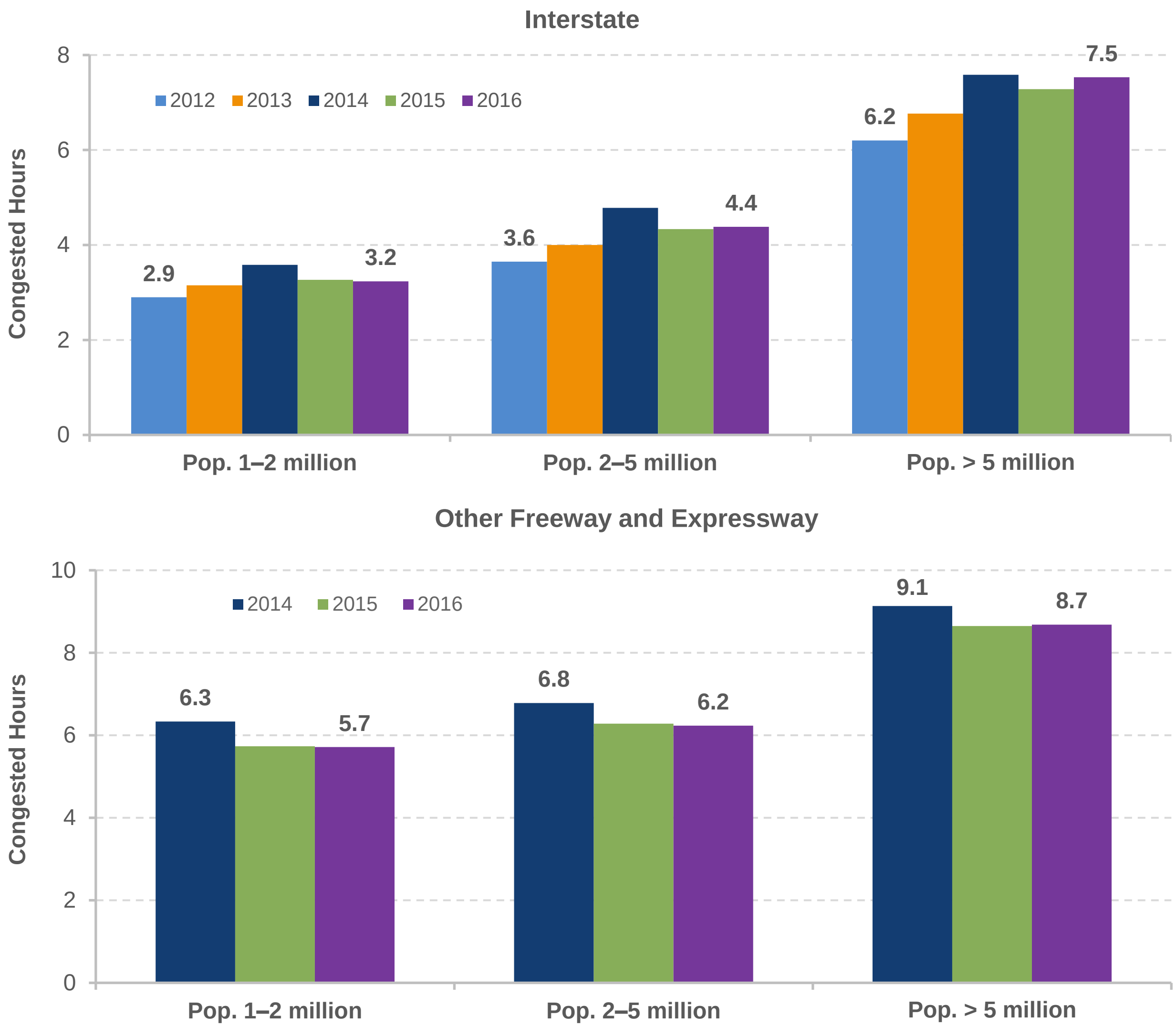
Note: Congested hours are averaged across metropolitan areas, road sections, and periods weighted by VMT using volume estimates derived from FHWA's Highway Performance Monitoring System over the 52 largest metropolitan areas (populations greater than 1 million). Data cover all Interstate highways (Interstate functional class) and other limited-access highways (Other Freeway and Expressway functional class) in these areas. Data on Interstate highways start in 2012; full-year data on other freeways and expressways start in 2014. Population is from United States Census Bureau 2014 Metropolitan Statistical Areas Population Estimates for 2010.

Source: FHWA staff calculation from the National Performance Management Research Data Set.

For both Interstate highways and other freeways and expressways, congested hours per day peaked in 2014. For the 52 largest metropolitan areas combined, congested hours per day rose from 3.6 in 2012 to 4.6 in 2014, before tailing off to 4.3 hours in 2015 and rebounding to 4.4 hours in 2016. The trend was similar for other freeways and expressways, with daily congested hours tailing off from 7.4 hours in 2014 to 6.5 hours in 2016.

Exhibit 4-4 shows that for both Interstate highways and other freeways and expressways, the values for different-sized metropolitan areas tended to move in tandem.

Exhibit 4-4 ■ Congested Hours for the 52 Largest Metropolitan Areas, 2012–2016



Note: Congested hours are averaged across metropolitan areas, road sections, and periods weighted by VMT using volume estimates derived from FHWA's Highway Performance Monitoring System over the 52 largest metropolitan areas (populations greater than 1 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 2012; full-year data on other freeways and expressways start in 2014. Population is from United States Census Bureau 2014 Metropolitan Statistical Areas Population Estimates for 2010.

Source: FHWA staff calculation from the National Performance Management Research Data Set.

Similar to the trend for the TTI and PTI, congestion duration is higher on average in larger metropolitan areas. In areas with a population above 5 million, average congested hours reached 7.5 per day on Interstate highways and 8.7 per day on other freeways and expressways in 2016. In metropolitan areas with population between 2 and 5 million, road congestion eased to 4.4 hours and 6.2 hours per day on Interstate highways and on other freeways and expressways, respectively. Residents in metropolitan areas with population between 1 and 2 million experienced the lowest number of congested hours, averaging 3.2 hours on Interstate highways and 5.7 hours on other freeways and expressways in 2016.

Congestion in 52 Metropolitan Areas

The average congestion measures in metropolitan areas by population size do not reflect the variations within each group. For example, both Los Angeles and Philadelphia are metropolitan areas with population exceeding 5 million, but their congestion measures differed substantially in 2016. *Exhibits 4-5*, *4-6*, and *4-7* present estimated TTI, PTI, and congested hours by area size of the 52 largest metropolitan areas to provide more details about various dimensions of congestion. Six metropolitan areas did not have sufficient data coverage on the other freeway and expressway functional class to allow computation of these measures.

Among major metropolitan areas with populations above 5 million, the highest Interstate TTI values were observed in Los Angeles (1.7) and Washington DC (1.5), where 50 percent or more additional time was needed to travel during peak hours than off-peak hours (*Exhibit 4-5*). Los Angeles (3.5), and Dallas/Fort Worth (3.0) experienced the highest Interstate PTI values; Interstate highway travelers in these areas would need to depart early enough to allow for peak-period travel time to be at least triple that during off-peak hours to ensure on-time arrival 95 percent of the time.

Exhibit 4-5 ■ Travel Time Index, Planning Time Index, and Congested Hours in Metropolitan Areas with Population Above 5 Million, 2016

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	1.3	1.4	2.3	3.1	4.2	6.6
Chicago	1.4	1.2	2.4	2.2	7.7	8.2
Dallas/Ft Worth	1.4	N/A	3.0	N/A	6.2	N/A
Houston	1.4	N/A	2.9	N/A	5.8	N/A
Los Angeles	1.7	1.6	3.5	3.5	9.6	8.6
Miami	1.3	1.4	2.5	2.9	5.2	6.5
New York	1.3	1.4	2.3	2.9	7.7	10.2
Philadelphia	1.3	1.1	2.2	1.9	6.4	4.5
Washington, DC	1.5	1.4	2.9	3.6	7.3	9.4

Note: Travel time index and Planning time index are averaged across road sections, and periods weighted by VMT using volume estimates derived from FHWA's Highway Performance Monitoring System 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 2012; full-year data on other freeways and expressways start in 2014. Population is from United States Census Bureau 2014 Metropolitan Statistical Areas Population Estimates for 2010.

Source: FHWA staff calculation from the National Performance Management Research Data Set.

Los Angeles experienced the longest average congested Interstate hours (9.6) during the 16-hour period between 6 a.m. and 10 p.m. on a weekday. New York and Chicago also had relatively long congested time of 7.7 hours per weekday on Interstate highways. New York experienced average congested hours of 10.2 per weekday on other freeways and expressways.

Exhibit 4-6 shows that three of the four highest Interstate TTI values among metropolitan areas with populations between 2 and 5 million were located on the West Coast: Portland (1.5), San Francisco (1.5), and Seattle (1.5). The highest Interstate PTI values were observed in Portland (3.2) and San Francisco (3.2), as well as in San Juan (3.3). The PTI for other freeways and expressways in Charlotte was 4.0, indicating that drivers in that area would need to account for peak period trips taking quadruple the time of off-peak trips to arrive on time 19 days out of every 20.

Roads were classified as congested for more than 7 hours per weekday on Interstate highways of Denver, Orlando, Portland, San Francisco, and Seattle. In most areas with between 2 and 5 million in population, other freeways and expressways usually remained congested for a longer period than Interstate highways, with more than 9 hours of daily congestion observed in Charlotte (9.6), Portland (9.8), and Seattle (9.8).

Exhibit 4-6 ■ Travel Time Index, Planning Time Index, and Congested Hours in Metropolitan Areas with Population 2–5 Million, 2016

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	1.3	1.3	2.2	2.7	5.1	7.8
Boston	1.4	1.3	2.8	2.5	6.2	6.5
Charlotte	1.2	1.3	2.1	4.0	3.4	9.6
Cincinnati	1.2	1.1	1.9	2.3	2.8	5.6
Cleveland	1.1	1.1	1.9	2.1	2.5	3.7
Denver	1.4	1.2	2.8	2.8	7.1	6.4
Detroit	1.2	1.2	2.3	2.8	4.1	5.3
Kansas City	1.1	1.2	1.7	2.3	2.3	5.6
Minneapolis	1.3	1.4	2.3	2.9	5.1	7.7
Orlando	1.4	1.1	2.6	1.6	7.5	1.6
Phoenix	1.3	1.2	2.3	2.5	3.3	3.6
Pittsburgh	1.2	1.2	1.8	2.6	3.1	8.7
Portland	1.5	1.5	3.2	3.9	7.7	9.8
Riverside	1.2	1.4	1.8	2.8	4.7	7.1
Sacramento	1.2	1.4	1.9	2.7	3.9	5.3
St Louis	1.2	1.2	2.0	3.3	3.1	6.2
San Antonio	1.2	N/A	2.2	N/A	3.6	N/A
San Diego	1.3	1.3	2.5	3.0	3.7	5.6
San Francisco	1.5	1.5	3.2	3.4	7.5	7.6
San Juan	1.5	N/A	3.3	N/A	3.7	N/A
Seattle	1.5	1.3	2.8	2.9	7.1	9.8
Tampa	1.2	1.2	2.2	2.3	3.0	0.0

Note: Travel time index and planning time index are averaged across road sections, and periods weighted by VMT using volume estimates derived from FHWA's Highway Performance Monitoring System in the 22 metropolitan areas with populations of 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 2012; full-year data on other freeways and expressways start in 2014. Population is from United States Census Bureau 2014 Metropolitan Statistical Areas Population Estimates for 2010.

Source: FHWA staff calculation from the National Performance Management Research Data Set.

Congestion also affected smaller metropolitan areas with populations between 1 and 2 million (*Exhibit 4-7*). Interstate TTI values generally fell between 1.0 and 1.2 in areas of this size, except for Austin (1.4) and San Jose (1.5). Cleveland reported one of the lowest congestion measures in TTI, PTI, and congested hours. The highest Interstate PTI value was 3.3 in San Jose. The highest PTI value for other freeways and expressways among the 52 largest metropolitan areas reflected in the NPMRDS was observed in New Orleans (5.3), suggesting atypically low travel time reliability in this area.

Congestion Management in Cleveland, Ohio

The Ohio Department of Transportation and the Northeast Ohio Areawide Coordinating Agency (NOACA, the MPO for the Cleveland area) have jointly committed to managing congestion through incorporating system management and operation strategies into their planning processes. Working together, they are establishing policies on congestion management and prioritizing congestion mitigation strategies such as adding capacity to the transportation system, operating existing capacity with higher efficiency, and encouraging congestion-reducing strategies.

NOACA evaluates future operating conditions of all roadways on the NOACA Congestion Management Process (CMP) network using projected year 2035 traffic forecasts to highlight the worst congested roadway segments on the network. The NOACA CMP examines 2,400 segments in the network to support decision makers in identifying and funding projects that will help alleviate traffic congestion. For example, the I-480 corridor has the longest continuous segment of congestion in the system under existing and forecast traffic conditions. Widening roads to address increasing traffic demand is not cost-effective, and congestion management strategies need to be considered.

Reducing Congestion in Birmingham, Alabama

The Regional Planning Commission of Greater Birmingham (RPCGB) outlines five strategies to reduce congestion in the order they should be considered for each project:

1. Decrease the need for trip making;
2. Increase the use of transit over other modes;
3. Increase HOV use;
4. Enhance operations on existing roadway facilities; and
5. Increase roadway capacity through additional infrastructure.

Highway projects are evaluated against these five strategies to produce an evaluation matrix containing multiple congestion mitigation strategies.

The RPCGB completed many projects between 2006 and 2016 that helped reduce congestion in the Birmingham urbanized area. The majority of congestion mitigation projects involve capacity expansion, such as adding additional lanes on I-65 from CR-52 to CR-17 (Valleydale Road) and building new roads on SR-4 (Corridor-X, I-22) From CR-105 (Cherry Avenue) to East of I-65. Several projects improved intersections by adding a continuous center turn lane.

The RPCGB also undertook projects to improve operation efficiency. For example, a project was completed on 9.1 miles of SR-38 (US 280) from Hollywood Boulevard to Doug Baker Boulevard to improve access management such as reconfiguring and/or closing intersections. The project also upgraded traffic signal systems on this corridor and installed adaptive signal controls.

Exhibit 4-7 ■ Travel Time Index, Planning Time Index, and Congested Hours in Metropolitan Areas with Population 1–2 Million, 2016

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	1.4	N/A	2.8	N/A	5.2	N/A
Birmingham	1.0	N/A	1.3	N/A	0.6	N/A
Buffalo	1.1	1.2	1.8	2.3	4.3	9.1
Columbus	1.1	1.2	1.8	2.3	2.7	4.5
Hartford	1.2	1.1	1.9	2.0	2.7	3.8
Indianapolis	1.1	1.2	1.6	2.8	2.8	12.5
Jacksonville	1.2	1.3	2.0	3.5	2.7	9.0
Las Vegas	1.2	1.2	2.0	2.1	3.7	4.7
Louisville	1.1	1.2	2.0	3.5	3.0	4.8
Memphis	1.2	1.2	1.9	2.4	4.1	5.3
Milwaukee	1.2	1.2	2.2	1.9	4.3	3.3
Nashville	1.2	1.2	2.0	2.2	2.7	5.3
New Orleans	1.1	1.5	2.0	5.3	2.9	12.2
Oklahoma City	1.1	1.1	1.7	2.1	2.2	2.7
Providence	1.2	1.2	1.9	2.2	4.0	7.5
Raleigh	1.2	1.1	1.9	2.1	2.5	2.7
Richmond	1.1	1.1	1.4	1.8	1.5	5.2
Rochester	1.1	1.2	1.6	2.1	2.4	6.3
Salt Lake City	1.2	1.2	1.9	2.2	3.0	6.1
San Jose	1.5	1.4	3.3	3.2	6.0	5.5
Virginia Beach	1.2	1.2	2.5	2.7	5.5	8.1

Note: Travel time index and planning time index are averaged across road sections, and periods weighted by VMT using volume estimates derived from FHWA's Highway Performance Monitoring System over the 21 metropolitan areas with populations of 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 2012; full-year data on other freeways and expressways start in 2014. Population is from United States Census Bureau 2014 Metropolitan Statistical Areas Population Estimates for 2010.

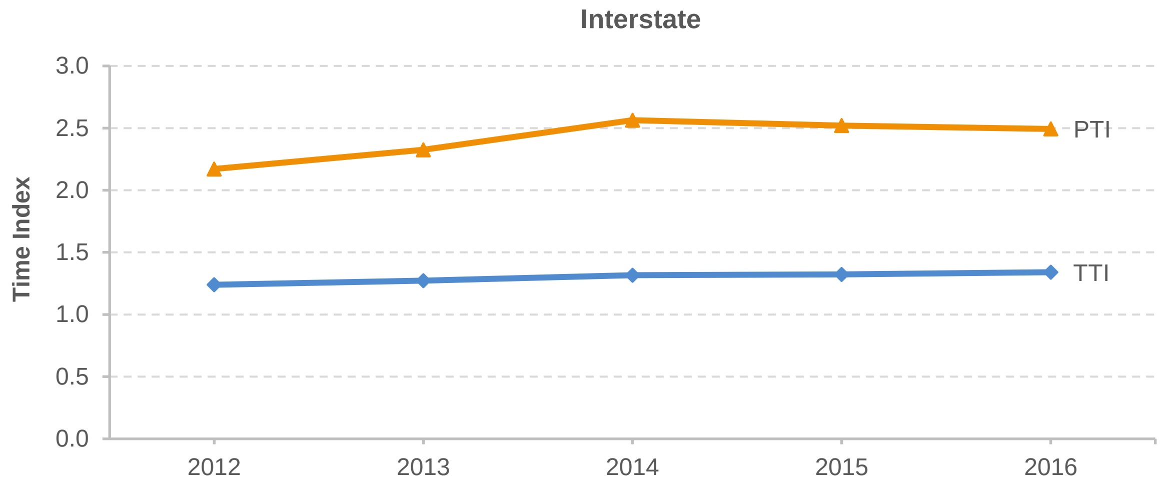
Source: FHWA staff calculation from the National Performance Management Research Data Set.

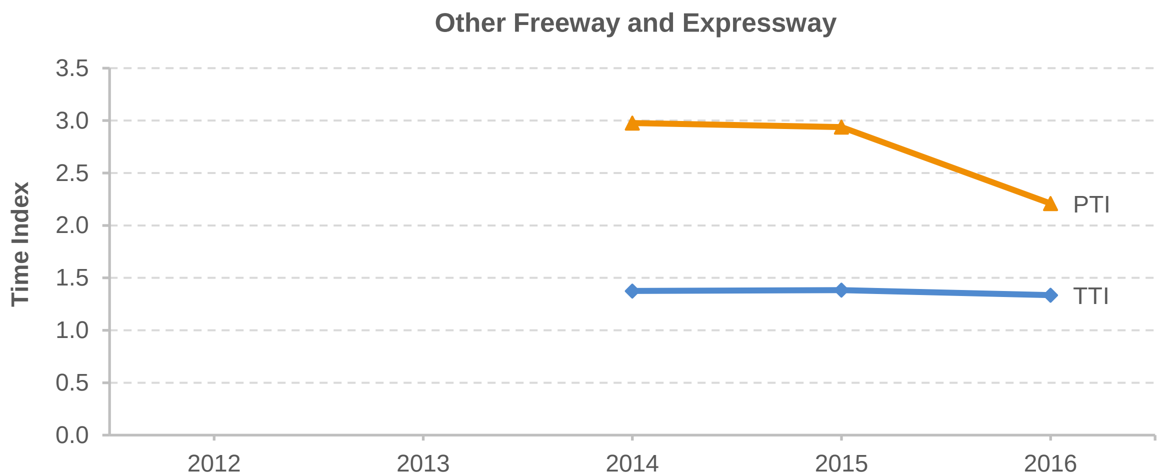
Correlation Between TTI and PTI

Exhibit 4-8 demonstrates that the average PTI has been consistently above the average TTI among the 52 largest metropolitan areas covered in the NPMRDS.

The relationship between TTI and PTI is also reflected in *Exhibit 4-9*, which compares 2016 PTI and TTI values for metropolitan areas of different sizes. Like *Exhibit 4-8*, *Exhibit 4-9* shows that the values of PTI are consistently higher than the values of TTI.

Exhibit 4-8 ■ Average Travel Time Index and Planning Time Index in the 52 Largest Metropolitan Areas, 2012–2016



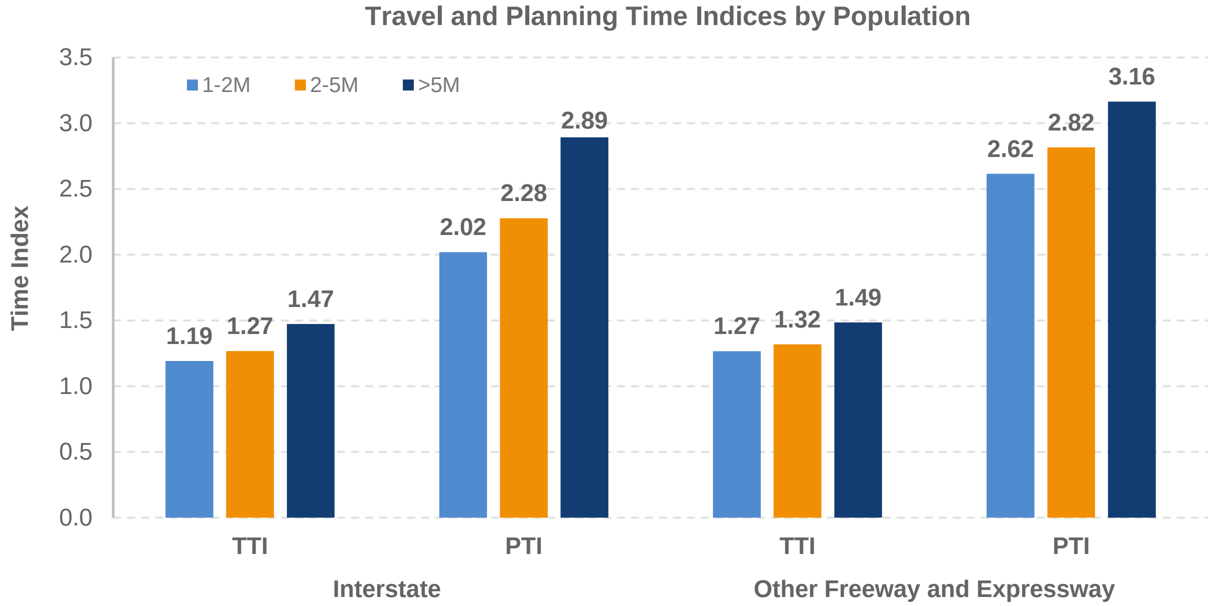


Note: Travel time index and planning time index are averaged across metropolitan areas, road sections, and periods weighted by VMT using volume estimates derived from FHWA's Highway Performance Monitoring System over the 52 largest metropolitan areas (populations greater than 1 million). Data cover all 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 2012; full-year data on other freeways and expressways start in 2014. Population is from United States Census Bureau 2014 Metropolitan Statistical Areas Population Estimates for 2010.

Source: FHWA staff calculation from the National Performance Management Research Data Set.

Drivers living in more populated urban areas tended to spend more travel time during peak hours than those living in less populated urban areas. The PTI difference between areas of different sizes was much larger than the TTI difference. This is particularly the case on Interstate highways, where PTI was 2.89 in metropolitan areas with populations above 5 million, compared with 2.02 in metropolitan areas with populations between 1 and 2 million, a difference of 0.87. In contrast, the Interstate TTI of 1.47 in metropolitan areas over 5 million in population differed from those with populations between 1 and 2 million by only 0.28.

Exhibit 4-9 ■ Travel Time Index and Planning Time Index by Population in the 52 Largest Metropolitan Areas, 2016



Note: Travel time index and planning time index are averaged across metropolitan areas, road sections, and periods weighted by VMT using volume estimates derived from FHWA's Highway Performance Monitoring System over the 52 largest metropolitan areas (populations greater than 1 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 2012; full-year data on other freeways and expressways start in 2014. Population is from United States Census Bureau 2014 Metropolitan Statistical Areas Population Estimates for 2010.

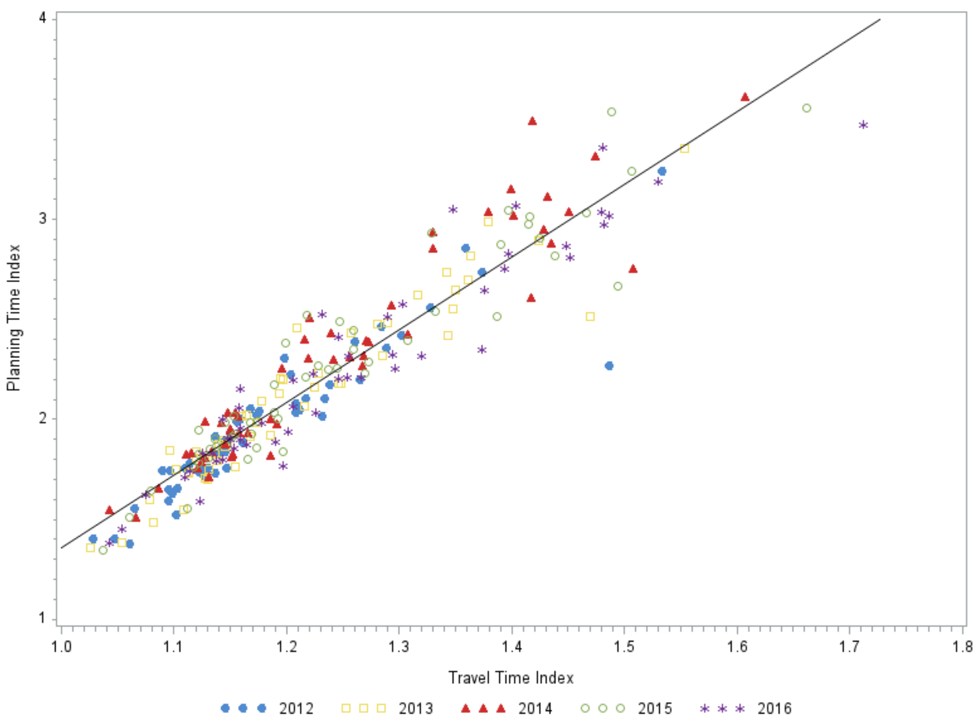
Source: FHWA staff calculation from the National Performance Management Research Data Set.

The PTI not only is consistently higher than the TTI, it is also correlated with the TTI. *Exhibit 4-10* presents the scatterplot of PTI values for individual metropolitan areas against TTI values, with different colors used to differentiate years. There is a clear linear correlation between TTI and PTI on Interstate highways, represented by the solid line in the graph. The scatterplot indicates that for TTI values between 1.0 and 1.4, where the majority of observations are concentrated, higher TTI values are closely associated with higher PTI values. In other words, higher levels of recurring congestion are associated with higher levels of non-recurring congestion. However, on highly congested Interstate highways where TTI values are above 1.4, the relationship between TTI and PTI becomes more disperse with less linear correlation. For example, the highest Interstate TTI reflected in the NPMRDS was 1.71 in Los Angeles in 2016. The Interstate PTI value for 2016 was 3.47, resulting in a data point well below the solid (linear correlation) line.

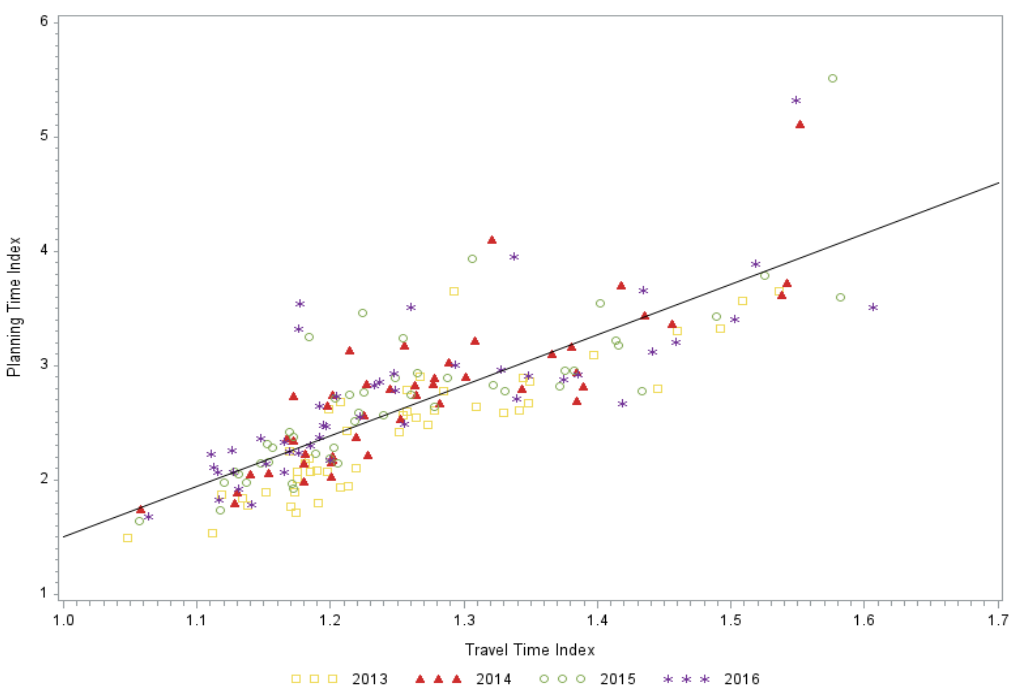
A comparison of the two charts in *Exhibit 4-10* reveals that PTI values showed a much larger variation relative to TTI values for other freeways and expressways than for Interstate highways. Additionally, there are more observed dots above the solid (linear regression) line, implying low travel reliability (high PTI) even in some cases where average travel time (TTI) is modest. This indicates that freeways that routinely experience severe congestion are also more vulnerable to extreme congestion when conditions deteriorate unexpectedly.

Exhibit 4-10 ■ Correlation Between Travel Time Index and Planning Time Index in the 52 Largest Metropolitan Areas, 2012–2016

Interstate



Other Freeway and Expressway



Note: Travel time index and planning time index are averaged across metropolitan areas, road sections, and periods weighted by VMT using volume estimates derived from FHWA's Highway Performance Monitoring System over the 52 largest metropolitan areas (populations greater than 1 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 2012; full-year data on other freeways and expressways start in 2014. Population is from United States Census Bureau 2014 Metropolitan Statistical Areas Population Estimates for 2010.

Source: FHWA staff calculation from the National Performance Management Research Data Set.

The correlation coefficient between TTI and PTI was 0.947 on Interstate highways and 0.814 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 substantial year-to-year variation in the distribution of the ratios between PTI and TTI on the graphs.

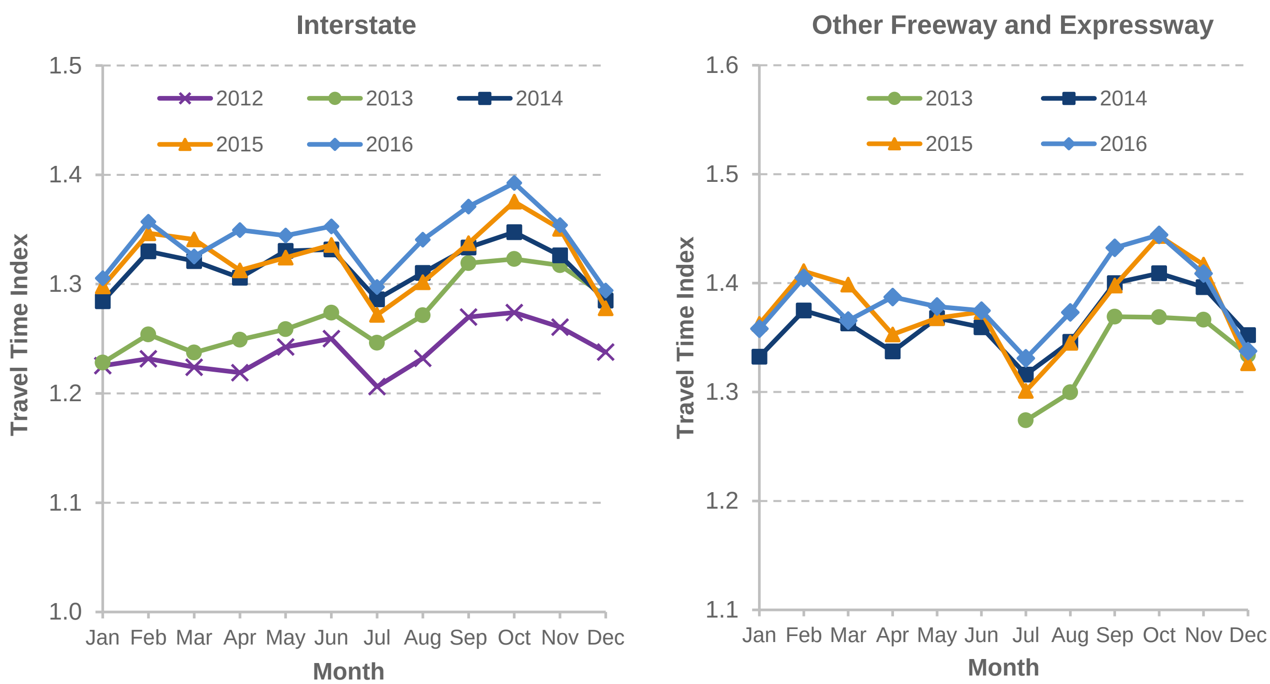
Seasonal Patterns in Congestion and Reliability

Road congestion varies over the course of a year. For each year from 2012 to 2016, the TTI stayed relatively flat 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 4-11*).

The TTI was consistently highest in October for all 5 years on both Interstates and other freeways and expressways. The month with the lowest TTI varied by year for Interstate highways: it was January in 2013, July in 2012 and 2015, and December in 2014 and 2016. On other freeways and expressways, the lowest TTI occurred consistently in July of each year.

Travel conditions tended to be stable in the first half of the year. Between July and October, peak-hour travel condition worsened substantially due to decreased speed and extended travel time. This is consistent with the public's perception of better travel conditions in summer during vacation season, with congestion rising in in September as schools are again in session.

Exhibit 4-11 ■ Monthly Travel Time Index in the 52 Largest Metropolitan Areas, 2012–2016



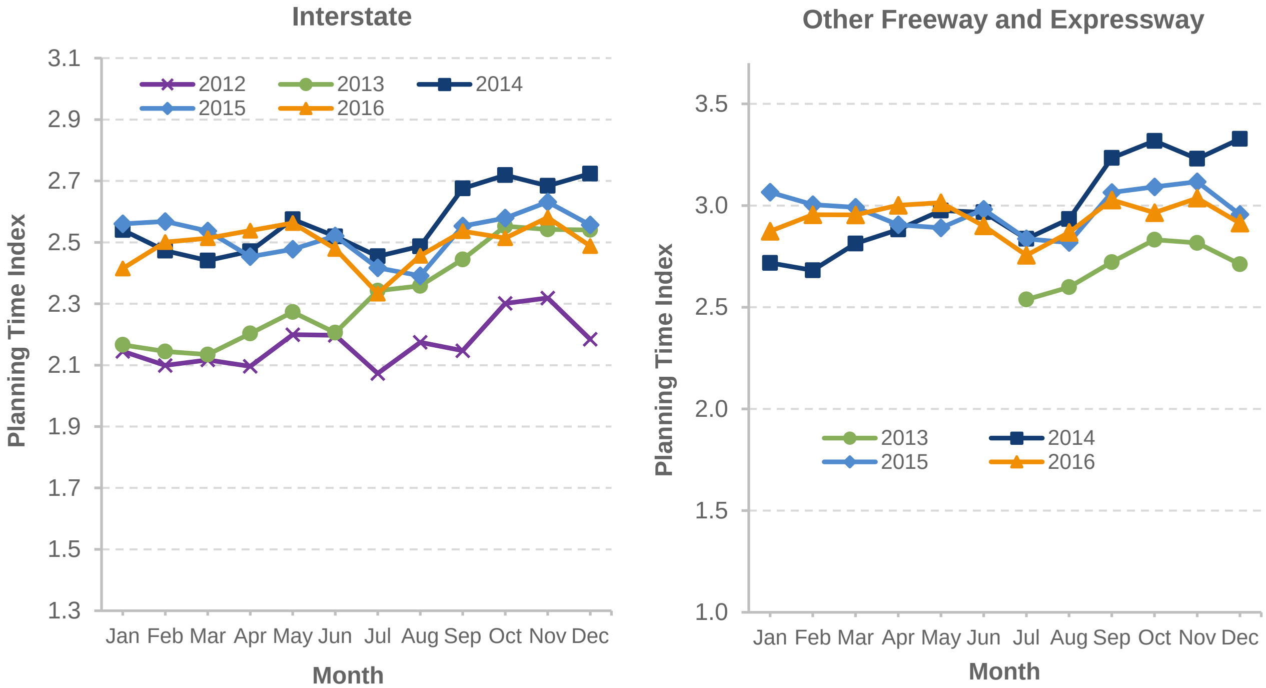
Note: Travel time index is averaged across metropolitan areas, road sections, and periods weighted by VMT using volume estimates derived from FHWA's Highway Performance Monitoring System over the 52 largest metropolitan areas (populations greater than 1 million). Data cover all Interstate highways (Interstate functional class) and other limited-access highways (Other Freeway and Expressway functional class) in these areas. Data on Interstate highways start in 2012; full-year data on other freeways and expressways start in 2014. Population is from United States Census Bureau 2014 Metropolitan Statistical Areas Population Estimates for 2010.

Source: FHWA staff calculation from the National Performance Management Research Data Set.

PTI generally fluctuated less in the first half of the year than the second, for each year from 2012 to 2016 on both Interstates and other freeways and expressways (See *Exhibit 4-12*). The month with the lowest PTI on highways varied by year: for Interstate highways it was March in 2013 and 2014, July in 2012 and 2016, and August in 2015; for other freeways and expressways it was February in 2014, August in 2015, and July in 2016.

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 in the last quarter, where PTI consistently swelled to a yearly high. Travelers experienced the highest monthly PTI values in the last quarter of the year: for Interstate highways it was October in 2013 and 2014, November in 2012, 2015, and 2016; for other freeways and expressways it was December in 2014 and November in 2015 and 2016.

Exhibit 4-12 ■ Monthly Planning Time Index in the 52 Largest Metropolitan Areas, 2012–2016

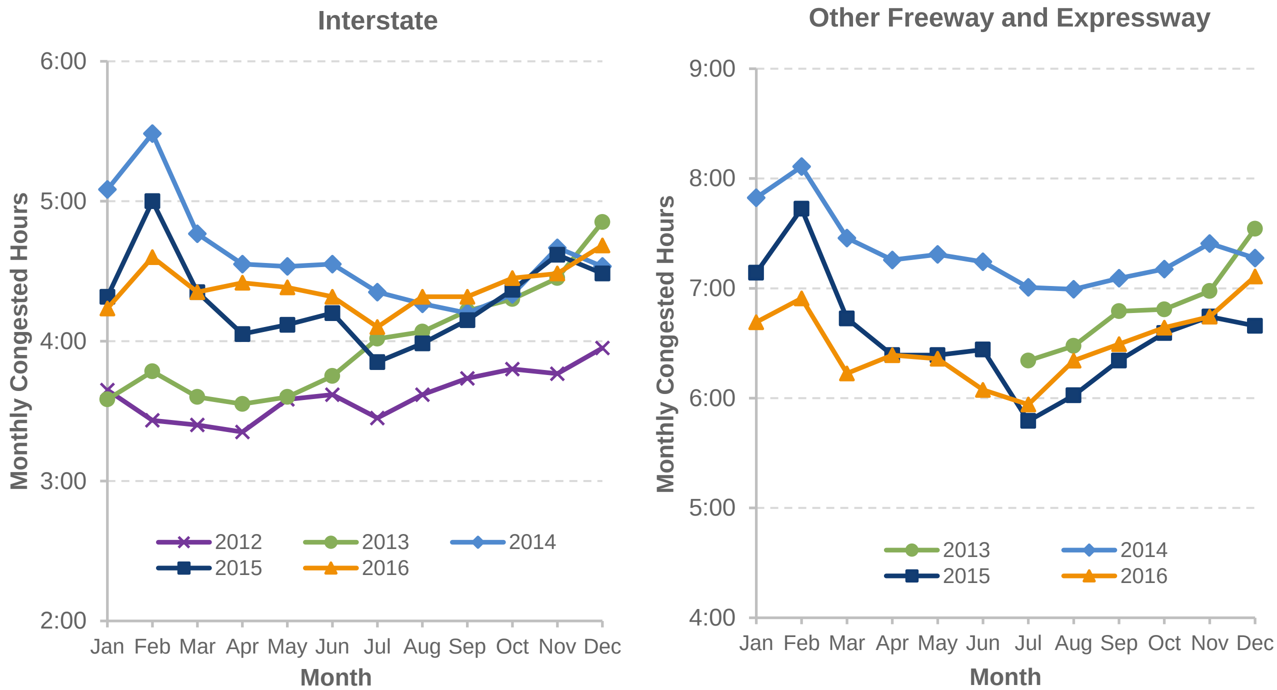


Note: Planning time index is averaged across metropolitan areas, road sections, and periods weighted by VMT using volume estimates derived from FHWA's Highway Performance Monitoring System over the 52 largest metropolitan areas (populations greater than 1 million). Data cover all Interstate highways (Interstate functional class) and other limited-access highways (Other Freeway and Expressway functional class) in these areas. Data on Interstate highways start in 2012; full-year data on other freeways and expressways start in 2014. Population is from United States Census Bureau 2014 Metropolitan Statistical Areas Population Estimates for 2010.

Source: FHWA staff calculation from the National Performance Management Research Data Set.

Congested hours revealed a different monthly pattern than those of TTI and PTI. High average daily congestion numbers were concentrated in winter months and shorter periods of congestion tended to occur in warmer months. The highest monthly congested hours values for the year occurred in February (2014 and 2015) and December (2012, 2013 and 2016) (see *Exhibit 4-13*). Other freeways and expressways experienced the shortest periods of congestion during the summer months of July 2015 and 2016 and August 2013. For Interstate highways, the months with the shortest periods of congestion on Interstate varied more, occurring in April (2012 and 2013), July (2015 and 2016), and September (2014).

Exhibit 4-13 ■ Monthly Congested Hours in the 52 Largest Metropolitan Areas, 2012–2016



Note: Congested hours are averaged across metropolitan areas, road sections, and periods weighted by VMT using volume estimates derived from FHWA's Highway Performance Monitoring System over the 52 largest metropolitan areas (populations greater than 1 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 2012; full-year data on other freeways and expressways start in 2014. Population is from United States Census Bureau 2014 Metropolitan Statistical Areas Population Estimates for 2010.

Source: FHWA staff calculation from the National Performance Management Research Data Set.

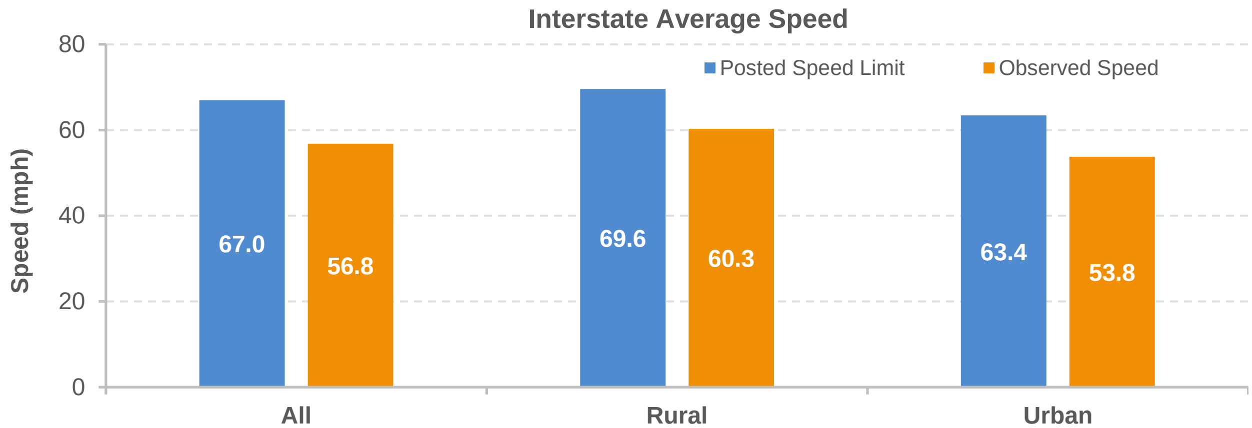
Mobility on Rural and Urban Interstates

In addition to estimating congestion on both Interstates and other freeways and expressways in urban areas, an FHWA study used NPMRDS, conflated with the 2013 Highway Performance Monitoring System (HPMS) geospatial network, to examine travel time and speed of the Interstate System for the entire Nation by urban/rural (see *Interstate Speed Profiles* at https://doi.org/10.1177/0361198118755713 for details on conflation methodology).

Average Speed on Interstates

The average speed of the entire Interstate Highway System in 2016 was 56.8 mph, including peak and off-peak travel, compared with an average speed limit of 67.0 mph (*Exhibit 4-14*). The average observed speed was 60.3 mph on rural Interstates, 6.5 mph higher than on urban Interstates (53.8 mph). The observed average speeds were about 10 mph lower than the average of posted speed limits on both rural and urban Interstates. The delays occur on Interstates for many road conditions that could slow traffic, such as regular congestion, adverse weather, work zones, incidents, special events, and traffic congestion.

Exhibit 4-14 ■ Average Observed Speed and Posted Speed Limit on Interstate, 2016



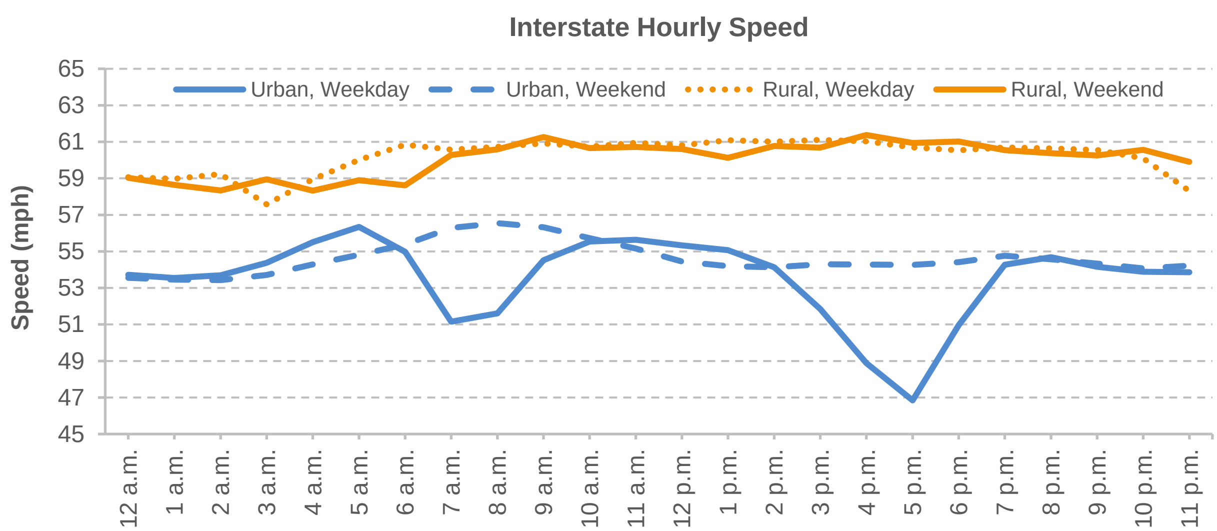
Note: Posted speed and observed speed are averaged over mainline Interstate highways.

Source: FHWA staff calculation from the National Performance Management Research Data Set and Highway Performance Monitoring System.

Speed by Hour of the Day on Rural and Urban Interstates

Traffic conditions generally vary by time of day, especially in urban areas where demand could exceed supply during peak travel times and along major commuter routes, causing congestion. *Exhibit 4-15* depicts the annual average speed by hour of the day on the Interstate System by urban/rural areas and weekday/weekend.

Exhibit 4-15 ■ Hourly Speed on Interstate, 2016



Note: Observed speed are averaged over mainline Interstate highways.

Source: FHWA staff calculation from the National Performance Management Research Data Set and Highway Performance Monitoring System.

Not surprisingly, the time-of-day speed variations for Interstate highways were larger on weekdays in urban areas than on weekends or in rural areas. The NPMRDS data clearly identified two weekday troughs on urban Interstate highways where average speed dropped substantially: the a.m. peak hour, approximately between 7:00 and 8:00 a.m., and the p.m. peak hour, between 5:00 and 6:00 p.m. Speed reduction is more noticeable during the p.m. peak hour, when average speed fell to 47 mph at 5 p.m., about 8 mph lower than that of weekend at the same time. On weekends, urban Interstate highways observed slightly higher speeds in the morning than in the afternoon, with no significant slowdowns throughout the day.

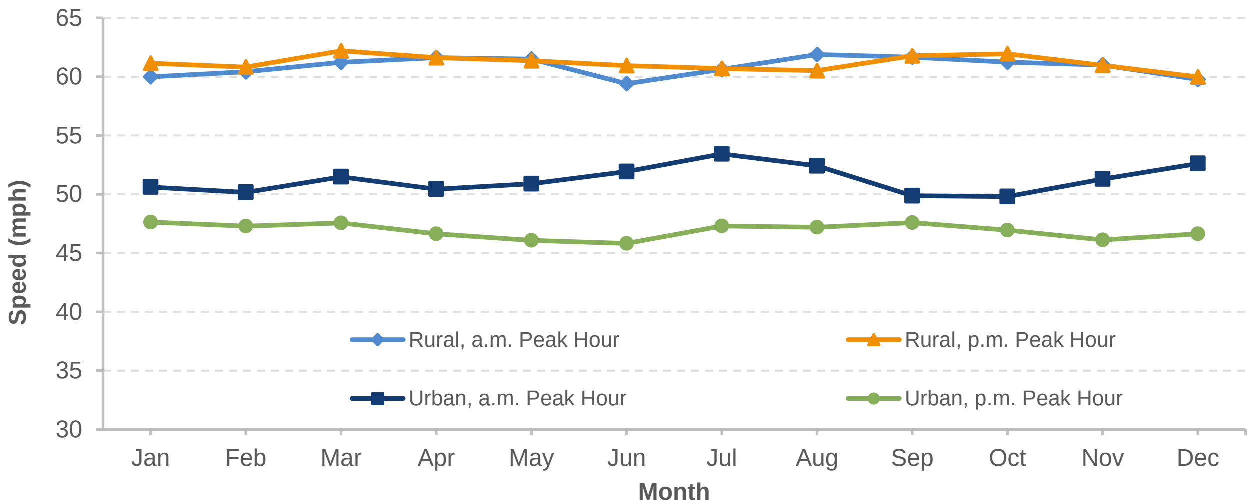
Unlike urban Interstate highways, rural Interstate highways operated at relatively consistent speeds. Average speed on rural Interstate highways was about 61 mph during the day, and dropped to about 59 mph during the overnight hours, possibly due to lack of street lights.

The lines of average weekend speeds were smoother for both rural and urban Interstates, implying relatively consistent speed. On urban Interstate highways, weekend drivers experienced higher speed than on weekdays at the same peak hours. For instance, the average speed at 8 a.m. was 56.5 mph on weekends, 4.9 miles higher than the speed at the same time on weekdays. The speed difference between weekday and weekend was even more evident at 5 p.m. on urban Interstates, where the average speed was 46.8 mph on weekdays but 7.5 miles higher on weekends. There were largely no significant speed differences between weekdays and weekends on rural Interstates.

Speed by Month on Rural and Urban Interstates

Exhibit 4-16 presents morning and afternoon peak hour travel speeds on both urban and rural Interstate highways. Average travel speed varies by month, with more noticeable variations on urban Interstate highways.

Exhibit 4-16 ■ Peak Hour Speed by Month on Interstate, 2016



Note: Observed speed is averaged over mainline Interstate highways.

Source: FHWA staff calculation from the National Performance Management Research Data Set and Highway Performance Monitoring System.

On urban Interstate highways, the a.m. peak hour average speeds in summer months from June to August were higher than the average speeds of other months, which is possibly related to fewer urban commuters and students traveling during summer vacation. The a.m. peak-hour speed picked up in November and December, reaching average speeds comparable to those of summer months, which might be associated with more long-distance Interstate travel around the winter holidays. The lowest a.m. peak hour average speeds occurred in April, September, and October.

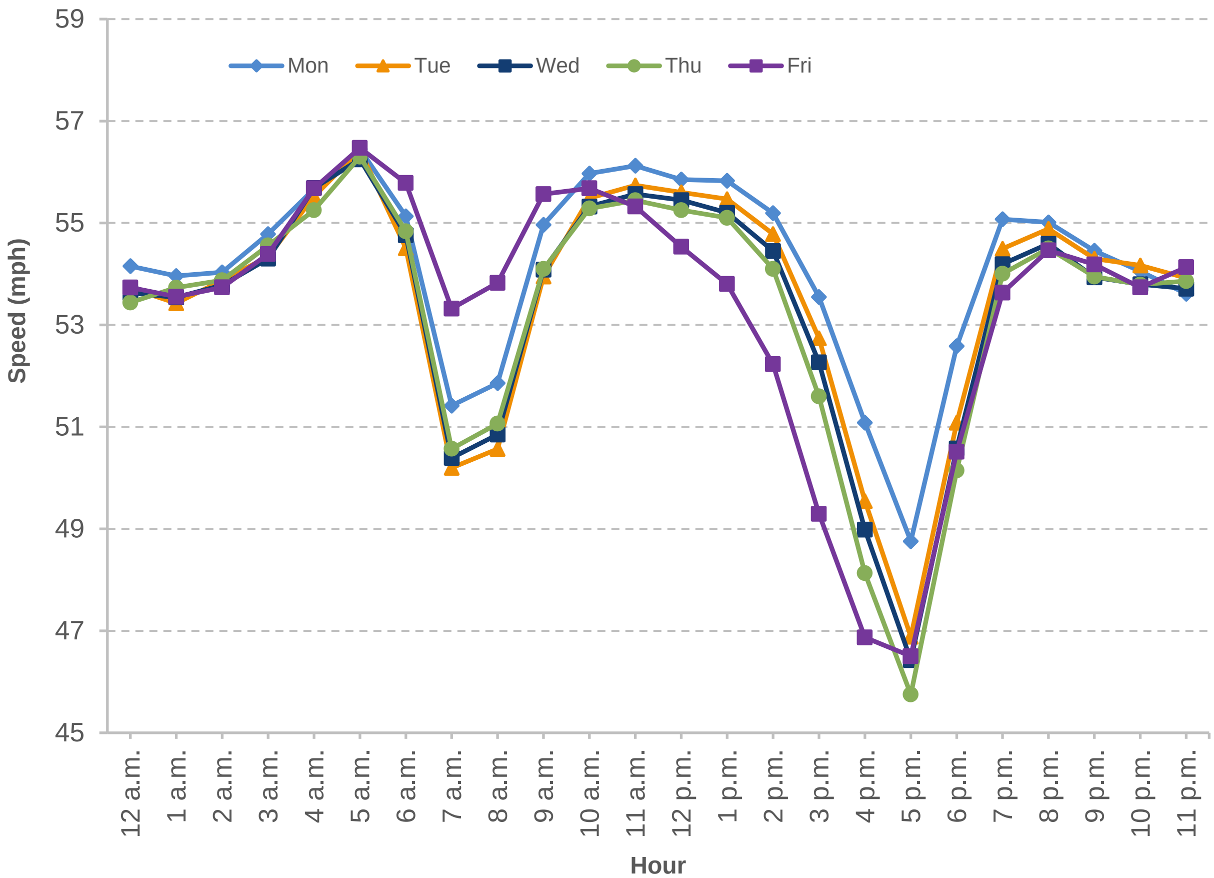
During p.m. peak hours, travelers on urban Interstate highways experienced the highest speed in January, March, and September and the lowest speeds in May and June. September was unique because it had higher speeds than most months in the p.m. peak hour, but the lowest speeds of the year in the a.m. peak hour.

On rural Interstates, a.m. and p.m. peak hour speeds were relatively uniform and limited in a small range between 59 and 62 mph. The highest a.m. peak hour speed was recorded in the months of August and September, and lowest in June and December. Traveling speed on rural Interstates during the p.m. peak hour was the highest in March and October, and the lowest in August and December.

Speed by Day of the Week on Urban Interstates

National average speeds on rural Interstate highways do not fluctuate much by hour of the day or by day of the week, but this is not the case for urban Interstate highways. In addition to the variations by hour identified in *Exhibit 4-15*, urban Interstate highways experienced variations by day of the week, as illustrated in *Exhibit 4-17*.

Exhibit 4-17 ■ Hourly Speed by Day of the Week on Urban Interstate, 2016



Note: Observed speed is averaged over mainline Interstate highways.

Source: FHWA staff calculation from the National Performance Management Research Data Set and Highway Performance Monitoring System.

Although all weekdays had similar speed trends of daytime troughs of congestion, individual hourly speed profiles by weekday were different. Monday tended to be the least congested weekday except in the morning peak period, during which Friday had the least congestion (a shallower trough). The Friday afternoon peak period started about one hour earlier than other weekdays.

The three middle weekdays (Tuesday, Wednesday, Thursday) follow typical weekday traffic conditions and experienced the most congested morning and afternoon peaks among all five weekdays.

For all weekdays, the afternoon peak period is consistently more congested than the morning peak period. The most congested afternoon peak period occurs on Thursday, when average speed dipped below 46 mph. The peak period on Friday afternoon tended to be longer than that of other weekdays.

Congestion Trends

This section focuses on examining congestion development from 2006 to 2016, based on the *2019 Urban Mobility Report*. As noted earlier, the Urban Mobility Report uses some of the same metrics as those presented above for 2012 to 2016, but the values were calculated using a different data source and methodology for a larger number of urban areas. Thus, the values presented in this section are not comparable with the values for the indicators reported above, although they represent similar concepts.

The average TTI first decreased during the economic downturn of 2009–2011, but subsequently rebounded and exceeded the pre-recession levels in urbanized areas. The TTI increased from 2011 to 2016 (*Exhibit 4-18*), consistent with the trend illustrated in *Exhibit 4-1*.

The Urban Mobility Report also 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. An average auto commuter logged 53 additional hours sitting in traffic during the peak traveling period in 2016, which is a substantial escalation from 42 hours in 2006. Even at a modest national VMT growth, this increase in average delay could translate into a massive increase in nationwide total delay time. Total travel delay surged by 27 percent over the decade and reached 8.6 billion hours in 2016.

Congestion wastes an enormous amount of fuel. Over the 10-year period of 2006–2016, wasted fuel rose by 0.2 billion gallons. In 2016, 3.3 billion gallons of extra fuel was purchased due to delays on roadways. Combining wasted fuel with time delay, the total cost of congestion was estimated to be $171 billion in 2016, $26 billion higher than in 2006. (The average cost of time was assumed to be $18.29 per hour of personal travel and $59.94 per hour of truck time in 2017 constant dollars, which differs from the value used in the analyses reflected in Part II of this report.)

National Congestion Trends Since 2016

The Urban Mobility Report estimates that delay per auto commuter rose to 54 hours in 2017, while total delay rose to 8.8 billion hours. The total cost of congestion was estimated to be $179 billion in 2017.

Exhibit 4-18 ■ National Congestion Measures, 2006–2016

Year	Travel Time Index	Delay per Auto Commuter (Hours)	Total Delay (Billions of Hours)	Total Fuel Wasted (Billions of Gallons)	Total Cost (Billions of 2017 Dollars)
2006	1.22	42	6.7	3.1	$115
2007	1.22	43	6.8	3.2	$121
2008	1.22	42	6.8	3.2	$127
2009	1.21	43	6.9	3.1	$124
2010	1.21	44	7.2	3.1	$132
2011	1.21	45	7.5	3.2	$143
2012	1.22	47	7.7	3.2	$150
2013	1.22	48	8.0	3.2	$157
2014	1.22	50	8.2	3.2	$163
2015	1.23	51	8.4	3.3	$165
2016	1.23	53	8.6	3.3	$171

Source: Texas Transportation Institute (2019).

TPM Delay and Congestion Measures

TPM establishes two performance measures to assess traffic congestion for the purpose of carrying out the Congestion Mitigation and Air Quality Improvement (CMAQ) Program in urbanized areas. One measure is the annual hours of peak hour excessive delay (PHED) per capita. The other measure is the percentage of non-single occupancy vehicles (non-SOV), which may include travel via carpool, van, public transportation, commuter rail, walking, or bicycling, as well as telecommuting. The non-SOV rule applies initially to urbanized areas of more than 1 million people that are also in nonattainment or maintenance areas for ozone, carbon monoxide, or particulate matter. In the second performance period (which begins on January 1, 2022), the population threshold changes to areas of more than 200,000. All States and MPOs with NHS mileage that overlaps within an applicable urbanized area must coordinate on a single, unified target and report on the measures for that area.

Access

Transportation is a vital link that allows full participation in the community and contribution to a better society. Improved access to transportation helps ensure that all Americans, including those with disabilities, have equal opportunity to participate in and enjoy the benefits of society.

Definition and Measurement

Access is defined as the ability of travelers to reach their desired destinations. It is a broad concept that is applicable to all user groups and modes, accounting for distance, travel time, and travel costs of reaching destinations. The measures of access provide a user-centric approach to compare the performance of the transportation system to the population's needs. They can also be used to understand the distribution of user benefits associated with transportation investment and land use development.

Sometimes the term "accessibility" is used in reference to specific requirements under The Americans with Disabilities Act (ADA) of 1990; to avoid confusion this report uses the term "access" when referring to access for the general population. Transportation accessibility in this report refers to the provision of transportation facilities, including pedestrian facilities, that are accessible to and usable by individuals with mobility, visual, hearing, and other disabilities.

Access to destinations refers to the ability of people in a community to reach employment and essential services, such as health care, education, transit, and recreation, among others, through a diverse transportation network. Access to destinations can be measured for different transportation modes, to different types of destinations, and at different times of the day. For example, access to health care can be defined as the number of medical facilities that can be reached by the public within a given time. *Access Across America: Auto 2016*[15] argues that "(j)obs are the most significant non-home destination, and job accessibility is an important consideration in the attractiveness and usefulness of a place or area." According to the American Community Survey,[16] 85 percent of commuting trips used cars, trucks, vans, and other private motor vehicles in 2016 in the United States.

A laborshed is defined as the area or region from which an employment center draws its commuting workers within a travel time threshold. The *Access Across America: Auto* report uses employee home and work locations in the U.S. Census Bureau's Longitudinal Employer-Household Dynamics program (LEHD). Auto travel times are evaluated from the centroid of the origin census block to the centroid of the destination census block based on detailed auto travel network and link speed data.

[15] Accessibility Observatory, University of Minnesota, 2018.
[16] (https://www.census.gov/programs-surveys/acs/data.html).

Access to jobs is calculated using average speed and job densities across entire metropolitan areas for an 8 a.m. Wednesday morning departure, weighted by the number of workers in in all blocks in a statistical area. *Exhibit 4-19* presents information on access to jobs that are reachable within a given travel time by automobiles for the 50 most populous metropolitan areas. This measurement of laborshed identifies the areas with the highest auto access to jobs in 2016 as major economic centers such as New York, Los Angeles, Chicago, and Washington.

Exhibit 4-19 ■ Access to Jobs by Vehicles by Travel Time, 2016

Metropolitan Area	Jobs Reachable within 60 Minutes	Compared to Jobs Reachable within 60 Minutes, Share of Jobs Reachable within		
		10 Minutes	30 Minutes	50 Minutes
New York	6,529,209	3%	35%	80%
Los Angeles	5,544,460	3%	37%	82%
Chicago	3,537,245	3%	33%	80%
Washington	3,039,577	3%	33%	80%
Dallas	2,985,510	3%	44%	89%
San Francisco	2,959,082	4%	33%	79%
Philadelphia	2,904,106	2%	30%	76%
Riverside	2,694,177	2%	22%	64%
Boston	2,651,404	3%	32%	78%
San Jose	2,621,869	6%	38%	75%
Baltimore	2,590,067	3%	29%	69%
Houston	2,570,577	4%	44%	89%
Atlanta	2,093,630	3%	34%	81%
Detroit	2,006,487	4%	46%	86%
Miami	1,935,235	5%	47%	87%
Minneapolis	1,727,354	5%	57%	91%
Phoenix	1,726,471	6%	59%	94%
Denver	1,604,629	6%	61%	90%
Seattle	1,595,463	5%	45%	85%
Providence	1,580,807	3%	24%	67%
San Diego	1,534,217	6%	50%	84%
Hartford	1,485,579	4%	36%	79%
Tampa	1,426,024	5%	41%	83%
Orlando	1,401,750	4%	49%	83%
Cleveland	1,375,378	3%	41%	85%
Cincinnati	1,203,048	4%	47%	86%
St. Louis	1,196,601	5%	54%	91%
Milwaukee	1,170,906	9%	54%	83%
Portland	1,135,524	6%	58%	91%
Charlotte	1,125,078	5%	49%	87%
Indianapolis	1,116,321	5%	54%	87%
Sacramento	1,092,420	7%	54%	86%
Columbus	1,078,073	7%	58%	87%
Raleigh	1,074,819	6%	53%	86%
Pittsburgh	1,072,265	3%	37%	81%
Kansas City	1,064,141	6%	61%	90%
Austin	1,031,311	8%	56%	86%
Salt Lake City	1,007,582	12%	64%	95%
San Antonio	944,741	8%	65%	90%
Nashville	843,120	5%	44%	87%
Las Vegas	821,502	14%	96%	100%
Louisville	727,100	8%	61%	88%
Richmond	707,197	7%	58%	84%
Virginia Beach	669,966	8%	56%	88%
Jacksonville	656,444	7%	59%	91%
New Orleans	619,656	10%	52%	82%
Oklahoma City	613,589	9%	67%	93%
Memphis	605,349	10%	71%	93%
Buffalo	601,055	11%	71%	92%
Birmingham	585,400	6%	49%	82%

Source: Accessibility Observatory, University of Minnesota (http://access.umn.edu/research/america/index.html).

Exhibit 4-19 shows the distribution of time it takes workers in U.S. metropolitan areas to drive to their job locations from their homes. Of the jobs reachable within 60 minutes of driving, less than 5 percent can be reached within 10 minutes in most metropolitan areas. Approximately one-third can be reached in 30 minutes or less in large metropolitan areas and more than half can be reached in 30 minutes or less in medium-size metropolitan areas. Generally speaking, less populous metropolitan areas tend to have more jobs concentrated within shorter commutes. For example, in New York City approximately 3 percent of jobs in the one-hour laborshed can be reached within 10 minutes, and 35 percent of jobs can be reached within 30 minutes. In the much smaller city of Memphis, 10 percent of jobs in the one-hour laborshed can be reached within 10 minutes and 71 percent of jobs can be reached within 30 minutes.

Lower speeds due to congestion reduce the number of jobs reachable within the same travel time. The *Access Across America: Auto* report measures the impact of congestion on access to jobs by comparing job accessibility during the morning commute peak (8 a.m.) with accessibility during free-flow traffic, measured by the percentage reduction in job access within a given travel time threshold that is caused by highway congestion compared with free-flow speeds.

The impact of congestion is more pronounced in city cores, and the negative impact of congestion on access to jobs eases as the travel time threshold increases (*Exhibit 4-20*). For example, a congestion impact of 42 percent at the 10-minute travel time threshold in New York City indicates that the number of workers who can access their jobs within 10 minutes is 42 percent lower during the morning commute peak compared with off-peak periods. At a 30-minute travel time threshold in New York City, job access is cut by 37 percent; at 50 minutes it is cut by 20 percent, whereas at 60 minutes it is cut by only 15 percent.

Exhibit 4-20 ■ Congestion Impact on Job Access by Travel Time, 2016

	Travel Time Threshold			
Metropolitan Area	**10 Minutes**	**30 Minutes**	**50 Minutes**	**60 Minutes**
New York	42%	37%	20%	15%
Los Angeles	43%	42%	23%	14%
Chicago	38%	33%	18%	11%
Washington	37%	34%	17%	12%
Dallas	32%	25%	8%	3%
San Francisco	36%	40%	24%	13%
Philadelphia	35%	29%	17%	14%
Riverside	25%	34%	46%	39%
Boston	43%	34%	20%	13%
San Jose	41%	24%	30%	18%
Baltimore	27%	24%	30%	25%
Houston	38%	29%	9%	4%
Atlanta	34%	32%	16%	10%
Detroit	22%	16%	7%	6%
Miami	36%	23%	10%	7%
Minneapolis	28%	15%	4%	2%
Phoenix	28%	19%	4%	2%
Denver	32%	16%	4%	4%
Seattle	37%	28%	15%	9%
Providence	24%	18%	34%	33%
San Diego	33%	19%	8%	9%
Hartford	28%	14%	9%	9%
Tampa	25%	20%	8%	6%
Orlando	29%	11%	5%	5%
Cleveland	26%	15%	5%	4%
Cincinnati	23%	14%	5%	5%
St. Louis	22%	11%	3%	2%
Milwaukee	23%	8%	4%	6%
Portland	35%	18%	6%	4%
Charlotte	26%	15%	5%	5%
Indianapolis	24%	11%	4%	4%
Sacramento	31%	12%	6%	8%
Columbus	27%	7%	4%	4%
Raleigh	20%	11%	5%	4%
Pittsburgh	38%	21%	10%	7%
Kansas City	18%	8%	2%	2%
Austin	34%	16%	5%	5%
Salt Lake City	21%	4%	2%	1%
San Antonio	27%	7%	4%	6%
Nashville	30%	18%	5%	4%
Las Vegas	21%	1%	0%	0%
Louisville	23%	6%	3%	4%
Richmond	19%	5%	2%	3%
Virginia Beach	21%	9%	4%	3%
Jacksonville	27%	10%	4%	3%
New Orleans	31%	7%	6%	7%
Oklahoma City	20%	6%	2%	1%
Memphis	17%	5%	2%	2%
Buffalo	19%	5%	1%	2%
Birmingham	25%	9%	6%	5%

Note: The congestion impact compares job accessibility between morning commute peak (8 a.m.) and the maximum accessibility achieved across the 24-hour period.

Source: Accessibility Observatory, University of Minnesota

Large metropolitan areas observe more noticeable negative impacts of congestion on access to jobs than do their medium-size counterparts. At the 30-minute travel time threshold, the congestion impacts are 42 percent in Los Angeles and 33 percent in Chicago, whereas the impacts are more limited at 5 percent in Memphis and Buffalo.

Separated Bike Lane Planning and Design Guide

This FHWA guide (https://www.fhwa.dot.gov/environment/bicycle_pedestrian/publications/separated_bikelane_pdg/page00.cfm) outlines planning considerations for separated bike lanes and provides a menu of design options covering typical one- and two-way scenarios. It includes options for providing separation, midblock design, and intersection design. A new State law required the California Department of Transportation (Caltrans) to address separated bike lanes in its Highway Design Manual. Caltrans used and referenced this FHWA guide in the development of its State-level guidance. The Minnesota Department of Transportation also used this guide to inform the development of Statewide design standards for separated bike lanes. Delaware metropolitan planning organizations used and recommended the guide in updating their bike plan and cycle track designs.

The definition of access is not limited to vehicles: it also includes other transportation modes such as pedestrians and bicycles. The boxes present examples of State departments of transportation and metropolitan planning organizations that are developing and enhancing their strategic plans to improve access to destinations for non-vehicle travelers.

Incorporating On-Road Bicycle Networks into Resurfacing Projects

This guidebook (https://www.fhwa.dot.gov/environment/bicycle_pedestrian/publications/resurfacing/resurfacing_workbook.pdf) helps communities integrate on-road bicycle facilities as part of their routine roadway resurfacing process. It is an efficient and cost-effective way for communities to create connected networks of bicycle facilities. Many States, including Connecticut, Florida, Iowa, Maine, Massachusetts, and Wisconsin, provided trainings and workshops on the guidebook and have incorporated some of its suggested approaches into their policies and programs. Some States and Michigan's Pioneer Valley metropolitan planning organization have hosted multi-State trainings or have worked with FHWA to extend trainings to local entities. Arkansas's State Plan includes objectives that are directly connected to recommendations in this resource.

Accessible Pedestrian Facilities

The pedestrian system (including sidewalks, shared-use paths and trails, street crossings, bus stops, and even temporary facilities to mitigate the impacts of construction) is a critical link in providing access to all components of the Nation's transportation environment. Accessible pedestrian routes, which provide continuous and clear pedestrian pathways, enhance mobility and encourage independence by increasing transportation choice. Much work has been done to prevent or eliminate barriers that hinder travel for individuals with mobility, visual, hearing, or other disabilities. Accessible pedestrian facilities improve the quality of life for those with disabilities by reducing barriers to services, opportunities, and social activities.

Nearly one in five adults under the age of 65 has difficulty getting around outside due to an impairment or health problem, with difficulty in walking cited as the most common problem.[17] However, many people with mobility, sensory, and cognitive impairments continue to encounter barriers in their efforts to gain access to work, school, commerce, health, and leisure activities. Often the built environment is a primary reason for this difficulty because it has historically been designed for people who do not have a disability. Design details for surfaces, streetscape furniture, sidewalks, signals, street crossings, and transit stops may render pedestrian facilities inaccessible.

[17] The Future of Disability in American, Institute of Medicine of the National Academies, 2007, p. 522. https://www.nap.edu/read/11898/chapter/1.

Accessible Shared Streets: Notable Practices and Considerations for Accommodating Pedestrians with Vision Disabilities

This FHWA report (available at https://www.fhwa.dot.gov/environment/bicycle_pedestrian/publications/accessible_shared_streets/fhwahep17096.pdf) reviews approaches for accommodating pedestrians with vision disabilities on shared streets where pedestrians, bicyclists, and motor vehicles are intended to mix in the same space. It describes specific challenges that pedestrians with vision disabilities face when navigating shared streets and provides strategies to address accessibility for pedestrians with vision disabilities in the planning and design process. The City of Minneapolis recently conducted a shared street study incorporating strategies to facilitate navigation and movement for people with visual disabilities in residential and commercial settings.

As a result, pedestrians with disabilities may be forced to walk in the street or otherwise be placed in direct conflict with motor vehicles or bicycles.

Strategic Agenda for Pedestrian and Bicycle Transportation

This document (https://www.fhwa.dot.gov/environment/bicycle_pedestrian/publications/strategic_agenda/) provides a framework to guide FHWA's pedestrian and bicycle initiatives and investments during the five-year period from Federal Fiscal Years 2017 to 2021. It establishes a strategic, collaborative approach for making walking and bicycling viable transportation options for people of all ages and abilities in communities throughout the United States. The Florida Department of Transportation used this document for guidance on data collection and implementation in its Pedestrian and Bicycle Strategic Safety Plan. It is also recommended to be included in updating design manuals by the Pennsylvania Department of Transportation.

The ADA requires pedestrian facilities in the public right-of-way to be accessible to and usable by individuals with disabilities. Common barriers to accessibility include issues such as curbs at street intersections with sidewalks, excessive sidewalk cross slopes, vision-dependent signal communications, and a variety of constraints posed by space limitations, roadway design practices, slope, and terrain. Accessible street designs can minimize multimodal conflicts by eliminating barriers for pedestrians, communicating street crossing information, and promoting predictable behavior for all roadway users. This ensures that the same degree of convenience, connection, and safety afforded to the public generally is also available to pedestrians with disabilities.

Achieving Multimodal Networks: Applying Design Flexibility and Reducing Conflicts

This guidebook (https://www.fhwa.dot.gov/environment/bicycle_pedestrian/publications/multimodal_networks/fhwahep16055.pdf) helps practitioners address topics such as intersection design, road diets, pedestrian crossings, transit and school access, freight, and accessibility. It highlights ways to apply design flexibility while focusing on reducing multimodal conflicts and achieving connected networks. A number of States, including Washington, Oregon, and Wyoming, have used this guidebook in their State or MPO Bicycle and Pedestrian Plans.

These projects aim to spur business growth and job creation, and to make communities more livable through improved transportation infrastructure. These goals are achieved by reducing barriers to safety, providing greater connectivity to activity centers, accelerating project delivery, incorporating data in planning decisions, and offering technology innovations.

Recent FHWA Resources

- ***2019 Recreational Trails Program (RTP) Annual Report***. (https://www.fhwa.dot.gov/environment/recreational_trails/overview/report/2019/report2019.pdf)
- ***Accessible Shared Streets: Notable Practices and Considerations for Accommodating Pedestrians with Vision Disabilities.*** (https://www.fhwa.dot.gov/environment/bicycle_pedestrian/publications/accessible_shared_streets/fhwahep17096.pdf)
- ***Achieving Multimodal Networks: Applying Design Flexibility and Reducing Conflicts*****.** (https://www.fhwa.dot.gov/environment/bicycle_pedestrian/publications/multimodal_networks/fhwahep16055.pdf)
- ***Case Studies in Realizing Co-Benefits of Multimodal Roadway Design and Gray and Green Infrastructure***. (https://www.fhwa.dot.gov/environment/bicycle_pedestrian/publications/multimodal_green_infrastructure/).
- ***Guidebook for Measuring Multimodal Network Connectivity.*** (https://www.fhwa.dot.gov/environment/bicycle_pedestrian/publications/multimodal_connectivity/)
- ***Guidebook for Developing Pedestrian and Bicycle Performance Measures***. (https://www.fhwa.dot.gov/environment/bicycle_pedestrian/publications/performance_measures_guidebook/pm_guidebook.pdf)
- ***Incorporating On-Road Bicycle Networks into Resurfacing Projects***. (https://www.fhwa.dot.gov/environment/bicycle_pedestrian/publications/resurfacing/resurfacing_workbook.pdf)
- ***Metropolitan Pedestrian and Bicycle Planning Handbook***. (https://www.fhwa.dot.gov/planning/processes/pedestrian_bicycle/publications/mpo_handbook/index.cfm)
- ***Noteworthy Local Polices That Support Safe and Complete Pedestrian and Bicycle Networks***. (https://safety.fhwa.dot.gov/ped_bike/tools_solve/docs/fhwasa17006-Final.pdf)
- ***Pursuing Equity in Pedestrian and Bicycle Planning***. (https://www.fhwa.dot.gov/environment/bicycle_pedestrian/resources/equity_paper/equity_planning.pdf)
- ***Safety for All Users Report***. (https://www.transportation.gov/sites/dot.gov/files/docs/mission/safety/303201/safety-all-users-report.pdf)
- ***Separated Bike Lane Planning and Design Guide***. (https://www.fhwa.dot.gov/environment/bicycle_pedestrian/publications/separated_bikelane_pdg/page00.cfm)
- ***Small Town and Rural Multimodal Networks***. (https://www.fhwa.dot.gov/environment/bicycle_pedestrian/publications/small_towns/fhwahep17024_lg.pdf)
- ***Strategies for Accelerating Multimodal Project Delivery***. (https://www.fhwa.dot.gov/environment/bicycle_pedestrian/publications/multimodal_delivery/)
- ***Strategic Agenda for Pedestrian and Bicycle Transportation***. (https://www.fhwa.dot.gov/environment/bicycle_pedestrian/publications/strategic_agenda/)

Mobility and Access – Transit

The basic goal of all transit operators is to connect people to the places they want to go in a safe and efficient manner. Transit operators seek to minimize travel times, make effective use of vehicle capacity, and provide 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 discussed in this chapter; transit safety data are summarized in Chapter 5.

The first section of this chapter 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 for transit, including operating expenditures per revenue mile or passenger mile, are discussed in Chapter 2.

The second section presents an analysis of the progress that transit agencies have made in improving accessibility to transit for persons with disabilities as well as an analysis of transit system coverage, frequency of service, and waiting times.

The National Transit Database (NTD) includes urban data reported by mode and type of service. As of December 2010, NTD contained data for 16 modes. Beginning in January 2011, FTA added new modes 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
- Demand-response taxi—previously reported as demand response

Data from NTD are presented for each new mode for analyses specific to 2016. 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.

KEY TAKEAWAYS

- The average speed of transit modes varies considerably. Modes such as trolleybus and streetcar operate mostly in mixed traffic rights-of-way and serve downtown areas. The average speed of these modes is less than 10 mph.
- Rail modes operate at average speeds of over 15 mph; modes with a long-distance commuter orientation, such as commuter rail average over 30 mph.
- The utilization of the fleet as measured by revenue miles per size of fleet increased appreciably for light rail (including streetcars) and commuter rail, whereas it declined for bus and demand response.
- Heavy rail vehicle occupancy increased by 17 percent from 2006 to 2016 but declined marginally on most other modes. Following four years of steady ridership increases, ridership declined by roughly 1.4 percent from 2014 to 2016.
- The mean distance between vehicle failures has shown steady improvement across all modes since 2009.
- Ridership in 2016 was 10.4 billion trips, an increase of 10.5 percent compared with 9.4 billion in 2006.
- As of 2016, 48 percent of transit passengers wait five minutes or less for transit vehicles to arrive and 74 percent wait 10 minutes or less. Only 3 percent wait more than 30 minutes.
- The level of ADA accessibility to transit service vehicles rose from 94 percent in 2006 to 95 percent in 2016. Light rail had the highest increase in accessibility, from 83 percent in 2006 to 93 percent in 2016.

Ridership

The two primary measures of transit ridership are unlinked passenger trips (UPTs) and PMT. An unlinked passenger trip, sometimes called a boarding, is defined as a journey on one transit vehicle. PMT is calculated based on UPTs 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 significant differences in the average trip length for the various modes.

Exhibit 4-21 provides total PMT for selected years between 2006 and 2016, showing steady growth across all major modes. The ferryboat, light rail, other rail, and vanpool modes grew at the highest rates, whereas heavy rail had the largest increase in total passenger miles (accounting for close to half the growth in total passenger miles).

Exhibit 4-21 ■ Transit Passenger Miles Traveled, 2006–2016

	Passenger Miles (in Millions)						Average Annual Rate of Change 2016 to 2006
Mode	2006	2008	2010	2012	2014	2016	
Rail	**26,972**	**29,989**	**29,380**	**31,176**	**32,672**	**32,944**	**2.0%**
Heavy Rail	14,721	16,850	16,407	17,516	18,339	18,357	2.2%
Commuter Rail	10,359	11,032	10,774	11,121	11,600	11,768	1.3%
Light Rail[1]	1,866	2,081	2,173	2,489	2,675	2,756	4.0%
Other Rail[2]	25	26	26	50	59	64	9.7%
Nonrail	**22,351**	**23,723**	**23,247**	**23,993**	**24,340**	**23,378**	**0.5%**
Fixed-route Bus[3]	20,390	21,198	20,570	21,142	21,429	20,411	0.0%
Demand Response[4]	753	844	874	887	917	943	2.3%
Ferryboat	178	390	389	402	414	490	10.7%
Trolleybus	164	161	159	162	158	154	-0.6%
Vanpool	689	992	1,087	1,254	1,310	1,288	6.5%
Other Nonrail[5]	176	138	169	145	112	92	-6.3%
Total	**49,322**	**53,712**	**52,627**	**55,169**	**57,012**	**56,322**	**1.3%**
Percent Rail	54.7%	55.8%	55.8%	56.5%	57.3%	58.5%	

[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.

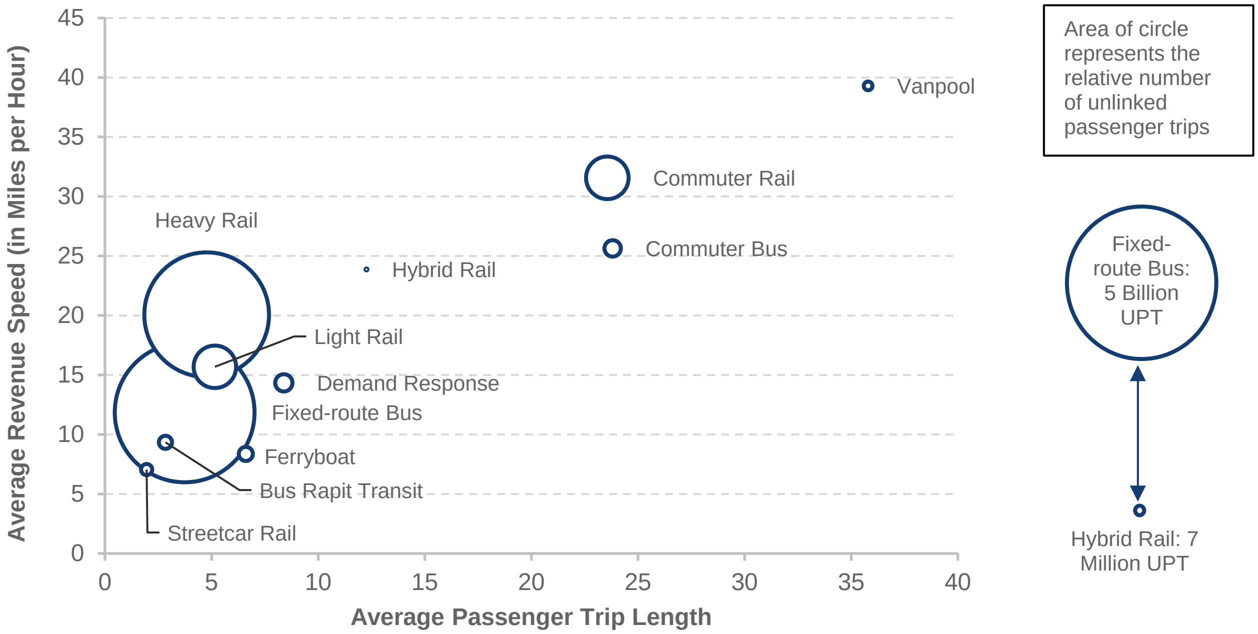
[5] Includes aerial tramway and público.

Source: National Transit Database.

Growth in demand response (up 2.3 percent per year) could reflect demand from the growing number of elderly citizens. Light rail (up 4.0 percent per year) enjoyed increased capacity during this period due to expansions and addition of new systems. The rapidly increasing popularity of vanpools (up 6.5 percent per year), particularly the surge between 2006 and 2008 (up 44 percent over that period), can be attributed partially to rising gas prices: Regular gasoline sold for more than $4 per gallon in July of 2008. FTA also encouraged vanpool reporting during this period, successfully enrolling many new vanpool systems to report to NTD. *Exhibit 4-22* depicts average passenger trip length (defined as PMT per UPT) vs. revenue speed (defined as VRMs per vehicle revenue hours), and UPTs 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 and walking. Therefore, the average trip length of an individual mode as depicted in

Exhibit 4-22 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.

Exhibit 4-22 ■ Transit Urban Average Unlinked Passenger Trip Length vs. Average Revenue Speed for Selected Modes



Source: National Transit Database.

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.

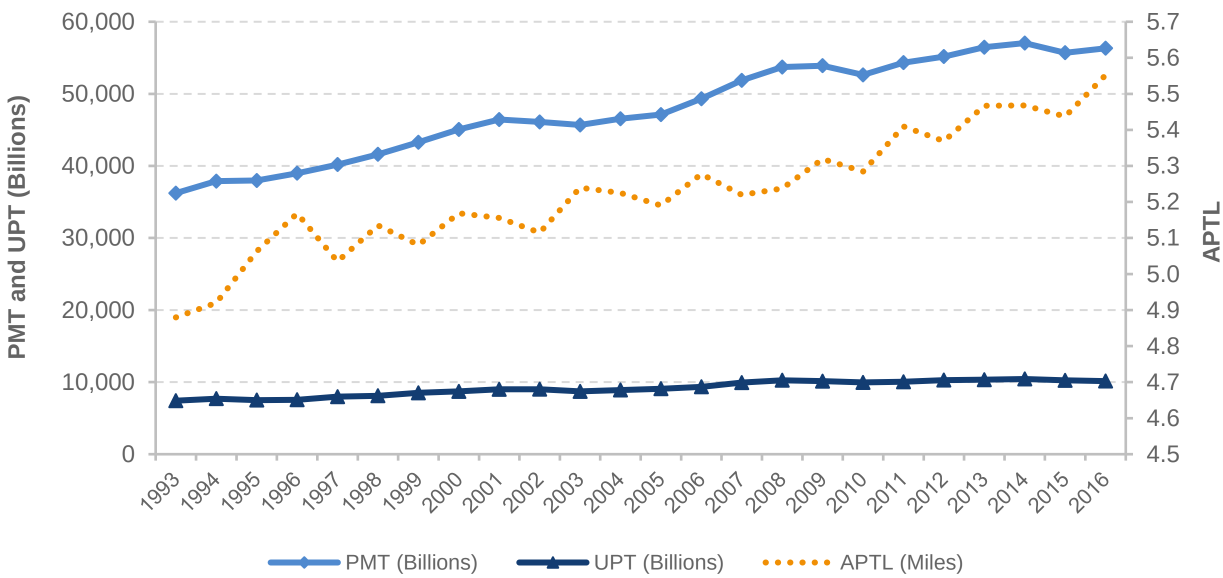
Commuter bus and commuter rail, on the other hand, are fixed-route modes, and a high percentage of commuters require other modes to reach their final destinations. Additionally, commuter bus and commuter rail are not as fast as vanpools due to more frequent stops near areas of attraction and generation of trips, among other factors. Prior to being introduced in 2011, hybrid rail was reported as commuter rail and light rail. However, 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 a 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 mph). Heavy rail and light rail have higher average speeds 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 those of commuter rail and commuter bus.

Transit Travel Trends

As shown in *Exhibit 4-23*, UPT trends since 1993 have generally mirrored those of PMT, increasing and decreasing in the same years. From 1993 to 2016, PMT increased on average by 1.9 percent annually, outpacing UPT, which grew by 1.3 percent per year. This was reflected in an increase in average passenger trip lengths. In 1993, the average transit trip was 4.9 miles. By 2016, the average transit trip increased to 5.6 miles, a 14-percent increase. The increase is due in part to the expansion of service areas into growing suburbs. UPT and PMT have decreased more recently, starting in 2013 and going through to 2016 and beyond.

Exhibit 4-23 ■ PMT, UPT, and APTL, 1993–2016

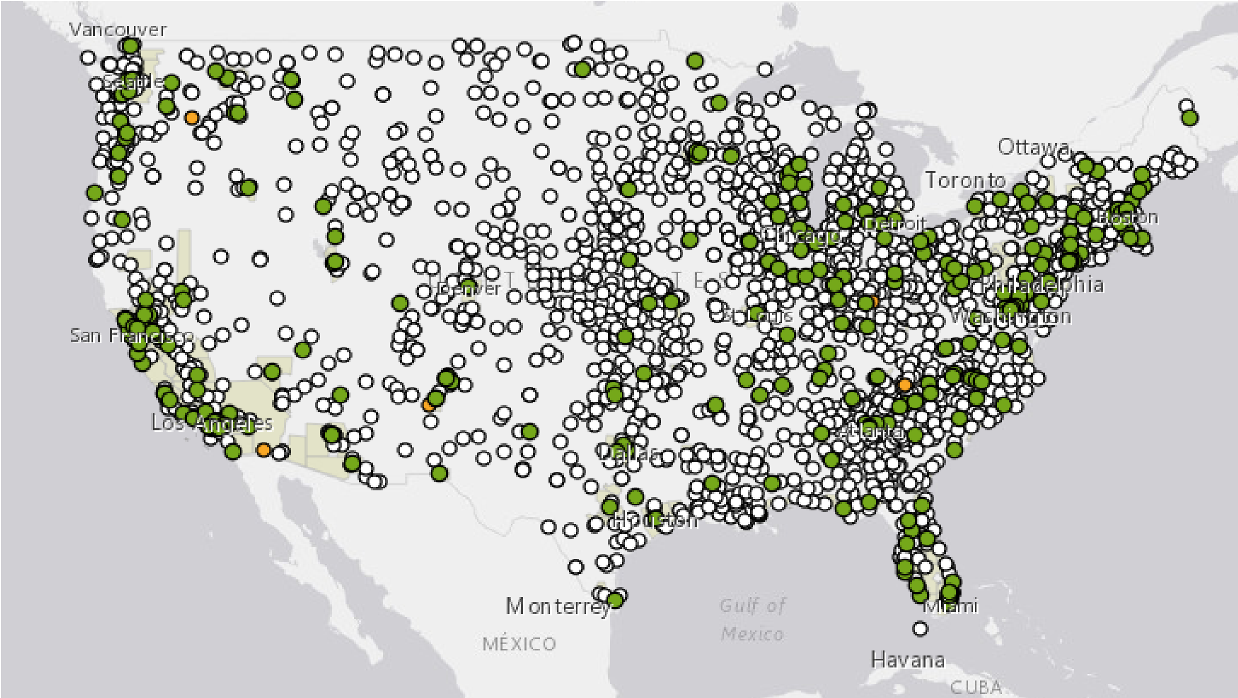


Notes: PMT is passenger miles traveled; UPT is unlinked passenger trips; APTL is average passenger trip length.
Source: National Transit Database.

National Transit Map

In 2016, FTA 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 April 2018, the National Transit Map included route maps from 331 participating transit providers (see *Exhibit 4-24*). The National Transit Map is available at https://www.bts.gov/content/national-transit-map.

Exhibit 4-24 ■ Transit Agencies in the Continental United States and Agencies Participating in the National Transit Map, 2018



Note: Participating agencies are represented by green dots, declining agencies by orange dots, and agencies not yet contacted by white dots; metropolitan planning organizations appear as light brown rectangular or irregular shapes.

Source: Bureau of Transportation Statistics, National Transit Map, updated on April 24, 2018.

Exhibit 4-25 shows the 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, Connecticut are exceptions: Both have smaller populations than the other areas. Given their proximity to large metropolises (San Francisco and New York, respectively), the data show high ridership for trips between the small satellite areas and major cities.

Exhibit 4-25 ■ Market Share of Public Transit of Work Trips for the Top 10 Urbanized Areas, 2016

Rank	Urbanized Area	Public Transit Share	Margin of Error ±
1	New York–Newark, NY–NJ–CT Urbanized Area (2010)	33.0%	0.3%
2	San Francisco–Oakland, CA Urbanized Area (2010)	19.6%	0.5%
3	Washington, DC–VA–MD Urbanized Area (2010)	15.7%	0.4%
4	Boston, MA–NH–RI Urbanized Area (2010)	14.2%	0.4%
5	Chicago, IL–IN Urbanized Area (2010)	13.0%	0.3%
6	Concord, CA Urbanized Area (2010)	12.1%	1.0%
7	Bridgeport–Stamford, CT–NY Urbanized Area (2010)	10.8%	0.8%
8	Champaign, IL Urbanized Area (2010)	10.5%	2.0%
9	Seattle, WA Urbanized Area (2010)	10.3%	0.4%
10	Philadelphia, PA–NJ–DE–MD Urbanized Area (2010)	10.0%	0.3%

Note: Urbanized area refers to a Census-designated urban area with 50,000 residents or more.

Source: American Community Survey 2016.

The National Household Travel Survey and Key Public Transportation Characteristics 2009–2017

The 2017 National Household Travel Survey is based on data collected over a one-year period, starting in the second quarter of 2016 and ending in the first quarter of 2017.

Introduction

All analyses in this section are concentrated in three mode groups:

Group 1: Includes cars, SUVs, vans, and trucks, but not taxis and other transportation network company (TNC) services (alternatively referred to as ridesharing) such as Uber, Lyft, and other providers, which are designated as "private vehicles."

Group 2: The second group, which includes public transportation modes and is designated as "PTRANS" (public transit), includes up to three subgroups:[18]

NHTS Designation	C&P Designation
Local Bus and Commuter Bus	Bus
Amtrak/Commuter Rail	Commuter Rail
Heavy Rail, Light Rail, and Streetcars	Local Rail

Group 3: Due to extraordinary growth in TNC services between the 2009 and 2017 NHTS surveys, the analyses in this section added a separate group to consider them.

The NHTS data were surveyed and thus probabilistic, with the margin of error (MOE) provided by FHWA's querying tool or calculated when not retrievable from the tool. The analyses that follow do not generally show the MOE although it is calculated and factored into each analysis.

The NHTS provides summaries at the 95-percent confidence level. Whenever this level yields nonsignificant estimates, a 90-percent level is tried, and if significant at that level is presented as statistically significant. Differences between variables that fall within the MOEs are indicated in the text. Otherwise, the reader should assume the differences are statistically significant.

Most of the analyses in this section rely on data changes between the 2009 and 2017 surveys. The 2017 survey differed significantly from the 2009 survey in many respects, such as sampling method. In the specific case of public transportation, the composition and granularity of public transportation modes changed as shown in *Exhibit 4-26.*[19]

All other modes not included in these three groups are not presented or discussed in the analyses below. Thus, the sum of individual modes depicted in the exhibits does not equal the "All Modes" total, which sums all modes including those not considered here.

[18] Information on these modes is available in the NTD *2018 Policy Manual*, located at https://www.transit.dot.gov/sites/fta.dot.gov/files/docs/ntd/117156/2018-ntd-policy-manual_1.pdf, and NHTS *Data User Guide* at https://nhts.ornl.gov/assets/2017UsersGuide.pdf.

[19] Further information on these and other mode changes is available in the 2017 NHTS *Data User Guide* at https://nhts.ornl.gov/assets/2017UsersGuide.pdf.

Exhibit 4-26 ■ Public Transportation Mode Correspondence between 2009 and 2017 NHTS Surveys

Item	2009 NHTS	2017 NHTS
1	Local and Commuter Bus services were two distinct modes.	Merged these two modes into a single "Local or Commuter Bus" mode.
2	The following rail modes were separate modes: ▪ Heavy Rail (Subway and Elevated) ▪ Streetcar and Trolley	Merged into a single "Subway/Elevated, Light Rail, and Streetcar" mode.
3	Commuter Rail and Amtrak/Intercity were separate modes	Combined into "Amtrak/Commuter Rail" mode.

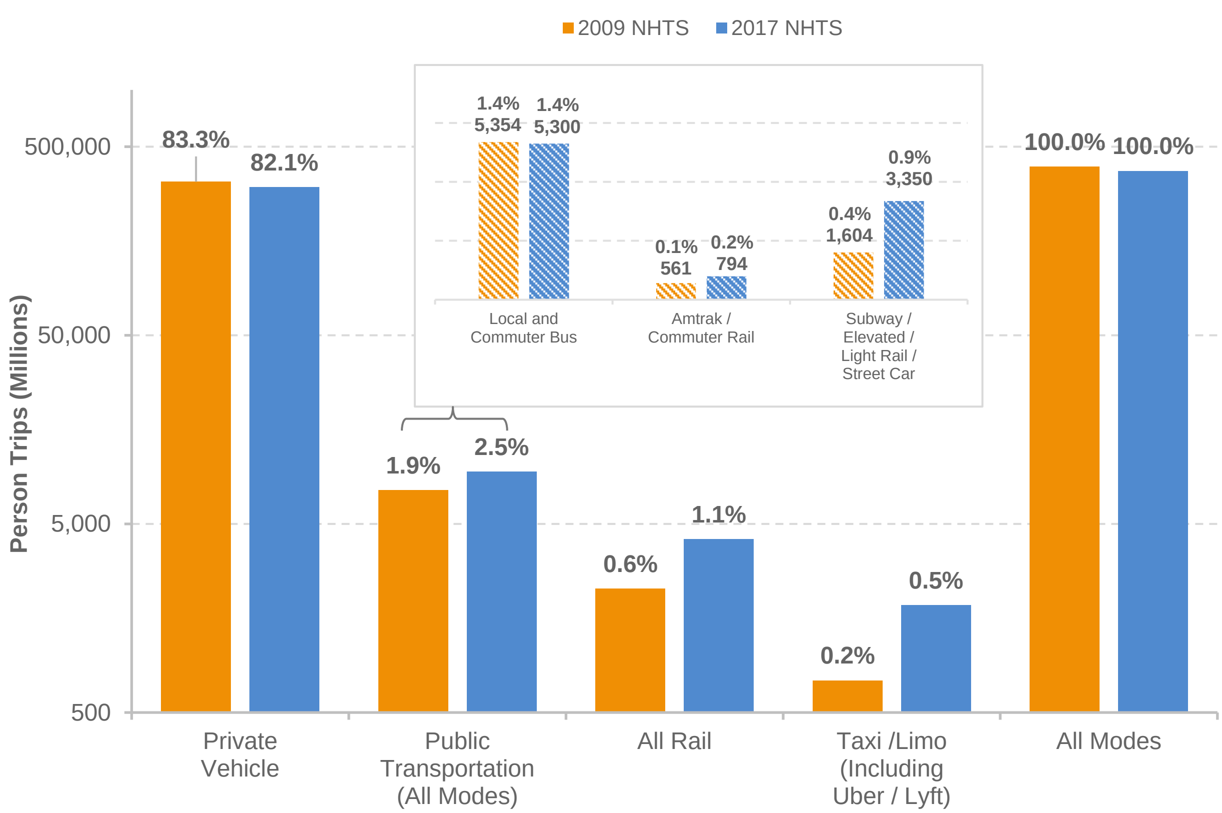
Source: 2017 NHTS Data User Guide (https://nhts.ornl.gov/assets/2017UsersGuide.pdf).

Market Share of Person Trips, All Modes and All Purposes, 2009 and 2017 NHTS

Exhibit 4-27 depicts the estimated share of all trips, for all purposes and all modes, from the 2009 and 2017 surveys.

There were more Americans in 2017 than in 2009, but they traveled less. The number of person trips decreased from 391.3 billion in 2009 to 371.1 billion trips in 2017, a five-percent decrease. Overall, the average number of trips per person decreased from 1.4 in 2009 to 1.2 trips/person in 2017, a 17-percent decrease.

Exhibit 4-27 ■ Market Share Change of Public Transportation, Private Vehicles, and Taxi Trips, 2009 and 2017



Note: NHTS is National Household Travel Survey.

Public or Commuter Bus, Amtrak/Commuter Rail, and Subway/Elevated/Light Rail/Streetcar are all subsets of Public Transportation.

Source: NHTS, FHWA, 2017.

Public transportation had the largest increase in the number of trips and market share among all modes. The number of trips rose from 7.5 billion in 2009 to 9.4 billion in 2017, a 25-percent increase. As *Exhibit 4-28* shows, this considerable increase was due to the rise in local rail trips (heavy rail, light rail, streetcars, etc.), which more than doubled from 1.6 billion in 2009 to 3.4 billion in 2017, an increase of 1.7 billion trips. Commuter rail trips also increased, but due to their low market share cannot be reliably quantified.

Bus trips, which account for over 50 percent of all public transportation trips, remained essentially unchanged. The number of trips using TNCs increased dramatically, from 738 million trips in 2009 to 1.8 billion trips in 2017, 1.1 billion more trips or a 143-percent increase.

The count of all persons in the two surveys included all individuals in the United States more than 5 years old. The number of persons increased by 14 percent over the period, whereas the number of trips decreased by 5 percent.[20]

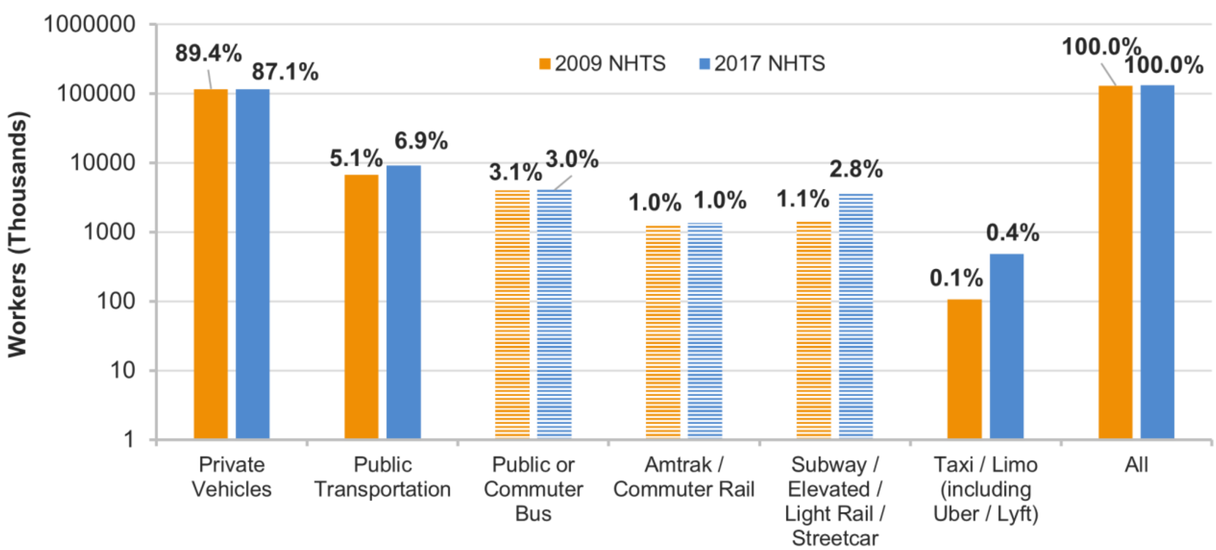
Market Share of Persons Commuting to Work by Public Transportation

On a per-person basis, the market share of commuting to work by public transportation was higher in 2017 than in 2009, but the increase in persons is commensurate to the increase when all trips and purposes are considered as shown in *Exhibit 4-27*. "Workers" are a subset of the overall transportation market, and represent commuting work trips.

Public transportation has a higher share of the market when rail trip purposes are included, at 6.9 percent in the 2017 NHTS, divided equally between rail and bus as shown in *Exhibit 4-28*.

Compared with the 2009 NHTS, public transportation had the greatest increase in market share, from 5.1 percent in 2009 to 6.9 percent in 2017. This increase was due to the more than 100-percent increase in the share of local rail modes. The bus market remained unchanged. The total share is less than 100 percent because only private vehicles and public transportation were included in the analysis. All other modes account for the difference.

Exhibit 4-28 ■ Market Share of Mode of Transportation to Work, 2009 and 2017



Note: NHTS is National Household Travel Survey.

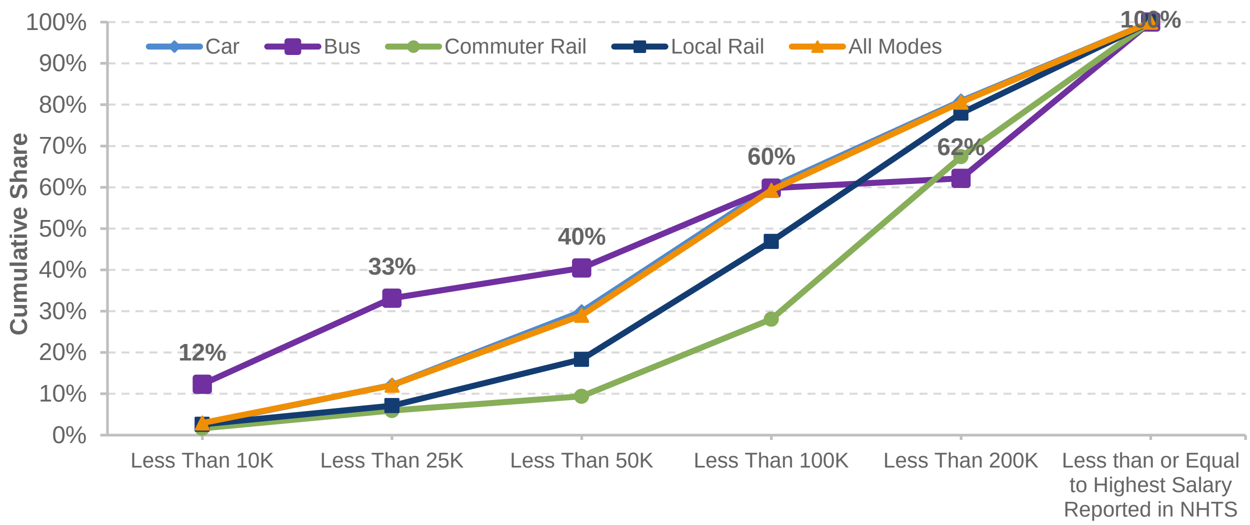
Public or Commuter Bus, Amtrak/Commuter Rail, and Subway/Elevated/Light Rail/Streetcar are all subsets of Public Transportation.

Source: NHTS, FHWA, 2017.

[20] Source: Summary of Travel Trends–2017 National Household Survey (https://nhts.ornl.gov/assets/2017_nhts_summary_travel_trends.pdf).

Exhibit 4-29 shows the distribution of cumulative household income of work trips by mode. Private vehicles ("cars" in the exhibit) are included for comparison. Bus, which accounts for 45 percent of the public transportation market, has the lowest household income distribution of all modes. Approximately 56 percent of bus commuters earn less than the national median household income ($53,156 in 2016), and 26 percent earn less than the poverty level of households with three people (the average household size of bus commuters).

Exhibit 4-29 ■ Distribution of Cumulative Household Income of Work Trips by Mode, 2017

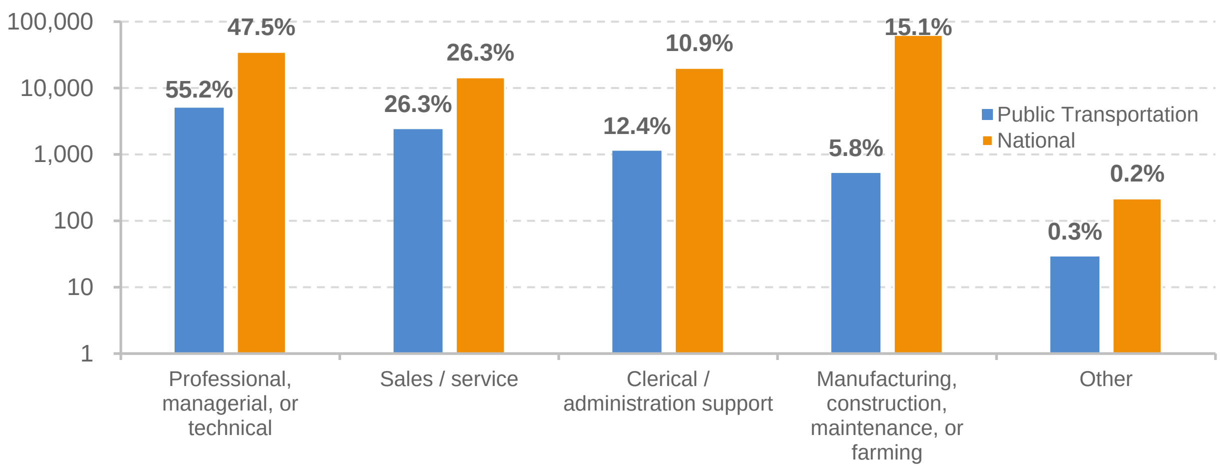


Source: National Household Transit Survey, FHWA, 2017.

Job Market

More than 50 percent of public transportation commuters work in the professional, managerial, or technical category; the second most common category is sales or service. The national distribution is similar to that for public transportation except in the manufacturing and construction category, where the national share is three times greater than that of public transportation commuters (see *Exhibit 4-30*).

Exhibit 4-30 ■ Public Transportation Commuting by Job Category, 2017



Source: National Household Transit Survey, FHWA, 2017.

System Capacity

Exhibit 4-31 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 (the time when a vehicle is available to the general public and there is an expectation of carrying passengers). 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 2006, with an average annual rate of change of 2.6 percent.
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. Thus, a heavy rail car that seats 2.4 times more people than a full-size bus provides 2.4 capacity-equivalent miles for each revenue mile it travels.

Exhibit 4-31 ■ Rail and Nonrail Vehicle Revenue Miles, 2006–2016

Mode	Vehicle Revenue Miles (in Millions)						Average Annual Rate of Change 2006 to 2016
	2006	2008	2010	2012	2014	2016	
Rail	**997**	**1,053**	**1,056**	**1,056**	**1,109**	**1,143**	**1.4%**
Heavy Rail	634	655	647	638	657	676	0.6%
Commuter Rail	287	309	315	318	339	344	1.8%
Light Rail[1]	73	86	92	99	112	121	5.2%
Other Rail[2]	3	3	2	1	1	1	-6.9%
Nonrail	**2,673**	**3,171**	**3,235**	**3,273**	**3,469**	**3,584**	**3.0%**
Fixed-route Bus[3]	1,910	2,026	1,996	1,978	2,047	2,126	1.1%
Demand Response[4]	607	948	1,010	1,046	1,155	1,186	6.9%
Ferryboat	2	3	3	3	3	4	7.8%
Trolleybus	12	11	12	11	11	11	-0.4%
Vanpool	110	158	181	207	228	234	7.8%
Other Nonrail[5]	32	25	32	27	25	23	-3.5%
Total	**3,670**	**4,225**	**4,291**	**4,328**	**4,578**	**4,727**	**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.

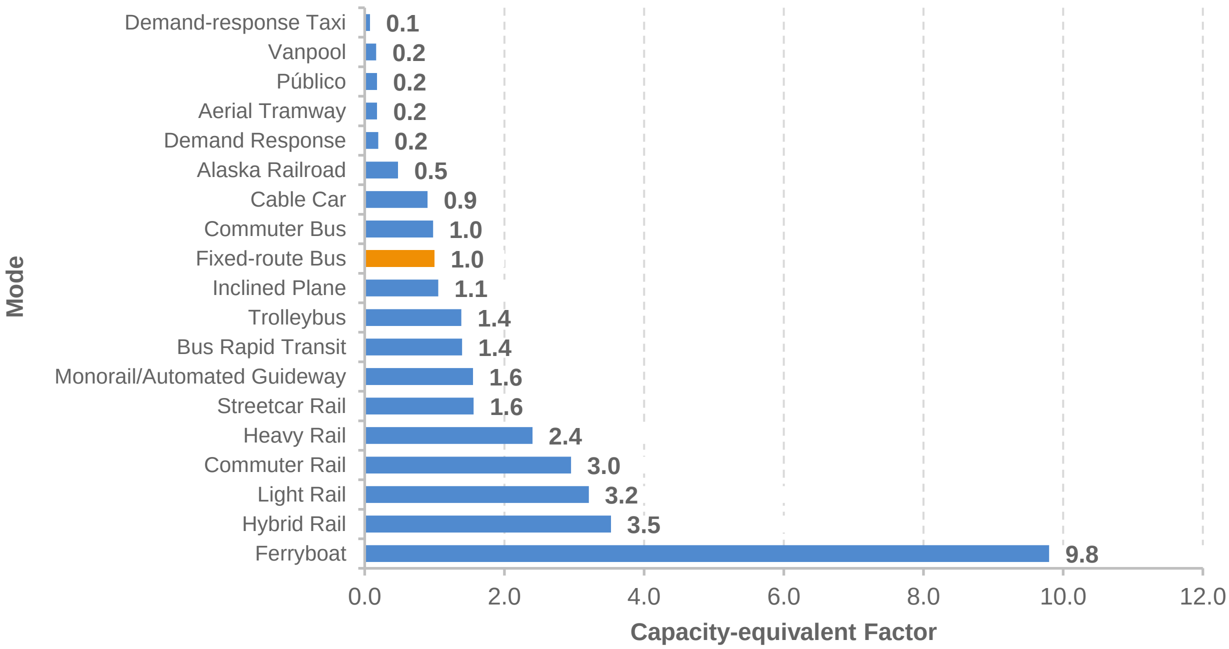
[5] Includes aerial tramway and público.

Source: National Transit Database.

Exhibit 4-32 shows the 2016 capacity-equivalent factors for each mode. Unadjusted 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 motor bus fleet changes slightly from year to year as the proportion of large, articulated, and small buses varies. The average capacity of the bus fleet in 2016 was 37 seated and 22 standing, or 59 riders.

A typical vanpool vehicle has 20 percent of the capacity of a typical bus, and a typical ferry vehicle has 10 times more than a typical bus.

Exhibit 4-32 ■ Capacity-equivalent Factors by Mode, 2016



Note: 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 4-33 shows total capacity-equivalent VRMs. Demand response showed the most rapid expansion in capacity-equivalent VRMs from 2006 to 2016, followed by vanpool, light rail, and ferryboat. 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 4,668 million in 2006 to 5,476 million in 2016, an increase of 17 percent.

Exhibit 4-33 ■ Capacity-equivalent Vehicle Revenue Miles, 2006–2016

Mode	2006	2008	2010	2012	2014	2016	Average Annual Rate of Change 2016 to 2006
Rail	**2,576**	**2,703**	**2,714**	**2,760**	**2,932**	**3,030**	**1.6%**
Heavy Rail	1,592	1,621	1,599	1,580	1,582	1,625	0.2%
Commuter Rail	777	844	860	888	996	1,018	2.7%
Light Rail[1]	201	235	252	284	345	378	6.5%
Other Rail[2]	6	4	3	9	9	9	4.1%
Nonrail	**2,091**	**2,267**	**2,262**	**2,255**	**2,352**	**2,446**	**1.6%**
Fixed-route Bus[3]	1,910	2,026	1,996	1,980	2,041	2,128	1.1%
Demand Response[4]	113	159	176	183	218	222	7.0%
Ferryboat	22	32	35	35	35	38	5.6%
Trolleybus	18	16	17	16	17	16	-1.2%
Vanpool	20	27	30	34	38	39	6.6%
Other Nonrail[5]	8	6	8	7	4	4	-7.1%
Total	**4,668**	**4,970**	**4,976**	**5,015**	**5,284**	**5,476**	**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.

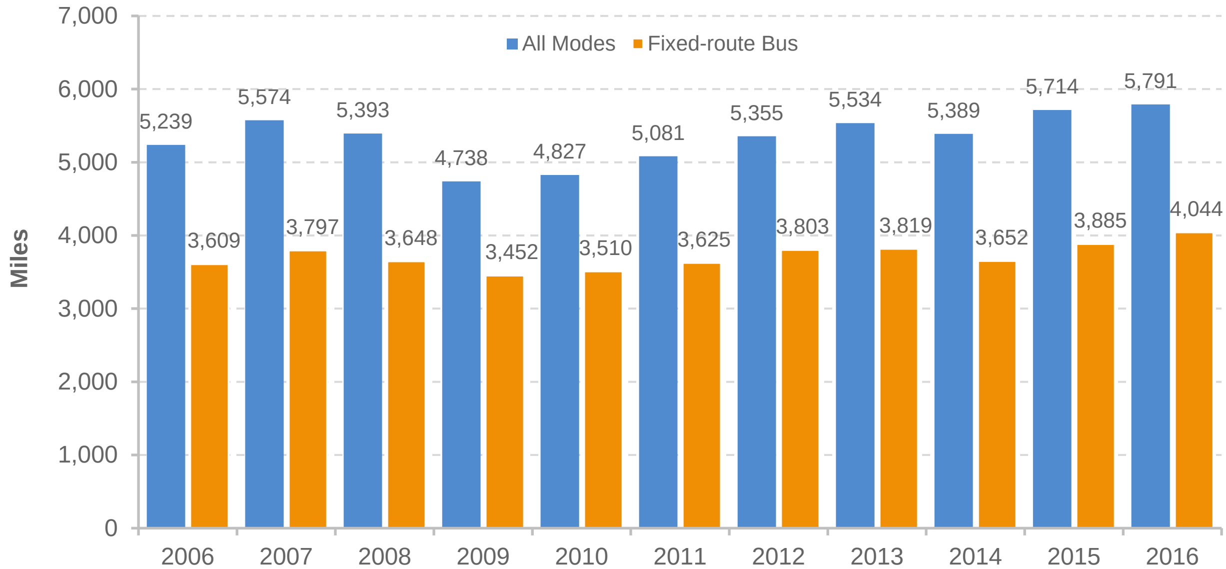
Note: The 2012 data do not include agencies that qualified for and opted to use the small systems waiver of the National Transit Database.

Source: National Transit Database.

Maintenance Reliability

Mean distance between failures, shown in *Exhibit 4-34*, is calculated as 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 caused by guideway conditions, which would include congestion for roads and slow zones (due to system or rail problems) for track, but began doing so in 2018. Miles between failures for all modes combined increased by 11 percent between 2006 and 2016, a 1.0 percent annual average increase. Miles between failures for all modes combined increased in 2007, decreased until 2009, then increased steadily until 2016. The trend for fixed-route bus is nearly identical to that of all modes combined. Miles between failures for fixed-route bus increased by 12 percent between 2006 and 2016.

Exhibit 4-34 ■ Mean Distance Between Urban Vehicle Failures, 2006–2016



Notes: Only directly operated vehicle data were used to calculate mean distance between failures. Data from 2014 to 2016 do not include agencies that qualified for and opted to use the small systems waiver of the National Transit Database.

Source: National Transit Database.

Transit System Characteristics for Americans with Disabilities

Transit access and accessibility are central elements of a multimodal transportation system that meets the needs of people of all ages and abilities. Compliance with the Americans with Disabilities Act (ADA) of 1990 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.

ADA requirements ensure that transit services, vehicles, and facilities are accessible to and usable by persons with disabilities (e.g., wheelchair users), and provide for complementary paratransit service for those individuals whose disabilities prevent the use of an accessible fixed-route system.

Exhibit 4-35 presents the change in the level of ADA accessibility of transit service vehicles from 2006 to 2016. The level of accessibility rose from 94 percent in 2006 to 95 percent in 2016. The most significant increases were in other rail vehicles, including monorail, automated guideway, inclined plane, and cable cars, whose accessibility rose from 46 percent in 2006 to 80 percent in 2016. Commuter rail passenger and self-propelled cars saw an increase in ADA accessibility from approximately 55 percent in 2014 to over 80 percent in 2016. In 2006, commuter rail and other rail vehicles had the smallest share of ADA-accessible passenger cars compared with other rail modes, such as heavy rail and light rail.

Exhibit 4-35 ■ ADA Accessibility by Vehicle Type, 2006–2016

Vehicle Type	Active Fleet 2006	ADA Fleet 2006	ADA Fleet Share 2006	Active Fleet 2016	ADA Fleet 2016	ADA Fleet Share 2016	Change in Fleet	% Change in Share
Buses, Cutaways, and Over-the-road Buses	67,934	66,922	98.5%	61,411	60,794	99.0%	-9.6%	0.5%
Vans (Demand-response Service)	13,167	11,591	88.0%	11,359	9,006	79.3%	-13.7%	-8.7%
Heavy Rail Passenger Cars	11,083	10,511	94.8%	11,841	11,405	96.3%	6.8%	1.5%
Articulated Buses	2,294	2,290	99.8%	5,522	5,500	99.6%	140.7%	-0.2%
Commuter Rail Passenger Coaches	3,423	1,892	55.3%	3,648	3,031	83.1%	6.6%	27.8%
Commuter Rail Self-propelled Passenger Cars	2,576	1,768	68.6%	2,785	2,343	84.1%	8.1%	15.5%
Light Rail Vehicles and Streetcars	1,802	1,459	81.0%	2,378	2,046	86.0%	32.0%	5.1%
All Other Rail Vehicles[1]	143	65	45.5%	208	166	79.8%	45.5%	34.4%
All Other Nonrail Vehicles[2]	1,080	1,021	94.5%	1,348	984	73.0%	24.8%	-21.5%
Total	**103,502**	**97,519**	**94.2%**	**100,500**	**95,275**	**94.8%**	**-2.9%**	**0.6%**

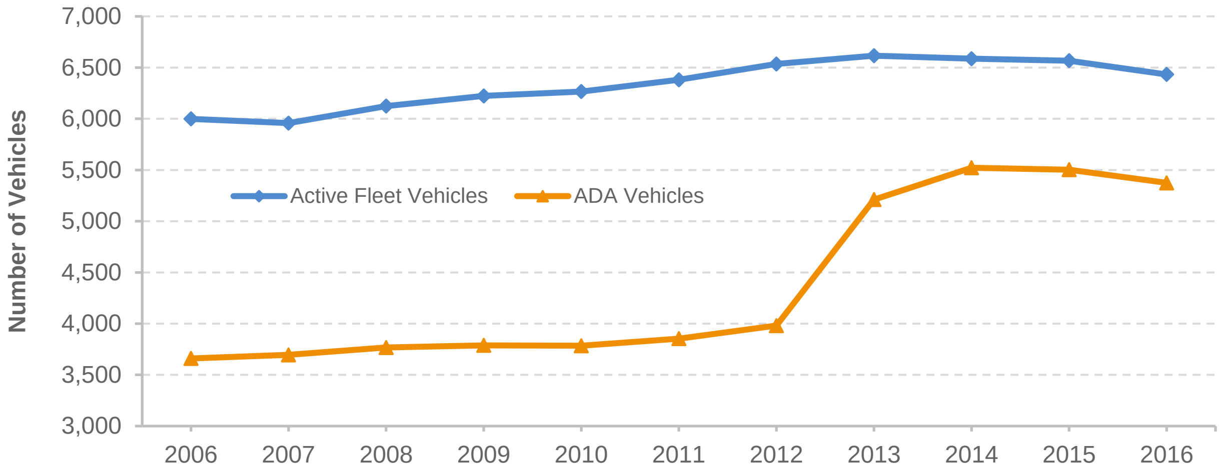
[1] Monorail vehicles, automated guideway vehicles, inclined plane vehicles, and cable cars.

[2] Ferryboats, trolleybuses, school buses, and other vehicles.

Source: National Transit Database.

Exhibit 4-36 depicts the trends in the total active fleet and the ADA-accessible fleet for 2006–2016. The data show that the ADA-accessible fleet increased steadily from 2006 to 2012 at an average rate of approximately 54 passenger cars per year, whereas the total fleet increased at an average of 89 cars 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 61 percent to 84 percent in just two 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, provisions allow inaccessible cars to remain in service if making them accessible would harm the structural integrity of the vehicles.

Exhibit 4-36 ■ Total Active Fleet and ADA Fleet for Commuter Rail, 2006–2016



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 4-37* presents the changes between 2006 and 2016 in the number of urban transit ADA stations and the percentage of total ADA-compliant stations by mode. In 2016, 80.7 percent of total transit stations were either 100 percent accessible or self-certified as accessible, an increase from 72 percent in 2006. 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, 30 were accessible but not fully compliant, and 35 were self-certified as accessible as of February 22, 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. Eight key rail stations that are not yet compliant are in the planning, design, or construction stages. These stations are in New York (two), Miami (one), and Cleveland (five). Of these, four stations are under FTA-approved time extensions to 2020. FTA continues to focus its attention on the four stations that are not accessible and are not under a time extension, and on the four stations with time extensions that will be expiring in the coming years.

Exhibit 4-37 ■ ADA Accessibility of Stations, 2006 and 2016

Mode Category	2006 Stations	2006 ADA Stations	2006 ADA Stations Share	2016 Stations	2016 ADA Stations	2016 ADA Stations Share
Fixed-route Bus	1,308	1,221	93.3%	1,780	1,739	97.7%
Other Nonrail[1]	53	48	90.6%	139	121	87.1%
Commuter Rail	1,169	712	60.9%	1,261	873	69.2%
Heavy Rail	1,042	479	46.0%	1,051	574	54.6%
Light Rail	764	635	83.1%	871	807	92.7%
Other Rail[2]	68	66	97.1%	264	218	82.6%
Total	**4,404**	**3,161**	**71.8%**	**5,366**	**4,332**	**80.7%**

[1] Includes ferryboat, aerial tramway, and trolleybus.

[2] Includes hybrid rail, automated guideway, monorail, streetcar rail, and inclined plane.

Source: National Transit Database.

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. 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 that began 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 4-38 shows directional route miles by mode over the past 10 years. Growth in both rail (14.5 percent) and nonrail (4.2 percent) route miles is evident over this period. The average 3.7-percent rate of annual growth for light rail outpaces the rate of growth for all other major modes due to the significant increase in new systems in the past 10 years.

Exhibit 4-38 ■ Transit Directional Route Miles, 2006–2016

Mode	2006	2008	2010	2012	2014	2016	Average Annual Rate of Change 2016 to 2006
Rail	**10,978**	**11,317**	**11,720**	**12,067**	**12,298**	**12,573**	**1.4%**
Heavy Rail	1,617	1,617	1,617	1,622	1,622	1,646	0.2%
Commuter Rail	6,970	7,256	7,532	7,674	7,795	7,912	1.3%
Light Rail[1]	1,392	1,446	1,581	1,766	1,877	2,004	3.7%
Other Rail[2]	998	998	991	1,005	1,005	1,011	0.1%
Nonrail	**227,823**	**230,170**	**237,712**	**240,176**	**239,836**	**237,408**	**0.4%**
Fixed-route Bus[3]	227,187	229,113	236,615	238,903	238,388	235,876	0.4%
Ferryboat	210	601	641	817	990	1,074	17.7%
Trolleybus	425	456	456	456	458	458	0.7%
Total	**238,800**	**241,487**	**249,432**	**252,243**	**252,134**	**249,981**	**0.5%**
Percent Nonrail	95.4%	95.3%	95.3%	95.2%	95.1%	95.0%	

[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. The 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.

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 wait 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 wait time, passengers are less frustrated and could be more willing to use transit.

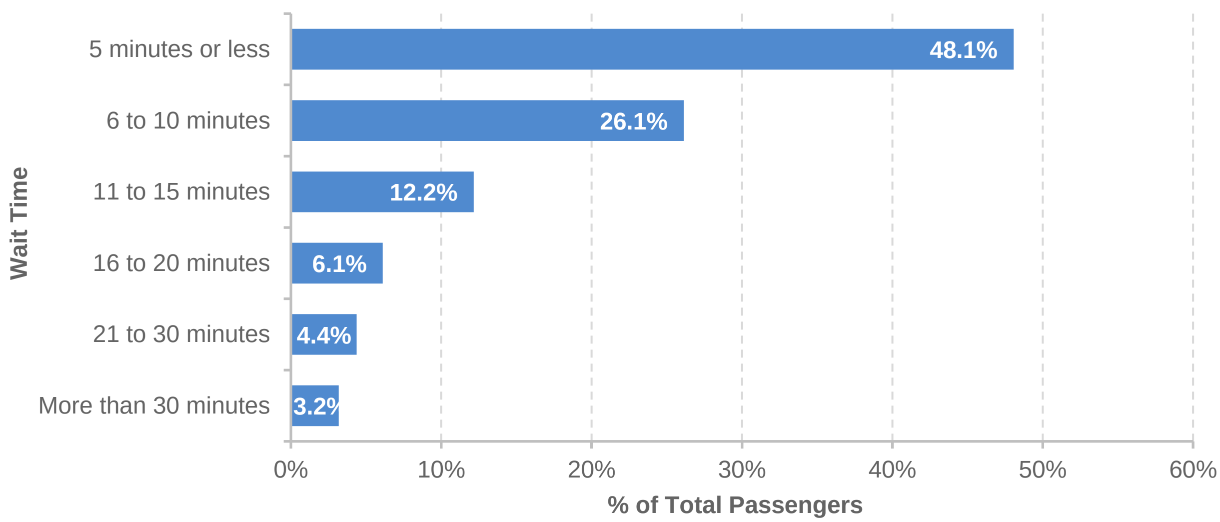
Exhibit 4-39 shows findings on wait times from the 2016 FHWA National Household Travel Survey. The survey found that 48.1 percent of passengers who ride transit wait 5 minutes or less and 74.2 percent wait 10 minutes or less. The survey also found that 7.6 percent of passengers wait 21 minutes or more. 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, or arrive closer to the scheduled time for equally reliable services that are more frequent. Overall, wait times of five minutes or less are clearly associated with good service that is either frequent or 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.

Transit System Resilience

Transit systems are managed to be resilient because they are required to operate on a daily basis through all but the worst weather. 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, transit providers are some of the most resilient community institutions. Although FTA does not collect systematic data on transit infrastructure resiliency upgrades, 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 4-39 ■ Distribution of Passengers by Wait Time, 2017



Source: National Household Travel Survey, FHWA.

Vehicle Occupancy

Exhibit 4-40 shows vehicle occupancy by mode for selected years from 2006 to 2016. Vehicle occupancy is calculated by dividing passenger miles traveled (PMT) by VRMs, resulting in the average passenger load in a transit vehicle. From 2006 to 2016, average passenger load increased by 17 percent for heavy rail (mostly reflecting significant ridership increases in the New York urbanized area) but declined marginally for commuter rail, light rail, and bus.

Exhibit 4-40 ■ Unadjusted Vehicle Occupancy: Passenger Miles per Vehicle Revenue Mile, 2006–2016

Mode	2006	2008	2010	2012	2014	2016
Rail						
Heavy Rail	23	26	25	27	28	27
Commuter Rail	36	36	34	35	34	34
Light Rail[1]	26	24	24	25	24	23
Other Rail[2]	9	9	11	8	9	10
Nonrail						
Fixed-route Bus[3]	11	11	11	11	11	10
Demand Response[4]	1	1	1	1	1	1
Ferryboat	98	118	119	125	128	132
Trolleybus	14	14	14	14	14	14
Vanpool	6	6	6	6	6	6
Other Nonrail[5]	6	6	5	5	5	5

[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.

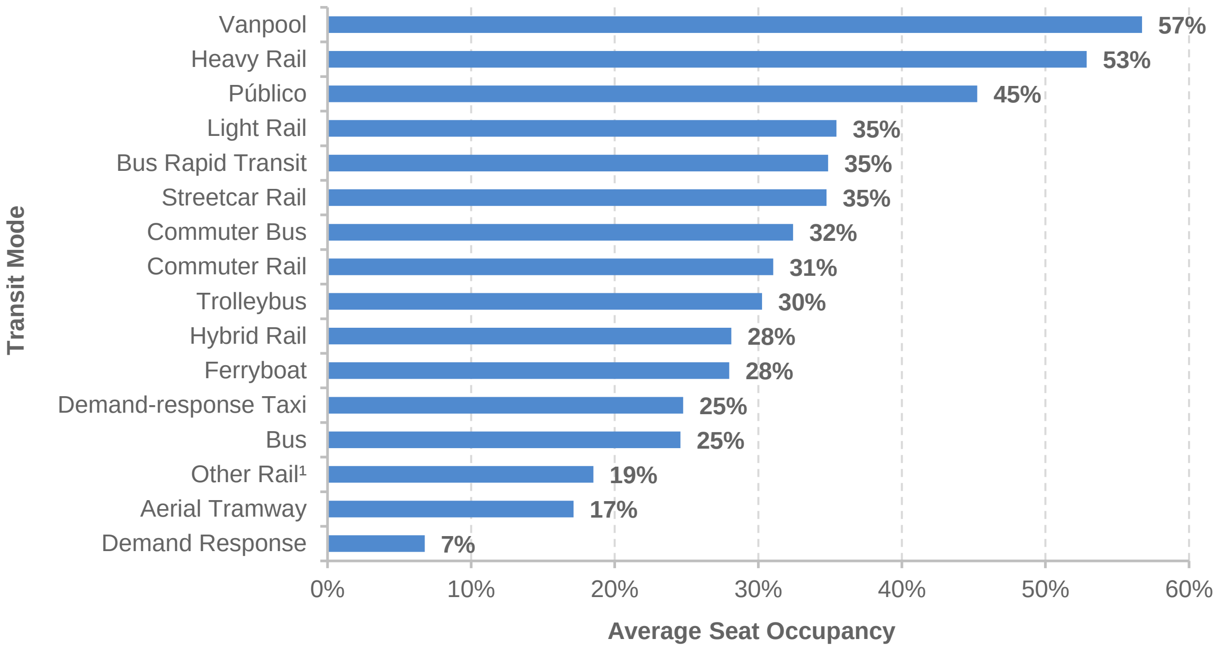
[5] Includes aerial tramway and público.

Source: National Transit Database.

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. The weighted average seating capacity for some modes are vanpool, 10; heavy rail, 51; light rail, 65; ferryboat, 471; commuter rail, 110; fixed-route bus, 39; demand response, 17.

As shown in *Exhibit 4-41*, the average seating capacity utilization ranges from 7 percent for demand response to 57 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 with low ridership. 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 (loops on a bus route that allow buses to reverse direction before reaching the end of the route). 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).

Exhibit 4-41 ■ Average Seat Occupancy Calculations for Passenger-carrying Transit Modes, 2016



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

Notes: Aerial tramway 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. These 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

Revenue miles per active vehicle (service use), defined as the average distance traveled per vehicle in service, can be measured by the ratio of VRMs per active vehicles in the fleet. *Exhibit 4-42* provides vehicle service use by mode for selected years from 2006 to 2016. Heavy rail, generally offering long hours of frequent service, had the highest vehicle use during this period. Vehicle service use for heavy rail appears to be stable across the past few years. Vehicle service use for commuter rail, light rail, and vanpool shows an increasing trend. Vehicle service use for trolleybus shows a decreasing trend. Vehicle service use for nonrail modes other than trolleybus appears to be relatively stable over the past few years with no apparent trends in either direction.

Exhibit 4-42 ■ Vehicle Service Utilization: Average Annual Vehicle Revenue Miles per Active Vehicle by Mode, 2006–2016

Mode	Vehicle Revenue Miles (Thousands of Miles)						Average Annual Rate of Change 2016 to 2006
	2006	2008	2010	2012	2014	2016	
Rail							
Heavy Rail	57	58	57	56	57	57	0.0%
Commuter Rail	43	45	45	44	46	48	1.1%
Light Rail[1]	40	44	43	42	46	47	1.8%
Nonrail							
Fixed-route Bus[2]	30	31	31	31	28	28	-0.7%
Demand Response[3]	22	29	28	28	20	20	-0.7%
Ferryboat	21	22	25	23	21	21	0.2%
Trolleybus	19	19	20	20	20	15	-2.5%
Vanpool	14	14	15	15	15	15	1.1%

[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.

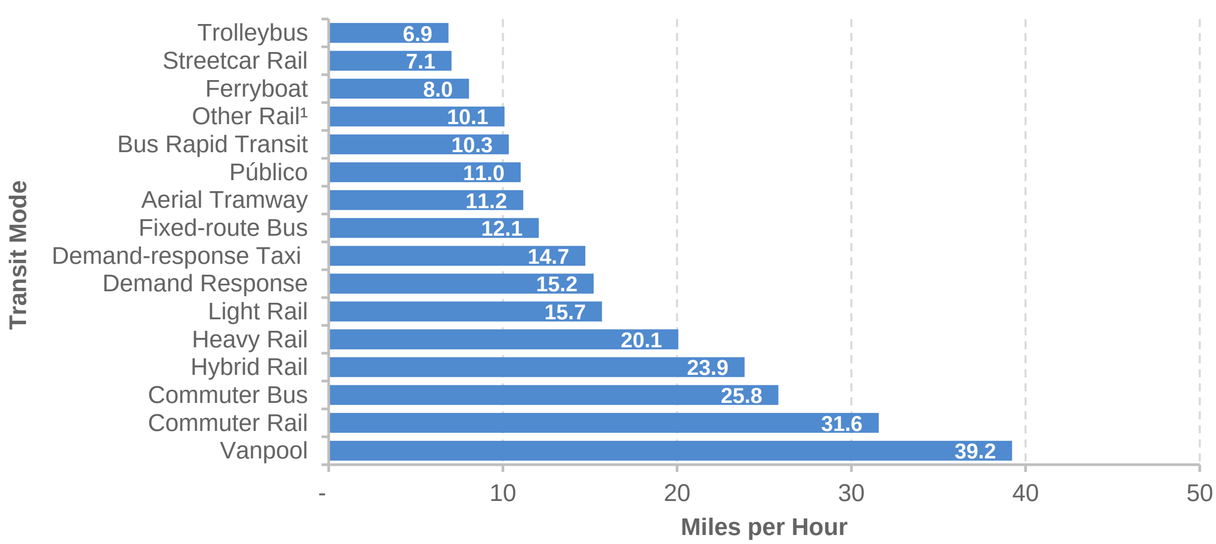
Notes: Does not include agencies that qualified for and opted to use the small systems waiver of the National Transit Database. Rail category does not include Alaska railroad, cable car, inclined plane, or monorail/automated guideway. Nonrail category does not include aerial tramway or público.

Source: National Transit Database.

Average Operating (Passenger-carrying) Speeds

Average vehicle operating speed is an approximate measure of the speed 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 4-43* presents the results of these average speed calculations.

Exhibit 4-43 ■ Average Speeds for Passenger-carrying Transit Modes, 2016



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

Note: The table does not include services provided by agencies that qualified for and opted to use the small systems waiver of the National Transit Database.

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 has 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.

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.

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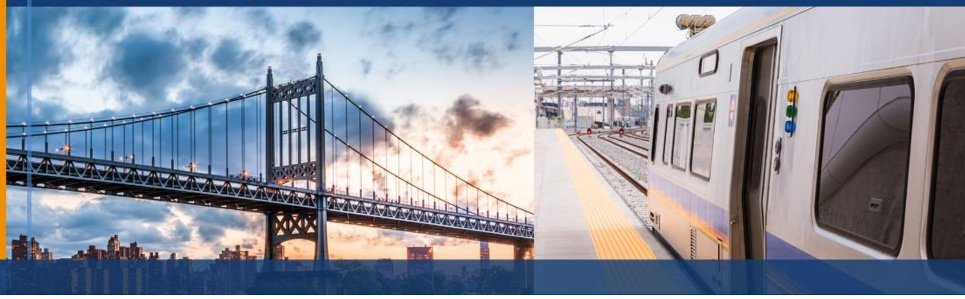


CHAPTER 5: Safety

Safety – Highways

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.

These coordinated efforts, coupled with a comprehensive focus on shared, reliable safety data, enables these three DOT administrations to concentrate on their areas of expertise and responsibility while working toward the Nation's safety goals and encourages a more unified endeavor.

KEY TAKEAWAYS

- DOT's top priority is to make the U.S. transportation system the safest in the world.
- Great progress has been made in reducing overall roadway-related fatalities and injuries despite increases in population and travel. From 2006 to 2016, highway fatalities have decreased by nearly 12 percent.
- The fatality rate per 100 million VMT dropped from 1.42 in 2006 to 1.18 in 2016.
- From 2009 to 2016, fatalities involving pedestrians, bicyclists, and other nonmotorists have increased 44 percent, up to over 7,000 in 2016. This is following a decline that occurred from 2006 to 2009.
- 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.

This chapter provides data on highway crashes, 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 for roadway infrastructure. FHWA supports improvements in safety elements as part of all road and bridge construction and system preservation projects. The Highway Safety Improvement Program (HSIP) is FHWA's primary infrastructure safety funding program. HSIP 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.

Highway Fatalities and Injuries

Statistics discussed in this section are drawn primarily from the Fatality Analysis Reporting System (FARS). FARS is a nationwide census of fatal crashes that provides 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). (See Chapter 1.)

In addition to FARS, NHTSA estimates injuries nationally through the Crash Report Sampling System (CRSS). The CRSS dataset provides a statistically based annual estimate of total nonfatal injury crashes. It is important to note that nonfatal safety statistics in this section, compiled in early 2018 using CRSS data through 2015, 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.

CRSS builds on the retiring, long-running National Automotive Sampling System General Estimates System (NASS GES). CRSS is a sample of police-reported motor vehicle traffic crashes involving all types of motor vehicles, pedestrians, and cyclists, ranging from property-damage-only crashes to those that result in fatalities. The target population of the CRSS is all police-reported traffic crashes of motor vehicles (motorcycles, passenger cars, SUVs, vans, light trucks, medium- or heavy-duty trucks, buses, etc.). The CRSS target population is the same as the previous NASS GES target population.

In 2016, 34,439 fatal crashes (see *Exhibit 5-1*) occurred on our Nation's roadways, resulting in 37,461 fatalities (see *Exhibit 5-2*). In 2015, 6.1 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 in 2015, 32,539 involved at least one fatality, approximately 1.6 million crashes resulted in injuries that were not life-threatening, and 4.5 million crashes resulted in damage or harm to property alone. From 2006 to 2016, fatal crashes decreased by 15.8 percent. From 2006 to 2015, injury crashes decreased by 5.8 percent, and property-damage-only crashes increased by 11.4 percent.

Traffic Fatality Trends Since 2016

Although this report focuses primarily on data through 2016, more recent data show that 36,560 people died in crashes on U.S. roadways during 2018, a 2.4-percent decrease from the 37,473 people killed in 2017 and a 3.3-percent decrease from the 37,806 people killed in 2016. The fatality rate per 100 million VMT decreased from 1.19 in 2016 to 1.17 in 2017 and to 1.13 in 2018. The number of urban fatalities was larger than the number of rural fatalities in 2016, 2017, and 2018. In 2017 and earlier, rural fatalities were larger than urban fatalities.

From 2017 to 2018, the number of passenger vehicle (including passenger cars and light trucks) occupant fatalities decreased from 23,663 in 2017 to 22,697 in 2018, a 4.1-percent decrease. Motorcyclist fatalities decreased from 5,229 in 2017 to 4,985 in 2018 (a 4.7-percent decrease). Large truck occupant fatalities increased from 878 in 2017 to 885 in 2018 (a 0.8-percent increase). Pedestrian fatalities increased from 6,075 to 6,283 (a 3.4-percent increase). Pedalcyclist fatalities increased from 806 to 857 (a 6.3-percent increase).

The share of total crashes related to roadway departure rose from 48 percent in 2016 to 51 percent in 2018. The share of total crashes relating to intersections held roughly constant at 27 percent over this period.

The above figures come from the 2018 FARS Annual Report File and the 2017 FARS Final File, both released in October 2019, as well as the 2016 FARS Final File released in October 2018. All other 2016 FARS data in the chapter are derived from the FARS 2016 ARF File, which was released in 2017. The FARS 2016 ARF File included a preliminary figure of 37,461 fatalities for 2016; this figure was adjusted upward to 37,806 in the 2016 FARS Final File.

Exhibit 5-2 displays trends in motor vehicle fatality counts and fatality rates from 1980 to 2016, as well as injury counts, and injury rates from 1980 to 2016. The motor vehicle fatality count rose to above 51,000 in 1980 and then dropped to less than 44,000 in 1982. The fatality count declined following the recession in the early 1990s from 44,599 in 1990 to less than 39,250 in 1992 but remained above 40,000 every year from 1993 through 2007. Between 2007 and 2009, there was an overall 17.9-percent reduction in fatalities, coinciding with the 2008–2009 economic recession. An 8.4-percent increase in fatalities occurred in 2015, and a 5.6-percent increase occurred in 2016. 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 rate per 100 million VMT provides 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 more depth how different demographic groups, such as male drivers aged 16–20 vs. male drivers aged 21–44, experience different fatality rates.

Exhibit 5-1 ■ Crashes by Severity, 2006–2016

Year	Crash Severity						Total Crashes	
	Fatal		Injury		Property Damage Only			
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
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**
2015	32,539	0.5	1,579,226	26.0	4,465,324	73.5	**6,077,089**	**100.0**
2016	34,439	0.5	2,116,000	31.0	4,670,000	68.5	**6,821,000**	**100.0**

Source: Fatality Analysis Reporting System and National Automotive Sampling System General Estimates System, National Center for Statistics and Analysis, NHTSA.

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. The rate dropped significantly from 14.68 in 2005 to 10.69 in 2010, then remained steady until 2014, and it increased 7.5 percent from 2014 to 2015.

The fatality rate, expressed in terms of 100 million VMT, has remained less than 2.00 since 1992 and declined smoothly from 1992 through 2004. From 2005 to 2010, the rate dropped significantly from 1.46 to 1.11 and varied little from 2010 through 2014. In 2015 and 2016, the rate increased in back-to-back years, from 1.08 in 2014 to 1.15 in 2015 and 1.18 in 2016 (*Exhibit 5-2*).

Also shown in *Exhibit 5-2* are the national estimates for people nonfatally injured in motor vehicle crashes from 1988 through 2016. A historic low of 2,061,000 injured was reached in 2011 with an injury rate of 70 per 100 million VMT. Since 2011, the injury count rose 9.6 percent to 2,258,000 in 2015, and the rate rose slightly to 73 per 100 million VMT.

Trends in Nonfatal Statistics Since 2015

Estimates of nonfatal crashes for the year 2016 were not yet available in the CRSS at the time this section was originally prepared. Based on more recent data compiled in early 2020, estimated total crashes decreased from 6.8 million in 2016 to 6.7 million in 2018. Over this two-year period, crashes involving property damage only rose from 4.7 million to 4.8 million, whereas those resulting in injuries decreased from 2.1 million to 1.9 million. The estimated number of people injured in these crashes decreased from 3.1 million to 2.7 million. The estimated number of crashes involving injuries—and the number of injuries resulting from these crashes—both increased sharply from 2015 to 2016, but this may be attributable in part to improved reporting and estimation procedures.

Safety Innovations

The overall decline in roadway fatalities over the past decade 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. DOT-related developments over this time have included an increase in the HSIP spending rate and roadway safety infrastructure improvements such as median barriers, rumble strips, roundabouts, SafetyEdge^{SM}, Innovative Intersection and Interchange Geometrics, High Friction Surface Treatments, the use of data and analytical tools, increased seat belt use, more side air bags, and electronic stability control in vehicles.

Exhibit 5-2 ■ Summary of Fatality and Injury Rates, 1980–2016

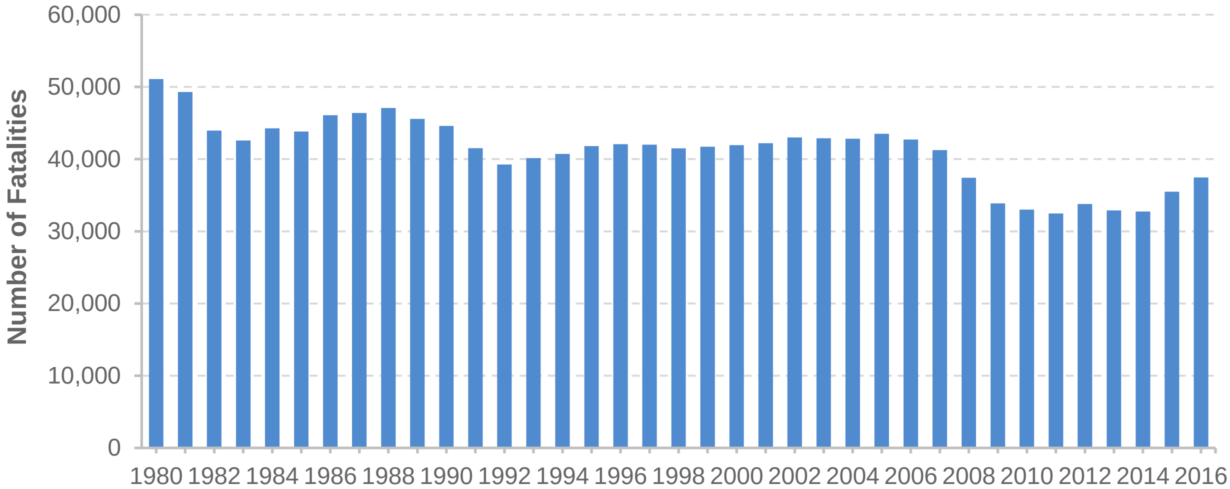
Year	Fatalities	Resident Population (Thousands)	Fatality Rate per 100,000 Population	Vehicle Miles Traveled (Millions)	Fatality Rate per 100 Million VMT	Injured	Injury Rate per 100,000 Population	Injury Rate per 100 Million VMT
1980	51,091	227,225	22.48	1,525,104	3.35			
1982	43,945	231,664	18.97	1,595,010	2.76			
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[1]	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
2015	35,485	321,419	11.04	3,095,373	1.15	2,258,000	703	73
2016	37,461	323,071	11.70	3,174,408	1.18	3,062,000	948	96

[1] Fatalities subsequently rose to 40,150 in 1993.

Sources: Fatality Analysis Reporting System and National Automotive Sampling System General Estimates System, National Center for Statistics and Analysis, NHTSA; U.S. Census Bureau for resident population data.

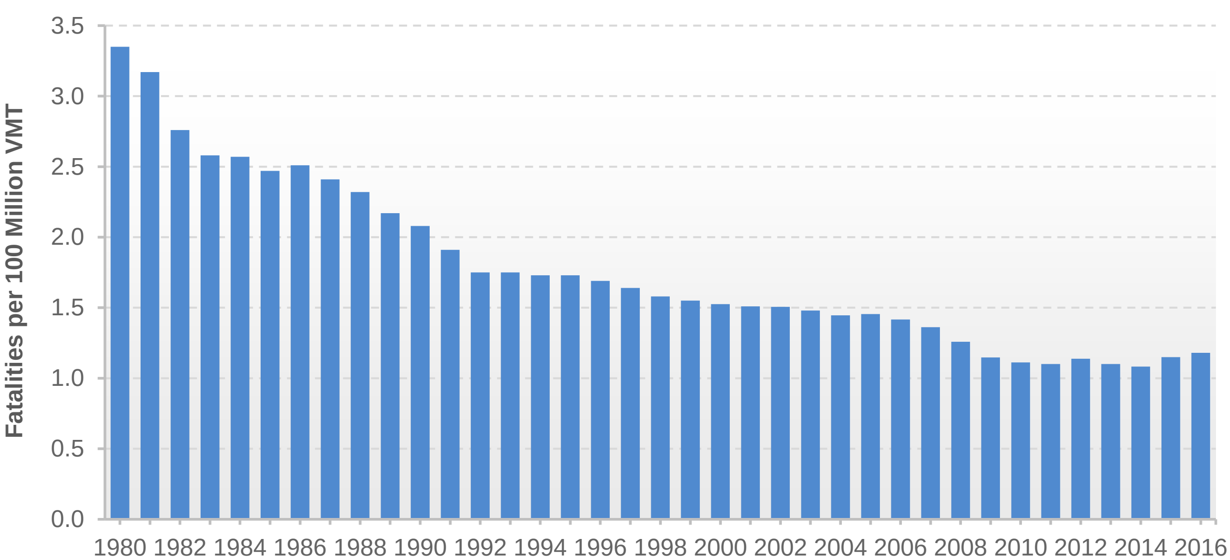
The trends since 1980 of the fatality counts and fatality rates per 100 million VMT, as discussed above and shown in *Exhibit 5-2*, are displayed graphically in *Exhibits 5-3* and *5-4*. *Exhibit 5-3* shows the number of motor vehicle fatalities from 1980 to 2016. *Exhibit 5-4* shows the motor vehicle fatality rates per 100 million VMT from 1980 to 2016.

Exhibit 5-3 ■ Fatalities, 1980–2016



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

Exhibit 5-4 ■ Fatality Rates per 100 Million VMT, 1980–2016



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 2006 through 2016. In 2016, rural roads accounted for 29.8 percent of travel and 48.5 percent of roadway fatalities, whereas urban roads accounted for 70.2 percent of travel and 51.2 percent of roadway fatalities, with 0.3 percent of roadway fatalities being "unknown rural or urban." From 2006 to 2016, the number of fatalities on rural roads decreased from 23,646 to 18,321, resulting in a 22.5-percent reduction. Over the same period, the number of fatalities on urban roads rose from 18,791 to 19,357, a 3.0-percent increase.

Exhibit 5-5 ■ Fatalities by Functional System, 2006–2016

Functional System	2006	2008	2010	2012	2014	2016	Percent Change 2006 to 2016
Rural Areas (under 5,000 in population)							
Interstate	2,887	2,422	2,113	1,835	1,762	2,282	-21.0%
Other Principal Arterial	4,554	4,395	3,986	4,219	4,044	5,496	20.7%
Minor Arterial	4,346	3,507	3,015	3,482	3,316	3,391	-22.0%
Collector	7,325	6,505	5,314	5,178	4,502	4,789	-34.6%
Local	4,294	4,060	3,540	3,452	3,024	2,336	-45.6%
Unknown Rural	240	98	121	201	143	27	-88.8%
Subtotal Rural	23,646	20,987	18,089	18,367	16,791	18,321	-22.5%
Urban Areas (5,000 or more in population)							
Interstate	2,663	2,300	2,124	2,150	2,332	2,799	5.1%
Other Freeway and Expressway	1,690	1,538	1,232	1,150	1,125	1,114	-34.1%
Other Principal Arterial	5,447	4,504	4,294	4,538	4,951	6,624	21.6%
Minor Arterial	3,807	3,128	2,945	3,065	3,069	4,232	11.2%
Collector	1,513	1,256	1,069	1,236	1,219	2,267	49.8%
Local	3,622	3,461	2,978	3,195	3,127	2,295	-36.6%
Unknown Urban	49	31	17	37	94	26	-46.9%
Subtotal Urban	18,791	16,218	14,659	15,371	15,917	19,357	3.0%
Unknown Rural or Urban	271	218	251	44	36	128	-52.8%
Total Highway Fatalities	**42,708**	**37,423**	**32,999**	**33,782**	**32,744**	**37,806**	**-23.3%**

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

These declines varied greatly by roadway functional system, as shown in *Exhibit 5-5*. For example, rural Interstate fatalities decreased by 21.0 percent from 2006 to 2016, whereas those on rural "Other Principal Arterial" roads increased by 20.7 percent. In urban areas, Interstate fatalities increased by 5.1 percent, whereas those on urban other freeways and expressways decreased by 34.1 percent and those on urban other principal arterials increased by 21.6 percent during the same period. The functional system category in Exhibit 5-5 "local" refers to the functional class of the roadway; in addition, the term local is also used in this chapter to refer to the ownership of locally owned roads.

Exhibit 5-6 ■ Fatality Rates by Functional System, 2006–2016

Functional System	Fatality Rate (per 100 Million VMT)						Percent Change 2006 to 2016
	2006	2008	2010	2012	2014	2016	
Rural Areas (under 5,000 in population)							
Interstate	1.12	1.00	0.86	0.75	0.76	0.92	-17.6%
Other Principal Arterial	1.96	1.98	1.77	1.89	1.88	2.45	24.9%
Minor Arterial	2.67	2.31	2.00	2.34	2.36	2.36	-11.5%
Collector	2.91	2.69	2.31	2.26	2.16	2.31	-20.8%
Local	3.22	3.08	2.67	2.65	2.40	1.83	-43.2%
Subtotal Rural	2.28	2.12	1.84	1.88	1.82	1.93	-15.5%
Urban Areas (5,000 or more in population)							
Interstate	0.56	0.48	0.44	0.44	0.45	0.50	-11.2%
Other Freeway and Expressway	0.78	0.69	0.56	0.51	0.49	0.45	-42.9%
Other Principal Arterial	1.17	0.97	0.94	0.99	1.06	1.37	17.2%
Minor Arterial	1.01	0.83	0.79	0.83	0.79	1.03	1.8%
Collector	0.87	0.72	0.59	0.69	0.59	1.01	16.4%
Local	1.36	1.28	1.09	1.16	1.06	0.75	-44.9%
Subtotal Urban	0.95	0.82	0.74	0.77	0.76	0.86	-9.0%
Total Highway Fatality Rate	**1.42**	**1.26**	**1.11**	**1.14**	**1.08**	**1.19**	**-16.5%**

Source: Fatality data from Fatality Analysis Reporting System, National Center for Statistics and Analysis, NHTSA; VMT data from Highway Performance Monitoring System.

Exhibit 5-6 shows the fatality rates per 100 million VMT for rural and urban functional systems between 2006 and 2016. During that time, the fatality rate in rural areas declined by 15.5 percent, and, in urban areas, the fatality rate declined by 9.0 percent. Among urban roads, urban Interstate highways and Other Freeway and Expressway were the safest functional systems, with fatality rates of 0.50 and 0.45 respectively in 2016, whereas urban Other Principal Arterials had the highest fatality rate of 1.37. Among rural roads, Interstates had the lowest fatality rate of 0.92 in 2016, whereas all other functional systems had far higher fatality rates, as shown in *Exhibit 5-6*. From 2006 to 2016, urban local roads had the largest urban fatality rate decline with a 44.9-percent reduction followed by urban other freeways and expressways with a 42.9-percent reduction. Rural local roads had the large rural fatality rate decline (43.2-percent drop).

Local Road Safety Plan

A local road safety plan (LRSP) provides a framework for identifying, analyzing, and prioritizing roadway safety improvements on local roads. The LRSP development process and content are tailored to local issues and needs. The process results in a prioritized list of issues, risks, actions, and improvements that can be used to reduce fatalities and serious injuries on the local road network. While local roads are less traveled than State highways, they have a much higher rate of fatal and serious injury crashes. Developing an LRSP is an effective strategy to improve local road safety for all road users and support the goals of a State's overall strategic highway safety plan. Information is available at https://safety.fhwa.dot.gov/provencountermeasures/local_road. 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.

Despite the overall decreases in fatality rates on both urban and rural functional systems from 2006 to 2016, rural roads remain far more dangerous than urban roads, evidenced by a fatality rate that is 2.23 times higher (1.92 per 100 million VMT on rural roads compared to 0.86 on urban roads). In 2016, rural Interstates had a fatality rate that is 1.84 times higher than urban Interstates (0.92 per 100 million VMT compared with 0.50). 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 typically maintain Interstate highways, whereas other roads are maintained by either the State or a variety of local organizations, including cities and counties.

Safety Data, Planning & Performance

The DOT strategic goal on safety is "Reduce transportation-related fatalities and serious injuries across the transportation system." 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 reflects a State's analysis of 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 5 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.

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. As of February 2018, membership has grown to 460 members since the coalition's inception in 2016. RTZ is focusing on both short-term activities, including funding for innovative safety activities, and on a long-term vision for zero traffic fatalities. RTZ funded seven innovative 2017 safety grants totaling $1 million throughout the United States. The projects are intended to be a springboard for others to easily replicate for fast deployment of effective countermeasures. This effort is part of the RTZ's "pushing what works" element to get ahead of the recent uptick in traffic fatalities. The coalition is working on a future scenario document that will help to chart the course over the next 30 years to realize a roadway transportation system with zero fatalities. All 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 whereas FHWA, NHTSA, and FMCSA provide an advisory and supportive role.

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.

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 conducted a second safety data capabilities assessment in each State in 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 provide predictive capabilities of expected safety performance based on roadway geometric and traffic factors.

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 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 advance the abilities of State and local highway agencies to incorporate explicit, quantitative consideration of safety into their planning and project development decision-making.

FHWA's Role in Highway Safety Improvement

Since 2015, vehicles have traveled more than 3 billion miles annually on U.S. highways. Highway safety is affected by many factors, including highway infrastructure, vehicle characteristics, occupant behavior, traffic volume, weather, and more. FHWA exercises leadership throughout the multidisciplinary highway community to make the Nation's roadways safer for all users. FHWA has identified three focus areas with the greatest potential to reduce highway fatalities using infrastructure-oriented improvements: (1) roadway departure, (2) intersection crashes, and (3) pedestrian/bicycle crashes. These three focus areas encompass almost 90% of the traffic fatalities in the United States. Within these focus areas, FHWA promotes 20 proven safety countermeasures, such as median barriers, roadside design improvement at curves, walkways, rumble strips, and dedicated left- and right-turn lanes at intersections. The fatality rate per VMT in 2014 was the lowest since the collection of FARS fatality data began in 1975. As traffic fatalities have risen in 2015 and 2016, FHWA continues to expand the use of proven safety countermeasures and develop other methods for the improvement of highway safety.

Data Driven Safety Analysis (DDSA) uses tools to analyze crash and roadway data to predict the safety impacts of highway projects. DDSA allows agencies to target investments with more confidence and reduce severe crashes on the roadways. To date, 75 percent of states are applying DDSA in one or more of their project development processes. This effort is a result of collaborative work by AASHTO, FHWA, the Transportation Research Board and industry over the past two decades.

Legislative Elements

In 2016, FHWA published the HSIP and Safety Performance Management Measures (Safety PM) Final Rules in the *Federal Register*. The HSIP Final Rule updated the 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 section 150 of title 23 United States Code (U.S.C.), 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 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's design and operations, characteristics of the vehicles (fleet mix, safety features, power) and users' travel (VMT, speed, use of safety features, headway, fatigue, distraction), and interactions with non-occupants, all affect the safety of the Nation's highway system. FHWA collaborates with other agencies to understand more clearly the relationship among contributing factors and to address crosscutting ones, with a focus on infrastructure design and operation.

In 2014, FHWA reexamined crash data to identify the most common crash types relating to roadway characteristics. FHWA established three focus areas to address these factors: roadway departure, intersection, and pedestrian/bicyclist-involved crashes. These three areas were selected because they account for 87 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 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 2016, roadway departure, intersection, and pedestrian/bicyclist fatalities accounted for 48 percent, 27 percent, and 19 percent, respectively, of the 37,461 fatalities. Note that these three categories overlap, and 11 percent of fatalities involve more than one of these three focus areas. 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 described in more detail below. Of the 37,461 fatalities in 2016, 13 percent do not involve a focus area.

Exhibit 5-7 shows how the number of fatalities for these crash types has changed between 2006 and 2016. During this period, roadway departure fatalities decreased by 20.2 percent, intersection-related fatalities increased by 0.5 percent, and pedestrian/bicyclist-involved fatalities increased by 22.6 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 program 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, 2006–2016

Crash Type	2006	2008	2010	2012	2014	2016	Percent Change 2006 to 2016
Roadway Departures[1]	22,665	19,878	17,423	17,582	16,381	18,095	-20.2%
Intersection-related[1,2]	10,213	8,956	8,636	8,851	8,692	10,267	0.5%
Pedestrian-related[1,3]	5,722	5,273	5,075	5,741	5,814	7,013	22.6%

[1] Some fatalities may overlap; for example, some intersection-related fatalities may involve pedestrians.

[2] Definition for intersection crashes was modified beginning in 2016.

[3] Definition for pedestrian crashes was modified beginning in 2016.

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

Roadway Departures

In 2016, the number of roadway departure fatalities was 18,095, which accounted for 48.3 percent of all traffic fatalities. 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 its lane.
- 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 signs or yield signs, or without any traffic control devices), 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 2016, 27 percent of fatalities were related to intersections, with 35 percent occurring in rural areas and 65 percent occurring in urban areas, as shown in *Exhibit 5-8*. From 2006 to 2016, intersection-related fatalities have increased by 0.5 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.

Intersection Focus States and Countermeasures

Intersection Focus States receive additional training and technical 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.

Six proven countermeasures associated specifically with intersection safety are:

- Leading pedestrian interval (LPI): This gives pedestrians the opportunity to enter an intersection 3-7 seconds before vehicles are given a green indication
- Reduced left-turn conflict intersections: Geometric designs that alter how left-turn movements occur in order to simplify decisions and minimize the potential for related crashes.
- 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.
- Systemic Application of Multiple Low-Cost Countermeasures at Stop-Controlled Intersections: This systemic approach to intersection safety involves deploying a group of multiple low-cost countermeasures, such as enhanced signing and pavement markings, at a large number of stop-controlled intersections within a jurisdiction. It is designed to increase driver awareness and recognition of the intersections and potential conflicts.
- Pedestrian hybrid beacons: Pedestrian-activated warning device located on the roadside or on mast arms over midblock pedestrian crossings.
- 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.

Exhibit 5-8 ■ Intersection-related Fatalities by Functional System, 2016

	Fatalities	
Functional System	**Count**	**Percent of Total**
Rural Areas (under 5,000 in population)		
Principal Arterial	1,323	13.5%
Minor Arterial	795	8.1%
Collector (Major and Minor)	909	9.3%
Local	384	3.9%
Subtotal Rural	**3,411**	**34.8%**
Urban Areas (5,000 or more in population)		
Principal Arterial	3,144	32.1%
Minor Arterial	1,672	17.1%
Collector (Major and Minor)	766	7.8%
Local	801	8.2%
Subtotal Urban	**6,383**	**65.2%**
Total Highway Fatalities[1]	**9,794**	**100.0%**

[1] Total excludes 473 intersection-related fatalities not identified by functional class.

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

Pedestrians, Bicyclists, and Other Nonmotorists

In 2016, 18.7 percent of the transportation-related fatalities were nonmotorists.[21] *Exhibit 5-9* shows that in 2016, 6,000 pedestrians, 838 pedalcyclists, and 175 other nonmotorists were killed, totaling 7,013 nonmotorists fatalities.

Overall from 2006 through 2016, nonmotorist fatalities have risen by 22.6 percent. 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 44.2-percent increase up to 2016. Pedestrian fatalities rose from 4,120 in 2009 to 6,000 in 2016, an increase of 45.6 percent. Pedalcyclist fatalities rose from 630 in 2009 to 838 in 2016, an increase of 33 percent.

Pedestrian and Bicyclist Safety Focus States and Cities and Countermeasures

FHWA expanded its pedestrian focus area to include bicyclist and other nonmotorist fatalities in 2015. FHWA designates 16 Focus States and 35 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. As of 2015, the current list of Focus States includes California, Arizona, New Mexico, Texas, Louisiana, Florida, Georgia, North Carolina, Tennessee, Missouri, Illinois, Indiana, Michigan, Pennsylvania, New Jersey, and New York. The 35 Focus Cities are distributed throughout those 16 Focus States, including seven in California, six in Florida, and five in Texas, as well as one or two Focus Cities in each of the remaining Focus States.

The Focused Approach to Safety has helped Focus States and Focus 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 and implementation.

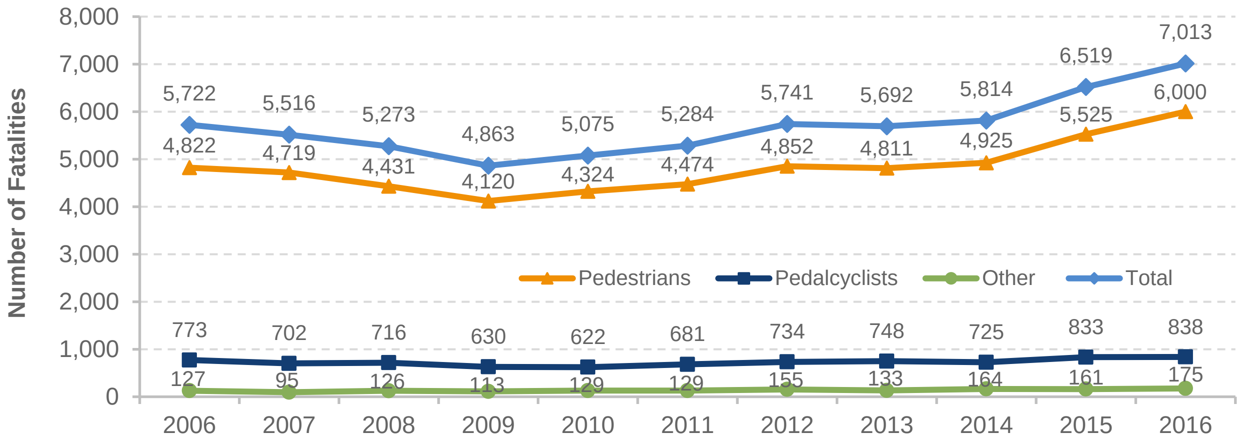
Focused Approach offers free technical support and training courses to Focus States and Focus Cities, as well as free bimonthly webinars on a comprehensive, systemic approach to preventing pedestrian and bicyclist crashes. Training is also available at a cost to non-focus States and cities through the Pedestrian and Bicycle Information Center, made possible by the National Highway Institute.

Four proven countermeasures associated specifically with pedestrian and bicyclist safety are:

- Walkways: Any type of defined space or pathway for use by a person traveling by foot or using a wheelchair. These include pedestrian walkways, shared-use paths, sidewalks, or roadway shoulders.
- Pedestrian Crossing Islands in Urban and Suburban Areas: A raised island, located between opposing traffic lanes at intersection or midblock locations, which separate crossing pedestrians from motor vehicles.
- Leading Pedestrian Interval: This gives pedestrians the opportunity to enter an intersection 3–7 seconds before vehicles are given a green indication. With this head start, pedestrians can better establish their presence in the crosswalk before vehicles have priority to turn left.
- Pedestrian hybrid beacons: These pedestrian-activated warning devices are located on the roadside or on mast arms over midblock pedestrian crossings.

[21] 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 mph), persons in motorized toy cars, and persons on two-wheeled, self-balancing types of devices.

Exhibit 5-9 ■ Pedestrian, Bicyclist, and Other Nonmotorist Traffic Fatalities, 2006–2016



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.

Safe Transportation for Every Pedestrian (STEP) Advances Pedestrian Hybrid Beacons (PHBs)

According to NHTSA, 2018 witnessed the most pedestrian fatalities since 1990, accounting for approximately 17 percent of all roadway fatalities (6,283). In 2018, 74 percent of pedestrian fatalities occurred away from intersections (e.g., mid-block locations) and approximately 25 percent occurred at intersections. Through the STEP initiative, FHWA will promote road diets, pedestrian refuge islands, crosswalk visibility enhancements, rectangular rapid flashing beacons, leading pedestrian intervals, and pedestrian hybrid beacons to improve pedestrian crossing locations.

The pedestrian hybrid beacon is a beneficial intermediate option between enhanced signing and a full pedestrian signal. It provides positive stop control in areas without the high pedestrian traffic volumes that typically warrant signal installation. These beacons have been proven to reduce pedestrian crashes by 55 percent, and their ability to improve crossing opportunities can boost quality of life for pedestrians of all ages and abilities. Pedestrian hybrid beacons are considered a proven safety countermeasure by FHWA.

Safety – Transit

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, which the Federal Railroad Administration (FRA) manages and collects. This section presents statistics and counts of basic aggregate data, such as injuries and fatalities from NTD and FRA. For 2016, 62 rail transit systems, 639 urban fixed-route bus providers, and 372 rural agencies provided safety event data. Reported events occurred on transit property or vehicles, involved transit vehicles, or affected people using public transportation systems. Data on fatalities and fatality rates are presented following a discussion on NTD data.

Agencies operating 30 or fewer vehicles in peak service, which report to the NTD using a small systems waiver, are exempted from reporting detailed safety event data by mode and victim type. However, the total aggregate data reported by these agencies account for a very small share of the Nation's transit safety events.

KEY TAKEAWAYS

- The total number of transit fatalities in 2016 (excluding commuter rail) was 257 people, of which 13 were transit passengers.
- Transit rail fatalities increased by 53 percent from 2006 to 2016.
- Most fatalities in transit are due to collisions. In 2016, 205 people died because of collisions, accounting for 81 percent of all transit fatalities.
- A majority of transit rail fatalities occur at transit stations. In 2016, 79 people died at transit stations, or 55 percent of all transit rail fatalities. These deaths were due primarily to suicides.
- Most bus fatalities occur on roadways at intersections. In 2016, 79 people died on roadways, or 75 percent of all fatalities.
- Together, rail modes accounted for 58 percent of noncommuter rail fatalities, and bus accounted for 42 percent. However, rail accounted for 30 percent of injuries, whereas bus accounted for 70 percent.
- There were 7,267 noncommuter rail injuries in 2016. These injuries required medical assistance at facilities away from the scenes of the accidents.
- In 2016, 97 people died in commuter rail accidents, a 42 percent increase from 2006 (68 people). The total number of fatalities in transit, including commuter rail, increased by 53 percent between 2006 and 2016, from 230 in 2006 to 353 in 2016.

Incidents, Fatalities, and Injuries, Excluding Commuter Rail

A transit agency records a safety event in the NTD for events that meet certain thresholds as described in the box below. Rural and small urban systems report only total fatalities and injuries. 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.

Injury and fatality data in the NTD are reported by the types of people involved in incidents. Passengers are defined as individuals 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 (or workers) are individuals who work for the transit agency, including both staff and contractors (excluding construction). Public includes pedestrians, occupants of other vehicles, and other persons. Individuals who come into contact with the transit system intending to harm themselves are considered suicides. A suicide is a subset of passenger, patron, worker, trespasser, and other person types.

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. Thus, these statistics 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 Sorts 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.

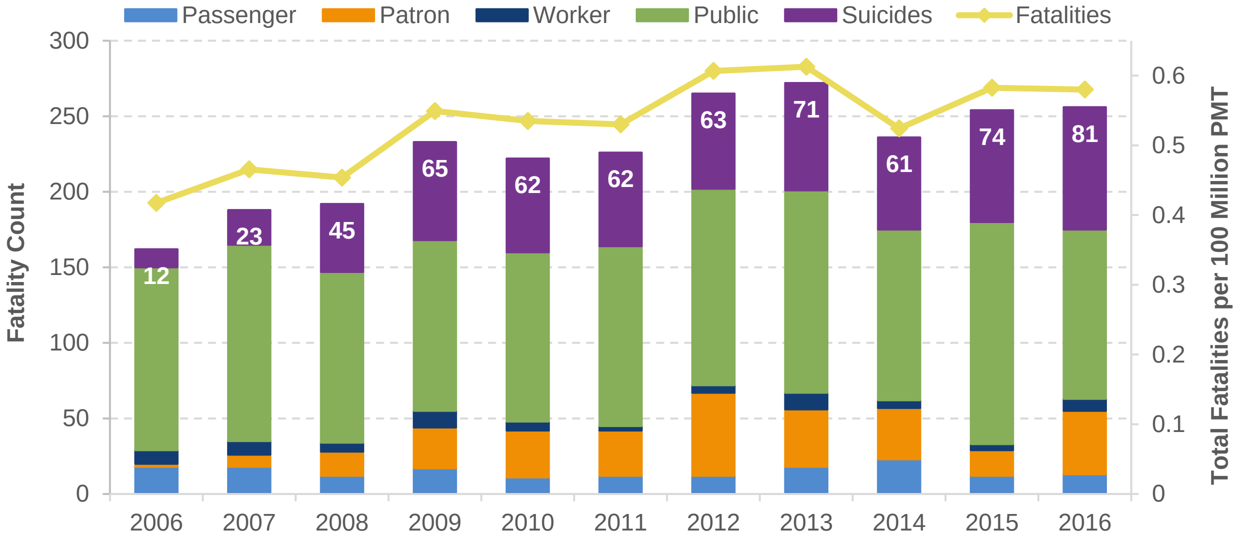
Additionally, a transit agency records an incident whenever certain security situations occur on transit property, such as:

- 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.

Fatalities by Person Type, Event Type, and Location

Despite a decline in 2014, fatality measures have exhibited a general upward trend over the past decade. *Exhibit 5-10* shows data on fatalities, both in total fatalities and fatalities per 100 million passenger miles traveled (PMT) for FTA-oversight systems. Suicides and fatalities involving station patrons have accounted for an increasing share of transit fatalities over this period. The interactions between transit, vehicles, pedestrians, cyclists, and motorists at rail grade crossings, pedestrian crosswalks, and intersections all influence overall transit safety performance. Most fatalities and injuries result from interactions with the public on busy city streets. Suicides are also a leading cause of fatalities which have increased from 12 suicides in 2006 to 81 in 2016. Pedestrian fatalities accounted for approximately 13 percent of all transit fatalities in 2016.

Exhibit 5-10 ■ Annual Transit Fatalities, Including Suicides, 2006–2016

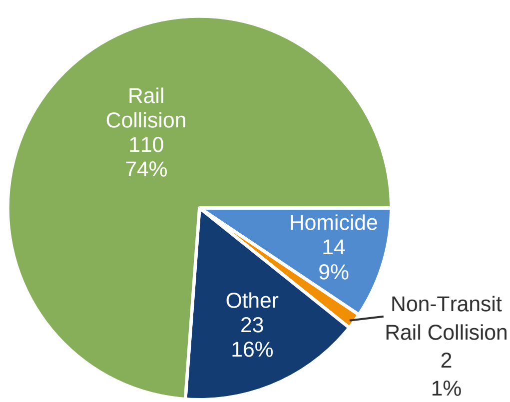


Notes: The right Y-axis displays total fatalities per 100 million passenger miles traveled (PMT) Including suicides. Fatality totals include both directly operated (DO) and purchased transportation (PT) service types.

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

Exhibits 5-11 and *5-12* depict fatalities by event type in 2016. In 2016, there were 257 transit fatalities, 108 occurring on nonrail modes and 149 on rail. Fatalities in transit are due mostly to collisions; this is the case for both rail and nonrail categories. Overall, collisions accounted for more than 80 percent of all fatalities in 2016. Collisions are primarily with vehicles at grade crossings. The number of deaths due to homicide accounted for only 8 percent of fatalities on nonrail and 9 percent on rail, mostly involving nonusers of transit.

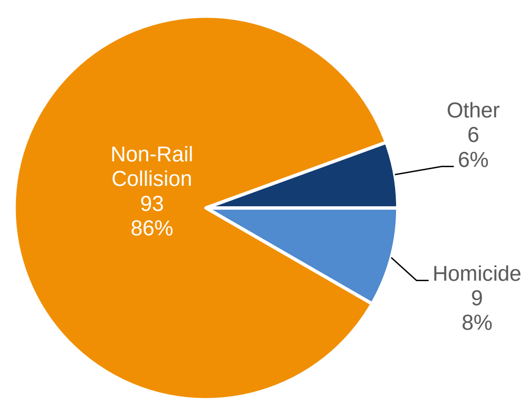
Exhibit 5-11 ■ Transit Fatality Event Types, Rail, 2016



Notes: Exhibit includes data for rail transit modes, excluding commuter rail. Two NTD event type categories were updated in 2016.

Source: National Transit Database.

Exhibit 5-12 ■ Transit Fatality Event Types, Nonrail, 2016



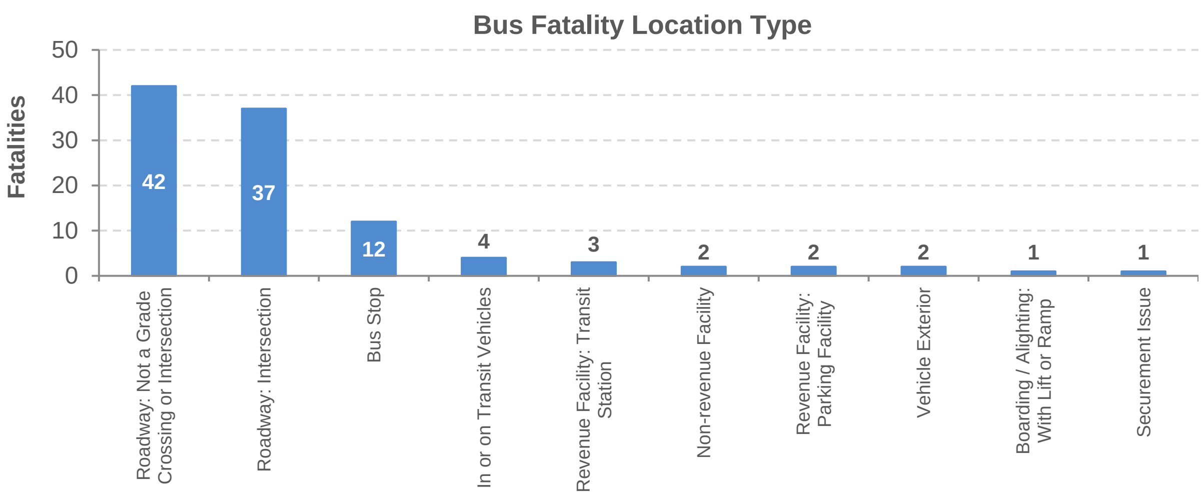
Notes: Exhibit includes data for nonrail transit modes. Two NTD event type categories were updated in 2016.

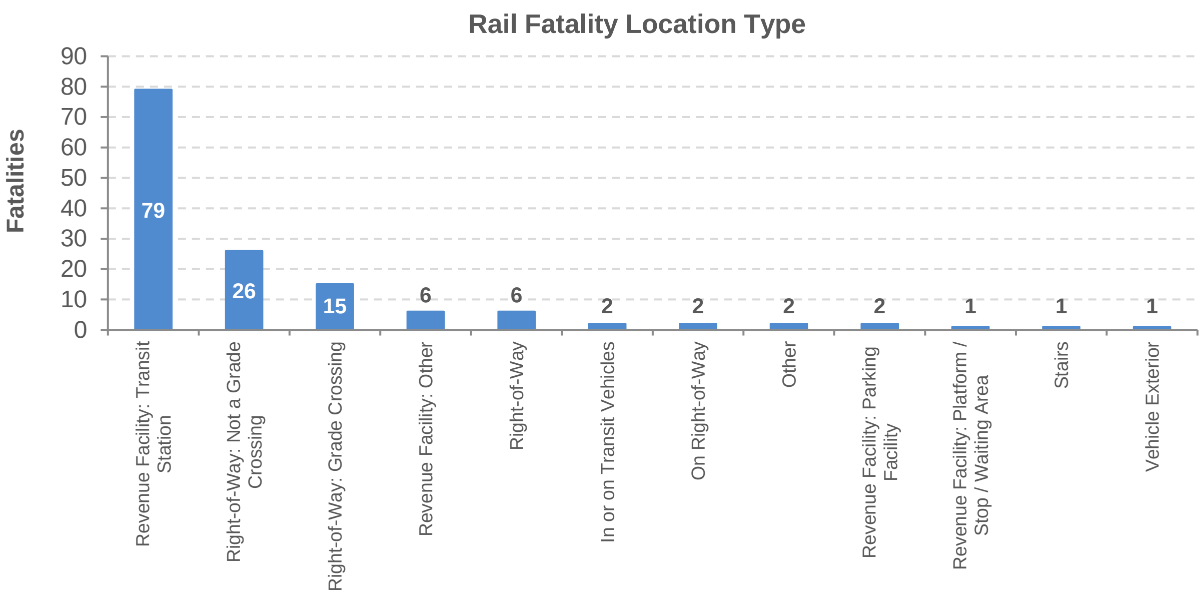
Source: National Transit Database.

Exhibit 5-13 shows fatalities by location type for bus and rail modes. Close to 75 percent of bus fatalities occur on roadways, and most victims are members of the public (not riders). In contrast, more than half of all rail fatalities occur at transit stations. In addition, 35 percent of bus fatalities occurred at roadway intersections and 10 percent of rail fatalities occurred at crossings. The interactions between transit, vehicles, pedestrians, cyclists, and motorists at rail grade crossings, pedestrian crosswalks, and intersections all influence overall transit safety performance.

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 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.[22]

Exhibit 5-13 ■ Bus and Rail Fatality Types by Location, 2016





Note: NTD event type categories were updated in 2016.

Source: National Transit Database.

[22] *2014 Annual Report: The U.S. Department of Transportation's Status of Actions Addressing the Safety Issue Areas on the National Transportation Safety Board's Most Wanted List.*

Derailments

Derailment events and level of severity are proportional to the average condition of tracks and other related asset types, combined with operating factors such as passenger car loads, speed, and frequency of service. *Exhibit 5-14* shows derailments by rail mode. Light rail is the single mode with the highest number of derailments, followed by streetcar and heavy rail. Heavy rail, which is a fast and high-capacity mode, had an average of 0.18 injuries per system. Light rail, the second fastest mode, had an average of 0.14 injuries per system; and streetcars, which operate in mixed traffic at low speeds, had only 0.13.

Cable cars are treated as a special case because they are unique, historical systems that operate in mixed traffic and are pulled by cables at low speeds. The age of these assets affects the occurrence of derailment accidents.

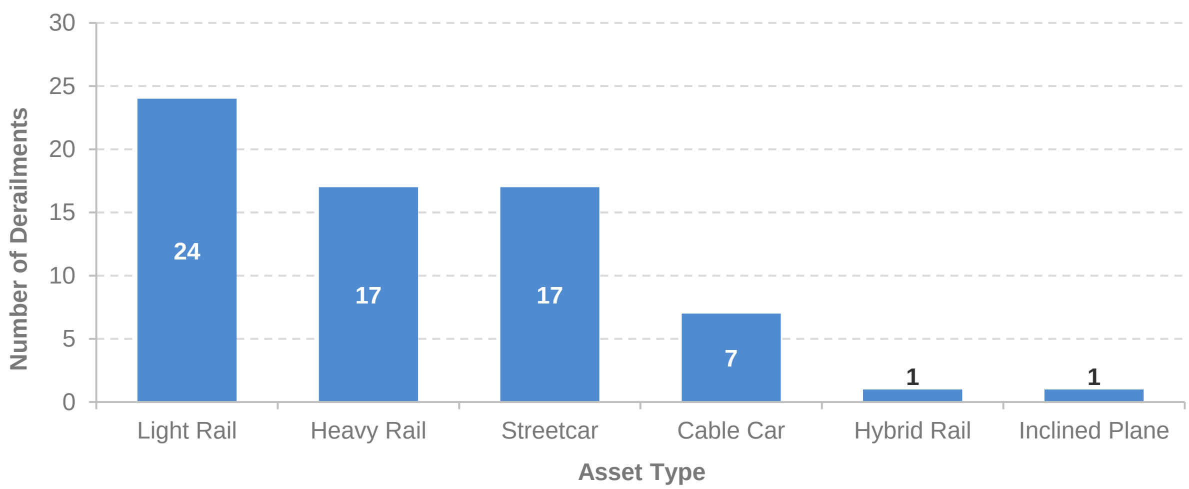
The number of derailment accidents per million vehicle revenue miles shows that heavy rail has the lowest rate, at 0.01, followed by hybrid rail and light rail.

The average cost in property damage per derailment incident is highest for heavy rail, at an average of $57,080 per accident, more than twice the same cost for light rail ($27,164) which in turn is 8 times more costly than cable car at $3,571 per accident.

Heavy rail systems are usually faster systems compared to light rail, and require very complex, diversified, and expensive asset types to operate. Heavy rail derailments are less frequent but severe when it happens in revenue service.

It should be noted that derailment events happen not only in revenue service, but also during deadhead (trips performed without accepting passengers) and maneuvers at yards and/or end stations. These incidents are usually less serious, and injure mostly employees of the agencies.

Exhibit 5-14 ■ Derailments by Rail Mode, 2014–2016



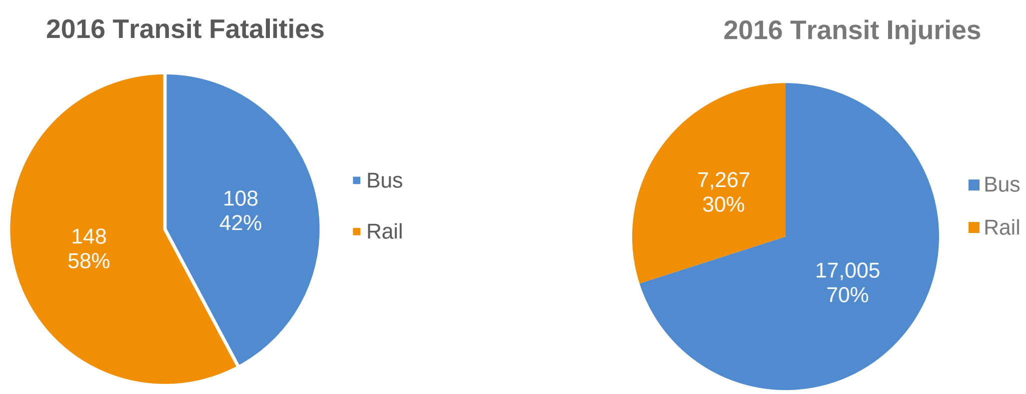
Mode	Number of Systems	Number of Derailments	Estimated Property Damage	Resulting Injuries	VRM	Derailments per Million VRM	Average Injuries per System	Property Damage per Derailment Accident
Light Rail	22	24	$651,940	3	313,838,084	0.08	0.14	$27,164
Heavy Rail	17	17	$970,363	3	1,969,675,073	0.01	0.18	$57,080
Streetcar	15	17	$23,750	2	17,355,137	0.98	0.13	$1,397
Cable Car	1	7	$25,000	2	848,353	8.25	2.00	$3,571
Hybrid Rail	7	1	$15,000	0	5,919,936	0.07	0.00	$15,000
Inclined Plane	5	1	$0	0	116,200	8.61	0.00	$0

Source: National Transit Database Safety Analysis 2014–2016.

Fatalities and Injuries by Mode

Rail accounts for a larger share of transit fatalities (58 percent), while bus accounts for a larger share of transit injuries (70 percent) as shown in *Exhibit 5-15*, which depicts the split of fatalities and injuries between rail modes and fixed-route bus. The most common type of rail accident involves 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, common bus fatalities occur with other vehicle occupants (in collision accidents) and collisions with pedestrians near crossings.

Exhibit 5-15 ■ Transit Fatalities and Injuries by Mode, 2016



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

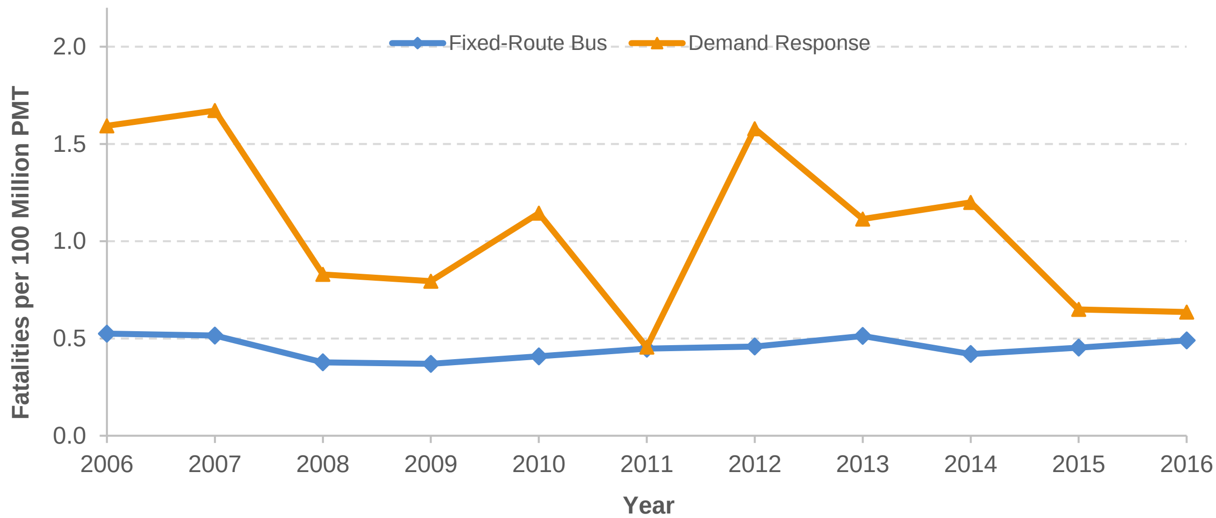
Exhibit 5-16 shows fatalities (including suicides) per 100 million PMT for fixed-route bus and demand-response transit. Note that the fatality rate for demand-response transit is more volatile than for fixed-route bus. This observation is expected, as fewer people use demand-response transit and even one or two more fatalities in a year can increase the rate 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 5-17 shows fatalities per 100 million PMT for heavy rail and light rail (including suicides). Heavy rail fatality rates remained relatively stable from 2008 through 2016. Suicides represent a large share of fatalities for heavy rail—approximately 57 percent in 2016. Light rail typically experiences more incidents than does heavy rail, as many systems consist of streetcars operating in mixed traffic with both automobiles and pedestrians present.

Fatality, Incident, and Injury Rates by Mode, Excluding Suicides

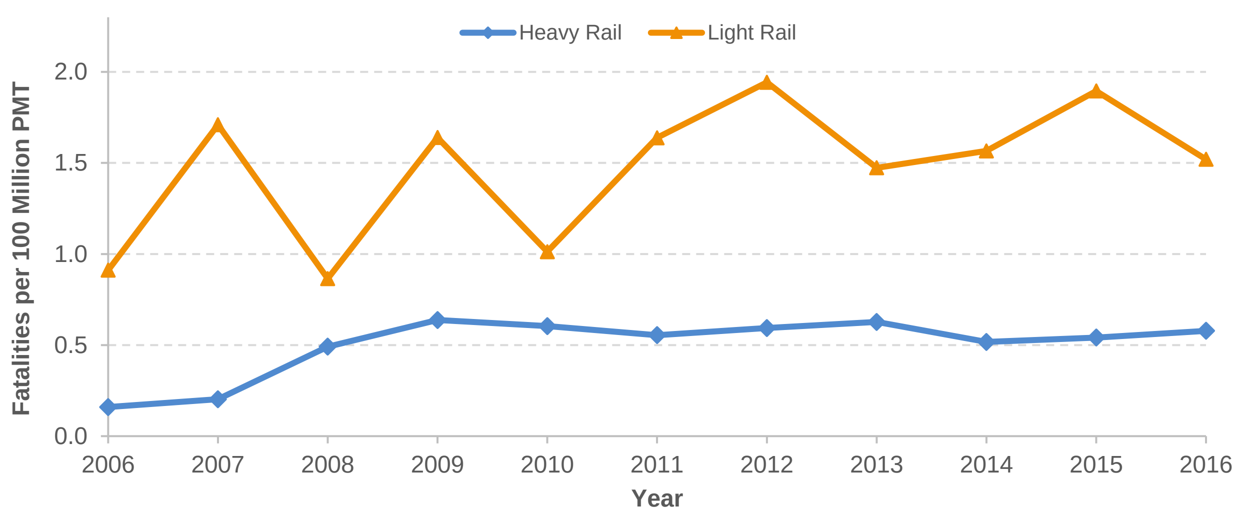
The analysis presented in *Exhibit 5-18* is by mode, which includes all major modes reported in the NTD except for commuter rail. Safety data for commuter rail are included in FRA's Rail Accident/Incident Reporting System (RAIRS). Before 2011, RAIRS did not include a separate category for suicides, which *are* reported in NTD for all modes. Therefore, for comparative purposes, suicides are excluded from this analysis.

Exhibit 5-16 ■ Annual Transit Fatality Rates by Highway Mode, 2006–2016



Note: Fatality totals include both DO and PT service types.
Source: National Transit Database.

Exhibit 5-17 ■ Annual Transit Fatality Rates by Rail Mode, 2006–2016



Note: Fatality totals include both DO and PT service types.
Source: National Transit Database.

Exhibit 5-18 shows incidents and injuries per 100 million PMT reported in the NTD for the two main highway modes in transit (fixed-route bus and demand-response transit) and the two main rail modes (heavy rail and light rail). Commuter rail is presented separately as those data were collected according to different definitions in RAIRS. With the exception of a general decline in the incident and injury measures for most modes after 2007, the data in *Exhibit 5-18* do not indicate any clear long-term trends.

Exhibit 5-18 ■ Transit Incidents and Injuries by Mode, 2006–2016

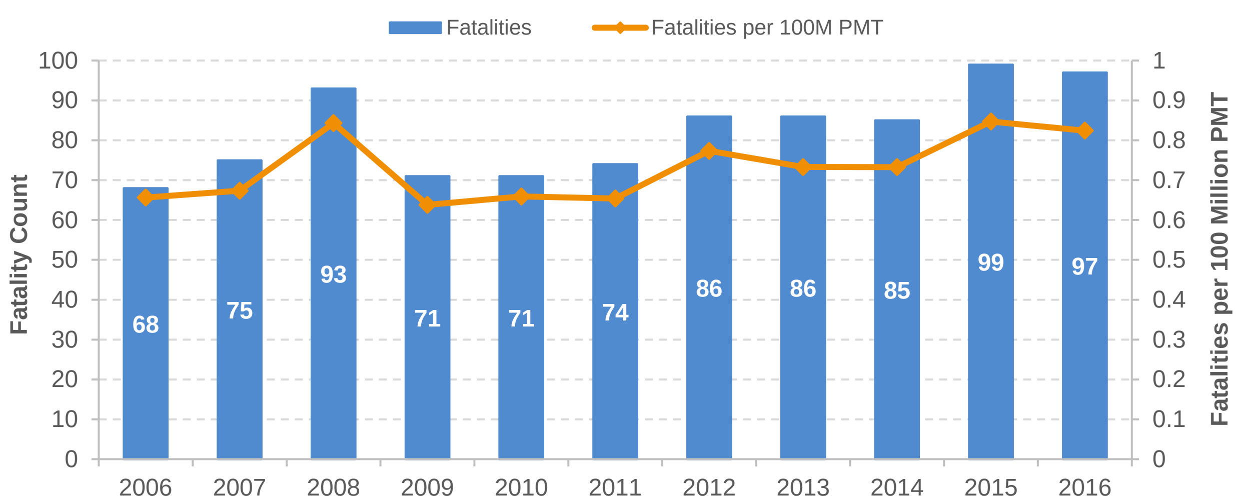
Analysis Parameter	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Incidents Per 100 Million PMT											
Fixed-Route Bus	69.62	66.86	54.15	58.28	55.28	46.26	45.20	47.63	49.07	55.68	55.12
Heavy Rail	42.86	43.49	53.34	53.16	54.62	49.39	48.58	49.87	41.17	41.43	41.27
Light Rail	60.67	61.29	48.58	45.76	40.09	39.68	36.94	40.67	41.40	48.59	47.90
Demand Response	375.15	404.13	204.28	194.77	165.23	151.82	142.48	153.98	165.33	174.43	192.39
Injuries Per 100 Million PMT											
Fixed-Route Bus	62.64	68.89	66.89	72.27	71.96	62.87	62.65	65.30	66.94	73.30	71.65
Heavy Rail	42.86	43.49	53.34	53.16	54.62	49.39	48.58	49.87	41.17	41.43	41.27
Light Rail	60.67	61.29	48.58	45.76	40.09	39.68	36.94	40.67	41.40	48.59	47.90
Demand Response	375.15	404.13	204.28	194.77	165.23	151.82	142.48	153.98	165.33	174.43	192.39

Source: National Transit Database.

Commuter Rail Fatalities, Incidents, and Injuries, Excluding Suicides

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 (suicides not included). *Exhibit 5-19* shows the number of fatalities, and the fatality rate, for commuter rail. Following a significant decrease in 2009, both measures have shown a general upward trend since 2010. For commuter rail, the total number of fatalities in 2016 was 97, with a fatality rate of 0.82—significantly higher than the national aggregate rate of 0.58.

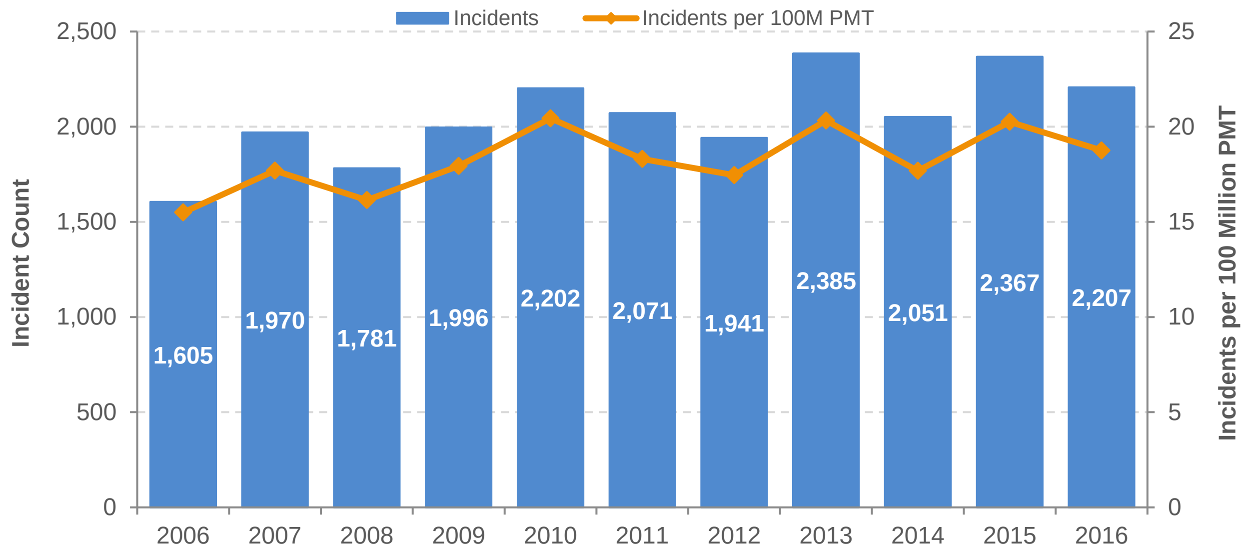
Exhibit 5-19 ■ Commuter Rail Fatalities, 2006–2016



Source: Federal Railroad Administration Rail Accident/Incident Reporting System.

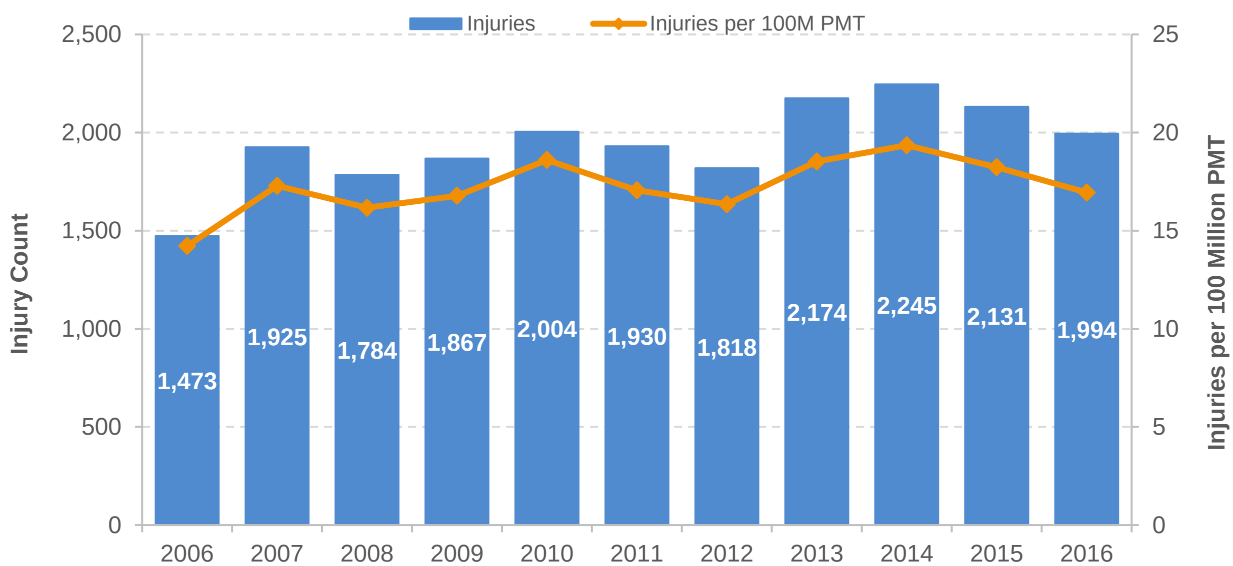
Exhibits 5-20 and *5-21* show the number of commuter rail incidents and the number of injuries per 100 million PMT, respectively. Although commuter rail has a very low number of incidents per PMT, commuter rail incidents are far more likely to result in fatalities than incidents occurring on any other 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 through 2013. Incidents increased through 2015 and decreased in 2016, whereas injuries decreased through 2016. The average rates of increase for commuter rail fatalities, incidents, and injuries from 2006 to 2016 are 3.6 percent, 3.1 percent, and 3.2 percent, respectively.

Exhibit 5-20 ■ Commuter Rail Incidents, 2006–2016



Source: Federal Railroad Administration Rail Accident/Incident Reporting System.

Exhibit 5-21 ■ Commuter Rail Injuries, 2006–2016



Source: Federal Railroad Administration Rail Accident/Incident Reporting System.

CHAPTER 6: Infrastructure Conditions

Infrastructure Conditions – Highways

Pavement and bridge conditions directly affect vehicle operating costs. 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 mph on an Interstate highway could accelerate wear and tear faster than hitting the same pothole at 25 mph. 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

- The share of vehicle miles traveled (VMT) on Federal-aid highways on pavements with good ride quality rose from 47.0 percent in 2006 to 48.9 percent in 2016. In 2016, 59.6 percent of VMT on the National Highway System (NHS) was on pavements with good ride quality.
- The share of bridges weighted by deck area classified as in good condition rose from 46.1 percent in 2006 to 47.4 percent in 2016. The deck area-weighted share of bridges classified as in poor condition decreased from 9.0 percent to 5.9 percent over this period.
- The shares of NHS bridges in 2016 weighted by deck area classified as in good, fair, and poor condition were 44.5 percent, 50.3 percent, and 5.2 percent, respectively.
- The classification of a bridge as in poor condition does not imply that the bridge is unsafe. If a bridge inspection determines a bridge to be unsafe, it is closed.

Factors Affecting Pavement and Bridge Performance

Pavement and bridge conditions are affected both by environmental conditions and by traffic volumes. 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. Environmental conditions include factors such as freeze-thaw cycles, in which water seeps into cracks in pavement and then freezes, causing cracks to expand and ultimately contributing to the formation of potholes. Pavement and bridge deterioration accelerates on facilities with high traffic volumes, particularly facilities used by large numbers of heavy trucks. Deterioration can be mitigated through a variety of actions, including reconstruction, rehabilitation, and pavement preservation. 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.

Summary of Current Highway and Bridge Conditions

As discussed in the Introduction to Part I, as part of the implementation of the Transportation Performance Management 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. States have begun reporting under the PM-2 rule. 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 the amount of cracking on both concrete and asphalt pavements.

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.

The National Bridge Inventory (NBI) is a record of data reported to the Federal Highway Administration (FHWA) from the States, Federal agencies, and Tribal governments on the condition of the Nation's bridges. The HPMS and NBI are discussed in greater detail later in this section.

Exhibit 6-1 ■ Condition Rating Classifications Used in the 24th C&P Report

Condition Metric	Rating Criteria	Good	Fair	Poor
Pavement Ride Quality	The 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 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).

Notes: IRI is International Roughness Index; PSR is Present Serviceability Rating.

Source: FHWA (https://www.federalregister.gov/documents/2017/01/18/2017-00550/national-performance-management-measures-assessing-pavement-condition-for-the-national-highway).

This chapter does not include statistics for overall pavement condition ratings, but it does include data on the ratings for the individual distresses for 2016. These data are presented in *Exhibit 6-3*, *Exhibit 6-4*, and *Exhibit 6-5*.

Data presented for the 2006–2016 period are limited to ride quality only, as data collection for the other pavement distresses began in 2010. Although 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 the Nation's road mileage that are not on Federal-aid highways.)

Tunnels

The National Tunnel Inventory will contain an annual record of inventory and condition data for all tunnels reported according to the National Tunnel Inspection Standards. The collection of data began in 2018. The goal is to report these data in addition to highway and bridge data in future editions of the C&P Report. See https://www.fhwa.dot.gov/bridge/tunnel/.

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 deck of a bridge is the portion of the structure that carries the traffic over the bridge. The superstructure is the entire portion of a bridge structure that primarily receives and supports traffic loads and in turn transfers these loads to the bridge substructure. The substructure is the abutments, piers, and other bridge components below the bridge superstructure that support the span of a bridge superstructure.

A culvert is a structure under a roadway, usually for drainage. For the purposes of this report the term culvert refers to a bridge-class culvert. A bridge-class culvert has a clear opening of more than 20 feet measured along the centerline of the roadway between extreme ends of the openings for multiple boxes or multiple pipes that are 60 inches or more in diameter. A bridge-class culvert does not have a substructure, deck, or superstructure. The roadway is on top of earthen fill material above the top of the bridge-culvert.

The PM-2 rule redefined the criteria for determining structurally deficient bridges and made them equal to the criteria that classify bridges as being 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. Whereas 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 vs. Raw Counts

This section presents condition data based on raw counts of actual miles of pavement or number of bridges and other data weighted by lane miles, VMT, bridge average daily traffic (ADT), bridge annual average daily truck traffic (AADTT), or bridge deck area.

Although 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. Some bridge data are presented based on actual bridge counts, whereas other data are weighted by bridge deck area or bridge traffic.

Current Pavement Conditions

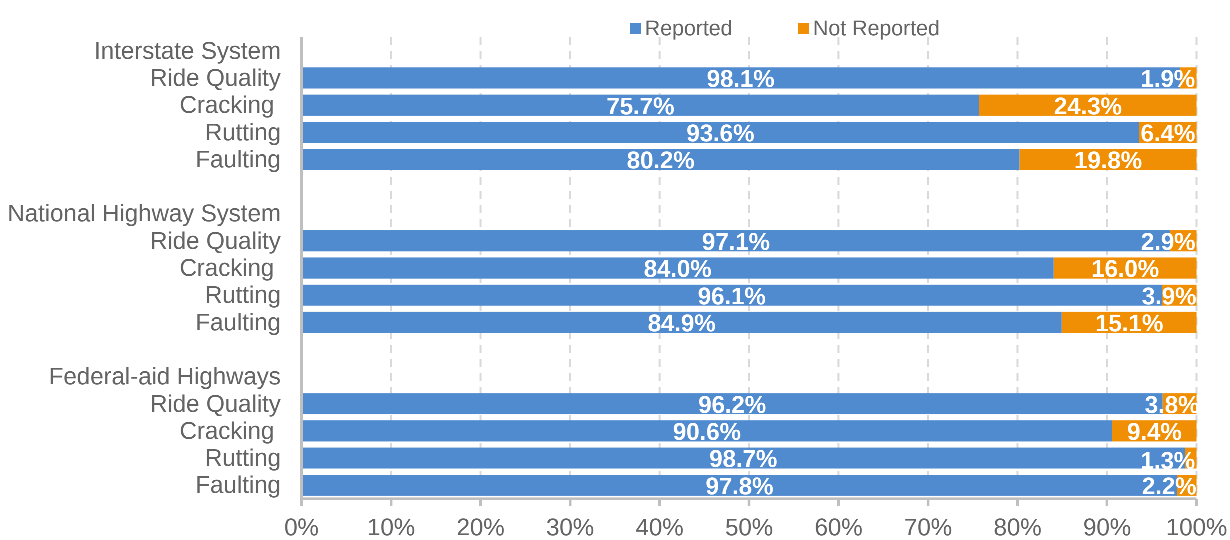
Although HPMS data reporting requirements for the IRI date back many years (on a universe or sample basis, depending on the type of roadway)—and data reporting for cracking, rutting, and faulting date back to 2010—as of 2016, there were a number of highway sections for which these data were omitted. In some cases, States provided an alternative Present Serviceability Rating 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 2016 for each distress type for Interstate highways, the NHS, and Federal-aid highways. The goal is to have 100 percent of all distresses reported for the Interstate System and the NHS and for all sample sections on Federal-aid highways. The quantity of data reported by State DOTs has improved since the last C&P Report. This increases the accuracy of the statistics reported in this chapter.

Exhibit 6-2 shows that States reported ride quality for 98.1 percent of the Interstate System. For cracking data, only 75.7 percent of the Interstate was reported; 93.6 percent of rutting data was reported for the Interstate; faulting data was reported for 80.2 percent. The percentages of data reported for the National Highway System for the same distresses were 97.1 percent, 84.0 percent, 96.1 percent, and 84.9 percent respectively. For Federal-aid highways, ride quality was reported for 96.2 percent of the sample sections, cracking was reported for 90.6 percent, rutting was reported for 98.7 percent, and faulting was reported for 97.8 percent.

Overall, reporting of distresses is better on Federal-aid highways than on the Interstate System or the National Highway System. This may be due to differences in reporting: reporting on Federal-aid highways is based on random samples dispersed across all Federal-aid highways; on the Interstate System and the NHS the recording of distresses is to be for every tenth of a mile.

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.

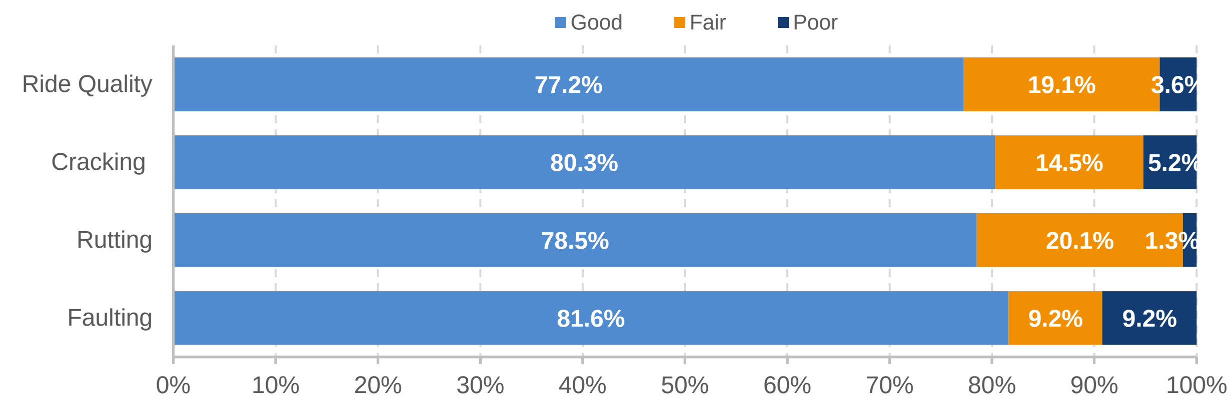
Exhibit 6-2 ■ Percentage of Pavement Data Reported



Source: Highway Performance Monitoring System.

As shown in *Exhibit 6-3*, approximately 77.2 percent of pavements on the Interstate System (weighted by lane miles) were rated as having good ride quality (roughness) in 2016; 19.1 percent had fair ride quality, and 3.6 percent had poor ride quality. The shares of pavement rated good for cracking, rutting, and faulting were 80.3 percent, 78.5 percent, and 81.6 percent, respectively, whereas the shares rated poor were 5.2 percent, 1.3 percent, and 9.2 percent, respectively.

Exhibit 6-3 ■ Interstate Pavement Condition, Weighted by Lane Miles, 2016

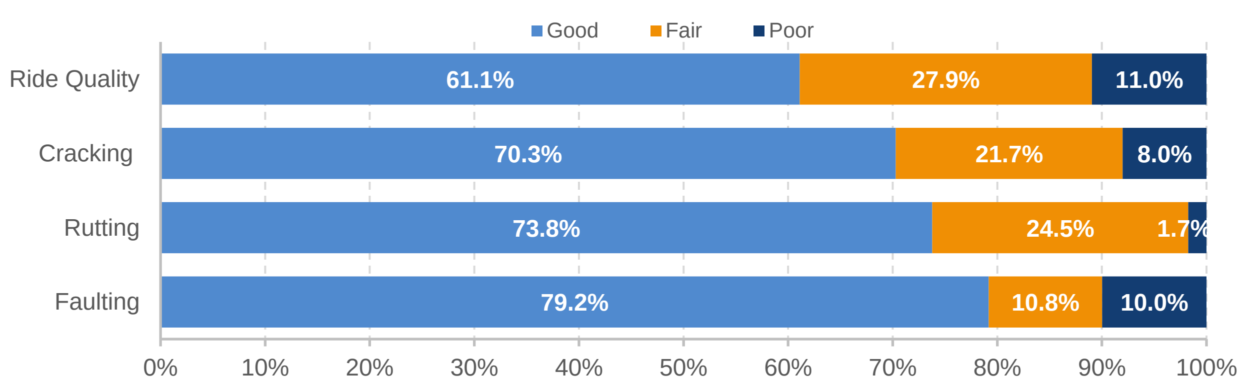


Source: Highway Performance Monitoring System.

For NHS pavements, *Exhibit 6-4* shows that 61.1 percent of lane miles were rated as having good ride quality in 2016, 27.9 percent had fair ride quality, and 11.0 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. This may reflect budgetary differences based on VMT: States may choose to rehabilitate the Interstate system due to the heavier traffic volumes.

The lane mile-weighted shares of cracking, rutting, and faulting pavement rated good for the NHS were 70.3 percent, 73.8 percent, and 79.2 percent, respectively, in 2016—all below the comparable values for Interstate highways. The share of NHS lane miles rated poor in 2016 was 8.0 percent for cracking, 1.7 percent for rutting, and 10.0 percent for faulting pavement.

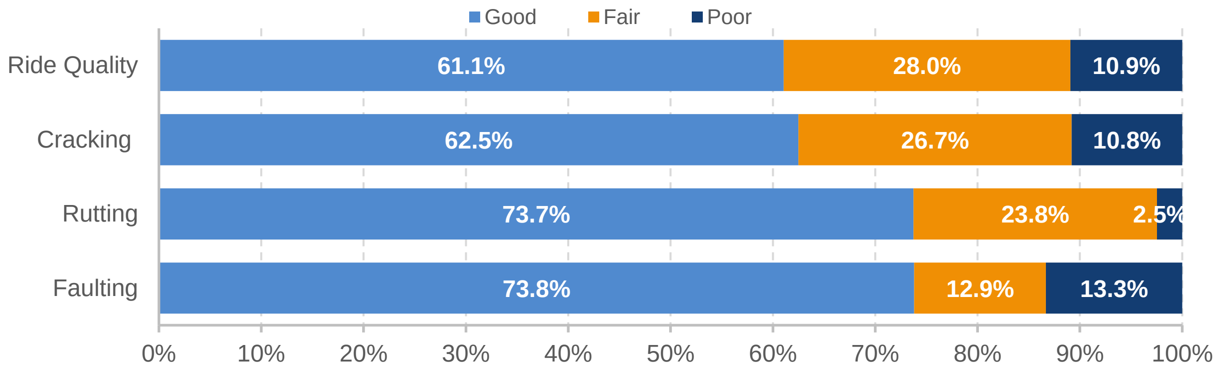
Exhibit 6-4 ■ National Highway System Pavement Condition, Weighted by Lane Miles, 2016



Source: Highway Performance Monitoring System.

Overall, the majority of Federal-aid highways, weighted by lane miles, are rated in good condition. *Exhibit 6-5* shows the percentage of Federal-aid highway lane miles rated good was 61.1 percent for ride quality, 62.5 percent for cracking, 73.7 percent for rutting, and 73.8 percent for faulting. The percentage of Federal-aid lane miles rated poor was 10.9 percent for ride quality, 10.8 percent for cracking, 2.5 percent for rutting, and 13.3 percent for faulting.

Exhibit 6-5 ■ Federal-aid Highway Pavement Condition, Weighted by Lane Miles, 2016



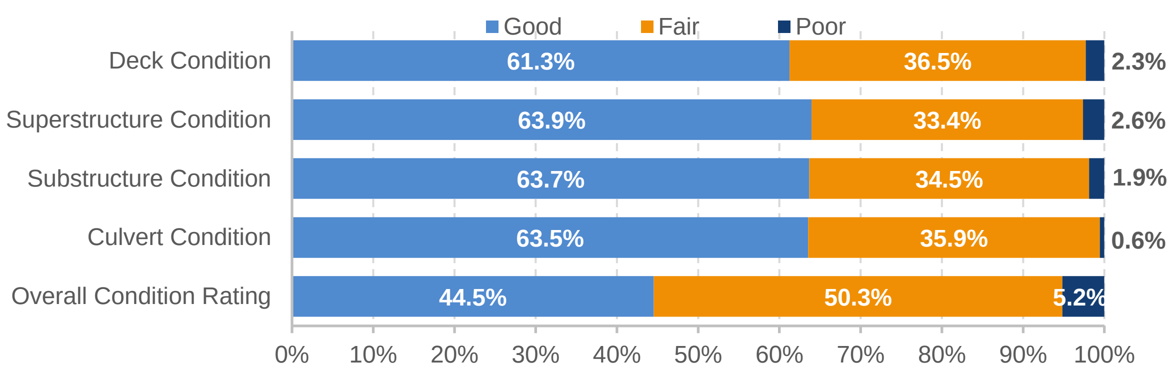
Source: Highway Performance Monitoring System.

Current Bridge Condition

The majority of NHS bridges are in either good or fair condition. The deck-area weighted share of NHS bridges with decks in good condition is shown in *Exhibit 6-6* as 61.3 percent for 2016; the shares for superstructure and substructure were 63.9 percent and 63.7 percent, respectively. The share of NHS culverts in good condition was 63.5 percent in 2016. Applying the PM-2 classification rules (all individual bridge components rated good) results in an overall share of 44.5 percent of NHS deck area rated as good.

The deck-area weighted share of NHS bridges with decks in poor condition was 2.3 percent for 2016; the shares for superstructure and substructure were 2.6 percent and 1.9 percent, respectively; the share for culverts was 0.6 percent. Applying the PM-2 classification rules (any of the individual bridge components rated poor) results in an overall share of 5.2 percent of NHS deck area rated as poor.

Exhibit 6-6 ■ National Highway System Bridge Conditions, Weighted by Deck Area, 2016

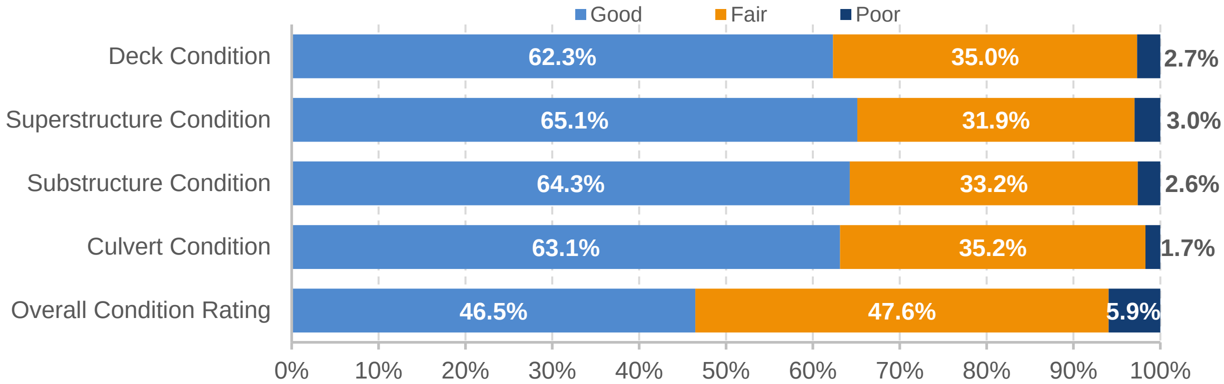


Source: National Bridge Inventory.

Exhibit 6-7 shows deck-area weighted condition data for all bridges on public roads. The shares of deck area rated good for deck, superstructure, and substructure were 62.3 percent, 65.1 percent, and 64.3 percent, respectively. For all culverts for which data were reported, the share rated as good was 63.1 percent in 2016. Applying the PM-2 classification rules results in an overall share of 46.5 percent of all deck area rated as good.

The deck-area weighted share of all bridges with decks in poor condition systemwide was 2.7 percent for 2016; the shares for superstructure, substructure, and culverts were 3.0 percent, 2.6 percent, and 1.7 percent, respectively. Applying the PM-2 classification rules results in an overall share of 5.9 percent of deck area rated as poor.

Exhibit 6-7 ■ Systemwide Bridge Conditions, Weighted by Deck Area, 2016



Source: National Bridge Inventory.

Historical Trends in Pavement and Bridge Conditions

Pavement ride quality data are only available for Federal-aid highways. This section presents data on changes in pavement ride quality on Federal-aid highways since 2006, 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.

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.

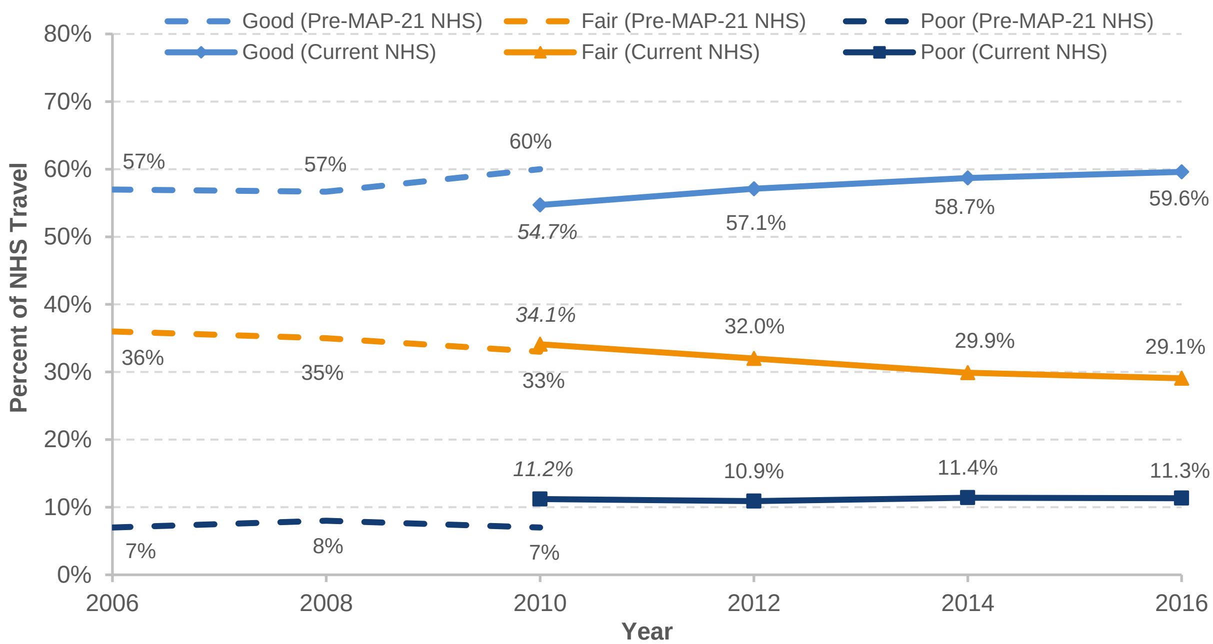
National Highway System Pavement and Bridge Trends

In 1998, DOT began establishing annual targets for pavement ride quality. Since 2006, DOT has used the share of VMT on the NHS on pavements with good ride quality as its performance metric.

MAP-21 expanded the definition/parameters of 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 and 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 defined as part of the NHS.

With the expanded definition of the NHS, the percentage of pavement in fair quality declined whereas the percentage of pavement in good or poor quality increased. The share of VMT on NHS pavements with good ride quality rose from 57 percent in 2006 to 60 percent in 2010 based on the pre-expansion definition of the NHS, and from an estimated 54.7 percent in 2010 to 59.6 percent in 2016 based on the post-expansion NHS. From 2006 to 2010, the share of VMT on NHS pavements with poor ride quality remained the same at 7 percent; this share increased slightly from an estimated 11.2 percent to 11.3 percent from 2010 to 2016.

Exhibit 6-8 ■ National Highway System Pavement Ride Quality, Weighted by VMT, 2006–2016

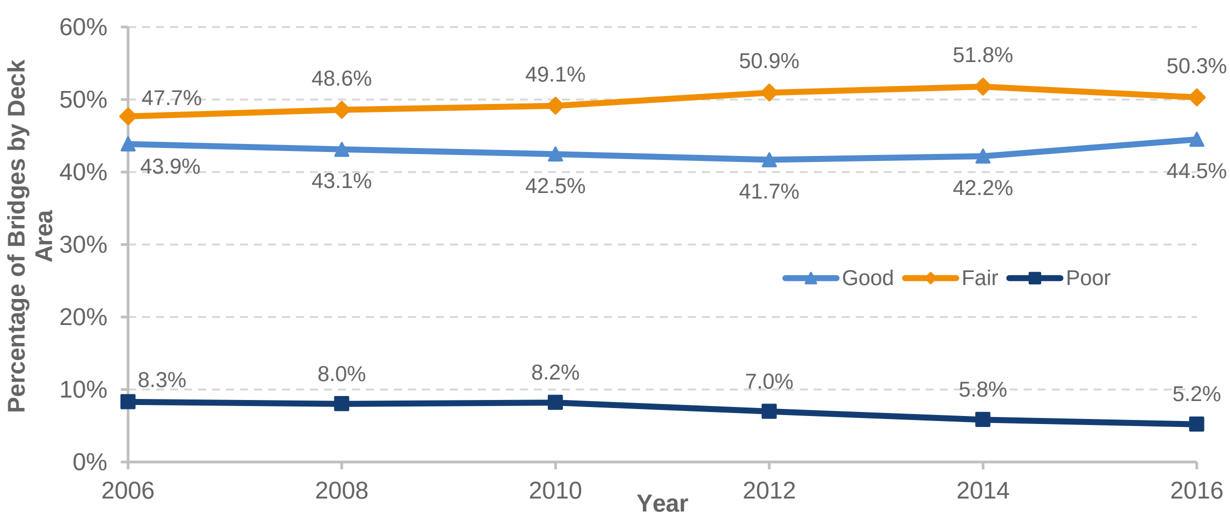


Notes: NHS is National Highway System. VMT is vehicle miles traveled. Data for odd-numbered years are omitted. Italicized 2010 values shown for the current NHS are estimates as presented in the 2013 C&P Report. Exact values cannot be determined, as the 2010 HPMS data were collected based on the pre-MAP-21 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 shows an improved performance of bridges on the NHS from 2006 through 2016. The share of total deck area on bridges rated poor declined from 8.3 percent in 2006 to 5.2 percent in 2016. The deck area on bridges in good condition increased from 43.9 percent in 2006 to 44.5 percent in 2016; the share of deck area on bridges classified as fair (i.e., not good or poor) increased over this period from 47.7 percent in 2006 to 50.3 percent in 2016.

Exhibit 6-9 ■ National Highway System Bridge Condition Ratings, Weighted by Deck Area, 2006–2016



Note: Odd-numbered years are omitted.

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 144,610 bridges in 2016. The number of NHS bridges in poor condition decreased from 6,166 bridges in 2006 to 5,044 bridges in 2016. The total percentage of NHS bridges in poor condition by deck area decreased from 8.3 percent in 2006 to 5.2 percent in 2016.

Exhibit 6-10 ■ National Highway System Bridges Rated Poor, 2006–2016

	2006	2008	2010	2012	2014	2016
Count						
Total Bridges	115,202	116,523	116,669	117,485	143,165	144,610
Structurally Deficient Bridges[1]	6,339	6,272	5,902	5,237	5,951	
Poor Bridges	6,166	6,126	5,781	5,121	5,825	5,044
Percent Structurally Deficient[1]						
By Bridge Count	5.5%	5.4%	5.1%	4.5%	4.2%	
Weighted by Deck Area	8.4%	8.2%	8.3%	7.1%	6.0%	
Weighted by ADT	6.6%	6.4%	6.0%	5.1%	4.3%	
Percent Poor						
By Bridge Count	5.4%	5.3%	5.0%	4.4%	4.1%	3.5%
Weighted by Deck Area	8.3%	8.0%	8.2%	7.0%	5.8%	5.2%
Weighted by ADT	6.5%	6.3%	5.9%	5.0%	4.2%	3.5%

[1] The PM-2 rule redefined the criteria for determining structurally deficient bridges and made it equal to the criteria that classify bridges as being in poor condition. This exhibit contains 2006 to 2014 data based on the previous definition for reference purposes. Future editions of the C&P Report will not contain this information.

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 41.5 percent in 2006 to 40.2 percent in 2016, 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 47.0 percent to 48.9 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-heavily traveled parts of the system are lagging behind.

Ride quality ratings of poor, when analyzed by either VMT or mileage, have consistently worsened. From 2006 to 2016, the share of miles with pavement ride quality classified as poor increased from 15.8 percent to 22.0 percent; over the same period, the share of Federal-aid highway VMT on pavements with poor ride quality increased from 14.0 percent to 17.1 percent. However, when ride quality is analyzed by lane-miles, the share of lane-miles of poor pavement ride quality decreased from 19.9 percent in 2006 to 17.4 percent in 2016.

Exhibit 6-11 ■ Pavement Ride Quality on Federal-aid Highways, 2006–2016

	2006	2008	2010	2012	2014	2016
By Mileage						
Good	41.5%	40.7%	35.1%	36.4%	38.4%	40.2%
Fair	42.7%	43.5%	44.9%	43.9%	39.4%	37.8%
Poor	15.8%	15.8%	20.0%	19.7%	22.2%	22.0%
Weighted by Lane Mile						
Good	41.1%	40.6%	36.4%	35.6%	37.0%	38.2%
Fair	39.0%	39.6%	48.7%	48.3%	46.7%	44.4%
Poor	19.9%	19.8%	14.9%	16.1%	16.3%	17.4%
Weighted By VMT						
Good	47.0%	46.4%	50.6%	44.9%	47.0%	48.9%
Fair	39.0%	39.0%	31.4%	38.4%	35.7%	34.0%
Poor	14.0%	14.6%	18.0%	16.7%	17.3%	17.1%

Note: 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

Both poor pavement and poor ride quality ratings increased between 2008 and 2010. The percentage of pavement mileage with good ride quality declined from 40.7 percent to 35.1 percent, whereas 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 2006 to 47.4 percent in 2016. The comparable shares weighted by deck area increased slightly from 46.1 percent in 2006 to 46.5 percent in 2016. The shares by bridge traffic on good bridges increased from 45.6 percent in 2006 to 48.1 percent in 2016.

Bridge Condition Trends Since 2016

Based on recent data from the National Bridge Inventory, the number of bridges in poor condition decreased from 47,619 in 2017 to 45,031 in 2020, a decrease of 5 percent.

The share of bridges classified as poor dropped from 10.4 percent in 2006 to 7.9 percent in 2016. The share of bridges weighted by deck area rated as poor was lower (9.0 percent in 2006, dropping to 5.9 percent in 2016), suggesting that larger bridges are in better shape on average than smaller ones. The share of bridges weighted by average daily traffic rated poor was even lower (7.1 percent in 2006, dropping to 3.9 percent in 2016), suggesting that well-traveled bridges are in better shape on average than less traveled ones.

Exhibit 6-12 ■ Systemwide Bridge Conditions, 2006–2016

	2006	2008	2010	2012	2014	2016
Count						
Total Bridges	597,561	601,506	604,493	607,380	610,749	614,387
Bridges in Good Condition	287,969	287,317	286,534	287,194	287,701	291,412
Bridges in Fair Condition	246,309	252,217	258,277	262,878	269,734	274,306
Bridges in Poor Condition	62,297	61,002	59,305	57,049	52,905	48,559
Structurally Deficient Bridges	75,422	72,883	70,431	66,749	61,365	
Percent Good						
By Bridge Count	48.2%	47.8%	47.4%	47.3%	47.1%	47.4%
Weighted by Deck Area	46.1%	45.8%	45.2%	44.7%	44.7%	46.5%
Weighted by ADT	45.6%	44.7%	44.4%	44.0%	44.5%	48.1%
Percent Fair						
By Bridge Count	41.2%	41.9%	42.7%	43.3%	44.2%	44.6%
Weighted by Deck Area	44.7%	45.3%	46.0%	47.3%	48.3%	47.6%
Weighted by ADT	47.1%	48.2%	48.9%	50.2%	50.6%	47.9%
Percent Poor						
By Bridge Count	10.4%	10.1%	9.8%	9.4%	8.7%	7.9%
Weighted by Deck Area	9.0%	8.8%	8.7%	7.8%	6.7%	5.9%
Weighted by ADT	7.1%	7.0%	6.5%	5.7%	4.7%	3.9%
Percent Structurally Deficient[1]						
By Bridge Count	12.6%	12.1%	11.7%	11.0%	10.0%	
Weighted by Deck Area	9.6%	9.3%	9.1%	8.2%	7.1%	
Weighted by ADT	7.4%	7.2%	6.7%	5.9%	4.9%	

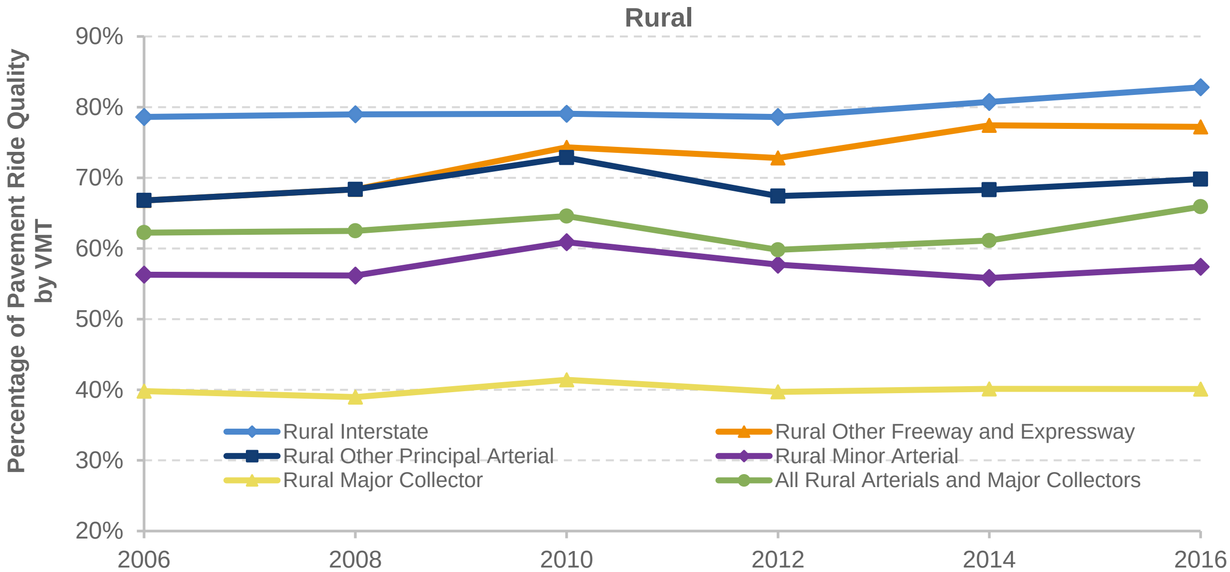
[1] The PM-2 rule redefined the criteria for determining structurally deficient bridges and made it equal to the criteria that classify bridges as being in poor condition. This exhibit contains 2006 to 2014 data based on the previous definition for reference purposes. Future editions of the C&P Report will not contain this information.

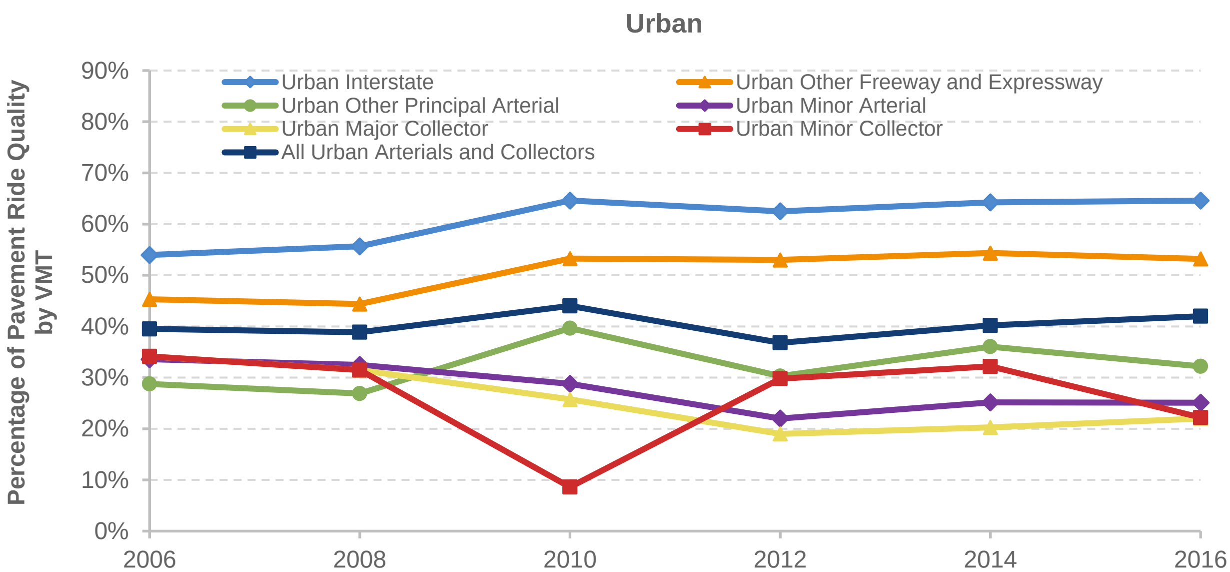
Source: National Bridge Inventory.

Pavement and Bridge Conditions by Functional Class

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, but it is still possible to draw some significant conclusions from the data. Rural Interstates have the best ride quality of all functional systems, with 82.8 percent of VMT on pavements with good ride quality in 2016, up from 78.6 percent in 2006. The share of urban Interstate System VMT on pavements with good ride quality from 2006 to 2016 rose sharply from 54.0 percent to 64.6 percent.

Exhibit 6-13 ■ Pavement Ride Quality Rated Good by Functional Class, Weighted by VMT, 2006–2016



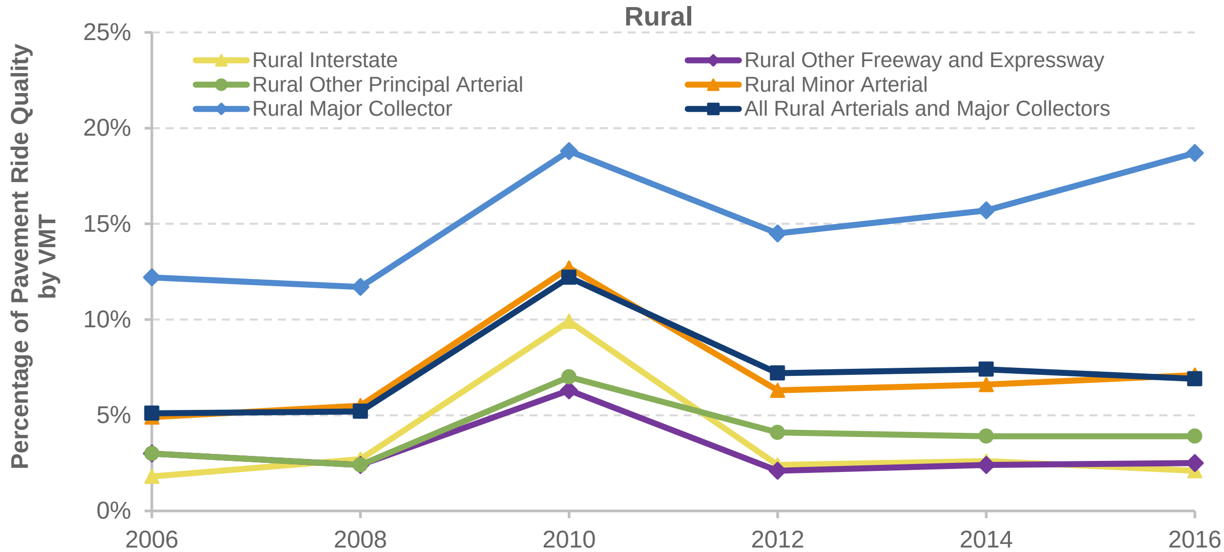


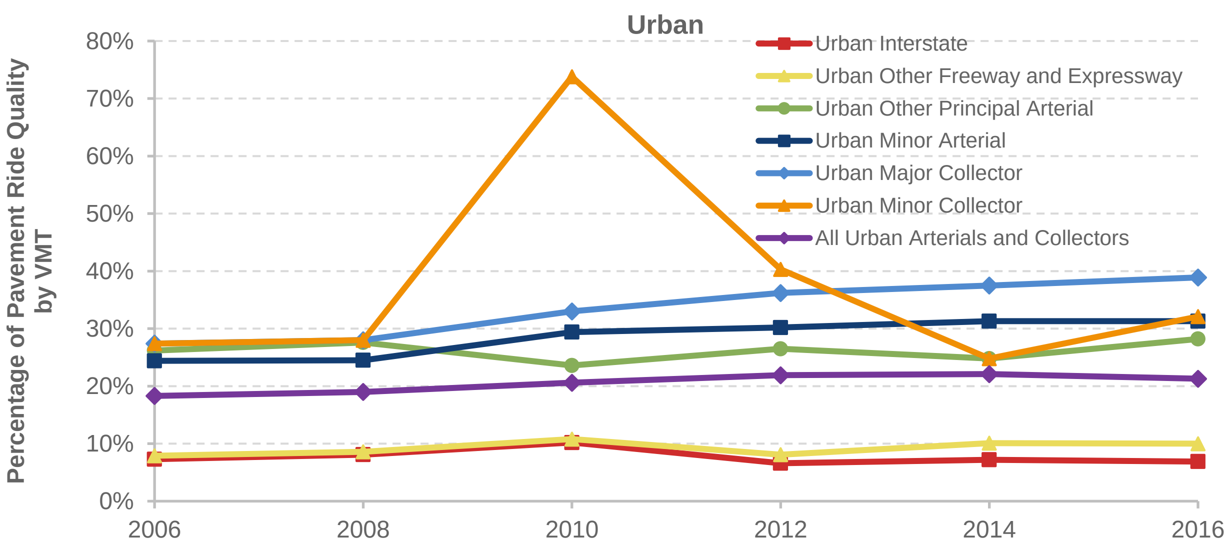
Note: VMT is vehicle miles traveled. Odd-numbered year data are omitted. Prior to 2010, the Rural Other Freeway and Expressway class was included as part of Rural Other Principal Arterial; the Urban Major Collector and Minor Collector classes were combined into a single category called Urban Collector.

Source: Highway Performance Monitoring System.

The share of Rural Arterial and Major Collector VMT on pavements with good ride quality rose from 62.2 percent in 2006 to 65.9 percent in 2016, whereas the comparable share of Urban Arterial and Collector VMT rose from 39.5 percent to 42.0 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, as defined in Chapter 1) 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.

Exhibit 6-14 ■ Pavement Ride Quality Rated Poor by Functional Class, Weighted by VMT, 2006–2016





Note: VMT is vehicle miles traveled. Odd-numbered year data are omitted. Prior to 2010, the Rural Other Freeway and Expressway class was included as part of Rural Other Principal Arterial; the Urban Major Collector and Minor Collector classes were combined into a single category called Urban Collector.

Source: Highway Performance Monitoring System.

Exhibit 6-13 illustrates that, in general, 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 2016 ranged from 82.8 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 2016 ranged from 64.4 percent for Urban Interstates to 22.0 percent for Urban Major Collectors. An exception to this general pattern was that Urban Minor Collectors showed a slightly higher percentage of VMT on pavements with good ride quality than did Urban Major Collectors in 2016. 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 illustrates the share of pavements with poor ride quality by functional class. In 2016, Urban Major Collectors had the highest percentage of VMT on poor ride quality pavements at

38.9 percent, up from 27.4 percent (for Urban Major and Minor Collectors combined) in 2006. Rural Interstate had the lowest VMT-weighted share of pavements with poor ride quality in 2006 at 1.8 percent, which rose to 2.1 percent by 2016. The VMT-weighted share of VMT on All Rural Arterials and Major Collectors combined rose from 5.1 percent in 2006 to 6.9 percent in 2016; the comparable share for All Urban Arterials and Collectors rose from 18.3 percent to 21.3 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. Among the Rural functional classes, Rural Major Collectors had the highest share of VMT on pavements with poor ride quality rising from 12.2 percent in 2006 to 18.7 percent in 2016. 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 32.1 percent in 2016, placing it at less than Urban Major Collectors at 38.9 percent. Among the Urban functional classes, Urban Interstate had the lowest share of VMT on pavements with poor ride quality, falling from 7.3 percent in 2006 to 6.9 percent in 2016.

Exhibit 6-15 shows that the highest share of bridge deck area rated as good condition was on Urban Other Freeways and Expressways, which increased from 50.0 percent in 2006 to 54.8 percent in 2016. The lowest share of rural bridge deck area rated as good condition in 2016 was 41.0 percent for Rural Interstates, down from 42.4 percent in 2006. The lowest share of urban bridge deck area in good condition in 2016 was 38.2 percent for Urban Interstates.

The overall percentages of rural and urban bridge deck area classified as good were 47.1 percent and 44.8 percent respectively. Overall rural bridges have been consistently in better condition, when rated by deck area, since 2006. Urban bridge deck area in good condition increased from 43.2 percent in 2006 to 44.8 percent in 2016.

Exhibit 6-15 ■ Bridges Rated Good, Weighted by Deck Area, by Functional Class, 2006–2016

Functional Class	Percent Good Condition					
	2006	2008	2010	2012	2014	2016
Rural						
Interstate	42.4%	40.1%	39.3%	37.1%	39.0%	41.0%
Other Principal Arterial	54.9%	53.9%	53.4%	53.7%	53.1%	52.6%
Minor Arterial	47.7%	47.7%	46.9%	45.7%	46.1%	49.1%
Major Collector	48.6%	48.1%	47.5%	47.9%	47.4%	47.2%
Minor Collector	50.5%	49.4%	49.0%	49.0%	48.4%	48.4%
Local	52.0%	54.0%	51.5%	51.5%	52.5%	52.4%
Subtotal Rural	**47.2%**	**46.8%**	**46.1%**	**45.7%**	**45.8%**	**47.1%**
Urban						
Interstate	36.7%	36.5%	36.3%	34.9%	35.6%	38.2%
Other Freeway and Expressway	50.0%	48.8%	48.4%	49.3%	48.9%	54.8%
Other Principal Arterial	42.4%	43.0%	42.8%	41.8%	41.3%	43.0%
Minor Arterial	45.5%	44.6%	45.0%	44.0%	42.7%	45.0%
Collector	48.7%	47.9%	48.9%	47.9%	48.2%	49.6%
Local	51.4%	51.0%	49.9%	50.2%	50.7%	50.7%
Subtotal Urban	**43.2%**	**42.9%**	**42.8%**	**42.1%**	**42.1%**	**44.8%**
Total Good	**46.1%**	**45.8%**	**45.2%**	**44.7%**	**44.7%**	**46.5%**

Source: National Bridge Inventory.

Exhibit 6-16 shows share of bridge deck area 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 (6.2 percent in 2006, dropping to 3.1 percent in 2016) has fallen below that for Rural Interstates (6.4 percent in 2006, dropping to 3.6 percent in 2016), and the share for Urban Other Freeway and Expressway (8.0 percent in 2006 dropping to 3.5 percent in 2016) has remained below that for Urban Interstates (9.3 percent in 2006, dropping to 6.1 percent in 2016).

The share of bridge deck area rated as poor was generally lower in rural areas (8.5 percent in 2006, dropping to 5.9 percent in 2016) than in urban areas (9.4 percent in 2006, dropping to 6.0 percent in 2016). The exception was 2014, when 6.9 percent of rural bridge deck area was rated as poor vs. 6.6 percent of the urban bridge deck area.

Overall there was a decline in bridge deck area rated in poor condition in both rural and urban areas from 9.0 percent in 2006 to 5.9 percent in 2016. Among all functional classes, the highest share of bridge deck area rated in poor condition was for Rural Local, although this was reduced from 10.7 percent in 2006 to 8.9 percent in 2016. Rural Other Principal Arterials had the lowest share of bridge deck area in poor condition in 2016 at 3.1 percent.

Exhibit 6-16 ■ Bridges Rated Poor, Weighted by Deck Area, by Functional Class, 2006–2016

Functional Class	Percent Poor Condition					
	2006	2008	2010	2012	2014	2016
Rural						
Interstate	6.4%	7.2%	7.6%	5.9%	5.1%	3.6%
Other Principal Arterial	6.2%	6.0%	5.6%	4.2%	3.6%	3.1%
Minor Arterial	9.3%	9.2%	8.6%	7.9%	7.5%	6.0%
Major Collector	9.5%	9.1%	8.9%	8.2%	8.0%	7.2%
Minor Collector	8.5%	8.4%	8.3%	7.9%	7.5%	7.1%
Local	10.7%	10.6%	10.2%	10.0%	9.8%	8.9%
Subtotal Rural	**8.5%**	**8.5%**	**8.2%**	**7.4%**	**6.9%**	**5.9%**
Urban						
Interstate	9.3%	8.9%	9.5%	7.8%	6.2%	6.1%
Other Freeway and Expressway	8.0%	7.8%	7.5%	7.4%	5.0%	3.5%
Other Principal Arterial	11.0%	10.4%	10.0%	9.3%	7.8%	6.9%
Minor Arterial	10.2%	9.7%	9.0%	8.4%	7.9%	7.1%
Collector	9.4%	9.3%	8.6%	7.9%	7.1%	6.0%
Local	7.7%	7.8%	8.1%	7.7%	7.0%	6.6%
Subtotal Urban	**9.4%**	**9.0%**	**9.0%**	**8.1%**	**6.6%**	**6.0%**
Total Poor	**9.0%**	**8.8%**	**8.7%**	**7.8%**	**6.7%**	**5.9%**

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 58.6 percent of Federal-aid highway lane-miles in 2016, whereas 40.9 percent was owned by a combination of local governments and other State agencies. The remaining 0.5 percent of lane-miles was owned by the Federal government.

Exhibit 6-17 ■ Federal-aid Highway Pavement Ride Quality by Owner, Weighted by Lane Miles, 2016

	Federal	State Highway Agencies	Other
Federal-aid Highways[1]			
Percent Lane-miles owned	0.5%	58.6%	40.9%
Good	65.2%	63.7%	25.9%
Fair	26.3%	28.8%	35.6%
Poor	8.5%	7.5%	38.5%

[1] Based on International Roughness Index data only, rather than a combination of International Roughness Index and Present Serviceability Rating data.

Source: Highway Performance Monitoring System.

Weighted by lane miles, approximately 65.2 percent of federally owned routes on Federal-aid highways were classified as having good ride quality in 2016; the comparable share for State-owned Federal-aid highways was 63.7 percent. The share of Federal-aid lane miles owned by other entities with good ride quality was much lower, at 25.9 percent. Only 7.5 percent of State-owned Federal-aid highway lane miles had poor ride quality in 2016; the comparable shares for Federal and Other were 8.5 percent and 38.5 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 (47.0 percent) or federally owned (46.6 percent) bridges.

However, local governments also had a higher share of bridges rated poor (10.2 percent) than at the State (5.4 percent poor) or Federal (8.1 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 (33.0 percent) and higher shares rated poor (24.2 percent) than do bridges owned by Federal, State, or local governments.

Exhibit 6-18 ■ Bridge Conditions by Owner, 2016

	Federal	State	Local	Private/Other[1]	Total
Percentages					
Percent Owned	1.7%	48.2%	49.9%	0.2%	100.0%
Classified as Good	46.6%	47.0%	47.9%	33.0%	47.4%
Classified as Fair	45.3%	47.6%	41.8%	42.8%	44.7%
Classified as Poor	8.1%	5.4%	10.2%	24.2%	7.9%

[1] 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 submit data 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

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;

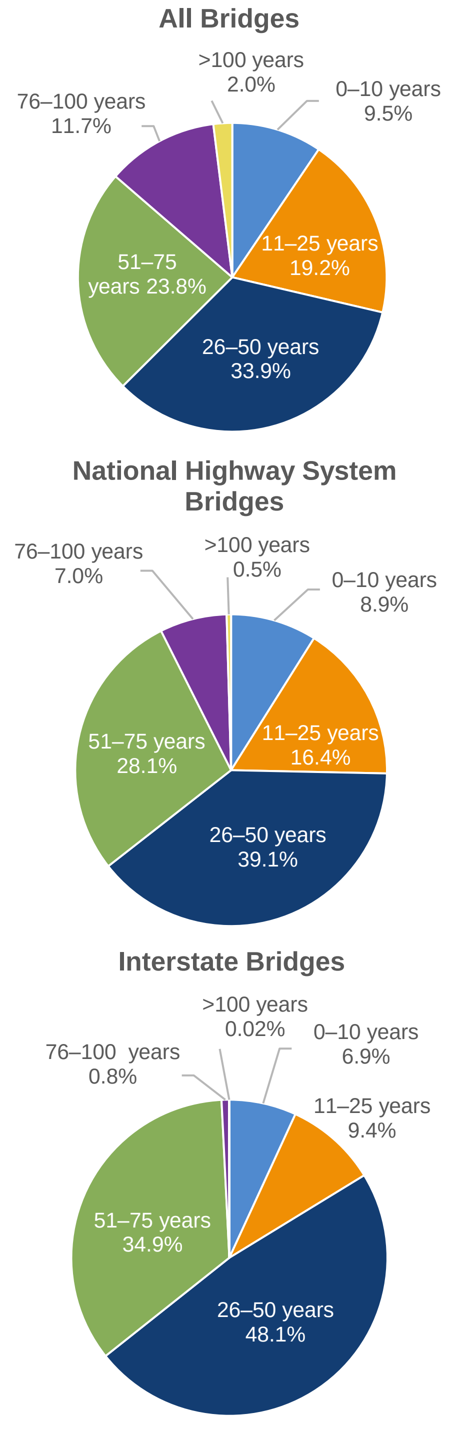
- the loading to which the structure has been subjected during its life;
- the climate of the area where the structure is located; and
- any additional stresses from events such as flooding to which the structure has been subjected.

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 maintenance of the deck, superstructure, or the substructure, or lack of rehabilitation work. The second structure could have had the same increases in heavy truck traffic but received timely maintenance activities on all parts of the structure and proper rehabilitation activities. In this example, the first structure would have a low serviceability level, whereas the second structure would have a high serviceability level.

Exhibit 6-19 identifies the age composition of all highway bridges in the Nation. As of 2016, approximately 33.9 percent of the Nation's bridges were between 26 and 50 years old. For NHS bridges, 39.1 percent were in this age range, whereas 48.1 percent of the Interstate bridges fell into this age range. Approximately 23.8 percent of all bridges are 51 years old to 75 years old, 11.7 percent are 76 to 100 years old, and 2.0 percent are more than 100 years old. The percentages of NHS bridges in these groups are 28.1 percent, 7.0 percent, and 0.5 percent, respectively. Interstate bridges in these groups are 34.9 percent, 0.8 percent, and 0.02 percent, respectively.

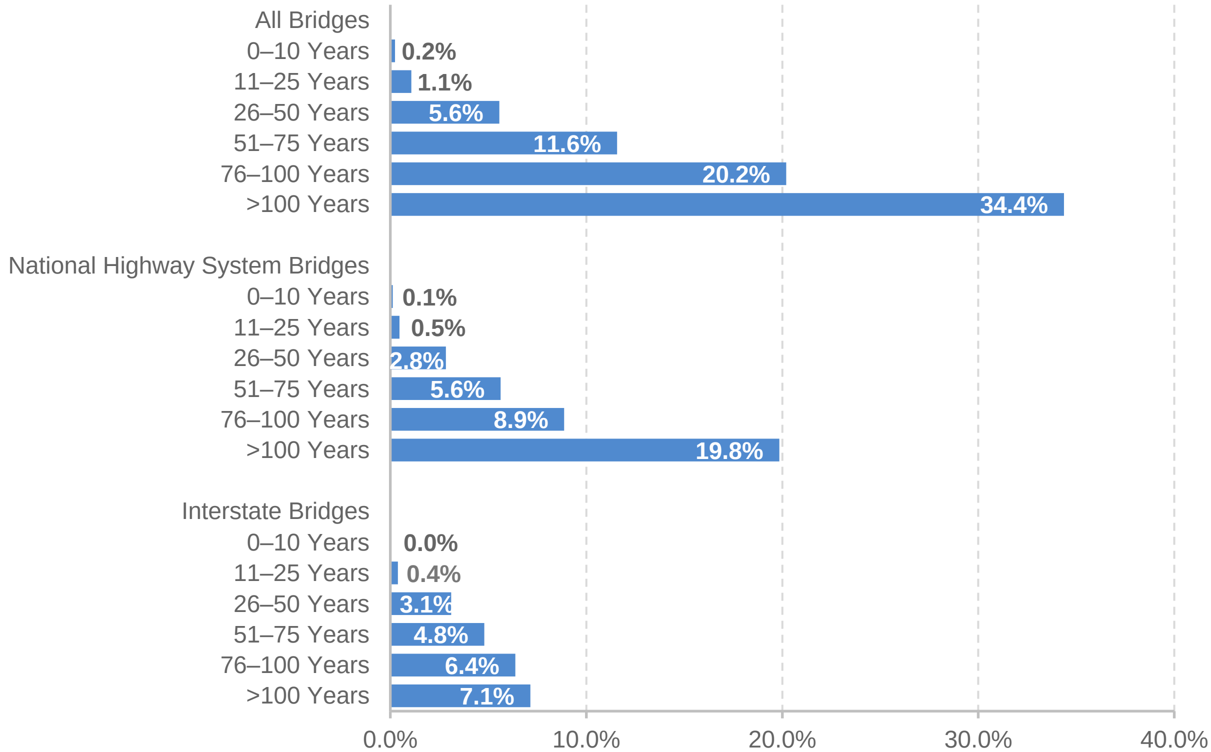
Higher percentages of older bridges tend to have a higher rate/percentage of being classified as poor. *Exhibit 6-20* identifies the distribution of poor condition bridges within the age ranges presented in *Exhibit 6-19*. The percentage of bridges classified as poor generally tends to rise as bridges age. Although only 5.6 percent of bridges in the 26-to-50-year age group are rated as poor, the percentage is 11.6 percent for bridges 51 to 75 years of age, 20.2 percent for bridges 76 to 100 years of age, and 34.4 percent for bridges over 100 years old. 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.

Exhibit 6-19 ■ Bridges by Age, 2016



Source: National Bridge Inventory.

Exhibit 6-20 ■ Bridges Rated Poor by Age, 2016



Source: National Bridge Inventory.

Innovative Strategies to Achieve State of Good Repair

Transportation agencies have limited resources—in terms of 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.

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. Improving project delivery continues to be a priority for FHWA. Projects that are delivered faster and more efficiently can minimize disruptions caused by construction.

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 preservation program will slow the rate of pavement deterioration while also providing a safer, smoother ride to the traveling public. The purpose is to select projects that improve existing pavements with emphasis on minimizing life-cycle costs. Applying a pavement 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 pavement preservation, 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.

Also, State DOTs have developed Transportation Asset Management Plans (TAMP) as a tool to guide project selection and financial investment in order to achieve the level of state of good repair for pavements and bridges.

Pavement Preservation (When, Where, and How)

Constructing new facilities or major rehabilitation is a relatively expensive undertaking. Such actions, such as capital improvement projects involve work to improve the structural condition of the pavement. The benefit of this approach is a return of the pavement to a state of good repair through reconstruction or a major improvement through major rehabilitation work. Capital improvement is usually undertaken when a pavement 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. Pavement preservation is less expensive than rehabilitation and can be used to maintain and improve the quality of a pavement section or a bridge.

Highway pavements are subject to traffic loads and environmental elements that will contribute to their deterioration over time. Pavement preservation 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.

Pavement preservation includes work that is planned and performed to improve or sustain the condition of the transportation facility in a state of good repair. Pavement preservation activities generally do not add capacity or structural value but do restore or maintain the transportation facility's overall condition.

Benefits of the 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 preservation 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 preservation will aid in setting achievable performance targets.
- **Flexibility**. Retaining a mix of successful treatments in the preservation 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.

Ultra-high Performance Concrete Connections

Ultra-high performance concrete (UHPC) can be used to create the simple, strong, long-lasting connections needed for successful construction using prefabricated bridge elements (PBEs).

Prefabricated bridge elements are structural components of a bridge that are built offsite then brought, ready to erect, to the project location. Prefabricated bridge elements 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 the speed with which they can be constructed, rely on the connections between the elements. Field-cast UHPC has emerged as a solution for creating connections between prefabricated concrete components with more robust long-term performance than conventional PBE 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 prefabricated bridge elements 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 prefabricated bridge elements results in robust connections that can provide better long-term performance than connections constructed by conventional methods.

Asset Management Plans

Asset Management is defined in 23 U.S.C. 101(2)(2) as "a strategic and systematic process of operating, maintaining, and improving physical assets, with a focus on both engineering and economic analysis based upon quality information, to identify a structured sequence of maintenance, preservation, repair, rehabilitation, and replacement actions that will achieve and sustain a desired state of good repair over the lifecycle off the assets at a minimum practicable cost."

Under 23 CFR 515.7 **Process for establishing the asset management plan**, a State shall develop a risk-based asset management plan that describes how the NHS will be managed to achieve system performance effectiveness and State DOT targets for asset condition, while managing the risks, in a financially responsible manner, at minimum practicable cost over the life cycle of its assets.

When preparing the asset management plan, State DOTs are encouraged to include all infrastructure assets within the highway right-of-way and to include other public roads in addition to the NHS. However, the risk-based asset management plan shall include, at a minimum, the following:

- An inventory of pavements and bridges on the National Highway System;
- Objectives of the plan and the measures of how those objectives will be evaluated;
- Identification of the gap between current conditions and desired conditions of the NHS network of roadways and bridges;
- Lifecycle planning for all pavements and bridges on the NHS;
- A risk management analysis for all pavements and bridges on the NHS;
- A financial plan showing how all projects for pavements and bridges on the NHS will be paid for;
- Investment strategies.

The deadline for submission of initial transportation asset management plans (TAMP) was April 30, 2018. All states have met the deadline for submission of their initial TAMPs. The deadline for submission to the FHWA of a current, fully compliant TAMP that meets all requirements of 23 U.S.C. 119 and 23 CFR Part 515 was June 30, 2019.

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.

The 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 Present 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—at 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 (6.1 meters) 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.

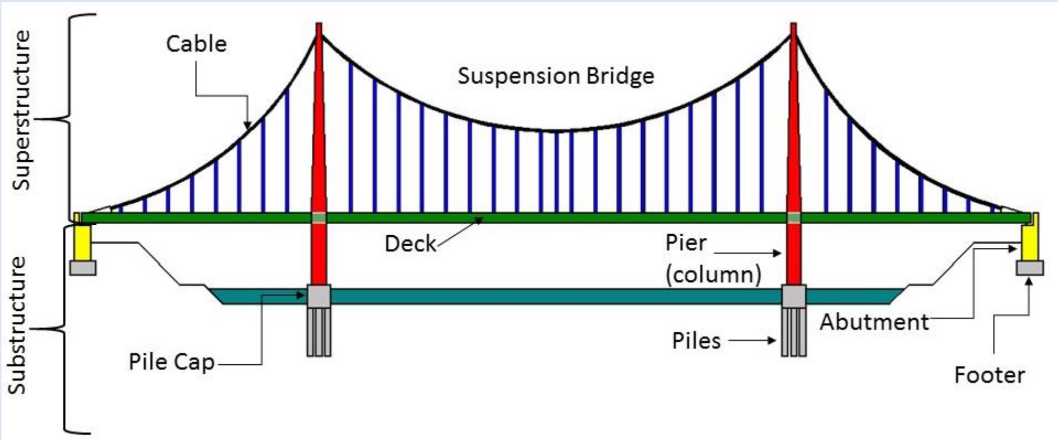
Bridge Element Data

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. Although 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 are valuable for refined conditions and needs assessments.

Whereas there are three primary bridge components, there are more than one hundred standard bridge elements of unique type. Element categories exist 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, different elements are 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 the unique elements present on a bridge, quantifying the size of each element in terms of square feet, linear feet, or both, 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 support data-driven needs assessments. The element data recording methodology and definitions are provided in the *American Association of State Highway and Transportation Officials Manual for Bridge Element Inspection* (see *Exhibit 6-21*).

Many State 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 are collected for bridges on the NHS. These data are now reported to FHWA.

Exhibit 6-21 ■ Diagram of Selected Bridge Elements



Infrastructure Conditions – Transit

This section reports on the quantity, age, and physical condition of transit assets, which 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. Data on quantity, age, and physical condition can be used to determine how well the infrastructure can support an agency's objectives and set a foundation for consistent measurement. Chapter 4 addresses issues relating to the operational performance of transit systems.

KEY TAKEAWAYS

- The total replacement value of transit assets was $850 billion in 2016, of which $334 billion (39 percent) were nonreplaceable assets.
- The backlog in 2016 was $105 billion, comprising about 12 percent of all transit assets. Systems and stations accounted for 48 percent. Guideway elements accounted for only 23 percent, even though they accounted for more than 50 percent of replaceable value.
- The share of vehicles below the SGR condition threshold increased for all nonrail transit vehicle types. In 2006, 15 percent of nonrail vehicles were not in SGR. In 2016, the share increased to 21 percent.
- The share of rail vehicles not in SGR increased from 4 percent in 2006 to 10 percent in 2016.
- The average fleet age of all buses was 6.3 years in 2016, up from 6.0 years in 2006.
- The average fleet age of rail vehicles increased from 18.9 years in 2010 to 20.8 years in 2016.

The Federal Transit Administration (FTA) uses a numerical rating scale that ranges from 1 to 5 (see *Exhibit 6-22*) 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 to be not in a state of good repair (SGR). At the low 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 major rehabilitation expenditures, in addition to vehicle age. The conditions of wayside control systems and track are based on an estimated intensity 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 7 represents the level of investment required to attain and maintain SGR by rehabilitating or replacing all assets having estimated condition ratings that are less than this minimum condition value.

In 2012, the Moving Ahead for Progress in the 21st Century Act (MAP-21) amended Federal transit law to direct 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.

Exhibit 6-22 ■ 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.

TAM Plans developed by transit agencies operate on a 4-year cycle that highlights asset inventories and assessments and prioritizes investment with support of a decision support tool, such as TERM.

The complete TAM Plan does not need to be submitted to FTA, although it must be available for review and as part of ongoing oversight. In addition, each entity developing a TAM Plan must report annually to FTA's National Transit Database (NTD).

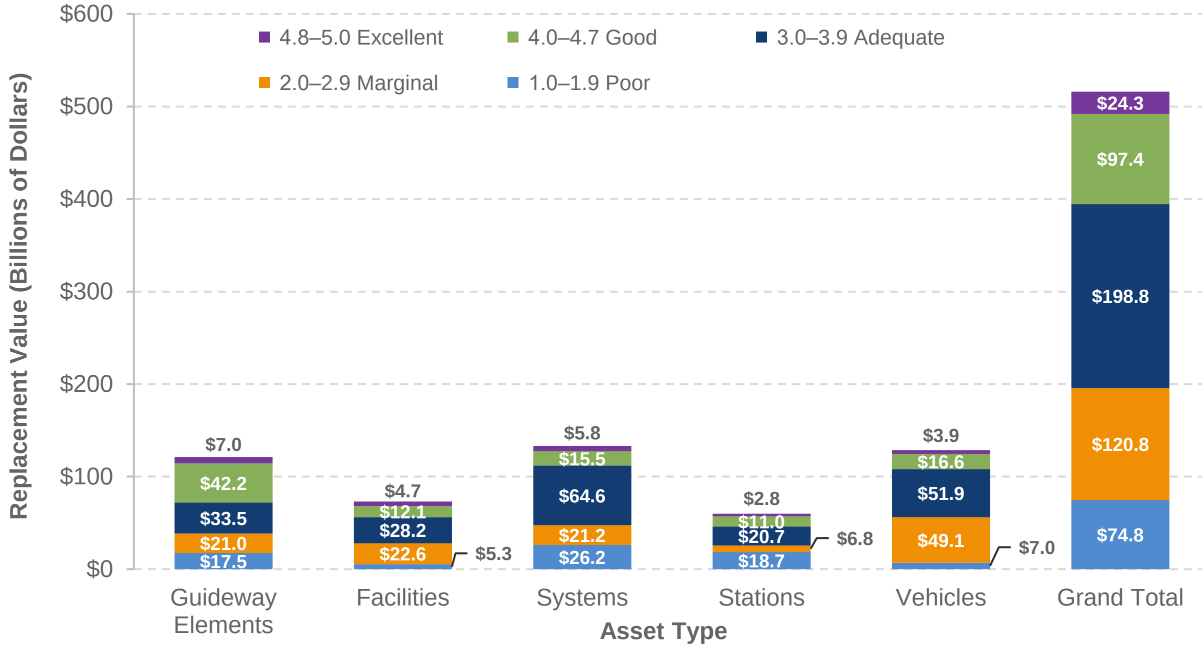
FTA has estimated typical deterioration schedules for vehicles, maintenance facilities, stations, train control systems, electric power systems, and communication systems through special on-site engineering surveys. Transit vehicle conditions also reflect the most recent information on vehicle age, use, and level of maintenance from the NTD. The information used in this edition of the C&P Report is from 2016; 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. FTA is currently in the process of updating the deterioration schedules for guideway structures (including bridges and tunnels), facilities, buses, and some station types. The impact of these updates will be reflected in the next edition of this report.

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 32 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 6-23* 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 6-23 ■ Distribution of Asset Physical Conditions by Asset Type for All Modes, 2016



Note: Exhibit includes replaceable assets, which should be replaced once they are below condition 2.5, and excludes nonreplaceable assets.

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 2016 was estimated at $849.7 billion (in 2016RM dollars). These estimates, presented in *Exhibit 6-24*, 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 $727.9 billion, or roughly 86 percent of all transit assets. Nonrail assets were estimated at $107.4 billion. Joint assets totaled $14.3 billion; these are assets that serve more than one mode within a single agency and can include administrative facilities, intermodal transfer centers, agency communication 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 61 percent and 39 percent of all transit assets, 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, historic buildings (stations and maintenance facilities) 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—which are assessed based on typical industry capital reinvestment levels for these asset types—are counted toward the SGR backlog.

Exhibit 6-24 ■ Estimated Value of the Nation's Transit Assets, 2016

Transit Asset	Value (in Billions of 2016 Dollars)			
	Nonrail	Rail	Joint Assets	Total
Replaceable Assets				
Maintenance Facilities	$33.2	$31.0	$8.9	$73.1
Guideway Elements	$2.4	$118.8	$0.0	$121.2
Stations	$6.9	$52.7	$0.3	$60.0
Systems	$5.9	$123.5	$3.8	$133.3
Vehicles	$55.1	$72.2	$1.3	$128.6
Total: Replaceable Assets	**$103.5**	**$398.2**	**$14.3**	**$516.1**
Nonreplaceable Assets				
Guideway Elements	$3.5	$283.9	$0.0	$287.4
Stations	$0.0	$45.6	$0.0	$45.6
Vehicles	$0.4	$0.2	$0.0	$0.6
Total: Nonreplaceable Assets	**$3.9**	**$329.7**	**$0.0**	**$333.6**
Total: All Assets	**$107.4**	**$727.9**	**$14.3**	**$849.7**

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 2006 to 2016 in *Exhibit 6-25*. 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 increased by 5 percent, from 6.0 to 6.3, from 2006 through 2016. 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 between 3.2 and 3.3, remaining near the bottom of the adequate range over the 10-year period. However, the percentage of vehicles below the SGR replacement threshold (condition level 2.5) increased from 13.2 percent in 2006 to 21.4 percent in 2016. 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 19.5 percent in 2016. From 2008 to 2012, however, the percentage of full-sized buses below the SGR replacement threshold decreased from 11.6 percent to 10.4 percent.

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-size buses has remained relatively flat since 2004.

Exhibit 6-26 presents the age distribution of the Nation's transit buses, and *Exhibit 6-27* 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 55 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 6-25 ■ Transit Bus Fleet Count, Age, and Condition, 2006–2016

	2006	2008	2010	2012	2014	2016
Articulated Buses						
Fleet Count	3,422	3,900	4,654	4,836	5,373	5,061
Average Age (Years)	5.4	6.3	6.6	7.0	7.2	7.3
Average Condition Rating	3.3	3.2	3.2	3.2	3.2	3.0
Below Condition 2.5 (Percent)	2.5%	1.4%	2.9%	1.7%	13.8%	12.2%
Full-Size Buses						
Fleet Count	44,866	45,999	45,783	45,314	45,717	42,447
Average Age (Years)	7.4	7.9	7.8	8.0	8.4	8.3
Average Condition Rating	3.1	3.1	3.1	3.1	3.0	2.9
Below Condition 2.5 (Percent)	11.0%	11.6%	11.0%	10.4%	16.0%	19.5%
Medium-Size Buses						
Fleet Count	6,875	7,577	8,169	7,615	7,753	7,495
Average Age (Years)	8.1	8.2	7.9	7.3	7.6	8.1
Average Condition Rating	3.0	3.0	3.1	3.2	3.1	2.9
Below Condition 2.50 (Percent)	17.0%	14.4%	14.3%	11.2%	10.3%	13.5%
Small Buses						
Fleet Count	7,539	8,689	8,743	8,434	8,267	6,949
Average Age (Years)	6.1	6.5	6.7	6.7	7.1	7.6
Average Condition Rating	3.2	3.1	3.1	3.1	3.0	2.9
Below Condition 2.5 (Percent)	11.4%	15.8%	18.4%	19.6%	22.7%	25.3%
Cutaways						
Fleet Count	9,427	19,477	23,268	26,983	26,753	38,861
Average Age (Years)	4.3	4.6	4.1	4.4	4.8	4.9
Average Condition Rating	3.5	3.4	3.6	3.4	3.3	3.4
Below Condition 2.5 (Percent)	13.0%	18.6%	16.4%	15.4%	16.7%	19.9%
Subtotal: Bus						
Total Fleet Count	**72,129**	**85,642**	**90,617**	**93,182**	**93,863**	**100,813**
Weighted Average Age (Years)	**6.8**	**7.0**	**6.7**	**6.7**	**7.1**	**6.9**
Weighted Average Condition Rating	**3.2**	**3.2**	**3.2**	**3.2**	**3.1**	**3.1**
Below Condition 2.5 (Percent)	**11.5%**	**13.4%**	**13.0%**	**12.3%**	**16.2%**	**19.2%**
Vans						
Fleet Count	20,714	28,846	30,650	28,759	29,207	26,581
Average Age (Years)	3.2	3.7	3.6	3.8	3.8	4.1
Average Condition Rating	3.5	3.4	3.4	3.3	3.3	3.5
Below Condition 2.5 (Percent)	19.1%	25.3%	20.8%	25.7%	27.2%	29.9%
Total: Bus and Van						
Total Fleet Count	**92,843**	**114,488**	**121,267**	**121,941**	**123,070**	**127,394**
Weighted Average Age (Years)	**6.0**	**6.1**	**5.9**	**6.0**	**6.3**	**6.3**
Weighted Average Condition Rating	**3.2**	**3.2**	**3.3**	**3.2**	**3.2**	**3.2**
Below Condition 2.5 (Percent)	**13.2%**	**16.4%**	**15.0%**	**15.5%**	**18.8%**	**21.4%**

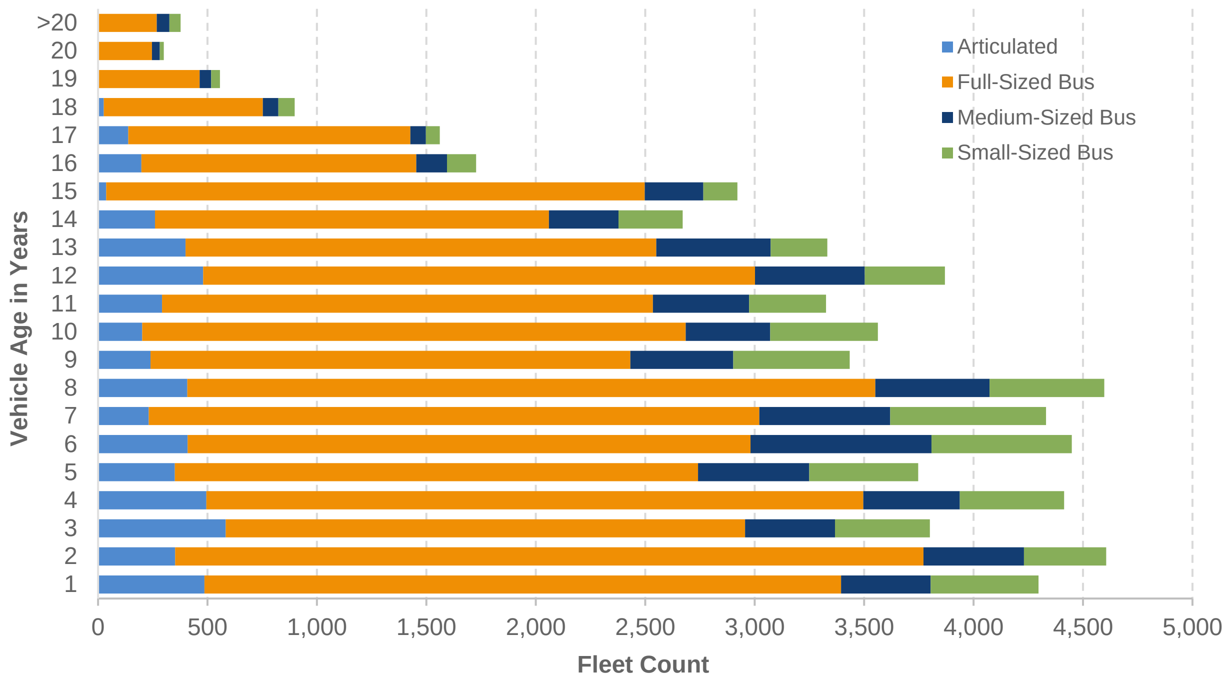
Note: Table excludes NTD records with no date built values.

Note: Rural fleet not included in period 2004–2007 due to lack of data.

Sources: Transit Economic Requirements Model (TERM); National Transit Database.

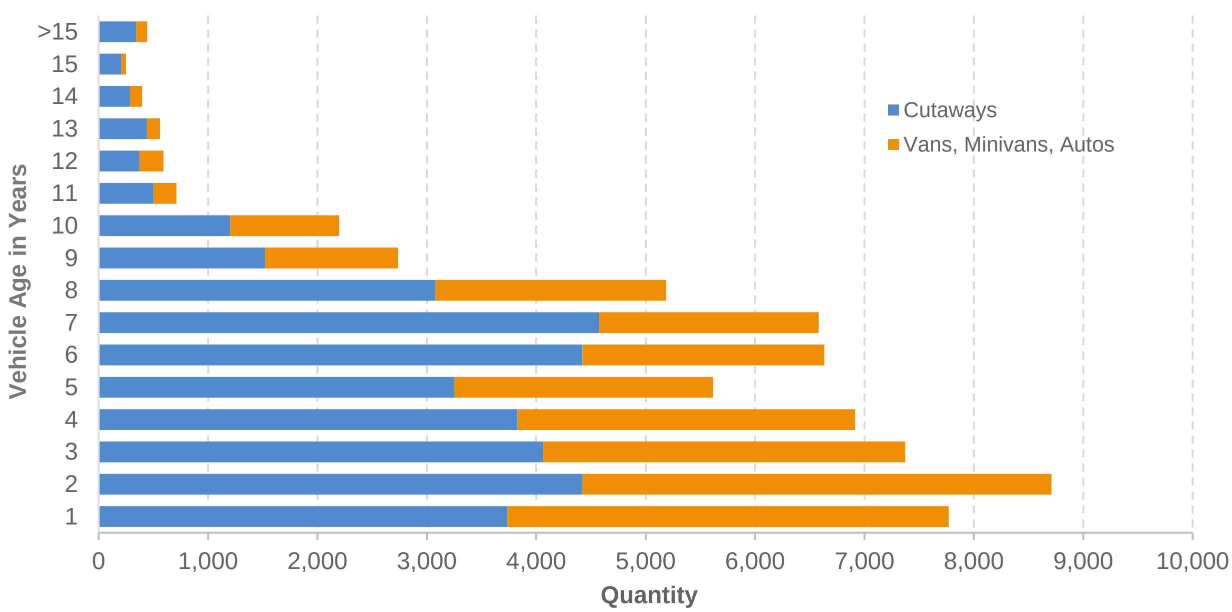
Note that the share of the bus fleet with an average age below their expected average useful life (*Exhibit 6-26)* was quite high in 2016. Most of the buses in the national fleet were 8 years old or less.

Exhibit 6-26 ■ Age Distribution of Fixed-route Buses, 2016



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

Exhibit 6-27 ■ Age Distribution of Vans, Minivans, Autos, and Cutaways, 2016



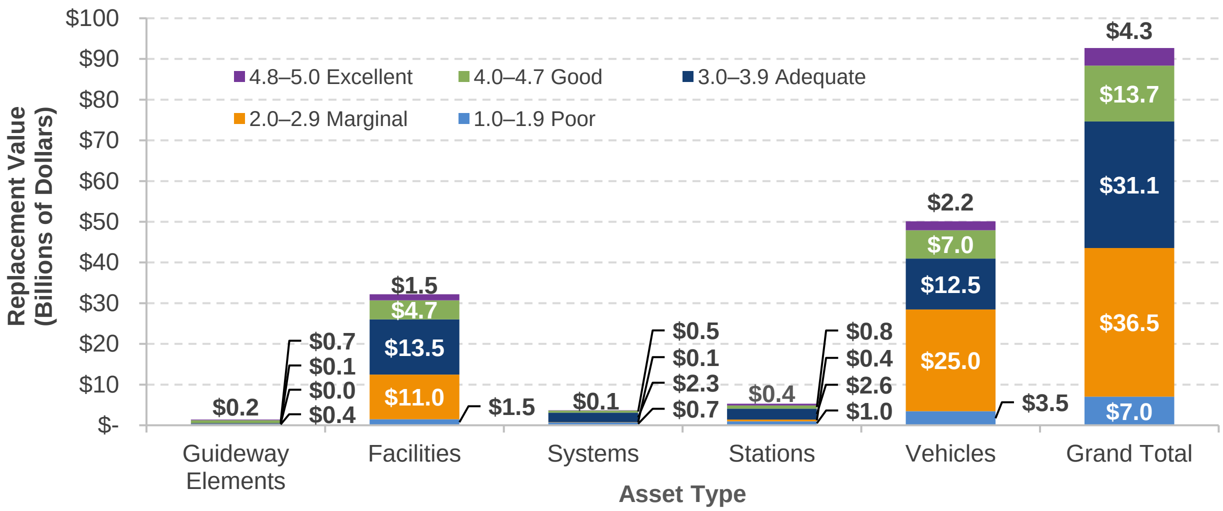
Source: Transit Economic Requirements Model (TERM) and National Transit Database.

A distinction should be made between cutaway, small, and medium-size buses. Cutaways are buses less than 28 feet in length, operating mostly in a demand-response capacity. Small buses are vehicles between 28 and 32 feet long, operating mostly as fixed-route assets. Medium-size buses are vehicles between 32 and 38 feet long.

Other Bus Assets (Urban and Rural Areas)

The more comprehensive capital asset data described earlier in this chapter enable more complete reporting of the overall condition of bus-related assets. *Exhibit 6-28* shows TERM estimates of current conditions for the major categories of replaceable fixed-route bus assets. Vehicles comprise roughly half of all fixed-route bus assets, and maintenance facilities make up roughly one-third. Thirty-nine percent of bus maintenance facilities are rated below condition 3.0, compared with roughly one-half for bus, paratransit, and vanpool vehicles.

Exhibit 6-28 ■ Distribution of Estimated Asset Conditions by Asset Type for Fixed-route Bus, 2016



Note: Exhibit includes replaceable assets, which should be replaced once they are below condition 2.5, and excludes nonreplaceable assets.

Source: Transit Economic Requirements Model (TERM).

Rail Vehicles

NTD compiles annual data on all rail vehicles; these data are shown in *Exhibit 6-29*, 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 21 years old—since 2006. 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 2006. The percentage of vehicles below the SGR replacement threshold (condition 2.5) remained between 2.8 and 3 percent from 2006 to 2014, and increased to 9.9 percent in 2016 (primarily reflecting aging heavy rail fleets). Most vehicles in lesser condition occur in the heavy rail fleet. Notably, the percentage of heavy rail vehicles below the SGR threshold increased from 11.4 to 16.3 percent from 2014 to 2016.

From 2006 to 2016, the Nation's rail transit fleet grew at an average annual rate of roughly 1 percent. This rate of growth was due largely to the rate of increase in the heavy rail fleet (which represents slightly more than half of the total fleet and grew at an average annual rate of 0.8 percent over this period). The annual rate of increase in light rail has been appreciably higher, averaging 2.9 percent while accounting for only 11 percent of the total fleet count. In contrast, the annual rate of increase in commuter rail locomotive and commuter rail passenger coach fleets was intermediate between heavy and light rail, and averaged approximately 2.5 percent and 0.9 percent respectively while accounting for only 4 and 18 percent of the total fleet count. The growth rates for these rail transit types may reflect recent rail transit investments in small and medium-size urban areas where the size and population density do not justify the greater investment needed for heavy rail construction.

Exhibit 6-29 ■ Rail Fleet Count, Age, and Condition, 2006–2016

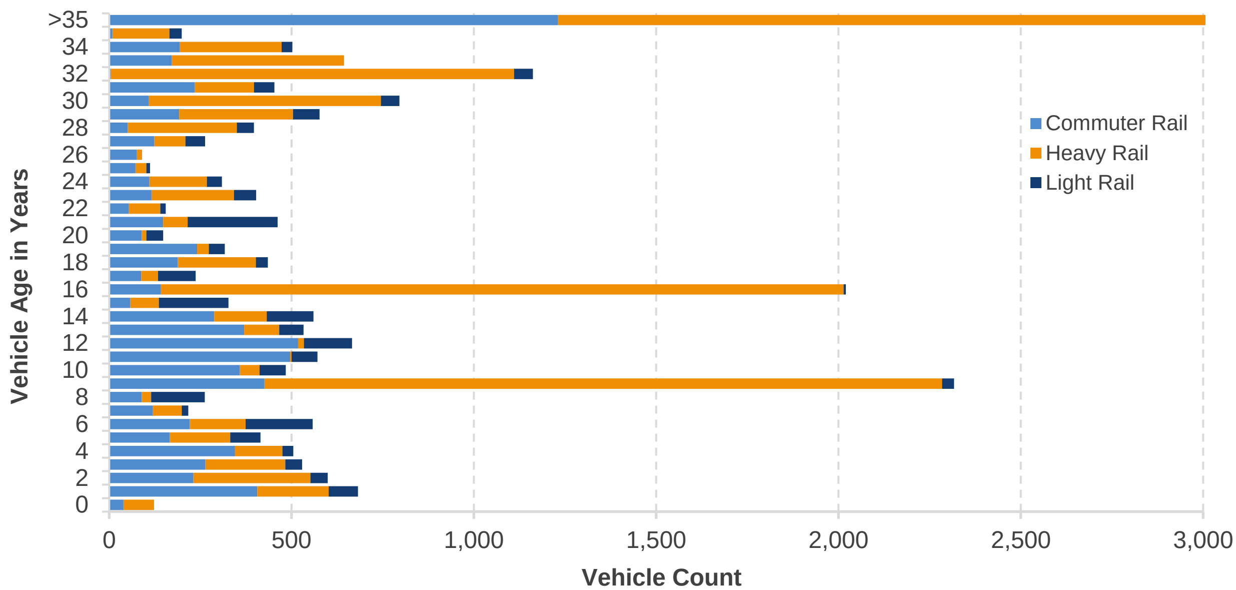
	2006	2008	2010	2012	2014	2016
Commuter Rail Locomotives						
Fleet Count	740	790	822	877	898	946
Average Age (Years)	16.7	19.6	19.4	17.8	19.5	19.7
Average Condition Rating	4.0	3.6	3.6	3.7	3.7	3.6
Below Condition 2.5 (Percent)	0.0%	0.0%	0.0%	1.8%	1.8%	2.7%
Commuter Rail Passenger Coaches						
Fleet Count	3,671	3,539	3,711	3,758	3,742	4,027
Average Age (Years)	16.8	19.9	19.1	20.2	18.9	18.7
Average Condition Rating	4.1	3.6	3.7	3.6	3.6	3.7
Below Condition 2.5 (Percent)	0.0%	0.0%	0.0%	0.4%	4.7%	4.5%
Commuter Rail Self-propelled Passenger Coaches						
Fleet Count	2,933	2,665	2,659	2,930	2,945	2,946
Average Age (Years)	14.7	18.9	19.7	19.7	17.5	17.4
Average Condition Rating	3.8	3.7	3.7	3.6	3.7	3.7
Below Condition 2.5 (Percent)	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%
Heavy Rail						
Fleet Count	11,075	11,570	11,648	11,587	11,859	11,967
Average Age (Years)	22.3	21.0	18.8	19.9	20.7	22.9
Average Condition Rating	3.3	3.3	3.4	3.4	3.4	3.3
Below Condition 2.5 (Percent)	5.5%	6.1%	5.2%	3.7%	11.4%	16.3%
Light Rail[1]						
Fleet Count	1,832	2,151	2,222	2,241	2,416	2,428
Average Age (Years)	14.6	17.1	18.1	14.6	17.8	18.3
Average Condition Rating	3.7	3.6	3.5	3.6	3.5	3.5
Below Condition 2.5 (Percent)	6.4%	7.1%	6.9%	6.3%	2.8%	2.0%
Total Rail						
Total Fleet Count	**20,251**	**20,715**	**21,062**	**21,393**	**21,860**	**22,314**
Weighted Average Age (Years)	**19.3**	**20.1**	**18.9**	**19.3**	**19.6**	**20.8**
Weighted Average Condition Rating	**3.6**	**3.5**	**3.5**	**3.5**	**3.5**	**3.4**
Below Condition 2.5 (Percent)	**3.6%**	**4.2%**	**3.6%**	**2.8%**	**7.4%**	**9.9%**

[1] Excludes vintage streetcars.

Source: Transit Economic Requirements Model and National Transit Database.

Exhibit 6-30 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 12 percent of rail vehicles. Roughly one-third of heavy rail and commuter rail vehicles are more than 25 years old—with about 3,300 heavy and commuter rail vehicles exceeding 35 years in age. Just under half (47 percent) of all rail vehicles, including 46 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.

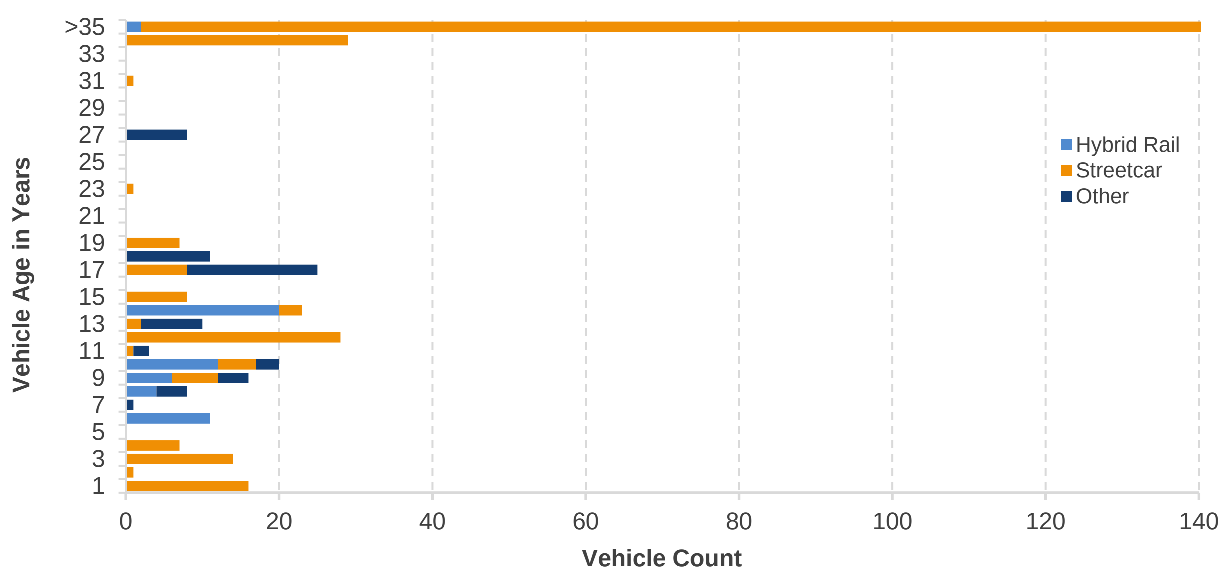
Exhibit 6-30 ■ Age Distribution of Heavy, Commuter, and Light Rail Transit Vehicles, 2016



Source: Transit Economic Requirements Model (TERM).

Comparing the results shown in *Exhibit 6-30* with the age distribution of transit buses and vans displayed in *Exhibit 6-26* and *Exhibit 6-27,* rail vehicles lack the relatively clear pattern of preferred retirement age that is found in buses and vans. *Exhibit 6-31* presents the age distribution of the Nation's hybrid rail, streetcar, and other rail transit vehicles. Streetcar rail vehicles account for 72 percent of the vehicles presented in *Exhibit 6-31*, whereas hybrid rail vehicles account for 10 percent. Roughly three-fourths of streetcar rail vehicles are more than 25 years old, with about two-thirds (65 percent) being more than 35 years old.

Exhibit 6-31 ■ Age Distribution of Hybrid Rail, Streetcar, and Other Rail Transit Vehicles, 2016

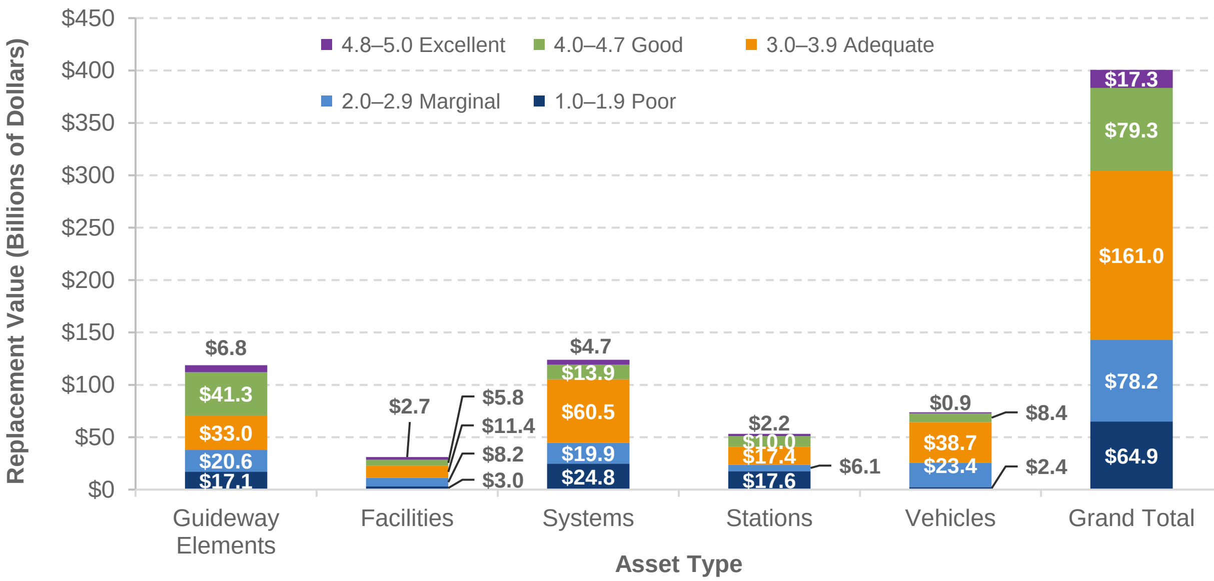


Source: Transit Economic Requirements Model (TERM).

Other Rail Assets

Assets associated with nonvehicle transit rail can be divided into five general categories: guideway elements, facilities, systems, stations, and vehicles. TERM estimates of the condition distribution of replaceable assets for each category are shown in *Exhibit 6-32*.

Exhibit 6-32 ■ Distribution of Asset Physical Conditions by Asset Type for All Rail, 2016



Note: Exhibit includes replaceable assets, which should be replaced once they are below condition 2.5, and excludes nonreplaceable assets.

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

The largest category by replacement value is systems, which consist of power, communication, and train control equipment and have a replacement value of $123.9 billion, of which $24.8 billion is rated below condition 2.0 (20 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.

The second 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 $118.8 billion, of which $17.1 billion is rated below condition 2.0 (4 percent) and $20.6 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 with common life expectancies. Service life for track, for example, depends highly on the amount of use it receives and its location.

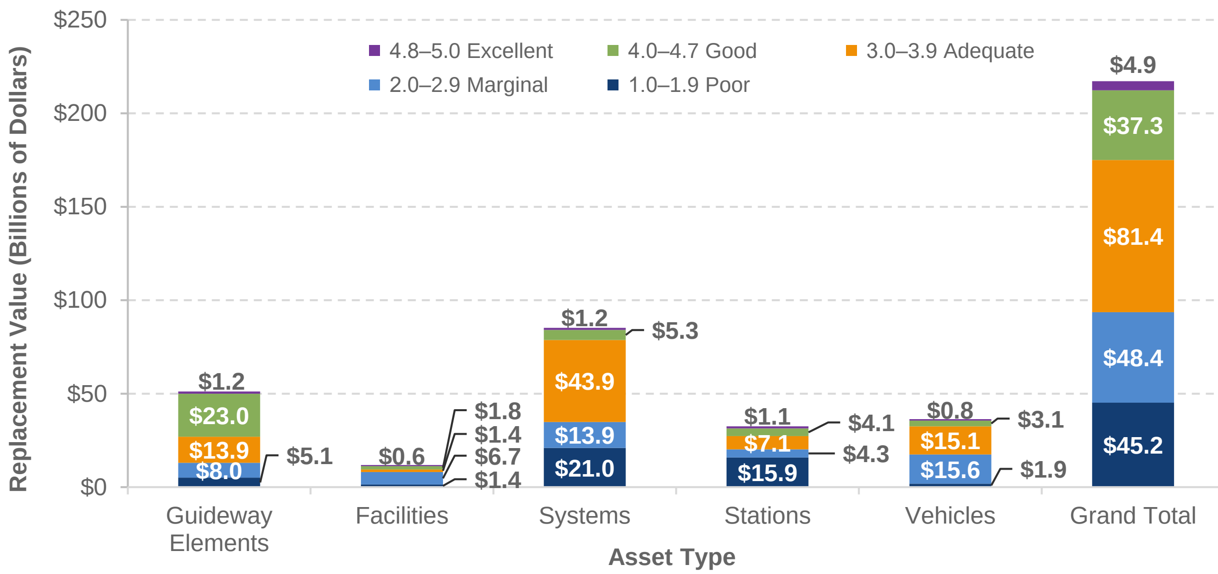
Stations have a replacement value of $53.2 billion, of which $17.6 billion is rated below condition 2.0 and $6.0 billion is rated between conditions 2.0 and 3.0.

Facilities, consisting principally of maintenance and administration buildings, have a replacement value of $31.1 billion. The value of facilities rated below condition 2.0 is $3.0 billion, and the value of facilities between conditions 2.0 and 3.0 is $8.2 billion.

Almost half of rail transit vehicles are in heavy rail systems. Heavy rail represents $525.7 billion (72 percent) of the total transit rail replacement cost of $732.1 billion. Heavy rail serves some of the Nation's oldest and largest transit systems, including Boston, New York, Washington, San Francisco, Philadelphia, and Chicago.

Exhibit 6-32 depicts the replacement value of national transit assets by category for different rail modes. The condition distribution of heavy rail assets, which represent the largest share of U.S. rail transit assets, is shown in *Exhibit 6-33*. *Exhibit 6-34* shows the average age and relative condition of nonvehicle transit assets for fixed-route bus and rail modes reported for 2016.

Exhibit 6-33 ■ Distribution of Asset Physical Conditions by Asset Type for Heavy Rail, 2016



Note: Exhibit includes replaceable assets, which should be replaced once they are below condition 2.5, and excludes nonreplaceable assets.

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

Exhibit 6-34 ■ Nonvehicle Transit Assets: Age and Condition, 2016

Category	Mode Type	Average Age	Avg. Condition	Percent Below Condition 2.5
Facilities	Rail	39.0	3.3	25%
	Fixed-route Bus	30.3	3.3	7%
	All	34.0	3.3	15%
Guideway Elements	Rail	72.5	2.8	43%
	Fixed-route Bus	25.5	4.1	12%
	All	72.1	2.8	43%
Stations	Rail	61.4	2.7	56%
	Fixed-route Bus	22.4	3.3	16%
	All	58.8	2.8	54%
Systems	Rail	37.0	3.1	24%
	Fixed-route Bus	26.1	3.4	17%
	All	36.3	3.1	24%

Source: Transit Economics Requirement Model (TERM).

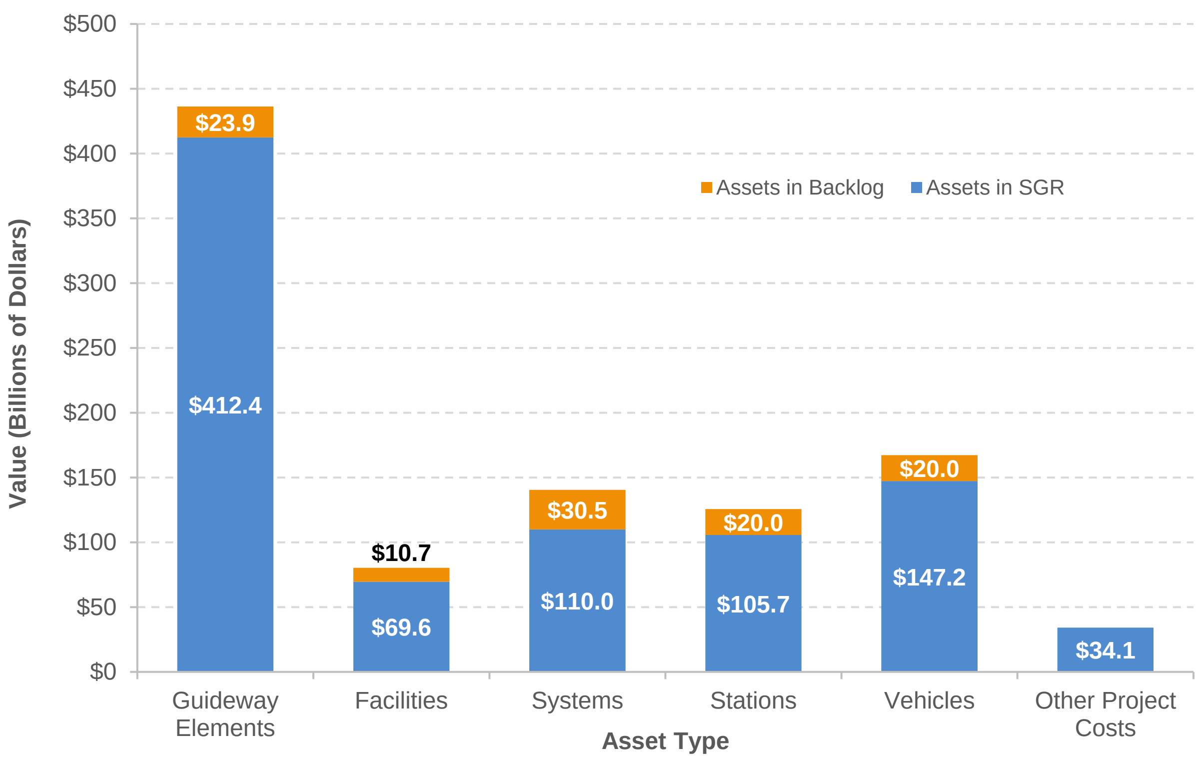
Asset Conditions and SGR

The preceding discussion in this section focused on the value of transit assets in excellent, good, adequate, marginal, or poor condition. The rest of this section considers the value of assets in SGR vs. 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 earlier with the proportions of assets in or out of SGR. This assessment of the value of transit assets in SGR vs. assets in the reinvestment backlog was estimated using 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 6-35 presents the value of both replaceable and nonreplaceable transit assets in SGR vs. those assets in the reinvestment backlog, segmented by asset type. Based on this analysis, roughly $879 billion or 89 percent of all transit assets are in SGR, with the remaining $105 billion (11 percent) making up the reinvestment backlog. The backlog consists of $23.8 billion for guideway, $11.0 billion for facilities, $30.6 billion for systems, $19.9 billion for stations, and $20.0 billion for vehicles. *Exhibit 6-35* includes both replaceable and nonreplaceable assets whereas *Exhibit 6-23* only displays conditions for nonreplaceable assets. These exhibits are somewhat comparable to the extent that the backlog assets in *Exhibit 6-35* correspond to those assets that are in poor condition or are both in marginal condition and below condition 2.5 (assets in marginal condition but above 2.5 are considered to be in SGR).

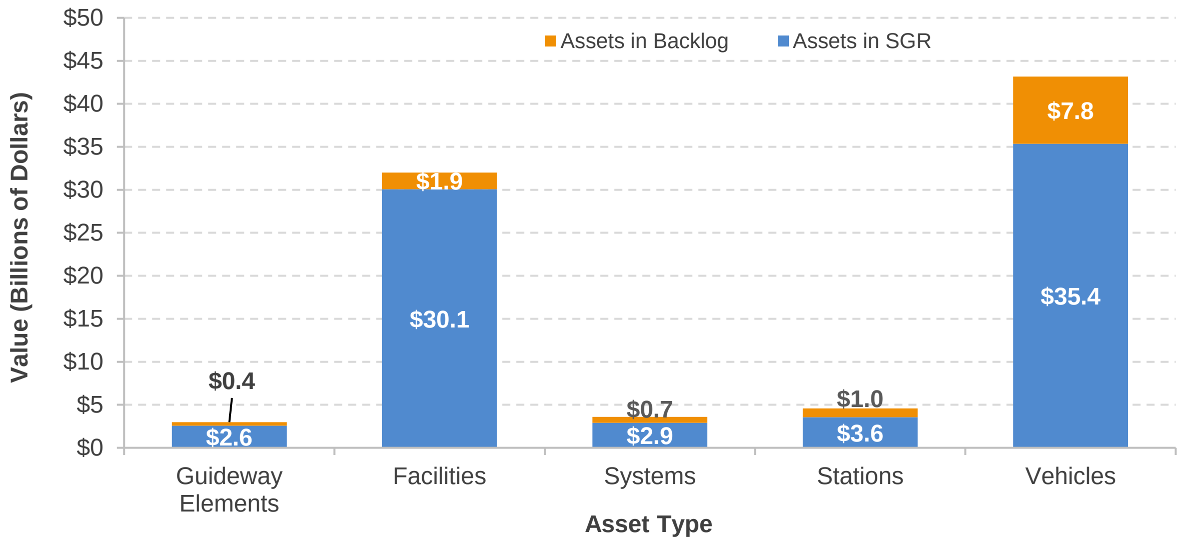
Exhibit 6-35 ■ Value of U.S. Transit Assets in SGR vs. Backlog by Asset Type, 2016



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

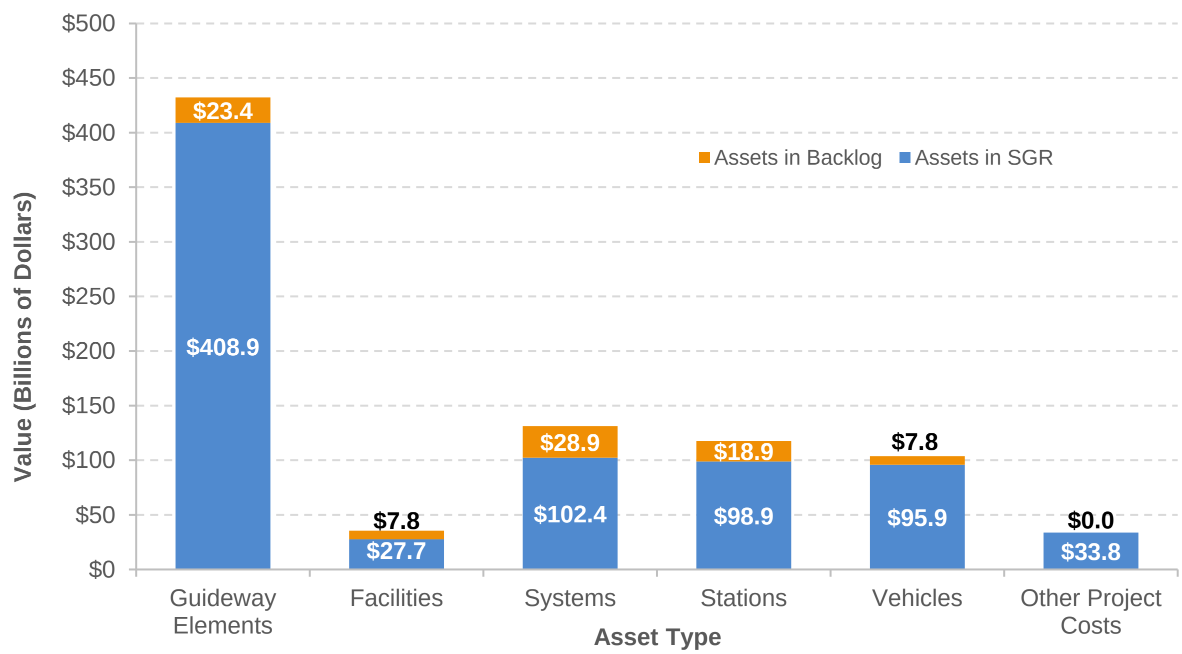
Exhibit 6-36 and *Exhibit 6-37* provide a similar presentation of transit assets in SGR vs. those in the backlog, segmented by fixed-route bus and all rail assets, respectively. *Exhibit 6-36* highlights the fact that 87 percent of fixed-route bus asset value and 82 percent of the bus backlog are concentrated in vehicle fleet and facilities holdings. The value of rail assets in SGR and the value of those in the backlog are similar to those found for all transit assets in *Exhibit 6-37*, demonstrating rail's large share of total transit asset value. Based on these two charts, the reinvestment backlog constitutes 14 percent of fixed-route bus asset holdings and 10 percent of rail asset holdings (by value).

Exhibit 6-36 ■ 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 6-37 ■ Value of U.S. Transit Assets in SGR vs. Backlog by Asset Type for Rail, 2016



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 address the potential contributions of different public or private revenue sources.

The four investment-related chapters in Part II measure investment levels in constant 2016 dollars, except where noted otherwise. The chapters consider scenarios for investment from 2017 through 2036 that are geared toward maintaining some indicator of physical condition or operational performance at its 2016 level, sustaining investment at recent levels, or achieving some objective linked to benefits vs. costs. The average annual investment level over the 20 years from 2017 through 2036 is presented for each analyzed scenario.

Chapter 7, **Capital Investment Scenarios**, defines the core scenarios and examines the associated projections for conditions 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 Analysis**, explores some implications of the scenarios presented in Chapter 7, and discusses potential alternative methodologies. It includes a comparison of highway projections from previous editions of the C&P Report with current findings. This edition includes a special section looking back at the 1968 Highway Needs report, in recognition of the 50^{th} anniversary of the report series.

Chapter 9, **Sensitivity Analysis**, explores the impacts on scenario projections of changes to several key assumptions that are relatively arguable, 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.

Capital Investment Scenarios

Within this report, the term "investment" refers to capital spending, which does not include spending on maintenance. This includes capital spending on the rehabilitation of pavement, bridge, and transit assets that may be described as "maintenance" in other contexts. Additional discussion of the distinction between capital and maintenance spending is contained in Chapter 2 of this report.

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 system conditions 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 analytical models used to develop the projections 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 quantifying them and valuing them monetarily, and these other benefits and costs can and do affect project selection. In addition, actual project selection can be guided by other considerations outside benefit-cost analysis (BCA).

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. Due to data limitations, Chapter 7 factors these elements into the investment levels associated with each scenario using scaling procedures external to the models. 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. Thus, to develop scenarios based on all roads, nonmodel-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 types of capital spending identified as "system enhancement" in Chapter 2. This includes targeted safety-focused projects (e.g., adding rumble strips).

Whereas Chapter 7 focuses on investment scenarios for all roads, Chapter 10 includes model-based projections for Federal-aid highways, the National Highway System, and the Interstate System separately.

Sustain Recent Spending Scenario

Some earlier C&P Report editions included analyses showing the impacts of sustaining spending at base-year levels, but the 2008 C&P Report was the first to include a full-fledged scenario projecting the impact of sustaining investment at base-year levels in constant-dollar terms. This approach was retained in subsequent editions; most recently, the 23rd C&P Report included a "Sustain 2014 Spending" scenario. Although this scenario has proven useful in providing a frame of reference to readers, one issue with this approach was that spending levels in a single base year could be influenced by one-time events, and might not be representative of typical annual spending. This edition replaces this scenario with a Sustain Recent Spending scenario, based on average annual spending over 5 years (2012–2016) converted to base-year (2016) constant dollars. This approach is expected to smooth out annual variations and make the scenarios more consistent between editions of this report. (In addition, as discussed in Chapter 2, the 2016 highway spending data presented in this C&P Report were all estimated, as actual data were not available in time for inclusion. Basing the scenario on a range of years rather than a single year reduces the influence of these estimated data.)

Exhibit II-1 presents the derivation of the annual investment level for the Sustain Recent Spending scenario. Using the National Highway Construction Cost Index (NHCCI) to convert spending from current dollars to constant 2016 dollars yields an average annual capital spending level from 2012 to 2016 of $106.9 billion. The Sustain Recent Spending scenario projects the potential impacts of sustaining capital spending at this level in constant-dollar terms over the 20-year period of 2017 through 2036.

Exhibit II-1 also shows the portion of total capital spending that was directed toward Interstate highways, the National Highway System, and Federal-aid highways. This distribution varied significantly by year (for example, the share of capital spending directed toward Interstate highways was 19.5 percent in 2012 compared to 24.0 percent in 2014), illustrating the utility of smoothing out the analysis using a multiyear perspective.

Exhibit II-1 ■ Derivation of Annual Investment Level for the Sustain Recent Spending Scenario, Highways

Functional System	2012	2013	2014	2015	2016	5-Year Average
National Highway Construction Cost Index (2003 Quarter 1 = 1.0000)						
Four-quarter Average	1.6016	1.6130	1.6816	1.6984	1.6606	
Highway Capital Spending, All Levels of Government (Billions of Dollars)						
Current Dollars	$105.3	$98.7	$105.4	$109.3	$112.9	$106.3
Constant 2016 Dollars[1]	$109.2	$101.6	$104.1	$106.9	$112.9	$106.9
Highway Capital Spending, by System (Billions of Constant 2016 Dollars) [2]						
Interstate Highway System	$21.2	$19.8	$25.0	$25.7	$26.4	$23.6
National Highway System	$56.6	$52.7	$55.6	$57.1	$59.2	$56.2
Federal-aid Highways	$81.9	$76.3	$78.3	$80.4	$84.1	$80.2
All Roads	$109.2	$101.6	$104.1	$106.9	$112.9	$106.9

[1] Spending was converted from current to 2016 constant dollars by taking the value for a given year, dividing by the index value for that year, and multiplying by the index value for 2016.

[2] Note: The distribution by system in 2013 was estimated based on 2012 data; the distribution by system in 2015 and 2016 was estimated based on 2014 data.

Sources: FHWA Bulletin: Highway Funding 2013–2016, Table HF-10B; Highway Statistics, various years, Tables HF-10A and PT-1.

Maintain Conditions and Performance Scenario

The Maintain Conditions and Performance scenario also assumes that capital spending in constant-dollar terms remains flat between 2017 and 2036—not at the recent spending level, but instead at the level that would result in selected performance indicators having the same values in 2036 as in 2016. 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 bridges that are in poor condition, weighted by deck area.

Improve Conditions and Performance Scenario

The investment levels for the Improve Conditions and Performance scenario are estimates of what would be needed to exactly 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. Given the existence of a backlog of unmet capital investment needs, the investment pattern of this scenario is front loaded, with the highest investment levels in the earliest years.

Implications of Capital Spending under the Improve Conditions and Performance Scenario for Non-capital Spending

Maintenance and other-non capital spending are substantial, constituting roughly half of all highway expenditures (see Chapter 2, Exhibit 2-2). One important question about the Improve Conditions and Performance scenario is how increasing the capital investment level could affect future non-capital costs.

While the HERS model focuses on capital investments, in estimating the benefits of such investments it considers their impact on routine 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. As such, increases in capital spending on rehabilitation projects generally reduce the need for future maintenance spending by improving pavement condition. Conversely, increases in spending on 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. Based on the mix of projects included in the Improve Conditions and Performance scenario for this report, HERS projects an overall decline in maintenance costs per mile of 27.4 percent. The NBIAS model similarly estimates lower maintenance costs as bridge condition improves; NBIAS does not simulate capacity expansion projects.

The increased capital investment under the Improve Conditions and Performance scenario would likely result in additional planning costs, as the volume and complexity of projects included would tend to be greater than what is currently reflected in long-term capital investment plans. It is however unclear whether such increased planning costs would be directly proportional to increased capital investment levels. 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.

To the extent that increased spending under the Improve Conditions and Performance scenario were financed through the issuance of bonds, this would tend to increase future bond interest and bond redemption expenses.

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 NBI database, which covers bridges in all highway functional classes, and evaluates improvements that generally fall within the system rehabilitation category.

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 considers the 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 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.

Capital Improvements Modeled in HERS and NBIAS vs. Capital Improvement Type Categories Presented in Chapter 2

Exhibit 2-13 (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 2-13*, HERS splits spending on "reconstruction with added capacity" among these categories.

For some of the detailed categories in *Exhibit 2-13*, 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. 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.

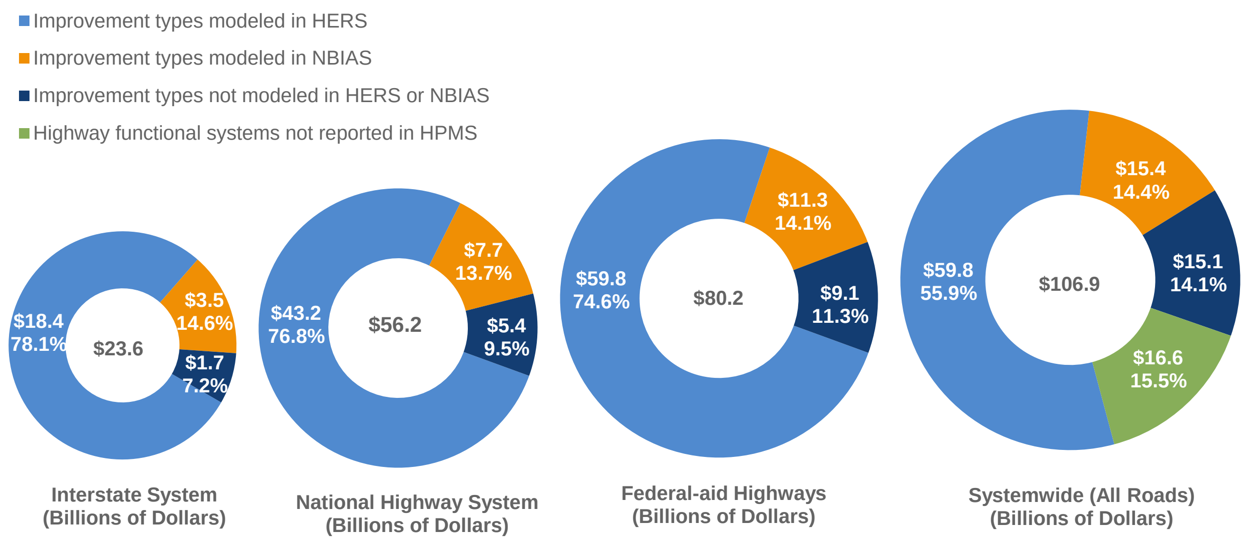
Some other comparability issues include:

- Some of the relocation expenditures identified in *Exhibit 2-13* 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 2-13* 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 rehabilitation and expansion investments.

Nonmodeled spending also includes types of capital expenditures classified in Chapter 2 as system enhancements (safety enhancements, traffic operation improvements, and environmental 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. (Part IV of this report references a recommendation to begin capturing Model Inventory of Roadway Elements [MIRE] data in the HPMS. The inclusion of such data would help facilitate direct analysis of safety-oriented investments within HERS in the future.)

Exhibit II-2 shows that the systemwide highway capital spending for the Sustain Recent Spending scenario was $106.9 billion. (The Sustain Recent Spending scenario is discussed in greater detail in Chapter 7.) Of that spending, $59.8 billion (55.9 percent) was for the types of improvement that HERS models, and $15.4 billion (14.4 percent) was for the types of improvement NBIAS models. The other $31.7 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.

Exhibit II-2 ■ Distribution of Recent Capital Expenditures by Investment Type



Note: VMT is vehicle miles traveled; HERS is Highway Economic Requirements System; NBIAS is National Bridge Investment Analysis System.

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

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 $80.2 billion in spending by all levels of government on capital improvements to Federal-aid highways in the Sustain Recent Spending scenario, 74.6 percent was within the scope of HERS, 14.1 percent was within the scope of NBIAS, and 11.3 percent was for spending not captured by either model. The percentage distribution differs somewhat for the Interstate System, with a higher share within the scope of HERS and NBIAS (78.1 percent and 14.6 percent, respectively) and a smaller share captured by neither (7.2 percent).

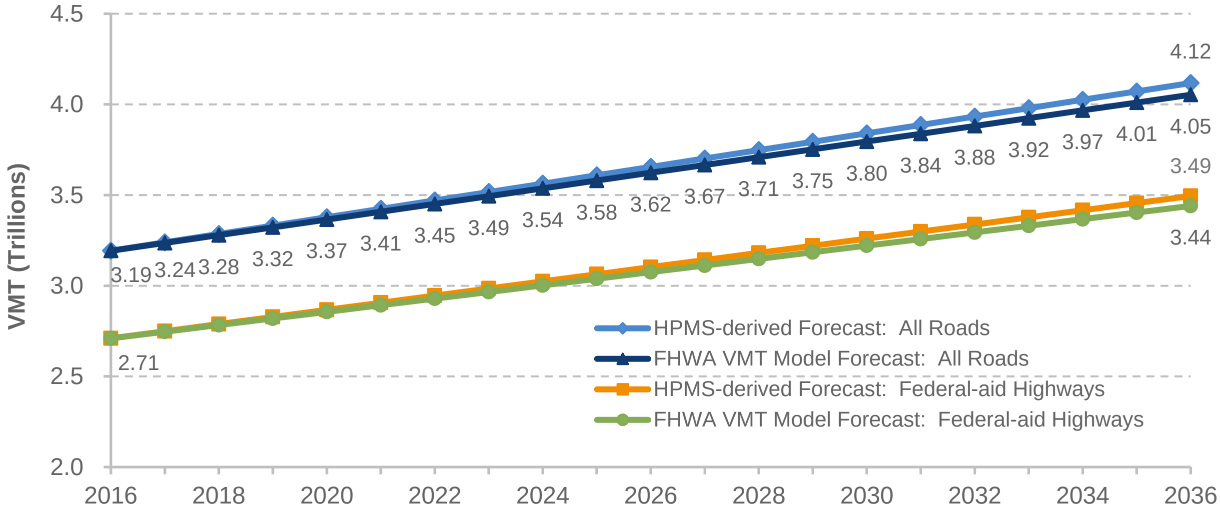
Future Travel Volumes Assumed in HERS and NBIAS

As discussed in Chapter 9 (Traffic Growth Projections section), the HERS and NBIAS modeling in this edition of the C&P Report supplements section-level travel forecasts from the Highway Performance Monitoring System (HPMS) and bridge-level traffic forecasts from the National Bridge Inventory (NBI) with a 20-year national-level vehicle miles traveled (VMT) forecast from an FHWA econometric model. Aggregating the forecasts for individual sample sections yields a composite, weighted average annual travel growth rate of 1.28 percent. (Aggregating the traffic forecasts for individual bridges yields an average of 1.35 percent per year.) These location-specific forecasts were scaled down proportionally so that the national average would match the 1.2-percent value published online as *FHWA Forecasts of Vehicle Miles Traveled (VMT): Spring 2018*.

Exhibit II-3 translates the HPMS-derived VMT growth rate and the FHWA VMT model forecast into projected VMT for each year from 2016 to 2036. Although the HPMS-derived forecast applies only to Federal-aid highways (the HPMS sample is limited to Federal-aid highways), this growth rate is applied to all VMT for illustrative purposes. A 1.2-percent annual FHWA VMT growth rate implies that national VMT will rise from 3.19 trillion in 2016 to 4.05 trillion in 2036, with VMT on Federal-aid highways rising from 2.71 trillion to 3.44 trillion over this period. Applying the 1.28-percent HPMS-derived forecast annual growth rate would yield national VMT of 4.12 trillion, of which 3.49 trillion would be on Federal-aid highways.

Consistent with the approach used in the last several C&P Reports, future VMT is assumed to grow linearly (so that one-twentieth of the additional VMT is added each year), rather than geometrically (growing at a constant annual rate). With linear growth, the annual percentage rate of growth gradually declines over the forecast period. This approach is logically consistent with the FHWA national VMT forecasting model, which projects lower average annual VMT growth rates over 30 years than it does over 20 years.

Exhibit II-3 ■ Annual Projected Highway VMT Based on HPMS-derived Forecasts or FHWA VMT Forecast Model, 2016–2036



Note: VMT is vehicle miles traveled; HPMS is Highway Performance Monitoring System. Year-by-year values are shown only for the "FHWA VMT Model Forecast: All Roads" line, as these would be most appropriate for citation as FHWA's official forecast.

Sources: Highway Performance Monitoring System; FHWA Forecasts of Vehicle Miles Traveled, May 2018.

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 130,000 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 with respect 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 road 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.

The HERS model relies on a variety of 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 reflect real-world dynamics more accurately. See Appendix A for a discussion of recent and ongoing enhancements to the model.

Operations Strategies

HERS considers the impacts of certain types of highway operational improvements that feature intelligent transportation systems.[23] The operations strategies HERS currently evaluates are:

- Arterial management: upgraded signal control, electronic roadway monitoring, emergency vehicle signal preemption, variable message signs.
- Freeway management: ramp metering, electronic roadway monitoring, variable message signs, integrated corridor management, active traffic management (dynamic lane and merge controls, dynamic speed limits, queue warning systems).
- Incident management: detection, verification, response.
- Traveler information: 511 systems, advanced in-vehicle navigation systems with real-time traveler information.

It is important to note that HERS does not analyze the benefits and costs of these investments. Instead, a separate preprocessor predicts where such investments would most likely occur and estimates the impacts of these operations strategies on the performance of highway sections where they would be deployed. The resulting output is entered into HERS as the starting point for its analysis of pavement improvements and widening options. Due to the nature of this two-step process, HERS does not directly analyze tradeoffs between these types of operational improvements and potential widening options.

The analyses presented in this edition assume that the deployment of operational improvements over the next 20 years will continue at a rate consistent with existing patterns. HERS is also equipped to analyze the impact of a more aggressive deployment strategy over 20 years or over 5 years. The 2013 C&P report and 2015 C&P report included sensitivity analyses exploring the impacts of these alternatives.

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 VMT, to changes in the average user cost of travel. Such changes could result from either:

- 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., travel delay increases) and increases travel demand when changes are for the better (e.g., pavement condition improves); or

[23] https://www.pcb.its.dot.gov/eprimer/default.aspx

- Deviations from the presumed user cost of travel built into the baseline demand forecasts (e.g., changes in fuel prices not considered in the forecasts).

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 highway sections, the initial 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 offset 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. This feature works in both directions: if the conditions and performance of a highway section worsen relative to base year conditions, a portion of projected future travel on that section would be suppressed.

One implication of the inclusion of travel demand elasticity in HERS is that the overall projected level of future VMT is directly affected by the assumed level of future highway capital spending. Simulations with relatively higher investment levels that lead to reductions in average user costs will project higher future traffic volumes than will simulations with relatively lower investment levels that lead to increases in average user costs. The annual projected VMT values identified in *Exhibit II-3* represent inputs to this process, and typically would not match the outputs from this process.

National Bridge Investment Analysis System

The scenario estimates specific to bridge repair and replacement discussed in this edition of the C&P 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 are based on synthesized element-level data. Examples of bridge elements include bridge decks, steel girders used for supporting the deck, concrete pier caps on which girders are placed, concrete columns used for supporting the pier cap, and bridge railings. Bridge elements are discussed in greater detail in Chapter 6 and Appendix B.

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 life-cycle 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. Under this analysis, replacement of a bridge is recommended if a bridge evaluation results in lower life-cycle costs compared with the recommended MR&R work. (Notwithstanding the use of the term "maintenance," the MR&R actions considered in NBIAS are actually capital improvements; preventive maintenance, such as cleaning scuppers or washing bridges, is not modeled.)

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 investment analyses presented in this report are based on results from the Transit Economics Requirements Model (TERM). The transit section of Chapter 10 evaluates the impact of varying levels of capital investment on various measures of conditions and performance, whereas the transit section of Chapter 7 provides a more in-depth analysis of specific investment scenarios.

TERM includes a benefit-cost test that is applied to expansion scenarios to determine which investments are cost-effective and which are not. For scenarios in which this test is enabled, TERM reports investment costs only for investments that pass the test.

The Sustain Recent Spending scenario projects the potential impacts of sustaining preservation and expansion spending at recent spending levels, based on average annual spending over 5 years (2012–2016) converted to base-year (2016) constant dollars. *Exhibit II-4* presents the derivation of the annual investment level for this scenario. Using the RS Means Construction Index to convert spending from current dollars to constant 2016 dollars yields an average annual capital spending level from 2012 to 2016 of $18.9 billion. The Sustain Recent Spending scenario projects the potential impacts of sustaining capital spending at this level in constant-dollar terms over the 20-year period of 2017 through 2036. The scenario applies BCA to prioritize investments within this constrained budget target.

Exhibit II-4 ■ Derivation of the Annual Investment Level for the Sustain Recent Spending Scenario, Transit

Functional System	2012	2013	2014	2015	2016	5-Year Average
RS Means Construction Index (2016 = 100)						
Four-quarter Average	92.73	94.37	97.58	99.37	100.00	
Transit Capital Spending, All Modes (Billions of Dollars)						
Current Dollars	$16.8	$17.1	$17.4	$19.3	$19.4	$18.0
Constant 2016 Dollars	$18.4	$18.4	$18.1	$19.7	$19.4	$18.9
Annual Transit Capital Expenditures, by Purpose (Billions of Constant 2016 Dollars)						
Preservation	$10.7	$11.7	$11.6	$12.6	$12.7	$11.6
Expansion	$7.7	$6.8	$6.6	$7.0	$6.7	$7.2

Note: Excludes reduced reporter agencies.

Source: National Transit Database.

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 benchmark assumes no future ridership growth, focusing solely on the preservation of existing assets, and does not apply the TERM benefit-cost test. The SGR Benchmark estimates the cost of maintaining what is currently in service as an analytical exercise.

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 to expand the transit asset base to support projected ridership growth over 20 years, based on forecasts linked to the average annual growth experienced between 2001 and 2016. The Low-Growth scenario projects ridership growth at 0.3 percent per year below the historical trend (over 15 years), whereas 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. The resulting ridership rate in the Low-Growth scenario is 1.28 percent per year. 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.

The data used to support TERM's needs estimates are derived from a variety of sources—including fleet investment and transit performance data obtained from the National Transit Database (NTD), asset inventory data provided by local transit agencies (at FTA's request), and historical annual rates of ridership growth calculated by region, agency size, and mode. The rate used in the Low-Growth scenario decreases the 15-year historical growth rate for all modes by 0.3 percent without allowing any growth rates to go below zero. The resulting ridership rate in the Low-Growth scenario is 1.28 percent per year. The rate in the High-Growth scenario is 1.82 percent per year. Appendix C contains a detailed description of the analysis methodology used by TERM, and Chapter 8 provides additional detail on the growth rates.

Transit Economic Requirements Model

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).

The data used to support TERM's needs estimates are derived from a variety of sources—including fleet investment and transit performance data obtained from the National Transit Database (NTD), asset inventory data provided by local transit agencies (at FTA's request), and historical annual rates of ridership growth calculated by region, agency size, and mode. Appendix C contains a detailed description of the analysis methodology used by TERM, and Chapter 8 provides additional detail on the growth rates.

Preservation Investments

TERM estimates current and future preservation investment needs by first assessing the 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 an 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 subsequent years). 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.

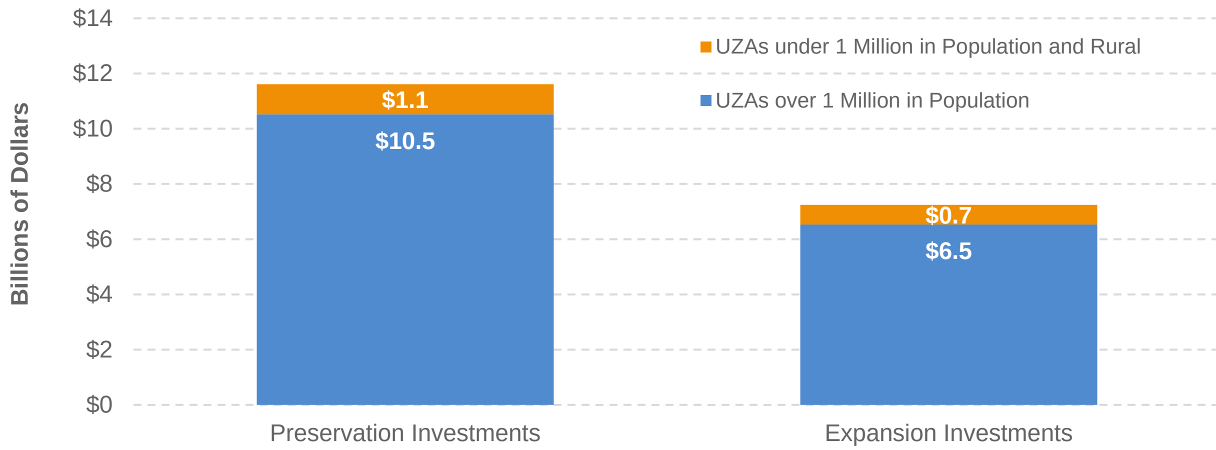
To assess the level of investment required to maintain existing service quality, TERM estimates the rate of growth in transit vehicle fleets required to maintain current vehicle occupancy levels given the projected growth rate in transit passenger miles. In addition to assessing the level of investment 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.

Recent Investment in Transit Preservation and Expansion

Exhibit II-5 shows the broad composition of average annual capital expenditures by U.S. transit agencies over the period 2010–2016. Of the total spending of $18.9 billion, $11.6 billion or 61.6 percent was devoted to preserving existing assets, and the rest was spent on expansion investments.

As expected, preservation and expansion spending were concentrated in the large urban systems. Urbanized areas with populations greater than 1 million accounted for an average of 90.6 percent of preservation spending and 90.2 percent of expansion spending. Smaller urbanized and rural areas accounted for the rest. Although preservation and expansion spending for rural systems is small relative to that for large urban systems, rural transit service has been growing at roughly 2 percent annually since 2008. Every State and four U.S. Territories provide some form of rural transit service in low-density areas, improving the accessibility for Americans living in these areas.

Exhibit II-5 ■ Recent Transit Capital Expenditures (Average 2012–2016)



Source: National Transit Database.

Comparisons Between Report Editions

The base year of the analysis typically advances 2 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.

Choice of 5-year Period for Sustain Recent Spending Scenario

The shift from a Sustain Current (1-year) Spending scenario to a Sustain Recent (5-year) Spending scenario was driven by a desire to smooth out the effects that one-time events could have on spending patterns in a particular year. This report often looks back 10 years in documenting conditions, performance, and funding trends, but this period was considered too long to be representative of typical recent spending. Although shorter periods, such as 3 years, were considered, a 5-year period was ultimately selected based on an examination of historical annual spending patterns.

Although the 5-year (2012–2016) average annual highway capital spending level of $106.9 billion is higher in constant-dollar terms than the $112.9 billion estimated for 2016 alone, this is not always the case for 5-year averages vs. single-year values. For example, had a Sustain Recent Spending scenario been presented in the 23rd C&P Report, it would have had a higher annual funding level than the Sustain 2014 Spending scenario that was presented, as the 5-year average from 2010 to 2014 was higher in constant-dollar terms than highway capital spending in 2014 alone.

Similarly, although the 5-year (2012–2016) average annual transit capital spending level of $19.5 billion is higher in constant-dollar terms than the $18.5 billion spent in 2016 alone, the gap would be much smaller if comparing the average from 2010–2014 with 2014 spending.

Modeling Considerations

Applying an economic approach to transportation investment modeling 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." Although 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 economically focused and in other ways more sophisticated over time. The HERS model was first utilized in the production of the 1995 C&P Report. TERM was introduced in the 1997 C&P report, whereas NBIAS was first used in the 2002 C&P report. Each of these tools has subsequently undergone several rounds of updates and refinements to expand their accuracy and coverage. Appendix D describes an ongoing *Reimagining the C&P Report in a Performance Management-Based World* effort initiated by the Federal Highway Administration in late 2012, which includes an evaluation of alternative methodologies to replace or improve the BCA-driven tools currently used in the C&P Report.

As in any modeling process, simplifying assumptions have been adopted to make 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 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.

Each of the models used in this report—HERS, NBIAS, and TERM—omits various types of investment impacts from its BCAs. To some extent, these omissions reflect 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.

HERS, NBIAS, and TERM have not yet evolved to the point that they can be used for direct multimodal analysis. Although the three models use BCA, their methods for implementing this analysis are very different. Each model is based on a separate, distinct database. Each model 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 BCA approach 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.

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 earlier in this section, the analysis in Chapter 9 of this edition of the C&P Report enables uncertainty to be addressed by exploring the sensitivity of the scenario projections to changes in the underlying parameters (e.g., discount rates, value of time saved, statistical value of lives saved). As much as is 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.

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.

CHAPTER 7: Capital Investment Scenarios

Capital Investment Scenarios – Highways

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

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

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

KEY TAKEAWAYS

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

Scenarios Selected for Analysis

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

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

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

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

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

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

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

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

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

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

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

Scenario Spending Levels and Sources

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

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

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

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

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

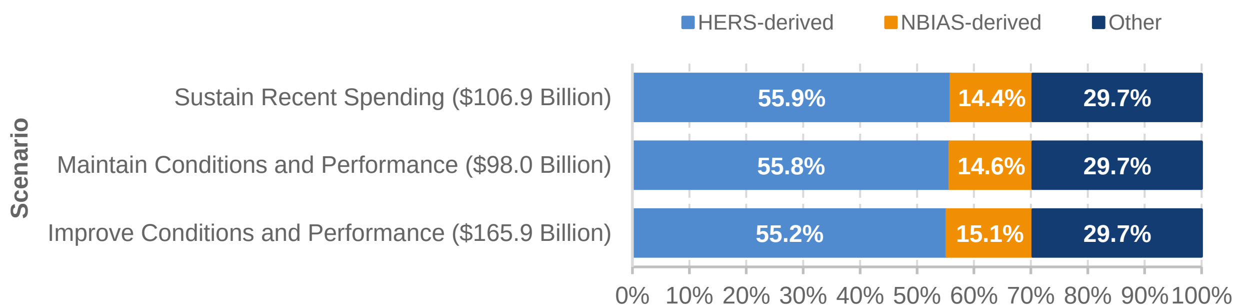
The estimated level of annual investment needed to achieve the objectives of the Maintain Conditions and Performance scenario is $98.0 billion, 8.3 percent less than the Sustain Recent Spending scenario level. This suggests that recent levels of investment would be sufficient to keep overall conditions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

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

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

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

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



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

Key Limitations of the HERS Model

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

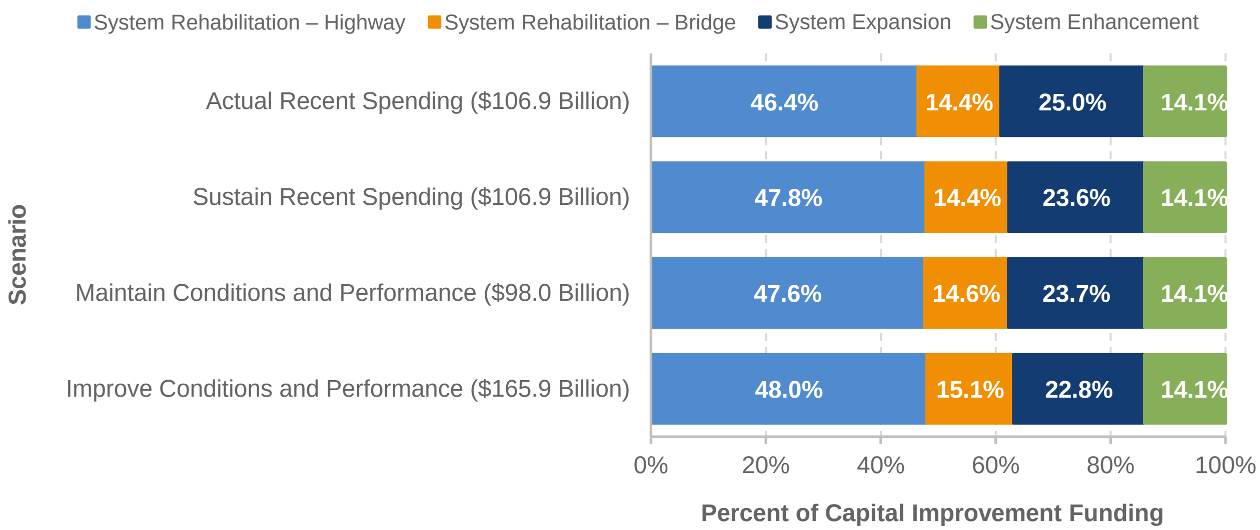
The NBIAS-derived component represents rehabilitation spending on all bridges, including those not on Federal-aid highways. Other (nonmodeled) spending, which accounted for 29.7 percent of total investment in 2016, is assumed to comprise the same share in all systemwide scenarios. The nonmodeled share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

Systemwide Scenario Spending Patterns and Conditions and Performance Projections

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

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

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

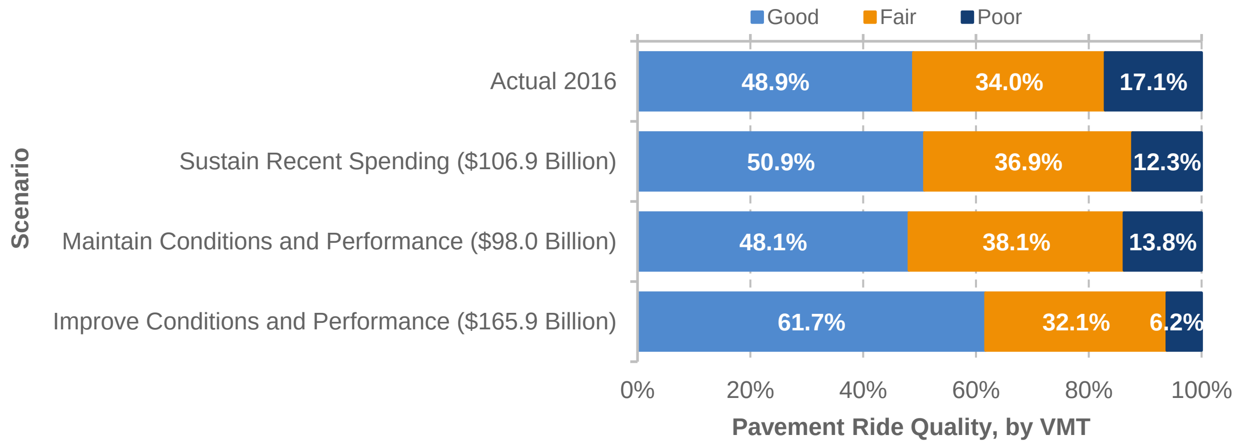


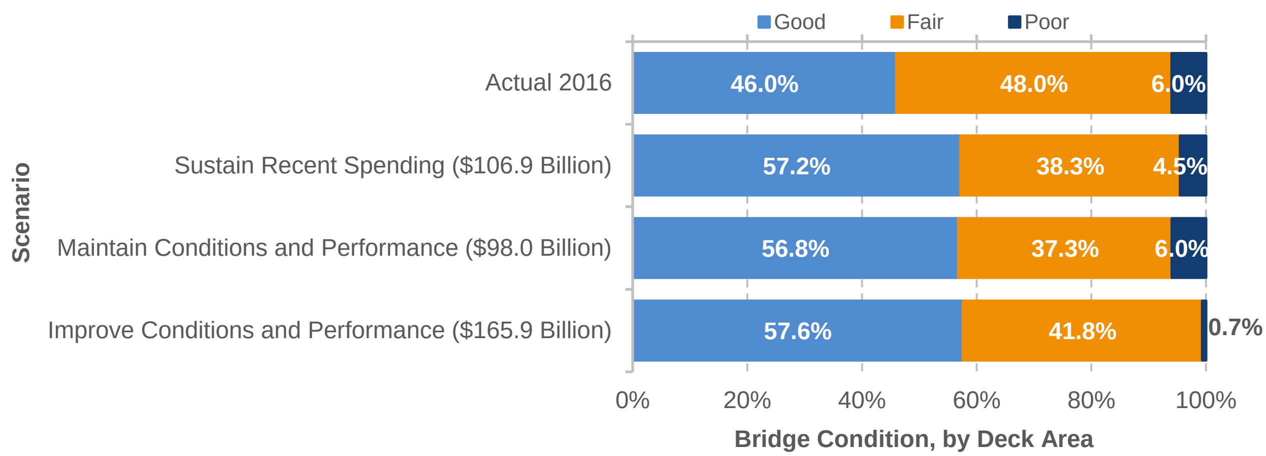
Average Annual Distribution by Capital Improvement Type (Billions of 2016 Dollars)				
Capital Improvement Type	**Actual Recent Spending Distribution**	**Sustain Recent Spending Scenario**	**Maintain Conditions & Performance Scenario**	**Improve Conditions & Performance Scenario**
System Rehabilitation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

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

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

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





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

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

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

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

VMT-Weighting vs. Deck Area-Weighting

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

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

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

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

Improve Conditions and Performance Scenario

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

Spending by System and by Capital Improvement Type

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

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

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

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

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

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

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

Spending by Improvement Type and Highway Functional Class

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

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

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

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

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

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

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

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

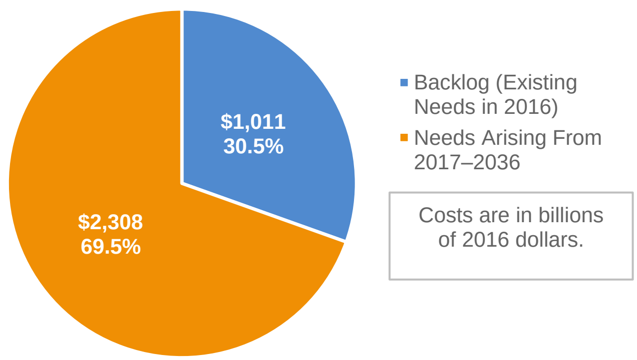
Sources: Highway Economic Requirements System and National Bridge Investment Analysis System.

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

Highway and Bridge Investment Backlog

The investment backlog represents all highway and bridge improvements that could be economically justified for immediate implementation, based solely on the current conditions and operational performance of the highway system (without regard to potential future increases in VMT or potential future physical deterioration of infrastructure assets). Unlike NBIAS, HERS does not routinely produce rolling backlog figures over time as an output, but is equipped to do special analyses to identify the base-year backlog. Under this analysis, any potential improvement that would correct an existing pavement or capacity deficiency and that has a benefit-cost ratio greater than or equal to 1.0 is considered part of the current highway and bridge investment backlog.

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



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

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

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

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

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

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

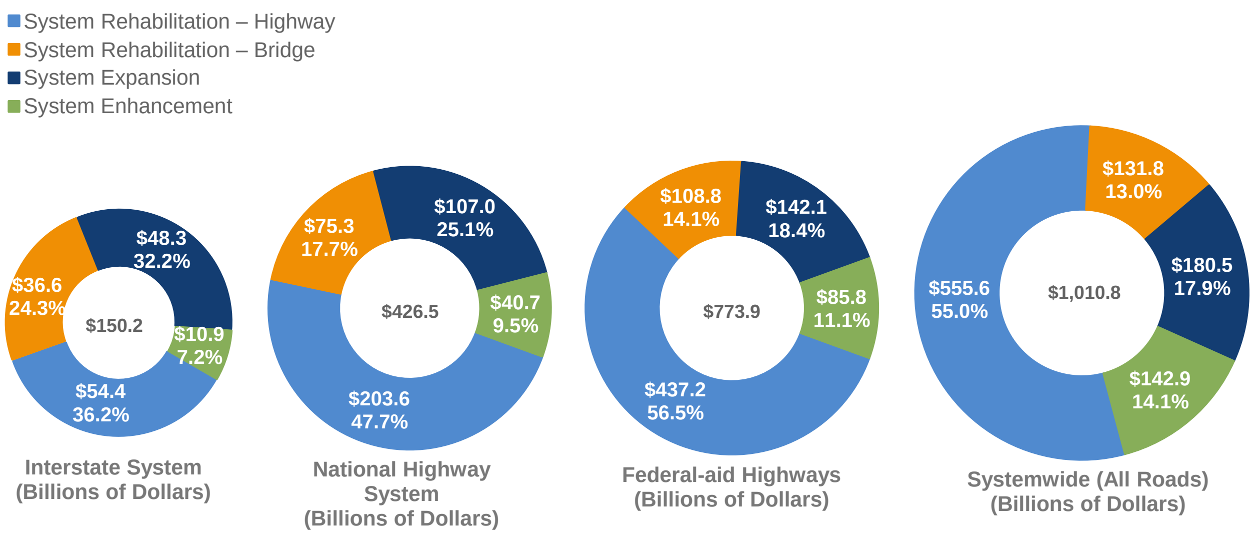
Why Does the Bridge Backlog Presented in Exhibit 7-9 Differ from Bridge Backlog Figures Estimated by Some Other Organizations?

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

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

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

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



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

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

[1] Italicized values are estimates for those system components and capital improvement types not modeled in HERS or NBIAS, such as system enhancements and pavement and expansion improvements to roads functionally classified as rural minor collector, rural local, or urban local for which HPMS data are not available to support a HERS analysis.

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

Capital Investment Scenarios – Transit

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

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

KEY TAKEAWAYS

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

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

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

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

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

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

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

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

Exhibit 7-10 ■ SGR Benchmark and Transit Investment Scenarios

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

[1] To prioritize investments under constrained funding.

[2] Replace at condition 2.5.

Source: Transit Economic Requirements Model (TERM).

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

- **SGR benchmark:** The level of expenditures required to immediately attain and then to maintain SGR over the upcoming 20 years, which would cover preservation needs but excludes expansion investments, is roughly 50 percent higher than that currently expended on asset preservation. The SGR benchmark is valuable in evaluating the gap between existing funding capacity and the level of investment required to quickly attain and maintain an optimal SGR (i.e., condition 2.5).
- **Sustain Recent Spending scenario:** Total preservation spending under this scenario is well below that of the SGR benchmark and the other scenarios, indicating that sustaining recent spending levels is insufficient to attain the backlog elimination of the SGR benchmark and ridership growth objectives of the Low-Growth scenario, or the High-Growth scenario. In this report, FTA estimates that recent capital reinvestment levels are roughly sufficient to maintain the current size of the SGR backlog, whereas the recent level of expansion investments is marginally below that required to support expected ridership growth.
- **Low-Growth and High-Growth scenarios:** The level of investment to address expected preservation and expansion needs is estimated to be roughly 23 to 30 percent higher than that currently expended by the Nation's transit operators. Preservation and expansion needs are highest for UZAs exceeding 1 million in population. (These UZAs are listed in Chapter 1, *Exhibit 1-16*.)

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

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

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

[1] Includes 37 urbanized areas.

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

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

Source: Transit Economic Requirements Model.

Sustain Recent Spending Scenario

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

TERM's funding allocation: The following analysis of the Sustain Recent Spending scenario relies on TERM's allocation of the recent preservation and expansion expenditures to the Nation's existing transit operators, their modes, and their assets over the upcoming 20 years, as depicted in *Exhibit 7-12*. As with other TERM analyses involving the allocation of constrained transit funds, TERM allocates limited funds based on the results of the model's benefit-cost analysis, which ranks potential investments based on their assessed benefit-cost ratios (with the highest-ranked investments funded first).

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

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

[1] Totals may not sum due to rounding.

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

Source: Transit Economic Requirements Model and FTA staff estimates.

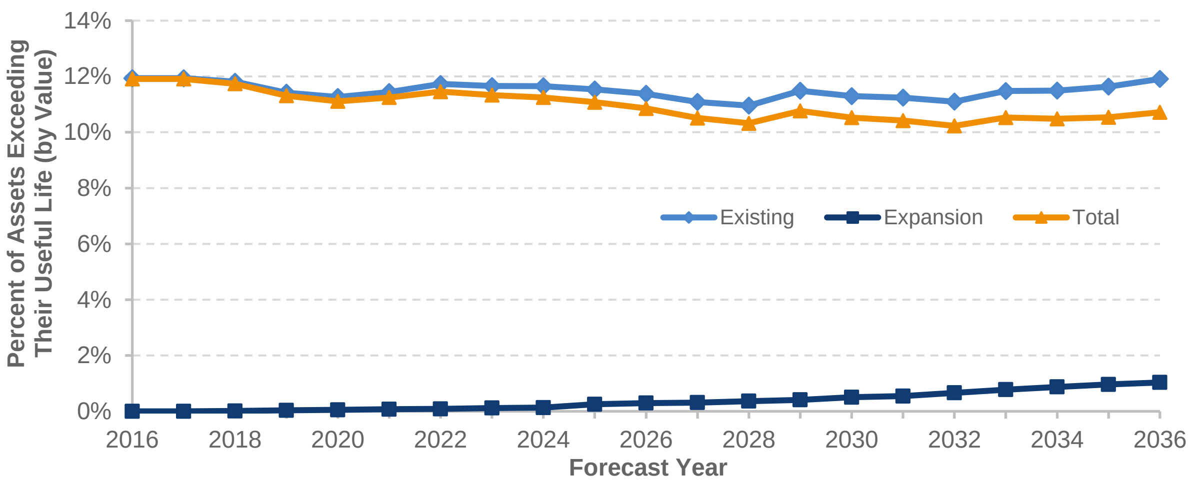
Preservation Investments

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

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

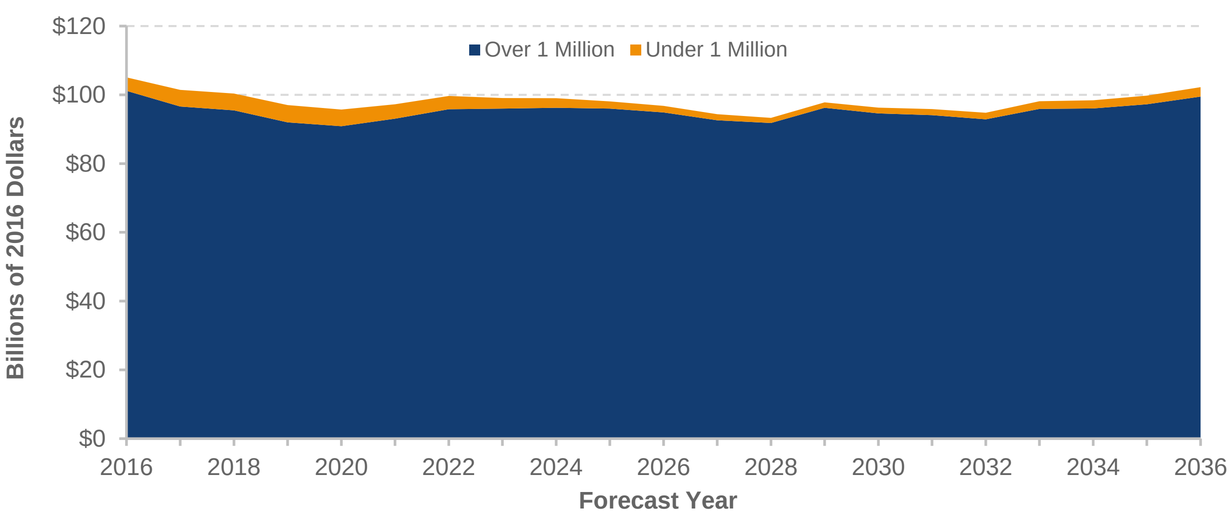
The chart in *Exhibit 7-14* also divides the backlog amount according to size of transit service area, with the lower portion showing the backlog for UZAs having populations greater than 1 million and the upper portion showing the backlog for all other UZAs and rural areas combined. This segmentation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

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



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

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



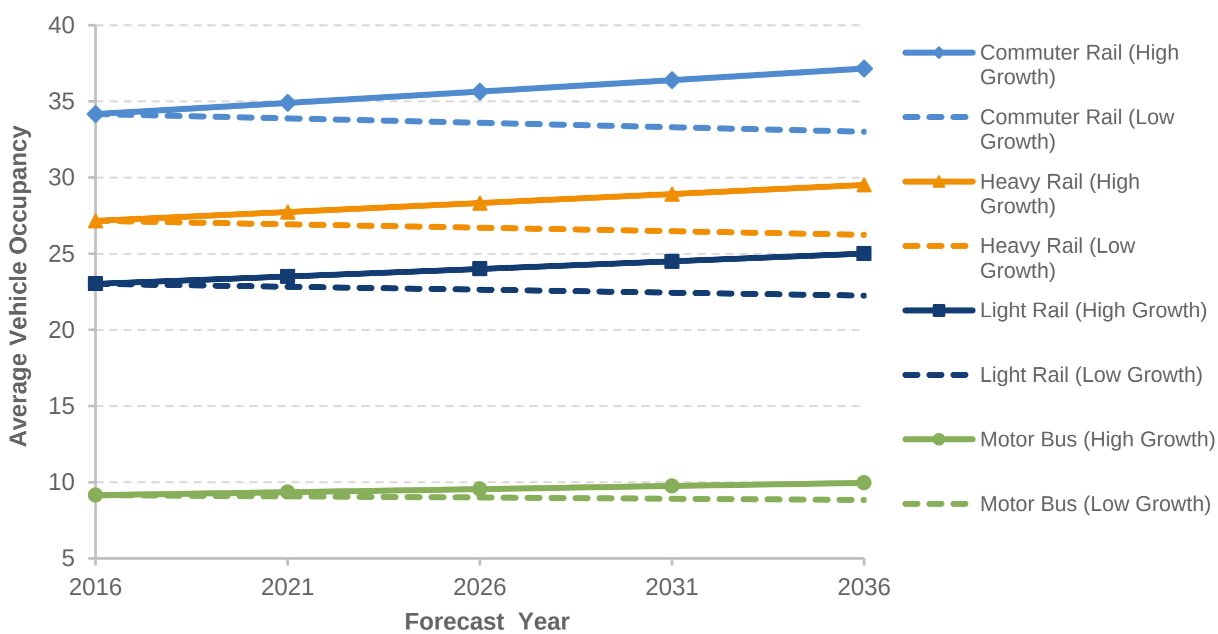
Source: Transit Economic Requirements Model.

Expansion Investments

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

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

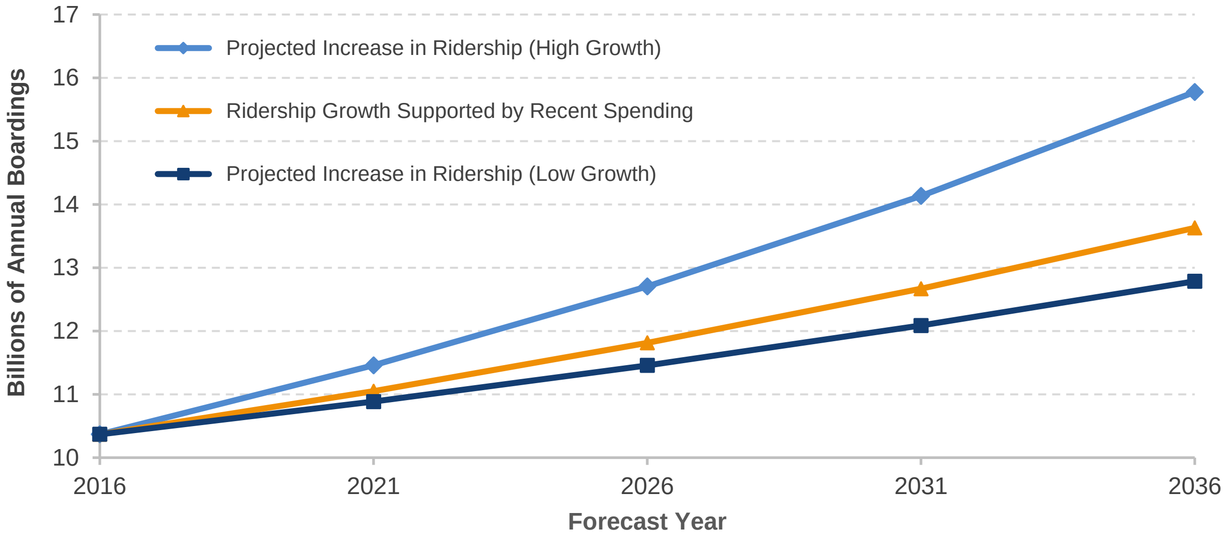
Exhibit 7-15 ■ Sustain Recent Spending Scenario: Capacity Utilization by Mode Forecast, 2016–2036



Source: Transit Economic Requirements Model.

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

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



Source: Transit Economic Requirements Model.

State of Good Repair Benchmark

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

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

What Is the Definition of State of Good Repair?

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

SGR Investment Levels

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

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

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

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

[1] Totals may not sum due to rounding.

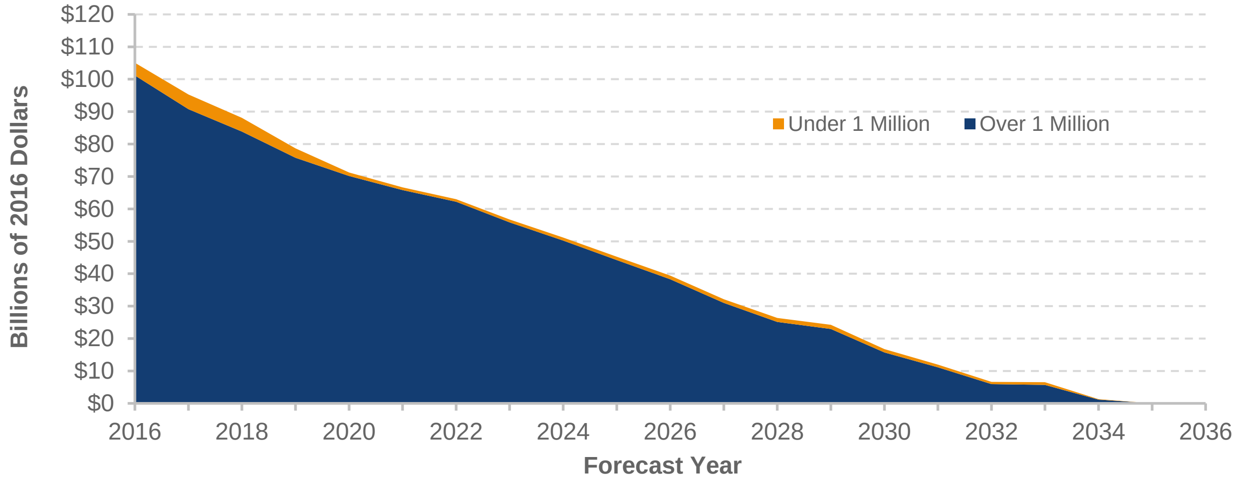
Note: All investment values in billions of 2016 dollars.

Source: Transit Economic Requirements Model.

Impact on the Investment Backlog

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

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

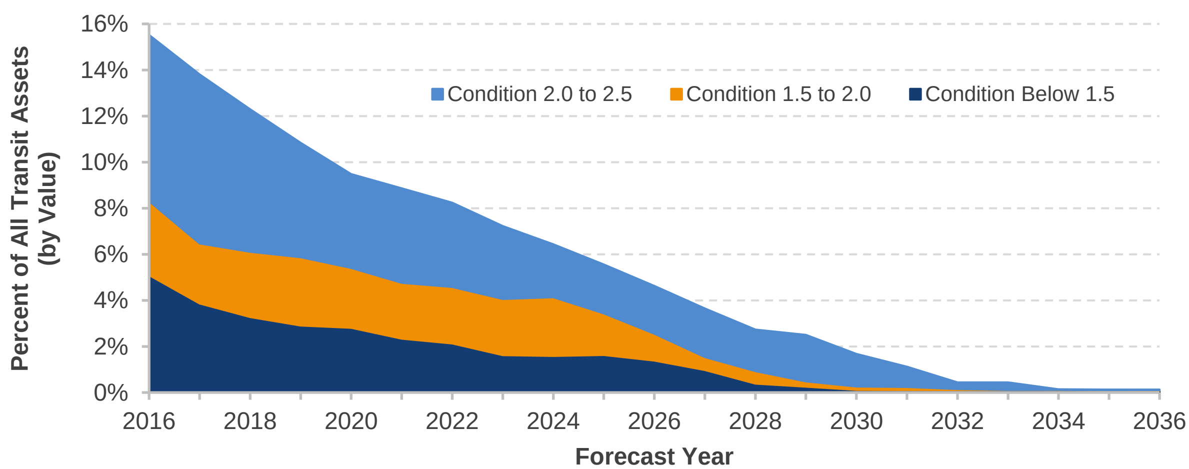


Source: Transit Economic Requirements Model.

Impact on Conditions

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

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



Source: Transit Economic Requirements Model.

Low-Growth and High-Growth Scenarios

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

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

Low-Growth and High-Growth Assumptions

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

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

Low-Growth and High-Growth Scenario Investment Levels

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

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

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

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

[1] Totals may not sum due to rounding.

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

Source: Transit Economic Requirements Model.

Low-Growth Investment Levels

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

High-Growth Investment Levels

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

Impact on Conditions and Performance

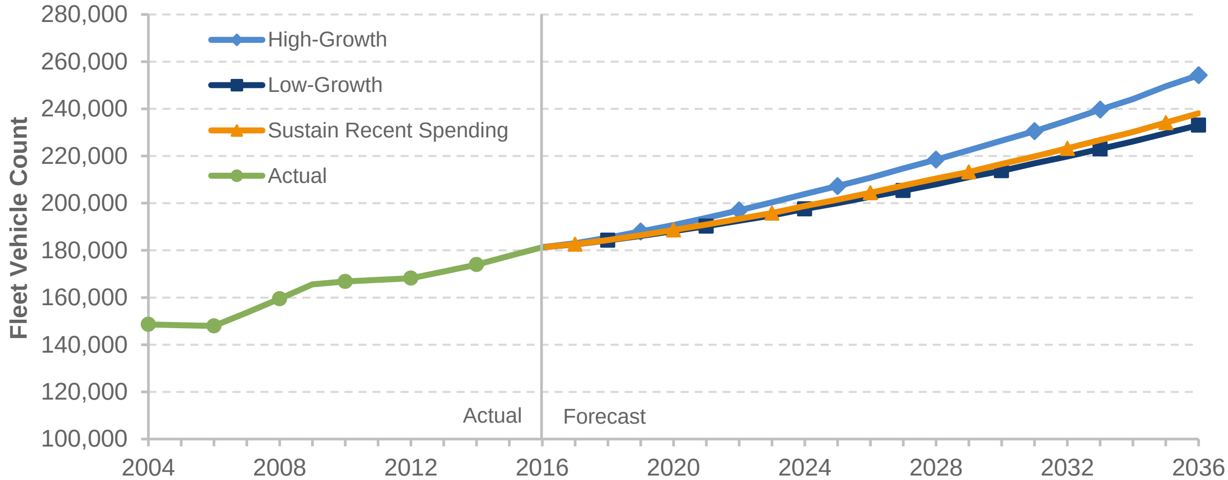
The impact of the Low-Growth and High-Growth rate preservation investments on transit conditions is essentially the same as that already presented for the SGR benchmark in *Exhibits 7-18* and *7-19*. As noted earlier, the Low and High-Growth scenarios use the same rules to assess when assets should be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

Forecasted Expansion Investment

This section compares key characteristics of the national transit system in 2016 to their forecasted TERM results over the next 20 years for different scenarios. It also includes expansion projections of fleet size, guideway route miles, and stations broken down by scenario to better understand the expansion investments that TERM forecasts.

TERM's projections of fleet size are presented in *Exhibit 7-21*. The projections for the Low-Growth and High-Growth scenarios create upper and lower targets around the projected Sustain Recent Spending scenario to preserve existing transit assets at a condition rating of 2.5 or higher and expand transit service capacity to support differing levels of ridership growth while passing TERM's benefit-cost test.

Exhibit 7-21 ■ Projection of Fleet Size by Scenario

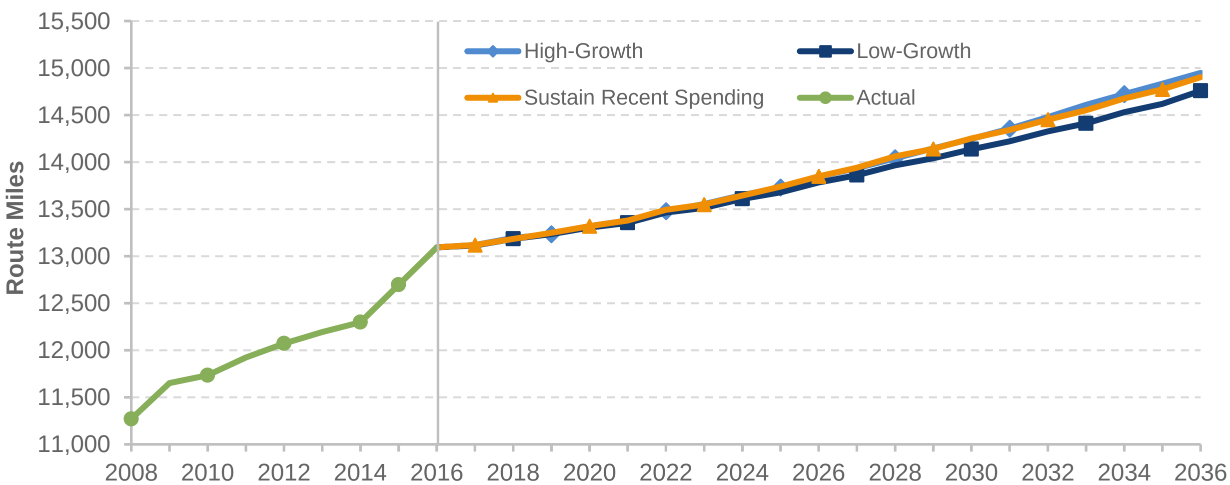


Note: Data through 2016 are actual; data after 2016 are estimated based on trends.

Source: Transit Economic Requirements Model.

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

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

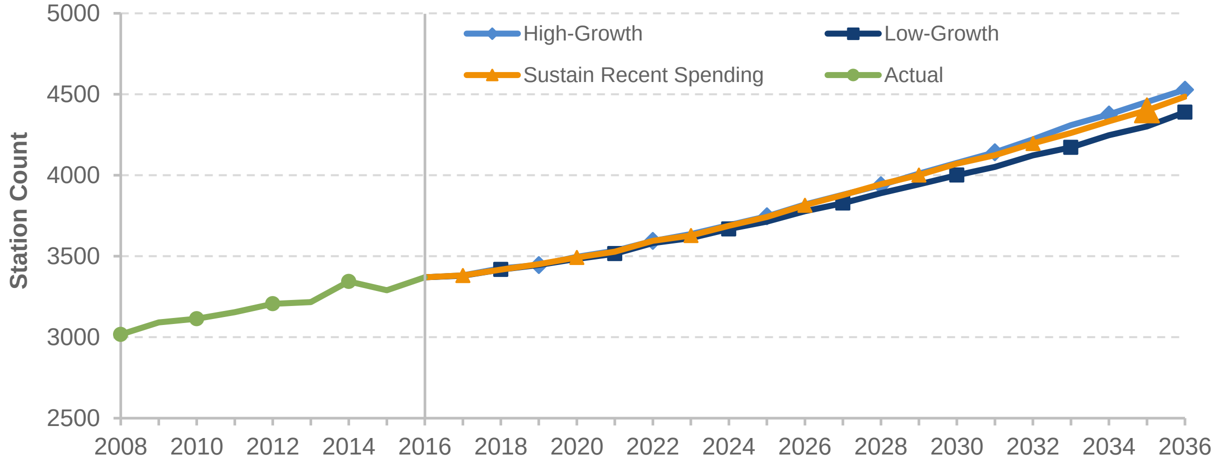


Note: Data through 2016 are actual; data after 2016 are estimated based on trends.

Source: Transit Economic Requirements Model.

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

Exhibit 7-23 ■ Projection of Rail Stations by Scenario

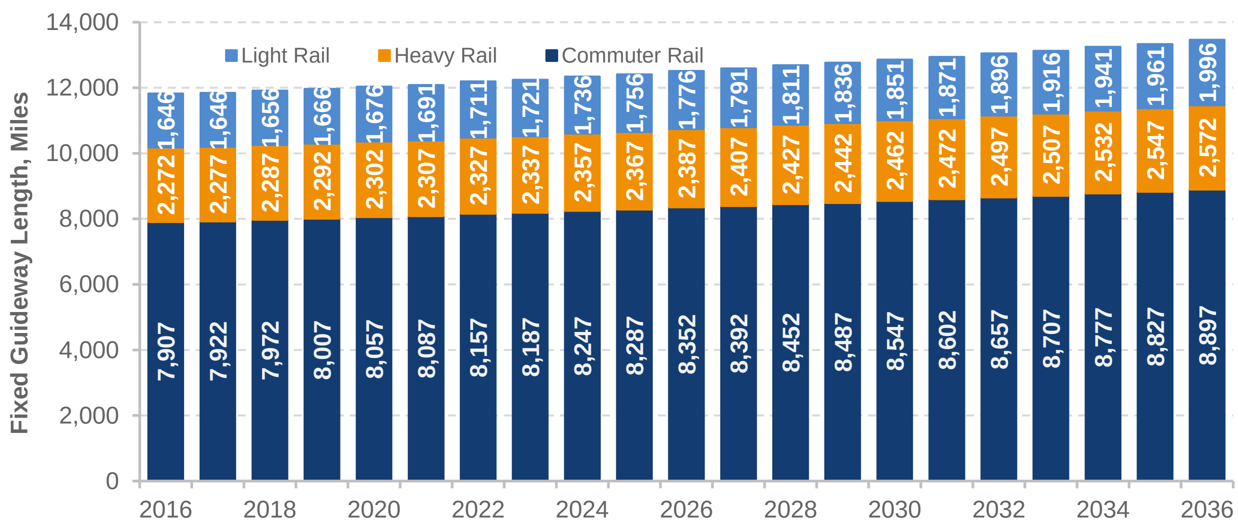


Note: Data through 2016 are actual; data after 2016 are estimated based on trends.

Source: Transit Economic Requirements Model.

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

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



Source: Transit Economic Requirements Model.

Scenario Impacts Comparison

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

Exhibit 7-25 includes the following measures:

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

Exhibit 7-25 ■ Scenario Investment Benefits Scorecard

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

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

Source: Transit Economic Requirements Model.

Scorecard Comparisons

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

Preservation Impacts

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

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

Expansion Impacts

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

CHAPTER 8: Supplemental Analysis

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Expected Useful Service Life Consumed for Replaceable Assets under Three Growth Scenarios and the SGR Benchmark 8-34
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Supplemental Analysis – 50th Anniversary

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

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

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

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

KEY TAKEAWAYS

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

Forecast of VMT and Registration

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

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

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

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

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

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

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

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

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

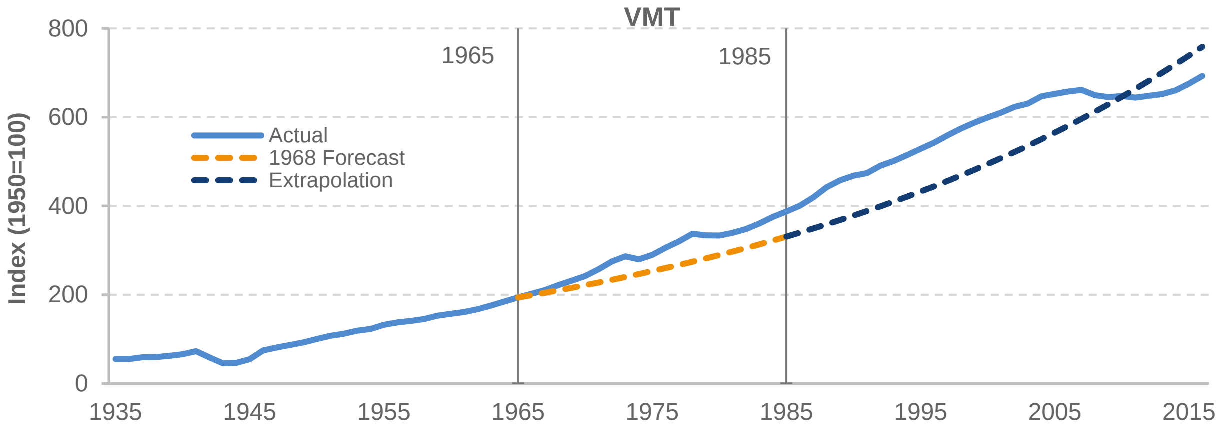
Forecasts of national motor vehicle registrations were summarized from projections by the States, based on assumptions of population and vehicle registration trends. The population projection was from the Bureau of the Census. The 1968 C&P Report underestimated the wide adoption of vehicle ownership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

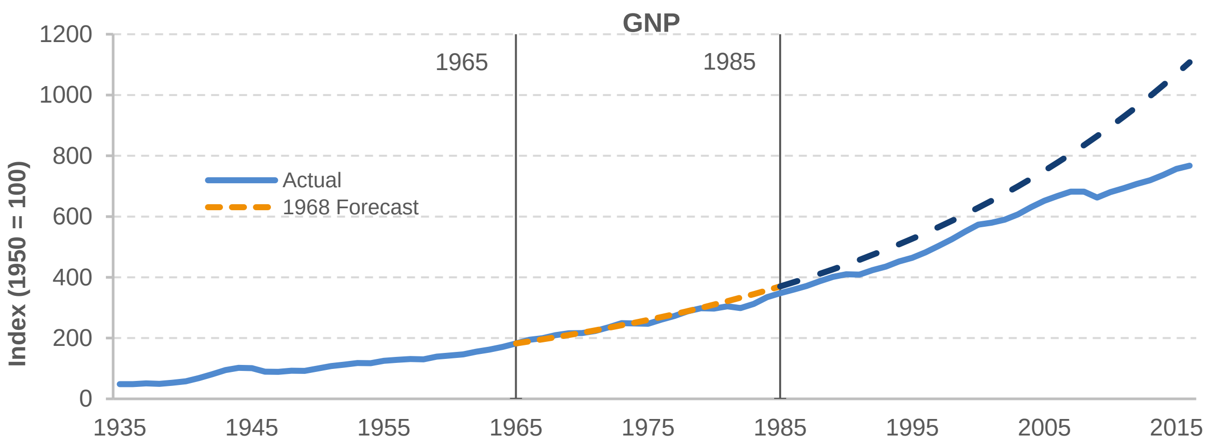
[26] Landsberg, Hans H., Leonard L. Fischman, and Joseph L. Fisher. 1963. *Resources in America's Future: Patterns of Requirements and Availabilities, 1960–2000*. Published for Resources for the Future by Johns Hopkins Press, Baltimore, MD.

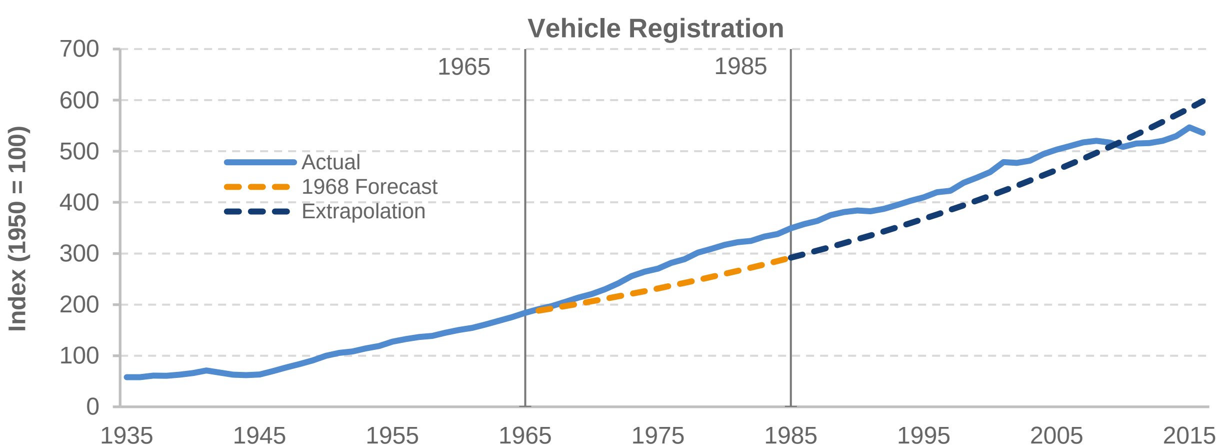
Extrapolations through 2016

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

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







Note: Values are normalized to 100 in 1950.

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

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

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

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

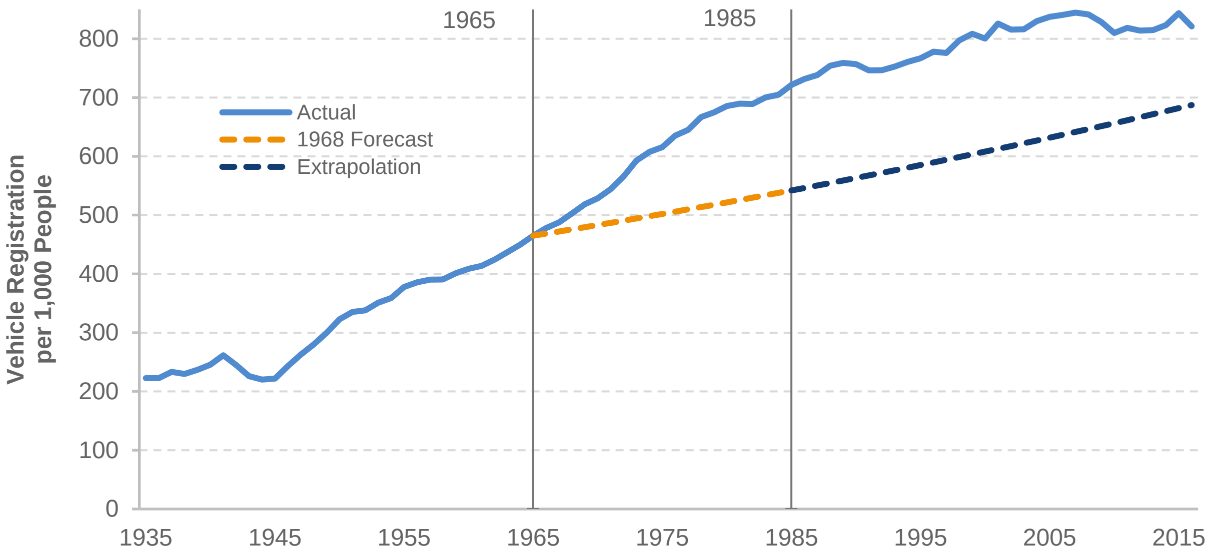
Vehicle registration followed a similar trend as VMT and its growth slowed in the mid-2000s. Registered vehicles increased at a much slower pace (1.4 percent per year) from 1986 to 2016, less than half of the growth rate from 1965–1985 (3.3 percent). Thus, extrapolating the projected annual growth rate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

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

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

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

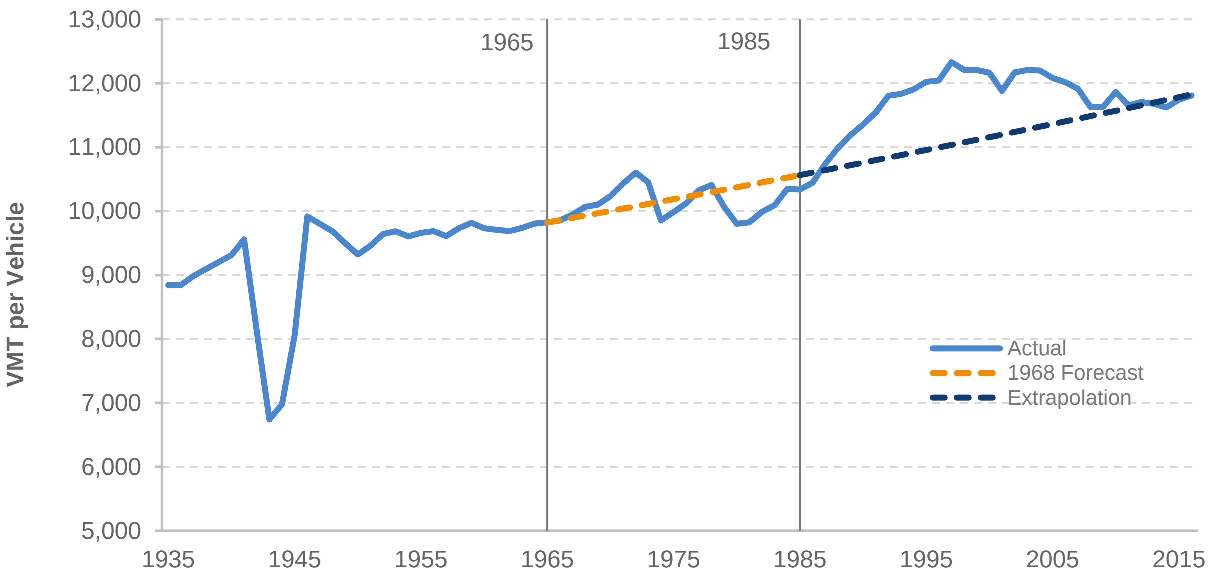
Exhibit 8-3 ■ Vehicle Registration per 1,000 People, 1936–2016



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

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

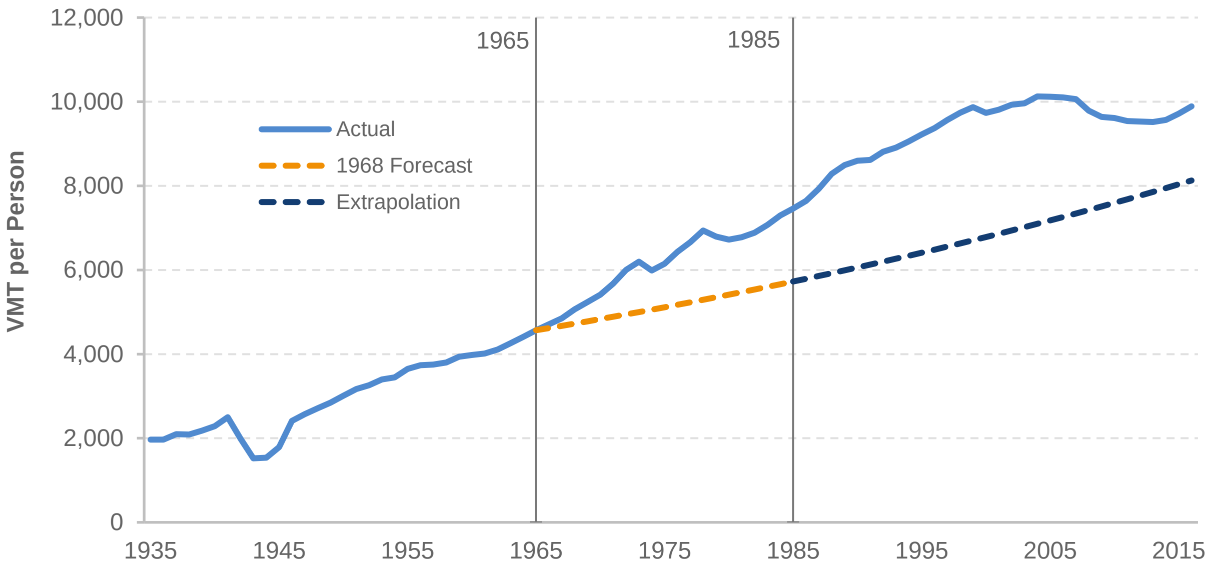
Exhibit 8-4 ■ Annual VMT per Vehicle, 1936–2016



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

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

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



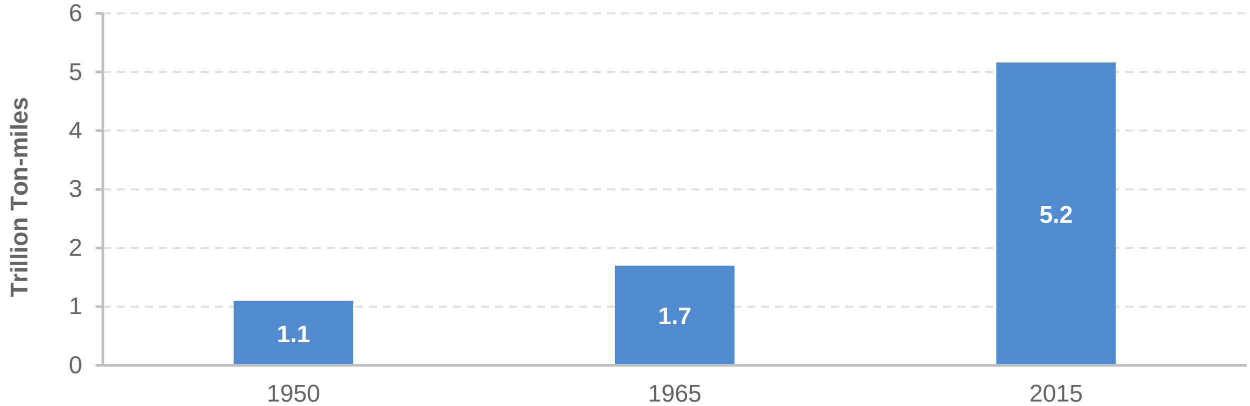
Sources: Forecast from 1968 National Highway Needs Report, Figure 4; actual population from U.S. Census Bureau; VMT 1935–1992 from Highway Statistics Summary to 1995; VMT 1993–2016 from Highway Statistics.

Modal Distribution of Freight

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

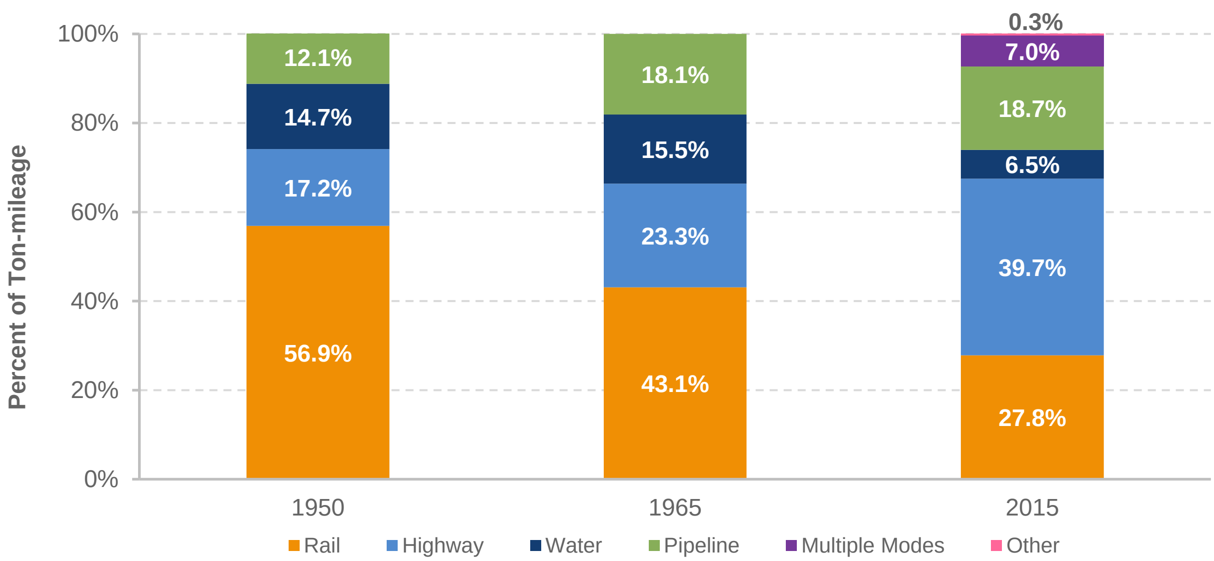
The composition of freight transportation also changed substantially over the past half century. The share of railroads by ton-miles decreased from 56.9 percent in 1950 to 43.1 percent in 1965, and dropped further to 27.8 percent in 2015 (*Exhibit 8-7*). Trucks on highways almost completely took over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

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



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

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



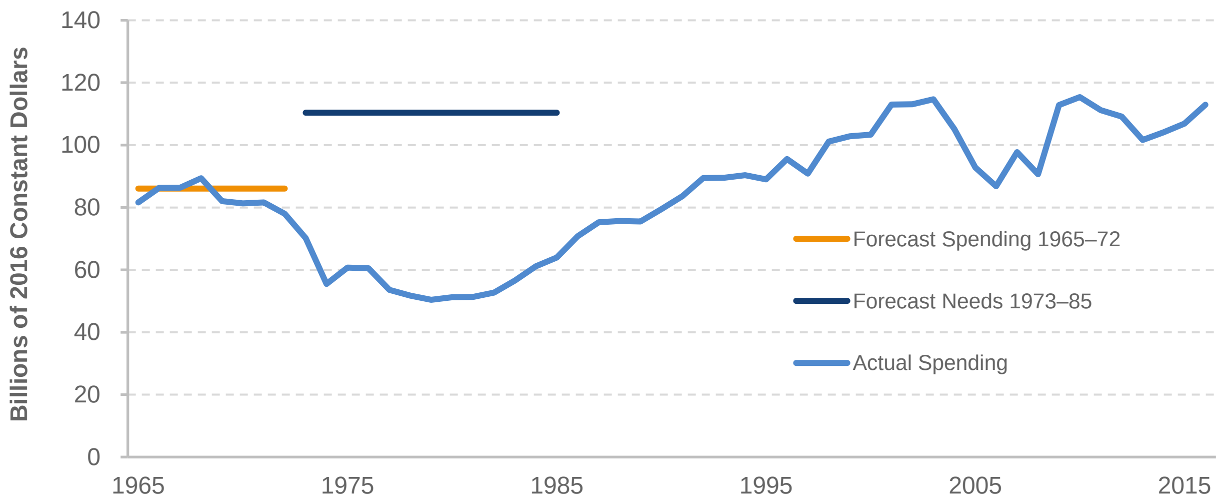
Sources: Freight transport in 1950 and 1965 from the 1968 National Highway Needs Report, Figure 2; in 1997–2015 from the Freight Analysis Framework (FAF4) at https://faf.ornl.gov/fafweb/Extraction1.aspx.

Estimates of Future Investment Needs

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

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

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



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

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

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

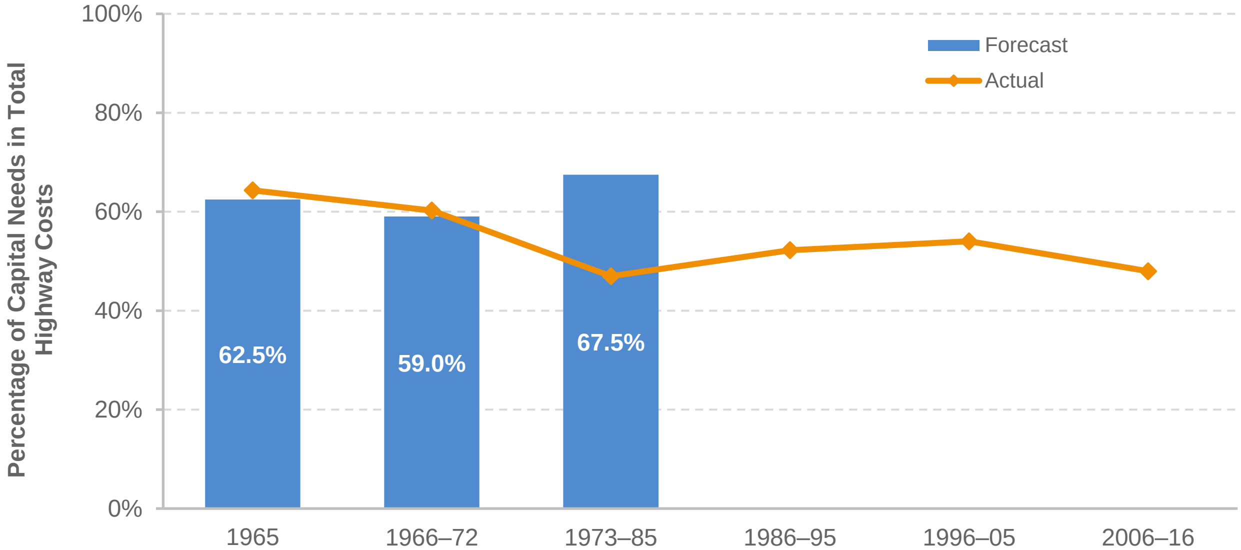
- While the needs estimates presented were not based on benefit-cost analysis, the report referenced its importance in actual project selection. The needs assessment in the 1968 C&P Report was an aggregate of the State highway departments' estimates of future highway needs for the period of 1965–1985,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

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

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

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

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



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

Topics Covered

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

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

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

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

Evolution of the C&P Report

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

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

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

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

Exhibit 8-10 ■ List of C&P Reports

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

Source: FHWA staff compilation.

Supplemental Analysis – Highway

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

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

KEY TAKEAWAYS

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

Comparison with the 23rd C&P Report

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

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

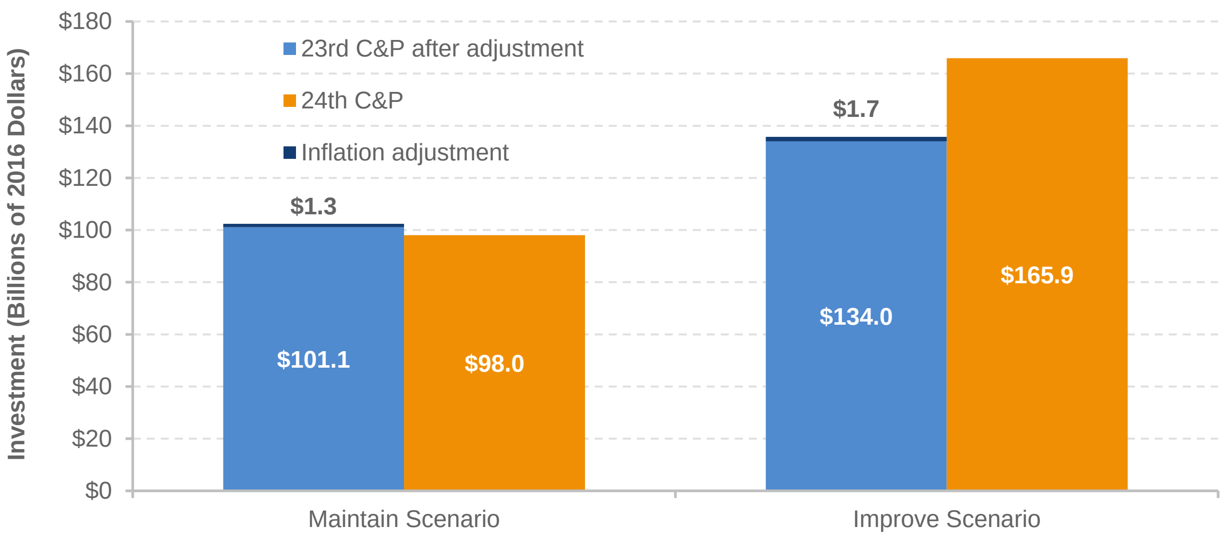
In the Maintain scenario, the targets of components derived from the Highway Economic Requirements System (HERS) were set as spending at the lowest level at which (1) the projected average International Roughness Index (IRI) in 2036 matches (or is better than) the value in 2016 and (2) the projected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

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

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

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

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



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

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

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

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

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

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

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

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

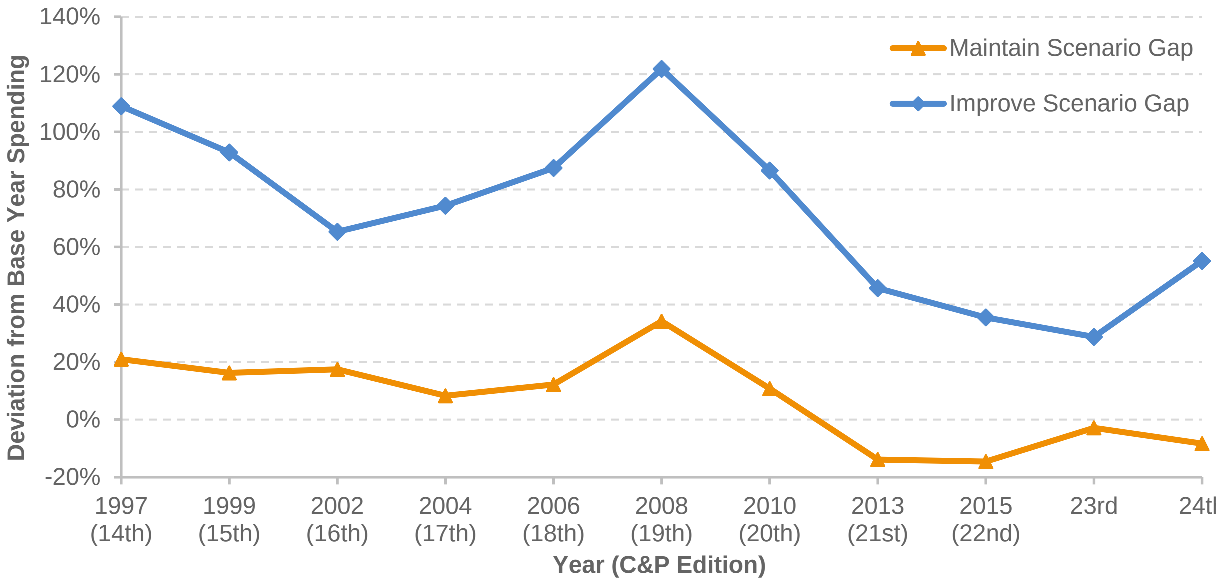
Sources: Highway Economic Requirements System.

Comparisons of Implied Funding Gaps

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

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

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



Note: Amounts shown correspond to the primary investment scenario associated with maintaining or improving the overall highway system in each C&P Report; the definitions of these scenarios are not fully consistent among reports. Negative numbers signify that the investment scenario estimate was lower than base-period spending. The base-period for the 24th edition is the average from 2012 to 2016, expressed in 2016 Dollars. The base period for previous editions was a single year; the base years for the 2013, 2015, and 23rd editions were 2010, 2012, and 2014, respectively. The base years for the 1997 to 2010 editions were each two years prior to the cover dates (i.e., the base year for the 1997 edition was 1995; the base year for the 2010 edition was 2008).

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

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

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

Changes in actual capital spending by all levels of government combined can substantially alter these spending gaps, as can sudden, large swings in construction costs. The large increase in the gap between base-year spending and the primary "Maintain" and "Improve" scenarios presented in the 2008 C&P Report coincided with a large increase in construction costs experienced between 2004 and 2006 (the base year for the 2008 C&P Report). The decreases in the gaps presented in recent editions coincided with subsequent declines in construction costs.

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

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

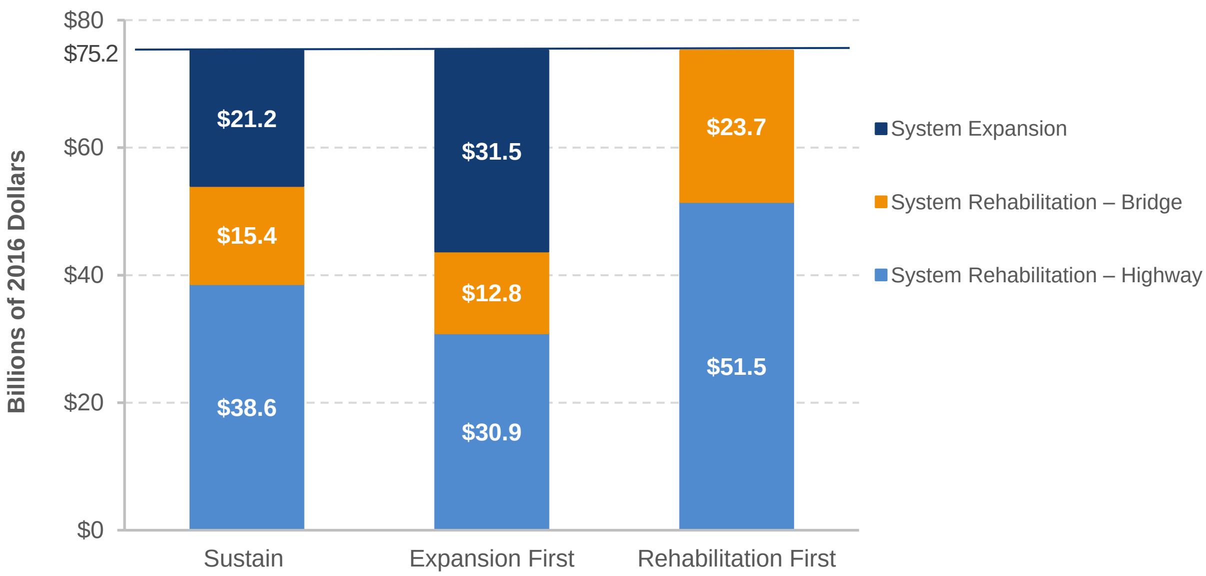
Allocation of Investment

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

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

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

Exhibit 8-14 ■ Capital Investment under Alternative Allocations



Source: FHWA staff analysis.

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

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

Alternative Allocation of Investment in HERS

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

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

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

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

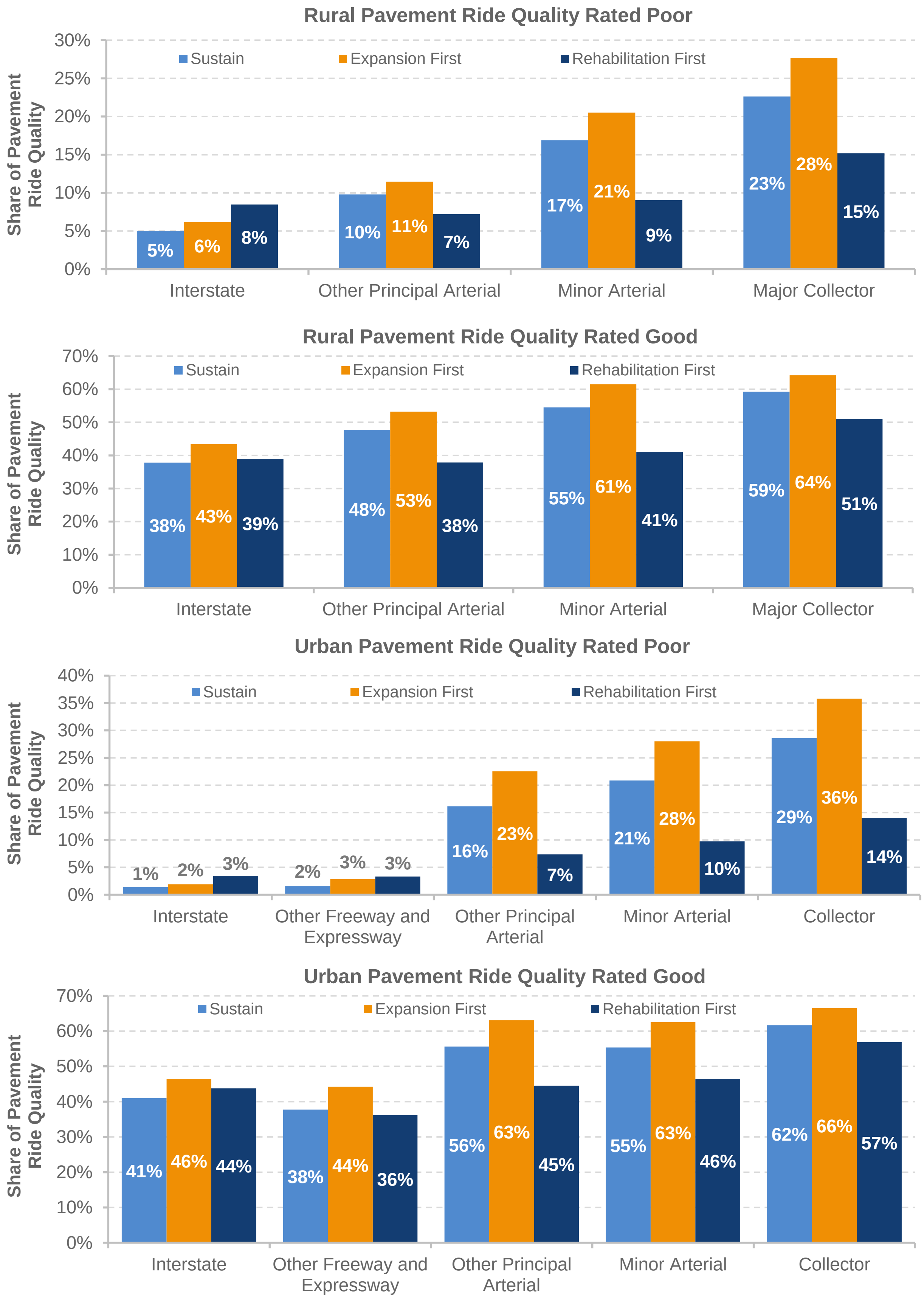
Source: Highway Economic Requirements System.

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

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

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

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

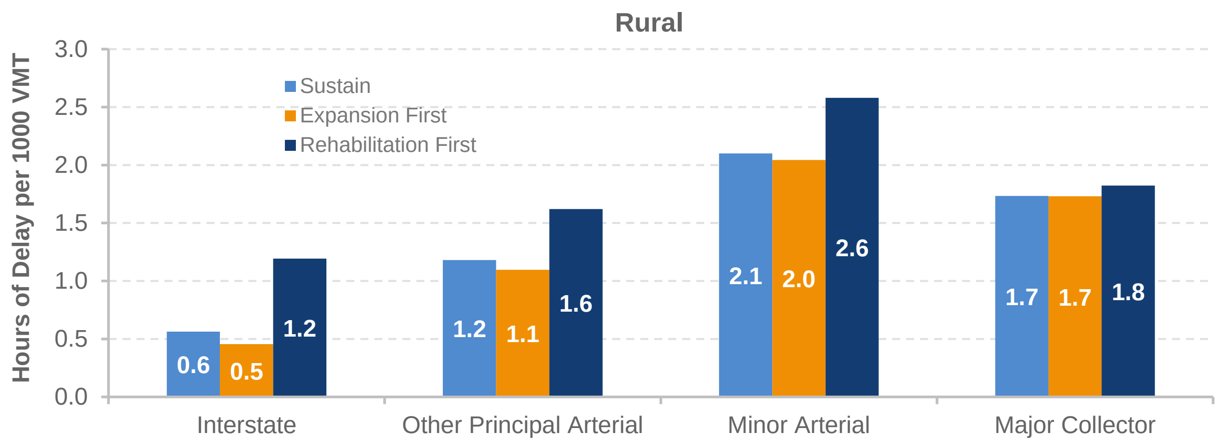


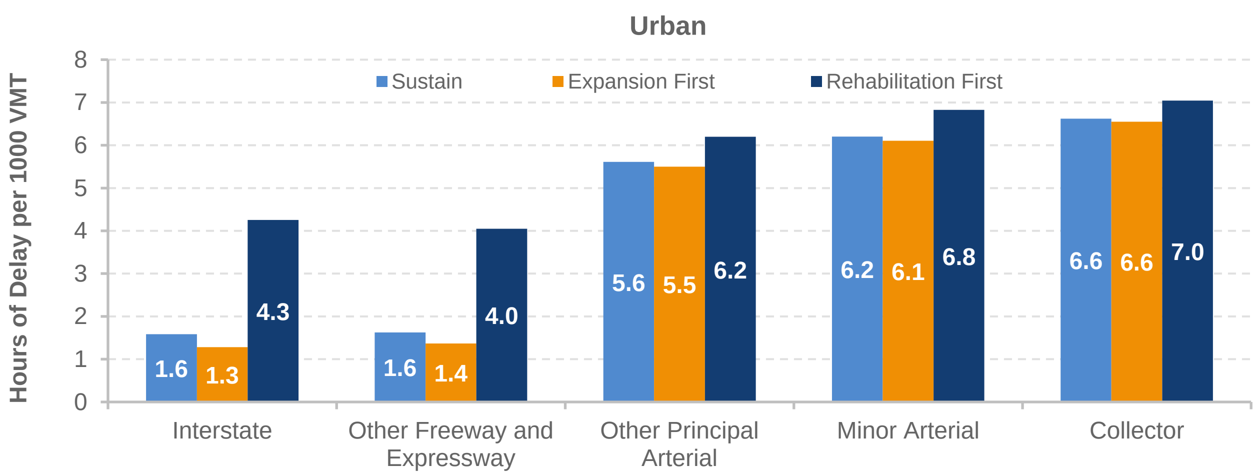
Source: Highway Economic Requirements System.

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

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

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





Source: Highway Economic Requirements System.

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

Alternative Allocation of Investment in NBIAS

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

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

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

Note: NBIAS is National Bridge Investment Analysis System.

Source: National Bridge Investment Analysis System.

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

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

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

Note: Shares are weighted by bridge deck area.

Source: National Bridge Investment Analysis System.

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

Implications of Alternative Investment Strategies

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

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

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

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

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

Timing of Investment

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

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

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

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

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

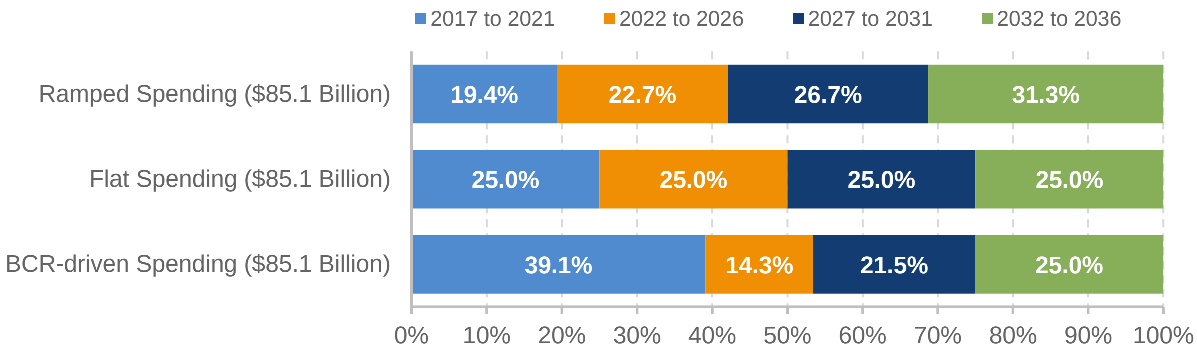
Alternative Timing of Investment in HERS

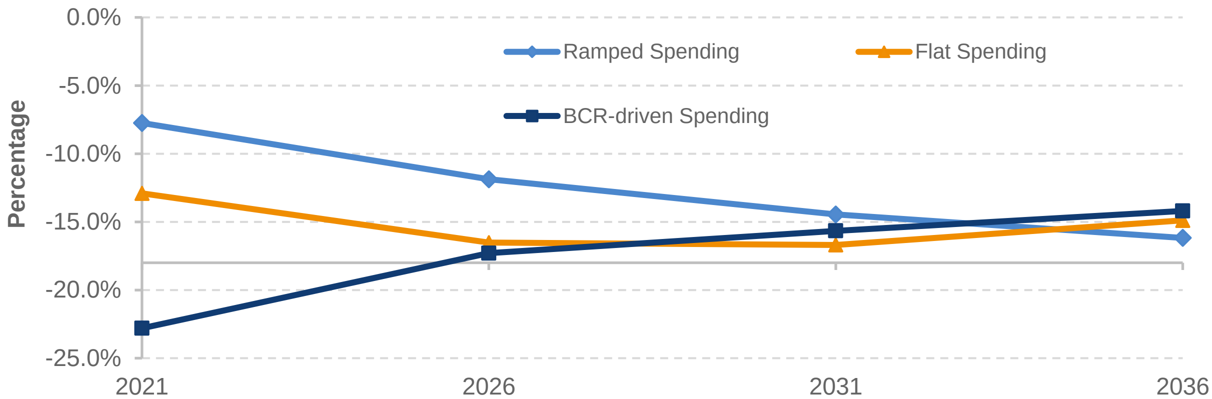
Exhibit 8-20 presents information regarding how the timing of investment would affect the distribution of spending among the four 5-year funding periods considered in HERS and how these spending patterns could affect performance in pavement condition (measured using the IRI) and delay per VMT. Three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

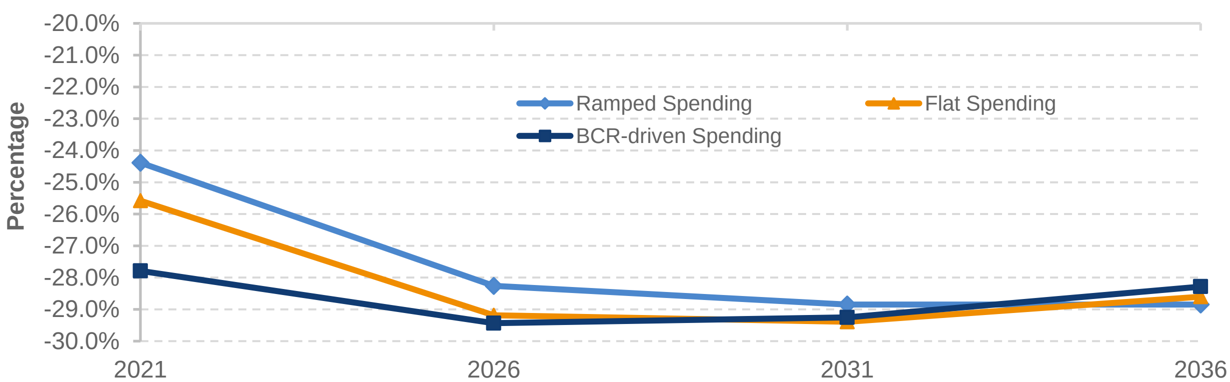
As shown in the top panel of *Exhibit 8-20*, investment under the flat spending alternative is equally distributed over time so that each 5-year period accounts for exactly one-quarter of the total 20-year investment.

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

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







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

Source: Highway Economic Requirements System.

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

Impacts of Alternative Investment Patterns

An obvious difference among the three alternative investment patterns is that the higher the level of investment within the first 5-year analysis period, the better the level of performance achieved by 2021.

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

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

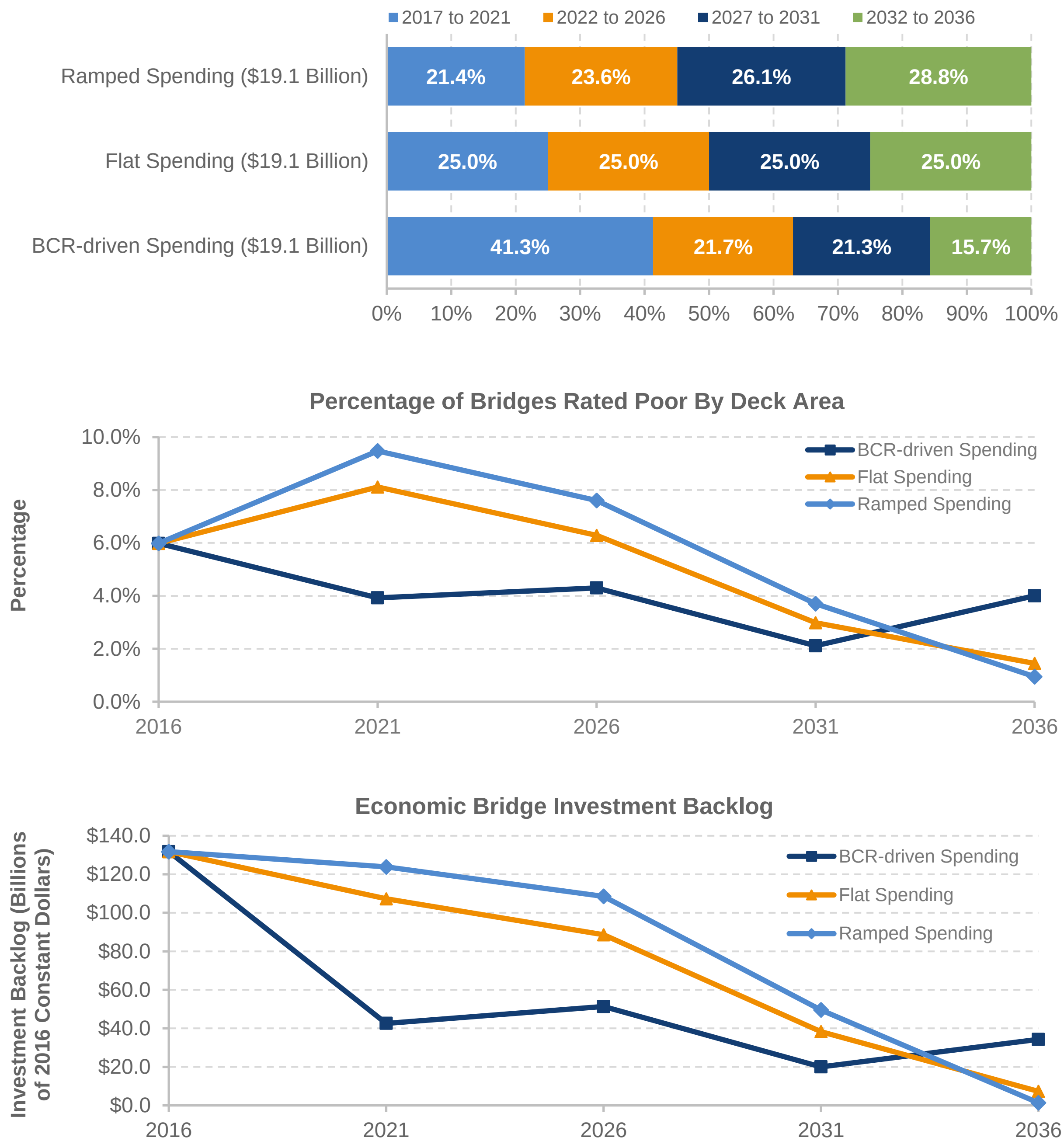
These results show that the BCR-driven approach achieves the highest IRI and delay reductions in the medium run (the first 5-year period) because existing backlog is addressed first. The ramped spending approach results in the smallest pavement and delay improvement over the same period. System performance,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

Alternative Timing of Investment in NBIAS

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

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

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



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

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

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

Supplemental Analysis – Transit

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

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

KEY TAKEAWAYS

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

Asset Conditions under Investment Scenarios

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

New Technologies in Bus Fleets

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

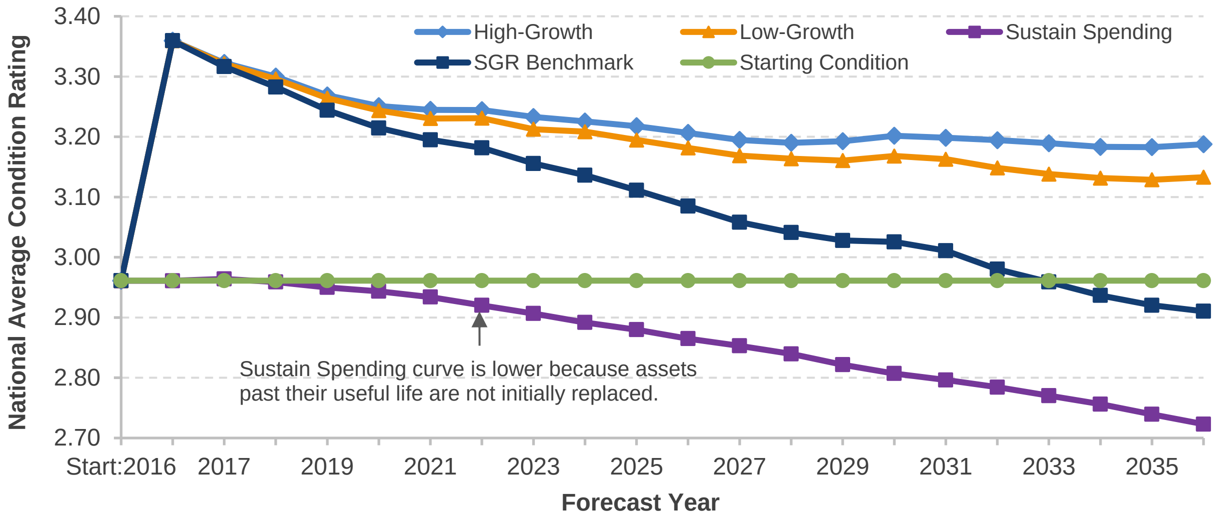
Asset Condition Forecasts and Expected Useful Service Life Consumed

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

Sustain Recent Spending Scenario

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

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



Note: SGR is state of good repair.

Source: Transit Economic Requirements Model.

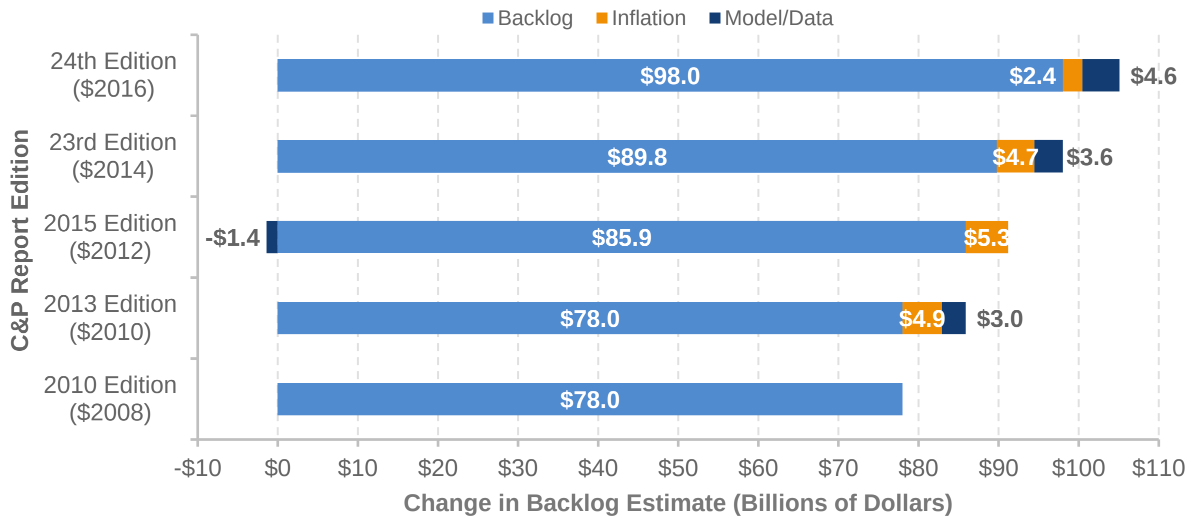
Backlog Estimates Across Recent C&P Reports

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

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

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

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



Source: Transit Economic Requirements Model.

SGR Benchmark and Growth Scenarios

In contrast to the Sustain Recent Spending scenario, the SGR Benchmark and the Low-Growth and High-Growth scenarios are all financially unconstrained with respect to reinvestment needs. Rather, the SGR Benchmark and the two growth scenarios assess the level of investment required to both eliminate the current investment backlog and to address all ongoing reinvestment needs as they arise, such that all assets remain in an SGR (i.e., a condition of 2.5 or higher). The unconstrained nature of these scenarios accounts for the significant improvement in asset conditions at the end of the first year of analysis, at which time all overage assets have been replaced and the SGR backlog has been entirely eliminated.

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

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

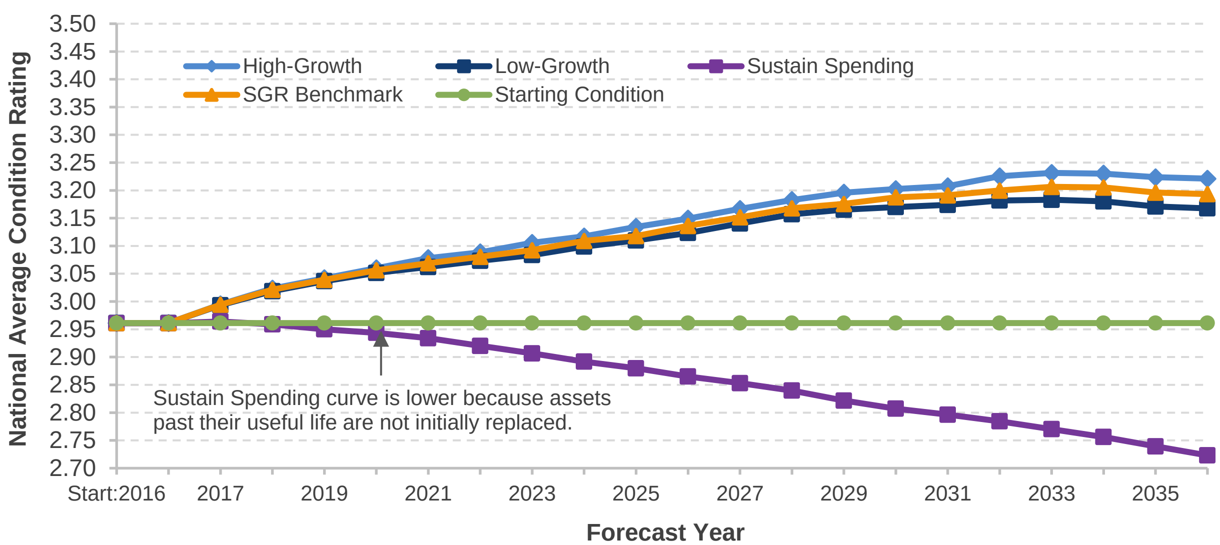
Alternative Methodology

As noted earlier, the level of investment (including funding and physical resources) needed to eliminate the SGR backlog in 1 year is likely infeasible. Hence, the financially unconstrained assumptions in the SGR Benchmark and the Low-Growth and High-Growth scenarios (e.g., spending of unlimited transit investment funds each year) are unrealistic. As indicated in *Exhibit 8-22*, the elimination of the backlog in the first year and the resulting jump in asset conditions in Year 1 can be attributed to this unconstrained assumption.

An alternative methodology is for all three scenarios to use a financially constrained reinvestment rate to eliminate the SGR backlog by Year 20 while maintaining the collective national transit assets at a condition rating of 2.5 or higher. This analysis indicates that investing $18.0 billion annually in preservation would eliminate the backlog in 20 years.

Exhibit 8-24 presents the more realistic condition projections for the two growth scenarios and the benchmark using this alternative methodology. The Low-Growth and High-Growth scenarios and the SGR Benchmark are financially constrained, so the investment strategies result in replacing assets at later ages, in worse conditions, and potentially after the end of their useful lives. However, the outcome under this modified, more realistic approach is the same for each scenario and for the same reasons: conditions ultimately decline marginally under the SGR Benchmark but improve under the Low-Growth and High-Growth scenarios (being pulled up for the latter two by the impact of increasing annual levels of expansion investment).

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



Note: SGR is state of good repair.

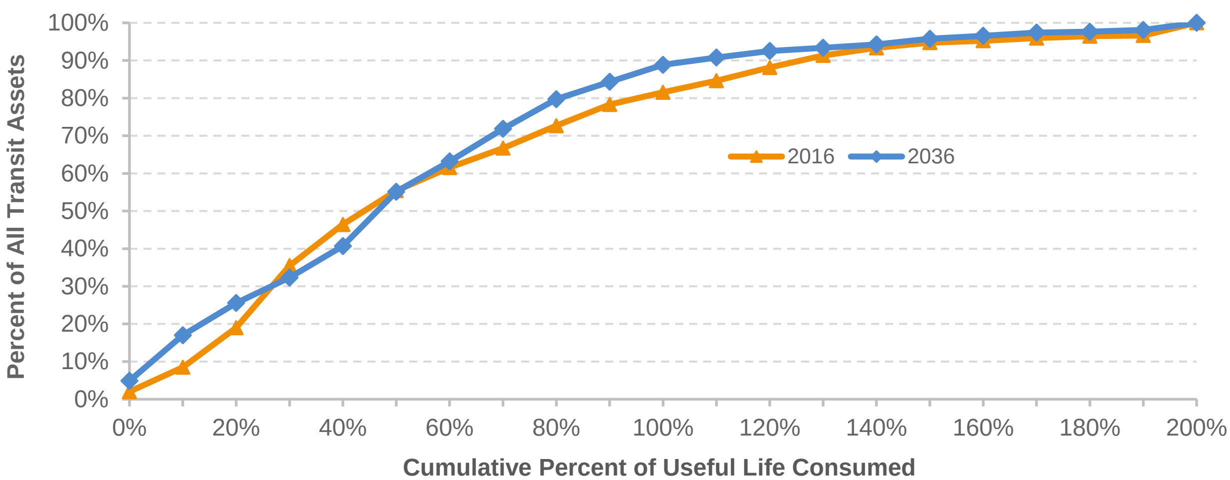
Source: Transit Economic Requirements Model.

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

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

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

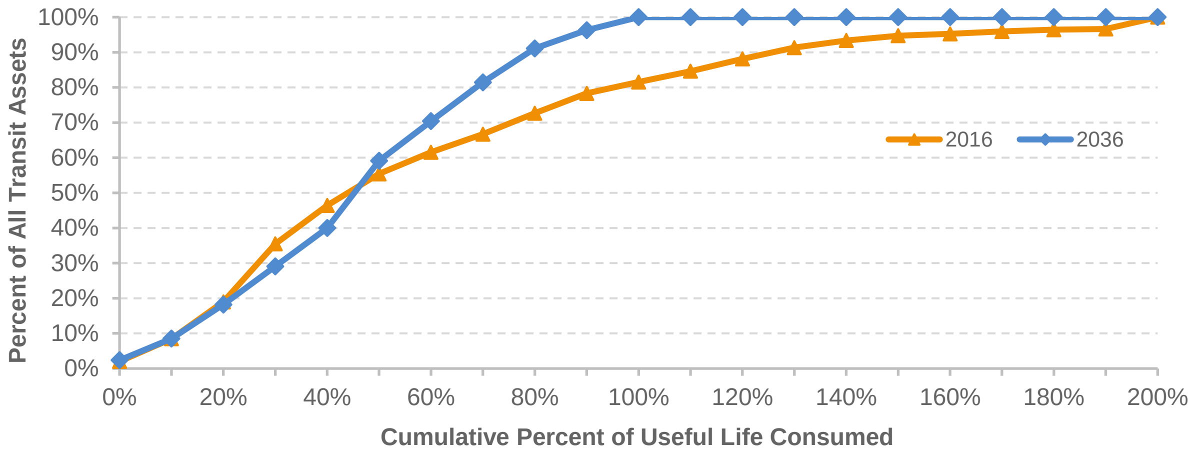
Exhibit 8-25 ■ Sustain Recent Spending Scenario – Cumulative Asset Percent of Useful Life Consumed (Replaceable Assets)



Source: Transit Economic Requirements Model.

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

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

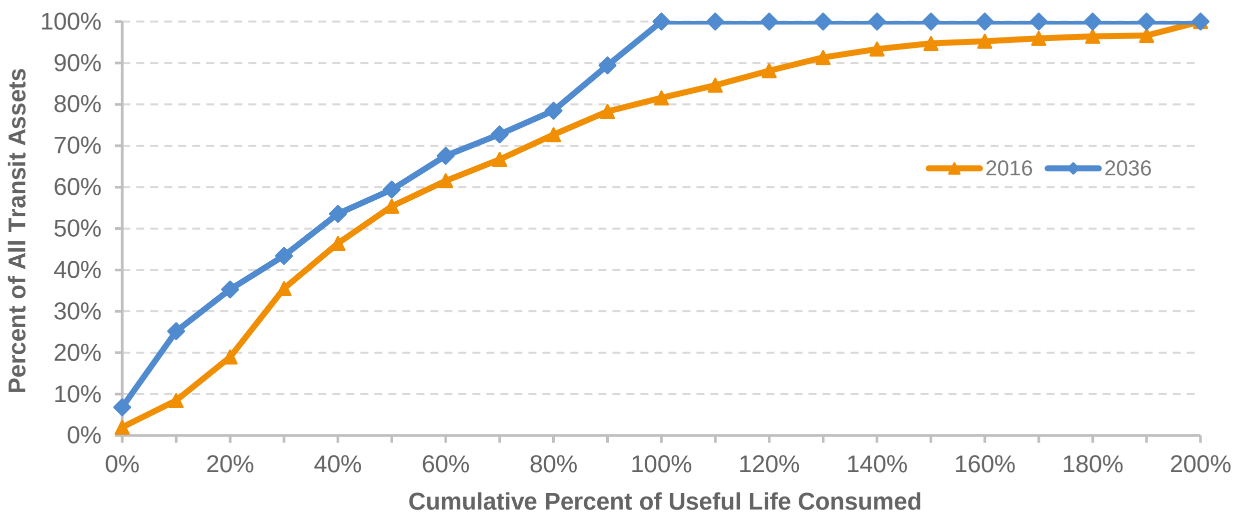


Note: SGR is state of good repair.

Source: Transit Economic Requirements Model.

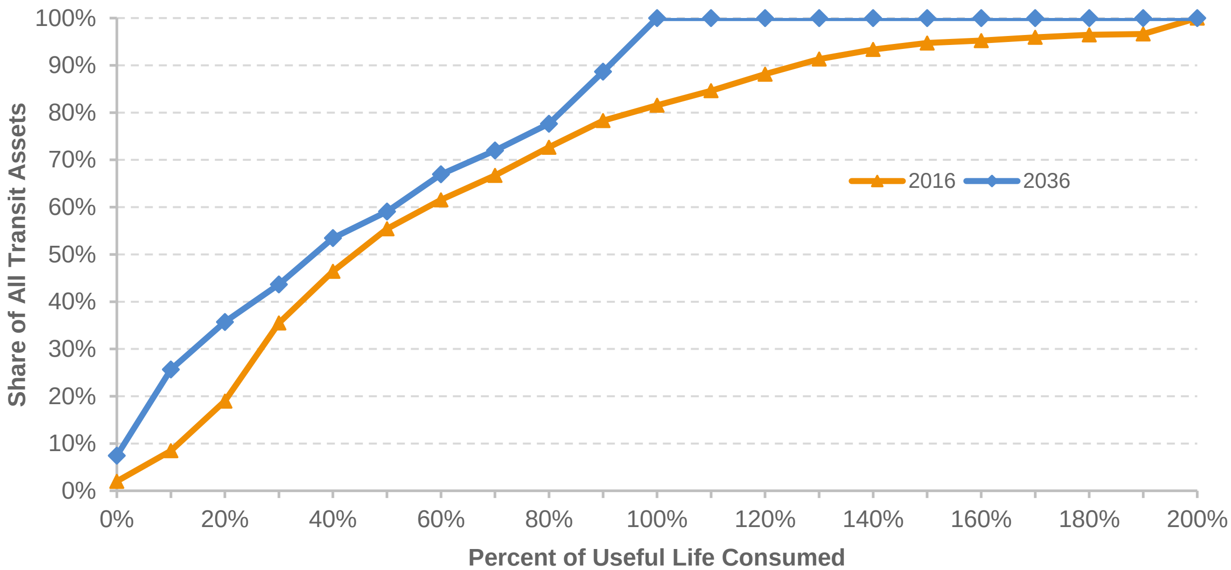
Finally, *Exhibits 8-27* and *8-28* present projections for the percentage of useful life consumed under the Low-Growth and High-Growth scenarios respectively (which are financially unconstrained with respect to reinvestment needs and invest in expansion assets to support low to high rates of ridership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

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



Source: Transit Economic Requirements Model.

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



Source: Transit Economic Requirements Model.

Effect of New Technologies on Transit Investment Scenarios

The investment scenarios presented in Chapter 7 implicitly assume that all replacement and expansion assets will use the same technologies that are currently in use today (i.e., all asset replacement and expansion investments are "in kind"). As with most other industries, however, the existing stock of assets used to support transit service is subject to ongoing technological change and improvement, and this change tends to result in increased investment costs (including future replacement needs). Although many improvements are standardized and hence embedded in the asset (i.e., the transit operator has little or no control over this change), it is common for transit operators to select technology options that are significantly more costly than preexisting assets of the same type. A key example is the frequent decision to replace diesel motor buses with compressed natural gas or hybrid buses. This increase in the cost of new assets would tend to increase current and long-term reinvestment costs and, in a budget-constrained environment, would increase the expected future size of the investment backlog. This increase might be offset by lower operating costs from more reliable operation, longer useful lives, and improved fuel efficiency, but this possible offset is not captured in this assessment of capital investment scenarios under current methodologies used in this report.

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

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CHAPTER 9: Sensitivity Analysis

Sensitivity Analysis – Highways

Sound practice in investment modeling includes analyzing the sensitivity of key results to changes in the underlying assumptions. This section analyzes how changes in some of the assumptions would affect the estimate of the average annual levels of highway investment for two scenarios presented in Chapter 7.

KEY TAKEAWAYS

- The Improve Conditions and Performance scenario is highly sensitive to the real discount rate assumed in the analysis. Substituting a 3-percent discount rate for the 7-percent discount rate assumed in the baseline would increase its average annual investment requirements by 20.0 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. Substituting a high or low value of a statistical life changes by only 1 percent the estimate of average annual investment requirements, in part because neither model evaluates the need for improvements that are primarily safety-focused.
- Reducing projected average annual VMT growth from 1.2 percent per year to 0.9 percent per year would reduce the average annual investment levels for both scenarios by 7.2 percent for the Maintain Conditions and Performance scenario and by 8.1 percent for the Improve Conditions and Performance scenario.

Scenarios Analyzed

The Improve Conditions and Performance scenario is defined in terms of the level of investment estimated to be cost-beneficial (i.e., all potential projects with a benefit-cost ratio greater than or equal to 1.0 are implemented). For this scenario, any change in assumptions that increases the value of benefits (or decreases costs) will result in a higher average annual investment level. Conversely, any change in assumptions that reduces the value of benefits (or increases costs) will result in a lower average annual investment level.

The situation for the Maintain Conditions and Performance scenario is a little more complicated, as it is defined in terms of the level of investment needed to maintain certain specific performance indicators in 2036 at 2016 levels. The Highway Economic Requirements System (HERS) inputs to this scenario identify the lowest level of investment at which the 2036 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 are better than) those in the 2016 base year. In practice, the binding constraint was maintaining average IRI; average delay improved (i.e., was reduced) under this scenario. Because system rehabilitation spending has a larger impact on average IRI than does system expansion spending, changes to assumptions that cause HERS to increase the share of investment directed toward system rehabilitation relative to system expansion will tend to reduce the level of investment needed to achieve the goals of this scenario. Conversely, changes to assumptions that cause HERS to place more value on system expansion relative to system rehabilitation will tend to increase the level of investment needed to maintain average IRI.

The National Bridge Investment Analysis (NBIAS) inputs to this scenario identify the lowest level of investment at which the percentage of bridges in poor condition (weighted by deck area) in 2036 matches that in 2016. This indicator is influenced by the relative level of investment directed toward bridge replacement vs. bridge rehabilitation, which can affect the investment level needed to achieve the goals of the scenario.

Alternative Economic Analysis Assumptions

The U.S. Department of Transportation (DOT) periodically issues guidance on valuing changes in travel time and traveler safety for use in benefit-cost analysis; the Office of Management and Budget (OMB) provides guidance on the choice of discount rate. 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 spent by travelers 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 2016. In the analyses presented in Chapters 7 and 10, traveler time savings are valued per person hour at $14.20 for personal travel and between $27.56 and $34.96 for business travel (Appendix A, Valuation of Travel Time Savings section). 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 personal travel, the values per person hour of travel are estimates subject to considerable uncertainty. 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, the present analysis includes sensitivity tests that set values of personal travel time savings lower or higher than the baseline. In line with DOT guidance, these values are 35 percent and 60 percent of median hourly household income, respectively.

Exhibit 9-1 shows the effects of these variations on spending levels in the two scenarios reexamined in this chapter. Assuming lower values of time reduces the average annual investment level for the Maintain Conditions and Performance scenario by 4.2 percent and for the Improve Conditions and Performance scenario by 3.8 percent. Conversely, assuming higher values of time increases the average annual investment level for both scenarios.

For the NBIAS-derived component of the scenarios, the effects of changing the assumed value of time are small (at most, a 1.1-percent change in average annual investment levels), consistent with bridge capacity expansion being outside the model's scope. The bridge preservation actions evaluated by NBIAS would have minimal effect on travel times, except where they would eliminate long detours caused by vehicle weight restrictions on a bridge.

Exhibit 9-1 ■ Impact of Alternative Value of Time Assumptions for Personal Travel on Highway Investment Scenario Average Annual Investment Levels

Alternative Time Valuation Assumptions for Personal Travel as Percentage of Hourly Earnings	Maintain Conditions and Performance Scenario		Improve Conditions and Performance Scenario	
	Billions of 2016 Dollars	Percent Change from Baseline	Billions of 2016 Dollars	Percent Change from Baseline
Baseline[1] (50% of Hourly Earnings)	**$98.0**		**$165.9**	
HERS-derived Component	$54.7		$91.7	
NBIAS-derived Component	$14.3		$25.1	
Other (Nonmodeled) Component	$29.1		$49.2	
Lower (35% of Hourly Earnings)	**$93.9**	**-4.2%**	**$159.6**	**-3.8%**
HERS-derived Component	$51.9	-5.1%	$87.5	-4.5%
NBIAS-derived Component	$14.2	-0.8%	$24.8	-1.1%
Other (Nonmodeled) Component	$27.9	-4.2%	$47.3	-3.8%
Higher (60% of Hourly Earnings)	**$100.2**	**2.2%**	**$169.8**	**2.4%**
HERS-derived Component	$56.1	2.6%	$94.2	2.8%
NBIAS-derived Component	$14.4	0.4%	$25.3	0.9%
Other (Nonmodeled) Component	$29.7	2.2%	$50.4	2.4%

[1]1The baseline levels shown correspond to the systemwide scenarios presented in Chapter 7. The investment levels shown are average annual values for the period from 2017 through 2036. Business travel is valued at 100% of hourly earnings for all three alternatives.

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

Sources: Highway Economic Requirements System; 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 2016 Spending scenario presented in Chapter 7, the values for these HERS and NBIAS components total $75.2 billion. In 2016, nonmodeled spending accounted for 29.7 percent of total investment and is assumed to form the same share in all scenarios presented in Chapter 7.

Likewise, the nonmodeled component is set at 29.7 percent of the total investment level in the sensitivity analysis for the Maintain Condition and Performance and the Improve Condition and Performance scenarios presented in this section. 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.

For the HERS-derived component of the Improve Conditions and Performance scenario, reducing the value of traveler time results in a 5.5-percent reduction in average annual investment levels, whereas increasing the value of traveler time results in a 4.2-percent increase. 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 (i.e., benefits decline) and more when traveler time savings are valued more (i.e., benefits increase).

For the HERS-derived component of the Maintain Conditions and Performance scenario, reducing the value of traveler time results in a 6.3-percent reduction in average annual investment levels.

Reducing the value of travel time savings makes capacity expansion improvements relatively less attractive, causing HERS to make a larger share of funds available for the system rehabilitation improvements that more directly affect pavement roughness. This allows the criteria for the scenario to be met (maintaining average pavement roughness) at a lower overall cost. Conversely, increasing the value of time makes capacity expansion improvement relatively more attractive, reducing the share of investment available for system rehabilitation, and requiring a higher overall level of HERS investment to achieve the scenario objective of maintaining average pavement roughness.

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 a 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. The rationale is that for a potential Federal investment to be deemed cost-beneficial, the expected rate of return should be at least as high as the average before-tax rate of return on private-sector investments, which in the United States, has been about 7 percent in real dollars (net of inflation) over the long term. This approach to setting the discount rate is common in benefit-cost analyses of public investment in transportation infrastructure, in the United States and abroad.

In 2003, OMB's Circular A-4 recommended that regulatory analyses use both 3 percent and 7 percent as alternative discount rates.[27] The justifications for these recommendations also apply to benefit-cost analyses of public investments, so 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. Some governmental organizations use discount rates much closer to 3 percent than to 7 percent for benefit-cost analyses of transportation infrastructure investments. In the United States, examples include the discount rates of 1.7 percent and 4.0 percent reported to be used by the Minnesota Department of Transportation and the Florida Department of Transportation respectively.[28] For comparison, the sensitivity tests performed in this section also consider the use of a 10 percent discount rate, per the OMB policy prior to 1992.

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 do 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 (BCR) for all potential projects. As a result, some potential projects that had a BCR below 1.0 (i.e., costs exceed benefits), based on a higher assumed discount rate, would have a BCR above 1.0 (i.e., benefits exceed costs) if a lower discount rate were assumed.

[27] https://obamawhitehouse.archives.gov/omb/circulars_a004_a-4/

[28] *Use of Benefit-Cost Analysis by State Departments of Transportation*, Federal Highway Administration, n.d., available at: https://www.fhwa.dot.gov/policy/otps/pubs/bca_report/. A relatively low discount rate was also recommended for use in the benefit-cost analyses conducted by Seattle public utilities; the document that developed this recommendation clearly delineates the issues in selecting a discount rate (see *Updating The Discount Rate for Benefit-Cost Analyses at Seattle Public Utilities,* Bruce Flory, n.d., available at http://mrsc.org/getmedia/9d05a8d7-b36d-4af4-8e1c-94491c351bb0/s42discrate.pdf.aspx.

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. The analysis in this report essentially follows DOT's guidance on the "value of a statistical life" saved in 2016, which recommends a base value of $9.6 million, but also requires 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.

As revealed in previous C&P reports, the HERS and NBIAS models are both much less sensitive to changes in the assumed value of a statistical life than they are to the assumed value of time. This is an artifact of the types of improvements captured by the models, which omit the types of targeted safety improvements that have the most direct impact on reducing crashes and fatalities. As noted in Part IV of this report, proposed changes to the HPMS include the addition of Model Inventory of Roadway Elements (MIRE) safety-related data into the HPMS framework. The future availability of such data would facilitate future analysis of targeted safety improvements in HERS.

Applying the recommended alternatives in HERS and NBIAS would increase both scenarios by approximately 1 percent, assuming a higher value of a statistical life, and reduce both scenarios by approximately 1 percent, assuming a lower value of a statistical life.

Since the Improve Conditions scenario is defined around exhausting all opportunities for implementing cost-beneficial projects, lowering the discount rate increases its average annual investment level. Accordingly, *Exhibit 9-2* 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 16.5 percent, due almost entirely to the 20.0 percent increase in the HERS component; the NBIAS component increases by only 3.5 percent. Conversely, raising the discount rate from the baseline value of 7 percent to 10 percent reduces the total level of investment in the Improve Conditions and Performance scenario by $20.0 billion.

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 projects than for system expansion projects. Because the preservation share of spending increases, the $53.4 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. Conversely, an increase in the discount rate from the baseline value of 7 percent to 10 percent marginally increases spending in this scenario because the preservation share of spending decreases.

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 4.9 percent. The reduction in the discount rate expands the set of bridge improvement options that satisfy the NBIAS requirement that any selected improvements be cost-beneficial; with the choice set thus broadened, the model's estimate of the cost to maintain the deck-area weighted share of bridges rated poor at the base-year level decreases. When the discount rate is increased from the baseline value of 7 percent to 10 percent, the estimate of cost to maintain decreases by 1.7 percent. The explanation is that the increase in the discount rate favors projects that address functional deficiencies rather than structural deficiencies connected to bridge condition. Moreover, the target in the Maintain scenario is to keep unchanged from the base year level the percent of deck area in poor condition. Thus, since the increase in the discount rate reduces the share of spending that would address condition problems, the total amount of spending must increase to meet the condition target.

Exhibit 9-2 ■ Impact of Alternative Discount Rate Assumptions 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 2016 Dollars	Percent Change from Baseline	Billions of 2016 Dollars	Percent Change from Baseline
Baseline[1] (7% Discount Rate)	**$98.0**		**$165.9**	
HERS-derived Component	$54.7		$91.7	
NBIAS-derived Component	$14.3		$25.1	
Other (Nonmodeled) Component	$29.1		$49.2	
Lower (3% Discount Rate)	**$95.2**	**-2.8%**	**$193.2**	**16.5%**
HERS-derived Component	$53.4	-2.3%	$110.0	20.0%
NBIAS-derived Component	$13.6	-4.9%	$25.9	3.5%
Other (Nonmodeled) Component	$28.2	-2.8%	$57.3	16.5%
Higher (10% Discount Rate)	**$98.6**	**0.6%**	**$145.9**	**-12.0%**
HERS-derived Component	$55.3	1.2%	$79.5	-13.3%
NBIAS-derived Component	$14.1	-1.7%	$23.2	-7.6%
Other (Nonmodeled) Component	$29.2	0.6%	$43.3	-12.0%

[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 2017 through 2036.

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

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

Traffic Growth Projections

For each of the approximately 130,000 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 on a section-by-section basis. The drawbacks to using these forecasts are: (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 adjust their forecasts for recent changes in the trend rate of national VMT growth (as discussed in the 2015 C&P Report, Chapter 9).

The modeling in this edition of the C&P Report thus supplements the section-level forecasts from the HPMS with national-level VMT forecasts from an FHWA econometric model. The Volpe National Transportation Systems Center developed this FHWA 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. The most recent documentation for the supporting model is available at http://www.fhwa.dot.gov/policyinformation/tables/vmt/vmt_model_dev.cfm.

The national forecasts used in the present analysis were published online as *FHWA Forecasts of Vehicle Miles Traveled (VMT): Spring 2018.*[29] For all vehicle types combined, VMT growth is forecast to average 1.2 percent annually over 20 years starting in 2017. This forecast is conditional on certain baseline projections for economic growth. In alternative scenarios where economic growth is projected to be higher or lower than in the baseline, VMT growth is forecast to average 0.9 percent or 1.3 percent. The highway investment scenarios presented in this C&P report (Chapter 7) use the baseline forecast of VMT growth, while the alternative forecasts are used in the sensitivity test presented in this section.

This report's modeling also uses the breakdown by vehicle category in the FHWA econometric forecasts (*Exhibit 9-3*). 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, 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).[30]

Exhibit 9-3 ■ Projected Average Percent Growth per Year in VMT by Vehicle Class, 2017–2036

Vehicle Class	VMT Growth Rate		
	Baseline	From Low-economic Growth Forecast	From High-economic Growth Forecast
Passenger Vehicles	1.1	0.9	1.3
Single-unit Trucks	1.8	1.4	2.3
Combination Trucks	1.6	1.2	1.9
All Vehicles	**1.2**	**0.9**	**1.3**

Source: FHWA National Vehicle Miles Traveled Projection.

Alternative Growth Rates

In the Improve Conditions and Performance scenario, replacing the baseline traffic growth assumptions with the low-growth assumptions reduces by 9.6 percent the HERS component of the estimated investment level needed to achieve the scenario's objective of funding all cost-beneficial improvements (*Exhibit 9-4*). For all investment components of the Improve Conditions and Performance scenario, the change from baseline to low-growth assumptions reduces the NBIAS component by much less, 2.8 percent, making for an overall reduction (both model components) of 8.1 percent. For the Maintain Conditions and Performance scenario, this same sensitivity test has somewhat less effect on the required investment level: reductions of 8.7 percent (HERS component), 1.4 percent (NBIAS component), and 7.2 percent (both components).

Replacing the baseline traffic growth assumptions with the high-growth assumptions has a much smaller effect on the estimated investment requirements. This is consistent with the annual VMT growth rate under the high-growth assumptions, 1.3 percent, not much exceeding the 1.2 percent under the baseline assumptions. The percentage increase in the estimated investment requirement is 2.1 percent in the Improve Conditions and Performance scenario and 1.9 percent in the Maintain Conditions and Performance scenario. As in the sensitivity test discussed earlier in this section that

[29] https://www.fhwa.dot.gov/policyinformation/tables/vmt/vmt_forecast_sum.pdf
[30] In this calculation, the section-specific VMT growth rates in the State-supplied forecasts in the HPMS and NBI are initially assumed to apply to each vehicle category. The HPMS section-level forecasts are adjusted upward or downward proportionally, as needed to conform to the alternative value for nationwide VMT growth.

reduces the VMT growth rate, the percentage effect is again considerably larger for the HERS component of the investment requirement than for the NBIAS component.

An assumption of higher future VMT growth would increase the estimated benefits for both system expansion projects (higher demand translates into higher benefits for improvements that produce travel time savings) and system rehabilitation projects (higher VMT increases the rate of deterioration of existing assets). Increased rates of asset deterioration would also result in higher levels of investment needed to maintain assets in their current condition state.

Exhibit 9-4 ■ 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 2016 Dollars	Percent Change from Baseline	Billions of 2016 Dollars	Percent Change from Baseline
Baseline[2] (1.2% per Year, Tied to May 2018 Baseline Forecast)	**$98.0**		**$165.9**	
HERS-derived Component	$54.7		$91.7	
NBIAS-derived Component	$14.3		$25.1	
Other (Nonmodeled) Component	$29.1		$49.2	
Lower (0.9% per Year, Tied to May 2018 Low Economic Growth Forecast)	**$91.0**	**-7.2%**	**$152.5**	**-8.1%**
HERS-derived Component	$49.9	-8.7%	$82.9	-9.6%
NBIAS-derived Component	$14.1	-1.4%	$24.4	-2.8%
Other (Nonmodeled) Component	$27.0	-7.2%	$45.2	-8.1%
Higher (1.3% per Year, Tied to May 2018 High Economic Growth Forecast)	**$99.9**	**1.9%**	**$169.4**	**2.1%**
HERS-derived Component	$55.9	2.3%	$93.8	2.3%
NBIAS-derived Component	$14.3	0.3%	$25.3	1.1%
Other (Nonmodeled) Component	$29.6	1.9%	$50.2	2.1%

[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 2017 through 2036.

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

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

What if Traffic Doesn't Grow?

Although VMT at the national level has sometimes decreased year-to-year, VMT has traditionally increased over the long run as population and the economy grew. However, exploring a no-growth analysis is of interest, both to serve as a conservative estimate of investment needs over the 20 years from 2015 through 2034 and to highlight the portion of the baseline analysis that is attributable to future traffic growth. Similar to the analyses presented in *Exhibit 9-4*, the HERS and NBIAS models were re-run under the assumption of zero growth in VMT over 20 years, with an adjustment made for other non-modeled capital spending types.

Eliminating the baseline assumption of 1.2-percent annual growth in VMT would reduce the average investment level under the Maintain Conditions and Performance scenario by 19.8 percent (to $78.6 billion) and would reduce the average annual investment level under the Improve Conditions and Performance scenario by 25.6 percent (to $123.4 billion). As in the other tests that varied the projected VMT growth, the estimate of investment needs for highway capacity expansion and pavement preservation (obtained from HERS) is much more sensitive to the assumed traffic growth rate than to the estimate of investment needs for bridge preservation (obtained from NBIAS).

Sensitivity Analysis – Transit

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 these input variables. Note that, by definition, funding under the Sustain Recent Spending scenario does not vary with changes in any input variable, and thus this scenario is not considered in this sensitivity analysis.

KEY TAKEAWAYS

- TERM is sensitive to changes in replacement thresholds. A 0.5-point change in the condition scale results in up to a 34-percent change in replacement needs.
- Modeled changes in capital costs under different scenarios are as follows:
  - SGR (no benefit-cost analysis [BCA] test): the change in capital costs for preservation costs is comparable to the change in replacement investment costs.
  - High- and Low-Growth scenarios (applies to BCA test): a 25-percent increase in capital cost results in a 13- to 14-percent increase in investment.
- Preservation expenditures have low sensitivity to variations in value of time. Doubling the value of time cost (from $12.80 to $25.60) increases investment by 6–8 percent.
- TERM is relatively insensitive to changes in the discount rate. Dropping the discount rate from 7 percent to 3 percent leads to an increase of only 1 percent in investment levels.

Changes in Asset Replacement Timing (Condition Threshold)

Each of the three investment scenarios, as well as the SGR benchmark, examined in Chapter 9 assumes that assets are replaced at condition rating 2.5, as determined by TERM's asset condition decay curves. (In this context, 2.5 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. Within this context, replacement at condition 2.5 assumes that assets are replaced close to or soon after they have attained their expected useful lives. Replacement at condition 2.5 can therefore be thought of as providing a replacement schedule that reflects asset life expectancy (the optimal time for asset replacement) but that is also potentially conservative, in the sense that many assets are replaced after their expected replacement age. Later replacement may be related to funding constraints (meaning some assets must be retained in service past their expected useful life) and to the time required to plan, fund, and procure replacement assets. Similarly, some assets can require replacement *before* attaining their expected life, for example due to premature asset failure, requirements for expanded asset capacity (e.g., a larger station), or other factors.

Importantly, the 2.5 replacement threshold only applies to *replaceable* assets. In contrast, nonreplaceable assets are subject only to ongoing maintenance and rehabilitation activities that help preserve these asset types and are inexpensive compared with the assets' initial acquisition cost. Unlike replaceable assets, nonreplaceable assets are not subject to the 2.5 replacement threshold, and their condition continues to decay beyond that point (at a very slow rate of decline). Examples of nonreplaceable assets include assets with very long useful lives such as elevated structures, subway stations, and tunnels.

Exhibit 9-5 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 9-5*, 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. Note that investment needs do not strictly increase with the replacement threshold in the High- and Low-Growth scenarios. As the replacement threshold increases, more assets begin to fail the benefit-cost test and are not replaced, resulting in lower total investment than at lower replacement thresholds.

Exhibit 9-5 ■ Impact of Alternative Replacement Condition Thresholds on Transit Preservation Investment Needs by Scenario (Excludes Expansion Impacts)

Replacement Condition Thresholds	SGR Benchmark		Low-Growth Scenario		High-Growth Scenario	
	Billions of 2016 Dollars	Percent Change from Baseline	Billions of 2016 Dollars	Percent Change from Baseline	Billions of 2016 Dollars	Percent Change from Baseline
Very Late Asset Replacement (2.00)	$11.9	-34%	$17.6	-24%	$19.1	-22%
Replace Assets Later (2.25)	$15.0	-17%	$20.5	-12%	$22.1	-10%
Baseline (2.50)	$18.1		$23.2		$24.7	
Replace Assets Earlier (2.75)	$21.1	17%	$26.0	12%	$26.6	8%
Replace Assets Much Earlier (3.00)	$23.3	29%	$27.1	17%	$27.6	12%

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. Sources of these data include the Federal Transit Administration's Capital Cost Database (which documents as-built costs for a sample of New Starts projects from 1980 through 2016), and ongoing sampling of agency asset inventory holdings and replacement costs. Asset prices in the current version of TERM have been converted from the dollar-year in which assets were acquired (which vary by agency and asset) to 2016 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 9-6* shows, TERM projects that a 25-percent increase in capital costs (i.e., all costs are set to 125 percent of the value used in this C&P Report) would lead to proportional growth in the SGR benchmark, but would be 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 in terms of which projects are carried out), whereas the two cost-constrained scenarios do employ this test. Hence, for the Low-Growth and 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. For these latter two scenarios, a 25-percent increase in capital costs would yield roughly a 13- to 14-percent increase in needs that pass TERM's benefit-cost test.

Exhibit 9-6 ■ 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 2016 Dollars	Percent Change from Baseline	Billions of 2016 Dollars	Percent Change from Baseline	Billions of 2016 Dollars	Percent Change from Baseline
Baseline (No Change)	$18.1		$23.2		$24.7	
Increase Costs by 25%	$22.6	25%	$26.5	14%	$28.0	13%

Source: Transit Economic Requirements Model.

Changes in the Value of Time

The most significant source of transit investment benefits, as assessed by TERM's BCA, 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 Recent Spending scenario uses TERM's estimated benefit-cost ratios to allocate fixed levels of funding to preferred investments, whereas the computation of the SGR benchmark does not.)

Exhibit 9-7 shows the effect of varying the value of time on the needs estimates of the Low-Growth and High-Growth scenarios. 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. This multiplier reflects the observation that people view time in a transit vehicle as productive, whereas time spent waiting is viewed as "wasted."

Exhibit 9-7 ■ 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 2016 Dollars	Percent Change from Baseline	Billions of 2016 Dollars	Percent Change from Baseline
Reduce by 50% ($6.8)	$20.6	-11%	$22.1	-13%
Baseline ($13.6)	$23.2		$25.3	
Increase by 100% ($27.2)	$24.7	6%	$26.9	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 8 percent to a decrease of about 14 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 earlier 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 9-8*, 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 a 1-percent increase.

Exhibit 9-8 ■ Impact of Alternative Discount Rates on Transit Investment Estimates by Scenario

Discount Rates	Low-Growth Scenario		High-Growth Scenario	
	Billions of 2016 Dollars	Percent Change from Baseline	Billions of 2016 Dollars	Percent Change from Baseline
7% (Baseline)	$23.2		$24.7	
3%	$23.4	1%	$25.0	1%

Source: Transit Economic Requirements Model.

Under this sensitivity test, investment needs are higher for the lower discount rate (3 percent) 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 vs. 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 "SGR" 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.

No Ridership Growth

This analysis considers the impact of setting the level of ridership growth to 0 percent for both the Low- and High-Growth scenarios. This change effectively makes these two scenarios equivalent and limits scenario analysis to an assessment of 20-year reinvestment costs for existing transit assets. By definition, the SGR benchmark only considers reinvestment in existing transit assets and hence already assumes 0 percent ridership growth. In addition, the SGR benchmark, unlike the Low- and High-Growth scenarios, does not apply TERM's benefit-cost test.

The impact of reducing ridership growth to 0 percent is shown in Exhibit 9-9. As expected, there is no change in cost for the SGR benchmark. In contrast, the annual total cost of the Low- and High-Growth scenarios both decline to $16.6 billion (as both scenarios now assume the same 0-percent grow rate). Note further that the $16.6 billion annual cost of the Low- and High-Growth scenarios is less than the $18.1 billion for the SGR benchmark, as the latter does not apply TERM's benefit-cost scenario.

Exhibit 9-9 ■ Impact of 0% Rider Growth on Transit Investment Estimates by Scenario

No Ridership Growth	SGR Benchmark		Low-Growth Scenario		High-Growth Scenario	
	Billions of 2016 Dollars	Percent Change from Baseline	Billions of 2016 Dollars	Percent Change from Baseline	Billions of 2016 Dollars	Percent Change from Baseline
Baseline (No Change)	$18.1		$23.2		$24.7	
0% Ridership Growth	$18.1	0%	$16.6	-28%	$16.6	-33%

Source: Transit Economic Requirements Model.

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CHAPTER 10: Impacts of Investment

Impacts of Investment – Highways

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. The analyses described in this chapter make no explicit assumptions regarding how future investment in highways could be funded.

KEY TAKEAWAYS

- HERS results indicate it is cost-beneficial to reduce the percentage of travel on pavements with poor ride quality, but not necessarily to reduce average pavement roughness. For Interstate highways, average IRI would get slightly worse even at the Improve Conditions and Performance scenario level.
- Unlike for bridges overall, NBIAS results suggest that if spending is sustained at recent levels for bridges on Federal-aid highways, NHS bridges and Interstate bridges would be insufficient to keep the deck area-weighted share of bridges in poor condition from rising over time.

This section examines the types of investments used 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.

HERS, NBIAS, and Nonmodeled Inputs to the Improve Conditions and Performance Scenario

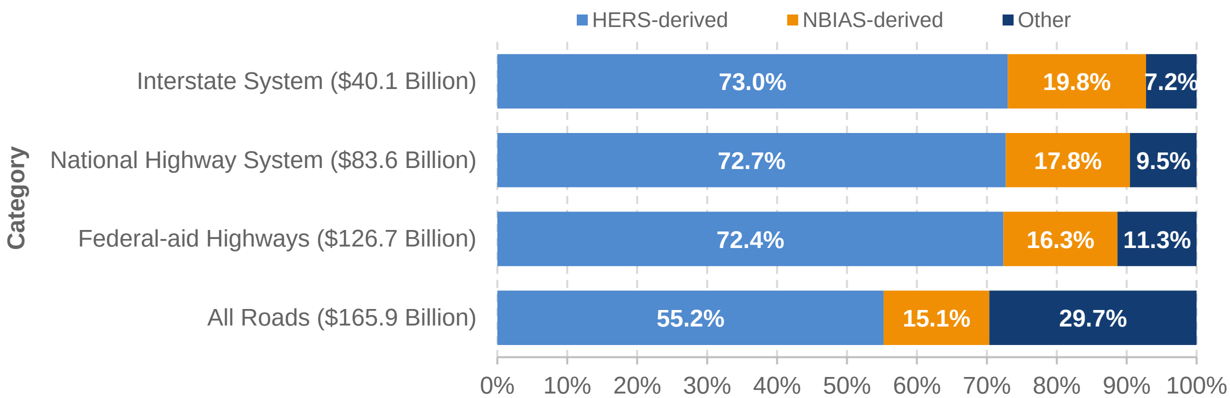
Exhibit 10-1 illustrates the derivation of the Improve Conditions and Performance scenario presented in Chapter 7. Of the $165.9 billion average annual investment level for all public roads under this scenario, 15.1 percent was derived from NBIAS (corresponding to the $25.1 billion identified as "System Rehabilitation – Bridge" in the "All Public Roads" row) and 55.2 percent was derived from HERS (corresponding to the $60.2 billion and $31.5 billion identified as "System Rehabilitation – Highways" and "System Expansion," respectively, in the "Federal-aid Highways" row). The remaining 29.7 percent was nonmodeled; this corresponds to the $23.5 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" ($19.4 billion, computed as $79.6 billion minus $60.2 billion) and "System Expansion" ($6.3 billion, computed as $37.8 billion minus $31.5 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 recent spending from 2012 through 2016.

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 ($40.1 billion), the National Highway System (NHS) ($83.6 billion, including the amount directed to Interstate highways), and Federal-aid Highways ($126.7 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 72.4 percent HERS-derived, 16.3 percent NBIAS-derived, and 11.3 percent nonmodeled. The average annual investment level for the National Highway System is 72.7 percent HERS-derived, 17.8 percent NBIAS-derived, and

9.5 percent nonmodeled. The share of spending by source of estimate for the Interstate System is similar, with 73.0 percent HERS-derived, 19.8 percent NBIAS-derived, and 7.2 percent nonmodeled.

Exhibit 10-1 ■ Improve Conditions and Performance Scenario, 2017 Through 2036: Distribution by System, by Source of Estimate, and by Capital Improvement Type



System Component	System Rehabilitation			System Expansion[1]	System Enhancement	Total	Percent of Total
	Highway[1]	Bridge[2]	Total				
Average Annual Investment in Billions of 2016 Dollars							
Interstate Highway System	$16.8	$7.9	$24.8	$12.4	$2.9	$40.1	24.1%
National Highway System	$37.1	$14.9	$51.9	$23.7	$8.0	$83.6	50.4%
Federal-aid Highways	$60.2	$20.7	$80.8	$31.5	$14.3	$126.7	76.3%
All Roads	$79.6	$25.1	$104.7	$37.8	$23.5	$165.9	100.0%

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

[1] The “HERS-derived” share includes most outlays (All Roads are not included in the HERS-derived share) 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.”

[2] The “NBIAS-derived” share includes all outlays classified as “System Rehabilitation: Bridge.”

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

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

Exhibit 10-2 introduces the seven 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 BCR of 1.0 in each year over the 20-year analysis period. The remaining six runs are funding-constrained, for which HERS ranks potential projects in order of BCR and implements them until the funding constraint is reached.

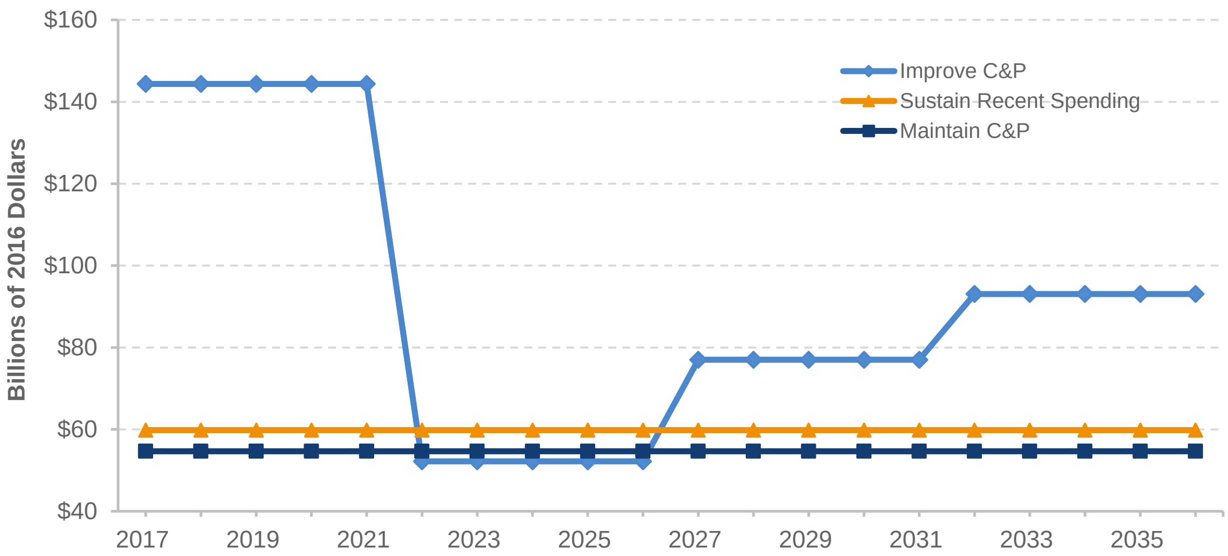
One funding level shown in *Exhibit 10-2* represents the spending level designed to match a specific level of performance in 2036; a spending level of $54.7 billion is projected to be adequate to allow average pavement roughness as measured by the International Roughness Index (IRI) in 2036 to match the level in 2016 (see discussion of IRI in Chapter 6) and for average delay to be at least as low in 2036 as it was in 2016. The Maintain C&P reference in *Exhibit 10-2* (in the "Link to Chapter 7 Scenario" column) signifies that this level of investment feeds into the Maintain Conditions and Performance scenario presented in Chapter 7. The Recent Spending reference indicates that this level of spending ($59.8 billion) supplies the Sustain Recent Spending scenario presented in Chapter 7. This represents the average annual level of constant-dollar investment from 2012 to 2016 that was directed toward the types of improvements modeled in HERS. The remaining four of the seven funding levels shown in *Exhibit 10-2* were selected to fill gaps between the three data points linked to specific scenarios, and to extend the lower end of the range of investment levels analyzed.

The portion of each investment level that HERS directs to system rehabilitation vs. system expansion is important, as these types of investments have varying degrees of influence on different performance measures. Investment in system rehabilitation (ranging from $26.8 billion to $60.2 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 $15.2 billion to $31.5 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 seven future funding levels for Federal-aid highways that were selected for further analysis in this section would translate into cumulative spending in 5-year intervals (corresponding to 5-year analysis periods used in HERS). Achieving a minimum BCR of 1.0 in all four funding periods would require a 20-year investment of $1.833 trillion for the "Improve C&P" scenario. Within that period, HERS would invest $722 billion in the first 5 years, $261 billion in the second 5 years, $385 billion in the third 5 years, and $465 billion in the fourth 5 years. This front-loaded pattern is driven by the existence of a backlog of cost-beneficial investment opportunities, as referenced in Chapter 7. The investment levels for the other six rows remain constant in each 5-year funding period based on how these analyses were defined.

Exhibit 10-2 ■ HERS Annual Investment Levels Analyzed for Federal-aid Highways, 2017–2036



Spending Modeled in HERS (Billions of 2016 Dollars)									Link to Chapter 7 Scenario
Average Annual Over 20 Years			Cumulative						
Total HERS Spending	System Rehabilitation Spending[1]	System Expansion Spending[1]	5-year 2017 through 2021	5-year 2022 through 2026	5-year 2027 through 2031	5-year 2032 through 2036	20-year 2017 through 2036		
$91.7	$60.2	$31.5	$721.8	$261.0	$385.0	$465.4	$1,833.2	Improve C&P
$80.0	$52.1	$27.9	$400.0	$400.0	$400.0	$400.0	$1,600.0	
$70.0	$45.2	$24.8	$350.0	$350.0	$350.0	$350.0	$1,400.0	
$59.8	$38.6	$21.2	$299.1	$299.1	$299.1	$299.1	$1,196.5	Recent Spending
$54.7	$35.2	$19.5	$273.3	$273.3	$273.3	$273.3	$1,093.3	Maintain C&P
$48.0	$30.7	$17.3	$240.0	$240.0	$240.0	$240.0	$960.0	
$42.0	$26.8	$15.2	$210.0	$210.0	$210.0	$210.0	$840.0	

Note: HERS is Highway Economic Requirements System.

[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.

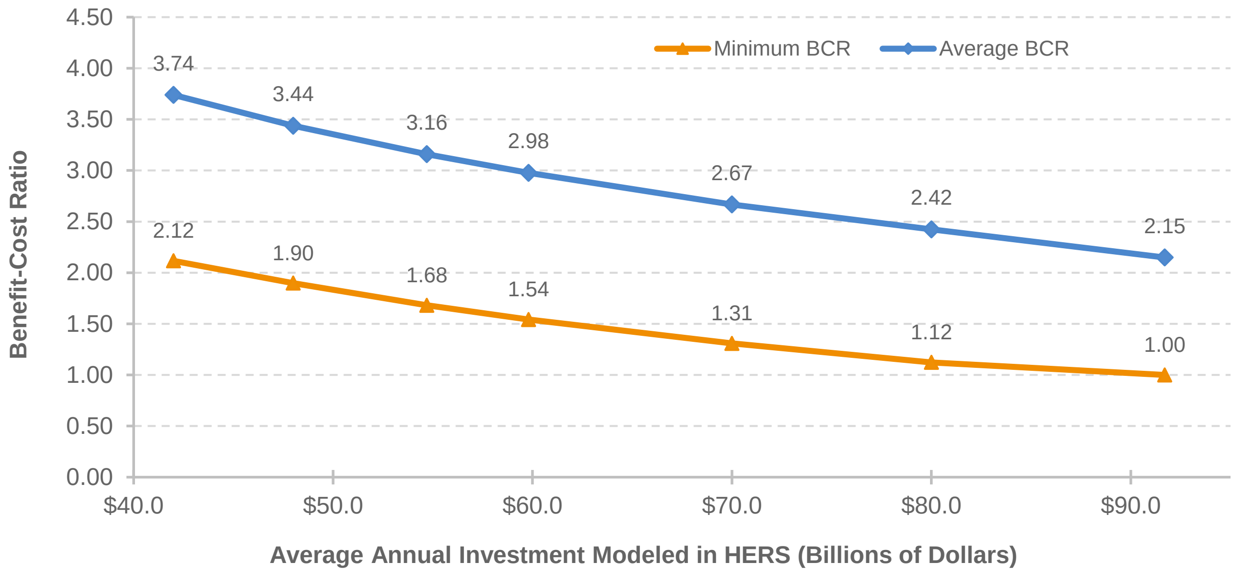
Source: Highway Economic Requirements System.

Exhibit 10-3 illustrates the marginal BCRs (i.e., the lowest BCR among the improvements selected within a funding period) associated with the seven future funding levels. *Exhibit 10-3* also provides the minimum BCRs across all funding periods (which represents 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. The marginal BCRs for the remaining rows vary by funding period, as these analyses held annual spending constant.

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, 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 $91.7 billion, the average BCR of 2.15 exceeds the minimum BCR of 1.00.

Exhibit 10-3 ■ Minimum and Average Benefit-Cost Ratios for Different Possible Funding Levels on Federal-aid Highways



HERS-modeled Investment on Federal-aid Highways Average Annual Investment (Billions of 2016 Dollars)	Benefit-cost Ratios[1]						Link to Chapter 7 Scenario
	Average BCR 20-year: 2017 through 2036	Marginal BCR[2]				Minimum BCR 20-Year: 2017 through 2036	
		5-year 2017 through 2021	5-year 2022 through 2026	5-year 2027 Through 2031	5-year 2032 through 2036		
$91.7	**2.15**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**Improve C&P**
$80.0	2.42	1.73	1.23	**1.12**	1.14	**1.12**	
$70.0	2.67	1.88	1.42	**1.31**	1.36	**1.31**	
$59.8	2.98	2.08	1.66	**1.54**	1.60	**1.54**	Recent Spending
$54.7	3.16	2.21	1.78	**1.68**	1.74	**1.68**	Maintain C&P
$48.0	3.44	2.38	1.95	**1.90**	1.97	**1.90**	
$42.0	3.74	2.59	2.17	**2.12**	2.18	**2.12**	

Note: HERS is Highway Economic Requirements System; BCR is benefit-cost ratio.

[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.

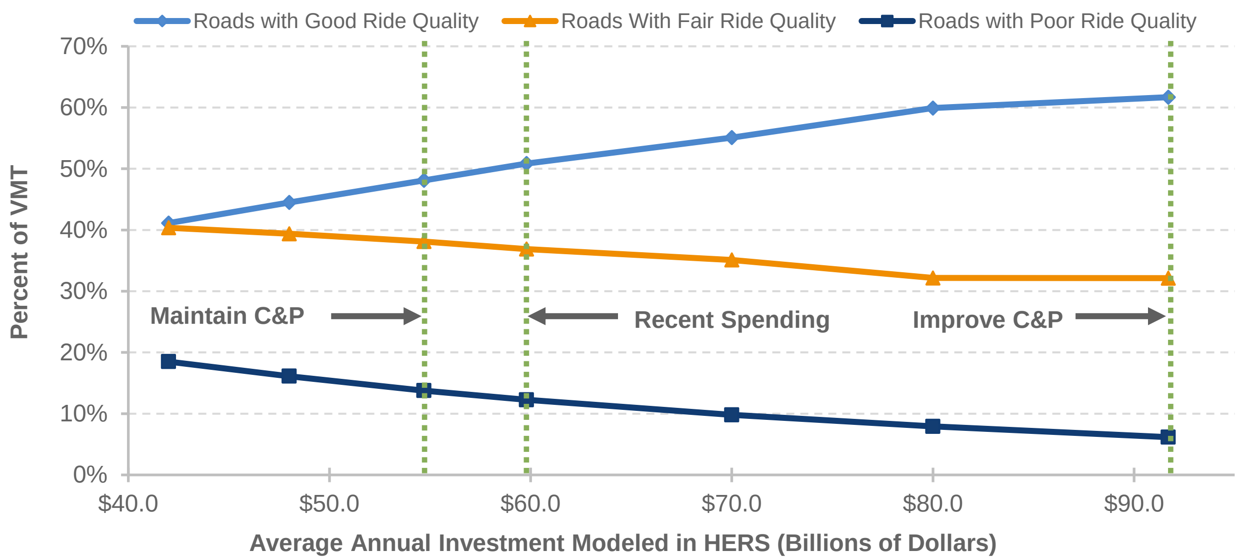
Impact of Future Investment on Ride Quality on Federal-aid Highways

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 2036 than they were in 2016. At the highest level of annual investment analyzed ($91.7 billion, including $60.2 billion for system rehabilitation), VMT-weighted average IRI is projected to decrease by 16.4 percent. For the $54.7 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 2036 as they were in 2016, whereas for the lower investment levels, Federal-aid highways are projected to have higher average IRI in 2036 than they did in 2016.

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 but the lowest annual level of investment analyzed ($42.0 billion, including $26.8 billion for system rehabilitation), the 2036 projection for the percentage of travel occurring on pavements with "poor" ride quality is lower than the 17.1 percent that occurred in 2016, 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, whereas the share of travel on roads with "fair" ride quality decreases roughly linearly with spending. The projections for the percentage of VMT with "good" ride quality for 2036 range from 61.7 percent at the highest level of average annual investment modeled to 41.1 percent at the lowest level of investment modeled.

As noted in Chapter 6, the IRI threshold of 170 used to identify fair ride quality was originally set to measure performance on the National Highway System (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 6.2 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 2036 Pavement Ride Quality Indicators for Federal-aid Highways



HERS-modeled Capital Investment Average Annual Spending (Billions of 2016 Dollars)		Projected 2036 Condition Measures on Federal-aid Highways[1,2]					
		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	Link to Chapter 7 Scenario
$91.7	$60.2	61.7%	32.1%	6.2%	97.1	-16.4%	Improve C&P
$80.0	$52.1	59.9%	32.2%	7.9%	101.1	-13.0%	
$70.0	$45.2	55.1%	35.1%	9.8%	106.5	-8.3%	
$59.8	$38.6	50.9%	36.9%	12.3%	112.5	-3.2%	Recent Spending
$54.7	$35.2	48.1%	38.1%	13.8%	116.2	**0.0%**	**Maintain C&P**
$48.0	$30.7	44.5%	39.4%	16.1%	121.3	4.4%	
$42.0	$26.8	41.1%	40.4%	18.5%	126.7	9.0%	
Base Year Values:		**48.9%**	**34.0%**	**17.1%**	**116.2**		

Note: IRI is International Roughness Index; VMT is vehicle miles traveled.

[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."

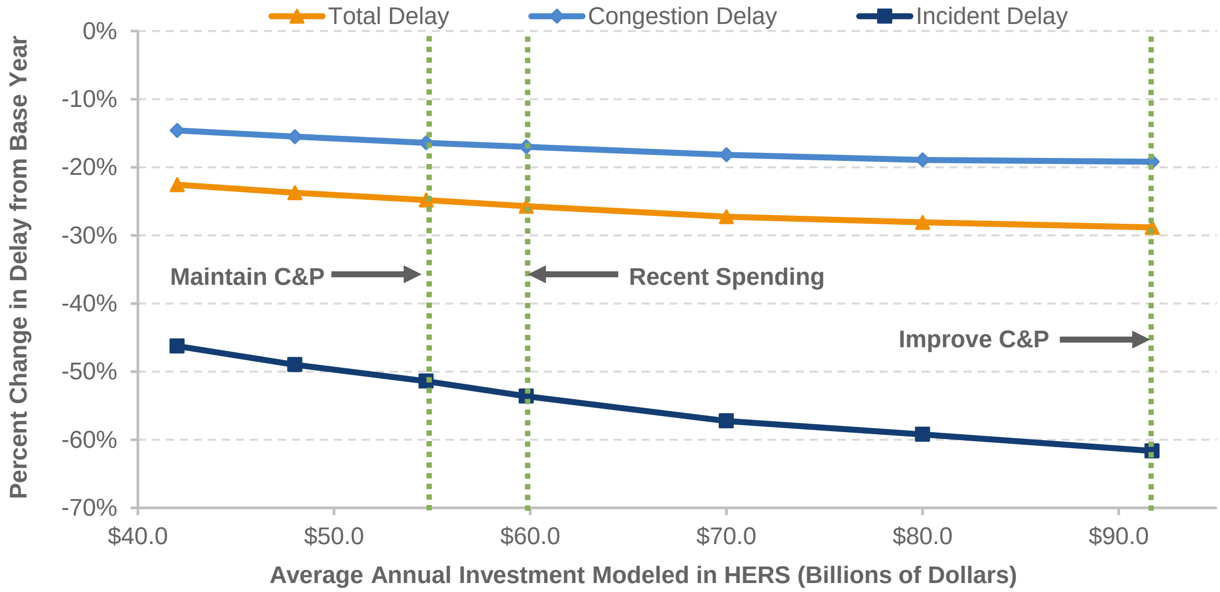
Source: Highway Economic Requirements System.

Impact of Future Investment on Travel Delay and Speed on Federal-aid Highways

Exhibit 10-5 shows the HERS projections for the impact of investment levels on average speed and travel delay. The exhibit splits out the portion of the investment that HERS allocates for system expansion, 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 $15.2 billion (which feeds into the Maintain Conditions and Performance scenario in Chapter 7) to an average annual investment of $31.5 billion (which feeds into 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.

Across all investment levels presented in *Exhibit 10-5*, annual delay per vehicle in 2036 is lower than the 2016 level (52.4 hours), with reductions in delay ranging from 11.8 hours (52.4 hours minus 40.6 hours) in the lowest level of investment analyzed to 15.1 hours (52.4 hours minus 37.3 hours) in the highest. The projected increases in average vehicle speed are narrow, ranging from 45.8 miles per hour to 46.4 miles per hour, compared with the 2016 level of 43.5 miles per hour.

Exhibit 10-5 ■ Projected Impact of Alternative Investment Levels on 2036 Highway Travel Delay and Speed on Federal-aid Highways



HERS-modeled Capital Investment Average Annual Spending (Billions of 2016 Dollars)		Projected 2036 Performance Measures on Federal-aid Highways					Link to Chapter 7 Scenario
				Percent Change Relative to Base Year			
Total	System Expansion[1]	Average Speed in 2036 (mph)	Annual Hours of Delay per Vehicle[2]	Total Delay per VMT	Congestion Delay per VMT	Incident Delay per VMT	
$91.7	$31.5	46.4	37.3	-28.8%	-19.2%	-61.6%	Improve C&P
$80.0	$27.9	46.3	37.7	-28.1%	-18.9%	-59.2%	
$70.0	$24.8	46.3	38.1	-27.2%	-18.2%	-57.2%	
$59.8	$21.2	46.1	38.9	-25.7%	-17.0%	-53.6%	Recent Spending
$54.7	$19.5	46.0	39.4	-24.8%	-16.4%	-51.4%	Maintain C&P
$48.0	$17.3	45.9	40.0	-23.7%	-15.5%	-49.0%	
$42.0	$15.2	45.8	40.6	-22.6%	-14.6%	-46.2%	
Base Year Values:		**43.5**	**52.4**				

Note: HERS is Highway Economic Requirements System; VMT is vehicle miles traveled.

[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 11,810, the average VMT per registered vehicle in 2016. 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.

Sources: Highway Economic Requirements System; Highway Statistics 2015, Table VM-1.

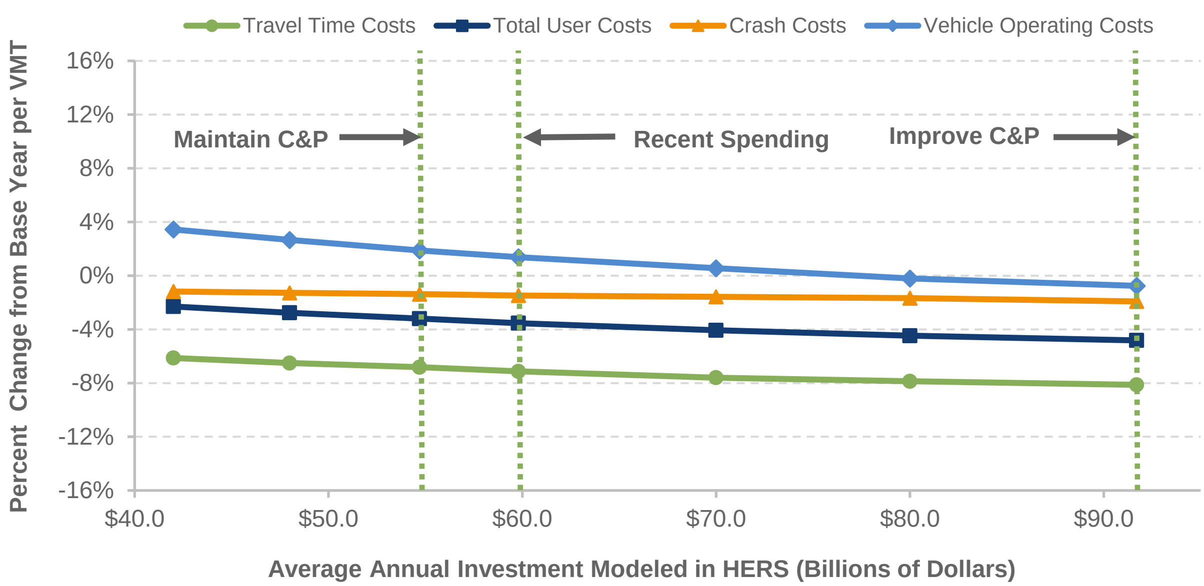
Some traffic basics are important to keep in mind when interpreting these results. In addition to congestion and incident delay, some delay inevitably results from traffic control devices, which interrupt traffic. For this reason, and because traffic congestion occurs only at certain places and times, *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 on Federal-aid Highways

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 2016 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 $1.355 per mile traveled in 2016.

Exhibit 10-6 ■ Projected Impact of Future Investment Levels on 2036 User Costs on Federal-aid Highways



HERS-modeled Investment on Federal-aid Highways Average Annual Investment (Billions of 2016 Dollars)	Projected 2036 Performance Measures on Federal-aid Highways: Average Total User Costs ($/VMT)	Percent Change Relative to Base Year Average per VMT: Total User Costs	Travel Time Costs	Vehicle Operating Costs	Crash Costs	Link to Chapter 7 Scenario
$91.7	$1.289	-4.8%	-8.1%	-0.8%	-1.9%	Improve C&P
$80.0	$1.294	-4.5%	-7.9%	-0.2%	-1.7%	
$70.0	$1.300	-4.1%	-7.6%	0.6%	-1.6%	
$59.8	$1.307	-3.5%	-7.1%	1.4%	-1.5%	Recent Spending
$54.7	$1.311	-3.2%	-6.8%	1.9%	-1.4%	Maintain C&P
$48.0	$1.317	-2.8%	-6.5%	2.7%	-1.3%	
$42.0	$1.324	-2.3%	-6.1%	3.4%	-1.2%	
Base Year Values:	**$1.355**					

Note: HERS is Highway Economic Requirements System; VMT is vehicle miles traveled.
Source: Highway Economic Requirements System.

Average user cost per VMT is projected to decrease from the 2016 values by 2.3 percent at the lowest level of spending ($42.0 billion) to 4.8 percent at the highest level of spending ($91.7 billion, which feeds into 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 2036 are projected to be between 1.2 percent and 1.9 percent lower than they were in 2016.

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* do not show how such investments affect highway safety.

Crash costs form the smallest of the three components of highway user costs. For 2016 travel on Federal-aid highways, HERS estimates the breakdown by cost component for each spending level. The average share of user costs across spending levels are as follows: crash cost, 15.0 percent; travel time cost, 52.8 percent; and vehicle operating cost, 32.2 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.

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 2016–2036 change in travel time cost per VMT ranges from a decrease of 8.1 percent at the highest level of assumed investment to a decrease of 6.1 percent at the lowest. These projections indicate that investing at the highest level rather than the lowest level would reduce the time cost of travel per VMT in 2036 by 2.0 percentage points, saving travelers hundreds of millions of hours per year in aggregate.

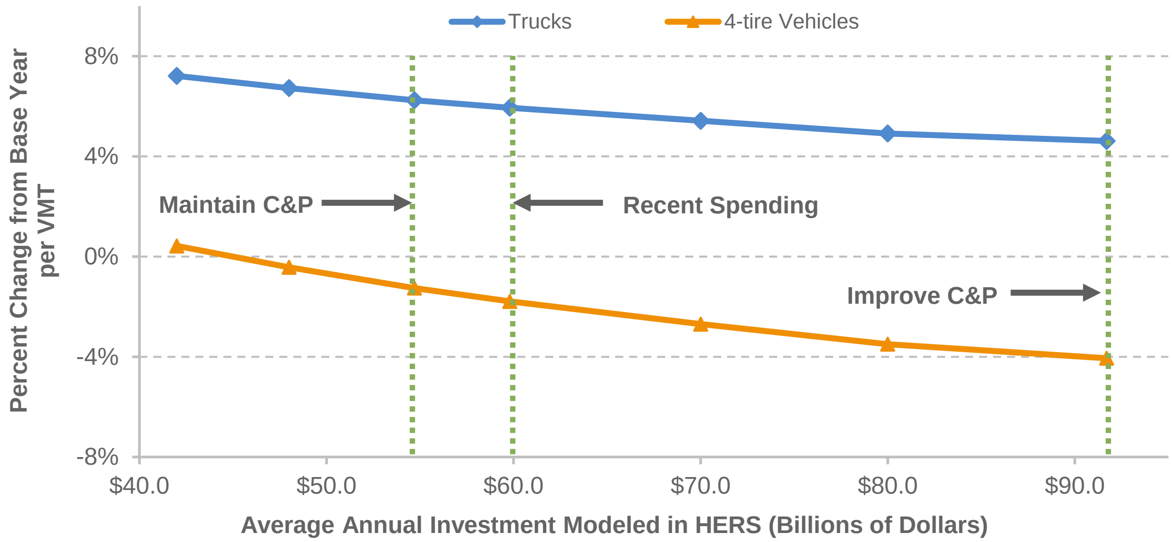
Impact on Vehicle Operating Costs

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). Vehicle operating costs per mile are projected to decline by 1.8 percent at the Sustain Recent Spending investment level and by 4.1 percent at the Improve C&P investment level for four-tire vehicles from 2016 to 2036. Vehicle operating costs per mile for trucks are projected to increase by 5.9 percent and 4.6 percent for the same period, respectively.

The projected changes in vehicle operating costs per VMT are driven by projected increases in fuel prices and fuel efficiency across the analysis horizon. The assumed paths of fuel efficiency are based on projections from the U.S. Energy Information Administration's Annual Energy Outlook 2017.[31] The average price of gasoline is assumed to increase between 2016 and 2036 by 44.7 percent, whereas the average price of diesel fuel is assumed to increase by 71.7 percent for the same period. The projected changes in fuel prices are countered by the fuel cost savings that would result from the improvements in vehicle energy efficiency for the same period. These changes are represented in HERS as increases in average miles per gallon of 50.1 percent for light-duty vehicles, 40.0 percent for six-tire trucks, and 37.1 percent for other trucks. The net result is that the average vehicle operating costs for four-tire vehicles are projected to decline across all but the lowest funding level (at $42.0 billion), whereas these costs for trucks are projected to increase across all funding levels.

[31] https://www.eia.gov/outlooks/aeo/pdf/0383(2017).pdf

Exhibit 10-7 ■ Projected Impact of Future Investment Levels on 2036 Vehicle Operating Costs on Federal-aid Highways



HERS-modeled Investment on Federal-aid Highways Average Annual Investment (Billions of 2016 Dollars)	Projected 2036 Performance Measures on Federal-aid Highways: Average Vehicle Operating Costs			Percent Change Relative to Base Year		Link to Chapter 7 Scenario
	All Vehicles ($/VMT)	4-tire Vehicles ($/VMT)	Trucks ($/VMT)	4-tire Vehicles	Trucks	
$91.7	$0.432	$0.360	$1.011	-4.1%	4.6%	Improve C&P
$80.0	$0.435	$0.362	$1.014	-3.5%	4.9%	
$70.0	$0.438	$0.365	$1.019	-2.7%	5.4%	
$59.8	$0.442	$0.368	$1.024	-1.8%	5.9%	Recent Spending
$54.7	$0.444	$0.370	$1.027	-1.3%	6.2%	Maintain C&P
$48.0	$0.447	$0.373	$1.031	-0.4%	6.7%	
$42.0	$0.451	$0.376	$1.036	0.4%	7.2%	
Base Year Values:	**$0.436**	**$0.375**	**$0.966**			

Note: VMT is vehicle miles traveled; HERS is Highway Economic Requirements System.

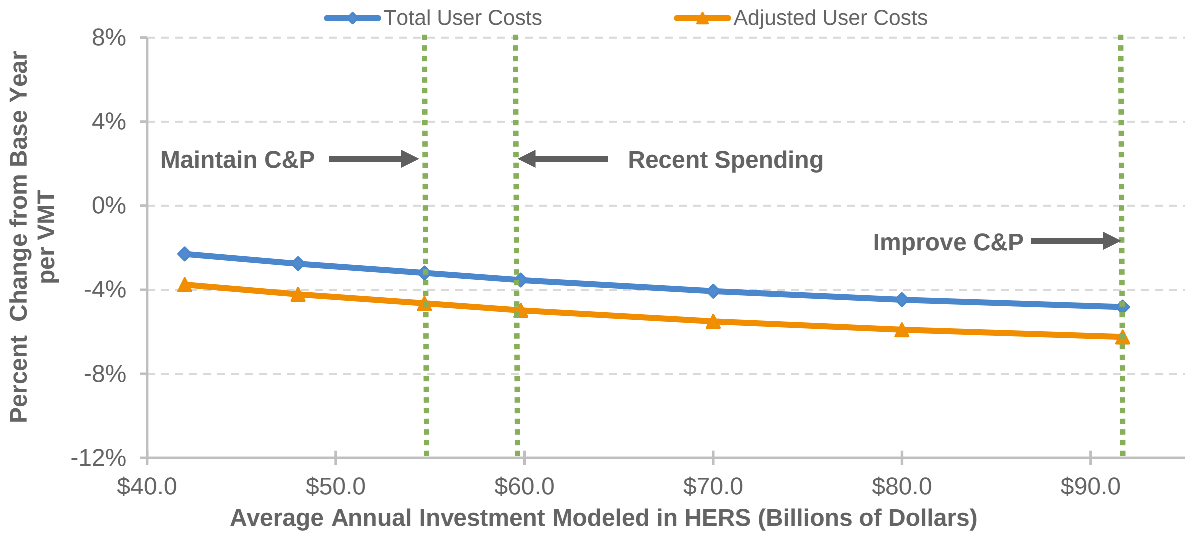
Source: Highway Economic Requirements System.

Impact of Future Investment on VMT

As discussed earlier, the travel demand elasticity features in HERS modify future VMT growth for each HPMS sample section based on changes to highway user costs. In addition, HERS is now programmed to assume that the baseline projections of future VMT already account for anticipated independent changes in user cost component values such as fuel prices and fuel efficiency.

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 2016 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 2016 user costs at $1.355 per mile. If the 2036 values assigned to those same user cost components were applied in 2016, however, HERS would compute 2016 user costs to be $1.375 per mile. This "adjusted baseline" is the relevant point of comparison when examining the impact of user cost changes on VMT.

Exhibit 10-8 ■ Projected Impact of Future Investment Levels on 2036 User Costs and VMT on Federal-aid Highways



HERS-modeled Investment on Federal-aid Highways Average Annual Investment (Billions of 2016 Dollars)	Projected 2036 Indicators on Federal-aid Highways: Average Total User Costs[1] ($/VMT)	Average Total User Costs[1] Percent Change vs. Actual 2016	Average Total User Costs[1] Percent Change vs. Adjusted Baseline	Projected VMT[2] Trillions of VMT	Projected VMT[2] Annual Percent Change vs. 2016	Link to Chapter 7 Scenario
$91.7	$1.289	-4.82%	-6.24%	3.585	1.48%	Improve C&P
$80.0	$1.294	-4.47%	-5.90%	3.552	1.44%	
$70.0	$1.300	-4.07%	-5.50%	3.532	1.41%	
$59.8	$1.307	-3.54%	-4.98%	3.508	1.37%	Recent Spending
$54.7	$1.311	-3.20%	-4.64%	3.493	1.35%	Maintain C&P
$48.0	$1.317	-2.76%	-4.21%	3.472	1.32%	
$42.0	$1.324	-2.30%	-3.76%	3.453	1.29%	
Base Year Values:	**$1.355**			**2.670**	**1.20%**	
Adjusted Baseline:	**$1.375**					

Note: VMT is vehicle miles traveled; HERS is Highway Economic Requirements System.

[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 2036 to the data for 2016 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 causes 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 vs. 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 1.2-percent baseline projection in all cases.

Source: Highway Economic Requirements System.

Although user costs are projected to increase in absolute terms from 2016 to 2036, they are projected to decline relative to the adjusted baseline by between 3.8 percent (at the lowest level of investment analyzed) and 6.2 percent (at the highest level of investment analyzed). 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 is higher than the 1.20-percent baseline projection in all cases, ranging from 1.29 percent to 1.48 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.

This subsection 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 analyses center on special HERS runs that used a database consisting only of NHS roads. The top row of each table in the exhibits that follow 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 Maintain Avg. IRI funding level represents the spending level projected to be adequate to allow average pavement roughness on NHS roads as measured by the IRI in 2036 to match the level in 2016. Recent Spending signifies the level of spending that maintains recent spending (2012 to 2016 average in constant-dollar terms) on NHS roads. Although these two investment levels are defined in a parallel manner to the Maintain Conditions and Performance and Sustain Recent Spending scenarios presented in Chapter 7, they do not represent direct inputs to those scenarios. Those Chapter 7 scenarios seek to maintain conditions or sustain spending, respectively, on Federal-aid highways; NHS conditions and NHS spending, respectively, are not held constant. The remaining three of the six investment levels presented in the next three exhibits were selected to fill gaps between the three data points linked to specific criteria, and to extend the lower end of the range of investment levels analyzed.

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 2036. Across the investment levels presented, HERS allocates between $19.2 billion and $37.1 billion in average annual spending on NHS roads to system rehabilitation and between $13.8 billion and $23.7 billion in average annual spending on NHS roads to system expansion.

Average user costs are projected to be lower in 2036 than they were for the adjusted baseline ($1.291 per VMT) for all investment levels presented. When implementing all cost-beneficial projects (the highest level of investment, an annual average of $60.8 billion), average total user costs are projected to be 6.81 percent lower ($1.203 per VMT) than were adjusted baseline user costs in 2016 ($1.291 per VMT). At the Maintain Recent Spending level of investment (an annual average of $43.2 billion), average total user costs are projected to be 5.57 percent lower ($1.219 per VMT) than were adjusted baseline user costs in 2016.

VMT on the NHS is expected to rise from 1.733 trillion in 2016 to 2.322 trillion in 2036 at the highest level of investment analyzed, equating to an average annual growth rate of 1.47 percent. At the lowest level of investment analyzed, VMT is projected to rise by 1.33 percent annually to 2.258 trillion.

Exhibit 10-9 ■ HERS Investment Levels Analyzed for the National Highway System and Projected Minimum Benefit-cost Ratios, User Costs, and VMT

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 2036[2]	Average 2036 Total User Costs ($/VMT)[3]	Projected 2036 VMT (Trillions)[4]	Description
$60.8	$37.1	$23.7	**1.00**	$1.203	2.322	BCR≥1.0
$53.0	$31.9	$21.1	1.05	$1.210	2.305	
$45.5	$27.0	$18.5	1.24	$1.217	2.291	Maintain Avg. IRI
$43.2	$25.6	$17.6	1.32	$1.219	2.286	Recent Spending
$38.0	$22.2	$15.8	1.54	$1.226	2.272	
$33.0	$19.2	$13.8	1.79	$1.233	2.258	
			Base Year Values:	**$1.270**	**1.733**	
			Adjusted Baseline:	**$1.291**		

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

[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 2036 to the data for 2016, 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 vs. the adjusted baseline user costs that are relevant.

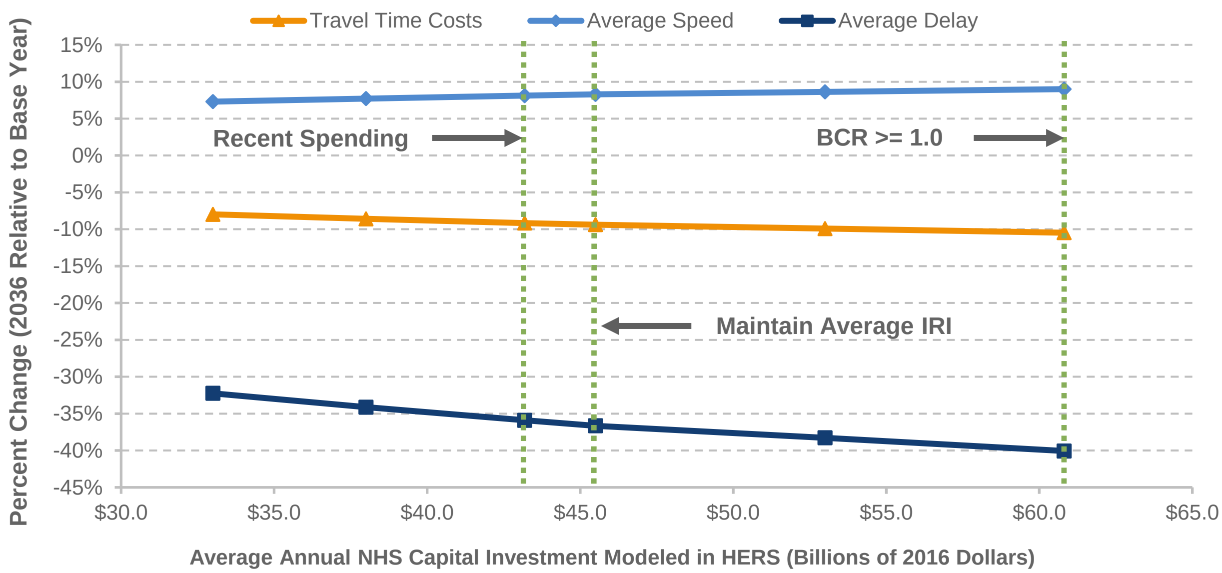
Source: Highway Economic Requirements System.

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 do preservation projects).

The graph is plotted based on the 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 2036 exceeds average travel speed in 2016 (49.9 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 $13.8 billion), the average travel speed in 2036 is projected to be 53.5 miles per hour. At the highest level of investment in system expansion (an annual average of $23.7 billion), the average travel speed in 2036 is projected to be 54.4 miles per hour.

Exhibit 10-10 ■ Projected Impact of Future Investment Levels on 2036 Highway Speed, Travel Delay, and Travel Time Costs on the National Highway System



HERS-modeled Investment on the NHS Average Annual Spending (Billions of 2016 Dollars)		Projected 2036 Performance Measures on the NHS				
			Percent Change Relative to Base Year			
Total	**System Expansion[1]**	**Average Speed (mph)**	**Average Speed**	**Average Delay per VMT**	**Travel Time Costs per VMT[2]**	**Description**
$60.8	$23.7	54.4	9.0%	-40.0%	-10.5%	BCR ≥ 1.0
$53.0	$21.1	54.2	8.6%	-38.3%	-9.9%	
$45.5	$18.5	54.0	8.3%	-36.6%	-9.4%	Maintain Avg. IRI
$43.2	$17.6	53.9	8.1%	-35.9%	-9.2%	Recent Spending
$38.0	$15.8	53.7	7.7%	-34.1%	-8.6%	
$33.0	$13.8	53.5	7.3%	-32.2%	-8.0%	
	Base Year Values:	**49.9**				

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

[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.

Sources: Highway Economic Requirements System; Highway Statistics 2016, Table VM-1.

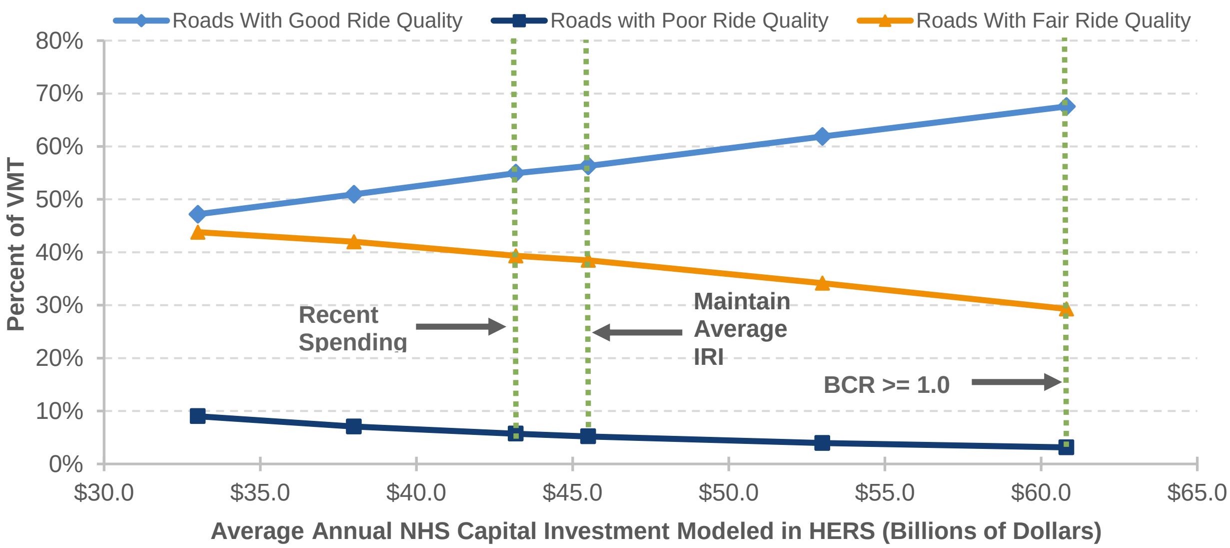
The global increase in average travel speed across investment levels corresponds to large decreases in average delay per VMT across investment levels. At the highest level of investment in system expansion, average delay per VMT in 2036 is projected to be 40.0 percent lower than it was in 2016. At the lowest level of investment in system expansion presented in the exhibit, average delay per VMT in 2036 is projected to be 32.2 percent lower than it was in 2016.

Travel time costs per VMT in 2036 are projected to decrease across the investment levels presented. Travel time costs per VMT in 2036 are projected to decrease by 10.5 percent relative to 2016 at the highest investment level and to decrease by 8.0 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 do expansion projects). 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 $37.1 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 3.1 percent of the VMT on the NHS, down from the 11.3 percent estimated for 2016.

Exhibit 10-11 ■ Projected Impact of Future Investment Levels on 2036 Pavement Ride Quality Indicators for the National Highway System



HERS-modeled Investment on the NHS Average Annual Spending (Billions of 2016 Dollars)		Projected 2036 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
$60.8	$37.1	67.6%	29.3%	3.1%	89.1	-9.8%	BCR ≥ 1.0
$53.0	$31.9	61.9%	34.2%	3.9%	93.7	-5.2%	
$45.5	$27.0	56.3%	38.5%	5.2%	98.8	**0.0%**	Maintain Avg. IRI
$43.2	$25.6	55.0%	39.3%	5.7%	100.3	1.5%	Recent Spending
$38.0	$22.2	51.0%	42.0%	7.1%	104.5	5.8%	
$33.0	$19.2	47.2%	43.8%	9.0%	109.2	10.5%	
Base Year Values:		**59.6%**	**29.1%**	**11.3%**	**98.8**		

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

[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.

At the highest level of investment, HERS also projects that pavements with an IRI below 95 (the criterion presented in Chapter 6 for rating ride quality as "good") will carry 67.6 percent of the VMT on the NHS, up from the 59.6 percent estimated for 2016. The model projects a declining share of NHS travel on pavements with "fair" ride quality, from 43.8 percent at the lowest investment level to 29.3 percent at the highest investment level. The latter is virtually the same as the NHS travel on pavements with "fair" ride quality at 29.1 percent in 2016. It is projected that the average IRI of the NHS system would rise to 89.1 at the highest investment level, achieving the classification of providing "good" ride quality at the aggregate level.

The model finds it to be cost-beneficial to reduce the VMT-weighted share of pavements with poor ride quality from 11.3 percent in 2016 to 3.1 percent in 2036 but predicts the costs of further reductions would exceed the benefits. 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.

Even at the lowest level of investment presented in *Exhibit 10-11* (an annual average of $19.2 billion allocated to system rehabilitation), the model projects that the share of NHS travel carried by pavements with an IRI above 170 would decline from 11.3 percent in 2016 to 9.0 percent in 2036. At this investment level, average IRI would increase to 109.2, and the share of NHS travel on pavements with an IRI below 95 would decline to 47.2 percent.

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 analyses center on special HERS runs that used a database consisting only of Interstate System roads.

As was the case for the NHS analyses presented earlier, 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 Recent Spending row in each table represents a run at which the average annual investment level over 20 years matches the average annual level from 2012 to 2016 in constant-dollar terms by all levels of government combined. The remaining investment levels presented in the next three exhibits 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 highways in 2036, along with the amount that HERS allocates to Interstate projects. Across the Interstate highway investment levels presented, HERS allocates between $6.3 billion and $16.8 billion in average annual spending to system rehabilitation and between $5.7 billion and $12.4 billion in average annual spending to system expansion.

Average user costs are projected to be lower in 2036 than the adjusted baseline ($1.178 per VMT) for all investment levels presented. At the highest level of investment presented in *Exhibit 10-12* (an annual average of $29.2 billion), average total user costs are projected to be 5.80 percent lower ($1.110 per VMT) in 2036 than they were in 2016. At the recent (2012 to 2016) level of investment (an annual average of $18.4 billion), average total user costs are projected to be 3.41 percent lower ($1.138 per VMT) in 2036 than they were in 2016.

Interstate VMT is projected to rise from 0.799 trillion in 2016 to 1.081 trillion in 2036 at the highest level of investment analyzed, equating to an average annual growth rate of 1.52 percent. At the lowest level of investment analyzed, Interstate VMT is projected to rise by 1.33 percent annually to 1.040 trillion.

Exhibit 10-12 ■ HERS Investment Levels Analyzed for the Interstate System and Projected Minimum Benefit-cost Ratios, User Costs, and VMT

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 2017 through 2036[2]	Average 2036 Total User Costs ($/VMT)[3]	Projected 2036 VMT (Trillions)[4]	Description
$29.2	$16.8	$12.4	**1.00**	$1.110	1.081	BCR ≥ 1.0
$21.3	$11.8	$9.5	1.00	$1.131	1.068	
$18.4	$10.0	$8.4	1.24	$1.138	1.062	Recent Spending
$15.0	$8.0	$7.0	1.70	$1.148	1.052	
$12.0	$6.3	$5.7	2.21	$1.161	1.040	
			Base Year Values:	**$1.149**	**0.799**	
			Adjusted Baseline:	**$1.178**		

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

[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 2036 to the data for 2016 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 causes 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 vs. the adjusted baseline user costs that are relevant.

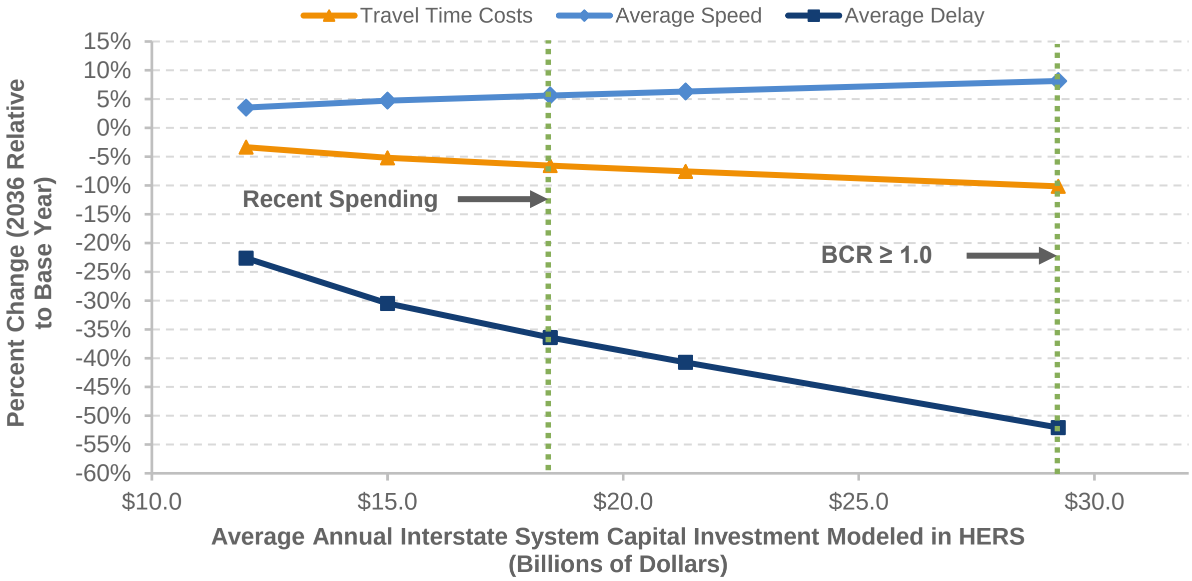
Source: Highway Economic Requirements System.

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 larger impact on travel time than do system rehabilitation projects).

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 10-13*, average speed on the Interstate System is projected to be higher in 2036 than was its 2016 level (62.7 miles per hour). At the highest level of investment presented in *Exhibit 10-13* (average annual investment in system expansion of $12.4 billion), average Interstate highway travel speed is projected to be 8.1 percent higher (67.8 miles per hour) in 2036 than it was in 2016. At the lowest level of investment presented in *Exhibit 10-13* (average annual investment in system expansion of $5.7 billion), average Interstate highway travel speed is projected to be 3.5 percent higher (64.9 miles per hour) in 2036 than it was in 2016.

Exhibit 10-13 ■ Projected Impact of Future Investment Levels on 2036 Highway Speed, Travel Delay, and Travel Time Costs on the Interstate System



HERS-modeled Investment on Interstate Highways		Projected 2036 Performance Measures on Interstate Highways				
Average Annual Spending (Billions of 2016 Dollars)			Percent Change Relative to Base Year			
Total	System Expansion[1]	Average Speed (mph)	Average Speed	Average Delay per VMT	Travel Time Costs per VMT	Description
$29.2	$12.4	67.8	8.1%	-52.0%	-10.2%	BCR ≥ 1.0
$21.3	$9.5	66.6	6.3%	-40.7%	-7.6%	
$18.4	$8.4	66.2	5.6%	-36.4%	-6.5%	Recent Spending
$15.0	$7.0	65.6	4.7%	-30.5%	-5.2%	
$12.0	$5.7	64.9	3.5%	-22.6%	-3.4%	
	Base Year Values:	**62.7**				

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

[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.

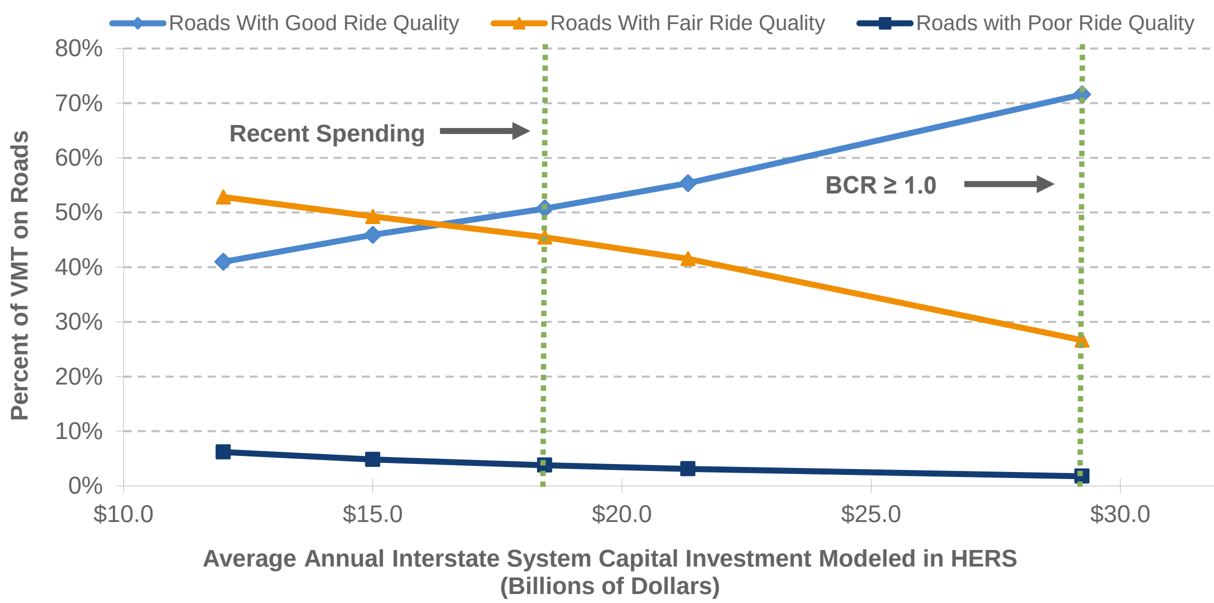
Sources: Highway Economic Requirements System; Highway Statistics 2016, Table VM-1.

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 presented in *Exhibit 10-13*, average delay per VMT in 2036 is projected to be 52.0 percent lower than it was in 2016. At the lowest level of investment presented in *Exhibit 10-13*, average delay per VMT in 2036 is projected to be 22.6 percent lower than it was in 2016. Travel time costs per VMT in 2036 are projected to decrease by 10.2 percent relative to 2016 at the highest investment level and to decrease by 3.4 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 amounts of Interstate System spending that HERS allocates to rehabilitation projects (which influence average pavement quality more than do expansion projects). The graph is plotted based on the 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 that of the corresponding share in 2016 (75.3 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. HERS projects that it would be cost-beneficial to halve the share of pavements with "poor" ride quality from 3.6 percent in 2016 to 1.8 by 2036. Further reductions below this point do not appear to be economically justified, as 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.

Exhibit 10-14 ■ Projected Impact of Future Investment Levels on 2036 Pavement Ride Quality Indicators for the Interstate System



HERS-modeled Investment on Interstate Highways		Projected 2036 Condition Measures Interstate Highways[1]					
Average Annual Spending (Billions of 2016 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
$29.2	$16.8	71.6%	26.6%	1.8%	84.2	1.9%	BCR ≥ 1.0
$21.3	$11.8	55.4%	41.5%	3.1%	95.0	15.0%	
$18.4	$10.0	50.7%	45.5%	3.8%	98.1	18.8%	Recent Spending
$15.0	$8.0	45.9%	49.3%	4.8%	102.3	23.8%	
$12.0	$6.3	41.0%	52.8%	6.2%	107.4	30.0%	
	Base Year Values:	**75.3%**	**21.1%**	**3.6%**	**82.6**		

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

[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.

At the highest level of investment presented in *Exhibit 10-14* (an annual average of $16.8 billion allocated to system rehabilitation), the model projects average pavement roughness on the Interstate System to be 1.9 percent higher in 2036 than it was in 2016. These results suggest that it would not be cost-effective to keep the average VMT-weighted IRI of the Interstate System at its 2016 level of 82.6 (well into the "good" range), and that allowing it to rise slightly to 84.2 would be economically advantageous.

Impacts of Investments Modeled by NBIAS

The expenditures modeled in NBIAS 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 earlier: each capital investment scenario presented in Chapter 7 combines one HERS analysis with one NBIAS analysis and makes adjustments to account for nonmodeled spending.

Bridge Investment Levels Analyzed

Exhibits 10-15 through *10-18* examine all bridges, bridges on Federal-aid highways, NHS bridges, and Interstate System bridges, respectively. The top row in each of these next four exhibits represents the level of investment at which the Economic Investment Backlog would be eliminated (i.e., all projects with an estimated BCR of 1.0 or higher would be implemented). These are labeled as either "Improve C&P" (for all bridges) or "BCR≥1.0" (for the three subsets of bridges presented) and reflect that the investment level for all bridges feeds directly into the Improve Conditions and Performance scenario in Chapter 7, whereas the levels for bridge subsets are defined in a comparable manner but do not directly feed into that scenario.

Each of the next four exhibits also contains a row for the level of investment at which the deck area-weighted share of bridges in poor condition in 2036 would match that in 2016 (labeled as Maintain C&P for the all-bridges value that feeds into the Maintain Conditions and Performance scenario in Chapter 7 and Maintain % Poor for the subsets of bridges). Each also contains a row corresponding to average annual spending on the types of capital investments modeled in NBIAS (labeled as Recent Spending).

The remaining rows in these exhibits were selected to fill gaps between the three data points linked to specific scenarios, and to extend the lower end of the range of investment levels analyzed.

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)

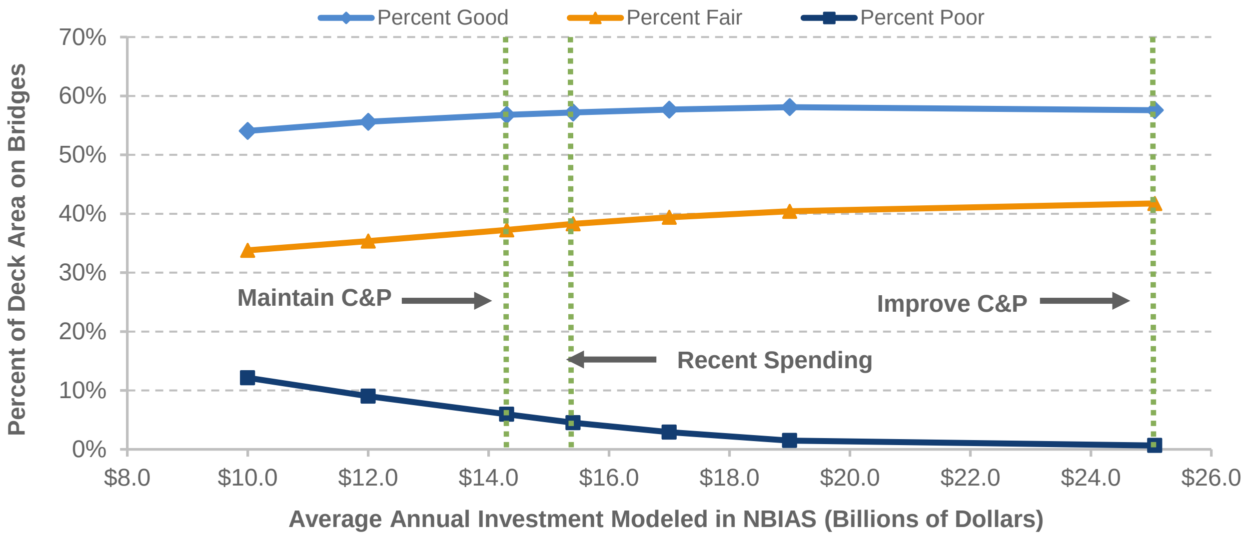
As described in Chapter 6, bridges in "good," "fair," and "poor" condition are defined by the degree of deterioration of the three major bridge components: deck, superstructure, and substructure. For a bridge to be classified as in "good" condition, all three major bridge components must be rated "good." 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 decision-making for bridge preventive maintenance, with 0 being the worst condition 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.

Impacts of Systemwide Investments Modeled by NBIAS

As indicated in *Exhibit 10-2*, of the $106.9 billion average annual investment in highways from 2012 to 2016 (in 2016 constant dollars), $15.4 billion (14.4 percent) 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, 2036. At $15.4 billion, the investment level feeding into the Sustain Recent Spending scenario presented in Chapter 7, projected performance for 2036 would improve relative to 2016 for each performance measure considered. The share of bridges classified as in "poor" condition would decrease from 6.0 percent to 4.5 percent, whereas the share of bridges classified as in "good" condition would increase from 46.0 percent in 2016 to 57.2 percent in 2036. The average Health Index would rise from 92.3 to 94.5. The Economic Investment Backlog would decrease to $56.7 billion (57.0 percent below its 2016 level of $131.8 billion).

Exhibit 10-15 ■ Projected Impact of Future Investment Levels on 2036 Bridge Condition Indicators for All Bridges



NBIAS-modeled Investment on All Bridges	Projected 2036 Condition Indicators—All Bridges					
	Weighted by Deck Area					
Average Annual Investment (Billions of 2016 Dollars)[1]	Percent Good	Percent Fair	Percent Poor	Health Index	Economic Investment Backlog (Billions of 2016 Dollars)[1]	Link to Chapter 7 Scenario
$25.1	57.6%	41.8%	0.7%	95.5	$0.0	Improve C&P
$19.0	58.1%	40.4%	1.5%	95.5	$8.1	
$17.0	57.7%	39.4%	2.9%	95.2	$31.4	
$15.4	57.2%	38.3%	4.5%	94.5	$56.7	Recent Spending
$14.3	56.8%	37.3%	**6.0%**	93.9	$76.9	Maintain C&P
$12.0	55.6%	35.4%	9.0%	92.4	$119.6	
$10.0	54.1%	33.8%	12.1%	90.8	$161.1	
Base Year Values:	**46.0%**	**48.0%**	**6.0%**	**92.3**	**$131.8**	

Note: NBIAS is National Bridge Investment Analysis System.

[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.

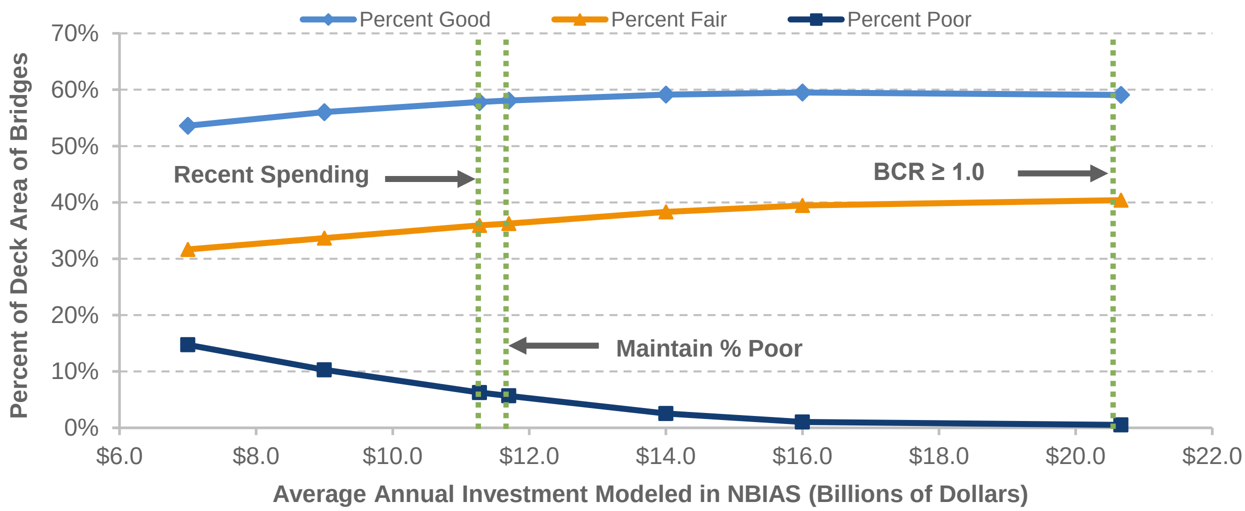
Source: National Bridge Investment Analysis System.

The highest level of spending shown in *Exhibit 10-15* averages $25.1 billion per year (this feeds into 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 0.7 percent and to eliminate the Economic Investment Backlog for bridges by 2036. 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).

Impacts of Federal-aid Highway Investments Modeled by NBIAS

For bridges on Federal-aid highways, *Exhibit 10-16* compares performance projections for 2036 at various levels of investment with measured performance in 2016. If spending on the types of improvements modeled in NBIAS were sustained at the recent (2012 to 2016) level of $11.3 billion (in constant dollars), performance results would be mixed. The average Health Index would rise (improve) from 92.3 to 93.7, whereas the percentage of bridges in "poor" condition weighted by deck area would rise (worsen) from 5.7 percent to 6.3 percent. Maintaining the share of bridges rated poor at 5.7 percent would require a higher level of annual investment ($11.7 billion). This finding deviates from the one identified earlier for all bridges for which sustaining spending at recent levels was projected to be more than sufficient to maintain this metric at base year levels.

Exhibit 10-16 ■ Projected Impact of Future Investment Levels on 2036 Bridge Condition Indicators for Federal-aid Highway Bridges



NBIAS-Modeled Investment on Federal-aid Bridges	Projected 2036 Condition Indicators—Federal-aid Bridges					
	Weighted by Deck Area				Economic Investment Backlog (Billions of 2016 Dollars)[1]	
Average Annual Investment (Billions of 2016 Dollars)[1]	Percent Good	Percent Fair	Percent Poor	Health Index		Description
$20.7	59.1%	40.4%	0.5%	95.5	**$0.0**	BCR ≥ 1.0
$16.0	59.5%	39.5%	1.0%	95.5	**$2.3**	
$14.0	59.1%	38.3%	2.5%	95.3	**$24.4**	
$11.7	58.1%	36.2%	**5.7%**	94.0	**$64.3**	Maintain % Poor
$11.3	57.8%	35.9%	6.3%	93.7	**$72.2**	Recent Spending
$9.0	56.0%	33.7%	10.3%	91.8	**$117.1**	
$7.0	53.6%	31.7%	14.7%	89.4	**$165.5**	
Base Year Values:	**45.3%**	**49.1%**	**5.7%**	**92.3**	**$108.8**	

Note: NBIAS is National Bridge Investment Analysis System; HERS is Highway Economic Requirements System; BCR is benefit-cost ratio.

[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.

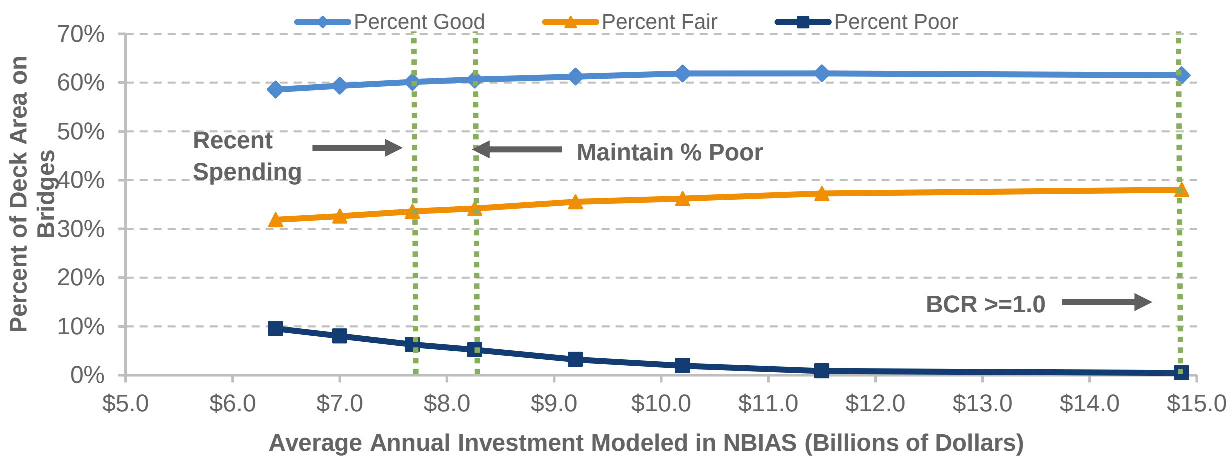
At the $20.7 billion average annual investment level consistent with the Improve Conditions and Performance scenario, NBIAS projects the percentage of bridges in "poor" condition weighted by deck area would decrease to 0.5 percent on Federal-aid highways. The Economic Investment Backlog would be reduced to zero by 2036, and the average Health Index would increase from 92.3 to 95.5.

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 was sustained at the recent (2012–2016) level of $7.7 billion in constant-dollar terms, the deck-area-weighted share of bridges in "poor" condition would increase from 5.2 percent in 2016 to 6.3 percent in 2036. The average annual investment needed to maintain this indicator at its 2016 level is higher at $8.3 billion. This finding deviates from the one identified above for all bridges for which spending in 2016 was estimated to be above the level needed to maintain this metric at base year levels.

The highest level of investment analyzed, $14.9 billion, is projected to reduce the Economic Investment Backlog to zero by 2036. The percentage of bridges in "poor" condition would decrease from 5.2 in 2016 to 0.5 percent in 2036. The average Health Index would increase from 92.3 to 95.6 during the same period.

Exhibit 10-17 ■ Projected Impact of Future Investment Levels on 2036 Bridge Condition Indicators for Bridges on the National Highway System



NBIAS-Modeled Investment on NHS Bridges	Projected 2036 Condition Indicators—NHS Bridges					
	Weighted by Deck Area					
Average Annual Investment (Billions of 2016 Dollars)[1]	Percent Good	Percent Fair	Percent Poor	Health Index	Economic Investment Backlog (Billions of 2016 Dollars)[1]	Description
$14.9	61.5%	38.0%	0.5%	95.6	**$0.0**	BCR>=1.0
$11.5	61.9%	37.3%	0.9%	95.6	**$0.5**	
$10.2	61.9%	36.2%	1.9%	95.5	**$11.4**	
$9.2	61.2%	35.5%	3.2%	95.1	**$25.5**	
$8.3	60.6%	34.2%	**5.2%**	94.2	**$43.4**	Maintain % Poor
$7.7	60.1%	33.6%	6.3%	93.7	**$54.3**	Recent Spending
$7.0	59.4%	32.6%	8.0%	92.9	**$68.5**	
$6.4	58.6%	31.9%	9.6%	92.1	**$80.7**	
Base Year Values:	**44.3%**	**50.5%**	**5.2%**	**92.3**	**$75.3**	

[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.

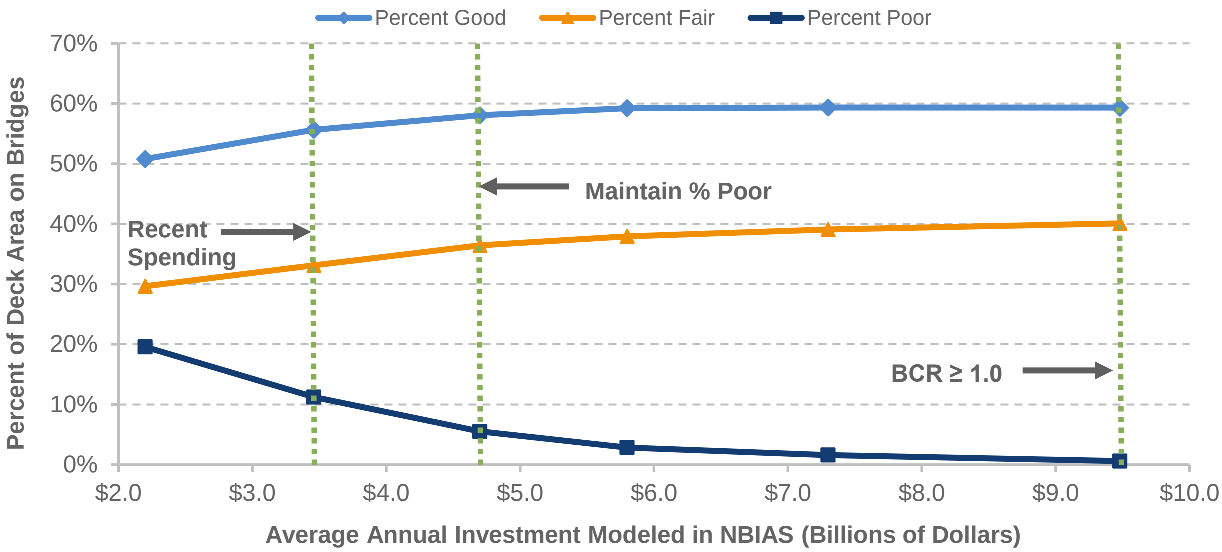
Source: National Bridge Investment Analysis System.

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 average annual spending on types of improvements modeled in NBIAS on Interstate bridges were sustained at the recent (2012–2016) level of $3.5 billion in constant-dollar terms, the share of bridges rated as poor would increase from 5.5 percent in 2016 to 11.2 percent in 2036, weighted by deck area. By 2036, the average Health Index would fall from 91.9 to 91.4, and the Economic Investment Backlog would increase from $42.1 billion in 2016 to $47.2 billion in 2036. An average annual investment of $4.7 billion would be needed to keep the deck area-weighted share of bridges in poor condition from rising above its 2016 level in 2036. For the highest level of investment analyzed (implementing all cost-beneficial projects identified), the average annual investment level of $9.5 billion is estimated to be sufficient to reduce the Economic Investment

Backlog to zero by 2036, decrease the deck area-weighted share of bridges rated as poor to 0.6 percent, and increase the average Health Index to 95.5.

Exhibit 10-18 ■ Projected Impact of Alternative Investment Levels on 2036 Bridge Condition Indicators for Interstate Bridges



NBIAS-modeled Investment on Interstate Bridges	Projected 2036 Condition Indicators—Interstate Bridges					
	Weighted by Deck Area					
Average Annual Investment (Billions of 2016 Dollars)[1]	Percent Good	Percent Fair	Percent Poor	Health Index	Economic Investment Backlog (Billions of 2016 Dollars)[1]	Description
$9.5	59.3%	40.1%	0.6%	95.5	**$0.0**	BCR ≥ 1.0
$7.3	59.3%	39.1%	1.6%	95.5	**$1.2**	
$5.8	59.2%	37.9%	2.8%	95.3	**$8.4**	
$4.7	58.0%	36.4%	**5.5%**	94.1	**$23.6**	Maintain % Poor
$3.5	55.6%	33.1%	11.2%	91.4	**$47.2**	Recent Spending
$2.2	50.8%	29.6%	19.6%	87.0	**$80.3**	
Base Year Values:	**38.8%**	**55.7%**	**5.5%**	**91.9**	**$42.1**	

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

[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 Investment – Transit

This section examines how different types and levels of annual capital investments would likely affect transit system condition and performance by 2036. 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 section then examines how variations in the level of annual capital spending are likely to affect future transit conditions and performance.

This edition of the C&P Report introduces a new cost-effectiveness optimization feature in TERM that affects the way TERM forecasts reinvestment needs. The new feature optimizes prioritization in the queue of assets to be replaced or rehabbed.

Applying this cost-effectiveness optimization to previous C&P Reports results in year-20 backlogs that are smaller than previously estimated. However, the size of the backlog at year 20 is not necessarily smaller in constant dollars than the backlog at year 0, because the size of the backlog is a function of the annual average investment applied to TERM for replacement and rehabilitation needs. Other factors include inflation and changes in the National Inventory between editions of the C&P Report.

A detailed discussion of the new cost-effectiveness optimization feature is presented later in in this section, under Impacts of Systemwide Investments Modeled by TERM.

KEY TAKEAWAYS

- The recent level of current investment in transit asset preservation ($11.6 billion) is roughly the amount required to maintain the SGR backlog at currently levels.
- If the recent level of preservation investment ($11.6 billion) is maintained, the average national asset condition is expected to decay from the adequate range to the marginal range by 2036.
- The recent level of investment in service expansion ($7.2 billion) is sufficient to accommodate an average annual ridership increase of 1.7 percent, higher than the 15 -year historical rate of 1.5 percent. This might result in less crowded conditions in stations, trains, and buses, and increased operating speeds.
- Recent investment levels are higher than required to accommodate the low ridership growth scenario (1.3 percent). If ridership grows at the 1.28–1.82-percent range (±0.3 percent around the 15-year historical growth rate), investment in expansion in the $705–$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 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; and
- Expansion Investments: Additional ridership (boardings) capacity.

Impact of Preservation Investments on Transit Backlog and Conditions

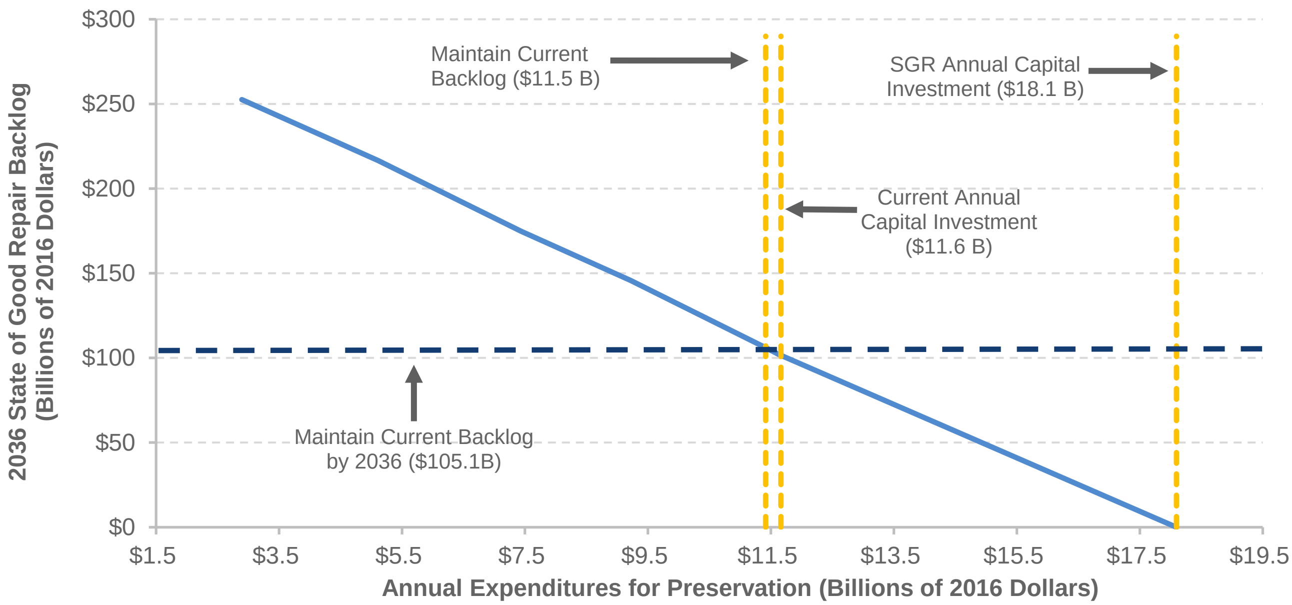
This subsection considers the expected impact of varying levels of aggregate capital reinvestment by all levels of government on the future investment backlog and physical condition (as of 2036) for the Nation's existing stock of transit assets.

Transit Backlog

The 2010 C&P 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 $105.1 billion (see Chapter 7).

Exhibit 10-19 presents the estimated impact of differing levels of annual capital reinvestment on the expected size of the reinvestment backlog in 2036. Here the reinvestment backlog is defined as the level of investment required to bring all the Nation's assets to an SGR. This includes replacing those assets that currently exceed their useful lives ($105 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 recent average rate of capital reinvestment of $11.6 billion is marginally higher than that required to maintain the SGR backlog and, if sustained over the next 20 years, would result in a reinvestment backlog of roughly $102.3 billion by 2036. In contrast, increasing the annual rate of reinvestment to an average of $18.1 billion would fully eliminate the backlog by 2036. Finally, an annual level of reinvestment of roughly $11.5 billion is required to maintain the backlog at its current level.

Exhibit 10-19 ■ Impact of Preservation Investment on 2036 Transit State of Good Repair Backlog in All Urbanized and Rural Areas



Average Annual Investment (Billions of 2016 Dollars)	Average Annual Percent Change vs. 2016	Average Condition Rating in 2036	Backlog in 2036 (Billions of 2016 Dollars)	Percent Change from Current Backlog	Funding Level Description
$18.1	4.2%	2.91	$0.0	-100.0%	SGR (unconstrained, replace at 2.50)
$11.6	0.0%	2.72	$102.3	-2.7%	Sustain recent spending
$11.5	-0.1%	2.71	$105.1	0.0%	Maintain current backlog
$9.2	-2.4%	2.60	$145.8	38.7%	
$7.4	-4.8%	2.53	$174.8	66.3%	
$5.1	-9.5%	2.43	$216.5	105.9%	
$2.9	-18.9%	2.34	$252.5	140.3%	

Notes: For this report, assets are considered past their useful lives once their estimated condition in TERM falls below condition 2.50. SGR is state of good repair.

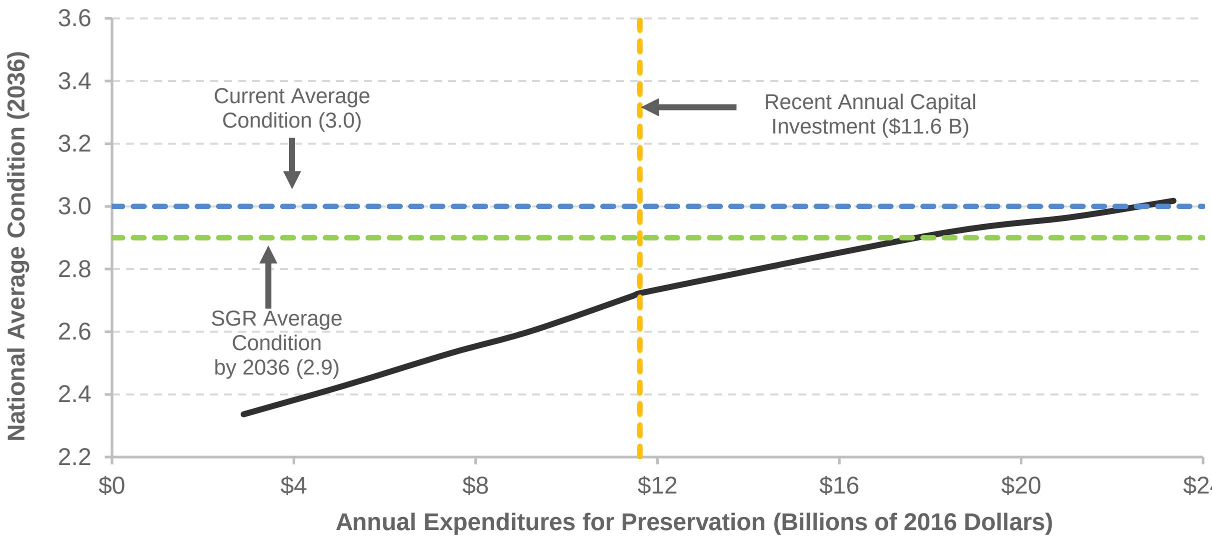
Source: Transit Economic Requirements Model.

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 2036. 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 recent levels to achieve each projected condition level.

Further review of *Exhibit 10-20* allows several observations: First, almost none of the selected reinvestment rates presented (including the recent level of reinvestment, which was $11.6 billion) is sufficient to maintain aggregate conditions at or near the current national average condition rating of 3.0. Only the two highest reinvestment rates presented here of $21.1 and $23.3 billion annually (replacement at condition rating 3.0 or 2.75), are 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 may not be sustainable in the long term (i.e., without including the influence of further expansion investments or replacing assets at an unreasonably early age).

Exhibit 10-20 ■ Impact of Preservation Investment on 2036 Transit Conditions in All Urbanized and Rural Areas



Average Annual Investment (Billions of 2016 Dollars) Total Capital Outlay	Average Annual Percent Change vs. 2016	Average Transit Conditions in 2036						Notes
		Asset Categories						
		Guideway	Facilities	Systems	Stations	Vehicles	All Transit Assets	
$23.3	6.5%	2.54	3.41	3.78	3.01	3.52	3.02	Unconstrained, replace at 3.00
$21.1	5.6%	2.51	3.40	3.68	2.97	3.41	2.97	Unconstrained, replace at 2.75
$18.1	4.2%	2.49	3.34	3.58	2.93	3.30	2.91	SGR (unconstrained, replace at 2.50)
$11.6	0.0%	2.36	2.68	3.52	2.45	3.29	2.72	Recent capital expenditures
$11.5	-0.1%	2.36	2.68	3.50	2.44	3.28	2.71	Maintain current backlog
$9.2	-2.4%	2.26	2.68	3.29	2.34	3.13	2.60	
$7.4	-4.8%	2.20	2.67	3.19	2.32	2.98	2.53	
$5.1	-9.5%	2.16	2.67	2.99	2.27	2.69	2.43	
$2.9	-18.9%	2.14	2.66	2.84	2.22	2.34	2.34	

Notes: 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. 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. SGR is state of good repair.

Source: Transit Economic Requirements Model.

Second, reinvestment at roughly $18.1 billion annually is required to attain an SGR condition by 2036, and this level of reinvestment is estimated to yield an average condition value of roughly 2.91 by that year. Given the definition of the SGR Benchmark (described in greater detail in Chapter 9), which seeks to eliminate the existing investment backlog and then address all subsequent rehabilitation and replacement activities "on time" thereafter, the 2.9 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 2.9 represents a more reasonable long-term condition target for existing transit infrastructure than the current aggregate rating of 3.0.

Another observation is that a significant level of reinvestment is required to alter the estimated 2036 average condition measure by a point or more. This result is also driven in part by a large proportion of transit assets that are either nonreplaceable (e.g., subway tunnels and stations) or assets that have 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, operations and maintenance cost impacts, and investment cost-effectiveness) 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. Although TERM predicts improvement in asset condition following asset replacement, it does not currently predict an improvement in condition following asset rehabilitation. This is because TERM's decay curves are currently "responsive" to replacements (as older assets in marginal and poor condition are replaced by new assets in excellent condition). In contrast, TERM's decay curves are not currently designed to improve an asset's condition following a rehabilitation. For this reason, expenditures beyond approximately $11.6 billion on the chart increase total cost as rehabilitation projects are added, but these projects do not contribute to an increase in condition. FTA expects that "rehab-responsive" decay curves will be developed and introduced in a future C&P Report.

Prioritization and the Cost-Effectiveness Investment Criterion

TERM uses a prioritization routine to determine the order in which reinvestment needs are addressed when funding is insufficient to cover the cost of all outstanding needs. Under these circumstances, TERM completes three analyses for each year of a 20-year, constrained model run. First, it assesses all reinvestment needs for each year of analysis. Next, it assigns a priority score to each reinvestment need, using the investment criteria identified above, and then ranks these needs from highest to lowest based on the assigned priority scores. Finally, it addresses the ranked reinvestment needs, from highest to lowest, subject to the available budget for that year of analysis. Once all available funds of an analysis year have been expended, the reinvestment process ends and any unaddressed needs for that year are added to the investment backlog (potentially to be addressed in a later year of analysis).

In contrast to previous C&P Reports, which relied on four investment criteria (condition, reliability, safety, and operations and maintenance cost impacts), all constrained needs analyses in this report also include the impact of an additional cost-effectiveness criterion. Here, "cost-effectiveness" is defined as the ratio of the cost of a reinvestment need to the number of riders benefiting from that reinvestment action (e.g., the cost of a bus replacement to the number of riders using the bus). This criterion is designed to function as a proxy cost-benefit measure for each investment need and in practice tends favor moderate- to lower-cost investments that benefit larger numbers of riders.

As noted above, the prioritization routine determines the order in which reinvestment needs are addressed. Hence, any changes to that routine—including inclusion of the cost-effectiveness criterion—will also result in changes to the backlog in which reinvestment needs are addressed. This change in turn affects the mix of asset needs that are ultimately addressed, the mix of asset needs that enter backlog, and the size of the backlog itself. These impacts can be seen below in *Exhibit 10-21*. Specifically, *Exhibit 10-21* shows the impact of the cost-effectiveness criterion on the size of the SGR backlog in year 20 of a model run. This impact is shown for two different TERM models: the model used for the 23rd C&P Report (with a start year of 2014) and the one used for this current 24th edition (with a start year of 2016). For both models, the size of the backlog in year 0 of the model runs is not affected by turning the cost-effectiveness criterion on or off (as start year backlog is fixed and not influenced by the selection of prioritization criteria). However, by year 20 of each model run the cost-effectiveness criterion has clearly affected the selection of which reinvestment needs are addressed and which are delegated to the backlog. For both models, inclusion of the cost-effectiveness criterion is found to reduce the size of the year-20 backlog by roughly $7.0 billion to $10.0 billion. Given that the annual budget constraint is fully utilized by each of these model runs, it is apparent that use of the cost-effectiveness criterion leads to a more cost-efficient use of investment funds, at least in terms of backlog reduction.

Exhibit 10-21 ■ Impact of the Cost-Effectiveness Criterion on the Year-20 Backlog

Edition	Analysis Start Year	Cost Year	Annual Budget ($Billions)	Cost-Effectiveness Criterion	SGR Backlog		
					Year 0	Year 20	Change
23rd C&P	2014	2014	$11.295	Off	$98.0	$116.2	
				On	$98.0	$108.8	($7.4)
24th C&P	2016	2016	$11.610	Off	$105.1	$113.0	
				On	$105.1	$102.3	($10.7)

Source: Transit Economic Requirements Model.

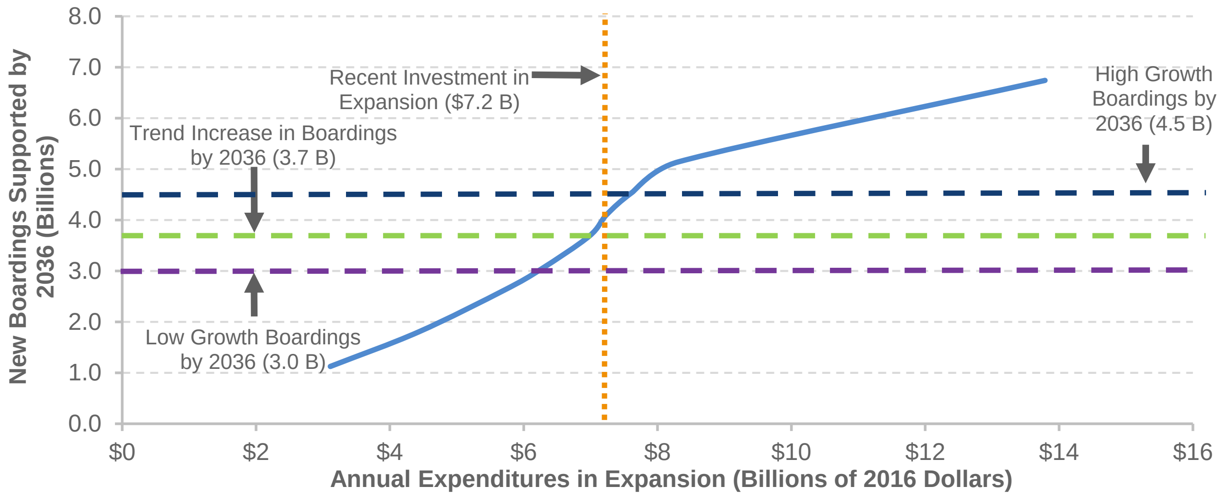
Impact of Expansion Investments on Transit Ridership

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 10-22 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 2036. 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 public funds.

The findings presented in *Exhibit 10-21* suggest the following trends. First, the recent rate of investment in asset expansion ($7.2 billion in 2016 dollars) could support roughly 4.1 billion additional boardings by 2036 (approximately a 1.7-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 recent level of transit capital expansion investment is more than that required to support future rider growth, assuming future growth aligns with the 15-year historical trend. The 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 10-22 ■ New Ridership Supported in 2036 by Expansion Investments in All Urbanized and Rural Areas



Total New Boardings by 2036				
Average Annual Investment (Billions of 2016 Dollars)	Average Annual Percent Change vs. Maintain Recent Spending	New Riders Supported (Billions of Annual Boardings)	Average Annual Growth in Boardings[1]	Funding Level Description
$13.8	6.0%	6.7	2.5%	Highest Growth Scenario (+1.0%)
$8.3	1.4%	5.1	2.0%	Higher Growth Scenario (+0.5%)
$7.6	0.5%	4.5	1.8%	High Growth Scenario (+0.3%)
$7.2	0.0%	4.1	1.7%	Maintain Recent Spending
$7.0	-0.4%	3.7	1.5%	15 Year Historic Growth Rate Trend
$6.3	-1.5%	3.0	1.3%	Low Growth Scenario (-0.3%)
$5.7	-2.4%	2.6	1.1%	Lower Growth Scenario (-0.5%)
$4.4	-3.9%	1.8	0.8%	Lower Growth Scenario (-1.0%)
$3.1	-9.8%	1.1	0.5%	Lowest Growth Scenario (-1.5%)

[1] As compared with total urban ridership in 2016; 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.

PART III: Freight

Overview

Freight transportation is the movement of raw materials, intermediate goods, and finished products from one location to another. This movement occurs along a complex, multimodal network composed of millions of miles of public roads, railways, navigable waterways, pipelines, and airways.[32]

This network connects raw materials to manufacturers, products to consumers, and American goods to domestic and international markets. Nearly all the goods and materials most Americans consume or produce require movement along the freight transportation system at some point. The ability to get freight where and when we want it is, in large part, what enables a high quality of life for all Americans. In 2015, our freight transportation system moved a daily average of about 49.3 million tons of freight worth more than $52.5 billion.[33]

The Nation's freight transportation system is dynamic, complex, and an extraordinary asset to our wellbeing and our country's economic health. Significant investments, however, are required to sustain the conditions and performance of our Nation's freight system and accommodate expected growing demand. By describing the conditions and performance of the National Highway Freight Network (NHFN), this section will support improved decision-making leading to a safer, more reliable, and more efficient freight transportation system.

Report Summary

- The FAST Act establishes the National Highway Freight Network (NHFN) and directs the Federal Highway Administration (FHWA) to prepare a biennial report on the conditions and performance (C&P) of the NHFN (hereafter termed the "*Highway Freight C&P* Report to Congress").
- This is the second edition of the *Highway Freight C&P* Report to Congress. It updates data in the previous edition to 2016 or the latest year available at the time of analysis and includes data on Critical Rural and Urban Freight Corridors (CRFCs and CUFCs) for the first time.
- The *Highway Freight C&P* Report to Congress supports decision- and policy makers in improved understanding of national infrastructure conditions and performance trends.
- The data presented in this report will help stakeholders make more effective decisions to meet challenges associated with an expected increase in demand.

Pursuant to 23 United States Code (U.S.C) §167(h), as amended by the Section 1116(a) of the Fixing America's Surface Transportation (FAST) Act of 2015, the Federal Highway Administration (FHWA) prepared this section to serve as the second edition of the biennial report on the conditions and performance (C&P) of the NHFN (referred to hereafter as the "*Highway Freight C&P* Report to Congress"). This section is part of the 24th edition of the *Status of the Nation's Highways, Bridges, and Transit: Conditions and Performance* Report to Congress (C&P Report).

23 U.S.C. §167(h) designates the NHFN and establishes a national policy of maintaining and improving the conditions and performance of this new network. The NHFN comprises four component subsystems: the Primary Highway Freight System (PHFS), other Interstate portions not on the PHFS, and Critical Rural Freight Corridors (CRFCs) and Critical Urban Freight Corridors (CUFCs), newly defined in the FAST Act.

States are responsible for designating CRFCs and CUFCs. In urban areas with a population of 500,000 or more, the representative metropolitan planning organization (MPO) may make the designation in consultation with the State; if the urban area population is under 500,000, the State makes the designation in consultation with the MPO. Designating CRFCs and CUFCs is optional but extends the flexibility of States to apply National Highway Freight Program (NHFP) funds. As of

[32] Public roads, including Interstates, comprise about 4 million miles. Bureau of Transportation Statistics, Freight Facts and Figures 2017, Table 3-1. https://www.bts.dot.gov/sites/bts.dot.gov/files/docs/FFF_2017.pdf
[33] Bureau of Transportation Statistics, Freight Facts and Figures 2017, p. 2-1. https://www.bts.dot.gov/sites/bts.dot.gov/files/docs/FFF_2017.pdf

May 1, 2018, 18 States submitted both CRFCs and CUFCs; an additional two States had submitted only CRFCs; and two other States had submitted only CUFCs.

With the inclusion of the newly submitted CRFCs and CUFCs, the NHFN consists of an estimated 54,310 miles, including 41,308 miles of Interstate and 9,541 miles of non-Interstate roads. CRFCs/CUFCs represent a total of 3,461 miles, or about six percent, of all NHFN mileage.

What's New

To address the FAST Act requirement for a biennial Highway Freight C&P Report, FHWA will update NHFN conditions and performance data to the latest years available when conducting the analysis. FHWA intends for each edition of the *Highway Freight C&P* Report to Congress to build on previous editions to add to and refine an understanding of NHFN conditions and performance. However, the Highway Performance Monitoring System (HPMS), Freight Analysis Framework (FAF), and other datasets used for the NHFN conditions and performance analysis are updated at different times, using different methodologies. As a result, the data reported here may represent different dates and should be viewed as snapshots in time. Future editions may include new conditions and performance indicators as additional information becomes available.

Highlights of NHFN Conditions and Performance

NHFN Conditions

- With the inclusion of the CRFCs and CUFCs submitted as of May 1, 2018, the NHFN's total mileage is 54,310 miles. Most mileage (about 77 percent) is in "good" condition, the same as the percentage of "good" condition mileage reported in the previous edition. Most (about 75 percent) NHFN mileage is of "good" ride quality.
- Of an estimated total of 54,263 bridges on the NHFN, more than half (53 percent) are in "good" condition and a relatively small percentage (4 percent) are in "poor" condition.

NHFN Performance

- As reported in the previous edition, many portions of the NHFN, including high-volume truck portions (defined as portions that carry more than 8,500 trucks per day), experience congestion.
- Average travel speeds for just over half (52 percent) of the Nation's top 25 domestic freight corridors experienced marginal increases or remained the same between 2011 and 2016. Over the same period, reliability decreased for 72 percent of these corridors.

This edition includes NHFN conditions and performance data from and prior to 2016, representing an update of two years over the previous (and first) edition, which appeared in the 23rd C&P Report. The previous edition used 2014 data from the HPMS; this edition uses 2016 HPMS data. The previous edition used data from FAF version 4. This edition continues to use FAF version 4 as there were no major FAF version updates since the last edition (the initial release of FAF version 5 is expected in late 2020).[34]

This edition includes some data with sources other than FAF version 4 and HPMS; the latest available data from these sources may be from years other than 2016. This edition excludes several exhibits from the previous edition that did not have any updates over the last two years.

This edition includes the following new indicators:

- NHFN pavement conditions:
  - Overall ride quality
  - Individual pavement distresses
  - Overall ride quality by roadway functional class

[34] Please visit www.bts.gov for FAF information and data. Descriptions of FAF versions are available at https://faf.ornl.gov/fafweb/News.aspx.

- NHFN bridge conditions:
  - Overall condition rating
  - Overall condition rating by roadway functional class

Notably, this edition includes CRFCs and CUFCs in the overall NHFN conditions and performance assessment.[35] This represents an important topic not covered in the previous edition; data on CRFCs and CUFCs had not yet been submitted when the previous edition was developed.

This edition benefitted from the implementation of data improvements identified in the previous edition. The first edition identified a need to better align NHFN with data sources (including the HPMS) to permit more seamless analyses of the Nation's freight transportation system. Since publication of the first edition, FHWA has developed and used new techniques to align HPMS and other datasets, such as the National Bridge Inventory (NBI), with the NHFN.

The first *Highway Freight C&P* Report to Congress provided a baseline understanding of NHFN conditions and performance using available data. This second edition improves this baseline by including additional indicators and examining new units of analysis not previously available, such as CRFCs and CUFCs.

Introduction

Section 1116(a) of the FAST Act of 2015 includes several provisions to better identify needs for the freight transportation system and increase Federal support for responding to these needs. Among other provisions, the FAST Act designates the NHFN and establishes a national policy of maintaining and improving the conditions and performance of this new network. The NHFN replaces the National Freight Network and Primary Freight Network established under the Moving Ahead for Progress in the 21st Century Act (MAP-21). The FAST Act requires the re-designation of the NHFN every 5 years and repealed Section 1116 of MAP-21, which allowed for an increased Federal share for certain freight projects. The FAST Act also directs FHWA to prepare a report describing the conditions and performance of the NHFN.

Pursuant to the requirements of 23 U.S.C. §167(h) as amended by Section 1116(a) of the FAST Act, FHWA prepared this section as the second edition of the *Highway Freight C&P* Report to Congress. This second edition builds on the foundation provided by the first edition while incorporating new data and analytical techniques to provide a more comprehensive view of the NHFN. This edition includes the following four major sections:

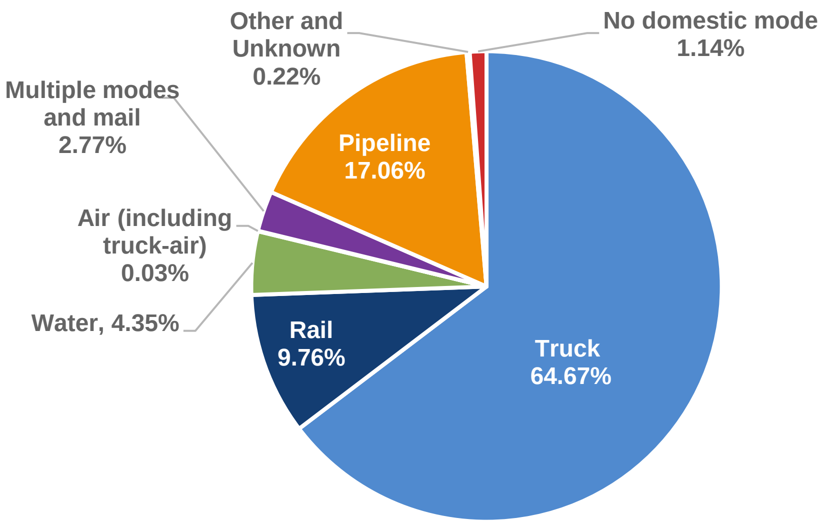
- **Federal Programs for Improved Freight Conditions and Performance** describes Federal programs that support improved freight conditions and performance as well as trends affecting freight movement along the NHFN and other freight transportation systems.
- **Freight Transportation Network Overview** describes the Nation's freight transportation networks, focusing on the NHFN and its component roadways.
- **Conditions and Performance** provides an analysis of NHFN condition and performance using key indicators.
- **Spotlight Topics** highlight topics that affect overall freight movement and have relevance for improved NHFN management, planning, and decision-making.

[35] The NHFN conditions and performance analysis presented in this section focuses on National Highway System (NHS) roadway functional classes. Due to data limitations, CRFCs/CUFCs at roadway functional classes below the NHS (e.g., rural minor collectors) were not included in the analysis. The analysis includes only CRFCs/CUFCs submitted as of May 1, 2018.

Federal Programs for Improved Freight Network Conditions and Performance

The freight transportation network is an extraordinary national asset, enabling economic activity and a high quality of life. However, the network has several areas of need, especially along the highway system, which is the dominant mode for freight by tonnage and value. *Exhibits III-1* and *III-2* show total tonnage and value moved by all freight modes in 2017, representing a two-year update on total freight tonnage and value figures since the last edition.

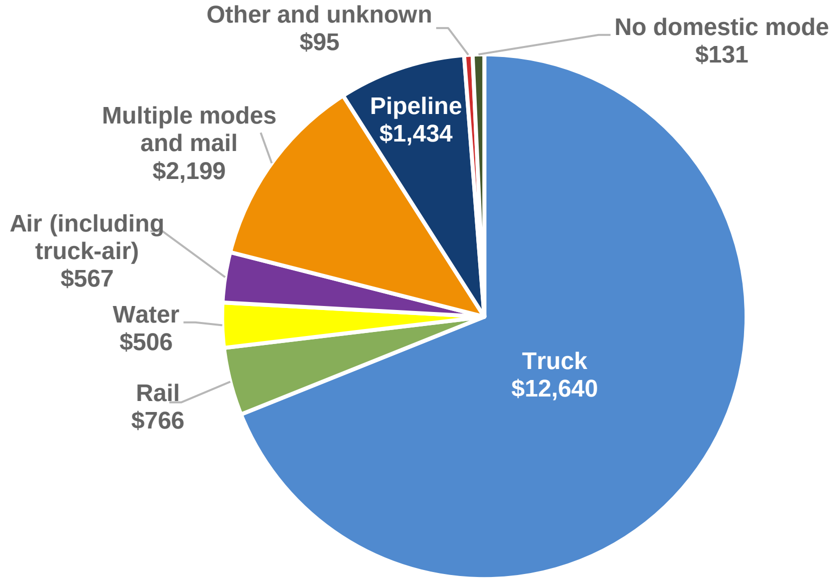
Exhibit III-1 ■ Freight Modal Share by Tonnage, 2017



Note: Approximately 17.9 billion tons of freight were moved in 2017 (total tonnage). Data do not include imports and exports that pass through the United States from a foreign origin to a foreign destination by any mode. Numbers may not add to totals due to rounding. Data in this version are not comparable to similar data in previous years because of updates to the Freight Analysis Framework. All truck, rail, water, and pipeline movements that involve more than one mode, including exports and imports that change mode at international gateways, are included in multiple modes and mail to avoid double counting. As a consequence, rail and water totals in this table are less than those in other published sources. **Multiple modes and mail** includes U.S. Postal Service, courier shipments, and all intermodal combinations, except air and truck. **Other and Unknown** primarily comprises unidentified modes but includes miscellaneous categories, such as aircraft delivered to customers and shipments through foreign trade zones. **Air (including truck-air)** includes truck moves to and from airports.

Source: U.S. Department of Transportation, Bureau of Transportation Statistics and Federal Highway Administration, Freight Analysis Framework, version 4.5.1, 2019 (https://www.bts.gov/faf).

Exhibit III-2 ■ Freight Modal Share by Value (billions of 2012 $), 2017



Note: Total freight moved in 2017 was worth approximately $18.3 trillion (in 2012 dollars). Data do not include imports and exports that pass through the United States from a foreign origin to a foreign destination by any mode. Numbers may not add to totals due to rounding. Data in this version are not comparable to similar data in previous years because of updates to the Freight Analysis Framework. All truck, rail, water, and pipeline movements that involve more than one mode, including exports and imports that change mode at international gateways, are included in multiple modes and mail to avoid double counting. As a consequence, rail and water totals in this table are less than those in other published sources. **Multiple modes and mail** includes U.S. Postal Service, courier shipments, and all intermodal combinations, except air and truck. **Other and Unknown** primarily comprises unidentified modes but includes miscellaneous categories, such as aircraft delivered to customers and shipments through foreign trade zones. **Air (including truck-air)** includes truck moves to and from airports.

Source: U.S. Department of Transportation, Bureau of Transportation Statistics and Federal Highway Administration, Freight Analysis Framework, version 4.5.1, 2019 (https://www.bts.gov/faf).

Expected economic and population growth in the coming decades will likely lead to increased freight demand, especially increased freight volumes moved by truck. There are substantial challenges to moving freight to meet this demand, especially where providing additional capacity may be difficult.

Congress created several Federal freight programs (described in greater detail below) with the aim of addressing these challenges and ensuring that the U.S. freight system and its highway network are prepared to support U.S. economic growth and competitiveness. The most recent of these is the FAST Act of 2015.

FAST Act Freight Provisions

The FAST Act's freight provisions provide a basis for Federal policies and resources to improve mobility on America's highways, create jobs and support economic growth, and accelerate project delivery and promote innovation. These provisions also guide the Federal approach to freight planning and decision-making. Several provisions aimed to improve the conditions and performance of the national freight network and support investment in freight-related surface transportation projects.

Summary of FAST Act Freight Provisions

- Established the NHFP, which authorizes $6.3 billion in formula funds over 5 years for States to invest in freight projects on the NHFN (FAST Act Sec. 1116, 23 U.S.C. § 167, 23 U.S.C. § 104(b)(5)),
- Required the Secretary to submit biennial reports to Congress on the conditions and performance of the NHFN (FAST Act Sec. 1116, 23 U.S.C. § 167(h)),
- Established a National Multimodal Freight Policy that includes national goals to guide decision-making (FAST Act Sec. 8001, 49 U.S.C. §70101),
- Required the development of a National Freight Strategic Plan to implement the goals of the new National Multimodal Freight Policy (FAST Act Sec. 8001, 49 U.S.C. § 70102),
- Established a National Multimodal Freight Network that assists States in strategically directing resources toward improved system performance for efficient freight movement and informs freight planning along the network (FAST Act Sec. 8001, 49 U.S.C. § 70103),
- Created a new discretionary freight-focused grant program that will invest $4.5 billion over 5 years (FAST Act Sec. 1105, 23 U.S.C. 117), and
- Required the Bureau of Transportation Statistics to collect and annually report on performance measures for the Nation's top 25 ports by 20-foot equivalent unit, tonnage, and dry bulk (FAST Act Sec. 6018, 49 U.S.C § 6314(b)).

National Highway Freight Program

The FAST Act establishes the NHFP, a new freight formula program designed to improve the efficient movement of freight on the NHFN, among other goals. The NHFP represents the first dedicated Federal funding source for freight. NHFP goals include investing in infrastructure and operational improvements that strengthen economic competitiveness, reduce congestion and the cost of freight transportation, improve reliability, and increase productivity. (See *Exhibit III-7* for NHFP goal areas that informed the conditions and performance indicators selected for this edition of the *Highway Freight C&P* Report to Congress).

NHFP funds may be obligated for projects that contribute to the efficient movement of freight on the NHFN and are consistent with other Federal freight planning requirements (see 23 U.S.C. §§ 134 to 135 and 49 U.S.C § 70202). To use NHFP funds for projects, States must identify relevant projects in their Statewide Transportation Improvement Program (STIP) and MPOs must do so in their Transportation Improvement Program (TIP). The projects must also be consistent with States' long-range statewide transportation plans and MPOs' metropolitan transportation plans. Effective December 4, 2017, pursuant to 23 U.S.C 167(i)(4), a State may not obligate NHFP funds apportioned to the State unless the State developed a FAST Act-compliant State Freight Plan, as required by 49 U.S.C. 70202(a).

Exhibit III-3 ■ Percentage of NHFP Funds Obligated or Unobligated, as of December 4, 2017, by Year of Fund Apportionment from FY 2016 to FY 2018

	FY2016	FY2017	FY2018
Obligated	83.7%	63.9%	9.8%
Unobligated	16.4%	36.1%	90.2%

Source: FHWA, Office of Freight Management and Operations.

Starting with the year in which NHFP funds are apportioned, States have four years to obligate them (i.e., States' authority to obligate Fiscal Year (FY) 2016 funds lapses on September 30, 2019). As of the second anniversary of the enactment of the FAST Act (December 4, 2017), States had obligated approximately 51 percent of all NHFP funds apportioned on a national basis through that date. *Exhibit III-3* depicts States' progress in obligating NHFP funds by year of fund apportionment.

Trends Affecting NHFN Freight Movement

The trends described below provide additional background for understanding NHFN freight conditions and performance, updated to 2016.

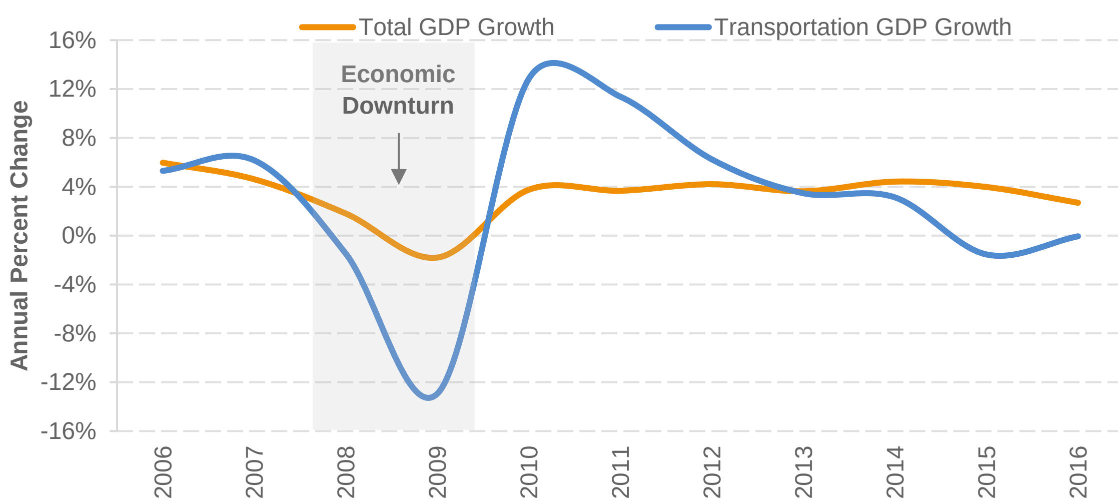
Economic Recovery and Freight Demand

"Freight demand" refers to the demand for both physical movement of inputs and for finished goods by freight carriers on all modes (road, rail, air, water, and pipeline). Increases in freight demand are linked to economic and population growth: a growing economy increases demand for freight, and increased freight demand in turn signifies economic growth. Conversely, freight demand, and thus freight transportation, contract when the economy slows.

The National Bureau of Economic Research dates the last economic downturn as lasting for approximately 19 months from December 2007 to June 2009.[36] Between June 2009 and September 2017, gross domestic product (GDP) increased by over 20 percent.[37] Unemployment rates declined over the same period, falling from 9.5 percent in June 2009 to 4.2 percent in September 2017.[38] As of 2016, total GDP for all sectors grew beyond its highest pre-downturn levels.[39] In close correlation to rising GDP and decreasing unemployment rates after the economic downturn, demand for freight transportation increased by 27.6 percent since a low point in 2009.[40]

Exhibit III-4 shows the correlation between total GDP and GDP growth attributed to the transportation sector (transportation GDP) from 2006 to 2016.[41]

Exhibit III-4 ■ Growth in Total GDP and Transportation GDP, 2006–2016



Source: U.S. Department of Commerce, Bureau of Economic Analysis, *National Income and Product Accounts Tables*, tables 1.1.5, 2.4.5, 3.11.5, 3.15.5, 4.2.5, 5.4.5, 5.5.5, and 5.7.5B (https://apps.bea.gov/iTable/iTable.cfm?reqid=19&step=2#reqid=19&step=2&isuri=1&1921=survey).

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[36] National Bureau of Economic Research, "US Business Cycle Expansions and Contractions." http://www.nber.org/cycles/cyclesmain.html.
[37] Bureau of Economic Analysis (BEA). "Vintage History of Quarterly Gross Domestic Product (GDP) and Gross Domestic Income (GDI) Estimates." https://www.bea.gov/data/gdp/gross-domestic-product/gdp-gdi-vintage-history
[38] Bureau of Labor Statistics. "Labor Force Statistics from the Current Population Survey: 2009 to 2017." https://data.bls.gov/pdq/SurveyOutputServlet
[39] BEA, "National Income and Product Accounts: Section 1: Domestic Product and Income." Table 10105-A. https://apps.bea.gov/iTable/iTable.cfm?ReqID=19&step=4&isuri=1&1921=flatfiles.
[40] U.S. Department of Transportation, "A Growing Economy and Freight Demand." Special Reports and Issue Briefs. December 2017. Unpublished as of January 2019.
[41] U.S. Department of Transportation, "A Growing Economy and Freight Demand." Special Reports and Issue Briefs. December 2017. Unpublished as of January 2019.

Freight Volume Shifts

DOT predicts increases in freight volume from 2015 to 2045, but freight flow patterns and changes over this period may not be uniform across all economic sectors, modes, and locations. Freight volumes reflect how different economic sectors are growing or contracting. However, regional and local economies also affect where, how, and how much freight is flowing in and around a particular area or locality.

KEY TAKEAWAYS

- Congress created the NHS, NN, and NHFN to identify roadways of strategic importance to the national economy and mobility.
- The NHFN is composed of four component roadway systems but the NHS represents over 90 percent of what makes up the NHFN. As of May 1, 2018, total NHFN mileage was 54,310, including CRFCs and CUFCs.
- The NHFN highlights critical components of the freight network that support States, MPOs, and others in prioritizing and programming projects to meet freight needs.

The Bureau of Transportation Statistics created the Freight Transportation Services Index (TSI) to provide an aggregated measure of freight traffic and transportation services output. The TSI is one indicator of freight flow volumes. The TSI for freight and passengers increased since the December 2007–June 2009 economic downturn, from 96.2 in June 2009 to 123.1 in June 2016.[42]

First-Mile and Last-Mile Connectivity

The U.S. economy is undergoing dramatic changes with major evolutions in manufacturing and trade, especially in first- and last-mile contexts. CRFCs and CUFCs, introduced in the FAST Act provide a flexible opportunity for States to work with MPOs to designate priority connectors to the NHFN that support intermodal connectivity as well as first- and last-mile connectivity from producers to consumers. The designation of CRFCs and CUFCs is intended to more effectively channel Federal investments to better serve local and regional freight needs.

Projected increases in freight demand and other trends—particularly e-commerce—will have substantial effects on freight flows, needs, and opportunities. Warehousing, supply chain and logistics changes, and other industry trends may also have impacts on freight origins, destinations, and freight volumes, especially volumes moving on first- and last-mile connectors. Intermodal and first-/last-mile connectivity will continue to benefit from targeted Federal resources that can leverage other public-sector or private industry investments.

Freight Transportation Network Overview

Every day, millions of trucks, trains, airplanes, ships, and barges move over American highways, local roads, railways, airways, and navigable waterways, transporting millions of tons of raw materials and finished goods. Pipelines also carry a variety of raw materials, primarily those used for energy purposes (e.g., natural gas, liquid petroleum, biofuels). The U.S. economy depends on safe, affordable, and reliable freight transportation to connect businesses to domestic markets and markets throughout the world.

All modes move freight, but trucking is the dominant mode for domestic freight movements by both tonnage and value (see Exhibits *III-1 and III-2)*. Trucks move a wide variety of goods, ranging from high-value, time-sensitive freight to lower-value bulk tonnage, such as some types of agricultural products, gasoline for local distribution, and municipal solid waste.

The Nation's highway freight transportation system is composed of the National Highway System (NHS), the National Network (NN), and the National Highway Freight Network (NHFN):

[42] Bureau of Transportation Statistics. Transportation Services Index: 2000 to 2020. https://www.transtats.bts.gov/OSEA/TSI/

- **The National Network (NN)**. This is the system of roadways officially designated to accommodate commercial freight-hauling vehicles as authorized by the Surface Transportation Assistance Act of 1982 (P.L. 97-424) and specified in the U.S. Code of Federal Regulations (23 CFR part 658).
- **The National Highway Freight Network (NHFN)**. 23 U.S.C. §167(h) designates the NHFN and establishes a national policy of maintaining and improving the conditions and performance of this new network. The NHFN highlights critical components of the freight network that support States, MPOs, and others in prioritizing and programming projects to meet freight needs. The NHFN comprises four component systems: the PHFS, other Interstate portions not on the PHFS, CRFCs, and CUFCs.

The National Highway System (NHS)

The NHS includes roadways that are of paramount importance to the Nation's economy, defense, and mobility. It is composed of the Interstate system, other principal arterials, the Strategic Highway Network, major Strategic Highway Network Connectors, and intermodal connectors. See Chapter 1 for additional details.

Note that these subsystems can overlap and are not mutually exclusive.

Freight Intermodal Connectors

Intermodal connectors are not statutorily defined but are important components of the Nation's highway freight transportation system. FHWA defines intermodal connectors as roads that provide first- or last-mile connection between major rail, port, airport, and intermodal freight facilities on the NHS.[43] These connectors are key conduits for the timely and reliable delivery of freight. Intermodal connectors are usually short (the majority are less than one mile in length).[44] They are typically local, county, or city streets that serve heavy truck volumes moving between intermodal freight terminals and the NHS, primarily in major metropolitan areas.

The introduction of CRFCs and CUFCs provides States an important opportunity to designate high-priority first- and last-mile connectors to the NHFN. CRFCs and CUFCs are eligible for NHFP funds that will help States improve local, regional, and statewide freight movement connectivity and efficiency.

Overview of the NHFN

The NHFN's four components are described below:

- ***Primary Highway Freight System (PHFS)***: The PHFS is a network of highways identified as the most critical highway portions of the U.S. freight transportation system, as determined by measurable and objective national data. 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.
- ***Other Interstate portions not on the PHFS***: These routes provide important continuity and access to freight transportation facilities. They change with additions and deletions to the Interstate Highway System.
- ***CRFCs***: CRFCs are public roads in nonurbanized areas that provide access and connection to the PHFS and the Interstate along with important ports, public transportation facilities, or other intermodal freight facilities.
- ***CUFCs***: CUFCs are public roads in urbanized areas that provide access and connection to the PHFS and the Interstate Highway System along with other ports, public transportation facilities, or other intermodal transportation facilities.

[43] FHWA, "Freight intermodal Connectors Study." April 2017. https://ops.fhwa.dot.gov/publications/fhwahop16057/index.htm
[44] FHWA, "Freight Intermodal Connectors Study." April 2017. https://ops.fhwa.dot.gov/publications/fhwahop16057/index.htm

Pursuant to Section 1116(a) of the FAST Act, States, and in certain cases, MPOs, can identify and submit CRFCs and CUFCs. However, designation is subject to mileage limitations. Total NHFN centerline mileage will therefore change when States elect to submit CRFCs and CUFCs, as well as with additions and deletions to the Interstate Highway System. *Exhibit III-5* provides mileage counts for each of the NHFN's four component roadways, including CRFCs and CUFCs.

Exhibit III-5 ■ National Highway Freight Network Mileage Counts by Component Roadway

NHFN Roadway Component	Mileage
PHFS	41,308 centerline miles
Other Interstate portions not on the PHFS	Estimated 9,541 centerline miles of Interstate nationwide
CRFCs	2,185 centerline miles
CUFCs	1,276 centerline miles

Note: PHFS is Primary Highway Freight System; CRFCs are Critical Rural Freight Corridors; CUFCs are Critical Urban Freight Corridors.
Source: FHWA, Office of Freight Management and Operations, as of May 1, 2018.

Exhibit III-6 is a map of the NHFN including all NHFN component roadways.

Exhibit III-6 ■ Map of the National Highway Freight Network

Note: The NHFN includes some mileages of such short length (including some CRFCs and CUFCs) that they may not be visible on a national-scale map. NHFN 2019 data (including CRFCs and CUFCs) were used to produce this map.
Source: FHWA, Office of Freight Management and Operations, 2019.

The NHFN also represents all functional classes of roadways. Each class describes the role that a roadway segment plays in serving traffic flows through a larger network. For example, Interstates are the highest classification within a broader category of arterials. Interstates represent the majority of all NHFN mileage.

Changes in NHFN Mileage Since May 2018

As of April 9, 2021, the NHFN consists of an estimated 57,943 miles, including 41,514 miles of Primary Highway Freight System (PHFS) and 9,710 miles of non-PHFS Interstate roads. The CRFCs and CUFCs represent a total of 6,720 miles (about 11.6 percent) of this total NHFN mileage.

The NHFN provides the transportation backbone for freight movements at the national, regional, and local levels. The next section focuses on describing NHFN conditions and performance.

NHFN Conditions and Performance

As in the previous edition, this edition uses a series of indicators to assess NHFN conditions and performance. FHWA used pertinent FAST Act NHFP goal areas as a framework to determine which indicators to include in this report. *Exhibit III-7* shows these NHFP goal areas and the selected indicators.

Exhibit III-7 ■ Conditions and Performance Indicators by FAST Act National Highway Freight Program Goal Areas

NHFP Goal Areas Pertinent to NHFN	Selected Indicator	Indicator Type
State of Good Repair	Pavement Condition	Conditions
	Overall Ride Quality and Ride Quality by Roadway Functional Class	
	Individual Pavement Distresses	
	Bridge Overall Condition and Condition by Roadway Functional Class	
	Bridge Deck Condition	
	Bridge Superstructure Condition	
	Bridge Substructure Condition	
	Culvert Condition	
Congestion, Economic Efficiency, Productivity, and Competitiveness	Peak-period Congestion on NHFN	Performance
	Peak-period Congestion on High-Volume Truck Portions of NHFN	
	Annual Average Travel Speeds for Top 25 Domestic Freight Corridors	
	Travel Time Reliability Index for Top 25 Domestic Freight Corridors	
Safety, Security and Resilience	Number of Fatal Crashes and Fatalities	

Source: FHWA, Office of Freight Management and Operations.

This edition expands the selected indicators to present additional information on NHFN pavement and bridge conditions. For greater detail, refer to the What's New section.

Each of the selected indicators and a corresponding assessment is presented in greater detail below.

Conditions

As discussed elsewhere in the C&P Report (see Chapter 6), as part of the implementation of the Transportation Performance Management framework established by MAP-21 and continued under the FAST Act, a Final Rule for Pavement and Bridge Performance Measures (PM-2) was published on January 18, 2017. This rule defines NHS pavement and bridge condition performance measures, along with minimum condition standards, target establishment, progress assessment, and reporting requirements. Although State reporting under the PM-2 rule had not yet commenced at the time this analysis was conducted, this edition continues a gradual shift toward reporting pavement and bridge measures consistent with those specified in the PM-2 rule.[45] The PM-2 rule only requires that targets be set for NHS pavement and bridges, but this edition applies the same criteria to NHFN pavement and bridges.

NHFN Pavement Condition

States report pavement condition to FHWA using the HPMS for Federal-aid highways. The 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. The HPMS also contains information on other pavement distresses, including faulting at the joints of concrete pavements, the amount of rutting on asphalt pavements, and the amount of cracking on both concrete and asphalt pavements.

Exhibit *III-8* identifies criteria for NHFN pavement "good," "fair," and "poor" classifications, 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 III-8 ■ Pavement Condition Indicator Classifications Used in the Highway Freight C&P Report to Congress

Conditions Indicator	Rating Criteria	Good	Fair	Poor
Pavement Ride Quality	The IRI measures the cumulative deviation from a smooth surface in inches per mile.	IRI < 95	IRI 95 to 170	IRI > 170
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 percentage 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 percentage 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

Source: FHWA (https://www.federalregister.gov/documents/2017/01/18/2017-00550/national-performance-management-measures-assessing-pavement-condition-for-the-national-highway).

The analysis presented in this section provides a baseline understanding of NHFN pavement condition, ride quality, and individual pavement distresses for expansion in future editions of this report. The data suggest that there may be opportunities to improve ride quality for roadways located lower down in the roadway functional class hierarchy.

Exhibit III-9 summarizes the overall ride quality of NHFN pavement in 2016 ("good," "fair," and "poor"). About three-quarters (77 percent) of NHFN pavement was rated "good," 19 percent was rated "fair," and 4 percent was rated "poor." These are the same NHFN pavement condition values provided in the previous edition (which used 2014 HPMS data). Between 2014 and 2016, NHFN pavement condition remained largely unchanged.

[45] As of 2020, State reporting under the PM-2 rule was well underway with pavement and bridge data reported by States in 2018. Mid-period performance will be reported in October 2020.

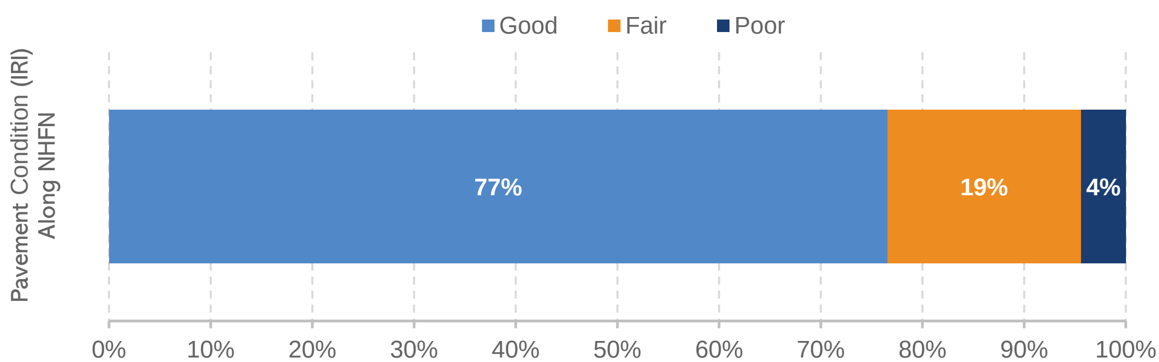
NHFN Pavement Condition Analysis: Centerline and Lane Miles

Information presented in Exhibit III-9 is based on an analysis of NHFN centerline miles. Centerline miles measure a road from start point to end point without regard for the number or size of roadway lanes.

IRI values reported in HPMS are based on centerline miles; reporting agencies use a consistent approach to calculate centerline miles. For these reasons, using centerline lines can help ensure a more consistent analysis. However, centerline miles do not provide information on the number or width of roadway lanes, thus presenting some limitation to their analysis.

Information presented in Exhibit III-10 and Exhibit III-11 is based on an analysis of NHFN mileage weighted by lane miles. Lane miles measure a road centerline multiplied by the number of lanes on that road. The PM-2 rule requires that targets be set on a lane-mile weighted basis for pavements. 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).

Exhibit III-9 ■ National Highway Freight Network Pavement Condition Based on IRI, 2016



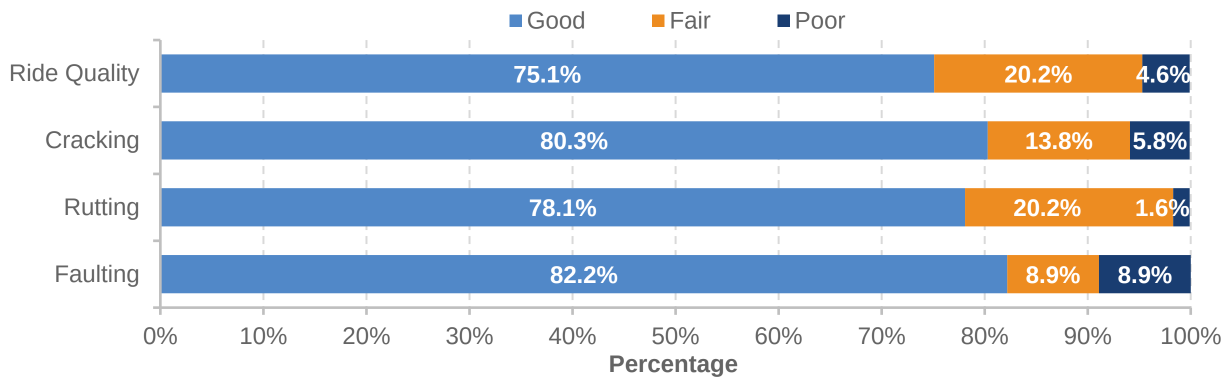
Note: NHFN is National Highway Freight Network; IRI is International Roughness Index. With the inclusion of the CRFCs and CUFCs submitted as of May 1, 2018, the total mileage of the NHFN is 54,310.

Source: Highway Performance Monitoring System, 2016.

Exhibit III-10 indicates that about three-quarters (75.1 percent) of NHFN mileage was rated as having "good" overall ride quality whereas a relatively small portion (4.6 percent) was rated as having "poor" ride quality. Most NHFN mileage with cracking, rutting, or faulting was still rated "good" (80.3 percent, 78.1 percent, and 82.2 percent, respectively). NHFN mileage with faulting had the highest percentage of "poor" pavement condition (8.9 percent of mileage), compared with NHFN mileage with rutting or faulting.[46]

[46] In accordance with the rating criteria presented in Exhibit III-8, cracking was calculated for all pavement types on the NHFN, rutting was calculated only for asphalt pavement types, and faulting was calculated only for concrete pavement types. About 73 percent of total NHFN lane miles are represented in the cracking value, 59 percent of total NHFN lane miles are represented in the rutting value, and 16 percent of total NHFN lane miles are represented in the faulting value.

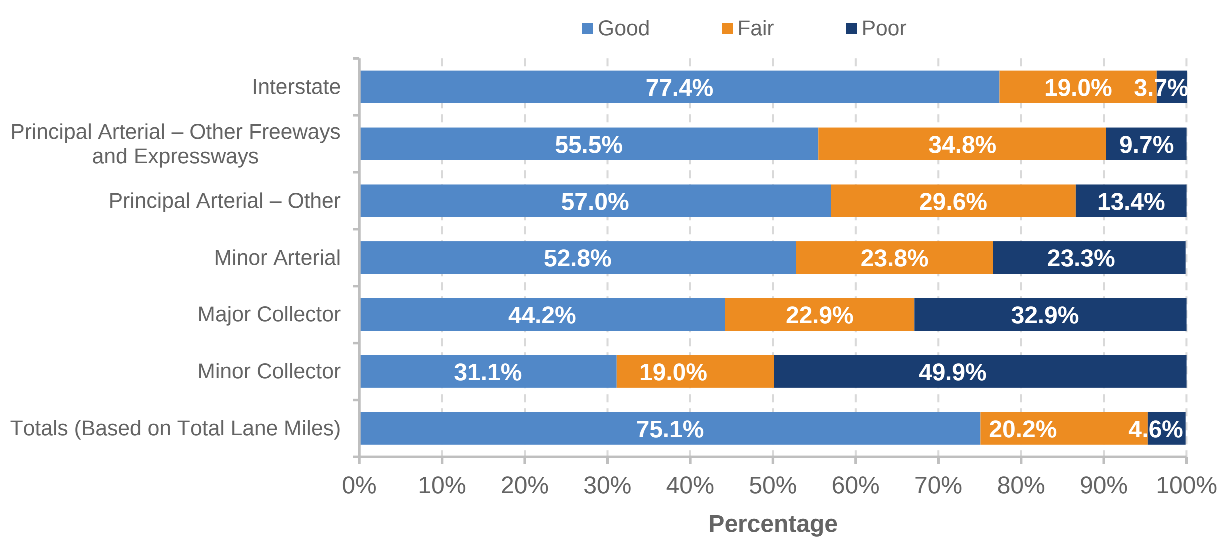
Exhibit III-10 ■ National Highway Freight Network Pavement Condition Overall Ride Quality and Individual Pavement Distresses, 2016



Sources: Highway Performance Monitoring System, 2016; National Highway Freight Network as of May 1, 2018.

Exhibit III-11 provides a second perspective on NHFN conditions, showing overall ride quality by roadway functional class. In general, ride quality along the NHFN declines with lower roadway functional class. For example, most NHFN Interstate mileage (approximately 77.4 percent) is rated as "good," whereas 31.1 percent of NHFN Minor Collector mileage is rated "good." Similarly, the percentage of mileage rated "poor" increases with lower roadway functional class. About 3.7 percent of NHFN Interstate mileage is rated "poor" whereas 49.9 percent of NHFN Minor Collector mileage is rated "poor."

Exhibit III-11 ■ National Highway Freight Network Ride Quality by Roadway Functional Class, 2016



Sources: Highway Performance Monitoring System, 2016; National Highway Freight Network as of May 1, 2018.

Bridges on the NHFN

The NBI was analyzed to inventory bridges on the NHFN. The analysis presented in this edition is based on an estimated total of 54,263 NHFN bridges (compared with 57,600 total NHFN bridges identified in the previous edition of this report).[47]

The PM-2 rule redefined the criteria for determining structurally deficient bridges and made them equal to the criteria that classify bridges as being in "poor" condition. The PM-2 rule considers only the first four of these metrics (deck condition, superstructure condition, substructure condition, and

[47] Due to limitations in available data and the analysis methodology used, the total number of NHFN bridges is estimated. For more information on the methodology, see the Data Quality and Procedures section.

culvert condition); if any one of these criteria is rated "poor," the bridge is classified as "poor."[48] A bridge is classified as "good" only if all metrics are rated as "good." The PM-2 rule only requires that targets be set for NHS bridges, but this section applies the same criteria to NHFN bridges.

The classification of a bridge in "poor" condition 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.

Exhibit *III-12* provides the bridge condition indicator classifications used in this edition of the *Highway Freight C&P* Report to Congress.

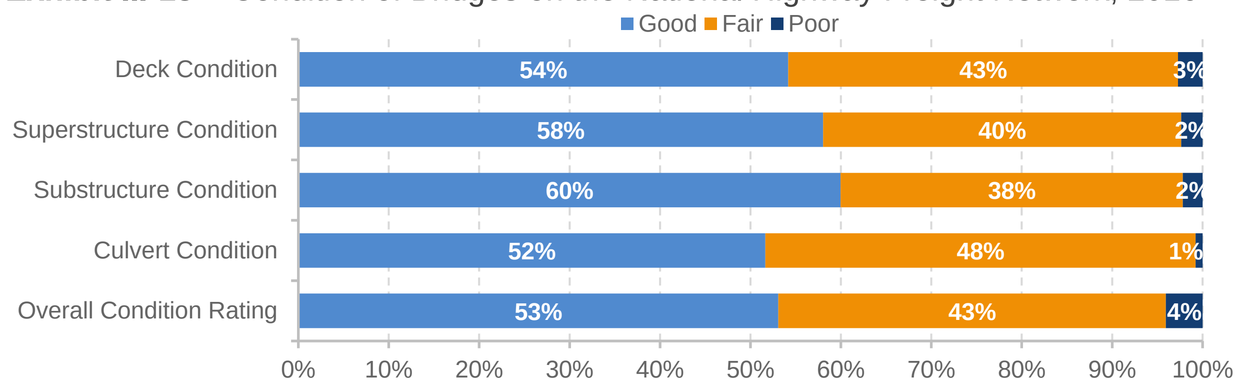
Exhibit III-12 ■ Bridge Condition Indicator Classifications Used in the Highway Freight C&P Report to Congress

Conditions Metric	Rating Criteria	Good	Fair	Poor
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

Source: FHWA (https://www.federalregister.gov/documents/2017/01/18/2017-00550/national-performance-management-measures-assessing-pavement-condition-for-the-national-highway).

Exhibit III-13 shows NHFN bridge deck, superstructure, substructure, and culvert condition, as well as an overall condition rating.[49] This edition reports on an overall condition rating for NHFN bridges for the first time; the data show that more than half of NHFN bridges (53 percent) are in "good" condition, 43 percent are in "fair" condition, and 4 percent are in "poor" condition. The data also indicate that bridge deck, superstructure, substructure, and culvert condition generally stayed the same between 2014 and 2016.

Exhibit III-13 ■ Condition of Bridges on the National Highway Freight Network, 2016



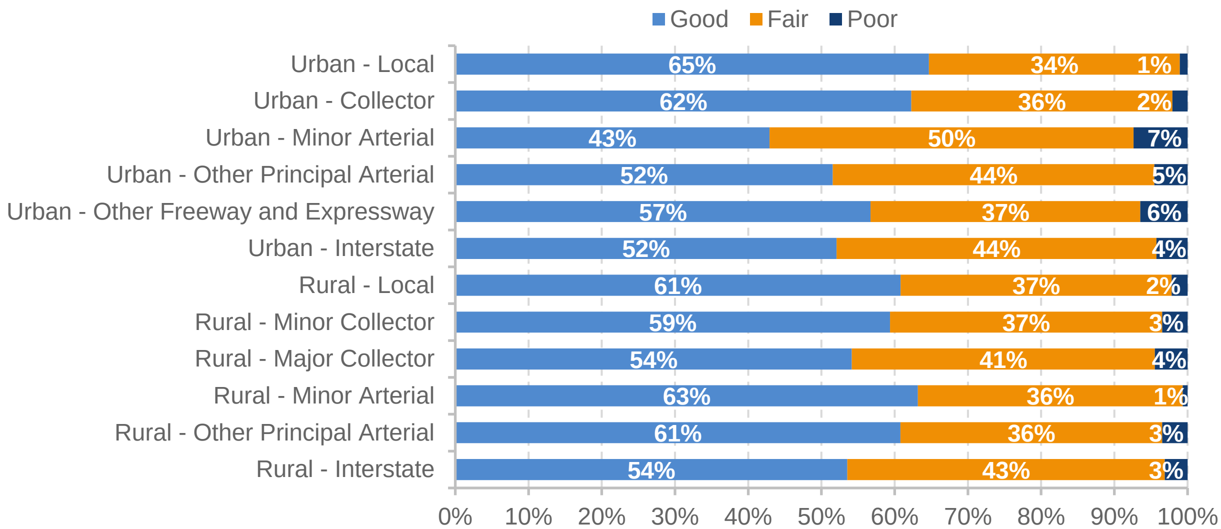
Source: National Bridge Inventory, 2016.

Exhibit III-14 shows the condition of NHFN bridges by roadway functional class.

[48] The bridge deck is the roadway or traveling surface of the bridge; the superstructure is the main part of the bridge, such as the beams, that rests on the substructure; the substructure is the foundation and other parts that support the superstructure. A culvert is a type of bridge substructure that allows water to flow through; a culvert is termed "bridge" if its length is greater than 20 feet, or 6.1 meters.

[49] Overall bridge condition data were not included in the previous edition of the *Highway Freight C&P* Report to Congress.

Exhibit III-14 ■ Condition of Bridges on the National Highway Freight Network, by Roadway Functional Class, 2016



Source: National Bridge Inventory, 2016.

NHFN Bridge Condition Analysis: Deck Length

Information presented in *Exhibit III-13* and *Exhibit III-14* was based on an analysis of NHFN bridge deck length rather than the number of bridges on the NHFN. Focusing the analysis on bridge deck length allows for a more neutral understanding of bridge conditions that avoids a potential data bias toward smaller bridges.

Performance

Safety

Safety indicators help enable decision makers and other stakeholders to monitor changes in system condition and performance against established visions, goals, and objectives. 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 majority of NHFN mileage. NHFN Interstates were combined with geocoded FARS data crash locations to obtain the crash data reported below. The data presented here show a rising trend in the number of crashes and fatalities on the NHFN, particularly on urban Interstate highways.

Exhibit III-15 shows the number of fatal motor vehicle crashes and fatalities on the NHFN in 2014, 2015, and 2016.

Exhibit III-15 ■ Fatal Crashes and Fatalities on the National Highway Freight Network, 2014–2016

	Rural/Urban Areas						Total	
	Rural Areas		Urban Areas		Unknown			
Year	Fatal Crashes	Fatalities	Fatal Crashes	Fatalities	Fatal Crashes	Fatalities	Fatal 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
2016	1,988	2,296	2,457	2,710	2	2	4,447	5,008

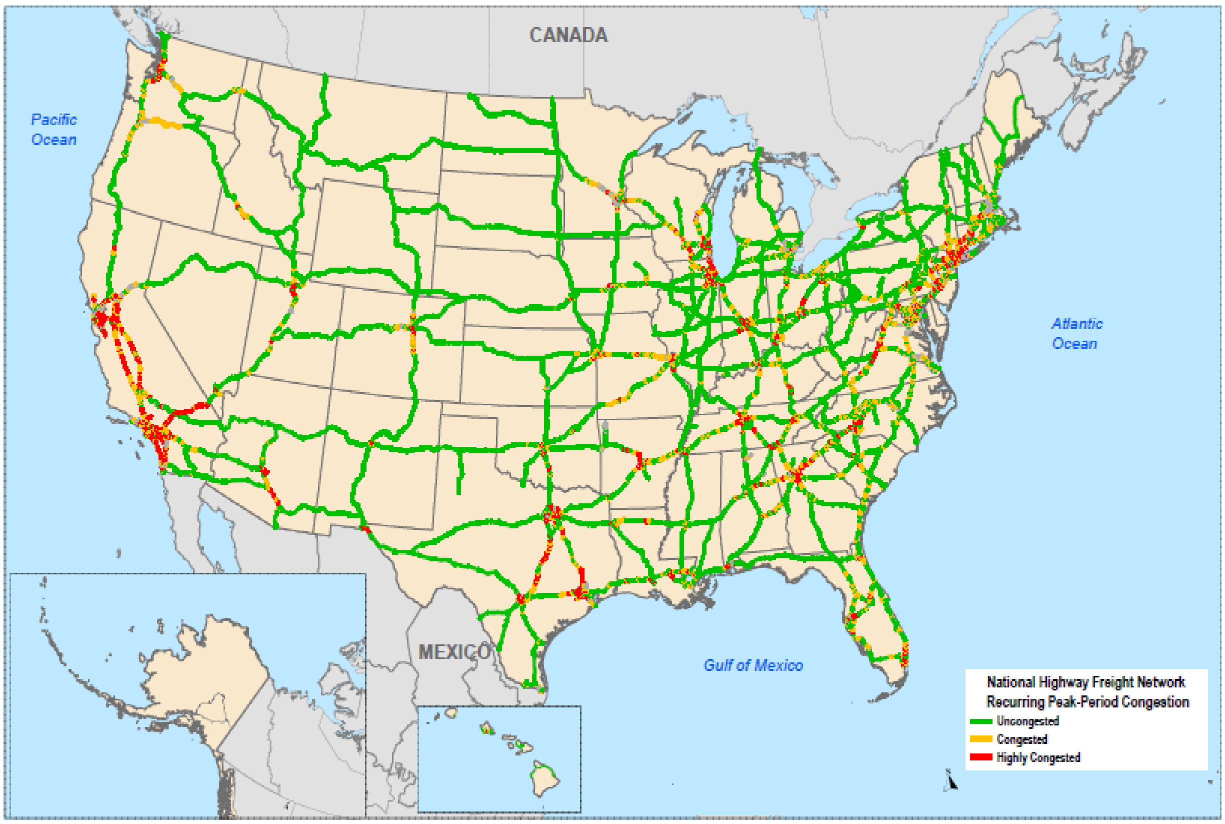
Source: National Highway Traffic Safety Administration, FARS 2016.

Congestion

Congestion on highways and bridges occurs when traffic demand approaches or exceeds the available capacity of the system. Congestion is typically described as either "recurring," meaning it takes place at roughly the same place and time every day, or "nonrecurring," which is caused by temporary disruptions (e.g., traffic incidents, bad weather, construction work) that render part of the roadway unusable. Congestion that negatively influences freight traffic tends to occur on a recurring basis during peak periods, particularly in and near major metropolitan areas.

Exhibit III-16 identifies estimated locations of peak-period congestion on the NHFN in 2015.[50] As in the peak-period congestion map presented in the previous edition of this report, most recurring, highly congested conditions occur within or near major metropolitan areas.

Exhibit III-16 ■ Estimated Peak-Period Congestion on the National Highway Freight Network, 2015



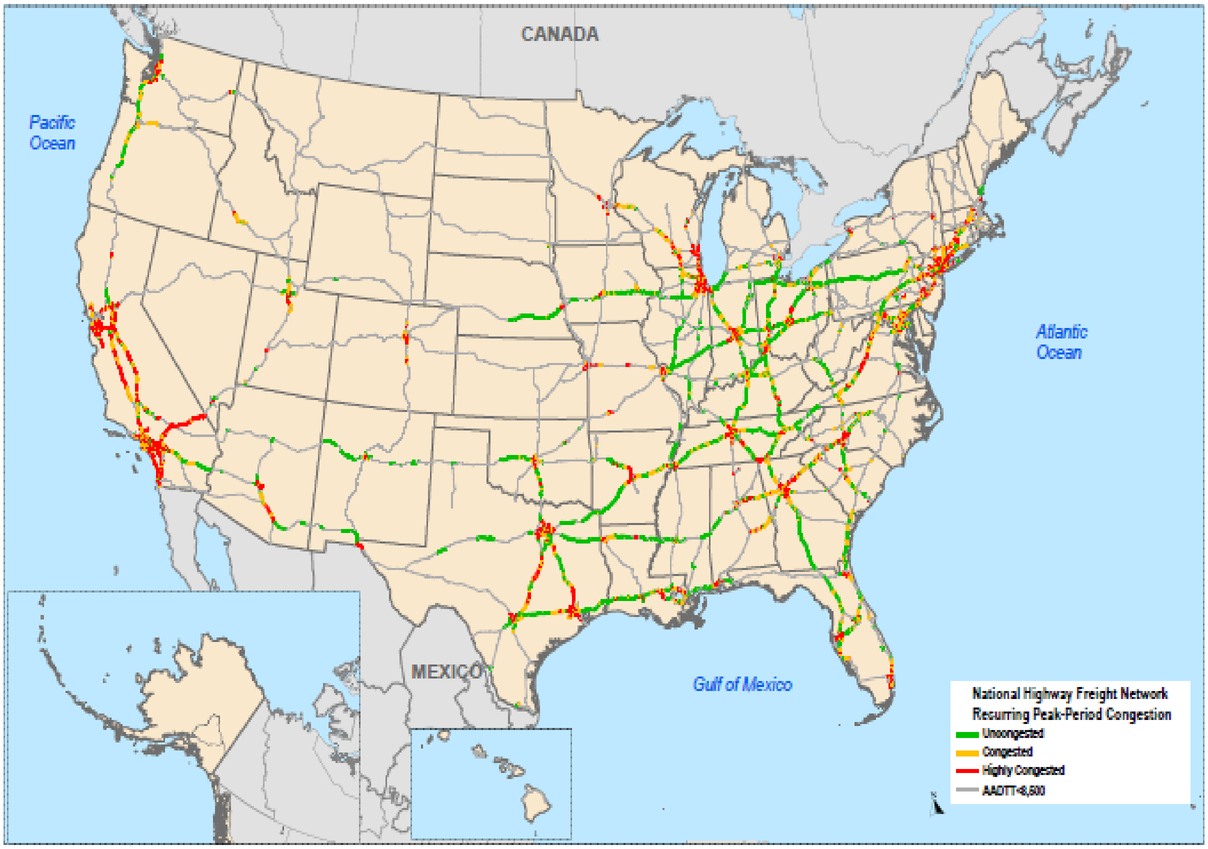
Note: This map uses FAF version 4.3, which is based in large part on results from the Commodity Flow Survey administered in 2012. FAF version 4 data beyond 2012 were estimated based on the 2012 CFS. **Highly congested** segments are stop-and-go conditions with volume/service flow ratios greater than 0.95. **Congested segments** have reduced traffic speeds with volume/service flow ratios between 0.75 and 0.95. The volume/service flow ratio is estimated using the procedures outlined in the Highway Performance Monitoring System Field Manual Appendix N.

Source: FHWA, Office of Freight Management and Operations, Freight Analysis Framework, version 4.3, 2016.

Exhibit III-17 illustrates the locations of estimated peak-period congestion on the high-volume truck portions of the NHFN as of 2015. 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. Similar to *Exhibit III-16,* the map indicates that highly congested conditions occur within or near major metropolitan areas. High-volume truck portions of the NHFN are more prone to experiencing congested conditions than portions with lower average truck volume.

[50] See *Exhibit III-16* and *Exhibit III-17* notes for explanation of why these locations are estimated.

Exhibit III-17 ■ Estimated Peak-period Congestion on High-Volume Truck Portions of the NHFN, 2015



Note: Note: This map uses FAF version 4.3, which is based in large part on results from the Commodity Flow Survey administered in 2012. FAF version 4 data beyond 2012 were estimated based on the 2012 CFS. **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. AADTT is average annual daily truck traffic. The volume/service flow ratio is estimated using the procedures outlined in the Highway Performance Monitoring System Field Manual Appendix N.

Source: FHWA, Office of Freight Management and Operations, Freight Analysis Framework, version 4.3, 2016.

FHWA Monitors Freight Performance Using Multiple Measures

FHWA routinely uses multiple measures to monitor freight system congestion and overall performance. For example, as part of its Freight Performance Measurement program, FHWA uses measures of travel time reliability and speed for corridors, border crossings, urban areas, freight intermodal connections, and freight bottlenecks.

Additional information is available on FHWA's website at http://ops.fhwa.dot.gov/freight/freight_analysis/perform_meas/.

Truck Travel Time Speed and Reliability

Truck travel time speed and reliability are two additional indicators of highway freight system performance. Slower speeds and unreliable travel times caused by congestion, inclement weather conditions, or other factors can increase fuel and driver costs and delay shipments, which in turn affect efficiency and productivity. Average travel speeds serve as an indicator of congestion for each corridor. Variability in travel times serves as an indicator of reliability for each corridor.

Exhibit III-18 displays annual average travel speeds on the top 25 domestic freight corridors on the NHFN over a 5-year timeframe (2011 through 2016). As in the previous edition, travel speeds are measured using data derived from FHWA National Performance Management Research Data Set (NPMRDS) truck probes.

FHWA, State DOTs, and MPOs use the NPMRDS to calculate transportation performance measures. The NPMRDS provides historical average travel times in five-minute increments daily covering the entire NHS. The NPMRDS collects vehicle probe-based travel time data for passenger vehicles and trucks. Probe data are collected from a variety of sources including mobile devices, connected autos, portable navigation devices, truck fleets, and sensors. The data provide nationwide coverage using data from over 700,000 trucks operating in North America. Most of the data are from medium to large fleets that operate tractor-trailer combination trucks in every sector of the industry and every region of the United States and Canada.

To determine the top 25 domestic freight corridors, in 2015 FHWA used FAF version 3 data, collected by NPMRDS vehicle probes, 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).[51]

Just over half (52 percent) of the top 25 domestic freight corridors by tonnage on the NHFN experienced an increase in speed in 2016 compared with 2011; the remaining corridors experienced a decrease in speed over this period. The I-84 Boise to I-86 corridor experienced the greatest increase in average speed, whereas the I-95 Richmond to New Haven corridor experienced the greatest decrease.

FHWA also uses the NPMRDS data to assess corridor-level travel time reliability, which it defines as the consistency or dependability in travel times, as measured from day to day and/or across different times of the day.[52] Travel time reliability is derived from measured average speeds of commercial vehicles for the Top 25 Domestic Freight Corridors annually. Compared with measures of congestion, measures of travel time reliability provide a different perspective of travel beyond a simple average travel time.

To the freight industry, reliability in the predictability of travel time is of critical importance. As one example, many industries rely on "just in time" manufacturing—having the right material, at the right time, at the right place, and in the exact amount needed. The ripple effect of a late delivery can be costly; frequent delivery delays disrupt the effectiveness of production. Poor reliability requires drivers to budget extra time when planning trips, tracking routes in real time, and making route adjustments in response to inconsistent travel time and excess delay. Unpredictable travel times may lead to negative impacts such as delayed deliveries or unwanted schedule changes that add cost to freight operations or deliveries[53] and may result in lost pay to and increased stress on truck drivers.

[51] FHWA, *Status of the Nation's Highways, Bridges, and Transit Conditions and Performance*: 23rd Edition: Part III: Highway Freight Transportation–Report to Congress. https://ops.fhwa.dot.gov/freight/infrastructure/nfn/rptc/cp23hwyfreight/iii_ch11.htm

[52] FHWA, Travel Time Reliability Measures. https://ops.fhwa.dot.gov/perf_measurement/reliability_measures/index.htm#targetText=Travel%20time%20reliability%20measures%20the,different%20times%20of%20the%20day.

[53] FHWA, Travel Time Reliability Measures. https://ops.fhwa.dot.gov/perf_measurement/reliability_measures/index.htm#targetText=Travel%20time%20reliability%20measures%20the,different%20times%20of%20the%20day.

Exhibit III-18 ■ Annual Average Travel Speeds for the Top 25 Domestic Freight Corridors by Tonnage on the National Highway Freight Network, 2011–2016

Corridor	2011	2012	2013	2014	2015	2016
I-5: Medford, OR to Seattle	56.64	56.33	56.12	54.94	56.15	55.99
I-5/CA 99: Sacramento to Los Angeles	56.19	56.05	56.11	55.99	56.11	56.25
I-10: Los Angeles to Tucson	59.53	59.42	59.42	58.6	59.54	59.45
I-10: San Antonio to New Orleans	61.79	61.45	61.77	60.82	61.78	61.75
I-10: Pensacola to I-75	64.69	63.9	64.03	63.99	64.27	64.57
I-30: Little Rock to Dallas	61.78	62.64	62.82	62.13	62.7	62.84
I-35: Laredo to Oklahoma City	61.06	61.45	61.05	59.76	60.29	60.57
I-40: Oklahoma City to Flagstaff	63.99	63.86	64.15	64.31	64.18	64.31
I-40: Knoxville to Little Rock	62.34	62.24	62.14	61.53	62.3	62.71
I-40: Raleigh to Asheville	62.42	62.36	62.32	61.62	61.9	62.05
I-55/I-39/I-94: St. Louis to Minneapolis	62	62.37	62.16	62.1	62.57	63.03
I-57/I-74: I-24 (IL) to I-55 (IL)	62.86	62.71	62.56	62.76	63.59	63.62
I-70: Kansas City to Columbus	61.51	61.94	61.81	61.5	61.98	62.35
I-65/I-24: Chattanooga to Nashville to Chicago	60.97	61.04	60.85	59.57	59.95	60.39
I-75: Tampa to Knoxville	62.74	62.47	62.39	61.67	62.13	62.15
I-75: Lexington to Detroit	60.18	60.76	60.66	59.3	59.43	60.19
I-78/I-76: New York to Pittsburgh	59.59	59.94	59.88	59.34	59.7	60.01
I-80: New York to Cleveland	60.78	61.12	61.13	60.68	61.14	61.59
I-80: Cleveland to Chicago	61.86	62.26	61.99	61.57	62.09	61.8
I-80: Chicago to I-76 (CO/NE border)	62.96	63.16	63.36	63.39	63.64	63.77
I-81: Harrisburg to I-40 (Knoxville)	62.38	62.42	62.6	62.6	62.53	62.65
I-84: Boise to I-86	61.81	62.53	62.53	62.43	62.91	63.36
I-94: Chicago to Detroit	59.89	60.54	59.95	58.74	59.24	59.59
I-95: Miami to I-26 (SC)	63.07	62.63	62.48	61.77	62.27	62.35
I-95: Richmond to New Haven	55.36	55.52	54.7	51.72	54.33	54.38

Notes: Weekdays 24/7, presented in miles per hour. Darker shading indicates lower annual average travel speed.

Source: National Performance Management Research Data Set (NPMRDS) 2016 as provided by FHWA, Office of Freight Management and Operations.

Exhibit III-19 shows truck travel time prediction reliability for the top 25 domestic freight corridors by tonnage on the NHFN over a five-year timeframe (2011 to 2016). 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 2016 travel time reliability index for I-5/CA 99: Sacramento to Los Angeles is 1.36. This means travel times in 2016 were 36 percent longer on heavy travel days, compared with normal days. *Exhibit III-19* indicates that from 2011 to 2016, truck travel time reliability decreased for the majority (72 percent) of top 25 domestic freight corridors.

Exhibit III-19 ■ Travel Time Reliability Index for the Top 25 Domestic Freight Corridors by Tonnage on the National Highway Freight Network, 2011–2016

Corridor	2011	2012	2013	2014	2015	2016
I-5: Medford, OR to Seattle	1.31	1.34	1.37	1.41	1.48	1.51
I-5/CA 99: Sacramento to Los Angeles	1.28	1.33	1.34	1.33	1.35	1.36
I-10: Los Angeles to Tucson	1.24	1.21	1.26	1.27	1.34	1.38
I-10: San Antonio to New Orleans	1.23	1.28	1.3	1.31	1.31	1.32
I-10: Pensacola to I-75	1.06	1.06	1.06	1.07	1.06	1.07
I-30: Little Rock to Dallas	1.21	1.15	1.14	1.17	1.18	1.21
I-35: Laredo to Oklahoma City	1.24	1.24	1.28	1.3	1.39	1.42
I-40: Oklahoma City to Flagstaff	1.1	1.12	1.11	1.11	1.12	1.11
I-40: Knoxville to Little Rock	1.17	1.18	1.2	1.24	1.16	1.15
I-40: Raleigh to Asheville	1.11	1.12	1.14	1.15	1.15	1.15
I-55/I-39/I-94: St. Louis to Minneapolis	1.15	1.13	1.14	1.14	1.15	1.13
I-57/I-74: I-24 (IL) to I-55 (IL)	1.09	1.12	1.15	1.14	1.1	1.14
I-70: Kansas City to Columbus	1.21	1.18	1.2	1.2	1.21	1.19
I-65/I-24: Chattanooga to Nashville to Chicago	1.26	1.26	1.29	1.34	1.34	1.33
I-75: Tampa to Knoxville	1.16	1.16	1.2	1.21	1.22	1.25
I-75: Lexington to Detroit	1.26	1.24	1.29	1.3	1.34	1.34
I-78/I-76: New York to Pittsburgh	1.16	1.2	1.2	1.21	1.22	1.23
I-80: New York to Cleveland	1.26	1.19	1.19	1.2	1.22	1.21
I-80: Cleveland to Chicago	1.18	1.14	1.17	1.21	1.17	1.24
I-80: Chicago to I-76 (CO/NE border)	1.13	1.12	1.12	1.12	1.12	1.14
I-81: Harrisburg to I-40 (Knoxville)	1.11	1.12	1.11	1.11	1.1	1.11
I-84: Boise to I-86	1.14	1.08	1.09	1.14	1.14	1.1
I-94: Chicago to Detroit	1.09	1.08	1.1	1.15	1.11	1.15
I-95: Miami to I-26 (SC)	1.17	1.18	1.21	1.23	1.26	1.31
I-95: Richmond to New Haven	1.62	1.59	1.69	1.85	1.76	1.75

Notes: Darker shading indicates a higher travel time reliability index value.

Source: National Performance Management Research Data Set 2016 as provided by FHWA, Office of Freight Management and Operations.

Overview of CRFCs and CUFCs

As noted earlier in this section, CRFCs and CUFCs are freight corridors that provide critical connectivity to the NHFN. By designating these important corridors, States can direct resources toward improved system performance and efficient movement of freight on the NHFN.[54] CRFCs and CUFCs provide links between NHFN and freight generators such as manufacturers, distribution points, and rail intermodal and port facilities. CRFCs and CUFCs are significant in establishing and strengthening States' first-/last-mile and intermodal connectivity, both integral components of an efficiently functioning freight system.

Submittal of CRFCs and CUFCs increases a State's NHFN mileage, allowing expanded use of NHFP formula funds and Infrastructure for Rebuilding America (INFRA) funds[55] for eligible projects that support national goals identified in 23 U.S.C. 167(b) and 23 U.S.C. 117(a)(2).[56]

States are responsible for designating CRFCs. States also designate CUFCs, in consultation with MPOs, in urbanized areas with populations under 500,000; in urbanized areas with populations over

54 FHWA, FAST Act Section 1116 National Highway Freight Program (NHFP) Guidance, Designating and Certifying Critical Rural Freight Corridors and Critical Urban Freight Corridors, Questions & Answers. Posted April 26, 2016, Update May 23, 2016. At https://ops.fhwa.dot.gov/fastact/crfc/sec_1116_gdnce.pdf.
55 Authorized in Section 1101(a)(5) of the FAST Act and administered pursuant to 23 U.S.C. 117.
56 FHWA, "FAST Act, Section 1116 NHFP Guidance: Designating and Certifying Critical Rural Freight Corridors and Critical Urban Freight Corridors." 2016. https://ops.fhwa.dot.gov/fastact/crfc/sec_1116_gdnce.htm.

500,000, MPOs are responsible for designating CUFCs in consultation with States, and for determining how to distribute CUFC mileage among the urbanized areas.

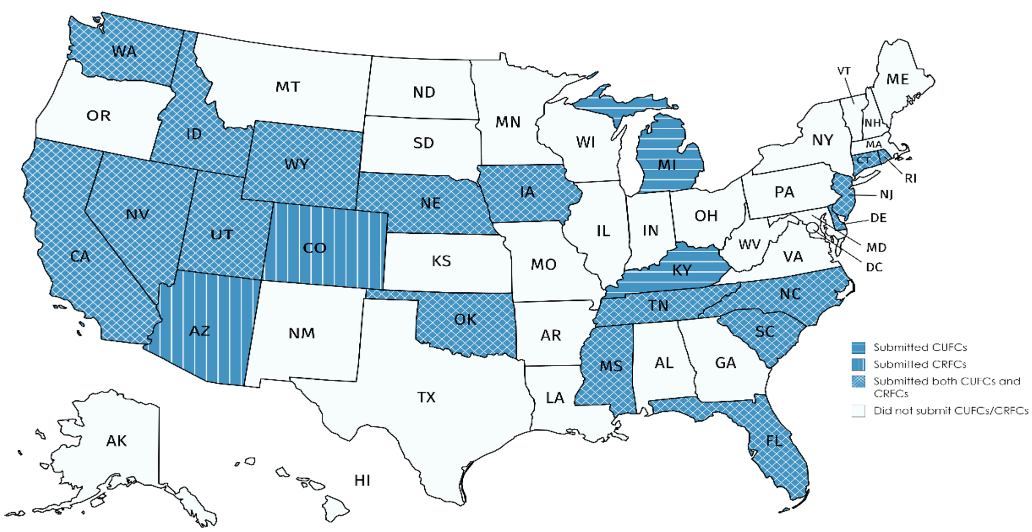
Each State is given a maximum total number of miles for CRFC and CUFC submittal; there is no deadline for submittals. The mileage maximums are based on centerline roadway mileage. Information on the estimated maximum limit of CRFC and CUFC mileage for each State is available on the FHWA NHFN website as part of the table of NHFN mileages by State.[57]

The CRFC and CUFC categories provide flexibility for States to designate any functional class of roadway, including local roads, as well as planned facilities. FHWA encourages States and MPOs, when making CRFC submittals, to consider first- or last-mile connector routes from high-volume freight corridors to key rural freight facilities, including manufacturing centers, agricultural processing centers, farms, intermodal, and military facilities. FHWA encourages States, when making CUFC submittals, to consider first- or last-mile connector routes from high-volume freight corridors to freight-intensive land and key urban freight facilities, including ports, rail terminals, and other industrial-zoned land.

Submitting CRFCs and CUFC designations and certifications is optional, but extends the flexibility of States to apply NHFP funds. As of May 1, 2018, 18 States had submitted both CRFCs and CUFCs. An additional two States had submitted only CRFCs, and two other States submitted only CUFCs.

Exhibit III-20 shows a map of States with CRFCs and/or CUFCs submitted as of May 1, 2018. Appendix F provides a full list of all submitted routes.

Exhibit III-20 ■ States with CRFCs and/or CUFCs



Note: CRFCs are Critical Rural Freight Corridors and CUFCs are Critical Urban Freight Corridors.

Source: FHWA, Office of Freight Management and Operations. Represents data as of May 1, 2018.

The submitted CRFCs and CUFCs comprised 3,461 total miles, representing about six percent of NHFN roadway mileage. CRFC and CUFC roads classified as "Principal Arterial-Other" make up more than half (60 percent) of total CRFC and CUFC mileage. *Exhibit III-5* provides a breakdown of the NHFN mileage, including the CRFC and CUFC components.

When submitting CRFCs and CUFCs, States are required to classify these corridors using one or more specific route identifiers (*Exhibit III-21* and *Exhibit III-22*). Of the 11 route identifier categories, there are seven identifiers for CRFCs and four identifiers for CUFCs. These identifiers describe general criteria for how States should classify their CRFCs and CUFCs.

[57] https://ops.fhwa.dot.gov/freight/infrastructure/nfn/maps/nhfn_mileage_states.htm

Exhibit III-21 ■ Route Identifiers for Critical Rural Freight Corridors

CRFC ID	Route/Facility Descriptor
A	Rural principal arterial roadway with a minimum of 25 percent of the annual average daily traffic of the road measured in passenger vehicle equivalent units from trucks
B	Provides access to energy exploration, development, installation, or production areas
C	Connects the PHFS or the Interstate System to facilities that handle more than: 50,000 20-foot equivalent units per year or 500,000 tons per year of bulk commodities
D	Provides access to a grain elevator, agricultural facility, mining facility, forestry facility, or intermodal facility
E	Connect to an international port of entry
F	Provides access to significant air, rail, water, or other freight facilities
G	Corridor that is vital to improving the efficient movement of freight of importance to the economy of the State

Note: PHFS is Primary Highway Freight System.

Source: FHWA, Office of Freight Management and Operations.

Exhibit III-22 ■ Route Identifiers for Critical Urban Freight Corridors

CUFC ID	Route/Facility Descriptor
H	Connects an intermodal facility to the PHFS, the Interstate System, or an intermodal freight facility
I	Located within a corridor of a route on the PHFS and provides an alternative highway option important to goods movement
J	Serves a major freight generator, logistic center, or manufacturing and warehouse industrial land
K	Corridor that is important to the movement of freight within the region, as determined by the MPO or the State

Note: PHFS is Primary Highway Freight System; MPO is metropolitan planning organization.

Source: FHWA, Office of Freight Management and Operations.

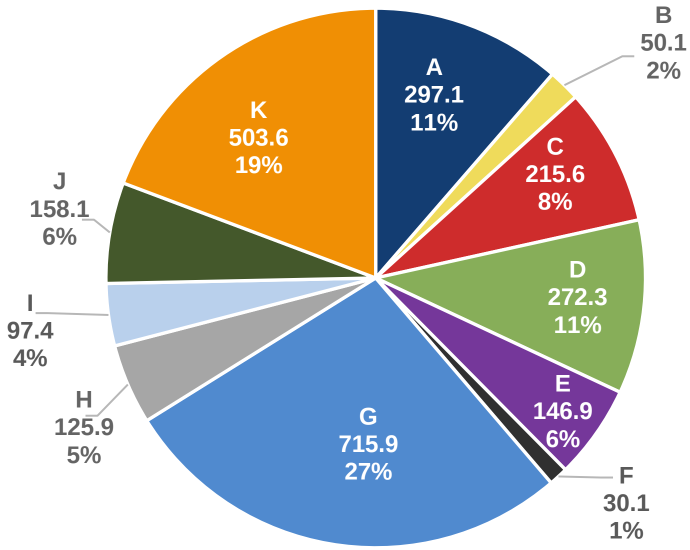
States were permitted to select multiple route identifiers for each submitted CRFC or CUFC route, and often did. About 30 percent of all submitted CRFC and CUFC routes had multiple (two or more) identifiers; about 60 percent of submitted CRFC and CUFC routes had only one unique identifier. The remaining 10 percent of submitted CRFC and CUFC routes did not have identifiers.

The frequency with which States selected multiple identifiers for the CRFCs and CUFCs indicates that States are using the flexibility inherent in these categories to identify high-priority corridors. Future analyses will further examine the methodologies employed by States to select their CRFCs and CUFCs, including the freight modeling tools, processes, or mechanisms that may have been used. The analysis presented here provides a baseline for expanded analyses in future editions of this *Highway Freight C&P* Report to Congress.

As *Exhibit III-23* demonstrates, among the CRFC and CUFC routes submitted with only one identifier, about 27 percent of mileage (about 715 miles total) was identified as category G, a "corridor that is vital to improving the efficient movement of freight of importance to the economy of the State."[58] About 19 percent of mileage (about 503 miles total) was identified as category K, a "corridor that is important to the movement of freight within the region, as determined by the MPO or the State."[59]

[58] Note that percentage is calculated by summing the total amount of CUFC route mileage submitted under category G, and dividing by the total route mileage of all CUFC and CRFC routes submitted as of May 1, 2018.
[59] See previous footnote for a description of how this percentage was calculated.

Exhibit III-23 ■ CRFC and CUFC Route Segment Length (in Miles) by Unique Identifier, 2018



Notes: CRFCs are Critical Rural Freight Corridors and CUFCs are Critical Urban Freight Corridors. See Exhibit III-21 and Exhibit III-22 for definitions of the route identifiers.

Source: FHWA, Office of Freight Management and Operations. Represents data as of May 1, 2018.

Spotlight Topics

This section provides an overview of several spotlight topics for freight transportation. These topics include issues, initiatives, or challenges that significantly impact freight transportation planning, management, and decision-making. These topics also provide additional context to better assess and understand freight system conditions, performance, and needs (including, but not limited to, the NHFN).

NHFN Data Quality and Procedures

With establishment of the NHFN, Congress provided a new opportunity to direct resources to improve a freight-specific roadway network. FHWA is still in the early stages of compiling NHFN data, identifying opportunities to expand or improve on these data, and understand where there may be gaps, inconsistencies, or other data needs to address. FHWA is working to create data visualization and analysis tools to better analyze NHFN data. Through these and other efforts, it is expected that the ability to analyze NHFN data will improve, becoming more comprehensive over time.

Jason's Law and the National Coalition for Truck Parking

One of the major challenges to the safe movement of freight is the availability of adequate truck parking. The first *Highway Freight C&P* Report to Congress provided an in-depth discussion of the pervasiveness of truck parking challenges across the country and affirmed truck parking as a priority topic for DOT and its operating administrations.

Section 1401 of MAP-21, identified as "Jason's Law," directed DOT to conduct a survey and a comparative assessment to:

1. Evaluate the capability of each State to provide adequate parking and rest facilities for commercial motor vehicles engaged in Interstate transportation.
2. Assess the volume of commercial motor vehicle traffic in each State.
3. Develop a system of metrics to measure the adequacy of commercial motor vehicle parking facilities in each State.

The Jason's Law Truck Parking Survey Results and Comparative Analysis of August 2015 (Truck Parking Survey) documented the location of more than 308,000 truck parking spaces, including over 36,000 at public rest areas and over 272,000 at private truck stops.[60] The Truck Parking Survey found that truck parking is a national problem, especially along key freight corridors. More than 75 percent of respondent truck drivers reported regularly experiencing problems with finding "safe parking locations when rest was needed." Ninety percent reported struggling to find safe parking at night. Other findings included:

- Truck parking capacity is a problem in all States, with the greatest problems more evident on major freight corridors and in large metropolitan areas.
- Consistent, continued measurement is important to provide data to understand dynamic truck parking needs and assess whether the situation is improving.
- 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 commodities to, from, and through States to better anticipate and plan for parking needs.
- Local regulations and zoning often create challenges for development of truck parking facilities.
- Public and private sector coordination is critical to address long-term truck parking needs.

In August 2015, DOT formed the National Coalition on Truck Parking (Coalition) in response to the needs identified in the Truck Parking Survey. The Coalition convenes stakeholders from transportation organizations, the freight industry, and other groups to engage in the following activities:

- Collaborate nationally and among regions to identify opportunities and solutions for truck parking needs.
- Share information on data and new analyses to understand needs and trends in truck parking.
- Encourage partnerships to implement solutions.
- Identify opportunities to use existing and new programs to support truck parking implementation.

State Freight Plans

Section 8001(a) of the FAST Act includes a provision that requires each State that receives funding under the NHFP to develop a State Freight Plan. These plans can help States address current or upcoming challenges affecting the movement of freight into, out of, and through their States; furthermore, they include information that supports a deeper analysis of freight infrastructure conditions and performance. The FAST Act established 10 requirements for State Freight Plans but the plans may be organized in any structure that works best for individual States. (See Appendix E for the list of 10 required elements.) States may also consider optional items to include in their State Freight Plans. A State Freight Plan must be updated every 5 years, and must address a 5-year forecast period, although DOT strongly encourages an outlook of two decades or more.

Another intent of FAST Act State Freight Plans is to help States coordinate their freight planning efforts and investment decisions among transportation modes. A plan that considers the needs and capabilities of the entire freight system, including providing improved connectivity between different modes, can increase efficiencies and lead to improved overall transportation safety.

As of May 1, 2018, 45 States and the District of Columbia had submitted FAST Act-compliant plans to FHWA. [61]

[60] FHWA, "Jason's Law Truck Parking Survey Results and Comparative Analysis." August 2015. https://ops.fhwa.dot.gov/freight/infrastructure/truck_parking/jasons_law/truckparkingsurvey/index.htm
[61] As of 2019, all 50 States and the District of Columbia had submitted FAST Act-compliant State Freight Plans to FHWA.

FHWA views FAST Act-compliant plans as a critical resource for States to use in prioritizing freight transportation investments and guiding future transportation policy-making. These plans ultimately reflect each State's analysis of its own economy and how key economic sectors rely on the freight transportation system. The more comprehensively a plan represents the State's freight-related transportation modes, the more useful it will be in meeting the freight transportation needs of the State's industries and MPOs, and supporting their decision-making processes.

Freight State-of-the-Practice Innovations: Freight Demand Modeling and Data Improvement Program

Understanding and forecasting freight flows enables a greater understanding of NHFN conditions and performance and can support planning for future transportation capacity, operation, preservation, safety and security, energy, and economy investment needs. Better freight flow data and models will enable State, regional, and local planners to predict freight movement trends more effectively and make more informed project investment decisions.

The FHWA Freight Demand Modeling and Data Improvement Program, funded by the Strategic Highway Research Program (SHRP2), developed tools and resources to improve freight data sets and freight modeling practices. The program also identified freight modeling and data priority needs, innovative ideas, and new solutions for broad application. The program assisted State departments of transportation and MPOs with development of advanced tools and models to forecast future freight flows.

As part of SHRP2, FHWA and the American Association of State Highway and Transportation Officials conducted a series of Freight Data Collaboration and Standardization Regional Forums, bringing together State departments of transportation and MPOs to identify areas of collaboration on regional or local freight data collection, standardization, and maintenance. The overall goal was to collaborate on improving freight data programs to support local, regional, and State freight transportation programs.

The Freight Demand Modeling and Data Improvement Program benefits State, regional, and local planners by providing them with tools to develop better freight data and models. This will improve planners' and modelers' abilities to predict freight movement trends and support more informed project investment decisions for safer, more reliable, and efficient freight movement.

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PART IV: Additional Information

Introduction

This section provides additional insights into topics touched on elsewhere in this report, specifically those pertaining to rural areas and technology.

Although this report is based largely on 2016 data, more recent data and trends are discussed herein, including information related to the coronavirus disease 2019 (COVID-19) pandemic. This historic event highlighted the Nation's heavy reliance on the transportation system for delivery of supplies, the innovative ways in which technology can provide alternatives to travel, and the unique qualities of rural and urban America. The COVID-19 pandemic, and Americans' response to it, provide an opportunity to consider how emerging technologies can influence the Nation's transportation needs and services in the future, despite growing disparities between urban and rural America.

Chapter 11 highlights rural America and its significant impact on the Nation's economy, transportation infrastructure, and reliable delivery of goods and services. This chapter explores rural topics including population, demographics, economics, and travel trends from both a highway and transit perspective.

Chapter 12 discusses the influence of technology on current and future transportation trends. This chapter highlights transformative technologies that are affecting transportation, including current research and demonstration projects using technology to improve accessibility and mobility.

CHAPTER 11: Rural America

Rural America – Highways

Rural areas play significant roles in the U.S. economy and culture. A century ago, half the population of the United States lived in rural areas.[62] Many rural residents were farmers, and communities were built around a lifestyle of self-sufficiency. Although there were a few motorized vehicles on the road, people in rural areas mainly traveled by horse and wagon and goods were shipped long-distance via railroads.

Today, rural communities look much different. They depend on transportation to help support their economies by providing access to job opportunities, professional services, and goods and services not readily available in the local marketplace. Although the population of rural areas is much smaller than that of suburban and urban communities, rural areas constitute approximately 97 percent of land in the United States[63] and account for 71 percent[64] (by length) of our Nation's roads.

Rural transportation networks allow residents of rural areas to access employment, education, and goods and services and make it possible for visitors to enjoy rural tourism destinations that support many local businesses. Some of the transportation challenges facing rural America resemble those in more urban areas, including economic, spatial, physiological, and social barriers to accessing economic and social opportunities. However, given the limited availability of modal options in rural areas, the distances and terrain that affect the cost of infrastructure and operations, and the evolving economic environment in many rural areas, dependence on a more limited transportation network—primarily rural highways—can be significantly greater than in urban areas.

KEY TAKEAWAYS

- Rural areas make up 18 percent of the population, constitute approximately 97 percent of land in the United States, and account for 71 percent (by length) of our Nation's roads.
- Rural areas account for 90 percent of America's weight-limited bridges; 80 percent of all poor-condition bridges are in rural areas.
- The distance, terrain, and evolving economic environment in many rural areas affect the cost of infrastructure and operations, which limits the availability of modal options, constrains the transportation network, and promote dependence on personal vehicles for mobility.
- Rural counties provide most of the Nation's food and produced $139.6 billion in agricultural exports in 2018.
- In 2017, rural households devoted 20 percent of their total budget to transport, compared with 13 percent for urban households.
- Approximately two-thirds of rural Americans (63 percent) had a broadband internet connection at home in 2019, up from about a third (35 percent) in 2007.
- Rural households account for 24 percent of all passenger vehicle miles traveled (VMT), with an average annual household VMT of 24,465—about 50 percent higher than that of urban households.
- A total of 95.13 billion vehicle miles of freight movement occurred on rural roads in 2018, significantly more than the 89.04 billion miles in urban areas.

[62] The 1920 census marked the first time in which over 50 percent of the U.S. population was defined as urban. https://www.census.gov/history/www/programs/geography/urban_and_rural_areas.html
[63] https://www.census.gov/library/stories/2017/08/rural-america.html
[64] https://www.fhwa.dot.gov/policyinformation/statistics/2018/hm12.cfm

Understanding the Rural Landscape

Daily travel in the United States has undergone significant change over the past few years with the introduction of new travel modes, transportation services, and business models, along with technology-enabled travel tools and apps. Understanding the impacts and implications of these changes on travel demand is important for policy development and resource planning. Travel mode options, quality and availability of infrastructure such as sidewalks and bike lanes, and the proximity of essential services including the number of grocery stores, jobs, and healthcare within a certain distance from home all vary based on where one lives.

Rural areas are heterogeneous, in that some lie just beyond the urban fringe within or near large metropolitan areas, whereas others are remote communities with limited access to major cities. In fact, according to the U.S. Census Bureau's American Community Survey (ACS), more than half (54.4 percent) of people living in rural areas live within a metro area.[65]

The word "rural" recalls small towns, pastoral landscapes, tight-knit communities, open recreation, and an agricultural economy. Rural can be all these things. For example, a rural community may be agricultural and cover a vast geographic area with a small population, a small mining town with a main street, or a bustling coastal town with seasonal tourism to support the local economy. This diversity makes it complicated to define rural for purposes of policy. Consequently, the similarities and differences between rural communities are important in a transportation context.

Rural and urban designations are used frequently and in many different contexts and applications. Rural definitions vary considerably across Federal agencies. The U.S. Census Bureau defines rural as whatever is not defined as urban—that is, rural encompasses everything not defined as individual urban areas.[66]

The U.S. Census Bureau definition seeks to draw the boundary around an urban area's "footprint" to include its developed territory. The U.S. Census Bureau classifies two types of urban areas: urbanized areas and urban clusters. Urbanized areas are areas with 50,000 or more people. Urban clusters are areas with at least 2,500 but fewer than 50,000 people.[67] This definition essentially combines cities such as New York City and Los Angeles into the same category as Des Moines (IA), Albuquerque (NM), Great Falls (MT), Charleston (SC), and Portland (ME). The aggregation of the majority of Americans into such a broad "urban" category can mask density and land use distinctions that are important to transportation policy, planning, and research.

Fortunately, FHWA's National Household Travel Survey (NHTS) categorizes home locations using both the Census definitions and a density variable (density centile ranging from 0 to 99) that divides the urban-rural spectrum[68] into five categories: [3,4]

1. Urban (high-density downtown areas and classic high-density neighborhoods with a density centile score between 75 and 99).
2. Second City (medium-density areas that serve as population centers for surrounding communities; satellite cities with a density centile score between 40 and 90).
3. Suburban (medium-density areas, connected closely to urban areas or second cities for employment and entertainment opportunities with a density centile score between 40 and 90).
4. Small Town (small towns, villages, and low-density areas outside suburbs with a density centile between 20 and 40).

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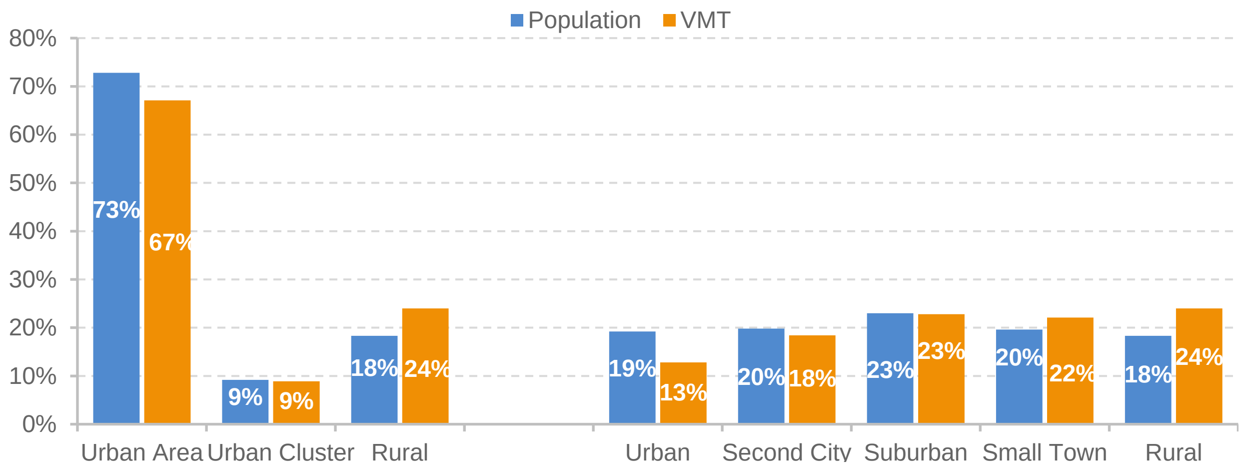
[65] https://gis-portal.data.census.gov/arcgis/apps/MapSeries/index.html?appid=7a41374f6b03456e9d138cb014711e01
[66] U.S. Census Bureau (2016). *Defining Rural at the U.S. Census Bureau. American Community Survey and Geography Brief*. https://www.census.gov/content/dam/Census/library/publications/2016/acs/acsgeo-1.pdf
[67] U.S. Census Bureau (2019). 2010 Census Urban and Rural Classification and Urban Area Criteria. https://www.census.gov/programs-surveys/geography/guidance/geo-areas/urban-rural/2010-urban-rural.html. Accessed March 2, 2020.
[68] Federal Highway Administration National Household Travel Survey (2009–2017). Derived Variables Descriptions, p.20. https://nhts.ornl.gov/2009/pub/DerivedAddedVariables2009.pdf

5. Rural (low-density farming communities and other rural areas with a density centile between 0 and 20).

Exhibit 11-1 illustrates the differences in population and travel estimates of vehicle miles traveled (VMT) based on the expanded categories. On the left side of the figure are the population and travel estimates grouped according to the Census urban and rural categories. As expected, this grouping shows the majority of households living in urban areas. On the right side of the figure, the same data are summarized using the more detailed urban-rural categories.

Exhibit 11-1 ■ Comparison of Population and VMT Distribution across Urban-Rural Categories, 2017[69]



Source: National Household Travel Survey.

As shown in *Exhibit 11-1,* suburban, small town, and rural areas may be more alike than they are different. Using the NHTS definition for "urban," urban communities are home for approximately 19 percent of Americans. The VMT numbers are much higher in areas outside of large cities, suggesting that less dense areas are more vehicle-dependent.

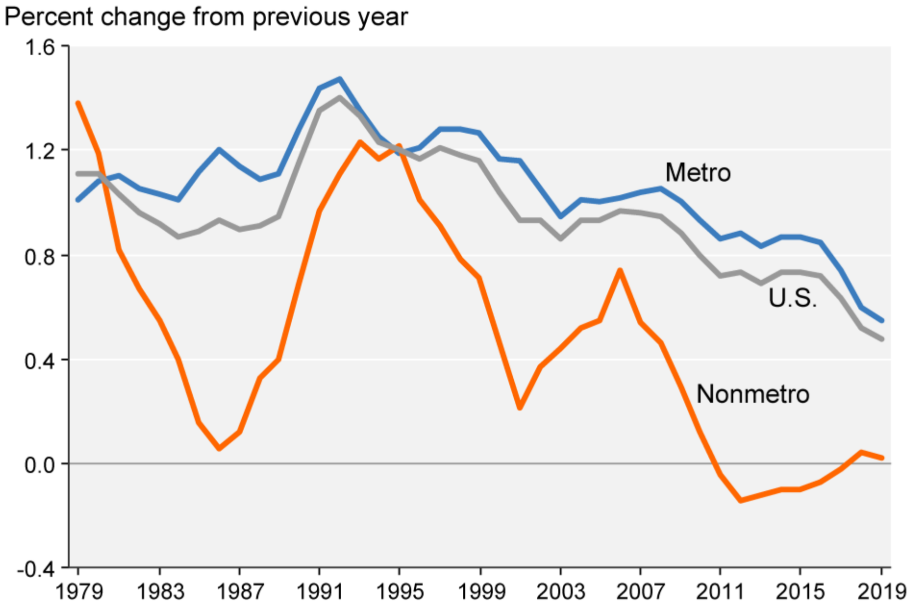
Population and Demographics

The size and density of a population often determine the availability and accessibility of transportation services; likewise, demographics of system users, such as age, income, and worker status, frequently determine transportation needs. The lower population density in rural areas can limit the number of transportation options available to rural residents because the level of demand does not match the level of investment needed. Rural communities have few high-density clusters, and accessing medical services, shopping, educational institutions, and work centers requires longer travel distances for rural households compared with those in urban areas.

Rural (nonmetro) population growth has consistently been below that of metropolitan areas over the past four decades (see *Exhibit 11-2*). The nonmetro population in the United States actually declined each year from 2011 to 2017, and was essentially stagnant in the two years following.

[69] Federal Highway Administration (2017). 2017 National Household Travel Survey. http://nhts.ornl.gov

Exhibit 11-2 ■ U.S. Metropolitan and Nonmetropolitan Population Change by Decade, 1979–2019



Note: Metro status changed for some counties in 1980, 1990, 2000, and 2010.
Source: USDA, Economic Research Service.[70]

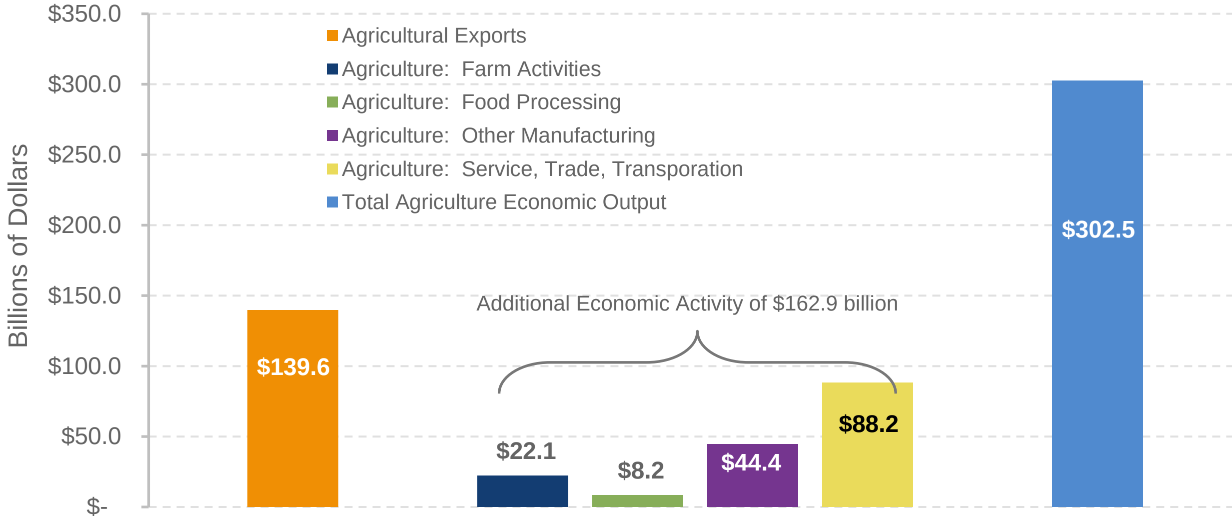
Rural Industries

Service industries account for the largest share of jobs and earnings in both rural and urban areas. However, rural areas are more dependent on industries such as farming, forestry, fishing, and mining, which account for more than 11 percent of rural earnings but only 2 percent of urban earnings. The manufacturing sector accounts for nearly 15 percent of earnings in rural areas and just over 9 percent in urban areas.[71]

The goods produced by rural industries provide products to consumers around the world. Today, 95 percent of the world's consumers are located outside of the United States. Rural areas, in many respects, are feeding the world and the growth in agricultural exports continues to have a positive impact on economic activity in the United States. According to the U.S. Department of Agriculture (USDA), rural areas produced $139.6 billion in agricultural exports in 2018.[72] As shown in *Exhibit 11-3*, USDA estimates that an additional $169.2 billion in economic activity, such as food processing, manufacturing, and transportation, was generated by these agricultural exports in 2018.[73] As consumers around the world continue to demand high-quality U.S. agricultural products, reliable roadway connections to intermodal hubs become increasingly important for rural areas.

[70] https://www.ers.usda.gov/topics/rural-economy-population/population-migration/
[71] https://www.ers.usda.gov/webdocs/publications/80894/eib162_forprinting.pdf?v=0
[72] https://www.ers.usda.gov/data-products/chart-gallery/gallery/chart-detail/?chartId=98298
[73] https://www.ers.usda.gov/data-products/chart-gallery/gallery/chart-detail/?chartId=98298

Exhibit 11-3 ■ Additional Economic Activity Generated by Agricultural Exports, 2018

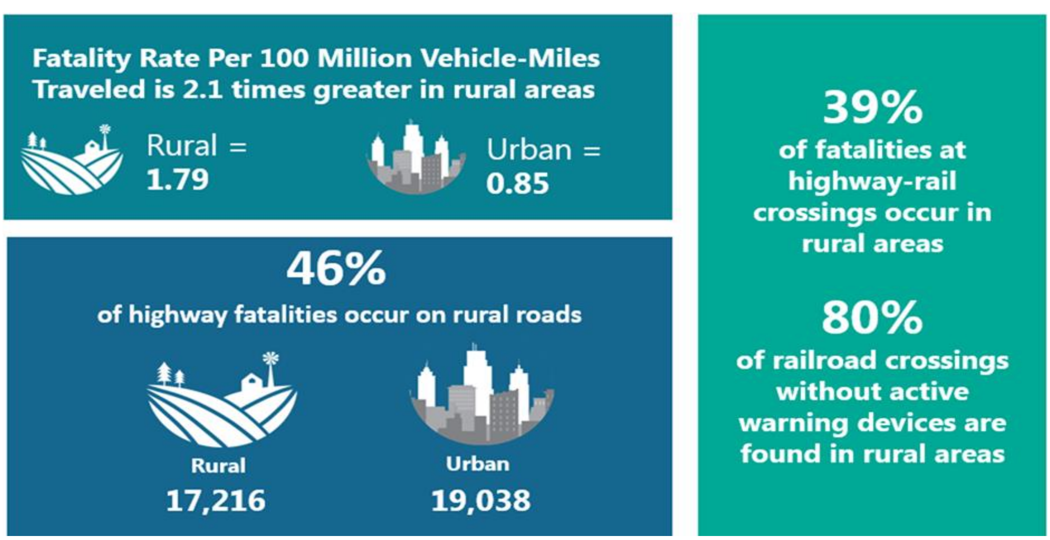


Source: USDA, Economic Research Service Agricultural Trade Multiplier, March 2020.

Rural America contributes more than just agricultural production. Access to transportation and destinations is essential to rural areas to support connections to jobs, to facilitate the movement of goods and people, to access opportunities for healthcare and education, and to provide links to other social services. Transportation sustains existing businesses and continues to be a critical factor in a company's decision to locate new business operations. For communities that depend on tourism and natural areas to help support their economy, transportation is the key link between visitors and destinations that can generate billions in tourism expenditures annually.

Rural transportation's role in the U.S. economy is demonstrated by the amount of transportation infrastructure located in rural areas: 69 percent of the Nation's lane miles are in rural areas, and two-thirds of rail freight originates in rural areas. This significant rural contribution provides economic gains throughout America, but also disproportionately affects these smaller communities and community infrastructure. For example, 90 percent of the Nation's bridges that are posted for weight limits are in rural areas, heavily affecting freight traffic routes. Rural America's traffic fatalities are disproportionately high, totaling 46 percent of fatalities in 2018 (see *Exhibit 11-4*).

Exhibit 11-4 ■ Rural Safety Statistics



Source: Bureau of Transportation Statistics, 2020.

Through the Rural Opportunities to Use Transportation for Economic Success (ROUTES) initiative, DOT will assist rural communities in accessing federal transportation grant programs. It will provide user-friendly information to these communities to assist them in applying for discretionary grants, and will improve sharing of rural data and analysis to achieve national transportation infrastructure goals.[74]

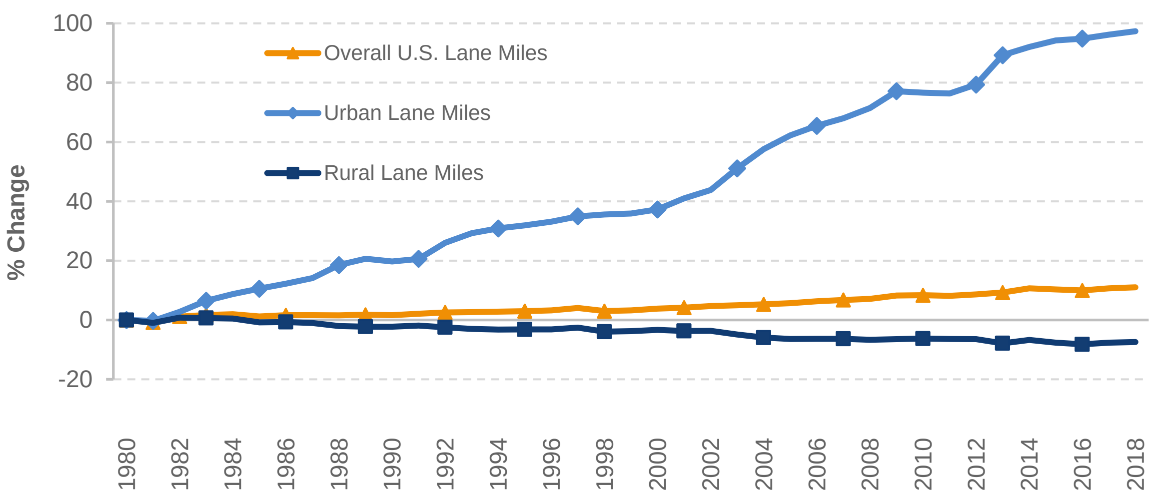
Modal Availability and Use

Transportation plays an important role in the overall economic health of communities, providing access to jobs, education, goods, and essential services. The type and number of transportation options vary by geography, primarily due to population size and density. Many transportation service models, such as bikeshare, commuter buses, and on-demand transportation, are costly to operate in less-dense areas and are less viable for the longer trips required to reach destinations in those areas.

The vast road network in the United States provides an accessible transportation option for rural, suburban, and urban areas alike. The majority of the U.S. rural road system was developed in the 1950s and was designed to meet the transportation needs of that time. With changes in population and industry, transportation demands have also changed. However, the basic infrastructure of the rural road system has not.

For example, as shown in *Exhibit 11-5*, total lane miles in the United States have grown by only about 10 percent since 1980. Much of this growth has been in urban areas, which have seen a 95-percent increase since 1980 compared with the decline in rural lane miles over the same period. Since lane miles are a fixed asset, this decline is likely related to changes in classification (from rural to urban) as well as to changes in infrastructure.

Exhibit 11-5 ■ Percentage Change in Lane Miles by Geography from 1980–2018



Source: Federal Highway Administration. (2020). Highway Statistics 2018: Public road lane miles by functional system, 1980–2018: Table HM-260.

Vehicle Ownership

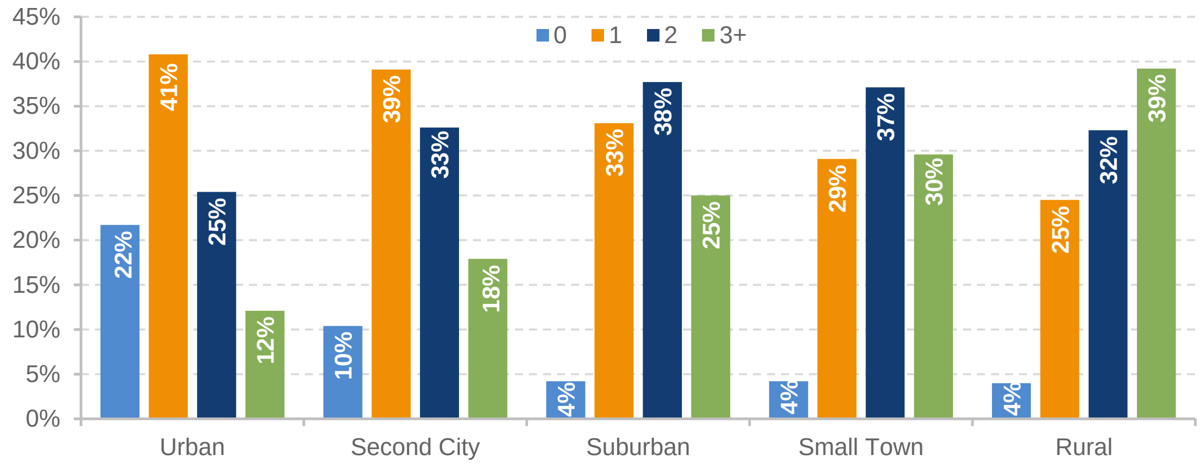
Vehicle ownership is often a major indicator of household mobility. As the number of household vehicles increases, the number of household person trips also increases. Zero-vehicle households have fewer annual person trips across all geographies. Households living in high-density areas, such as urban and small cities, typically have fewer vehicles compared with households in less-dense

[74] More information on the ROUTES Initiative can be found at https://www.transportation.gov/rural.

suburbs, small towns, and rural communities. The difference is likely due to the larger variety of mobility options, including walking and biking, available in high-density areas.

As shown in *Exhibit 11-6*, just under 22 percent of urban households have no vehicles compared with 4 percent of rural households. In fact, 39 percent of rural households have three or more vehicles.

Exhibit 11-6 ■ Percentage of 0, 1, 2, and 3+ Vehicle Households by Geography, 2017



Source: National Household Travel Survey.

Broadband Access

Throughout the United States, transportation provides access to jobs, education, goods and services, and social and civic activities. In rural areas, access to high-speed broadband internet provides much of the same or similar level of access without requiring long-distance travel. Small, remote, and rural communities are an important component of the Nation's identity, economy, and global competitiveness, but many of these communities are unable to take full advantage of services and resources offered through advances in communications, networking, and technology.

To a large extent, broadband is seen today as basic infrastructure. The National Broadband Plan, issued in 2010 by the U.S. Federal Communications Commission (FCC), states: "Like electricity a century ago, broadband is a foundation for economic growth, job creation, global competitiveness, and a better way of life."[75] The FCC has reframed the National Broadband Plan to serve the goal of Universal Service, the principle that all Americans should have access to communications services.[76]

KentuckyWired

Access to broadband is further challenged by lack of infrastructure, a growing national trend that links the ability to expand broadband access to leveraging assets such as highway rights-of-way.

States continue to respond to this challenge with coordinated and innovative solutions such as those being implemented in Kentucky, which will be the first State to build an open-access fiber optic cable network in every county—focusing initially on improving access in rural areas. The 3,200-mile KentuckyWired network will be State-constructed and partially leased to private companies. The fiber optic network will serve as a "middle mile," or backbone, that connects to local internet service providers (ISPs), similar in concept to an Interstate highway with exit ramps.

[75] https://www.fcc.gov/general/national-broadband-plan
[76] Federal Communications Commission (2009). Connecting America: The National Broadband Plan. https://transition.fcc.gov/national-broadband-plan/national-broadband-plan.pdf

The network will be open access, allowing local public or private ISPs, cities, partnerships, or other groups to connect to the network and extend services to local communities, universities, State government buildings, and community and technical colleges. Improved cellphone coverage is also anticipated as part of the initiative. Approximately 85 percent of the network will be aerial and 15 percent underground. Information and updates on the project's development can be found at https://kentuckywired.ky.gov/Pages/index.aspx.

The digital divide is getting smaller, with the number of Americans lacking a connection of at least 25 Mbps/3 Mbps (the Commission's current benchmark) dropping from 26.1 million Americans at the end of 2016 to 21.3 million Americans at the end of 2017. According to the FCC, the majority of those gaining internet access, approximately 4.3 million, were located in rural areas.[77] Similarly, Pew Research estimates that approximately two-thirds of rural Americans (63 percent) had a broadband internet connection at home in 2019, up from about a third (35 percent) in 2007.[78]

The lack of infrastructure, especially for communication and networking, is a central issue in underconnected rural communities. Rural communities are in desperate need of increased access to broadband networks, as high-speed internet has become the backbone of the 21st century economy. The Bureau of Economic Analysis estimates that the digital economy is growing by roughly 10 percent per year, nearly three times as fast as the overall economy.[79] Without adequate broadband services, rural residents are unable to participate in one of the fastest growing sectors of the United States' GDP.

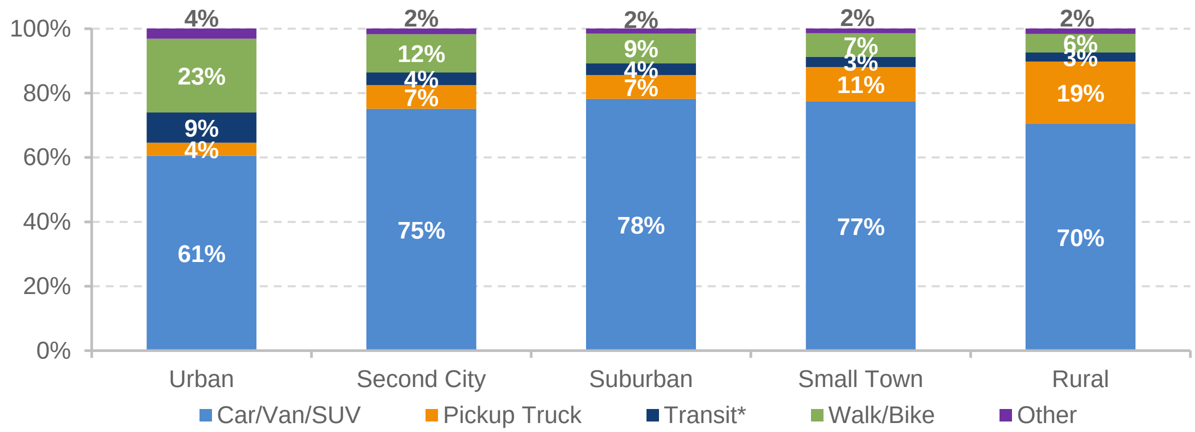
Other factors affecting broadband use in rural areas include the older average age of the population, higher poverty rates, and lower education levels. Reclassification of faster growing nonmetro counties to metro status during 2001–15 also increased the rural-urban gap because reclassified counties show higher rates of broadband use than counties that remain nonmetro.[80]

Travel Behavior in Rural Communities

Travel patterns for urban and rural households have historically been distinctly different. Urban households are more likely to use public transit, rideshare, bikeshare, and pedestrian facilities. Rural households typically require longer vehicle trips to reach their desired destinations and have limited access to public transit facilities. According to the 2017 NHTS, 24 percent of all passenger VMT occurs by rural households, with an average annual household VMT of 24,465, about 50 percent higher than that of urban households. Although 19 percent of the Nation's population lives in rural areas, 46 percent of highway fatalities occur on rural roads. This is an important issue for urban, suburban, and rural communities as 44 percent of rural VMT is from urban residents traveling to destinations outside their home metro areas.[81]

[77] https://docs.fcc.gov/public/attachments/FCC-19-44A1.pdf
[78] https://www.pewresearch.org/fact-tank/2019/05/31/digital-gap-between-rural-and-nonrural-america-persists/
[79] https://www.bea.gov/system/files/2019-04/digital-economy-report-update-april-2019_1.pdf
[80] https://www.ers.usda.gov/webdocs/publications/85740/eib182_brochure%20format.pdf?v=0
[81] U.S. Department of Transportation (2020). ROUTES Fact Sheet.
https://www.transportation.gov/sites/dot.gov/files/docs/mission/office-policy/rural/353086/routes-fact-sheet-web.pdf

Exhibit 11-7 ■ Mode of Travel by Geography, Person Trips, 2017



Source: National Household Travel Survey.

The personal vehicle is central to the transportation landscape in rural communities. Just under 90 percent of passenger trips in rural areas occur in automobiles, including pickup trucks, compared with 65 percent of trips in the largest urban areas (see *Exhibit 11-7*). Public transit is limited in rural communities: Less than 3 percent of rural households use public transit compared with 9.4 percent of urban households. Public transit includes buses, subway, commuter rail, paratransit, and fixed route services.

Mobility refers to the ease of person and freight movements such as travel time and distance. *Accessibility* is the ability of people and businesses to reach desired goods, services, and activities. Distances are longer in rural areas; however, mobility is often better overall due to low levels of congestion and other travel time barriers. However, low-density rural areas are particularly accessibility challenged due to limited transportation options. Transportation networks are developed to provide the opportunity for goods and people to reach desired destinations. In general, accessibility in a given area can be improved primarily by increasing the supply of transportation. Improved access can result from infrastructure improvements or from expanding existing transportation services, such as providing more frequent intercity buses or by increasing the number of available modes.

The availability of transit is limited in rural communities because providing transportation to a dispersed population is very expensive. In rural areas where a transit option is available, service is often infrequent and inconvenient. This is one reason why rural residents are more car-dependent than their urban counterparts. Residents who cannot drive often have very few alternative options for transportation. About 40 percent of rural residents live in an area with no public transit options at all.[82] Most others have only very limited access to transit. Walking or biking is often a poor option due to a lack of infrastructure and long trip distances. Mobility issues in rural counties are further complicated by a high percentage of older residents. The average age in the United States is generally increasing, and this trend is amplified in rural counties.

New transportation options such as shared mobility and the emergence of connected and automated vehicles, particularly in urban/suburban settings, may provide additional transportation options for rural communities. For example, the deployment of highly automated transit vehicles (SAE levels 4 and 5) could significantly improve the provision of transit and paratransit services to rural areas through labor cost savings and more door-to-door service. It is likely that demographics, geography, and access to technology will pose unique opportunities and risks for additional transportation alternatives in rural communities.

[82] Twadell, H. and Emerine, D. (2007). *Best Practices to Enhance the Transportation-Land Use Connection in the Rural United States*. NCHRP Report 582. Transportation Research Board, Washington, DC, p. 12

Freight Movement in Rural Areas

The transportation system is critical to the efficient movement of people and goods in urban and rural areas. The Fixing America's Surface Transportation (FAST) Act brought focus to both types of populations in its efforts to advance national policy on freight and goods movement. A detailed discussion of freight is included in the Highway Freight Transportation Conditions and Performance Report, first produced with the 23rd edition of the Conditions and Performance report, with an update included in Part III of this edition. Specific issues related to rural freight transportation are described in the following sections.

The FAST Act established a new National Highway Freight Program to improve the efficient movement of freight on the National Highway Freight Network (NHFN; see *Exhibit 11-8*) and supported several goals, one of which was to improve the safety, security, efficiency, and resilience of freight transportation in rural and urban areas. To support rural freight needs, the NHFN includes designation and inclusion of Critical Rural Freight Corridors (CRFC) in its set of four subsystems of roadways. The NHFN is composed of 57,800 miles, including 4,400 miles classified as Critical Rural Freight Corridors.

Exhibit 11-8 ■ Map of the National Highway Freight Network (NHFN), 2015

Source: FHWA Office of Infrastructure[83]

Trucks move 70 percent of freight in the United States by value. In addition, 42 percent of all truck VMT is on Interstates,[84] and 60 percent of Interstates are in rural areas. Freight tonnage is projected to increase by an average of 1.4 percent per year through 2045, and trucks are projected to carry the largest share of the additional freight traffic.[85] Nearly half of all truck VMT occurs on our Nation's rural

[83] https://ops.fhwa.dot.gov/freight/infrastructure/nfn/maps/nhfn_map.htm
[84] https://www.fhwa.dot.gov/policyinformation/statistics/2018/
[85] U.S. Department of Transportation (2018). Freight Facts & Figures 2017, Table 2-1. https://www.fhwa.dot.gov/policyinformation/statistics/2018/vm1.cfm#foot3

roads. In 2018, 95.13 billion VMT for goods movement was made by combination trucks on rural roads, significantly more than the 89.04 billion VMT by combination trucks in urban areas.[86]

The condition and maintenance of rural infrastructure affect the safety and efficiency of freight movements. Rural Interstates have the best ride quality of all roadways, with 82.8 percent of VMT in 2016 occurring on pavements with good ride quality. Within rural areas, roads designed for low capacity generally had higher shares of pavements with poor ride quality than did roadways designed for high capacity such as Interstates and freeways. Low- to moderate-capacity roads used to connect local traffic to freeways/expressways (Rural Major Collectors) had the highest share of VMT (18.7 percent) on pavements with poor ride quality in 2016.

Similarly, most of the Nation's bridges (72.2 percent) are in rural areas, over a third (33.1 percent) of which are on local roadways. The percentage of bridges rated as poor (by deck area) was generally lower in rural areas; however, the highest share of bridge deck area rated in poor condition (8.9 percent) in 2016 was located on local rural roads. Ninety percent of posted (limited weight) bridges are in rural areas, and heavy trucks cannot cross posted bridges. To find a safe bridge, heavy trucks hauling in rural areas must traverse three times the distance compared with metro areas.[87] Refer to Chapter 1 for an overview of the different roadway functional classifications and Chapter 6 for a detailed description of our Nation's roadway conditions.

Last-mile Delivery and Intermodal Connectors

Last-mile logistics refers to the final step of the delivery process from a distribution center or facility to the end user. Although the name implies it is the final mile of delivery, actual last-mile delivery can range from a few blocks to 50 or 100 miles.[88] For rural areas, the cost and efficiency of last-mile delivery from an e-commerce perspective is not usually an issue of congestion but one of economy of scale. A courier service may have deliveries at 10-mile intervals—far greater than in urban freight operations. This operation environment can affect the ability of a courier service to provide the same level of service (speed, frequency of operations, cost) to a rural customer that it would to an urban one.

Although the majority of freight logistics policy today seems to be trending toward solving the last-mile issues in urban settings, both the first and last mile are important to rural industries and producers. The first mile is critical because this is where farmers have the greatest logistical challenges prior to goods entering a State-operated highway system. Road quality and design, bridge load postings, safety issues, and weather are just a few of the challenges in both first- and last-mile delivery. For these participants in the freight system, the last mile is also important for obtaining goods and supplies critical to generating production outputs.

Modal exchange points, and access to these intermodal connectors—which are located primarily in rural settings—are also important to rural mobility. Intermodal connectors are key to many rural industries that rely on export to global markets, such as transferring agricultural product from truck to barge for movement to a coastal port for export. First-mile, last-mile, and modal exchange/transfer points are areas that could be greatly improved by emerging technologies such as blockchain, the Internet of Things (IoT), and possibly automation.

[86] U.S. Department of Transportation (2018). Freight Facts & Figures 2017, Table 2-1. https://www.fhwa.dot.gov/policyinformation/statistics/2018/vm1.cfm#foot3
[87] US Department of Transportation (2020). ROUTES Initiative. https://www.transportation.gov/rural#:~:text=Rural%20Opportunities%20to%20Use%20Transportation%20for%20Economic%20Success%20(ROUTES)%20is,disparities%20in%20rural%20transportation%20infrastructure.
[88] Cerasis (Undated). What Is Last Mile Logistics & Why Are More Shippers Looking at This Transportation Function? https://cerasis.com/last-mile/

Truck Parking

As discussed in Part III of this report, one of the major challenges to the safe movement of freight is the availability of adequate truck parking. Truck parking is vital to long-haul freight movement by trucks. Long-duration trips, many of which span rural areas of the country, require truck drivers to stop for service breaks and rest periods that can last for hours. Truck drivers rely on truck parking at commercial truck stops and parking at highway safety rest areas.

There is a nationwide shortage of truck parking, which is relevant to long-haul drivers and their ability to meet timeframes along their routes. Nationwide, 66 percent of truck parking is located in rural areas and 11 percent is located in small urban areas of less than 50,000 in population. The remaining 23 percent of truck parking is located in urbanized areas with populations above 50,000. The greater availability of land and the cheaper land prices in rural areas create an advantage for developing truck parking facilities at rural rest areas and truck stops. Nevertheless, parking needs and shortages in urban areas can impact delivery of goods from rural areas.

Another aspect of truck parking that is important in rural areas, such as in the western mountain States, is the provision of parking for trucks during road closures caused by winter storms or other extreme events.

Congestion and Performance

Although rural areas typically do not experience the levels of congestion or delays found in urban areas, nonrecurring delays in rural areas can be caused by weather, work zones, crashes, and other disruptions. System reliability is especially important to freight in any area, and major incidents or extreme weather events in rural areas can have significant impacts on freight movement across the Nation. For rural areas that lack a redundant transportation network, blizzards, flooding, landslides, wildfires, and other extreme events can cause major delays and alternate routes may require long, costly detours.

Rural industries such as agriculture, mining, lumber, and oil and natural gas production can generate significant truck traffic, heavier-than-typical loads, and movement of other equipment on rural roadways that may not be designed for this increased demand. In regions with natural resource production, roadways can be adversely affected by high truck volumes moving equipment and resources, slow overall traffic speeds, and traffic safety issues. These movements have a detrimental impact on the operations and quality of life in small communities lacking alternate truck routes.

Conclusion

As transportation, travel behavior, and the movement of goods are intricately tied to land use, a standard definition of "rural" for transportation applications is important for understanding system performance, user needs, and costs and benefits of investments across different geographies. With more refined categories within the urban-rural spectrum, the diversity of our Nation's communities is revealed with areas ranging from high-density urban cores (19 percent of the population) to suburban communities (23 percent) to low-density rural areas (18 percent of the population).

Although the population of rural areas is much smaller than that of suburban and urban communities, rural areas constitute approximately 97 percent of land in the United States and account for 71 percent (by length) of our Nation's roads. Rural transportation networks allow residents of rural areas to access employment, education, and goods and services, and make it possible for visitors to enjoy rural tourism destinations that support many local businesses.

Rural transportation systems are critical for the movement of goods across the United States and for rural communities' participation and contribution to the National economy. With limited transportation options, rural households are especially reliant on vehicles for travel as evidenced by the large proportion of VMT on rural roads. Rural households account for 24 percent of all passenger vehicle miles traveled (VMT), with an average annual household VMT of 24,465—about 50 percent higher than that of urban households. Although rural areas are typically free of the congestion, pollution, and travel time delays that plague large cities, just under 90 percent of passenger trips in rural areas occur in automobiles, including pickup trucks, compared with 65 percent of trips in the largest urban areas. This is important as it represents the modal limitations that affect accessibility, mobility, and affordability in rural communities. Safety is also a concern, with 46 percent of the Nation's highway fatalities occurring on rural roads.

Although rural economies support a wide and changing range of jobs from advanced manufacturing to recreational tourism, rural employment has not bounced back from the 2008–2009 recession. However, the economy in rural counties is diverse and not necessarily dependent only on farming or manufacturing, with the largest segment of the workforce in rural counties employed in professional, managerial, or technical occupations. This is all more the reason that rural communities are in desperate need of increased access to broadband networks, such as high-speed internet. The Bureau of Economic Analysis estimates that the digital economy is growing by roughly 10 percent per year, and without adequate broadband services rural residents are unable to participate in one of the fastest growing sectors of the United States' GDP.

The economic health of rural areas, and of the Nation as a whole, relies on the efficient movement of goods through the road network. A total of 95.13 billion vehicle miles of freight movement occurred on rural roads in 2018, significantly more than the 89.04 billion miles in urban areas. Rural industries such as agriculture, mining, lumber, and oil and natural gas production can generate significant truck traffic.

Federal programs, policy, and spending play significant roles in determining which communities thrive and which ones wane. Travel mode options, the quality and availability of infrastructure such as sidewalks and bike lanes, and the proximity of essential services all vary based on where one lives. Transportation networks are developed so that goods and people can reach desired destinations. Improved transportation service can result from infrastructure improvements or from expanding transportation services, such as providing additional modal options or non-transportation alternatives for people and businesses in rural communities. An awareness of these factors, in the context of existing transportation needs and services, allows stakeholders and providers to account for the interrelationship of urban and rural transportation systems and improve transportation services nationwide.

Rural America – Transit

This C&P Report defines "rural" based on the distinctions made in the Federal Transit Administration (FTA) formula grants programs. In these programs, an apportionment is made to States and territories for areas outside of urbanized areas with 50,000 or less in population. For simplicity, FTA refers to these areas as "rural areas." In practice, however, these rural areas also include a number of areas designated by the Census Bureau as urban areas with populations between 5,000 and 50,000. The Census Bureau defines these areas as "urban clusters."

KEY TAKEAWAYS

- In 2018, 1,301 rural systems and Tribes reported to the National Transit Database, representing roughly 1,600 separate modal services.
- Rural systems belong to one of two groups: systems located in clusters, and systems located in rural-designated census areas.
- Since 2008, rural ridership has increased by 46 percent, from 83.5 million trips in 2008 to 121.8 million in 2018, of which 74.2 million were bus trips.
- Bus and demand response serve distinct markets: bus demand is largely driven by recreational activities and tourism by non-residents during summer and winter months.
- The demand response market is of residents who are transit-dependent and have disabilities.
- The most common providers of rural service include city/county government or private nonprofit corporations.
- Demand response is the most common mode in operation in rural areas. In 2018, 1,140 systems out of 1,301 offered demand-response service, of which 772 were single-mode.
- Georgia and Kansas are the States with the largest number of rural systems.

Rural public transportation systems play a critical role in serving the mobility needs of rural communities. Some form of transit exists in the majority of rural communities, providing essential mobility to employment, medical services, schools, places of worship, and social and recreational destinations.

Although the majority of rural transit riders come from transportation-disadvantaged populations, rural transit systems in some areas provide service to discretionary transportation consumers as well.

Non-residents who travel to National Parks, ski resorts, and other recreational destinations in summer and winter months account for a significant share of rural transit demand. Supply in these areas is high during recreation seasons and low during the rest of the year. These recreational destinations are served by a small number of bus systems that operate nearby. For instance, within a 50-mile radius from all ski resorts in Colorado, 13 bus systems reported more than 15 million trips, 20 percent of the National total of 74.2 million bus rural trips in 2018.

Thus, rural transit serves two basic markets: transportation-disadvantaged populations and tourism. The former market is spread throughout the country; the latter is highly concentrated around attractions.

Rural transit riders have been found to share a number of common characteristics with rural populations. Compared with urban communities, rural communities include a greater share of elderly residents 65 years or older (17.5 percent vs. 13.8 percent) and persons with disabilities (15.3 percent vs. 12.0 percent).[89] Given the dispersed activities and longer distances traveled in rural areas, access to transit is challenging and the automobile is the predominant mode of travel. As a result, rural transit includes more demand-responsive services that provide point-to-point service in smaller vehicles than are typically found in urban areas.

[89] Based on data from the 2014 American Community Survey.

The 2017 National Household Travel Survey (NHTS) found that the share of private vehicles users (automobiles, SUVs, vans, and trucks) in urbanized areas and urban clusters was 80 percent and 90 percent respectively. The rural market segments in urban clusters had a relatively larger share of trucks compared with urbanized areas. The same survey revealed that the market share of public transportation (bus, and rail modes) for all trip purposes was 3 percent in urbanized areas and 0.2 percent in urban clusters in 2017. The survey also revealed that within public transportation markets, 20 percent of users in all urban clusters combined were below the poverty level; 10 percent were below the poverty level in urbanized areas,

According to the 2014–2018 American Community Survey (ACS) five-year estimates, the market share of private vehicles for work-related trips was 80 percent in urbanized areas and 90 percent in clusters, which include a relatively higher share of trucks and SUVs.

This chapter compiles information from the National Transit Database (NTD), the ACS, the NHTS, and the General Transit Feeds Specification (GTFS). Rural transit systems include transit providers receiving Section 5311 Non-Urbanized Area Formula Program funding. A number of rural transit providers also receive funding under the Section 5310, Transportation for Elderly Persons and Persons with Disabilities Program. However, nationwide data for 5310 services are not available, as providers are not required to report such data to the NTD. Therefore, rural transit providers not funded by the 5311 program but receiving funding from Section 5310 are not included in the data tables compiled in this section.

What is a Rural Area?

The U.S. Census Bureau defines a rural area as any area that is not urban. Urban areas are *"… densely settled core of census tracts and/or census blocks that meet minimum population density requirements*." To qualify as urban, the core must have a minimum population of 2,500 people.

The census divides urban areas into two tiers: urban clusters and urbanized areas. Clusters are urban areas with populations greater than 2,500 and less than 50,000. Urbanized areas are urban areas with population over 50,000.

Areas with population of less than 2,500 people are defined as census-designated rural areas.

For FTA, both urban clusters and census-designated rural areas are treated as rural for apportionment purposes. There were 1,301 rural systems in the United States in 2018, of which 1,167 were general transit systems and 134 were run by Indian Tribes.

This chapter splits rural systems into two groups: systems located in urban clusters, and systems in nonurban (rural) areas. The existence of a rural system in a cluster does not mean that all service is provided within its boundaries. Systems can serve adjacent rural areas and other secondary clusters. However, all NTD data are attributed to the clusters where systems are located.

- Type A systems: Systems in urban clusters (2,500–50,000 people)
- Type B systems: Systems in areas with less than 2,500 people

Not all rural transit systems were found to be Type A or B systems because the addresses of these systems are either inaccurate or too incomplete to be properly geocoded. There were 101 systems in this category in 2018, most of which were Tribal systems.

Excluding intercity bus providers, 1,301 rural systems reported to the NTD in 2018:

- 718 were geocoded by their headquarters location 693 urban clusters. These are Type A systems.
- 395 systems were geocoded by their headquarters location as not within the boundaries of any cluster. These are Type B systems.
- 134 Tribes were not included for lack of identifiable locations.
- 54 non-Tribal systems could not be geocoded due to inaccurate or incomplete addresses.

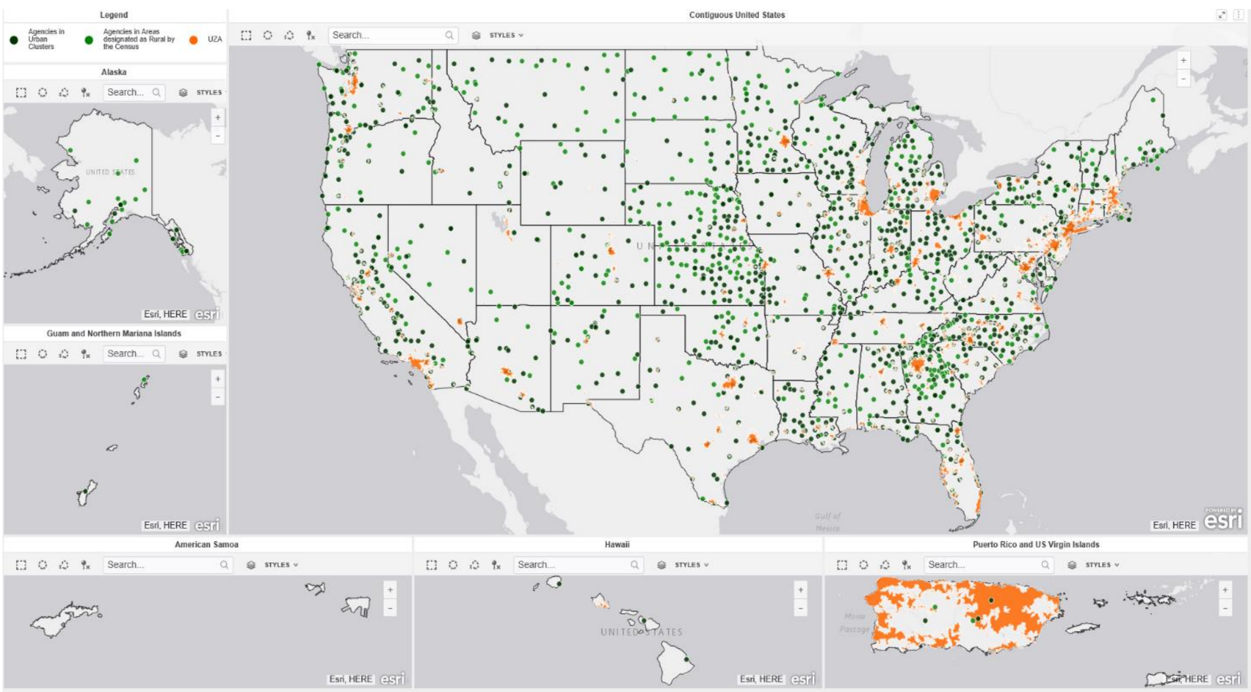
All systems, including Tribal systems and non-Tribal systems that are not geocoded, are included in all NTD aggregate analyses in this chapter.

Splitting systems into Type A and Type B allows normalized demographic analysis of Type A systems side by side with systems in urbanized areas, especially those with populations of less than 100,000 people, as discussed later in this chapter.

Exhibit 11-9 shows the geographic distribution of rural transit systems in the United States as of 2018. The map shows 1,136 systems, including Type A (indicated in dark green) and Type B (indicated in light green). The map does not show the locations of Tribal systems.

The distribution of rural systems is sparse and nonuniform. Some States have very few rural systems, whereas others—such as Kansas and Georgia—have large clusters of systems.

Exhibit 11-9 ■ Rural Transit Systems of the United States, 2018



Source: 2010 U.S. Census map overlaid by data generated from the National Transit Database.

System Infrastructure

Rural transit service in the United States is provided by 1,301 rural transit systems representing 55 percent of the transit systems in the country. Rural transit systems operate in every State. In 2018, 127 million transit trips were taken in rural areas, accounting for 1.3 percent of the total transit trips in the United States. The other 99 percent of trips were taken on urban transit systems. *Exhibit 11-10* shows the breakdown of systems, unlinked trips, and population between urban and rural areas.

Exhibit 11-10 ■ Urban and Rural Transit Systems, 2018

Geography	Systems	Percent of Systems	Unlinked Trips (millions)	Percent of Trips	Population (millions)	Percent of Population
Urban	1,052	45%	9,732	99%	261	81%
Rural	1,301	55%	127	1.3%	61	19%
Total	**2,329**		**9,859**		**321**	

Source: National Transit Database and American Community Survey.

Exhibit 11-11 shows that more than 70 percent of rural systems are either units of a city, county, or local government, or have been established as private nonprofit corporations; very few are independent public systems.

Exhibit 11-11 ■ Organization Types, 2018

Organization Type	Number	Percent
City, County or Local Government Unit or Department of Transportation	623	48%
Private Nonprofit Corporation	303	23%
Independent Public Agency or Authority of Transit Service	173	13%
Tribe	134	10%
Area Agency on Aging	39	3%
MPO, COG, or Other Planning Agency	16	1%
Other	13	1%
Total	**1,301**	

Note: Other represents private for-profit corporation, State government unit or department of transportation, other publicly owned or privately chartered corporation, private provider reporting on behalf of public entity, and subsidiary unit of a transit system, reporting separately. MPO is metropolitan planning organization; COG is council of governments.

Source: National Transit Database 2018.

As noted earlier, recreational activities account for a significant share of the total fixed-route supply and demand. Service is highly concentrated around ski resorts and National Parks. The 100 largest rural transit systems by ridership account for more than half of total ridership by all such systems. The more than 1,200 remaining systems account for less than half of total ridership on these systems.

Most of these large rural transit systems fall into one of four categories: recreational destinations, university towns, large-area providers, and other providers. A number of the largest rural transit systems are in university towns, including the local transit systems for the communities around Appalachian State University in North Carolina, Mississippi State University, Ohio University, Oklahoma State University, the University of Mississippi, the University of Wyoming, and Washington State University. Not all transit systems that service colleges and universities are included in the NTD.

Some States have established large area providers for rural public transportation. For example, Iowa has divided its 99 counties into 12 regions, each served by a regionwide provider. In Missouri, Oats Transit is a single provider that provides service across 87 counties. With nearly 1.6 million trips provided in 2018, it was the eighth-largest primarily rural transit system.

Finally, some rural transit systems have relatively large ridership due to unusual circumstances. For example, the Eastern Upper Peninsula Transportation Authority is the exclusive provider of ferry transportation for residents to three islands in eastern Michigan.

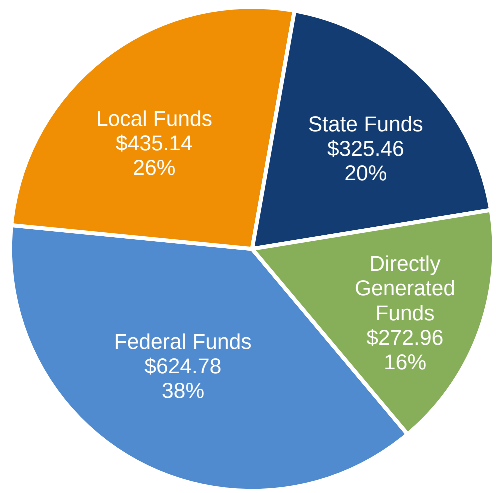
Finance

Chapter 2 presented an in-depth discussion of transit finance. This section discusses a few specific characteristics of rural transit finance.

As discussed in Chapter 2, transit funding comes from public funds allocated by Federal, State, and local governments, as well as from system-generated revenues. Total transit funding in 2018 was $1,658.3 million in 2018 dollars, of which $1,385 million was from public funds and $273 million was from directly generated funds, including fares, contract revenues, fare assistance funds, and other contributions such as donations, advertisement revenues, parking revenues, and concessions.

As shown in *Exhibit 11-12*, Federal sources contributed 38 percent of the funding for rural transit, with State and local sources combined contributing 46 percent. Directly generated funds accounted for the remaining 16 percent.

Exhibit 11-12 ■ Rural Sources of Funds, 2018



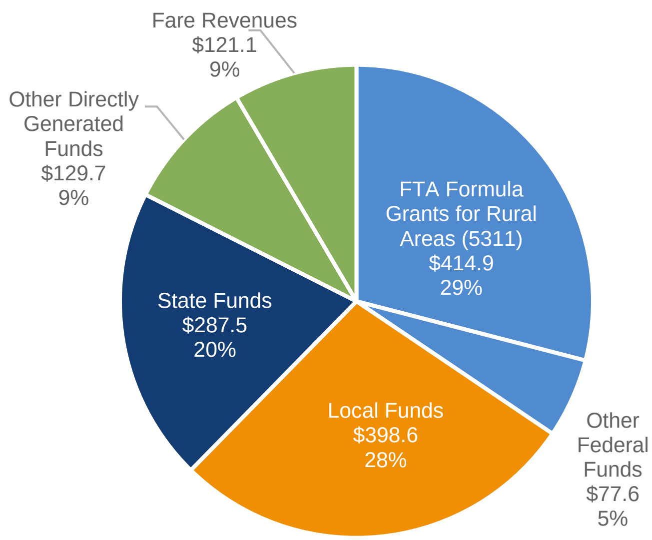
Source: National Transit Database, 2018.

Other Federal funds accounted for 5 percent of rural transit operations funding. These other Federal funds include the FTA Enhanced Mobility of Seniors and Individuals with Disabilities Formula Program (5310), capital assistance applied to operating expenses, Tribal funds, and other Federal funds.

According to Chapter 2, the total contribution of public funds to transit in the United States in 2018 was 72 percent. Rural transit relies more on public funds, and less on system-generated revenue, compared with urban transit. In 2018, public funds accounted for 84 percent of all rural transit funds. *Exhibit 11-13* breaks down the sources of rural operating funding. In 2018, public funds of $1.4 billion were spent on rural transit operations. Of this amount, Federal funding provided $492.5 million or 33 percent of total funding. State and local funding totaled $686.0 million, accounting for 48 percent of all funding for rural transit operations.

Exhibit 11-14 shows capital funding sources for rural transit in 2018. Capital funding in 2018 was $229.0 million, of which Federal sources accounted for 66 percent and State and local funds accounted for 32 percent. The share of Federal 5311 funds alone accounted for 31 percent, and the FTA bus and bus facilities program accounted for 21 percent. Other Federal funds include FTA Capital Program funds (5309), funds received from other DOT grant programs, FTA Enhanced Mobility of Seniors and Individuals with Disabilities Formula Program funds (5310), and funds from other programs.

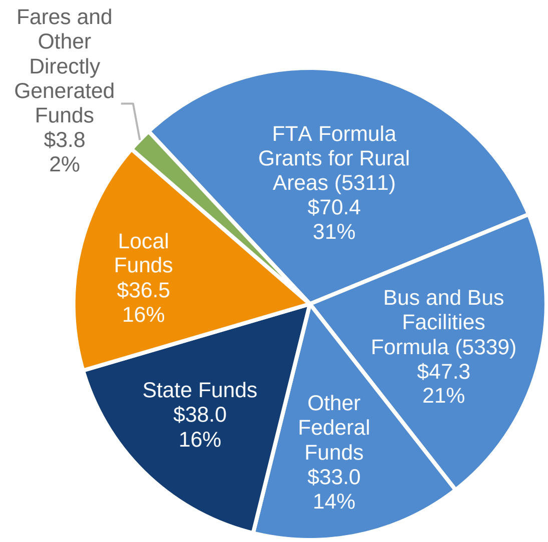
Exhibit 11-13 ■ Rural Operating Funding Sources, 2018



Note: Other Federal funds include FTA Capital Program funds (5309), funds received from other DOT grant programs, FTA Enhanced Mobility of Seniors and Individuals with Disabilities Formula Program funds (5310), and funds from other programs.

Source: National Transit Database, 2018.

Exhibit 11-14 ■ Rural Capital Funding Sources, 2018



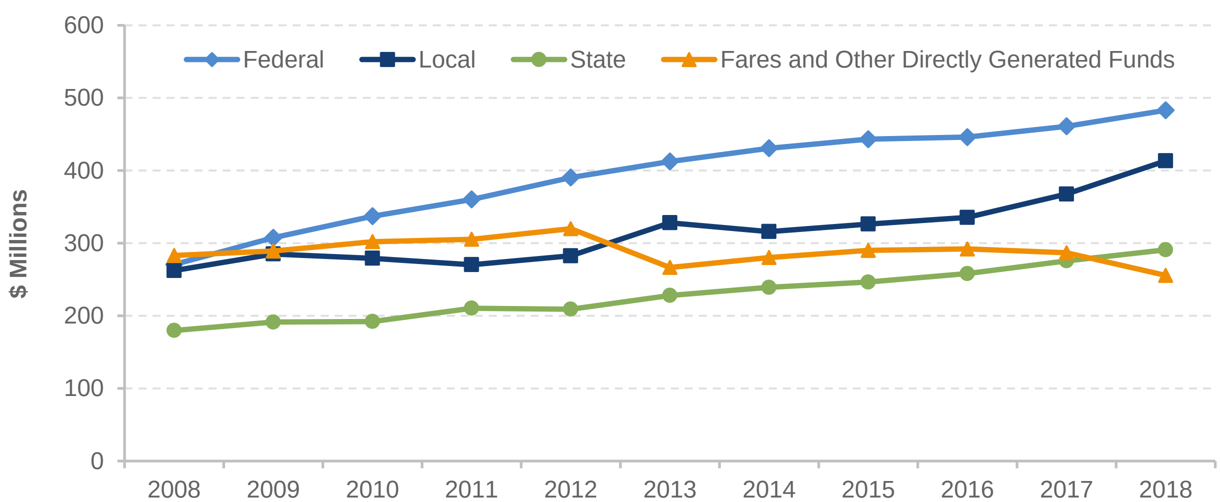
Note: Other Federal Funds include FTA Capital Program funds (5309), funds received from other DOT grant programs, FTA Enhanced Mobility of Seniors and Individuals with Disabilities Formula Program funds (5301), and funds from other programs.

Source: National Transit Database, 2018.

■ Federal Government ■ State Funds ■ Directly Generated Funds ■ Local Funds

As shown in *Exhibit 11-15*, funds from all public sources increased by an average of more than 4 percent per year. System-generated funds decreased by an average of 1 percent. Combined, the overall average annual increase was 3.4 percent per year.

Exhibit 11-15 ■ Rural Transit Sources of Operating Funding, 2008–2018

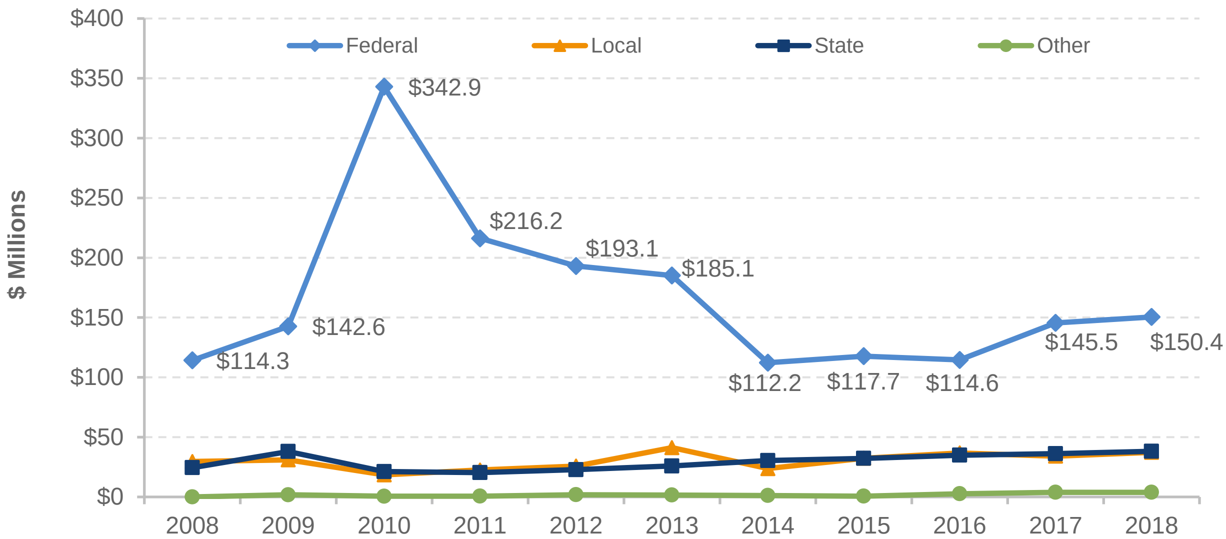


Source: National Transit Database, 2018.

Exhibit 11-16 shows that capital funding sources peaked in 2010, due to the Recovery Act, and decreased until 2014. State and local funding accounted for 32 percent on average.

For more information on the impact of the Recovery Act on transit finance, see the discussion on Federal funding in Chapter 2.

Exhibit 11-16 ▪ Rural Transit Sources of Capital Funding, 2008–2018



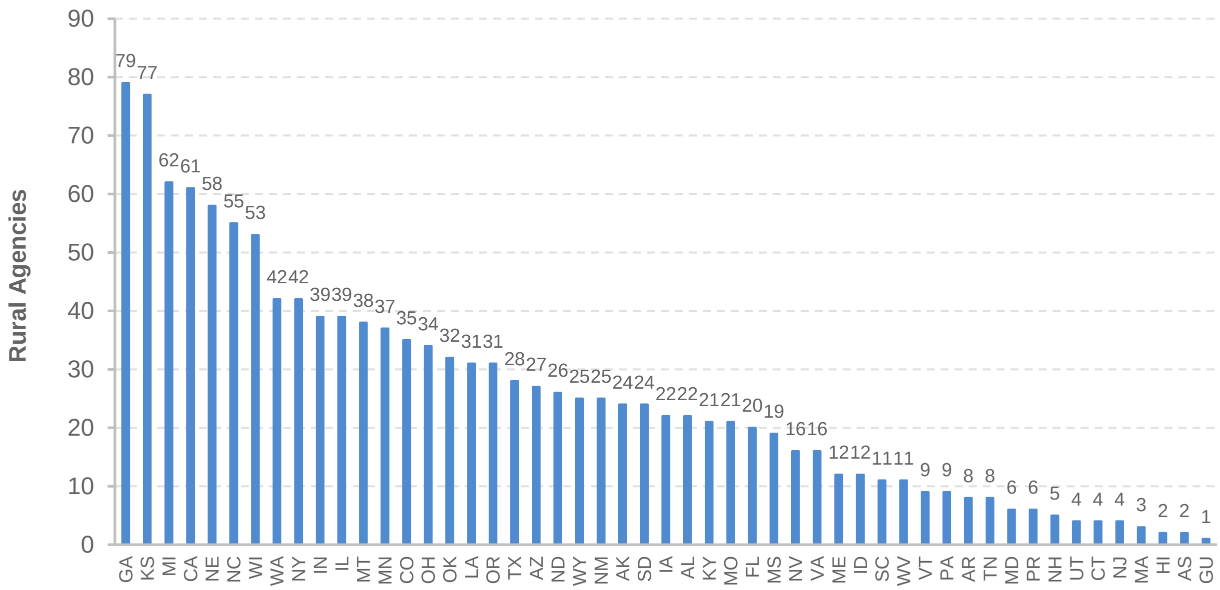
Source: National Transit Database, 2018.

Aggregate Data by State

Exhibit 11-17 shows States ranked by number of rural systems. Georgia and Kansas are the top two States in this regard, with 79 and 77 systems respectively. They are followed by Michigan, California, Nebraska, North Carolina, and Wisconsin, which each have 50–60 systems, followed by 30 States with 10–40 systems (ranging from 42 in Washington to 11 in West Virginia), and 14 States/territories with fewer than 10 systems each. As noted previously, the total number of systems in a State is partly a local decision. Some States have decided to establish large multi-county providers of rural public transportation that guarantee service coverage to all residents. Other States have largely left the development of rural transit services to individual municipal and county governments.

Thus, although the NTD does not currently explicitly collect service coverage information on a systematic basis, it is nevertheless self-evident that certain States with more rural transit systems almost certainly have more gaps in rural service coverage than do some States that ensure universal coverage through the establishment of regional rural transit providers. On the other hand, in some cases, localized municipal transit providers can provide higher-quality and more-frequent service coverage to the public than might otherwise be provided by a large regional provider. For example, a large regional provider may not provide service coverage seven days per week; instead, it may only serve certain communities on certain days.

Exhibit 11-17 ■ Rural Systems by State/Territories, 2018

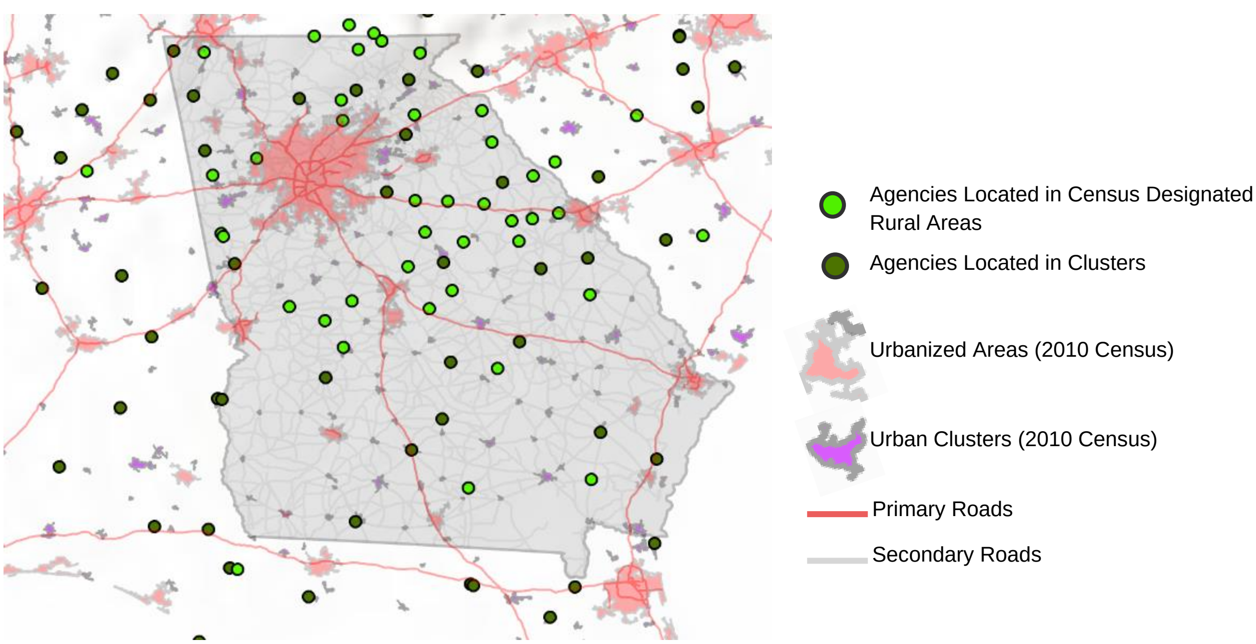


Source: National Transit Database.

The ranking by total area served within a State is not the same as the ranking by number of systems.

Exhibits 11-18 and *11-19* show the distribution of systems in Georgia and Kansas, the States with the largest number of systems. The geographic distribution of systems in Georgia is concentrated around the Atlanta urbanized area, becoming sparser in the southern part of the State.

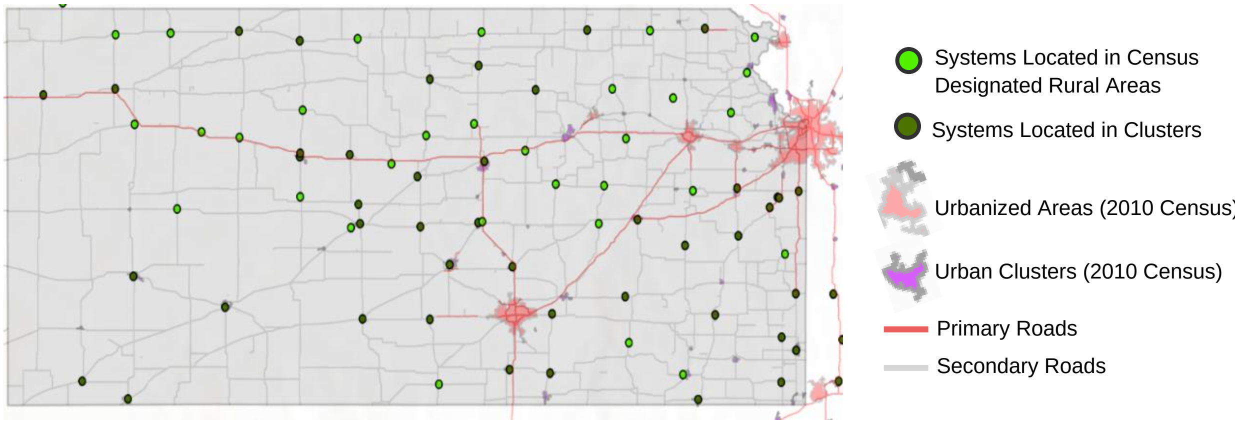
Exhibit 11-18 ■ Rural Systems in Georgia



Sources: National Transit Database; U.S. Census.

Systems in Kansas are more evenly distributed throughout the State than in Georgia. The urban clusters in Kansas are generally very small in area, and are barely visible at this scale. Westward, systems become sparser, especially in the Southwest.

Exhibit 11-19 ■ Rural Systems in Kansas

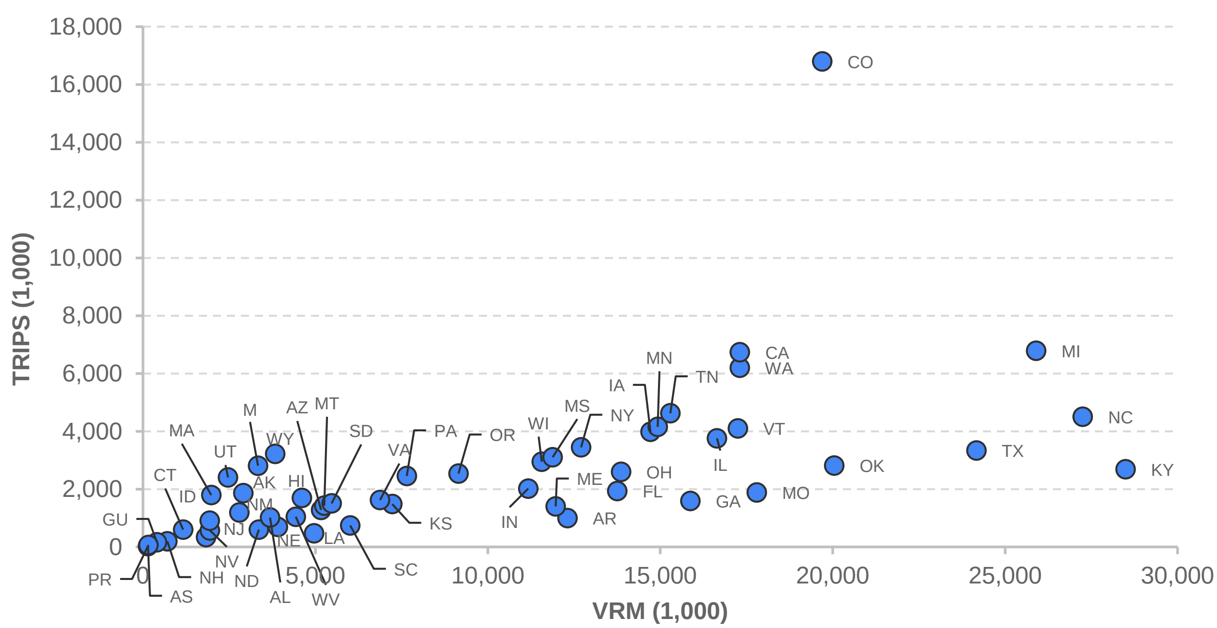


Sources: National Transit Database; U.S. Census.

Exhibit 11-20 shows aggregate service supply and demand by State, measured by vehicle revenue miles and unlinked passenger trips respectively. Colorado stands out as a State with by far the highest demand—more than twice that of Washington, California, and Michigan, the States with highest demand after Colorado.

Although comparisons between States should be avoided because supply and demand characteristics are constrained by geography, demographics, land use, and other local factors, the data suggest that service areas increase with demand. Population densities decrease and trip lengths increase, resulting in supply growth at rates higher than those for demand. Another key factor was the growth in demand-response service, which has typically low capacity.

Exhibit 11-20 ■ Supply (Vehicle Revenue Miles) and Demand (Trips) By State, 2018



Source: National Transit Database.

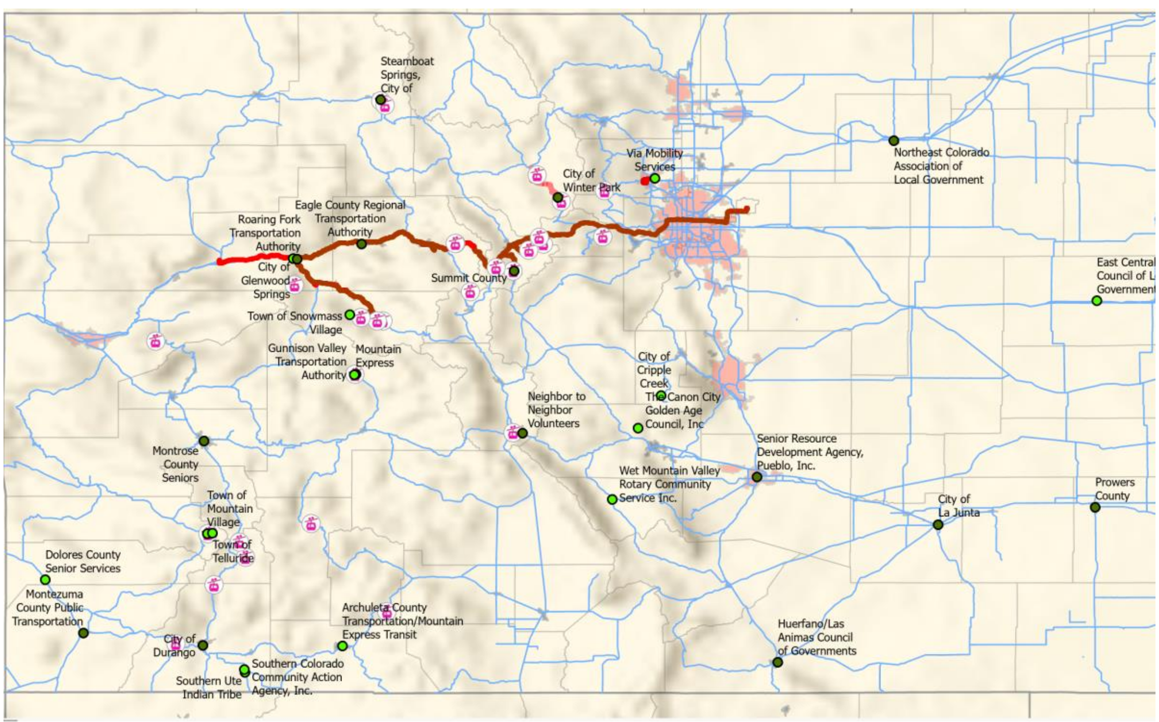
Transit Supply and Demand in Colorado

As *Exhibit 11-20* shows, Colorado is the single most transit-intense state in in rural America, and accounts for more than 20 percent of all rural transit demand in the country. Demand is intense in the winter months, during the ski season. Seven ski resorts and nine bus systems cluster in the southwestern portion of the State, but the majority of resorts are located along the East-West corridor from Denver to Roaring Fork.

Exhibit 11-21 shows the locations of all bus systems and ski resorts in the State. Unsurprisingly, most systems cluster within a short radius (on average less than 50 miles) from resorts. Combined, demand for these systems accounted for 15.3 million (91 percent) of the total 16.8 million trips in the rural areas of the State in 2018. The main corridor depicted in the map extends 150 miles westward, from Denver to Roaring Fork, in the intersection with the Aspen transit system. Most of the service supplied in this corridor is provided by four systems operating contiguously throughout its entire range.

The Town of Mountain Village, shown in the map in the southwestern part of the State, operates the only rural tramway system reported to the NTD. It has high demand, and carried 3 million people in 2018, 27 percent of all transit trips in rural Colorado. Bus ridership was 12.3 million, or 73 percent of trips.

Exhibit 11-21 ■ Transit Systems Routes in Colorado During Ski Season



Systems Not Located in Urban Areas - Type B Systems

Systems Located in Urban Clusters - Type A Systems

Urbanized Clusters (2010 Census)

Urban Areas (2010 Census)

Ski Resort

Transit System Segment

Primary and Secondary Roads

Source: General Transit Feeds Specification; U.S. Census; National Transit Database.

Modes and Performance

As shown in *Exhibit 11-22,* rural transit service takes many forms, including demand response, fixed-route bus (including buses with route deviation), commuter bus, vanpools, ferryboats, a bus rapid transit system, and an aerial tramway. Demand response is provided by 1,127 systems, or 87 percent of the 1,301 systems that reported to the NTD in 2018. Conventional fixed-route bus and route deviation comes in second, with 35 percent of systems. Note that systems generally operate more than one mode, therefore the sum of individual modes does not indicate the total number of systems.

Exhibit 11-22 ■ Number of Rural Systems by Mode, 2018

Mode	Abbreviation	Number of Systems
Demand Response and Taxi	DR	1,127
Conventional Fixed-Route Bus and Route Deviation	MB	460
Commuter Bus	CB	66
Vanpools	VP	19
Ferryboat	FB	10
Tramway	TR	1
Bus Rapid Transit	RB	1
Total	**ALL**	**1,301**

Note: The total number of systems (1,301) does not equal the sum of individual modes, as many systems operate more than one mode.

Source: National Transit Database.

Exhibit 11-23 presents aggregate statistics for the two most common modes, demand response (shown as DR in the table) and fixed-route bus (shown as MB in the table).

Exhibit 11-23 ■ Rural Supply and Demand for Bus and Demand Response, 2015–2018

Mode Aggregate Supply and Demand	2015		2018		Variation 2018/2015	
	DR	MB	DR	MB	DR	MB
Values						
Unlinked Trips (Millions)	47.4	69.1	47.2	74.2	-0.4%	7.4%
Revenue Hours (Millions)	18.5	5.8	20.4	7.0	10.3%	20.7%
Revenue Miles (Millions)	321	105.9	353.7	128.8	10.2%	21.6%
Vehicles Operated in Maximum Service	13,890	3,255	14,836	3,602	6.8%	10.7%
Fare Revenues (Millions of 2018 $) (*)	$51.0	$49.6	$50.3	$44.9	-1.4%	-9.5%
Operating Expenses (Millions of 2018 $)	$802.8	$433.0	$887.8	$530.3	10.6%	22.5%
Performance Indicators						
Trips per Mile (Service Effectiveness)	0.15	0.65	0.13	0.58	-11.0%	-11.4%
Cost per Mile (Cost Efficiency)	$2.50	$4.09	$2.50	$4.10	0.4%	0.7%
Cost per Trip (Cost-Effectiveness)	$16.93	$6.27	$18.80	$7.10	11.1%	14.0%
Fare per Trip	$1.08	$0.72	$1.07	$0.60	-1.4%	-16.0%
Subsidy per Trip	$15.86	$5.55	$17.74	$6.54	11.9%	17.9%
Farebox Recovery Ratio	6.4%	11.4%	5.7%	8.5%	-11.5%	-25.7%

Notes: *Including fare subsidies in 2018 but not in 2015.

Source: National Transit Database, 2008.

Demand response is the most common mode and was reported by 1,127 rural systems. It includes conventional demand response and taxis, of which 772 systems were DR-only systems. There were 527 bus systems in 2018, including conventional bus, commuter bus, and bus rapid transit.

Exhibit 11-23 shows aggregate supply and demand data by mode for 2015 and 2018. Only fixed-route bus and demand response are included. The 2015–2018 timeframe was chosen because the collection of financial data by mode was introduced in the NTD starting in 2014. Cost-effectiveness is defined as the ratio of operating cost per trip, and cost efficiency as operating cost per revenue mile or hour.

Bus

As shown in *Exhibit 11-23*, bus revenue miles and hours increased by more 20 percent between 2015 and 2018, and ridership increased by 7.5 percent. These increases were driven mostly by an increase in the demand for recreational attractions. Main attractions are National Parks and beaches in the summer, and ski resorts in the winter months. This market is highly concentrated around these destinations and accounts for over 50 percent of the National rural market.

Operating expenses increased at approximately the same rate as that reported for revenue miles and hours. Therefore, whereas cost per revenue mile and hour did not change significantly, cost per trip increased by more than 14 percent, from $6.20 in 2015 to $7.10 in 2018.

The increase in ridership was not followed by a proportional increase in fares. On the contrary, whereas ridership increased by 7.5 percent, fare revenues in 2018 decreased by 9.5 percent from those in 2015. The fares per trip decreased by 16 percent and the subsidy per trip increased by 18 percent.

Demand Response

The demand response market supplies service to low-income and transit-dependent populations, including people with disabilities. More than 770 systems offer demand response service only. Demand response is less cost-effective than bus but is more cost-efficient. This is because demand response operates smaller vehicles that are cheaper to operate but ultimately provide less service per vehicle. The cost per trip for demand response is usually greater than that for bus. *Exhibit 11-23* shows that cost per trip for demand response in 2018 was $19 per trip, compared with $7 per trip for bus. The cost per revenue mile for demand response in 2018 was $2.50, 40 percent less than the cost per mile for bus of $4.10.

Demand-response ridership remained roughly unchanged between 2015 and 2018. Revenue miles, revenue hours, and operating expenses on the other hand increased by slightly more than 10 percent, and fare revenues increased by over 30 percent, well above the increase in operating expenses. However, the impact of the increased recovery ratio is negligible because fares are much lower than operating expenses. A 10-percent increase in operating cost results in only a slightly less than 10 percent (9.7 percent) increase in subsidy per passenger.

Demand Response Supply-Demand Relationships

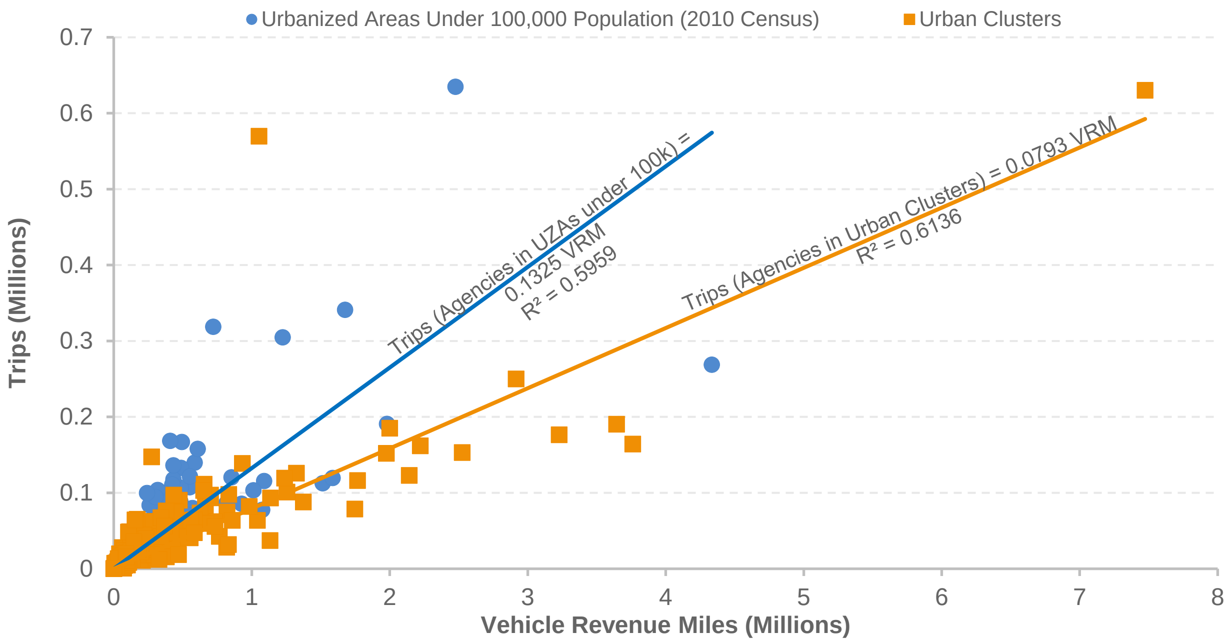
Exhibit 11-24 shows the shapes of two simple regression models of trips vs. revenue miles for demand response. The models represent two tiers: urbanized areas (UZAs) with populations greater than 50,000 and less than 100,000, and urban clusters. Demand response is the most common mode operated in urban clusters.

As discussed in the introduction to this chapter, these are Type A systems. There were 718 systems in 683 clusters in 2018. The ones that operated demand response were included in the models and are shown in the chart.

The models show that the service effectiveness (trips per mile) of systems in UZAs under 100,000 is better than in the cluster tier. The slopes of the UZAs under 100,000 and urban cluster tiers are 0.13 ± 0.013 and 0.08 ± 0.01 respectively. Thus, the two tiers do not overlap and the difference is statistically significant (95 percent confidence). Although not shown in the chart, this conclusion can be extended to the UZAs under 200,000 population tier.

The fact that these two tiers are separated by a population threshold does not necessarily imply that population alone is an explanatory factor. Candidate factors include population density, market share of public transportation and demand response, share of population eligible for demand service, and other factors. The analysis of these factors is beyond the scope of this chapter. As far as effectiveness is concerned, however, these two tiers are quite distinct.

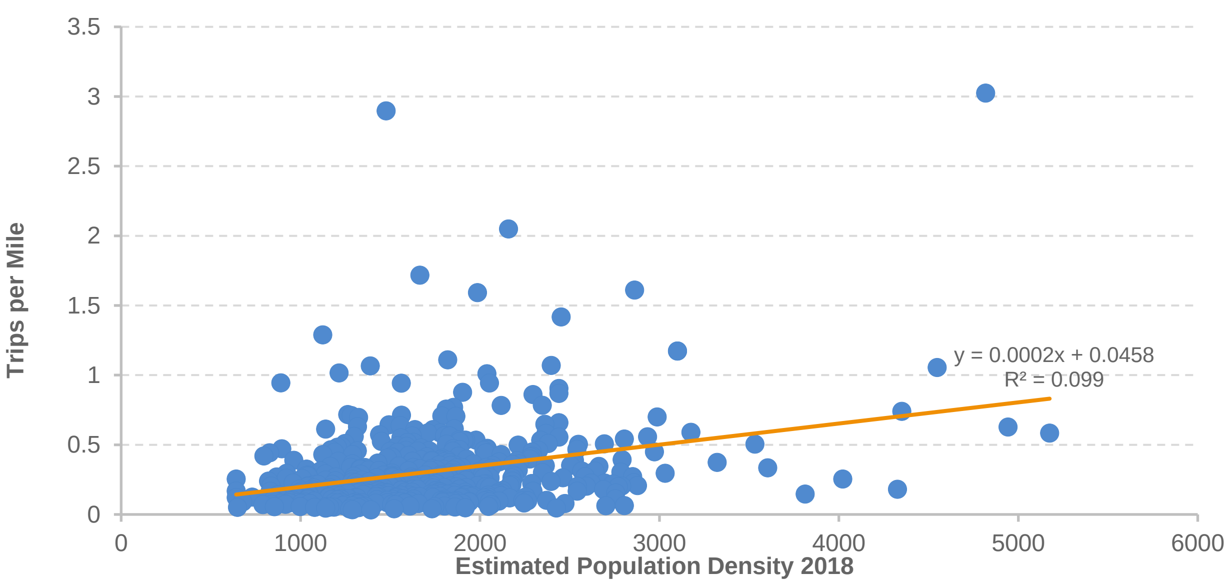
Exhibit 11-24 ■ Demand Response Supply and Demand by Tier, 2018



Source: National Transit Database; U.S. Census.

Exhibit 11-25 explores the relationship between service effectiveness and population density of rural systems located in urban clusters. The hypothesis is that the denser the area, the more effective is service supply. The exhibit suggests that a slightly positive relationship may exist over a wide density range of 1,000–5,000 people per square mile.

Exhibit 11-25 ■ Trips per Mile vs. Population Density of Clusters Served by Transit, 2018



Source: National Transit Database; U.S. Census.

Rural Fleet Inventory

Exhibit 11-26 shows the composition of rural fleets by mode and vehicle types. Cutaways and minivans are the most common vehicle types for demand-response service, with a fleet of more than 13,000 vehicles nationally. Cutaways also account for a large share of the fixed-guideway bus mode, and account for more than 50 percent of all rural vehicles.

These modes have smaller capacities than buses, but provide enough capacity to meet the demand of a mode with low ridership and low capacity utilization.

Exhibit 11-26 ■ Rural Fleet Composition by Mode and Vehicle Type, 2018

Mode	Bus	Cutaway	Minivan	Van	Other	Total
Demand Response	884	9,275	3,738	2,398	513	**16,808**
Bus	1,856	2,076	28	88	124	**4,172**
Vanpools			127	215	9	**351**
Total	**2,740**	**11,351**	**3,893**	**2,701**	**646**	**21,331**

Note: Does not include fleet with no recorded year of manufacture.

Source: National Transit Database 2018.

CHAPTER 12: Transformative Technologies

Transformative Technologies – Highways

Technology has always been an important engine for the U.S. economy, and innovation and ingenuity are fundamental elements of American culture. As technology becomes more advanced, the growing reliance on applications in daily activities is changing the way Americans live, shop, communicate, work, and travel. During the coronavirus disease 2019 (COVID-19) pandemic, people and businesses across the United States used technology to gain access to many social, economic, and educational activities. Advances in technology provide America with the potential to transform the future of transportation while increasing economic growth and overall productivity.

The transition from travel by horse and buggy to mass adoption and use of motor vehicles was a major socioeconomic transformation of the 20th century. Since then, the capacity, speed, efficiency, and geographic coverage of the surface transportation system have improved dramatically. However, changes in surface transportation have been largely incremental or stepwise improvements to existing transport technologies or operations.

For about a decade, technology has been changing the interface between users and the transportation system, particularly in urban environments. Wireless connectivity has made the sharing of information and modes of travel more efficient and user friendly. It also has allowed new transportation services to emerge. In the goods sector, technology enables more refined tracking and monitoring of shipments as they move from the warehouse to the customer's door, with this information shared more widely with clients and customers online. Technology is enabling alternative transportation options, such as autonomous goods and people movement, to become a more likely possibility.

KEY TAKEAWAYS

- Over the past decade, surface transportation has been revolutionized by major technological innovations.
- In 2018, 77 percent of Americans owned smartphones and about 57 percent of all digital media was consumed through mobile apps. This popularity has spurred advances in transportation technology such as real-time travel information and app-based on-demand transportation.
- The percentage of all U.S. households without a vehicle is 8.9 percent.
- Travelers can now request a ride; access a shared car, bicycle, or scooter for a short trip; ride a private shuttle on demand; and have groceries, packages, or take-out food delivered using internet-enabled smartphones and tablets.
- Up to 32 percent of car sharing members sold their personal vehicles, and between 25 percent and 71 percent of members avoided an auto purchase because of car sharing.
- In a recent pilot, Chicago estimates that scooters help to eliminate 300,000 miles of vehicle travel.
- According to the Bureau of Labor Statistics, almost one-third of workers said they could work from home in 2017–18.
- Rapid progress is being made in AV development with Level 3, 4, and 5 technologies (having higher levels of automated driving systems).

The major technological innovations discussed in this chapter that are likely to affect the amount and distribution of travel include:

- Information Technology
- Innovation in Transportation Services
- Emerging Modes, and
- Technology and Infrastructure.

Information Technology

The emergence of smartphones and the subsequent advancement and widespread adoption of smartphone technology fundamentally changed the availability, quality, and content of travel information. Smartphone technology has spurred the creation of countless "on-the-go" traveler mobile apps that are now key sources of information for travelers and service providers alike. The Pew Research Center estimates that, as of 2018, 77 percent of Americans own smartphones, compared with just 35 percent in 2011.[90] An estimated 57 percent of all digital media consumption now occurs through mobile apps as opposed to larger devices such as computers or tablets.[91] Although smartphones are no longer an emerging technology, the maturation of smartphone technology and mobile apps continues to shape the field of traveler information.

Exhibit 12-1 ■ Types of Information from the Consumer Point of View

• Predicted travel times	• Weather conditions/alerts	• Price/fare/cost
• Travel speeds	• Road/facility closures	• Alternative modes of travel
• Service schedules/ wait times • Areas of congestion	• Location of cameras, police, school zones, etc.	• Nearby services (e.g., gas stations, charging stations)
• Alternative routes to destination	• Snow plow status	• Vehicle availability
• Presence of tolls	• Wait times	• Parking availability
• Work zone locations	• Vehicle location	• Fitness goals
• Crash/incident locations	• Planned limited service (e.g., transit)	• Walking distance/time
• Special events	• Unplanned service interruptions	• Emissions/Fuel Use

Source: FHWA.

Traveler information encompasses a wide variety of media, modes, and types of information. From its roots in radio, television, and phone, traveler information has evolved at a rapid rate over the past decade, a trend that is expected to continue toward increasingly real-time, easily accessible information. As shown in *Exhibit 12-1*, a wide range of information is available to system users, in most cases at the touch of a button in real time.

The emergence and application of big data, the ability of public- and private-sector organizations to disseminate information, and the addition of vehicle-smartphone integration platforms to most new vehicles have significantly improved quality, accessibility, and usability of traveler information for trip making. With technology-enabled apps, increasing data availability, and more and more transportation services entering the information space, the variety of information available to system users is impressive.

Innovation in Transportation Services

During the latter half of the 20th century, the transportation system emphasized personal vehicle ownership and use and, to a lesser extent, the use of other modes such as transit, walking, biking, and taxis. However, recent technology innovations have expanded beyond traditional transportation and ownership models; more change has occurred in the last 6 years than in the last 60 years in terms of transportation options. The expansion of technology innovations into the transportation space is enabling new business models, providing new transportation choices for people and businesses, and increasing the private sector's participation in for-profit transportation services.

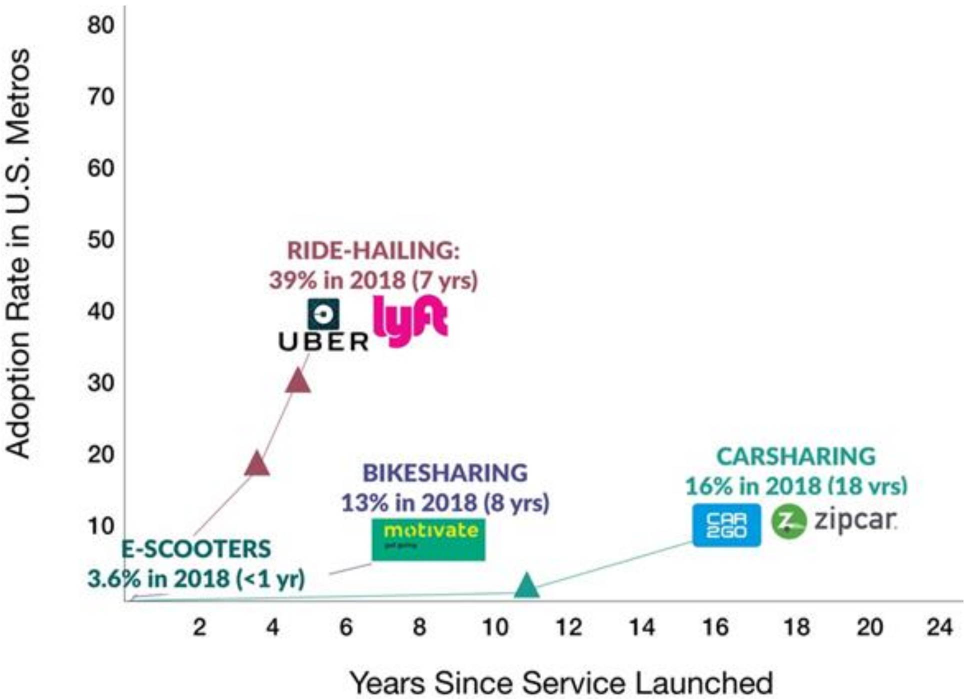
The changes underway in transportation services are sparking new innovations and shaping travel behavior in the United States. The options for accessing transportation are expanding for many users. People who were previously limited to auto ownership, biking, walking, calling a taxi, getting

[90] Pew Research Center (2018). *Mobile Fact Sheet*. http://www.pewinternet.org/fact-sheet/mobile/
[91] ComScore (2017). *The 2017 U.S. Mobile App Report*. https://www.comscore.com/Insights/Presentations-and-Whitepapers/2017/The-2017-US-Mobile-App-Report

a ride from a family member, or using transit if available now have a myriad of transportation options, in terms of the modes available (bike, car, transit, scooter), in terms of vehicle type (electric, gas, hybrid), and in terms of cost and ownership. Through innovations in transportation services, travelers can request a ride; access a shared car, bicycle, or scooter for a short trip; ride a private shuttle on-demand; and have groceries, packages, or take-out food delivered, all using internet-enabled smartphones and tablets.

In addition, new leasing models offered by several car manufacturers provide long-term vehicle subscriptions for an all-inclusive monthly fee. The subscription often includes insurance, roadside assistance, maintenance, and concierge service for on-demand car exchanges.[92] Other major business models emerging include shared mobility, on-demand services, microtransit, and broadband as a travel alternative.

Exhibit 12-2 ■ Transportation Services Adoption Curves in the United States [93]



Sources: National League of Cities, Micromobility in Cities—A History and Policy Overview; Clewlow and Mishra, 2017. Disruptive Transportation.

Shared Mobility

> **Shared mobility** is an umbrella term that encompasses a variety of membership-based transportation modes, including car sharing, ride sharing, bike sharing, and scooter sharing.

Shared mobility is a term used to describe motorized or nonmotorized vehicles that are shared among users. Shared mobility is one manifestation of the sharing economy and includes a variety of options, such as car sharing, bike sharing, and scooter sharing. These transportation options are typically membership-based services that provide short-term access to a motorized or nonmotorized vehicle for a fee. The services are provided mainly in urban areas, where auto ownership is lower and most trips involve shorter distances compared with those in suburban or rural areas.

[92] https://www.edmunds.com/car-leasing/what-are-car-subscription-services.html
[93] https://www.nlc.org/sites/default/files/2019-04/CSAR_MicromobilityReport_FINAL.pdf

Shared mobility is having a transformative impact on many cities by providing new ways to access goods and services. Shared mobility services can be *station-based*, in which the mode of transportation is picked up and returned to a fixed location, or *free-floating*, in which the mode of transportation can be picked up and dropped off in different locations. Peer-to-peer models also exist in which individuals rent out their personal transportation modes to others when not in use.

Shared mobility includes a variety of service models and transportation modes that meet the diverse needs of travelers, such as car sharing, station-based bike sharing (a bicycle picked up from and returned to any station or kiosk) and dockless bike sharing and scooter sharing (a bicycle or scooter picked up and left at any location).[94]

Car Sharing

Car sharing is a membership-based service that provides members access to an insured vehicle. Fuel (whether gas or electric) and free dedicated parking may also be included with membership. Car sharing is distinct from on-demand transportation services in that users are actually driving a vehicle themselves rather than being picked up and driven. Car sharing fundamentally changes the cost structure of driving: instead of using a private auto with fixed costs, car share users access a shared vehicle with variable costs. This "pay as you go" pricing model provides vehicle access on an as-needed basis without the cost of ownership. Access to vehicles via car share may have important impacts on household vehicle ownership levels, overall mode use, and the way emerging modes, such as automated vehicles (AVs) are marketed and available to the public. The most current studies and member survey results released by U.S. and Canadian car-sharing organizations show that up to 32 percent of car-sharing members sold their personal vehicles and between 25 percent and 71 percent of members avoided an auto purchase because of car sharing.[95]

Bike and Scooter Sharing

Bike sharing and scooter sharing are typically structured to provide customers point-to-point transportation for short-distance trips for a fee; membership in a sharing program typically reduces the fee paid. Most bike- and scooter-sharing operators are responsible for redistribution, maintenance, storage, and any parking costs. Electric scooter sharing is a recent outgrowth of the popularity of bike-sharing schemes. Bike sharing has two basic models:

- **Station-based:** Users can access bikes on an as-needed basis from a network of docking stations. Users can pick up and drop off bikes at different docking stations. The stations are unattended and accessible at all hours.
- **Dockless:** Dockless bike- or scooter-sharing systems do not require a docking station. With dockless systems, bicycles can be parked within a defined district at a bike rack or along the sidewalk. Smartphones are used to locate, unlock, and pay for dockless bikes or scooters.

Scooter sharing typically follows the dockless model.

Sharing is becoming a familiar practice and has the potential to impact vehicle miles traveled (VMT), mode choice, and car ownership. Although some shared mobility services such as car sharing and ride sharing have operated for decades, their impacts on these important mobility indicators are not well explored and require further research. Barriers to access and impact on travel demand are two important considerations. The location in neighborhoods, the payment requirements, and infrastructure suitability for use are just a few factors that influence whether the people who need more mobility options can actually use these travel modes. It is unclear, based on research conducted to date, whether shared mobility complements or substitutes for public transit. A few studies have attempted to quantify the impact of sharing on mobility indicators: for example, a 2016 Transportation Sustainability Research Center study of Car2Go members in Calgary, Canada;

[94] https://escholarship.org/uc/item/0z9711dw
[95] https://ops.fhwa.dot.gov/publications/fhwahop16022/ch3.htm

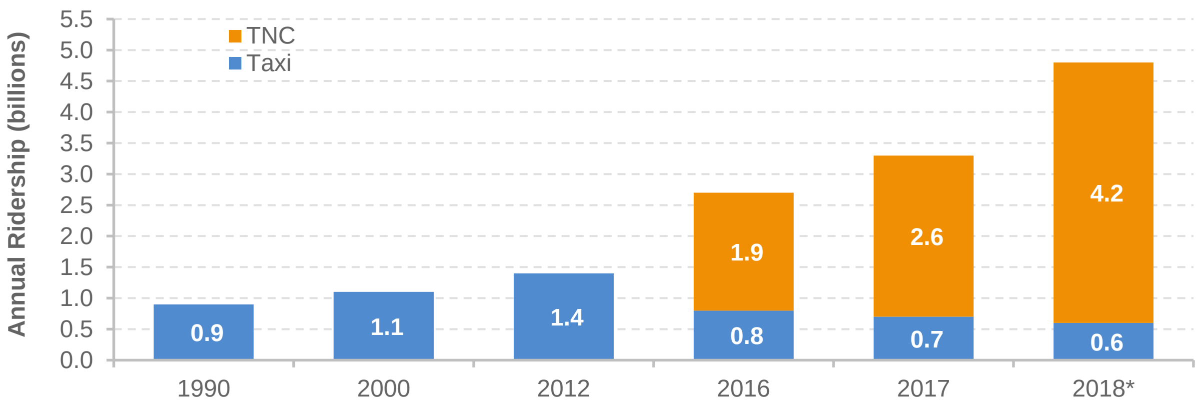
Vancouver, Canada; San Diego, California; Seattle, Washington; and Washington, DC, estimated a 6- to 16-percent decrease in VMT among members.[96]

On-Demand Ride Services (Ride Hailing)

On-demand ride services are provided by transportation network companies (TNCs), which offer app-based on-demand transportation. Travelers request a ride through a smartphone app that connects a driver to a traveler's location for pickup. Location, destination, time, payment, and basic safety functions are all integrated into a single app.[97]

The TNC service model has the potential to provide an additional travel option for users, including traditionally underserved populations such as older adults, low-income individuals, individuals with disabilities, or people living in rural areas. On-demand ride services fill gaps in transportation service as an alternative to vehicle ownership or taxi, bus, and subway services. TNCs also provide a means to avoid the cost or lack of off-street parking, as well as to avoid drinking and driving.[98] Between 2012 and 2017, the ridership for TNCs tripled (see *Exhibit 12-3*). The TNC service model, however, is not without other system impacts including curb space demands, trips without passengers (deadheading), and decreased demand for traditional ride-hailing services such as taxis.

Exhibit 12-3 ■ TNC and Taxi Ridership in the United States, 1990–2018 [99]



Note: The latest available data are for 2017; at that time, the ridership was projected to reach an annual rate of 4.2 billion passengers by the end of 2018.

TNC is Transportation Network Companies.

Source: The New Automobility: Lyft, Uber, and the Future of American Cities, by Schaller Consulting. (http://onlinepubs.trb.org/onlinepubs/sr/sr319AppendixB.pdf)

The true potential of on-demand services to fill mobility and access gaps is unclear. As with the shared mobility service model, it is unclear whether on-demand transportation will help to fill mobility gaps for traditionally underserved populations, for whom the availability and accessibly of new travel modes and transportation services is especially important. For example, the availability of a household vehicle varies across racial and ethnic groups, with minority populations being less likely to own a vehicle (See *Exhibit 12-4*).

[96] Martin, E., and S. Shaheen (2016). *Impacts of Car2Go on Vehicle Ownership, Modal Shift, Vehicle Miles Traveled, and Greenhouse Gas Emissions: An Analysis of Five North American Cities*. http://innovativemobility.org/wp-content/uploads/2016/07/Impactsofcar2go_FiveCities_2016.pdf

[97] https://policy.tti.tamu.edu/congestion/policy-implications-of-transportation-network-companies/

[98] National Academies of Sciences, Engineering, and Medicine (2020). *Transportation Network Companies (TNCs): Impacts to Airport Revenues and Operations Reference Guide,* Chapter 2. https://www.nap.edu/download/25759

[99] Schaller, B. (2018). *The New Automobility: Lyft, Uber and the Future of American Cities*. http://www.schallerconsult.com/rideservices/automobility.pdf

Exhibit 12-4 ■ Zero-Car Households by Race and Ethnicity, 2017

Race	White	African American	Hispanic	Asian
Percentage of Zero-Vehicle Households	8.9%	23.3%	11.4%	11.2%

Note: Race is self-identified. Other race categories are not included due to insufficient sample size. For the full list of Census race categories see https://www.census.gov/mso/www/training/pdf/race-ethnicity-onepager.pdf.

Source: 2017 National Household Travel Survey data.

The limited information available about TNC users and service areas suggests that TNCs primarily serve users who are younger, more educated, and have higher income. In the nine densest metropolitan areas,[100] TNC use is highest among:

- 25- to 34-year-olds, followed by those ages 18 to 24 and 35 to 54;
- Residents with a college degree; and
- Residents living in households with incomes of $50,000 or more.[101]

TNC use is a growing, substantial mode of travel in urban areas. Whether a variation on the TNC business model can be viable in suburban or rural areas remains to be determined.

A related business model that is gaining popularity is paired on-demand passenger ride and courier services, in which on-demand transportation service providers (e.g., TNCs) also provide package deliveries. Deliveries via these modes can either be made in separate trips or with mixed-purpose trips (e.g., for-hire drivers can transport packages and passengers in the same trip). Three major TNC operators (Lyft, Sidecar, and Uber) have in some form expanded their ride services to include package/item delivery, food delivery, or both.

Contingent-labor-driven platforms like Uber and Lyft use ride-hailing drivers that are categorized as "gig economy" workers, the implications of which must be considered. The Bureau of Labor Statistics estimated that there were 10.6 million "gig economy" workers (independent contractors by definition) in May 2017, making up 6.9 percent of the U.S. workforce.[102] One study focusing specifically on Uber estimated that the 832,655 drivers that worked on the Uber platform in 2016 represented about 0.56 percent of total full- and part-time employment in the economy.[103] Since the average driver works for just one-fourth of the year, Uber drivers accounted for 0.14 percent of total employment after adjusting to the full-year measure. Furthermore, if the part-time nature of Uber driving in a week is taken into account, Uber drivers were 0.07 percent of total full time equivalent employment, as the average driver worked less than half of a 40-hour week. Based on total hours worked and hourly compensation, however, Uber drivers accounted for roughly 0.022 percent of aggregate national compensation; their share of aggregate compensation was lower than their share of employment, as their average hourly compensation was substantially less than the average hourly compensation of private-sector workers. A separate review of empirical studies of TNC driver compensation found that a substantial portion of TNC drivers in California earned less than the equivalent of the State's minimum wage, when waiting time, maintenance expenses, and work time are fully accounted for.[104] In addition, "gig economy" workers usually lack employment benefits, such as health insurance and paid time off. Working with a wide variety of stakeholders to protect and support workers must remain a top policy priority.

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[100] Composed of Boston, Chicago, Los Angeles, Miami, New York, Philadelphia, San Francisco, Seattle, and Washington, DC.
[101] http://www.schallerconsult.com/rideservices/automobility.pdf
[102] Bureau of Labor Statistics. Contingent and Alternative Employment Arrangements — MAY 2017.
[103] Lawrence Mishel. 2018. Uber and the Labor Market: Uber Drivers' Compensation, Wages, and the Scale of Uber and the Gig Economy. Economic Policy Institute, Washington, DC.
[104] Michael Reich. 2020. Pay, Passengers and Profits: Effects of Employee Status for California TNC Drivers. UC Berkeley: Institute for Research on Labor and Employment Working Paper No. 107-20.

Microtransit

When introduced in American cities at the turn of the century, **jitneys** could be any vehicle that transported passengers for a cheap fare. Eventually the term was applied specifically to small buses.

Also in the category of on-demand ride services is microtransit or shuttle-based transit. Microtransit services are enabled by technology similar to the mobile smartphone apps underpinning the on-demand ride services discussed earlier in this section, and have been deployed as privately owned, on-demand alternatives to traditional transit service. These services often operate in areas that are not well served by existing bus lines or where travelers need better first/last-mile options. Costs are generally less than ride-sourcing but more than transit.

Microtransit is a more technology-enabled type of on-demand transit that can incorporate flexible routing, flexible scheduling, or both.[105] These services operate much like jitneys[106] of the past but are enhanced with information technology. Existing microtransit operators target commuters, primarily connecting residential areas with downtown job centers. Microtransit's use of smartphone technology avoids traditional and costly methods of booking rides, such as call centers or booking websites. The use of advanced technology has the potential to lower operating costs for services that target special populations, such as disabled individuals, older adults, and low-income groups.[107]

Broadband as a Transportation Alternative

The same enhanced communication capabilities that have enabled real-time traveler information have also enabled potential travelers to substitute communication for travel. Be it e-commerce, distance learning, remote banking, or electronic document transfer (among others), one of the most pervasive influences of communication capabilities on travel has been the opportunity to avoid travel and use communication tools instead.

Internet access has become a requirement for participating in the modern global economic system, and broadband internet has become an increasingly important factor in the economic health and sustainability of a region. The benefits of broadband can be especially powerful in rural communities where it can provide residents with nontravel options to access employment, education, medical care, shopping, and social activities. To a large extent, broadband is now viewed as part of basic infrastructure, much like paved roads and an electrical grid.

The importance of broadband access became hugely apparent with the onset of the COVID-19 pandemic, where the response to stay at home orders and transition to mandatory telework and distance learning made it clear that an in-home connection is vital to the functioning of the 21st century economy.

From 2010 to 2020, Americans with access to broadband internet increased from an estimated 74.5 percent to 93.5 percent.[108] Just under one-third of workers said they could work from home, according to Bureau of Labor Statistics estimates from the 2017–18 American Time Use Survey,[109] although this number has recently jumped significantly to 40.8 percent during the height of the COVID-19 pandemic.[110]

E-commerce is another important area linked to both the economy and travel. Consumers spent $601.75 billion online with U.S. merchants in 2019, up 14.9 percent from $523.64 billion the prior

[105] Cohen, A. and Shaheen, S. (2016). Planning for Shared Mobility. Prepared for American Planning Association, Washington, DC.
[106] https://www.merriam-webster.com/dictionary/jitney
[107] https://escholarship.org/uc/item/0z9711dw
[108] https://broadbandnow.com/research/broadband-2020
[109] https://www.bls.gov/news.release/flex2.t01.htm
[110] COVID-19 Impact Analysis Framework, 2021. University of Maryland CATT Laboratory. Last access 5/17/2021. https://data.covid.umd.edu/

year, according to the U.S. Department of Commerce.[111] That was a higher growth rate than that observed in 2018, when online sales reported by the Commerce Department rose 13.6 percent year over year.

As the number of the products and services available and the speed and quality of connectivity continue to increase, broadband service as an alternative to transportation is becoming more commonplace. Shopping, work, medical care, and education, among other activities, can now be accomplished without physical travel. As a means to access goods, services, and economic opportunities, the application of broadband service to fill transportation service gaps may be useful in maximizing access, mobility, and safety for all Americans.

Emerging Trends

Internet access, information technology, and new transportation service models have facilitated the emergence of new modes of travel and new ways of using traditional travel modes. The use, testing, and deployment of micromobility, vehicle automation, drones, and robotics have become common in the transportation sector. Coupled with advances in vehicle electrification, artificial intelligence, and mapping, these advances in how people and goods move through the system provide new opportunities and challenges for transportation workers and the safety, accessibility, and mobility of transportation users.

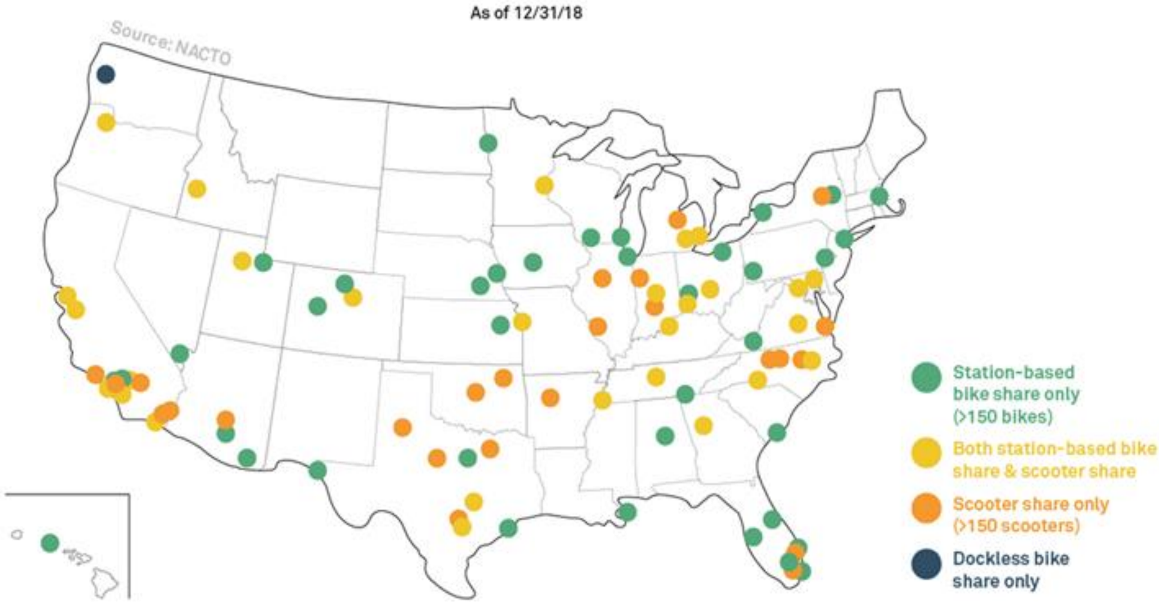
Micromobility

Micromobility is a broad term used to describe the use of a bicycle, scooter, or other low-speed transportation mode. As a primarily shared mobility service, micromobility enables users to have short-term access to a transportation mode on an as-needed basis.

Although docked bicycles continue to be a growing option in urban areas, dockless bikes have largely disappeared from most U.S. cities, in part replaced by shared scooters. E-scooters started appearing in cities across the United States in the autumn of 2017 and spring of 2018.[112] According to the National Association of City Transportation Officials, 84 million trips were taken on shared bikes and scooters in 2018.[113] In 2020, the number of permitted e-scooters in Washington, DC was expected to grow from 5,235 to at least 10,000,[114] and in San Francisco from 2,500 to at least 4,000.[115]

[111] https://www.census.gov/retail/index.html
[112] https://slate.com/business/2020/02/e-scooters-regulations-bird-lyft-lime-cities.html
[113] https://nacto.org/2019/04/17/84-million-trips-on-shared-bikes-and-scooters/
[114] https://wtop.com/business-finance/2019/12/10000-scooters-5000-e-bikes-approved-for-dc-streets-in-2020/
[115] https://abc7news.com/5568711/

Exhibit 12-5 ■ Shared Micromobility Across the United States.[116]



Source: NACTO, 2018.

The impact of micromobility on travel demand and mode share is still unclear, but early indications are that micromobility is used as an alternative to urban vehicle travel. In Chicago, a survey of e-scooter riders suggested that almost two-thirds of e-scooter trips would otherwise have been taken by car, taxi, or ride hail.[117] In Minneapolis, the city's Department of Public Works ran a similar survey, concluding that 55 percent of e-scooter trips would have been taken by personal vehicle, taxi, or on-demand ride services such as Uber or Lyft.[118]

Automated Vehicles

Automated vehicles represent a spectrum of levels of responsibility for the driving task from human to machine. Automated vehicles encompass a diverse range of automated technologies, from relatively simple driver assistance systems to Advanced Driver Assistance Systems (ADAS) (e.g., adaptive cruise control or parallel parking assist) to Automated Driving Systems (ADS), also known as autonomous vehicles.

The National Highway Traffic Safety Administration has adopted a framework for automated driving developed by the Society of Automotive Engineers International, which categorizes automation into six levels:

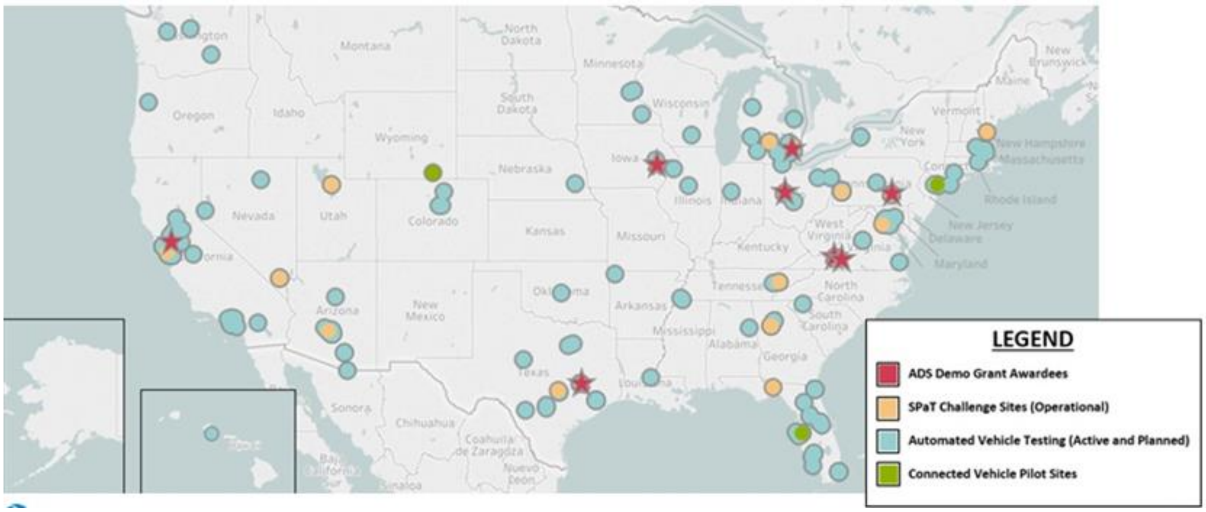
- Level 0 refers to vehicles with no automated technologies.
- Vehicles at Levels 1 and 2 control some aspects of steering, braking, or acceleration. Vehicles at these levels are already available for private ownership and currently operate on public roadways.
- Vehicles with Level 3, 4, and 5 technologies have ADS. Vehicles with ADS are still in development, and automakers and technology firms are actively testing them on public roads.

A Level 5 *ADS equipped vehicle* is the highest level of automation. AVs at Levels 4 and 5 do not require a steering wheel, a brake pedal, or an accelerator pedal. All driving functionality is handled through onboard computers, software, maps, and radar and light detection and ranging (LIDAR) sensors. Such vehicles are not yet operating freely on public roads other than as pilot programs with some developers testing on public roads in limited areas.

116 https://nacto.org/shared-micromobility-2018/
117 https://www.smartcitiesdive.com/news/breakdown-of-chicago-scooter-pilot-by-the-numbers/571461/
118 https://slate.com/business/2020/02/e-scooters-regulations-bird-lyft-lime-cities.html

A variety of private entities are partnering with local jurisdictions to participate in the deployment and testing of Level 3 and 4 vehicles across the Nation, with more than 500 active domestic testing demonstrations. These deployments assist jurisdictions in understanding the organizational, operational, and technical interfaces that may support the safe and effective integration of ADS into the roadway environment.

Exhibit 12-6 ■ Automated Vehicle Testing and Pilots in the United States.



Note: Based on publicly available information. This does not represent procurement-sensitive information.
Source: U.S. DOT

> Pennsylvania DOT is conducting a demonstration to solve the challenge of safely integrating AVs in work zones to improve worker safety.

In addition, DOT has awarded grants to eight sites under the ADS Demonstration Grants program.[119] These grant recipients will deploy ADS in the context of a variety of safety and operational scenarios in real roadway environments that will also provide information on how to safely integrate ADS into the transportation system. Pennsylvania DOT, for example, received a grant to develop a consistent approach to the safe integration of AVs in work zones by examining whether improved connectivity, enhanced visibility, and high-definition mapping will enable AVs to safely travel in and around work zones.[120]

Work is also occurring in the area of infrastructure uniformity for ADS. In January 2020, the National Committee on Uniform Traffic Control Devices provided new recommendations to FHWA regarding pavement markings for ADS.[121] The recommendations describe pavement marking changes that will support safe ADS navigation. The committee based the recommendations on research that analyzed the needs for machine vision to detect roadway features that help ADS correctly perceive roadway lanes. The committee considered pavement marking width and contrast.

Although fully automated vehicle technology or self-driving vehicles could bring in many benefits, including safety and efficiency, these technologies could also impact the labor market and employment in the transportation industry and beyond. Understanding the effects of automation on workers, supporting and empowering workers, and mitigating potential negative impacts are all critical. On one hand, new jobs would be created with ripple effects of automated vehicle technology on the overall

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[119] https://www.transportation.gov/av/grants
[120] https://www.transportation.gov/sites/dot.gov/files/docs/policy-initiatives/automated-vehicles/351461/36-penndot.pdf
[121] https://ncutcd.org/wp-content/uploads/meetings/2020A/04.19B-MKG-02.LineWidthforCAV.pdf

economy. On the other hand, some positions may be eliminated among vehicular drivers and at rest stations or in other hospitality sectors. The future is highly uncertain and it is challenging to predict how and when the automation technologies will be adopted, or to comprehend their full impacts on employment; however, several studies have attempted to estimate the potential job gains and losses. Although these studies use different methods, assumptions, and level of automation to examine the employment effect of automation on truck and bus industries, they all recognize potential negative impacts of vehicle automation on employment, especially for truck drivers. Despite the possible job impacts, some studies also note that lost jobs of truck and bus drivers can be offset by an expansion of the overall economy, leading to a net increase in jobs.

The Government Accountability Office (GAO) examined the potential impacts of automated trucking technology on the workforce.[122] Based on analysis of data, review of literature, and interviews with stakeholders, the GAO report suggests that the number of heavy truck jobs that might be lost is anywhere from under 300,000 to over 900,000, over a period of 10 to 20 years, depending on level of automation.

One recent FHWA report estimates potential job impacts from the adoption of automated truck technology using a general equilibrium model of the U.S. economy.[123] The study presents three scenarios to reflect the adoption of new trucks that are fully automated (SAE Level 4 and Level 5) in fleets.[124] The slow adoption scenario assumes 19 percent of newly purchased trucks would be fully automated in 10 years after the technology becomes available, and the fast adoption scenario assumes this ratio would reach 75 percent of new truck purchases in 10 years. The analysis estimates that the technology would lead to a net increase in overall employment in the economy, yielding between 26,400 jobs for the slow scenario and 35,100 jobs for the fast scenario each year. This expansion in employment is the result of broad economic growth in investment and consequent rise in labor demand. However, some industries, such as for-hire and in-house trucking, could suffer from fast adoption of automated trucks. It is estimated that a maximum loss of 11,000 jobs a year, or a decline of 1.7 percent of the long-haul driver workforce could result. This reduction in the workforce may last up to 5 years before the labor market absorbs the unemployed drivers.

There are still many open questions and unclear outcomes that affect cost, access, and safety as well as system performance, transportation revenue, and investment priorities. These include questions regarding private household vs. fleet ownership; the extent of mixed fleets (AV and non-AV) on roadways; infrastructure requirements such as traffic control devices, parking, and curb spaces; and how AVs intersect with emerging business models and technologies such as shared mobility and electrification. Labor unions, industry, local/state government, nonprofits, academia, and other stakeholders can work with DOT to examine and shape the impacts of new technologies on the transportation workforce.

DOT is actively preparing for the continual change from emerging technologies, including AVs. As such, DOT's mission is to ensure that the system of the future improves the quality of life for all people and communities. It is a DOT priority to engage with emerging technologies and guide the transportation future with an approach that keeps traveling Americans safe and promotes the improvement of transportation infrastructure.

Unmanned Aircraft

The adoption of Unmanned Aircraft Systems (UAS) is growing rapidly among both consumers and companies.

[122] U.S. Government Accountability Office. *Automated Trucking: Federal Agencies Should Take Additional Steps to Prepare for Potential Workforce Effects.* GAO-19-161. Washington, DC: March 2019.
[123] U.S. Department of Transportation, Federal Highway Administration (FHWA). *Macroeconomic Impacts of Automated Driving Systems in Long-Haul* Trucking. FWHA-JPO-21-847. January 28, 2021.
[124] Society of Automotive Engineers (SAE) level is a framework for automated driving that was developed by the Society of Automotive Engineers International, which categorizes driving automation into six levels. Level 4 is high automation and level 5 is full automation.

In 2016, the Federal Aviation Administration (FAA) issued a final rule to allow for routine civil operation of small UAS (including drones) in the National Airspace System.

Through the UAS Integration Pilot Program, FAA is also issuing air carrier certificates to selected commercial applications.[125] UPS Flight Forward was the first company to receive an air carrier certificate to operate a drone aircraft. UPS Flight Forward is focusing on drone delivery in healthcare operations, where the shorter transit times can have a large impact on healthcare.[126] Wing Aviation, a Google company, also received FAA approval to operate drone aircraft and is currently offering trial drone deliveries in Christiansburg, Virginia.

Other companies such as Walmart, Domino's, FedEx, and Amazon are working on approaches to drone-based package delivery. Amazon Prime Air is a service that aspires to deliver packages up to five pounds in 30 minutes or less using small drones.[127]

Infrastructure and Technology

Technology enables transportation agencies to enhance the way they operate and manage transportation systems. Infrastructure and technology, often via intelligent transportation systems (ITS), improve transportation safety and mobility through the integration of advanced communications technologies. Infrastructure and technology applications focus on both the infrastructure and vehicle as well as integrated applications between the two.

Payment Systems

New advancements in payment systems have increased the convenience of payment for all goods and services, including travel. In general, these technologies improve the efficiency of payment for road use and public transportation, and in some cases, allow for new forms of payment for road use such as mileage-based user fees and tolls. Whether through a vehicle-based transponder, a user's phone, or a digital card, the ability to pay without cash or cashier has opened up many opportunities to easily integrate pricing and fees into transportation services. Automated payments can now be found throughout the U.S. transportation systems.

Several toll facilities in the United States are now electronic-only. States such as California and Colorado have managed lanes that are all-electronic tolls only, requiring roadway users to have a toll pass or risk being fined.[128] Additionally, as consumers demand a more seamless interface with payment, there will be more opportunity for coordinated payments across modes and agencies. The Chicago region has a payment platform that works for Chicago Transit Authority, Metra commuter rail, and Pace suburban bus services.[129] In the future, such platforms may expand to include bike sharing, car sharing, TNCs, and other modes, giving consumers more choice.

Linked with dynamic management, new advances in payment systems also enable congestion pricing or other variable pricing applications. Emerging technologies such as open bankcards and pay-by-phone fare payment systems have been well received by system users and transportation agencies. Increased links between cellular GPS information and revenue are also creating more options for both customers and agencies in providing services and revenues. Digital payments are popular with transportation agencies from rail transit to toll operators. Common methods of digital payment include websites, smartphone apps, or "tap and go" kiosks on buses and train platforms. Smartphone apps also rely on digital payment, specifically on-demand transportation apps or transit apps that allow the user to purchase a trip in advance.

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[125] https://www.faa.gov/uas/advanced_operations/package_delivery_drone/

[126] https://pressroom.ups.com/pressroom/ContentDetailsViewer.page?ConceptType=PressReleases&id=1569933965476-404

[127] https://www.amazon.com/Amazon-Prime-Air/b?ie=UTF8&node=8037720011

[128] San Joaquin Hills Transportation Corridor Agency—FasTrak, website, accessed February 2019, https://thetollroads.com/accounts/fastrak

[129] https://www.transitchicago.com/howto/pay-for-your-fare/

Digital and automated payments are not uniformly supplied by the same organizations across the transportation system, and supply can vary by mode. Most current payment systems are mode-, area-, and agency-specific, but payment systems are moving toward integrated payment capability and national interoperability. Future technology that combines communication technology and payment applications may enable not only payment of tolls but also parking, transit, and TNC consumer travel payments under one account.

Connected Vehicles and Infrastructure

Modern communication technology is becoming more embedded within vehicles and the roadway infrastructure, allowing for continuous communication and data exchange between individual vehicles (V2V), or infrastructure and the greater transportation system (V2I). The term vehicle-to-everything (V2X) is often used to label all incoming or outgoing communications, including pedestrians, cyclists, mobile devices, the cloud, or even the electrical grid.[130]

The overall V2X technology has developed as a result of innovation during the past two decades in communication and location-sensing technology. ITS, more robust telecommunications networks, and GPS-based services have served as steps toward higher levels of connected vehicle technology.

Connected vehicles (CVs) are those with communications technologies that enable them to send and receive data and information, sense the physical environment around them, and interact with other vehicles or entities. Connectivity can be enabled through a variety of technologies. CV application areas include safety, navigation, diagnostics, convenience, and infotainment systems.

Connected vehicle technology has the potential to significantly improve safety through the avoidance of millions of accidents every year.[131] In addition, the presence of CVs is widely expected to have a positive impact on the performance of the road network by optimizing traffic flow and easing congestion. The Signal Phase and Timing (SPaT) Challenge provides an example of these technological advancements being put to use. Through the leadership of the Cooperative Automated Transportation Coalition, 26 States have responded to the challenge to deploy SPaT-enabled signalized intersections. Using dedicated short-range communication technology, the SPaT message defines the current intersection signal light phases including the current state of all lanes at the intersection. This technology allows CVs to plan their intersection approach, improving throughput and intersection safety. As of early 2020, 216 intersections transmit SPaT information, with 2,121 additional intersection being deployed.[132] A follow-on challenge is being developed in which the States that have responded to the SPaT challenge will be further challenged to outfit and deploy fleet vehicles equipped to receive and process SPaT messages.

Individual States have also begun V2X system testing and deployments. For example, the Colorado Department of Transportation is partnering with the private sector to build the largest network of connected vehicle infrastructure in the United States capable of real-time communication with roadway users.[133] The Virginia Department of Transportation has developed the Virginia Connected Corridors plan to test deployment of 64 roadside units deployed in the Fairfax area near Washington, DC.[134] Virginia also has a 2.2-mile test track, the Virginia Smart Road, which allows for the testing and development of CV technology on a controlled facility before real-world road testing.

DOT has played a significant role in supporting the research, development, and piloting of in-vehicle connectivity for safety purposes through its Advanced Transportation and Congestion Management Technologies Deployment (ATCMTD) program. The ATCMTD program funds grantees to deploy

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[130] National Academies of Sciences, Engineering, and Medicine (2018). Updating Regional Transportation Planning and Modeling Tools to Address Impacts of Connected and Automated Vehicles, Volume 2: Guidance. Washington, DC: The National Academies Press. https://doi.org/10.17226/25332

[131] https://www.its.dot.gov/research_areas/connected_vehicle.htm

[132] https://transportationops.org/spatchallenge

[133] https://www.codot.gov/programs/operations/intelligent-transportation-systems/innovation/connected-and-autonomous-technology-program

[134] Virginia Tech Transportation Institute, accessed February 2019, https://www.vtti.vt.edu/

advanced technologies to improve safety, efficiency, system performance, and infrastructure return on investment. Grantees in the ATCMTD program represent a diverse set of metropolitan and rural areas located across the United States and are deploying a range of advanced technologies, including CV applications, automated vehicles, adaptive signal systems, integrated corridor management, real-time traveler information systems, green technologies (e.g., electric vehicles), and infrastructure maintenance and monitoring systems, among other technologies.[135]

DOT is also sponsoring three CV pilot deployment tests in New York, Wyoming, and Tampa, Florida.[136] The New York and Tampa pilots are meant to provide valuable insight and data on the safety and congestion-relieving application of V2X technology in dense urban environments, and the Wyoming pilot focuses on safety benefits of V2X to the freight community.

To fully leverage the potentials of V2X and AVs to improve transportation safety, efficiency, and mobility, FHWA led the development of the Cooperative Automation Research Mobility Applications (CARMA) platform. CARMA is a multimodal effort among FHWA, the Federal Motor Carrier Safety Administration, the Intelligent Transportation Systems Joint Program Office, and the Volpe National Transportation Systems Center that is evaluating the concept of cooperative driving automation (CDA). Under CDA, vehicles exchange information with other vehicles and the infrastructure to perform shared maneuvers when confronted with traffic issues such as work zones or inclement weather. CARMA is based on open-source software and an agile development process to facilitate collaboration, research, and testing in CDA among the participating agencies, academia, and industry to rapidly advance automation on the Nation's transportation system.[137]

DOT ATCMTD Award: Texas Connected Freight Corridors

The Texas Connected Freight Corridors project is Texas' largest deployment of CV technology, using it to enable safe and efficient goods movement through key freight corridors in the Texas Triangle. With a focus on the freight community, the deployment strives to achieve a technology-ready sector that can easily integrate data from connected vehicle applications, as well as immediate improvement in safety and mobility for trucks operating on Interstates in Texas.

The Texas Connected Freight Corridors project will deploy CV technologies in more than 1,000 trucks and agency fleet vehicles that will be able to transmit data and receive warnings from these applications. Using a mix of communication technologies, advanced safety and congestion management systems will be applied to improve traveler information, asset condition assessment, and system performance. The deployment is expected to be operational in 2022.

The National Highway Traffic Safety Administration (NHTSA) is working toward requiring certain vehicles to be equipped with V2V communication technology with the capability to send and receive basic safety messages between vehicles.[138]

Another service enabled by vehicle connectivity is vehicle platooning. V2V communications combined with driver assistance systems such as adaptive cruise control and automated emergency braking allow vehicles to safely follow each other much more closely than in conventional driving. This ability to follow closer can increase the capacity of highways, and, for large trucks, enable significant fuel savings due to reductions in aerodynamic drag. Initial deployments of truck platooning systems are happening today and the DOT continues to study the impacts and opportunities related to truck platooning. Truck platooning uses vehicle-to-vehicle communications

[135] ATCMTD Grant 2020 Program Report (US DOT Draft)
[136] https://www.its.dot.gov/pilots/
[137] https://highways.dot.gov/research/operations/Cooperative-Driving-Automation
[138] https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/v2v_pria_12-12-16_clean.pdf

technology to allow trucks to follow each other more closely—at about one second apart—and travel in a more coordinated fashion. Benefits include increased throughput, improved fuel economy, and lower operating costs.[139] There is also the potential for more advanced leader-follower platooning in which the follow truck may potentially operate driverless while the lead truck is driven normally. This technology, while still in research and development, has the potential to address driver shortages as freight movements continue to grow.

Emerging state-of-the-art technologies and systems, such as CVs, will help usher in an era of improved safety, mobility, and system efficiency, and provide real-time data to support transportation planning and system operations.

Work Zone Technology

Work zones play a key role in the process of maintaining and upgrading our Nation's roadways. Unfortunately, daily changes in traffic patterns, narrowed rights-of-way, and construction activities associated with work zones often create a combination of factors resulting in crashes, injuries, and fatalities. These crashes also cause excessive delays, especially given the constrained driving environment. Work zone incidents affect everyone. In addition to vehicular crashes and fatalities, the leading causes of death in the road and bridge construction sector are runovers, backovers, and falls. Simply put, drivers, passengers, and construction workers are all at risk in work zones. Transportation agencies across the country are using technology to make travel through and around work zones safer and more efficient.

The Minnesota Department of Transportation is implementing a work zone technology application that uses real-time work zone activity information to improve situational awareness for operators and notifications for the public.[140] Pennsylvania's Automated Work Zone Speed Enforcement (AWZSE) program uses vehicle-mounted systems to detect and record motorists exceeding posted work zone speed limits using electronic speed timing devices.[141] AWZSE systems are only operational in active work zones where workers are present.

The next trend in transportation data is the availability of real-time work zone data. Through the Work Zone Data Exchange Specification,[142] DOT has facilitated the development of a work zone data format that enables infrastructure owners and operators to make harmonized work zone data available for transportation applications. The intent is to make travel on public roads safer and more efficient through ubiquitous access to data on work zone activity. Specifically, the project aims to get data on work zones into vehicles to help ADS and human drivers navigate more safely. The development has been facilitated by DOT, but stakeholders are developing the actual standards and specification.

Future Considerations

This is an exciting time in transportation, with many technological advancements underway that will improve the future transportation system. Transportation contributes to prosperity by enabling access to opportunities. New technologies can enhance that access, but there are many potential barriers and benefits to consider. These include understanding required capabilities for high-tech system operations and maintenance; identifying impacts on system performance, including accessibility, mobility, and safety for all system users; identifying impacts on the transportation workforce; and anticipating future policy, regulatory, and legislative needs.

Technology innovation has led to the emergence of on-demand and shared transportation services that will have a major impact on the movement of goods and people. Their market penetrations are

[139] FHWA Research and Technology Program (2017). Partially Automated Truck Platooning Demonstration Video. https://highways.dot.gov/research/
[140] https://www.dot.state.mn.us/guidestar/1996_2000/smart_work_zone/workzone.pdf
[141] https://workzonecameras.penndot.gov/
[142] https://www.transportation.gov/av/data/wzdx

accumulating, especially within urban areas. In addition, it seems likely that electrification, connectivity, and vehicle automation will cause similar or perhaps even greater transformations. Given the sizeable research and investments being made in transformative transportation technologies by the public and private sectors, their introduction to transportation systems will most certainly continue. However, the potential for these innovations to produce improvements in safety, mobility, and system performance implies that their rollout strategies will require careful consideration.

Transformative Technologies – Transit

Transportation and emerging technologies are inextricably linked. Throughout history, the need for new transportation modes has driven the development of new technologies; new technologies have in turn created new transportation modes. A desire to go to the moon fueled the development of booster rocketry, and the development of the airplane created air travel. Shared surface transportation evolved from horse-drawn coaches to train travel, taxis, bus and heavy rail systems, and shared services such as Lyft, Uber, and Via. Now, the ubiquitous and powerful mobile phone is at the center of enhanced traveler expectations for real-time information about a ride. New bus technologies such as low- and no-emission systems are transforming traditionally diesel-dependent public transportation fleets, reducing carbon emissions and addressing climate change goals.

KEY TAKEAWAYS

- FTA invested more than $30 million over four years for demonstration projects that explore new technologies and approaches that integrate public and private mobility services to increase service hours, geographic coverage, and accessibility.
- Smartphone-based Mobility as a Service (MaaS) technology helps millions of people plan and pay for trips, evaluate transportation options, identify vehicle locations and arrival times, and enjoy seamless, less stressful travel.
- More travel options through Transportation Network Companies (TNCs) and a wide array of shared-use mobility modes such as car, bike, and scooter sharing.
- Improved safety through development of collision avoidance technologies, railroad worker communication and alert systems, and operator visibility enhancements to improve the safety of pedestrians and other roadway users.
- Enhancing public transit operational effectiveness and efficiency through new technologies such as unmanned aerial systems, artificial intelligence, and robotics for asset management.

The new data generated by sensors and other technologies are enabling the use of artificial intelligence, machine learning, robotics, modeling, and simulation in ways that, today, might seem as far out as the Jetsons did in the 1960s. Safety for pedestrians, riders, bicyclists, and transit workers can expand while reducing fatalities and injuries through new safety technologies such as detection systems using radar, camera- and loudspeaker-equipped aerial drones, buried sensors, video analytics, and railway worker tracking systems. Soon, new multimodal payment systems enabled by a smart phone or a smart watch could expand contactless fare systems. Finally, the need to transform public transportation due to issues associated with the coronavirus disease 2019 (COVID-19) pandemic is prompting new uses for many of these technologies to address contact tracing, sanitation and decontamination of rolling and rail stock, and real-time routing to address crowding issues on shared transportation systems.

Transit is confronting changing demographics, economics, and consumer choices. Many millennials and members of Generation Z prefer to live in cities, are less likely to own personal vehicles compared with the general population, and choose to take transit. On the other hand, "gig economy" workers with changing work hours and locations may make transit service planning more difficult, and the increase in telework reduces demands for transportation, especially fixed-route systems. America's aging population requires senior transportation services that meets the needs of older adults and people with disabilities. Rural communities' mobility needs continue to be challenging. A lack of coordinated transportation options in frontier and Tribal communities can lead to isolation. Many people rely on public transportation to travel to work, to school, to visit friends/family, to be entertained, or to access health services, making it a lifeline to economic vitality and independent living.

Before discussing specific technologies, it is important to note how people's mobility expectations are changing: as consumer preferences shift, services must shift to accommodate their needs. New technologies are often the key to providing new services.

Changing Mobility Dynamics in Public Transportation

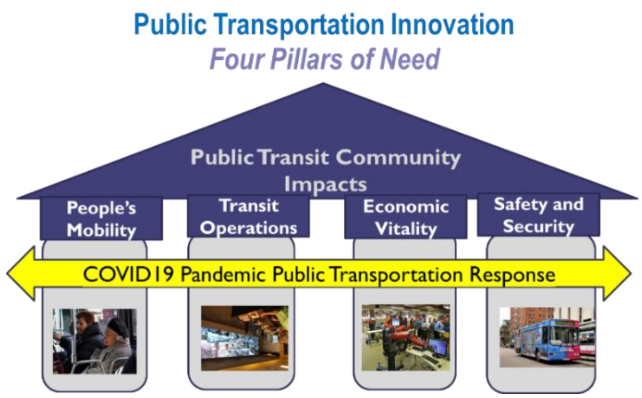
The past decade has brought challenges and opportunities for public transportation. Changing technologies, public policies, demographics, and consumer preferences have led to disruptions and transformations in public transportation as travelers across the United States began adopting a wide array of new mobility options and tools. Smartphone-based Mobility as a Service (MaaS) technology helps millions of people plan and pay for trips, evaluate transportation options, identify vehicle locations and arrival times, and enjoy seamless, less stressful travel. More travel options have become available, including services provided by Transportation Network Companies (TNCs) and a wide array of shared-use mobility modes such as car, bike, and scooter sharing. In many communities, transit agencies have incorporated MaaS technology into their operations and partner with TNC and shared-use mobility services to expand geographic coverage and hours of service.

Federal Transit Administration Research and Development Investments in New and Emerging Technologies

The Federal Transit Administration's (FTA) research mission is to advance public transportation by accelerating innovation. The FTA statutory research program supports innovations in promising emerging technologies to solve challenging issues facing public transportation. FTA fields research to meet public transit needs in four areas, as shown in *Exhibit 12-7*.

Emerging technologies and solutions using those technologies are categorized in three of the four areas of need: people's mobility, transit operations, and safety and security.

Exhibit 12-7 ■ The Four Pillars of Public Transportation Innovation



Source: FTA Technology Database.

Improving People's Mobility

In recent years, FTA has invested more than $30 million in grants for programs such as Mobility on Demand (MOD), Integrated Mobility Innovation (IMI), and Accelerating Innovative Mobility (AIM). Through these grants, transit agencies across the United States are experimenting with new technologies and approaches that integrate public and private mobility services to increase service hours, geographic coverage, and accessibility.

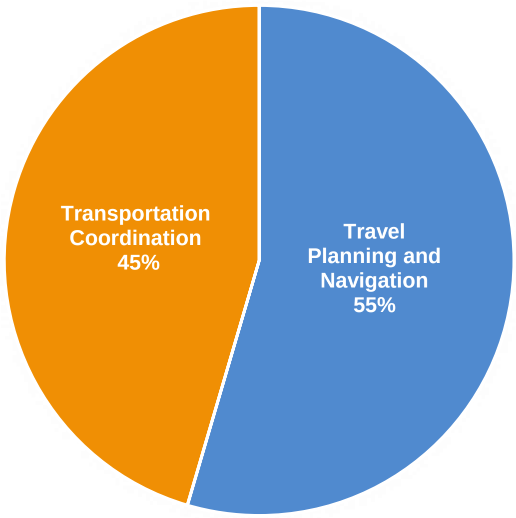
Major types of technologies that can expand mobility for travelers include transportation coordination technology and travel planning and navigation technology. *Exhibits 12-8, 12-9,* and *12-10* describe the 11 mobility innovation and technologies being demonstrated and evaluated under FTA-funded programs in the Spring of 2020.

Exhibit 12-8 ■ Mobility Innovation Technology Demonstrations

Technology Project Title	Project Sponsor	Technology Category	Technology Status
MOD Sandbox: Mobility Platform	City of Phoenix	Travel Planning and Navigation Technology to Improve Mobility	Demonstration Started
MOD Sandbox: Bay Area Fair Value Commuting Demonstration Project	City of Palo Alto	Travel Planning and Navigation Technology to Improve Mobility	Demonstration Started
MOD Sandbox: Integrated Carpool to Transit	San Francisco Bay Area Rapid Transit	Transportation Coordination Technology to Improve Mobility	Evaluation Completed
MOD Sandbox: Paratransit Mobility on Demand Demonstration	Pinellas Suncoast Transit Authority, Inc.	Transportation Coordination Technology to Improve Mobility	Demonstration Started
MOD Sandbox: Integrated Fare Systems–From Transit Fare to Bike Share	Chicago Transit Authority	Travel Planning and Navigation Technology to Improve Mobility	Demonstration Started
MOD Sandbox: Open Trip Planner Share Use Mobility	Tri-County Metropolitan Transportation District	Transportation Coordination Technology to Improve Mobility	Demonstration Started
MOD Sandbox: First and Last Mile Solution	Dallas Area Rapid Transit	Travel Planning and Navigation Technology to Improve Mobility	Demonstration Started
MOD Sandbox: Flexible Trip Planner Project	Vermont Agency of Transportation	Travel Planning and Navigation Technology to Improve Mobility	Evaluation Completed
Atlanta Region TMC Platform for One Click, Phase II	Atlanta Regional Commission	Transportation Coordination Technology to Improve Mobility	Deployment planning grants
Travel Management Coordination Center (TMCC) of Southern Wisconsin	Greater Wisconsin Agency on Aging Resources, Inc.	Transportation Coordination Technology to Improve Mobility	Deployment planning grants
Guided Augmented Independence Travel Aid (GAIT-Aid)	Design Interactive, Inc.	Travel Planning and Navigation Technology to Improve Mobility	Project Started

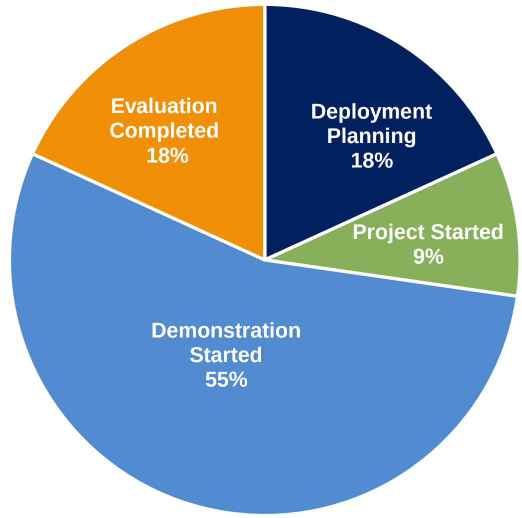
Source: FTA Technology Database.

Exhibit 12-9 ■ Mobility Technology Categories



Source: FTA Technology Database.

Exhibit 12-10 ■ Mobility Technology Deployment Status, March 2020



Source: FTA Technology Database.

Transportation Coordination Technology

FTA is investing in transportation coordination technology grants, supporting mobile apps, open trip planners, and call centers, to help organizations provide seamless travel across different types of transportation modes and services. Examples include:

- The Greater Wisconsin Agency on Aging established a Travel Management Coordination Center (TMCC) to provide access to healthcare and coordinate human services transportation for older adults, veterans, persons with disabilities, individuals with lower incomes, and other transit-dependent user groups. The TMCC sought to demonstrate how emerging cloud- and mobile-based technologies can eliminate barriers to coordinating transportation for human services.
- Bay Area Rapid Transit (BART) in San Francisco, California, piloted an integrated carpool-to-transit program in which participants were guaranteed a parking space at BART stations if they carpool, verified through a third-party app and enforced through the license plate list that the app provider delivered to BART each day.

Travel Planning and Navigation Technology

FTA is sponsoring research in trip payment, planning, and navigation technologies to help individuals, including people with disabilities, overcome barriers to using transit. Examples include:

- Design Interactive, Inc. is using Small Business Innovative Research (SBIR) funds to develop its Guided Augmented Independence Travel Aid (GAIT-Aid) software, which customizes trip planning and navigation for persons with mild cognitive impairments.
- The Vermont Agency on Transportation developed an online trip planner for people in rural portions of the State. The tool allows individuals to plan their trip using fixed-route public transit and connections to flexible transit options such as dial-a-ride, hail-and-ride, and deviated-fixed modes.

Ensuring Everyone's Safety

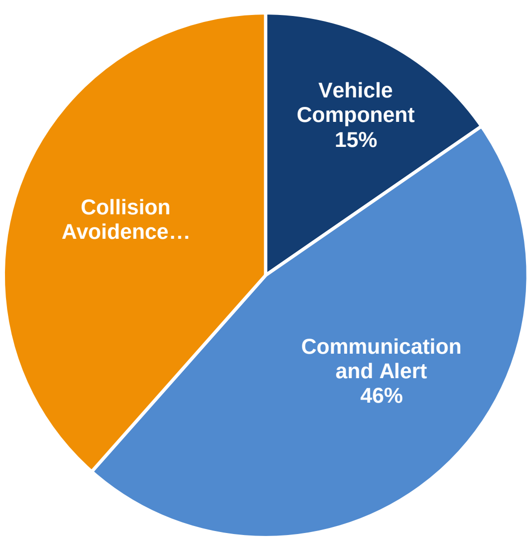
Public transportation is one of the safest modes of travel. Transit averages less than two fatalities per 100 million passenger miles traveled for Fixed-Route Bus, Heavy Rail, and Light Rail. However, certain types of safety events continue to pose challenges, such as bus collisions at intersections with vehicles and pedestrians, track worker injuries and fatalities, and suicides at rail stations. FTA is addressing these issues by investing in vehicle component, collision avoidance, and worker communication and alert technologies. *Exhibits 12-11, 12-12,* and *12-13* describe the 13 safety technologies being demonstrated and evaluated under FTA-funded programs in the Spring of 2020.

Exhibit 12-11 ■ Safety Technology Demonstrations

Technology Project Title	Project Sponsor	Technology Category	Technology Status
Demonstration and Commercialization of LRV Bumper for Enhanced Safety in Shared Right-of-Way Street Environments	Applied Research Associates, Inc.	Vehicle Component Technology to Improve Safety	Project Started
Wayside Worker Protection Demonstration	Metropolitan Atlanta Rapid Transit Authority	Communication and Alert Technology to Improve Safety	Demonstration Started
Driver Assist System (DAS) Technology to support Robust, Flexible Bus-on-Shoulder (BOS) and Narrow-Lane Operations for Robust Transit Service under All Operating Conditions	Minnesota Valley Transit Authority	Collision Avoidance Technology to Improve Safety	Evaluation Completed
Connected Vehicle Infrastructure-Urban Bus Operational Safety Platform	Battelle Memorial Institute	Collision Avoidance Technology to Improve Safety	Evaluation Completed
Innovative Platform Track Intrusion Detection System (PTIDS) Technology: A Demonstration on Los Angeles Metro Rail System	Los Angeles County Metropolitan Transportation Authority	Communication and Alert Technology to Improve Safety	Demonstration Started
Pierce Transit Collision Avoidance and Warning Research and Demonstration Project	Pierce Transit	Collision Avoidance Technology to Improve Safety	Demonstration Started
Transit Bus Mirror Configuration Research and Development	NY Metropolitan Transit Authority	Vehicle Component Technology to Improve Safety	Demonstration Started
CTA Operations Control Center Safety Enhancements Project	Chicago Transit Authority	Communication and Alert Technology to Improve Safety	Demonstration Started
Enhanced Employee Protection Warning System Including Roadway Worker Protection	Sacramento Regional Transit District	Communication and Alert Technology to Improve Safety	Demonstration Started
Fixed Location Train Detection and Worker Warning System	Maryland Department of Transportation	Communication and Alert Technology to Improve Safety	Demonstration Started
Collision Avoidance and Mitigation Technologies on LA Metro Bus Service Pilot	LA County Metropolitan Transportation Authority	Collision Avoidance Technology to Improve Safety	Project Started
Track Inspector Location Awareness with Enhanced Transit Worker Protection Pilot	Washington Metropolitan Area Transit Authority	Communication and Alert Technology to Improve Safety	Demonstration Started
Pedestrian and Cyclist Detection Devices for Buses	Novateur	Collision Avoidance Technology to Improve Safety	Demonstration Started

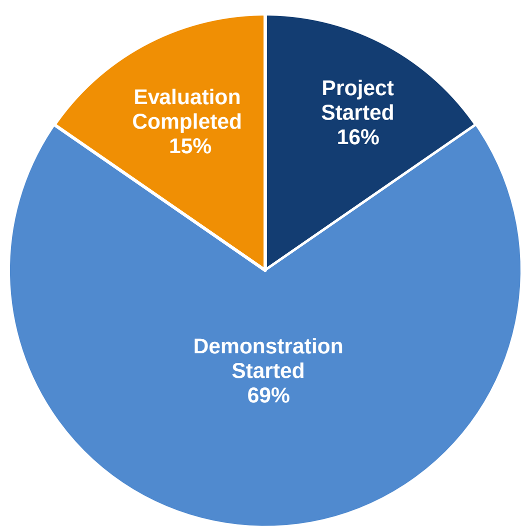
Source: FTA Technology Database.

Exhibit 12-12 ■ Safety Technology Categories



Source: FTA Technology Database.

Exhibit 12-13 ■ Safety Technology Deployment Status, March 2020



Source: FTA Technology Database.

Safer Vehicle Component Technology

FTA is investing in innovative bus and rail designs and materials that may help operators avoid collisions or reduce damage from accidents. Examples include:

- The Sacramento Regional Transit District is demonstrating a light rail vehicle crash-energy-management bumper system to reduce collision damage between light rail vehicles and autos. The bumper has an improved geometric profile and a segmented design that actuates at lower forces in the common collision scenario of corner impacts with automobiles. The technology is designed to prevent light rail vehicles from crashing on top of smaller vehicles.
- The New York Metropolitan Transportation Authority is designing a safer bus mirror that improves visibility for bus operators and decreases the possibility of collision with pedestrians due to blind spots.

Collision Avoidance Technology

FTA and its project sponsors are demonstrating vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) technology to help operators avoid accidents or warn drivers before a collision occurs. Examples include:

- The Los Angeles County Metropolitan Transportation Authority (LA Metro) will deploy smart cameras and interior display modules on buses that alert the driver both visually and audibly if a pedestrian or cyclist is in the driver's blind spot. LA Metro will also deploy a technology for fleet managers that tracks the location of vehicles and reports all warnings.
- The Novateur Corporation is designing a cyclist collision warning system for buses. The system will use sensors to measure the dynamics of pedestrians and cyclists near the bus and assess the risk of collision by combining this information with data on the movement of the bus and other environmental variables.

Worker Communication and Alert Systems

FTA is funding the development of technology to improve communication between workers, train operators, and control centers. Improved communication will create and safer conditions for track workers and the technology can alert workers when a train is approaching. Examples include:

- The Chicago Transit Authority is enhancing its Control Center's "QuicTrac" train tracking tool by 1) improving the tool's ability to alert others when the signal system loses train detection; 2) adding an overlay of the Worker Ahead wayside system on the QuicTrac display; and 3) including detection of red signal violations by a train.
- The Maryland Transit Administration has deployed the ZoneGuard system, an electronic roadway worker protection system that will continuously monitor the locations of light rail vehicles and roadway workers to warn roadway workers of approaching vehicles.

Bus Compartment Redesigns

FTA is investing in both new bus components and retrofits to improve safety for operators, travelers, pedestrians, and bicyclists. New technologies will increase operator visibility to improve the safety of pedestrians and other roadway users (e.g., minimizing bus operator blind spots). Advanced communication technologies will increase passenger accessibility for positive interactions between operators and passengers, including assisting passengers in need of special assistance. Improved ergonomics can reduce bus operator work-related health issues and injuries, and can improve operational efficiency by better locating instrument and control interfaces.

Enhanced ventilation systems can filter out contaminants and improve air quality inside vehicles. Advanced driver assistance technologies will help drivers detect people out of their line of sight and avoid collisions. Safety shields will protect bus operators from assault and infection. New sanitation methods could streamline bus maintenance and reduce depot time. Automated bus movement in maintenance depots can reduce worker exposure to infectious materials in buses, and robotic systems can clean rolling stock safely.

Improving Transit Operations

Public transit continues to use technologies to improve transit operations. For example, the percentage of transit vehicles running on alternative fuels or propulsion (i.e., compressed natural gas or battery electric vehicles) increased from 27 percent in 2012 to 32 percent in 2018.[143]

FTA's research and demonstration projects use technology to enhance public transportation operations across all aspects of system services, from the design of buses to the maintenance and management of important transit assets and ensuring a state of good repair. Key areas of focus include enhancing public transit operational effectiveness and efficiency through new technologies such as unmanned aerial systems, artificial intelligence, and robotics. FTA is also exploring new energy technologies and innovative bus designs in partnership with the Department of Energy. *Exhibits 12-14, 12-15*, and *12-16* display the 12 transit operations technologies being demonstrated and evaluated under FTA-funded projects in the Spring of 2020.

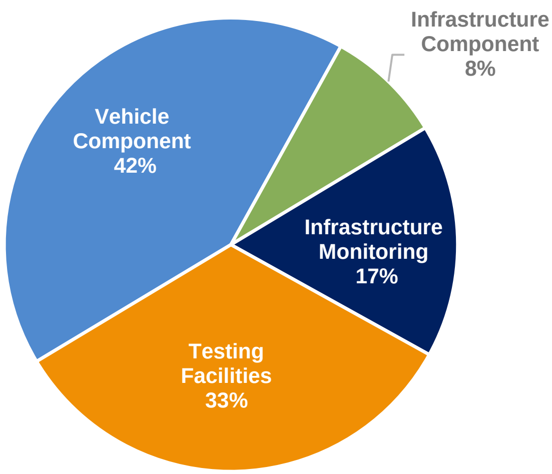
Exhibit 12-14 ■ Infrastructure Technology Demonstrations

Technology Project Title	Project Sponsor	Technology Category	Technology Status
Development of Bus Exportable Power System for Emergency Response	Center for Transportation and the Environment, Inc.	Vehicle Component Technology	Evaluation Completed
Resilient Concrete Crosstie and Fastening System Designs for Light Rail, Heavy Rail, and Commuter Rail Transit Infrastructure	University of Illinois	Infrastructure Component Technology	Evaluation Completed
Integrated Wheel/Rail Characterization and Safety through Advanced Monitoring and Analytics	New York Metropolitan Transportation Authority	Infrastructure Monitoring Technology	Evaluation Completed
Low or No (LoNo) Emission Component Assessment Program, Auburn University	Auburn University	Testing Facilities	Project Started
Low or No (LoNo) Emission Component Assessment Program, The Ohio State University	The Ohio State University	Testing Facilities	Project Started
Low or No (LoNo) Emission Bus Testing Centers, Auburn University	Auburn University	Testing Facilities	Project Started
Low or No (LoNo) Emission Bus Testing Centers, The Ohio State University	The Ohio State University	Testing Facilities	Project Started
MARTA Track Inspection and Asset Management Research and Demonstration	Metropolitan Area Rapid Transit Authority (MARTA)	Infrastructure Monitoring Technology	Demonstration Started
Thermoelectric Generation Demo	Center for Transportation and the Environment, Inc.	Vehicle Component Technology	Evaluation Completed
Reduced Engine Idle Load System	Center for Transportation and the Environment, Inc.	Vehicle Component Technology	Evaluation Completed
UTA Paratransit Accessory Electrification	Center for Transportation and the Environment, Inc.	Vehicle Component Technology	Evaluation Completed
Hybrid Beltless Alternator Retrofit	Maryland Department of Transportation	Vehicle Component Technology	Evaluation Completed

Source: FTA Technology Database.

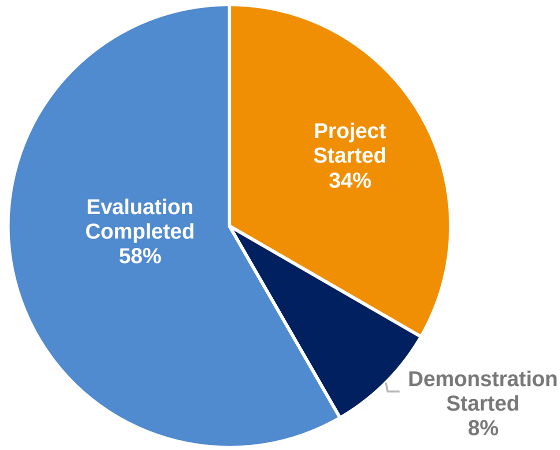
[143] FTA Quarterly Performance Report, January 2020

Exhibit 12-15 ▪ Infrastructure Technology Categories



Source: FTA Technology Database.

Exhibit 12-16 ▪ Infrastructure Technology Deployment Status, March 2020



Source: FTA Technology Database.

Resilient Vehicle and Infrastructure Components

FTA has sponsored research on innovative vehicle designs and components, including batteries, power systems, and materials that may increase energy efficiency, reduce emissions, and improve resilience during emergencies.

The Center for Transportation and the Environment, a nonprofit organization that receives FTA funding, has demonstrated a Bus Exportable Power Supply (BEPS) System that will give hybrid buses the capability to act as on-demand mobile electrical power generators during emergencies.

- The Center for Transportation and the Environment and the Utah Transit Administration have tested a high-voltage battery for paratransit vehicles that will recharge during travel and power the vehicle's heating, ventilation, and air conditioning (HVAC) system.
- The Maryland Department of Transportation retrofitted buses with a "Hybrid Beltless Alternator" system that can use power from rooftop hybrid batteries.
- The University of Illinois studied resilient rail concrete crosstie and fastening system designs and developed a prototype concrete cross tie that is designed to be more resilient to wear and tear and have a longer useful life.

Infrastructure Monitoring for State of Good Repair

FTA is investing in technology that can automate and improve transit agencies' ability to monitor track conditions to maintain track in a state of good repair and reduce potentially hazardous in-person inspections. Examples include:

- The New York Metropolitan Transit Authority is researching integrated wheel/rail safety characterization through a portfolio of advanced monitoring and analytics technologies.
- The Metropolitan Atlanta Rapid Transit Authority is demonstrating autonomous track inspection systems equipment that can be attached to revenue service rail vehicles, allowing them to identify track anomalies that can potentially lead to a track failure and monitor rail car vehicle performance as it interacts with the track.

In addition, FTA plans to study the deployment of unmanned aerial systems for monitoring infrastructure conditions. FTA is assessing techniques to monitor the health of transit assets using advanced sensors, and plans to research innovative construction techniques, nano-technology applications, and uses of artificial intelligence to enhance public transportation systems.

What Lies Ahead for Public Transportation in 2020 and Beyond

Many of the same technological, demographic, and economic forces that shaped the transportation world in the 2010s will continue to affect the design and provision of transit in the next decade.

Transit will also be affected by new and emerging issues such as the COVID-19 pandemic, which will require technological solutions for effective adaptation. The COVID-19 pandemic had a significant impact on public transportation. Many agencies cut or reduced services and laid off workers. For all agencies maintaining any level of service, the danger of infection required a new focus on sanitation, decontamination, social distancing, and taking any other measures necessary to reducing exposure to the virus. Sadly, some bus and rail workers died from COVID-19, highlighting the need to find more ways to keep everyone safe. Agencies are working on cost-effective and less personnel-dependent methods to sanitize public transit systems. Researchers are investigating new ways to reduce COVID-19 infection in vehicles with the use of ultraviolet light or special high-efficiency particulate air (HEPA) filtration. To reduce crowding or exposure, new communication methods to share real-time information on passenger loads are in development, and agencies are expanding and improving contactless fare options. Transit agencies are also investigating new service models such as providing food delivery services for youth and high-risk populations, transporting biohazard items, and providing dedicated routes for essential workers.

As more data are available to travelers, they can make informed decisions about ride sources, and agencies can optimize travel through transit routing and scheduling. Strategies to improve data governance, standardization, and interoperability are increasingly important as the transit industry operates in a more data-driven environment.

As public and private partnership for shared mobility services mature, new technologies that facilitate multimodal and contactless payment are emerging. These systems will require continued vigilance to ensure the security of consumer information and a strong focus on all aspects of data management and cybersecurity.

PART V: Changes to the Highway Performance Monitoring System

The Federal Highway Administration's (FHWA) Highway Performance Monitoring System (HPMS) receives highway information from State departments of transportation to determine the extent, use, condition, and performance of the Nation's highways. The information is used for transportation needs assessments, transportation performance measures, apportionment of highway funds to States, and many research applications. The HPMS data program has existed since 1978.

State departments of transportation report data to FHWA in a format and via a collection methodology specified in the *HPMS Field Manual*. FHWA provides an interface for States to report data, which they must submit each year by June 15th. 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). Data requirements that States must meet are specified in 23 CFR 490, which also specifies HPMS as the system of record.

In 2020, the current version of the HPMS (8.0) software application will reach the end of its software lifecycle. Several third-party software components will no longer be supported by their respective vendors. FHWA is taking this opportunity to evaluate the program to ensure it is consistent with current legislative requirements and provides the most efficient means to collect, store, analyze, and report critical data.

Stakeholder Outreach

From April through October 2017, FHWA conducted several sessions with HPMS data customers including external users as well as those within FHWA and the U.S. Department of Transportation (DOT). These sessions were designed to gather critical feedback on the scope and extent of data that HPMS should store. For example, FWHA's Office of Safety has an interest in the Model Inventory of Roadway Elements (MIRE). MIRE is a list of safety-related data collection items recommended by the Office of Safety, representing data that safety engineers deem beneficial to highway safety analysis. Having a place to store these data would have a positive impact on the Highway Safety Improvement Program goals. Currently, since no single database or other system stores MIRE data at the national level, and because States are encouraged to use MIRE in data reporting, the Office of Safety would like to add MIRE data elements to HPMS.

In the fall of 2017, FHWA reached out to stakeholders and data partners for insight to design HPMS, version 9.0. FHWA conducted four regional meetings and one virtual meeting for State departments of transportation to provide ideas regarding efficiencies. All but one State participated. These meetings were designed to identify more efficient ways to collect and receive required data. Many of the suggestions gathered from the workshops were used in the recommendations identified below.

Finally, FHWA held consultations with the software developer community to evaluate the technical feasibility of ideas generated in the stakeholder sessions.

Recommended Changes

FHWA's consultations with stakeholders and data partners produced the following recommended changes to HPMS. FHWA will implement these recommendations with the next version of HPMS (HPMS 9.0). Release of HPMS 9.0 is scheduled for the 2021 submittal from state departments of transportation (due Spring 2022).

Designation Process

Designation of roads on the National Highway System, the National Highway Freight Network, and various other networks, along with the functional classifications of highways, are proposed by State departments of transportation and then approved by FHWA. Currently, the designation of these roads relies on a manual process that is currently inconsistent between State departments of transportation and the official record approved by FHWA. This designation process will be implemented within the HPMS software application. States would submit a designation proposal via an HPMS interface, which FHWA would also use for review, approval, and adoption (with documentation). This process would provide access to the most current version of these critical highway systems, eliminate multiple versions of the same data, and establish a single version of record with a built-in update and approval process.

Incremental Data Reporting Process

Most data reported to HPMS from State departments of transportation do not change from year to year. For example, highway geometrics such as lane widths, shoulder type, and median widths are static; most data change only as a result of construction projects or natural disasters. Although most data do not vary, States are currently required to report all data annually. Greater efficiency could be gained by allowing States to report only on specific data items as they change rather than reporting the same data year after year.

Third-party Sources

The current HPMS program relies on State departments of transportation to provide all required data annually as specified in the *HPMS Field Manual*. Much of these data could be obtained through third-party vendors, crowdsourcing, and other means, which could relieve some of the burden from States, improve national consistency for some types of data, and potentially improve data accuracy. FHWA is currently evaluating the benefits and risks of such an approach. When an analysis of submitted data would affect their Federal-aid program funds, as is the case with performance targets, States would still be required to report data directly (rather than FHWA outsourcing data collection to a third-party vendor).

Data Economy

During the stakeholder outreach process, data collectors from partner State departments of transportation requested that data be reported in their native format. For example, the number of stop signs located on an identified road segment is an important consideration in determining highway capacity. Many States keep data on the location of stop signs, but when reporting to HPMS they need to go through the extra step of determining the number of stop signs on a given segment of road. It would be more efficient for States to report data in the form in which they were originally collected, rather than having to process data to meet the needs of individual specific applications. The recommended data economy strategy includes:

Removal of Calculated Data Items

HPMS includes several data items that States must derive from raw data. For example, in order to report on the number of turn lanes, State departments of transportation must process data from three or four attributes of an intersection into the code structure specified by the *HPMS Field Manual*. It would more efficient for States to simply report intersection attributes rather than report the derived turn lane data.

Hierarchical Data Structure

HPMS 8.0 includes two conflicting components: the spatial network known as the All Road Network of Linear Data (ARNOLD) and the attribution in HPMS of the roads represented by ARNOLD.

ARNOLD represents data at an individual road segment, whereas HPMS attributes represent the highway facility. For example, a divided highway is represented by a single feature in HPMS whereas ARNOLD would represent the highway as two road elements. The same concept is applied to intersections, interchanges, and roundabouts.

The data model for HPMS 9.0 should include a hierarchical structure that defines road features on multiple levels. This provides a more accurate and useful description of specific road features that are derived from a common collection effort.

Modernization Study

The results and details of the evaluation of the Highway Performance Monitoring System have been 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/).

PART VI: 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*. Appendices E and F provide information supporting the discussion of the conditions and performance of the National Highway Freight Network (NHFN) presented in Part III.

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.

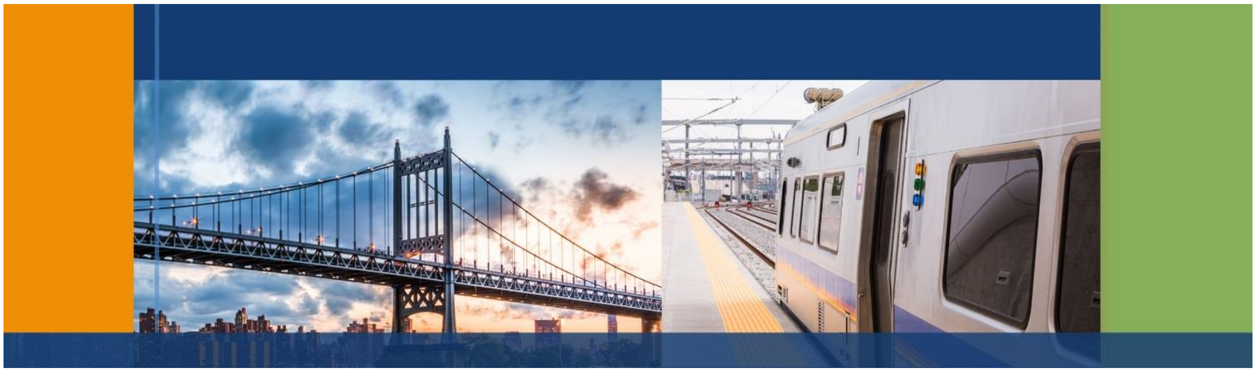
Appendix B details the **National Bridge Investment Analysis System** (NBIAS), which is used to examine potential future bridge rehabilitation and replacement investments.

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 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 E lists the required elements for State Freight Plans required under the Fixing America's Surface Transportation (FAST) Act.

Appendix F lists the Critical Urban Freight Corridors and Critical Rural Freight Corridors that States have designated as of May 1, 2018, for inclusion in the NHFN.



APPENDIX A: 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 was first used in the 1995 Conditions and Performance Report (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 23rd C&P Report. The most complete reference on the HERS model is the *Highway Economic Requirements System Technical Report*, which is currently being updated to align with HERS version 5.48 used for this edition of the C&P Report. The updated HERS Technical Report will be made available online.

Highway Economic Requirements System

The primary data source for the HERS model is information on a sample of approximately 130,000 representative highway segments collected from the States via the Highway Performance Monitoring System (HPMS). *Exhibit A-1* summarizes the types of input data used by HERS, the criteria HERS uses for rating a highway section as deficient, and the improvement options considered by HERS for remedying deficiencies.

For HPMS sample sections, HERS evaluates data on pavements, geometry, traffic volumes, and other characteristics. HERS then projects future conditions and performance of these sections by combining these data with many other model elements:

- Base-year estimates of prices and costs;
- Projections of future traffic growth on each section, fuel prices, and fuel efficiency;
- Physical relationships (equations) to predict pavement deterioration, travel delay, and fuel consumption rates by vehicle type;
- Behavioral relationships (equations) to predict, for example, travel demand induced by changes in travel time or vehicle operating cost; and
- Assumptions about future highway investment levels or policies (see Chapter 10).

HERS forecasts future conditions and performance across several funding periods—in this report, four consecutive 5-year periods. At the beginning of each period, the model checks for deficiencies in selected highway section characteristics. Of the characteristics on which HERS can rate a highway section as deficient (*Exhibit A-1*), only pavement roughness and traffic congestion are sufficient triggers for the model to evaluate improvement options. However, the evaluation of options to correct these triggering deficiencies also considers potential remedies for other deficiencies that may be present, such as improving narrow shoulders or realigning a section with excessive curvature.

Exhibit A-1 also presents the improvement options that HERS evaluates. For remedying pavement roughness, the options are reconstruction and resurfacing. The model selects reconstruction rather than resurfacing for a section when, at the start of the period: (a) roughness exceeds a certain engineering-based threshold, (b) the number of successive past resurfacings has already reached the limit of what is deemed feasible, or (c) the current surface type is too low-grade based on engineering-related criteria (e.g., an unpaved road that is sufficiently traveled and excessively rough). For traffic congestion, the main remedy in the model is to add lanes (with the number to be added determined by the model), although capacity can also be added through widening of lanes or shoulders. HERS does not consider types of targeted improvements that would primarily address safety issues, such as the addition of rumble strips, median treatments, or signalized intersection improvements. For most improvements of these types, evaluation would require road data beyond those HPMS currently provides.

Exhibit A-1 ■ HERS Model Overview

	HPMS Data Input Categories	Deficiency Criteria/ Improvement Triggers	Improvement Options
Pavement	▪ Surface & base types ▪ Roughness ▪ Distresses	▪ Surface type ▪ Roughness	▪ Reconstruction (w/option for surface type upgrade) ▪ Resurfacing (w/option for shoulder improvements)
Traffic/ Capacity	Traffic ▪ Average daily ▪ Vehicle type ▪ Peak period ▪ Directionality	▪ Congestion level (Volume/capacity)	▪ Adding lanes[1] ▪ Major widening[1]
Road Geometry	▪ Lanes ▪ Shoulders ▪ Medians ▪ Curves ▪ Grades ▪ Traffic control devices ▪ Intersections	▪ Lane width ▪ Right shoulder width ▪ Shoulder type ▪ Curves ▪ Grades	▪ Reduce curves[1] ▪ Reduce grades[1]
Other	▪ Speed limit ▪ Road work history ▪ Widening potential, etc. ▪ Miscellaneous		

[1] Improvement option only in combination with pavement preservation (resurfacing or reconstruction).

Source: HERS Technical Report.

HERS employs benefit-cost analysis to evaluate the potential improvements to a highway section; *Exhibit A-2* shows the categories of benefits and costs. Reductions in the costs of travel ("highway user benefits" are typically dominated by savings in the costs of travel time, but savings in vehicle operating costs can also contribute significantly. Although HERS captures the ancillary safety impacts of pavement and capacity improvements, it is not designed currently to capture impacts of targeted safety improvements; benefits from crash rate reductions thus contribute to the benefits that HERS estimates, but only modestly. The benefit-cost analysis in HERS also considers changes in vehicle emissions of pollutants, which are categorized as positive "benefits" if an improvement results in less pollution, or as "disbenefits" (negative benefits) if an improvement results in more pollution. The possibility of increased pollution arises because the improvements modeled in HERS typically worsen pollution by inducing more travel, which can outweigh the reductions in emissions that result from reduced traffic congestion (higher speeds). Whether positive or negative, the change in pollution costs is invariably a minor element in the HERS benefit-cost calculation.

Dividing these improvement benefits by the capital costs associated with implementing the improvement results in a benefit-cost ratio (BCR), which 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 marginal BCR falls below 1.0 (i.e., costs exceed benefits). Investment beyond this point is not justified economically because a decline in total net benefits would result.

Exhibit A-2 ■ Benefit-cost Analysis in HERS

Benefits & Costs Included		
User Benefits	Travel time savings	▪ Traveler time ▪ Time-related vehicle capital costs ▪ Time cost of freight in transit
	Vehicle operating cost savings	▪ Fuel ▪ Mileage-related depreciation ▪ Maintenance & repairs ▪ Tires ▪ Oil
	Crash risk reductions	▪ Fatalities ▪ Injuries ▪ Property damage
Agency Benefits	Road maintenance cost savings	▪ Adding lanes[1] ▪ Major widening[1]
	Project residual value[1]	
External Benefits/Costs	Changes in emissions of pollutants	▪ Carbon monoxide ▪ Volatile organic compounds ▪ Nitrogen oxides ▪ Sulphur dioxides ▪ Fine particulate matter
	Work-zone delays	
Capital costs	Costs of highway improvements	▪ Engineering ▪ Right-of-way ▪ Construction

[1] In comparison with an investment alternative that has a shorter expected service life; e.g., reconstruction vs. resurfacing.

Source: HERS Technical Report.

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.

Valuation of Travel Time Savings

With travel time savings typically the largest benefit to travelers from road improvements, the monetized values per unit of time saved are important parameters in any HERS analysis. *Exhibit A-3* 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 2016 dollars, and compares these with the 2014 values used in the 23rd C&P Report. For trucks, the values reflect not only the cost of the driver's time, but the benefits from freight arriving at its destination faster ("inventory value of cargo") and the opportunities for more intensive vehicle utilization when trips can be accomplished in less time ("vehicle capital cost"). The inventory value of the cargo component was minuscule in the case of combination trucks, and was not estimated for single unit trucks because of data issues and because some of these vehicles do not carry freight (e.g., garbage trucks).

Exhibit A-3 ■ Estimated 2016 Values of Travel Time by Vehicle Type

2016 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	$34.96	$34.31	$33.33	$29.75	$30.73	$27.56	$30.60	$30.60
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	$46.52	$45.52	$45.48	$41.03	$35.16	$41.33	$31.10	$31.10
Vehicle Capital Cost per Vehicle	N/A	N/A	N/A	$12.04	$20.51	$8.06	$16.25	$13.47
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	**$46.52**	**$45.52**	**$45.48**	**$53.07**	**$55.67**	**$49.39**	**$47.45**	**$44.73**
Share of Vehicle Use for Business Travel	11.0%	9.7%	21.9%	100.0%	100.0%	10.1%	100.0%	100.0%
Personal Travel								
Value of Time per Person Hour	$14.20	$14.20	$14.20	N/A	N/A	$14.20	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	**$22.36**	**$24.93**	**$23.28**	**N/A**	**N/A**	**$179.50**	**N/A**	**N/A**
Share of Vehicle Use for Personal Travel	89.0%	90.3%	78.1%	N/A	N/A	89.9%	N/A	N/A
Average Values per Vehicle Hour								
2016	**$25.03**	**$26.92**	**$28.13**	**$53.07**	**$55.67**	**$228.89**	**$47.45**	**$44.73**
2014 (from 23rd C&P Report)	$22.31	$23.95	$25.27	$50.17	$51.89	$204.84	$44.72	$42.11

Sources: U.S. DOT Revised Guidance on the Value of Travel Time in Economic Analysis (Revision 2 – 2016 Update) and internal DOT estimates.

Highway Operational Strategies

The Introduction to Part II discusses the allowance in HERS for future deployment of highway operational strategies. 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. *Exhibit A-4* lists 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-4 ■ 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.

Highway Economic Requirements System Improvement Costs

HERS contains estimates of typical cost per lane mile for different types of highway improvements. The estimates differ by highway functional class, type of improvement, and between rural and urban areas; additional breakdowns are included for rural locations by type of terrain and for urban locations by size of urbanized area. *Exhibit A-5* presents values for pavement improvements in rural areas used in the HERS runs that support this 24th C&P Report; *Exhibit A-6* contains comparable information for urban areas. *Exhibit A-7* and *Exhibit A-8* present values for capacity improvements in rural and urban areas, respectively.

For C&P Report editions from 2004 until the 23rd edition, cost estimates were based primarily on 2002 data with updates based on highway construction cost indices. Over time, however, the updates became less reliable because of limitations of the available indices. Whether costs of highway construction or other products are concerned, price-indexing over lengthy periods usually presents major challenges in adjusting for changes in product quality, product mix, or other confounding factors. For highway construction costs, an additional challenge arose when the Federal Highway Administration (FHWA) Bid Price Index was phased out (the data supplied by States became increasingly spotty) and replaced by the National Highway Construction Cost, which uses a proprietary database. This left ambiguous how to splice these two indices together to estimate cost changes between 2002 and 2005, which coincided with a period of great volatility in both indices. Moreover, even without this problem, the indices indicate only the overall change in costs; they do not pick up differences in the rates of cost change among improvements that differ by type and location characteristics.

Exhibit A-5 ■ Typical Rural Pavement Costs per Lane Mile Assumed in HERS by Type of Improvement

Category	Typical Costs (Thousands of 2016 Dollars per Lane Mile)						
	Resurfacing		Shoulder	Typical Reconstruction		Total Reconstruction	
	Resurface Existing Lane	Resurface and Widen Lane	Improve as Part of Resurfacing	Reconstruct Existing Lane	Reconstruct and Widen Lane	Reconstruct Existing Lane	Reconstruct and Widen Lane
Interstate							
Flat	$332	$979	$139	$1,160	$1,819	$1,604	$2,433
Rolling	$393	$1,157	$162	$1,372	$2,149	$1,890	$2,866
Mountainous	$500	$1,467	$201	$1,740	$2,722	$2,392	$3,623
Other Freeway and Expressway							
Flat	$312	$877	$120	$1,095	$1,670	$1,537	$2,273
Rolling	$368	$1,033	$139	$1,293	$1,970	$1,810	$2,675
Mountainous	$469	$1,311	$174	$1,640	$2,497	$2,290	$3,381
Other Principal Arterial							
Flat	$292	$798	$103	$1,030	$1,545	$1,472	$2,139
Rolling	$346	$942	$118	$1,217	$1,822	$1,732	$2,516
Mountainous	$440	$1,194	$148	$1,545	$2,310	$2,190	$3,180
Minor Arterial							
Flat	$266	$707	$85	$939	$1,386	$1,342	$1,933
Rolling	$314	$832	$98	$1,108	$1,634	$1,581	$2,275
Mountainous	$399	$1,054	$121	$1,405	$2,070	$1,997	$2,871
Major Collector							
Flat	$237	$618	$68	$840	$1,226	$1,212	$1,729
Rolling	$279	$728	$80	$992	$1,446	$1,426	$2,033
Mountainous	$355	$922	$99	$1,256	$1,830	$1,800	$2,565
Minor Collector							
Flat	$209	$548	$51	$752	$1,095	$1,102	$1,574
Rolling	$248	$645	$59	$887	$1,289	$1,296	$1,850
Mountainous	$314	$816	$73	$1,124	$1,631	$1,636	$2,334
Local							
Flat	$190	$500	$38	$688	$1,001	$1,029	$1,477
Rolling	$223	$588	$42	$810	$1,178	$1,211	$1,735
Mountainous	$281	$742	$52	$1,024	$1,487	$1,526	$2,185

Source: Highway Economic Requirements System.

For these reasons, FHWA funded a study to re-estimate typical construction costs with project-level data. The study identified 10 State departments of transportation that report pay item cost data at a geographic level—county or region—that is fine enough to allow demographics and terrain type to be characterized accurately for the local area for which the cost data were being reported. The pay item data reported by the State departments of transportation were mostly related to materials. Additional information was assembled from State departments of transportation websites, highway construction manuals, and commercial data sources, including labor and equipment costs associated with the work/pay items. The States included in the database collectively covered more than 700 counties across the United States. The assembled data represented, on average, 2 to 3 years of cost data from 2013 through 2015, and provided the basis for HERS cost estimates for 2014.

Exhibit A-6 ■ Typical Urban Pavement Costs per Lane Mile Assumed in HERS by Type of Improvement

Category	Typical Costs (Thousands of 2016 Dollars per Lane Mile)						
	Resurfacing		Shoulder	Typical Reconstruction		Total Reconstruction	
	Resurface Existing Lane	Resurface and Widen Lane	Improve as Part of Resurfacing	Reconstruct Existing Lane	Reconstruct and Widen Lane	Reconstruct Existing Lane	Reconstruct and Widen Lane
Interstate							
Small Urban	$581	$1,964	$405	$1,845	$3,244	$2,348	$3,972
Small Urbanized	$657	$2,239	$471	$2,107	$3,714	$2,725	$4,593
Large Urbanized	$787	$2,759	$624	$2,576	$4,587	$3,350	$5,667
Major Urbanized	$833	$3,028	$739	$2,789	$5,031	$3,604	$6,154
Other Freeway and Expressway							
Small Urban	$550	$1,758	$355	$1,740	$2,963	$2,257	$3,700
Small Urbanized	$622	$2,006	$416	$1,988	$3,394	$2,619	$4,281
Large Urbanized	$743	$2,465	$549	$2,426	$4,184	$3,216	$5,277
Major Urbanized	$789	$2,706	$652	$2,626	$4,588	$3,458	$5,729
Other Principal Arterial							
Small Urban	$520	$1,586	$309	$1,640	$2,720	$2,170	$3,466
Small Urbanized	$588	$1,808	$362	$1,872	$3,113	$2,515	$4,007
Large Urbanized	$703	$2,219	$477	$2,283	$3,832	$3,085	$4,936
Major Urbanized	$745	$2,432	$568	$2,468	$4,194	$3,317	$5,353
Minor Arterial							
Small Urban	$470	$1,352	$247	$1,470	$2,362	$1,974	$3,065
Small Urbanized	$532	$1,537	$286	$1,673	$2,694	$2,275	$3,527
Large Urbanized	$637	$1,882	$377	$2,035	$3,305	$2,779	$4,326
Major Urbanized	$675	$2,052	$442	$2,192	$3,597	$2,982	$4,674
Major Collector							
Small Urban	$410	$1,136	$208	$1,283	$2,017	$1,737	$2,642
Small Urbanized	$463	$1,290	$241	$1,460	$2,299	$1,995	$3,030
Large Urbanized	$544	$1,558	$316	$1,747	$2,779	$2,391	$3,653
Major Urbanized	$577	$1,702	$372	$1,881	$3,025	$2,560	$3,945
Minor Collector							
Small Urban	$367	$992	$154	$1,139	$1,770	$1,579	$2,385
Small Urbanized	$414	$1,121	$177	$1,290	$2,006	$1,800	$2,717
Large Urbanized	$488	$1,351	$231	$1,539	$2,414	$2,144	$3,253
Major Urbanized	$517	$1,464	$269	$1,650	$2,611	$2,290	$3,495
Local							
Small Urban	$337	$870	$118	$1,041	$1,578	$1,478	$2,184
Small Urbanized	$380	$985	$136	$1,178	$1,787	$1,677	$2,478
Large Urbanized	$447	$1,180	$178	$1,400	$2,139	$1,984	$2,947
Major Urbanized	$475	$1,278	$208	$1,500	$2,311	$2,114	$3,158

Source: Highway Economic Requirements System.

Exhibit A-7 ■ Typical Rural Capacity Costs per Lane Mile Assumed in HERS by Type of Improvement

Category	Typical Costs (Thousands of 2016 Dollars per Lane Mile)									
	Add Lane	Add Equivalent of One Lane of Capacity at High Cost Due to Obstacle to Widening of Type*:							New Construction	
	If No Obstacles (Normal Cost)	A	B	C	D	E	F	G	New Alignment (Normal)	New Alignment (High)
Interstate										
Flat	$1,604	$4,452	$5,685	$5,814	$9,621	$6,394	$4,288	$4,154	$5,205	$18,428
Rolling	$1,890	$5,777	$7,118	$6,650	$16,503	$7,793	$5,604	$5,421	$7,189	$25,450
Mountainous	$2,392	$9,486	$11,469	$9,971	$25,969	$12,931	$9,106	$8,706	$11,114	$39,343
Other Freeway and Expressway										
Flat	$1,537	$4,199	$5,381	$5,511	$9,221	$6,078	$4,025	$3,913	$4,917	$17,406
Rolling	$1,810	$5,495	$6,766	$6,359	$15,813	$7,396	$5,321	$5,163	$6,826	$24,163
Mountainous	$2,290	$8,933	$10,732	$9,454	$24,885	$12,037	$8,586	$8,236	$10,509	$37,201
Other Principal Arterial										
Flat	$1,472	$4,020	$5,157	$5,281	$8,823	$5,845	$3,849	$3,751	$4,712	$16,680
Rolling	$1,732	$5,265	$6,474	$6,121	$15,127	$7,063	$5,100	$4,959	$6,538	$23,145
Mountainous	$2,190	$8,427	$10,052	$8,983	$23,803	$11,211	$8,113	$7,808	$9,996	$35,389
Minor Arterial										
Flat	$1,342	$3,637	$4,728	$4,848	$8,296	$5,407	$3,455	$3,379	$4,306	$15,242
Rolling	$1,581	$4,812	$5,961	$5,660	$14,351	$6,514	$4,642	$4,525	$6,043	$21,395
Mountainous	$1,997	$7,655	$9,127	$8,246	$22,684	$10,156	$7,363	$7,102	$9,238	$32,703
Major Collector										
Flat	$1,212	$3,338	$4,393	$4,499	$7,769	$5,070	$3,161	$3,092	$4,004	$14,175
Rolling	$1,426	$4,408	$5,508	$5,247	$13,572	$6,032	$4,245	$4,141	$5,639	$19,962
Mountainous	$1,800	$6,915	$8,242	$7,541	$21,563	$9,149	$6,650	$6,428	$8,589	$30,405
Minor Collector										
Flat	$1,102	$3,006	$4,017	$4,117	$7,281	$4,685	$2,823	$2,772	$3,644	$12,900
Rolling	$1,296	$4,003	$5,049	$4,833	$12,824	$5,542	$3,836	$3,754	$5,189	$18,368
Mountainous	$1,636	$6,216	$7,406	$6,876	$20,456	$8,198	$5,969	$5,789	$7,890	$27,929
Local										
Flat	$1,029	$2,771	$3,738	$3,832	$6,869	$4,397	$2,587	$2,551	$3,372	$11,937
Rolling	$1,211	$3,715	$4,709	$4,536	$12,128	$5,170	$3,547	$3,483	$4,833	$17,110
Mountainous	$1,526	$5,674	$6,736	$6,369	$19,369	$7,419	$5,445	$5,303	$7,309	$25,873

* Obstacle widening types: A= Dense Development; B=Major Transportation Facilities; C=Other Public Facilities; D=Terrain Restrictions; E=Historic and Archaeological Sites; F=Environmentally Sensitive Areas; G=Parkland Areas

Source: Highway Economic Requirements System.

In addition to updating the cost estimates in HERS, the study also served to elaborate the model's treatment of obstacles to adding lanes. The HERS database includes separate estimates for the cost of adding lanes in the presence of obstacles such as dense development. In the past, the HPMS database indicated whether such obstacles were present on a sampled highway section; only recently was information added on the types of obstacles. In addition to dense development, these include major transportation facilities, other public facilities (e.g., schools, hospitals), terrain restrictions, historic and archaeological sites, environmentally sensitive areas, and parkland. As before, the estimates for high-cost lanes are differentiated by highway functional class and locational characteristics, as are normal-cost lanes. HERS also continues its practice of distinguishing low- and high-cost estimates for constructing highways on new alignments.

Exhibit A-8 ■ Typical Urban Capacity Costs per Lane Mile Assumed in HERS by Type of Improvement With and Without Obstacles to Widening

	Typical Costs (Thousands of 2016 Dollars per Lane Mile)									
	Add Lane	Add Equivalent of One Lane of Capacity at High Cost Due to Obstacle to Widening of Type*:							New Construction	
Category	If No Obstacles (Normal Cost)	A	B	C	D	E	F	G	New Alignment (Normal)	New Alignment (High)
Interstate										
Small Urban	$2,348	$5,772	$7,458	$7,516	$14,154	$8,145	$5,569	$5,376	$6,981	$24,713
Small Urbanized	$2,725	$7,502	$9,189	$8,879	$18,251	$10,068	$7,258	$7,022	$8,712	$30,842
Large Urbanized	$3,350	$9,349	$11,620	$10,321	$21,294	$13,001	$8,943	$8,511	$10,442	$36,968
Major Urbanized	$3,604	$11,027	$13,936	$12,650	$28,401	$16,485	$10,316	$9,696	$13,213	$46,775
Other Freeway and Expressway										
Small Urban	$2,257	$5,308	$6,925	$6,954	$13,594	$7,614	$5,089	$4,923	$6,558	$23,213
Small Urbanized	$2,619	$6,999	$8,619	$8,331	$17,524	$9,471	$6,747	$6,536	$8,228	$29,127
Large Urbanized	$3,216	$8,908	$11,031	$9,891	$20,442	$12,295	$8,517	$8,130	$9,935	$35,172
Major Urbanized	$3,458	$10,474	$13,173	$12,187	$27,264	$15,605	$9,788	$9,235	$12,546	$44,413
Other Principal Arterial										
Small Urban	$2,170	$4,954	$6,501	$6,502	$13,042	$7,192	$4,740	$4,588	$6,235	$22,072
Small Urbanized	$2,515	$6,586	$8,140	$7,873	$16,803	$8,966	$6,340	$6,145	$7,841	$27,756
Large Urbanized	$3,085	$8,530	$10,508	$9,525	$19,594	$11,657	$8,164	$7,815	$9,519	$33,697
Major Urbanized	$3,317	$10,022	$12,510	$11,825	$26,129	$14,829	$9,372	$8,878	$12,022	$42,556
Minor Arterial										
Small Urban	$1,974	$4,347	$5,822	$5,798	$12,270	$6,510	$4,116	$3,992	$5,655	$20,015
Small Urbanized	$2,275	$5,851	$7,338	$7,094	$15,863	$8,138	$5,594	$5,427	$7,149	$25,307
Large Urbanized	$2,779	$7,761	$9,602	$8,767	$18,569	$10,642	$7,404	$7,100	$8,756	$30,995
Major Urbanized	$2,982	$9,142	$11,444	$11,034	$24,917	$13,669	$8,502	$8,075	$11,100	$39,295
Major Collector										
Small Urban	$1,737	$3,806	$5,214	$5,159	$11,419	$5,903	$3,585	$3,472	$5,141	$18,200
Small Urbanized	$1,995	$5,148	$6,569	$6,346	$14,858	$7,344	$4,901	$4,748	$6,519	$23,079
Large Urbanized	$2,391	$6,881	$8,574	$7,898	$17,462	$9,498	$6,552	$6,286	$7,978	$28,243
Major Urbanized	$2,560	$8,229	$10,344	$10,211	$23,669	$12,473	$7,620	$7,248	$10,258	$36,312
Minor Collector										
Small Urban	$1,579	$3,320	$4,654	$4,576	$10,724	$5,337	$3,093	$3,004	$4,651	$16,465
Small Urbanized	$1,800	$4,545	$5,896	$5,698	$13,993	$6,642	$4,292	$4,164	$5,926	$20,977
Large Urbanized	$2,144	$6,184	$7,745	$7,211	$16,499	$8,565	$5,863	$5,640	$7,291	$25,809
Major Urbanized	$2,290	$7,410	$9,366	$9,481	$22,483	$11,422	$6,807	$6,494	$9,413	$33,323
Local										
Small Urban	$1,478	$2,964	$4,221	$4,123	$10,143	$4,898	$2,740	$2,669	$4,279	$15,146
Small Urbanized	$1,677	$4,107	$5,391	$5,215	$13,240	$6,109	$3,854	$3,747	$5,471	$19,368
Large Urbanized	$1,984	$5,668	$7,108	$6,706	$15,621	$7,834	$5,358	$5,173	$6,755	$23,911
Major Urbanized	$2,114	$6,681	$8,197	$8,792	$21,334	$10,061	$6,163	$5,982	$8,653	$30,632

* Obstacle widening types: A= Dense Development; B=Major Transportation Facilities; C=Other Public Facilities; D=Terrain Restrictions; E=Historic and Archaeological Sites; F=Environmentally Sensitive Areas; G=Parkland Areas

Source: Highway Economic Requirements System.

In the analysis conducted for this C&P Report edition, the update to the cost estimates reduced the estimates of investment needs in relation to the estimates that would have been obtained with the limited updating procedure used in the past several C&P Report editions. In the Maintain Conditions and Performance scenario, the reduction in average annual spending is from $118.0 billion to $98.0 billion, which equates to 16.1 percent; this simply indicates that the update had the overall effect of reducing the estimates of improvement costs. At the lower costs, however, more improvement projects pass the benefit-cost test; hence in the Improve Conditions and Performance scenario, the reduction in average annual spending is much smaller—from $167.5 billion to $165.9billion, or only 1.0 percent. Average annual investment in improvement types modeled in HERS is reduced from $68.7 billion to $54.7 billion (in the Maintain Conditions and Performance scenario) and from $92.8 billion to $91.7 billion (in the Improve Conditions and Performance scenario).[144]

Safety Costs

For each highway functional class, HERS estimates the average cost to society per vehicle crash from injuries and property damage. For injuries of varying severities, the estimated occurrence rate per crash is multiplied by the estimated cost per occurrence. The occurrence rates, which were last updated with 2007 data, indicate that few crashes produce fatalities. Across the highway functional classes, the numbers range from fewer than one death per 500 crashes on urban collectors to slightly over two deaths per 100 crashes on rural Interstates. The assumed cost per fatality equals the DOT estimate of the value of a statistical life in 2016, the base year for the modeling in this report. This value is a statistical summation of the benefit within the affected population of a reduction in crash fatality risk. Although few people would consider any amount of money to be adequate compensation for a person being seriously injured, much less killed, many can attach a value to changes in their risk of suffering an injury, even one that would be fatal, and indeed such valuations are implicit in everyday choices.[145]

The version of HERS used for this report incorporates new estimates of the cost per occurrence for nonfatal injuries and of the average per-crash property damage cost. The previous estimates captured only the costs from reported crashes. Although not a significant issue for crashes involving fatalities, many crashes involving lesser injuries or only property damage go unreported to authorities. The new estimates in the current version of HERS include costs from both reported and unreported crashes. The estimation procedures combine: (a) recent NHTSA estimates of property damage costs and of nonfatal injury rates by severity level with (b) DOT estimates for 2016 of the cost per nonfatal injury by severity level. For all nonfatal injuries, the inclusion of unreported occurrences increased the estimated cost per occurrence by 16.1 percent, and other modifications to the estimation procedures increased the estimate by a further 41.4 percent. For property damage, the new procedures increased the estimated cost per occurrence by 11.7 percent.

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/).

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[144] The reductions in the amount of investment programmed by HERS differ from the corresponding reductions in the scenario spending because of the application of the scaling procedures described in Chapter 10.

[145] 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, then 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.

Vehicle Operating Costs

Exhibit A-9 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-9* 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 \$0.303 vs. \$0.367). For a combination truck under the same conditions, the estimated reduction in operating costs would be 19 percent. (Note that these results would differ for roads with curves or grades.)

Exhibit A-9 ■ 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	$0.365	$0.318	$0.300	$0.303	$0.320	$0.351
95	$0.383	$0.337	$0.320	$0.324	$0.343	$0.378
170	$0.420	$0.374	$0.360	$0.367	$0.391	$0.433
Combination Trucks						
50	$0.936	$0.801	$0.750	$0.770	$0.853	$0.989
95	$0.980	$0.847	$0.801	$0.827	$0.918	$1.064
170	$1.074	$0.946	$0.911	$0.951	$1.062	$1.231

Source: Highway Economic Requirements System.

Emissions

For each of four types of emissions—CO, SOx, NOx, and PM—HERS estimates emission rates per VMT for three vehicle classes: four-tire vehicles; single-unit trucks; and combination trucks. The estimates are further differentiated by highway type according to location (rural vs. urban) and access arrangement (unrestricted vs. restricted). 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.

Unquantified Benefits

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.

Enhancements in Progress

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 American Transportation Research Institute Truck Data 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 nonfuel vehicle operating costs such as repair and maintenance, tire wear, mileage-related vehicle depreciation, and oil consumption. This effort is expected to be completed by the end of 2020.

Another research project underway will develop a Unified Pavement Distress Analysis and Prediction system (UPDAPS) for use in FHWA models. The project is specifically geared toward the pavement distress analysis requirements of HERS, the National Pavement Cost Model (NAPCOM), and the Pavement Health Track tool. The results of this project are expected to enable HERS to represent more accurately the relationship between pavement deterioration and factors such as traffic volumes and pavement characteristics.

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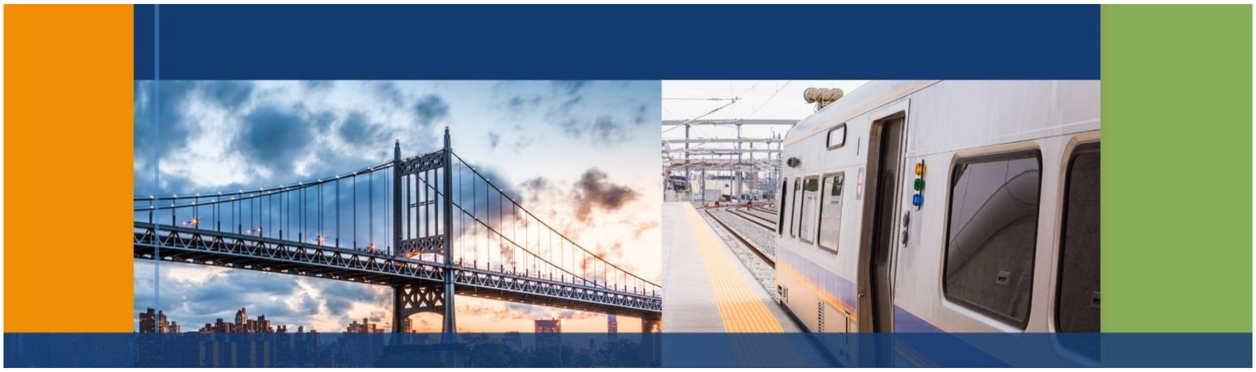


APPENDIX B: Bridge Investment Analysis Methodology

Bridge Investment Analysis Methodology

The National Bridge Investment Analysis System (NBIAS) is an investment analysis tool developed by the Federal Highway Administration (FHWA) to assess national bridge investment needs and evaluate the tradeoff between funding and performance. First introduced in the 1999 Conditions and Performance Report (C&P Report), NBIAS models the improvement needs of the more than 600,000 highway bridges in the National Bridge Inventory (NBI) and allows for the simulation of various investment scenarios. 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.

This appendix contains a brief overview of NBIAS, a technical description of the methods used in NBIAS to predict future nationwide bridge conditions and investment scenarios, and information on planned improvements to future versions of the system.

Overview

NBIAS is a software application that consolidates data from the NBI and other sources and incorporates economic forecasting analysis tools to estimate multiyear bridge repair, rehabilitation, and construction needs under multiple scenarios and budget constraints. It has multiple analytical capabilities and can be used to examine:

- Backlog of needs, in dollars and number of bridges;
- Schedule of work to be done under various investment scenarios (in dollars and number of bridges);
- User and aggregate economic benefits;
- Benefit-cost ratios for work performed; and
- Physical measures of bridge conditions.

NBIAS estimates functional and investment needs for bridges in the NBI through a combination of statistical models, engineering principles, and heuristic rules. Its analysis considers needs such as expansion (widening existing lanes), enhancement (raising or strengthening bridge structure), rehabilitation (maintenance and repair), and replacement. 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.

General Methodology

NBIAS analyzes each bridge in the NBI for each year in a multiyear analysis period through a program simulation model. The model simulates deterioration, traffic, preservation needs, functional needs, and costs. Outcomes can be grouped by type of work performed (i.e., maintenance, repair, widening), bridge functional classifications, bridges within the National Highway System, or bridges that are part of the Strategic Highway Network. Multiple financing scenarios can be run to better understand the impacts on overall bridge conditions of different budget constraints and investment approaches.

As illustrated in *Exhibit B-1*, the overall NBIAS approach can be summarized as follows:

- Data on the number, location, physical conditions, and traffic for the 600,000 highway bridges are pulled in from the NBI;
- Cost estimates for individual bridge elements and user parameters are pulled in from other FHWA sources;
- Deterioration algorithms for bridge elements are applied;

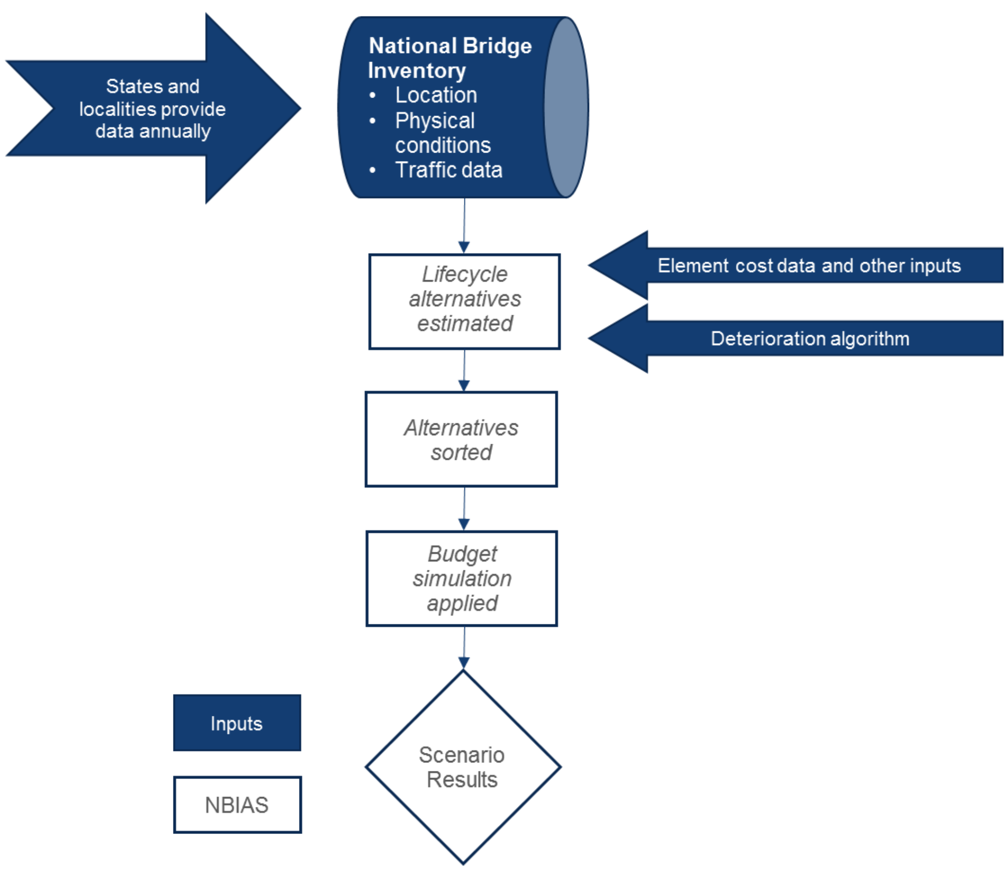
- Needs and estimates of alternative investment approaches for repair, rehabilitation, or replacement are estimated (based on the compiled data regarding conditions, projected deterioration, and cost estimates), and then sorted based on the performance implications of the different approaches along with their benefit-cost ratios;
- Budget constraints are applied to the set of bridges being analyzed; and
- Scenario results are presented for analysis.

When estimating bridge needs, NBIAS draws on the reported bridge conditions ratings to assess the condition of each bridge's elements and considers what changes are needed for those elements (see the "Bridge Element Data" box in Chapter 6 for more information on bridge elements in the NBI). NBIAS then assesses whether repairs or replacement of individual elements are needed, or if functional improvements—such as widening existing lanes and shoulders, increasing vertical or horizontal clearances, and strengthening (to carry heavier loads)—would be required.

NBIAS allows for multiple user-specified budget constraints. Users can set (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.

Once data are updated and the budget constraint applied, NBIAS calculates a tradeoff showing the effect of hypothetical funding levels on multiple performance measures using an adaptation of an incremental benefit-cost model.

Exhibit B-1 ■ Overview of NBIAS Approach

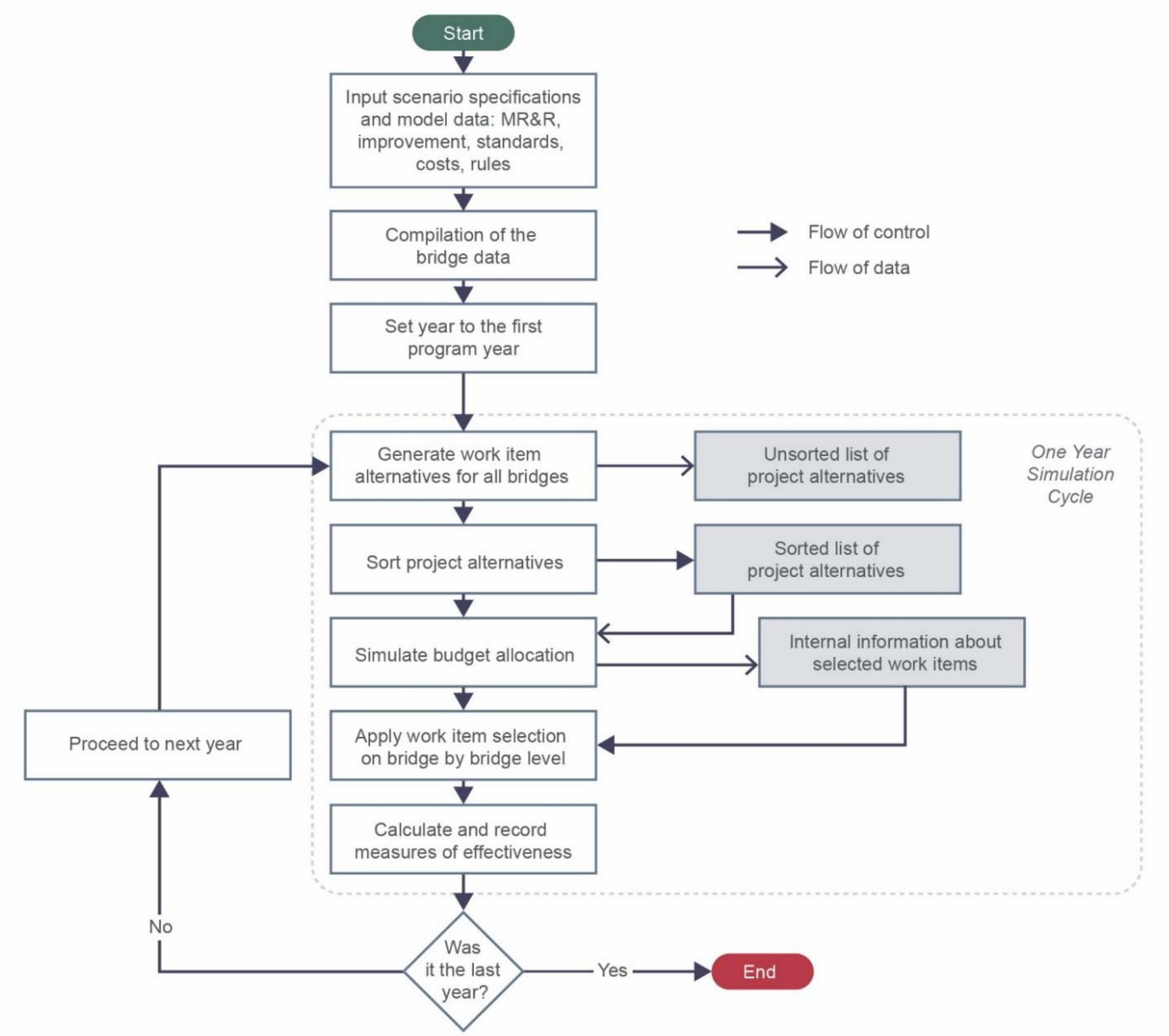


Note: NBIAS is National Bridge Investment Analysis System.

Exhibit B-2 is a more detailed flow chart of the series of steps in the NBIAS modeling and decision-making approach, performed for each year of the analysis period. The process begins with specifying scenarios and model data, compiling the bridge data, and then conducting multiple one-year simulation cycles. Models of element deterioration, feasible actions, and the cost and effectiveness of those actions are incorporated as major inputs into the analysis. Each simulation includes generating potential work, sorting the list of project alternatives, allocating the available budget, and simulating the results of the budget allocation.

Once the set of needs is established, the list of needs is sorted in decreasing order of incremental benefit-cost ratio (IBCR) of each alternative relative to the next cheaper alternative.[146] Projects are selected from that sorted list until the available budget is expended. This approach is repeated for each year of the analysis period, which may be up to 50 years.

Exhibit B-2 ■ NBIAS Program Simulation Steps



Note: NBIAS is National Bridge Investment Analysis System.

[146] The IBCR is essentially calculated by determining the differences in benefits and costs between two alternatives and then calculating the ratio of the equivalent worth of incremental benefits to that of incremental costs.

Bridge Data, Conditions, and Analysis Parameters

Before NBIAS can begin modeling bridge needs or any improvement scenarios, values for key inputs are needed. NBIAS must pull data on bridges and updated information costs for repairs and replacements and deterioration algorithms as needed. These key building blocks are discussed below.

Data on Bridge Inventory, Characteristics, and Cost

The NBIAS analyses presented in the 24th C&P Report build off the NBI database. The NBI covers nearly 600,000 bridges on public roads, including Interstate highways, U.S. highways, State and county roads, and publicly accessible bridges on Federal lands. Any bridge more than 20 feet long used for vehicular traffic is included in the inventory. The NBI includes identification information, bridge types, operational conditions, geometric data, and inspection data. States and localities submit data annually regarding the number, location, and general condition of their highway bridges.

Element-level cost data are pulled into NBIAS from other FHWA sources and incorporate a set of unit costs for various improvement and preservation actions. Replacement costs for structures are determined based on State-reported values gathered by FHWA. Improvement costs are adjusted to account for inflation.

Predicting Bridge Element Composition

Although the NBIAS uses NBI data to summarize and analyze the bridge inventory and overall conditions, it goes another level deeper in its analysis by evaluating bridges at the element level (e.g., deck, column, pier, railing). The system estimates the type, quantity, and condition of elements that exist for each bridge in the NBI by using 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 (e.g., truss, arch, suspension), material (e.g., wood, steel, concrete), 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 current 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 (for 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 in 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 applies deterioration algorithms to the elements and bridges in its database. NBIAS models bridge deterioration probabilistically; 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 (the same zones as in the Highway Performance Monitoring System).

Determining Maintenance, Repair, and Rehabilitation Needs

Once NBIAS has consolidated and organized data on bridge type, quantity, conditions, usage, costs for replacement or repair, and expected deterioration for elements on all the bridges in the NBI, it estimates the needs for those bridges by element. To determine maintenance, repair, and rehabilitation (MR&R) needs, NBIAS estimates the type, quantity, and condition of the 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.

Forming the Optimal Preservation Policy

The policy of MR&R in NBIAS is generated with the help of long- and short-term optimization models. The long-term model is formulated with the objective of keeping the elements in a condition that requires the minimum cost to maintain. The short-term model seeks to find a policy of remedial actions that minimize the cost of moving the inventory to conditions recommended by the long-term solution.

Applying the Preservation Policy

During the simulation process, the preservation policy is applied to each bridge in the NBI to determine bridge preservation work that is needed to minimize user and agency costs over time. 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 bridges in good, fair, and poor condition, weighted by deck area (to facilitate aggregating data between bridges).

Different Maintenance, Repair, and Rehabilitation Strategies

The modeling of a policy for maintenance, repair, and rehabilitation (MR&R) is an important input to NBIAS and can significantly influence the results due to the number of bridge replacements identified. MR&R in NBIAS is modeled using a linear optimization solved for each combination of structural element, condition state, operating environment, climate zone, and U.S. State. The output of the optimization is a specification of what action to take in each condition state to achieve the specific policy direction (minimize life-cycle costs, maximize bridge performance). User costs (for decks) are considered and a penalty function is included that varies based on condition.

Although the bridge analyses prepared for this report use a MR&R strategy directed at bringing all bridges to a good condition, described as a State of Good Repair strategy, several MR&R strategies can be used in NBIAS:

- Minimize MR&R Costs

  This strategy involves identifying and implementing a pattern of MR&R improvements that minimize 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. Previously, some 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 might call for a bridge to be replaced sooner than might actually be the case.

- 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 Costs 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, whereas smaller MR&R investments would be needed in the later years to sustain bridge conditions. This strategy is the most aggressive of the four available.

The State of Good Repair strategy, although the most aggressive, generates results more consistent with agency practices and recent trends in bridge condition than do the other strategies, and has been used in the previous two C&P reports.

(*Please note that, despite the similarity in names, the NBIAS State of Good Repair strategy and the state of good repair benchmark presented in Chapter 7 (Capital Investment Scenarios) are not the same. The state of good repair benchmark includes all investments identified as cost−beneficial by NBIAS and includes both MR&R investments and functional* improvements.)

Determining Functional Improvement Needs

NBIAS also assesses what functional improvements would be needed for bridges in the inventory. Functional improvement needs are determined by applying user-specified standards to the existing bridge inventory, subject to benefit-cost considerations. NBIAS also includes a set of standards by functional class that are derived from sufficiency rating calculations, standards prescribed by the Florida Department of Transportation models, and previous bridge investment analysis systems. For example, raising a bridge will be identified as a bridge improvement option if the vertical clearance under the bridge fails to meet the specified standard and if the costs associated with diverting traffic around the bridge exceed the cost of improving the bridge.

NBIAS estimates needs for the following types of bridge functional improvements:

- Widening existing bridge lanes,
- Raising bridges to increase vertical clearances,
- Strengthening bridges to increase load-carrying capacity, and
- Replacement.

When other functional improvements are determined to be infeasible, a replacement need is generated. NBIAS also 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 minimal tolerable conditions (the system user specifies the threshold for such a determination), the system might consider bridge replacement to be the only feasible alternative. 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.

When NBIAS selects a structure for replacement, it replaces it with one of the same type and capacity, irrespective of whether added capacity is needed. Thus, the cost of adding lanes to satisfy increased capacity demands is not included in the cost to construct the replacement structure, and the benefits of added capacity are considered as a separate project—even if there would be additional benefits (or cost savings) of combining the two.

When evaluating and prioritizing various functional improvement projects, the improvement benefits increase with the projected traffic. Therefore, whether a functional improvement is justified in NBIAS depends greatly on predicted traffic. In the current version of NBIAS, traffic predictions are made for each year in an analysis period based on NBI data and national level vehicle miles traveled forecasts prepared by the Volpe National Transportation Systems Center (see Chapter 10 for details).

Future NBIAS Enhancements Currently Underway

Several enhancements are being introduced for future versions of NBIAS. Two of these enhancements relate to refining the use of budget parameters in scenario analyses. One improvement is to enable the user to assign individual budgets for specific work categories, such as maintenance, rehabilitation, and replacement of bridges in poor condition, instead of providing a single budget for all actions. This capability will enable users to consider a broader array of potential alternative future investment strategies. The second improvement will modify NBIAS to improve its ability to determine budget levels required to meet user-defined performance measures. This feature will enable users 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.

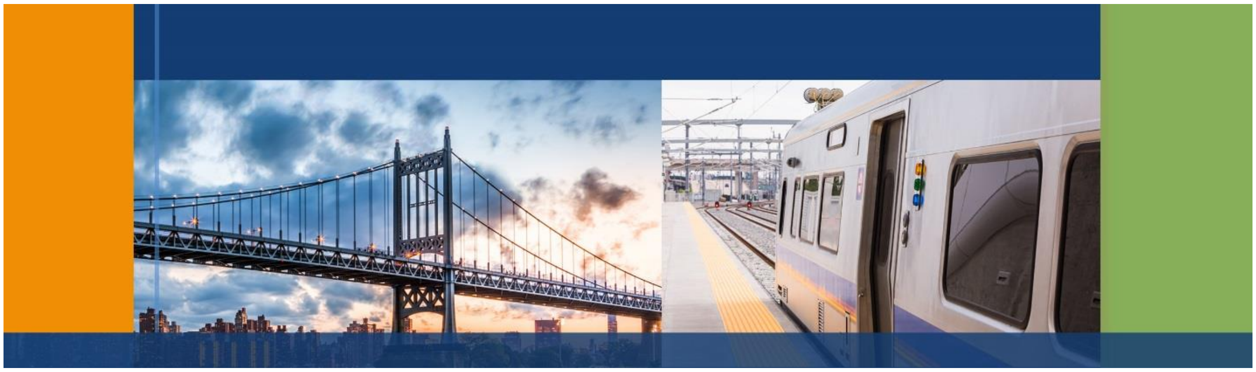
Another set of important enhancements relate to updating element specifications and refining element performance algorithms. NBIAS was developed using the AASHTO Commonly Recognized Elements specification. This standard was recently superseded by the AASHTO Manual for Bridge Element Inspection. FHWA 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.

Additionally, functionality is being added to NBIAS to enable analysis of culverts. Upcoming versions of NBIAS will incorporate projections of culvert deterioration, future overall culvert conditions, and estimation of the costs of culvert maintenance and replacement.

Culverts in the NBI and NBIAS

Culverts are structures that allow water to flow under another structure such as a roadway or bridge. 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 NBI reporting requirements. Currently, data for approximately 125,000 culverts are included in the NBI.

The current 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. Future versions of NBIAS currently under development will incorporate the necessary algorithms and data to include culverts.



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 biennial 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 (24th) 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 (rehabilitations and replacements) 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 here.

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 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 relationships and the ways in which 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 497 urbanized areas as well as for 10 regional groupings of rural operators. Fundamental data, such as current and anticipated population, in addition to more transit-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 959 urbanized transit agencies and 1,590 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 merged into a single agency mode within this table.

Asset Type Data Table

The asset type data table identifies approximately 500 different asset types used 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 in greater detail 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 earlier in this section 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 is 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 (although 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 (24^{th}) 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 Recent 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 assumptions 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 earlier in this section 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 in this section.

Asset Rehabilitation and Replacement Investments

TERM's asset rehabilitation and replacement forecasts are designed to estimate annual funding needs 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

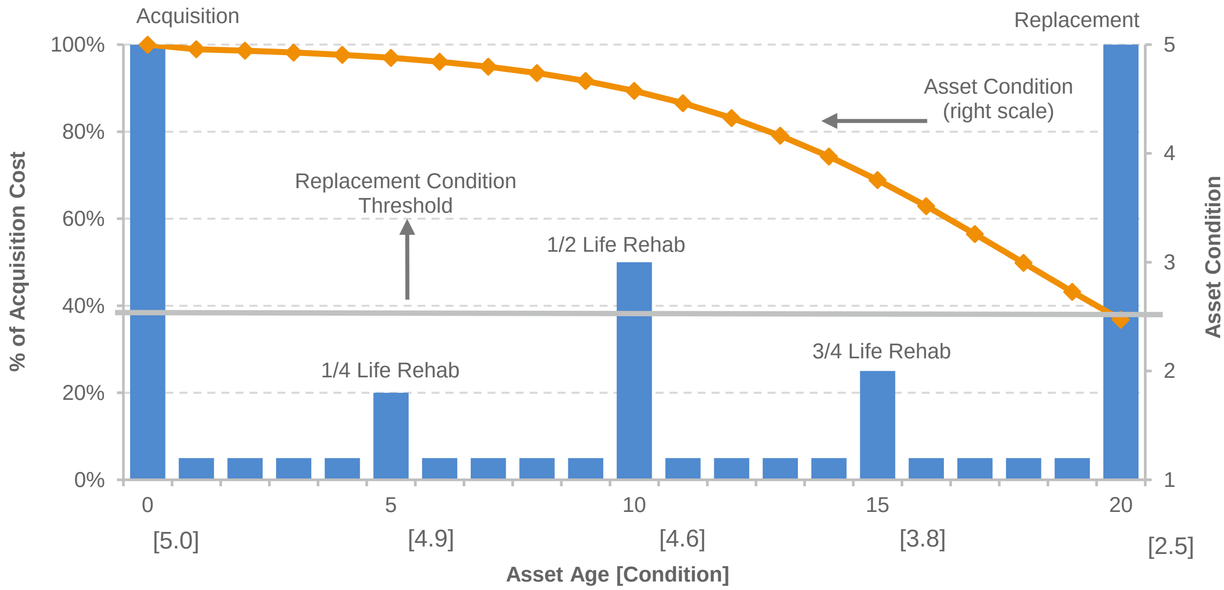
Source: Transit Economic Requirements Model (TERM).

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 it passes 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 497 urbanized areas (e.g., based on the urbanized area's specific growth rate projections or historical rates of transit passenger mile growth), whereas 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 projected growth in ridership is sufficient 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, whereas 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

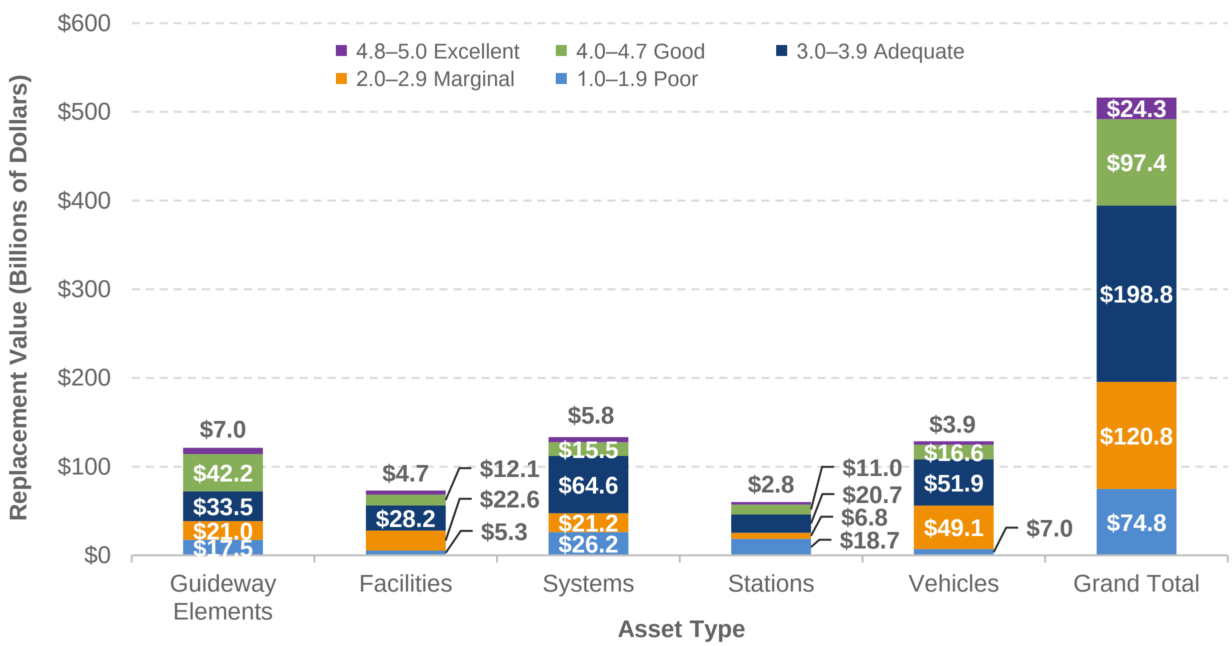
TERM asset decay curves were developed expressly for use within TERM and are comparable to asset decay curves used in other modes of transportation and bridge and pavement deterioration models. Although the collection of asset condition data is not uncommon within the transit industry, TERM asset decay 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 2016.

Exhibit C-3 ■ Distribution of Asset Physical Condition by Asset Type for All Modes, 2016

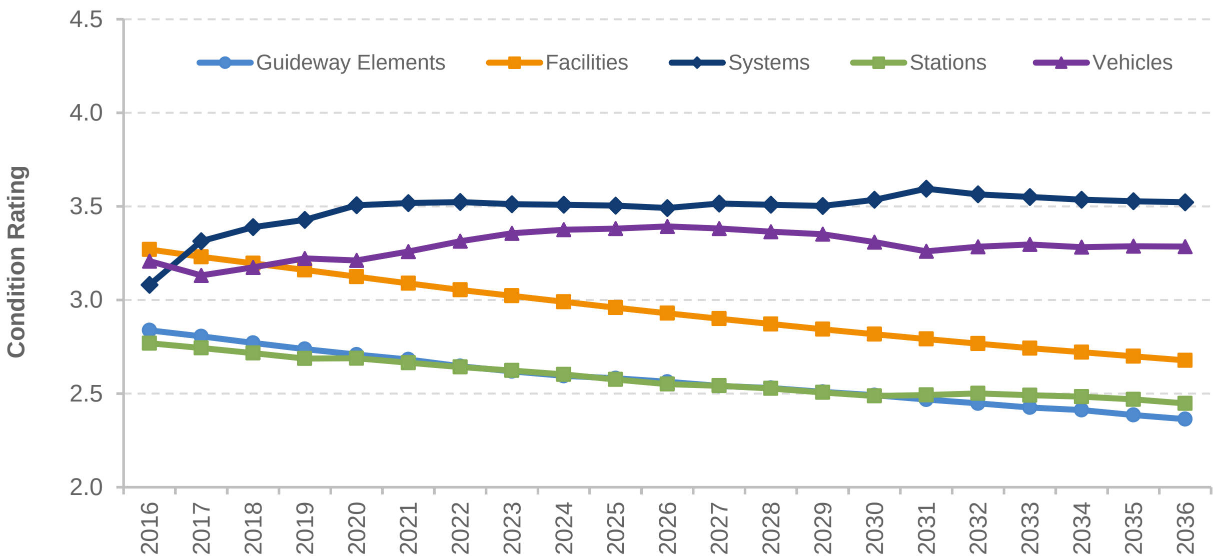


Source: Transit Economics Requirements Model (TERM).

Exhibit C-3 shows the proportion and replacement value of assets in each condition category (e.g., excellent, good) 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.

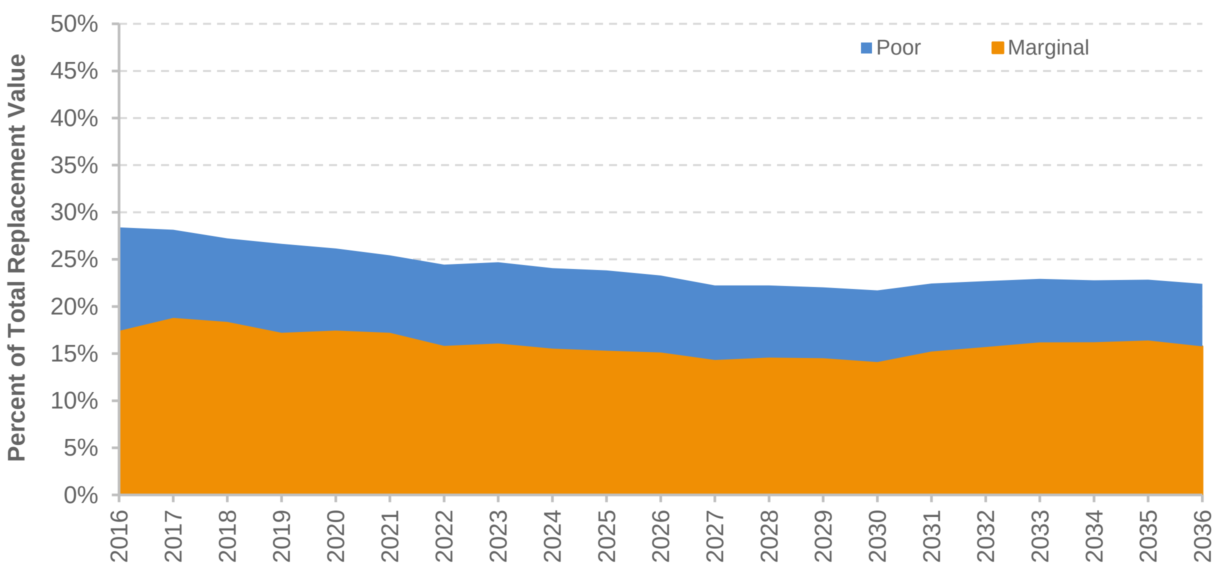
TERM also uses the decay curves to predict expected future asset conditions under differing capital reinvestment funding scenarios. An example of this type of analysis is presented in *Exhibits C-4* and *C-5*, which present TERM forecasts of the future condition of the national transit assets assuming 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-4 ▪ Weighted Average by Asset Category, 2016–2036



Source: Transit Economics Requirements Model (TERM), Sustain Recent Spending.

Exhibit C-5 ▪ Assets in Marginal or Poor Condition, 2016–2036



Source: Transit Economics Requirements Model (TERM), Sustain Recent Spending (excludes unreplaceable assets).

Determining the Timing of Reinvestment

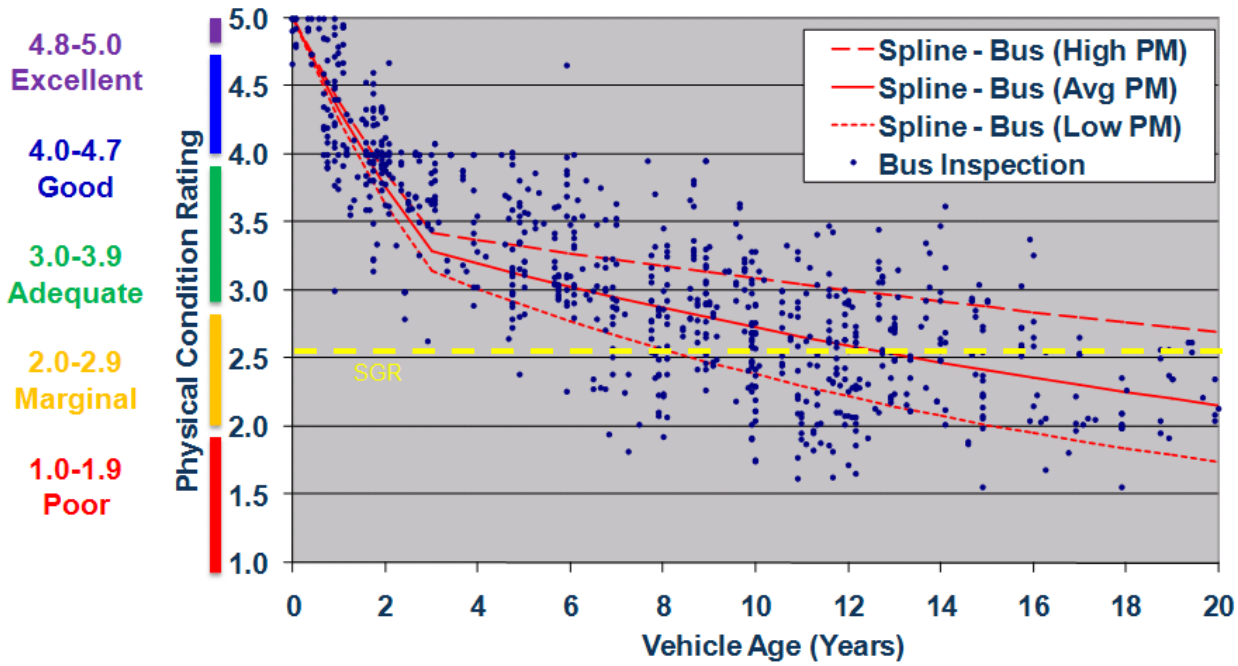
Another key use of the TERM asset decay curves is to determine when the individual assets identified in the asset inventory will require either rehabilitation or replacement, with the ultimate objective of estimating replacement needs and the size of the state of good repair (SGR) backlog. Over the 20-year 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 whereas others, such as radios, do not.

Developing 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: Federal Transit Administration; 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 (B/C < 1).

The TERM B/C module is a business case assessment of each agency-mode combination (e.g., "Metroville Bus" or "Urban City Rail") identified in the NTD. Rather than assessing the B/C 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 (rehabilitation-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 1 (B/C < 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.

The specific calculations used by the TERM B/C module—comparing the stream of investment benefits for agency mode "j" against the stream of ongoing costs, calculated over the TERM 20-year analysis horizon—is presented in this equation:

$$Benefit/Cost\ Ratio_{agency-mode\ j} =$$

$$\left\{ \frac{\sum_{t=1}^{20} \left\{ \left(\left(User,\ Agency\ \&Social\ Benefits_{j,t=0} \right) * \left(1 + TMP\ Growth_j\right)^t \right) / \left(1+i\right)^t \right\}}{\sum_{t=1}^{20} \left\{ \left(ReplaceCost_{j,t} + Expansion\ Cost_{j,t} + \left(O\ \&\ M\ Costs_{j,t} * \left(1 + TPM\ \ Growth_j\right)^t \right) \right) / \left(1+i\right)^t \right\}} \right\}$$

Why Use a Systemwide Business Case Approach?

TERM considers the cost-benefit of the entire agency rail investment vs. 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.

<u>Lack of Empirical Benefits Data</u>: The marginal benefits of transit asset reinvestment are 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 not well understood. No industry standard metrics exist that tie 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 (5) a central train control system and located on (6) a foundation, such as elevated structure, subway, or retained embankment. 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 B/C ratio. Similarly, all expansion investments are assigned the same failing B/C 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 share of investment benefits (roughly 86 percent of total benefits) accrues 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 vs. 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 earlier, little to no data are available to measure these cost savings. That said, some data do exist that can be used to evaluate these benefits, mostly related to fleet reinvestment, but were 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 section 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 SGR. 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 subject to four main limitations:

1. 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.
2. 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.
3. 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.
4. 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:

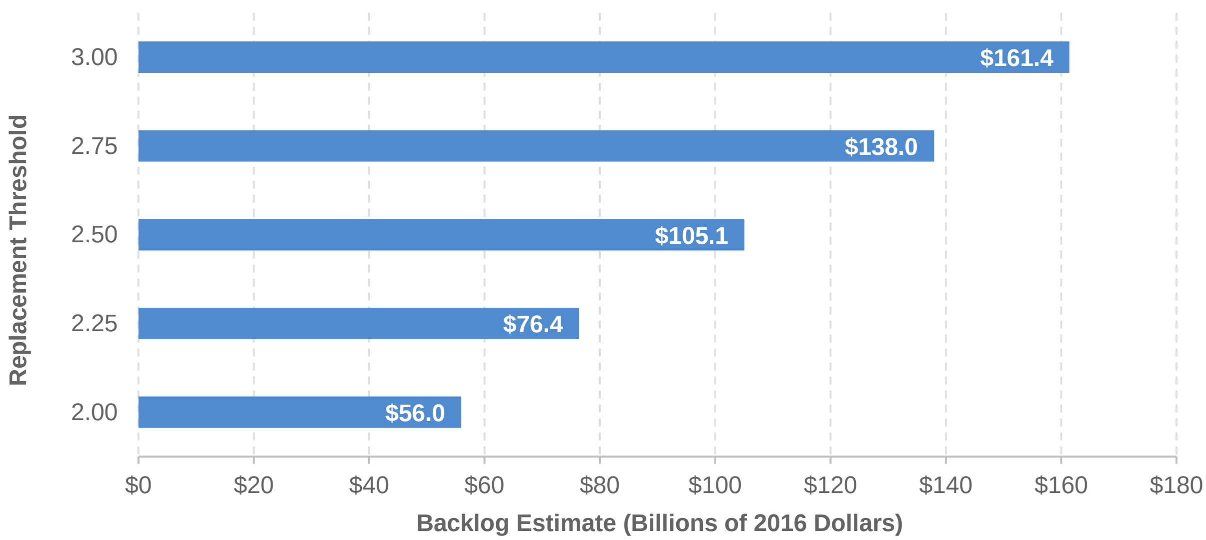
1. NTD data on vehicle assets, including vehicle types, quantities, and ages of all rail cars, buses, vans, and other revenue vehicles used by grantees to provide transit service.
2. Data requests to a sample of the Nation's largest (primarily rail) operators and special studies for all other asset categories.

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 varied and continues to undergo significant change. The nature and magnitude of these ongoing changes in local agency inventory quality and level of detail have similarly resulted in significant changes to the national inventory data set on which TERM relies. Consequently, these changes result in inventory data sets 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 estimated SGR backlog 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 (TERM).

What Does the Backlog Trend Reveal?

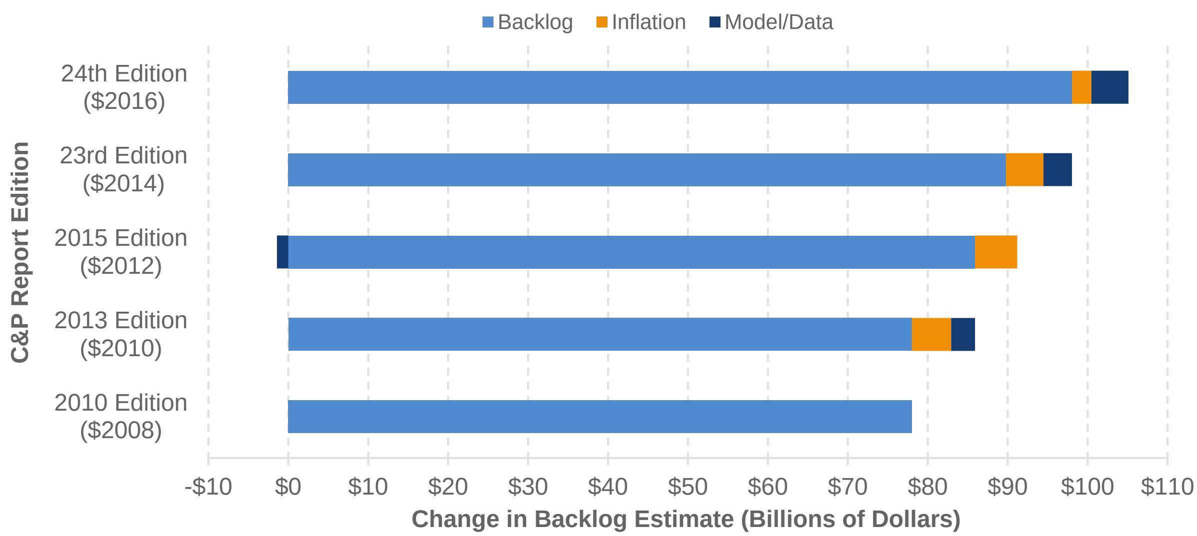
The backlog estimate has been increasing steadily since the first estimate was published in the 2010 C&P Report. Changes in the backlog over that period are a function of four causes:

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 2018 reports (63 percent) is caused by inflation, as shown in *Exhibit C-8*.

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 C-8 ■ Change in Backlog Estimate Since the 2010 C&P Report



Source: Transit Economic Requirements Model (TERM).

How to Eliminate or Mitigate the Issues?

Many of the 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. It is very likely that the SGR backlog estimate will undergo significant variation from recent levels after the first few years of expanded NTD reporting, followed by a steadier long-term rate of increase.

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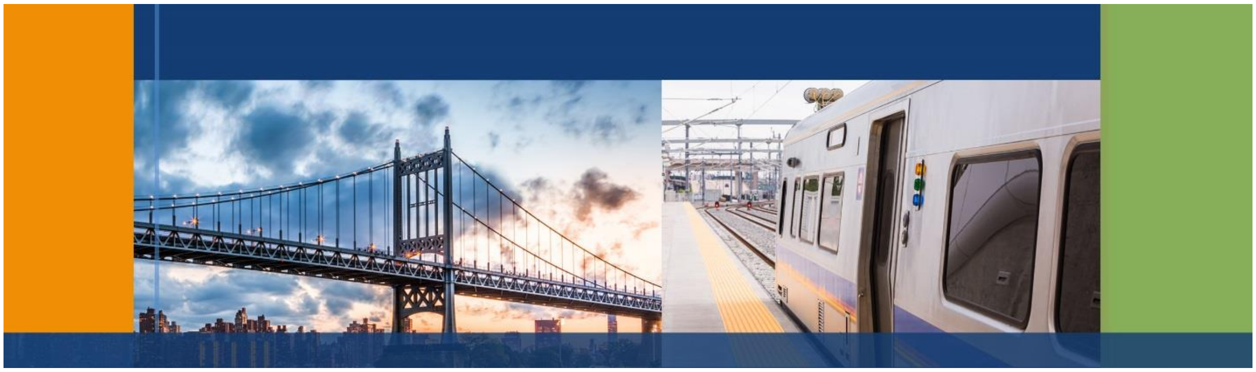


APPENDIX D: Reimagining the C&P Report

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 the Federal-aid Highway Program. States have set targets for several key performance measures and are reporting on their progress in meeting these targets. This shift toward more performance-driven and outcome-based programs has direct and indirect implications for future C&P Reports. At the most basic level, the introduction of other performance reporting requirements in MAP-21 might necessitate some content changes to future C&P Reports, both to take advantage of newly available data and to avoid unnecessary duplication of information presented elsewhere. The accompanying 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, TERM, and NBIAS.

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: communication and methodology. Two major research projects were initiated in 2014, one with the objective of enhancing communication approaches and the other aimed at improving estimation methodologies to compute investment needs.

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. Based on recommendations from the completed research project to enhance communication approaches, 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. 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.

Another potential improvement under consideration, based on recommendations from the research project on communication approaches, 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 of data 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 tables and images; and
- Facilitating more frequent data updates than are currently possible for the C&P Report.

A follow-on to the 2014 communication project is underway to explore alternatives for enhancing the current report, focusing on data visualization and an interactive Web-based design. The underlying goal of this multiyear effort 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 follow-on 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 being developed to help readers visualize complex information on highways, bridges, and transit, making the details easier to understand at a glance, some of which have already been integrated into the 23rd and this 24th edition. FHWA is exploring ways to condense contents of each chapter into formats that are more accessible to the public, such as bullet points, at-a-glance boxes, and content optimization for print layout.

For the online version of the C&P, FHWA is examining ways to present selected contents through interactive data visualization to convey information from in-depth and complex analytics. Through their intuitive interfaces, data visualization tools enable customized analytical views with flexibility and ease by multiple users with diverse demands. One option being considered is an online platform to support the use of more dynamic and interactive graphics, such as customized dashboards and charts filtered per the user's unique needs. For example, an interactive pavement ride quality dashboard would depict percent of vehicle miles traveled (VMT) on pavements with good, fair, and poor ride quality by functional classification. The user would have the option to filter results by year, by urban and rural boundary, ride quality (good/fair/poor), and roadway functional system. Then the user may decide to download the supporting data in different data formats, save an image for a presentation, or share the link to the exhibit on the social media.

Web-based User Interface

Another part of this follow-on effort is the development of a demonstration C&P website allowing FHWA to explore and evaluate visualization techniques and tools that could be used online. A goal of this exercise 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.

Methodology Improvement

The ability to analyze and forecast future investment needs of the Nation's highways and bridges has been and will continue to be a bedrock of FHWA responsibility. FHWA continues to seek ways to improve its analytical tools, as can be seen in its ongoing research project to improve estimation methodologies to compute investment needs.

Simulation modeling, used to forecast usage and investment needs, 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 Report reflect several analytical simplifications introduced to conduct 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, TERM, and NBIAS are being revised and updated continually to incorporate newly refined 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 potential alternative 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, value for money is another methodology that measures wider economic and reliability benefits.[147] 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

[147] 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/.

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 would be challenging.

Other assessed methodologies and tools that may be used to incorporate additional performance measures into the C&P Reports include integrated land use and transport models, 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—the 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 Methodology

After identifying BCA as the main methodology for investment prioritization for the C&P analysis, the second stage in this research effort involved identifying and specifying alternative techniques to refine the current BCA approach. After reviewing many options, four possible alternative refinements were picked for in-depth study to evaluate their feasibility and relevance to be integrated into the HERS framework: integrating performance measures, tradeoff analysis, freight analysis, and incorporating 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 tradeoff 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), tradeoff 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 167(h) of title 23, United States Code requires a biennial report describing the conditions and performance of the National Highway Freight Network, which is included in Part III of this report. Options for enhancing freight analysis capabilities for the C&P Report are being explored as part of the effort to reimagine the C&P Report. 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. Another option is to include additional logistics-specific benefits for national freight network corridors.

The 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 change 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 related to C/AV, including a time frame for introduction and adoption, market penetration, and automation level mix. Impacts of C/AV on highway conditions and performance are bracketed between different partial and full automation scenarios.

FHWA also considered the feasibility of integrating needs analysis for pedestrian and cyclist infrastructure and of integrating network analysis into the C&P highway needs assessment. However, these two enhancements can be implemented only after the establishment of data standards and appropriate modeling approaches. For current research efforts, only the four refinements discussed above are being further explored for the feasibility of being integrated into the HERS framework.

Integration of Performance Management and Needs Estimation

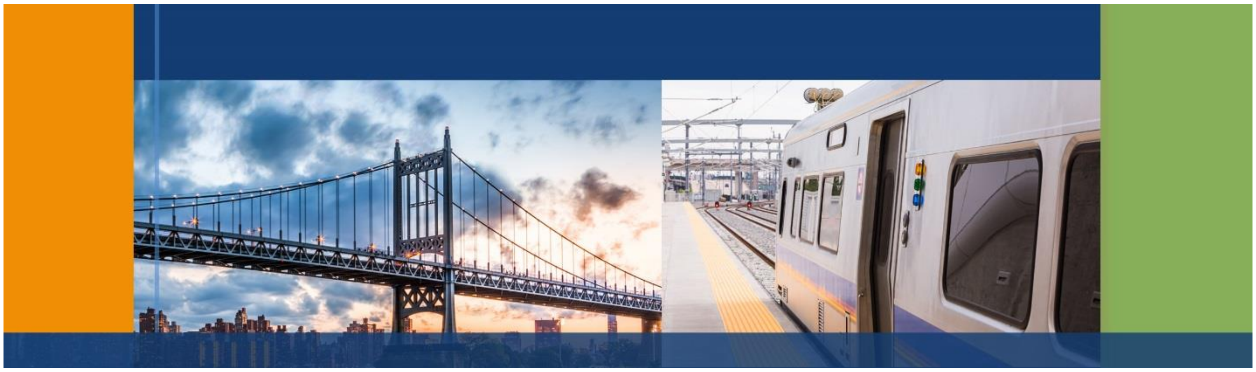
With the completion of the systematic review of tools and potential new improvements, the project has now moved to the next stage, which involves integrating the findings identified in the assessments of BCA refinements and alternative decision methodologies with HERS modeling. This combination will enable a detailed evaluation and comparison of several comprehensive approaches to upgrading the current national needs estimation process. The decision of feasible combination will be based on policy priority, data availability, the time requirement, and program coding complexity.

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.

Moving Forward

FHWA invited an external panel of experts representing State departments of transportation, MPOs, academia, and other experts to review the analytical framework of the C&P reports in mid-2018. The review presented a series of recommendations for research options to improve the methodologies, models, and tools in C&P reporting and the feasibility of implementation.

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.



APPENDIX E: List of Required Elements for State Freight Plans

List of Required Elements for State Freight Plans

Section 70202(b) of Title 49, United States Code (U.S.C.) lists 10 required elements that all State Freight Plans must address for each of the transportation modes:

1. An identification of significant freight system trends, needs, and issues with respect to the State;
2. A description of the freight policies, strategies, and performance measures that will guide the freight-related transportation investment decisions of the State;
3. When applicable, a listing of

    a. Multimodal critical rural freight facilities and corridors designated within the State under 49 U.S.C. § 70103 (National Multimodal Freight Network);

    b. Critical rural and urban freight corridors designated within the State under 23 U.S.C. § 167 (National Highway Freight Program);
4. A description of how the plan will improve the ability of the State to meet the national multimodal freight policy goals described in 49 U.S.C. § 70101(b) and the national highway freight program goals described in 23 U.S.C. § 167;
5. A description of how innovative technologies and operational strategies, including freight intelligent transportation systems, that improve the safety and efficiency of freight movement were considered;
6. In the case of roadways on which travel by heavy vehicles (including mining, agricultural, energy cargo or equipment, and timber vehicles) is projected to substantially deteriorate the condition of the roadways, a description of improvements that may be required to reduce or impede the deterioration;
7. An inventory of facilities with freight mobility issues, such as bottlenecks, within the State, and for those facilities that are State owned or operated, a description of the strategies the State is employing to address those freight mobility issues;
8. Consideration of any significant congestion or delay caused by freight movements and any strategies to mitigate that congestion or delay;
9. A freight investment plan that, subject to 49 U.S.C. § 70202(c)(2), includes a list of priority projects and describes how funds made available to carry out 23 U.S.C. § 167 would be invested and matched; and
10. Consultation with the State Freight Advisory Committee, if applicable.

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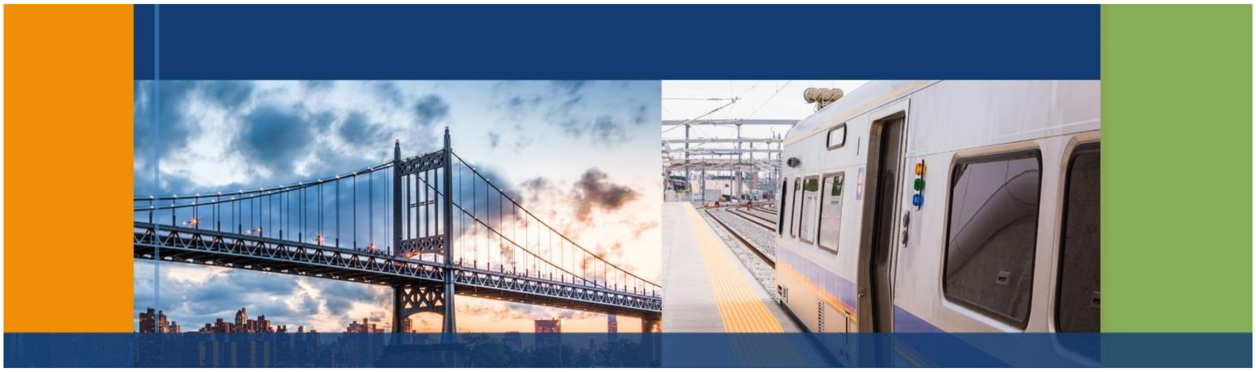

APPENDIX F: List of Critical Urban Freight Corridors and Critical Rural Freight Corridors

State	Route No.	Start Point	End Point	Length (miles)	CUFC and CRFC ID Codification	CUFC = U CRFC = R
Alabama						
Alaska						
Arizona	US 93	0.67	70.435	69.765	G	R
Arizona	US 93	91.35	168.249	76.899	G	R
Arizona	US 191	62.35	63.39	1.04	G	R
Arizona	SR 69	262	279.094	17.094	G	R
Arizona	S 085 1	0	0.647	0.647	G	R
Arizona	S 085 2	120.438	155.104	34.666	G	R
Arizona	SB 008 3	118.401	120.438	2.037	G	R
Arizona	SR 189	0	2.975	2.975	E	R
Arizona Subtotal				**205.123**		
Arkansas						
California	Britannia Boulevard	I-905	La Media Road	2.15	H, I, J, K	U
California	La Media Road	I-905	International Border	2.27	H, I, J, K	U
California	SR-11	Junction SR 905/SR 125	1/4 mile, 400' east of Sanyo Avenue	0.64	H, I, J, K	U
California	SR-11	Enrico Fermi Drive	Future Otay Mesa East Port of Entry	1.58	H, I, J, K	U
California	SR-11	1/4 mile, east of Sanyo Avenue	Enrico Fermi Drive	0.51	E, F, G	R
California Subtotal				**7.15**		
Colorado	006J	404.11	404.74	0.67	C, D, F, G	R
Colorado	006Z	0	0.6	0.63	C, D, F, G	R
Colorado	014C	236.1	236.92	0.82	C, D, F, G	R

State	Route No.	Start Point	End Point	Length (miles)	CUFC and CRFC ID Codification	CUFC = U CRFC = R
Colorado	017A	0	1.5	1.51	G	R
Colorado	017A	16	17.5	1.49	G	R
Colorado	050A	122	127	5.14	G	R
Colorado	050A	209	210	1.02	G	R
Colorado	050A	190	191	1	G	R
Colorado	050B	432.88	438.1	5.28	A, B, D, G	R
Colorado	085B	191	194.5	3.61	C, F, G	R
Colorado	085C	257	260	2.99	B, C, D, F, G	R
Colorado	138A	0	1.6	1.6	C, D, F, G	R
Colorado	138Z	0	0.61	0.64	C, D, F, G	R
Colorado	145A	48	55	5.96	G	R
Colorado	145A	60	71	10.98	G	R
Colorado	160A	144	186	41.77	G	R
Colorado	285B	119	120	1.01	G	R
Colorado	285B	125	126	1.01	G	R
Colorado	287A	72.47	77.64	5.21	A, B, D, G	R
Colorado	550B	70	81	11.01	G	R
Colorado	550B	87	96	8.92	G	R
Colorado	550B	48	54	5.96	G	R
Colorado	550B	64	65	1.01	G	R
Colorado Subtotal				**119.24**		
Connecticut	US 44	0	26.74	26.7	E	R
Connecticut	US 44	31.02	32.61	1.6	E	R
Connecticut	US 44	77.08	97.23	20.2	E	R
Connecticut	US 7	39.94	44.43	4.5	C	R
Connecticut	US 7	45.41	78.29	32.9	C	R
Connecticut	US 6	79.79	89.06	9.3	B	R
Connecticut	US 6	95.59	106.62	11	B	R
Connecticut	US 6	114.12	116.33	2.2	B	R
Connecticut	US 202	26.98	40.14	13.2	H	R
Connecticut	US 202	47.19	54.82	7.6	H	R
Connecticut	SR 20	23.27	25.21	1.9	D	R
Connecticut	SR 189	17.5	20.32	2.8	G	R
Connecticut	SR 2	43.58	54.25	10.7	A	R
Connecticut	US 44	26.74	31.02	4.3	E	U
Connecticut	US 44	32.61	46.27	13.7	E	U
Connecticut	US 44	46.44	53.47	7	E	U
Connecticut	US 7	44.43	45.41	1	C	U
Connecticut	US 6	76.58	79.79	3.2	B	U
Connecticut	US 6	89.06	95.59	6.5	B	U
Connecticut	US 6	106.62	114.12	7.5	B	U
Connecticut	US 202	40.14	47.19	7.1	H	U
Connecticut	US 202	54.82	55.63	0.8	H	U

State	Route No.	Start Point	End Point	Length (miles)	CUFC and CRFC ID Codification	CUFC = U CRFC = R
Connecticut	SR 20	21.87	23.27	1.4	D	U
Connecticut	SR 20	25.21	31.01	5.8	D	U
Connecticut	SR 189	12.87	17.5	4.6	G	U
Connecticut	SR 75	4.92	8.38	3.5	F	U
Connecticut	SR 2	36.96	43.58	6.6	A	U
Connecticut	SR 2	54.2 5	56.3	2.1	A	U
Connecticut Subtotal				**219.7**		
Delaware	US 202	Delaware/Pennsylvania line	I-95 Interchange	5.09	K	U
Delaware	US 13	I-495 Interchange	I-295 Interchange	1.81	I, J	U
Delaware	US 40	I-295 Interchange	SR 896	11.16	K, I	U
Delaware	DE 896	I-95 Interchange	Churchtown Road/Boyd's Corner intersection	10.46	J, K	U
Delaware	SR 1 (Segment A)	I-95 Interchange	US 13 Overpass (urban boundary)	4.77	H, K	U
Delaware	SR 1 (Segment B)	Former Gov. Lea Road crossover	Lorewood Grove Road (Exit 148)	4.12	H, K	U
Delaware	SR 1 (Segment C)	Paddock Road overpass	S. Smyrna Exit (Exit 114)	2.82	H, K	U
Delaware	SR 1 (Segment D)	Twin Willows Road overpass	Leipsic River crossing	0.82	H, K	U
Delaware	SR 1 (Segment E)	Emergency Access ramp	Dyke Branch Road	1.62	H, K	U
Delaware	SR 1 (Segment F)	Exit 104 ramp	0.35 mi. south of Leipsic Road overpass	1.7	H, K	U
Delaware	SR 1 (Segment G)	White Oak Road overpass	SR 9 Interchange (Exit 91)	5.9	H, K	U
Delaware	SR 1 (Segment H)	Mulberrie Point Road	SR 12 Interchange	2.45	H, K	U
Delaware	US 13 (Segment A)	Puncheon Run (Exit 97)	Longacre Drive	6.43	H, K	U
Delaware	US 13 (Segment B)	North of Barney Jenkins Road	South of Killens Pond Road	5.52	H, K	U
Delaware	US 13 (Segment C)	Cannon Road	North of Delmarva RV Center	4.66	H, K	U
Delaware	US 13 (Segment D)	Airport Road	Boyce Road	2.23	H, K	U
Delaware	US 13 (Segment E)	N. of Discount Land Road	Kurtz Road	0.66	H, K	U
Delaware	US 13 (Segment F)	Sycamore Road	Laurel Road	0.74	H, K	U
Delaware	US 13 (Segment G)	Near US 13 Dragway	Delaware/Maryland line	0.93	H, K	U
Delaware	US 9	US 13	.41 miles east of US 13	0.41	K	U
Delaware	SR 1 (Segment I)	US 13 Overpass (urban boundary)	Former Gov. Lea Road crossover	1.45	F, G	R
Delaware	SR 1 (Segment J)	Lorewood Road	Paddock Road	17.76	F, G	R
Delaware	DE 896	Churchtown Road/Boyd's Corner intersection	SR 1 Interchange (Exit 142)	3.72	F, G	R
Delaware	SR 1 (Segment K)	S. Smyrna Exit (Exit 114)	Twin Willows Road overpass	2.38	F, G	R
Delaware	SR 1 (Segment L)	Leipsic River Crossing	Emergency Access ramp	1.33	F, G	R
Delaware	SR 1 (Segment M)	Dyke Branch Road	Exit 104 ramp	0.37	F, G	R
Delaware	SR 1 (Segment N)	0.35 mi. S. of Leipsic Road overpass	White Oak Road overpass	1.27	F, G	R

State	Route No.	Start Point	End Point	Length (miles)	CUFC and CRFC ID Codification	CUFC = U CRFC = R
Delaware	SR 1 (Segment O)	SR 9 Interchange (Exit 91)	Mulberrie Point Road	4.07	F, G	R
Delaware	SR 1 (Segment P)	SR 12 Interchange	US 9, Lewes	26.07	F, G	R
Delaware	US 13 (Segment H)	Longacre Drive	N. of Barney Jenkins Road	1.38	F, G	R
Delaware	US 13 (Segment I)	S. of Killens Pond Road	Cannon Road	19.72	F, G	R
Delaware	US 13 (Segment J)	N. of Delmarva RV Center	Airport Road	0.81	F, G	R
Delaware	US 13 (Segment K)	Boyce Road	N. of Discount Land Road	1	F, G	R
Delaware	US 13 (Segment L)	Kurtz Road	Sycamore Road	0.3	F, G	R
Delaware	US 13 (Segment M)	Laurel Road	Near US 13 Dragway	5.95	F, G	R
Delaware	US 9	.41 miles east of US 13	SR 1, Lewes	24.59	D, G	R
Delaware	US 113	SR 1/US 113 Split	Delaware/Maryland line	37.29	D, G	R
Delaware Subtotal				**223.76**		
Florida	SR 20	SR 79	County Road 83 Alternate	10.37	B	R
Florida	SR 20	US 231	SR 79	1.17	A	R
Florida	SR 20	US 231	SR 79	16.68	C	R
Florida	SR 331	US 301	County Road 225 Alternate	1.87	A	R
Florida	SR 528	SR 417	I-95	37	G	R
Florida	US 231	I-10	Bayou George Drive	26.76	A	R
Florida	US 231	I-10	Bayou George Drive	42.34	D	R
Florida	US 27	E Palm Beach Road	I 75	6.17	A	R
Florida	US 27	Fort Meade Road	Highlands County line	0.43	G	R
Florida	US 27	Highlands County line	SR 80	6.12	A	R
Florida	US 27	Lake Josephine Drive	County Road 17N	1	G	R
Florida	US 27	Masterpiece Road	Fort Meade Road	9.69	G	R
Florida	US 27	Old US 27 Highway	E. Palm Beach Road	0.84	A	R
Florida	US 27	S. Sun and Lakes Blvd.	Highlands County line	3.08	A	R
Florida	US 27	SR 80	Lewis Blvd.	3.92	A	R
Florida	US 301	Clay County line	NE 193rd Street	26.88	A	R
Florida	US 301	NE Waldo Road	NW 77th Street	98.27	A	R
Florida	US 301	S. Walnut Street	NE Waldo Road	17.3	A	R
Florida	I-295	I-95	Heckscher Drive	6.77	H	U
Florida	I-295	SR 202	I-95	8.07	H	U
Florida	SR 105	Bount Island Road	I-295	1.22	H	U
Florida	SR 263	I-10	SR 363	6.76	K	U
Florida	SR 528	McCoy Road (SR 482)	SR 417	7.44	K	U
Florida	SR 528	SR 417	I-95	0.18	K	U
Florida	SR 869	I-95	I-75	24.96	K	U
Florida	US 231	Bayou George Drive	US 98	10.4	H	U
Florida	US 27	County Road 17N	S. Sun and Lakes Blvd.	7.94	K	U

State	Route No.	Start Point	End Point	Length (miles)	CUFC and CRFC ID Codification	CUFC = U CRFC = R
Florida	US 27	E. Palm Beach Road	I-75	0.15	J	U
Florida	US 27	Highlands County line	Lake Josephine Drive	20.67	K	U
Florida	US 27	I-4	SR 60	25.75	K	U
Florida	US 27	I-75	US 301	2.84	K	U
Florida	US 27	Lewis Blvd.	Old US 27 Highway	3.13	K	U
Florida	US 27	Old US 27 Highway	E. Palm Beach Road	0.07	J	U
Florida	US 301	I-10	Clay County line	7.51	K	U
Florida	US 301	NE 193rd Street	S. Walnut Street	4.38	K	U
Florida	US 301	NW 10th Street	Silver Springs Boulevard	0.69	K	U
Florida	US 301	NW 77th Street	NW 10th Street	4.89	K	U
Florida	US 41	S 22 ST	Big Bend Road	11.58	H	U
Florida	US 98	US 231	Sun Harbor Road	4.47	H	U
Florida Subtotal				**469.76**		
Georgia						
Hawaii						
Idaho	US-95	Lancaster Road (MP 436.78)	SH-53 (MP 438.86)	2.08	F, G	R
Idaho	SH-53	Washington Border (MP 0.0) (Varied MP and segments)	US-95 (MP 14.31)	14.31	D, F	R
Idaho	SH-54	SH-41 (MP 0.0)	US-95 (MP 7.89)	7.89	A, D	R
Idaho	US-12/95	Urbanized Area Border (MP 310.60)	Lewiston POE (MP 309.80)	0.8	C, D, F, G	R
Idaho	Main Street/Main Street Bypass/Mill Road in Lewiston	US-12 (MP 1.90)	Access road on east side of Clearwater Paper Reservoir (MP 3.67)	1.77	F	R
Idaho	SH-3	US-12 (MP 0.0)	Deary (MP 29.00)	29	D	R
Idaho	S. Lincoln Road-Jerome	I-84 (MP 0.0)	E 100S (MP 1.54)	1.54	D, F	R
Idaho	US-93	Southwest Twin Falls at US-30 (MP 41.50)	I-84 (MP 53.39)	11.89	G	R
Idaho	US-30	Intersection w/ SH-50 (MP 216.90)	Intersection w/ US-93 (MP 223.51)	6.61	D, F, G	R
Idaho	US-50	Intersection w/US-30 (MP 0)	I-84 (MP 4.80)	4.8	D, F, G	R
Idaho	Bedke Blvd.	SH-27 (MP 11.55)	US-30 (MP 10.0)	1.55	D, F	R
Idaho	US-30	Coors Facility (MP 253.37)	SH-27 (MP 257.48)	4.11	A, D, E, F, G	R
Idaho	100W	US-30 (MP 105.22)	SH-27 (MP 98.11)	7.11	D, E	R
Idaho	Idahome Road	I-84 (MP 4.03)	Dairy (MP 7.4)	3.37	D, F	R
Idaho	S 2750 E	Idahome Road (MP 100.00)	East Valley Dairy (MP 101.27)	1.27	D, F	R
Idaho	US-30	Georgetown Summit (MP 420.00)	Wyoming (MP 455.48)	35.48	D, F, G	R
Idaho	US-26	W 100 N. Blackfoot (MP 304.3)	I-15 (MP 306.1)	1.85	D, F	R
Idaho	US-20	Chester (MP 353.0)	Henry's Fork River (MP 363.5)	10.5	A, D, F, G	R

State	Route No.	Start Point	End Point	Length (miles)	CUFC and CRFC ID Codification	CUFC = U CRFC = R
Idaho	Seltice Way	S. Ross Point Road (MP 1.62)	Northwest Blvd. (MP 5.97)	4.35	I, J	U
Idaho	US-95	I-90 (MP 430.60)	US-53 (MP 436.90)	6.3	J, K	U
Idaho	SH-128	Washington border (MP 0.0)	US-12 (MP 2.09)	2.09	H, J	U
Idaho	3rd Avenue N	6th Avenue N. (MP 0.49)	US-12 (MP 1.22)	0.73	H, J	U
Idaho	US-12	Washington border (varied segments and MP) (MP 0.0)	Urbanized area boundary (MP 310.60)	5.25	H, J, K	U
Idaho	Southway Bridge	Washington border (center of bridge) (MP 0.0)	Snake River Avenue (MP 0.16)	0.16	K	U
Idaho	Main Street/Main Street Bypass/Mill Road (Lewiston)	US-12 (Varied segments and MP) (MP 100.00)	Access road on east side of Clearwater Paper Reservoir (MP 1.90)	1.09	J	U
Idaho	I-84 Bus. Cleveland Blvd./Centennial Way/Nampa-Caldwell Blvd.	I-84 (Varied MP and segments) (MP 0.94)	Midland Blvd. (Nampa) (MP 55.90)	7.42	I, J	U
Idaho	Northside Blvd. (Nampa)	Birch Lane {Varied MP and segments) (MP 0.50)	I-84 (MP 19.30)	0.86	J	U
Idaho	Franklin Blvd. (Nampa)	Birch Lane (MP 1.80)	Garrity Blvd. (MP 0.0)	1.8	J	U
Idaho	11th Avenue	Franklin Blvd. (MP 58.67)	3rd Street (MP 59.50)	0.83	H, J	U
Idaho	Chinden/US-20/26	Midland Blvd. (MP 28.25)	I-84 (MP 24.84)	3.41	H, J, K	U
Idaho	Chinden/US-20/26	Five Mile Road (MP 40.23)	Eagle Road (MP 42.09)	1.86	J, K	U
Idaho	Franklin Road (Nampa)/Idaho Center/Blvd.	Star Road (MP 1.32)	Idaho Center Blvd. (MP 0.34)	0.98	J	U
Idaho	SH-55/ Midland	Middleton Road (Varied MP and segments) (MP 15.63)	Cherry Lane (MP 101.12)	1.71	J, K	U
Idaho	SH-19	Farmway (MP 19.06)	Centennial (MP 19.92)	0.86	I, J, K	U
Idaho	Robinson Road	Airport Road (MP 3.28)	Franklin Road (MP 4.49)	1.21	J	U
Idaho	Gowen Road	Gowen Interchange (MP 5.50)	Orchard Interchange (MP 0.03)	5.47	H, J	U
Idaho	Cole Road	Victory Road (Varied MP and segments) (MP 14.27)	I-84 (MP 0.22 at westbound on- ramp)	1.19	J	U
Idaho	Franklin Road	Linder Road (Varied MP and segments) (MP 5.34)	I-184 (MP 2.88)	6.85	J	U
Idaho	Victory Road	Cole Road (MP 13.04)	Orchard Street (MP 14.53)	1.49	J	U
Idaho	Eisenman Road	Gowen Road (MP 102.91)	Freight Street (MP 100.94)	1.97	J	U
Idaho	S. Federal Way	SH-21 (Varied MP and segments) (MP 102.65)	Memory Road/I-84 (MP 100.17)	2.76	J	U
Idaho	US-91	US-30 (Varied MP and segments) (MP 3.44)	I-86 (MP 80.0)	3.13	I, J	U
Idaho	US-30	US-91 (MP 335.77)	I- 86 (MP 330.93)	4.84	J, K	U
Idaho	I-15 Bus/US-91/US-26	8161S. Street (Varied MP and segments) (MP 121.7)	Pancheri Drive (MP 5.71)	4.56	I, J, K	U
Idaho	Lindsay Blvd.	North of Iron Mule Saloon (MP 2.0)	Wardell Avenue (MP 0.89)	1.11	J	U

State	Route No.	Start Point	End Point	Length (miles)	CUFC and CRFC ID Codification	CUFC = U CRFC = R
Idaho Subtotal				**220.21**		
Illinois						
Indiana						
Iowa	US 21 8	Poweshiek Street	US 34	45.7	A, G	R
Iowa	US 18, US 218	I-35	Waterloo urbanized area boundary	45.7	A, G	R
Iowa	N. Dayton Avenue, Riverside Road	Old Bloomington Road	Stagecoach Road	1.5	A, B, D	R
Iowa	S. Pat ton St	I-29	Blvd. of Champions	1.2	J, K	U
Iowa	Blvd. of Champions	S. Patton Street	Harbor Drive	0.5	J, K	U
Iowa	Harbor Drive	S. Patton Street	Discovery Blvd.	2.1	J, K	U
Iowa	Discovery Blvd.	Harbor Drive	Aviation Blvd.	0.6	J, K	U
Iowa	Aviation Blvd.	Discovery Blvd.	I-29	0.4	J, K	U
Iowa	Iowa 92, Harry Langdon Blvd., South Avenue	I-29	IAIS Intermodal Yard	1.3	H, J, K	U
Iowa	Nebraska Avenue, River Road	I-29	Cargill AG Horizons	0.7	J, K	U
Iowa	S. Expressway, 29th Avenue, 23rd Avenue	I-29/I-80	Bartlett Grain and Hansen- Mueller Grain Elevators	1.4	J, K	U
Iowa	US 30, S. Dayton Avenue, SE 18th St	I-35	S. Dayton Avenue	1.3	J, K	U
Iowa	Dayt on Avenue	US 30	E. 13th Street	2	J, K	U
Iowa	E. 13th Street, N. Dayton Avenue	I-35	Old Bloomington Road	2.2	J, K	U
Iowa	SE Oralabor Road, SW State Street	I-35	SW Ordnance Road	3.9	J, K	U
Iowa	University Avenue	I-35/I-80	NW 90th Street/28th Street	1.9	J, K	U
Iowa	Mills Civic Parkway	I-35	Jordan Creek Pkwy	1.8	J, K	U
Iowa	US 218	I-380	Waterloo urbanized area boundary	10.7	I, J, K	U
Iowa	US 20, Iowa 58	I-380	Greenhill Road	9.4	I, J, K	U
Iowa	Plaza Dr, Dubuque Road, Elk Run Road	I-380	Newell Street	4.6	J, K	U
Iowa	Wright Bros Blvd. SW	I-380	Cessna Place SW	2.8	J, K	U
Iowa	US 30	C Street SW	Edgewood Road SW	4.3	I, J, K	U
Iowa	Edgewood Road SW	US 30	Wright Bros Blvd. SW	3.2	J, K	U
Iowa	US 218	I-80	Poweshiek Street	8.5	I, J, K	U
Iowa	Old Highway 218 S	US 218	Gringer Agriculture	1.5	J, K	U
Iowa	Iowa 1, US 61 Gilbert St, Court St	US 218	Front Street	3.7	J, K	U
Iowa	Iowa 130, Hillandale Road, Enterprise Way	I-80	Davenport Transload Facility	1.1	J, K	U
Iowa Subtotal				**164**		
Kansas						
Kentucky	KY 236	0	3.6	3.6	J	U

State	Route No.	Start Point	End Point	Length (miles)	CUFC and CRFC ID Codification	CUFC = U CRFC = R
Kentucky	KY 237	10.3	11.2	0.9	J	U
Kentucky	KY 338	0	0.36	0.36	J	U
Kentucky	KY 717	0	1.729	1.729	K	U
Kentucky	KY 1017	0	3.21	3.21	K	U
Kentucky	KY 1829	0	1.93	1.93	J	U
Kentucky	KY 3076	0	1.148	1.148	J	U
Kentucky	US 42	13.91	14.384	0.474	J	U
Kentucky	KY 236	2.277	2.801	0.524	J	U
Kentucky	KY 18 29	0	1.024	1.024	J	U
Kentucky	KY 136	18.65	19.548	0.898	H	U
Kentucky	KY 425	0	4.747	4.747	I	U
Kentucky	US 41	10.75	20.977	10.227	K	U
Kentucky	KY4	0	6.336	6.336	K	U
Kentucky	KY4	11.603	12.554	0.951	K	U
Kentucky	US 27	0	2.412	2.412	J	U
Kentucky	US27	11.417	15.278	3.861	J	U
Kentucky	US 60	1.536	4.693	3.157	K	U
Kentucky	US 60	10.176	12.04	1.864	K	U
Kentucky	KY 841	0	10.25	10.25	K	U
Kentucky	KY 841	34.727	38.881	4.154	K	U
Kentucky	KY 1447	6.47	9.242	2.772	J	U
Kentucky	KY 1747	0.347	0.837	0.49	H	U
Kentucky	KY 1934	0	7.182	7.182	J	U
Kentucky	US 150	1.93	2.73	0.8	J	U
Kentucky Subtotal				**75**		
Louisiana						
Maine						
Maryland						
Massachusetts						
Michigan	5 Mile Road	Napier Road	Beck Road	2		U
Michigan	Beck Road	M-14	5 Mile Road	1		U
Michigan Subtotal				**3**		
Minnesota						
Mississippi	I-20 Frontage Road	Industrial Park Drive	Madison Street	1.967	J	U
Mississippi	Madison St	I-20 Frontage Road	I-20		J	U
Mississippi	Gallatin St	South Street	I-20	1.445	K	U
Mississippi	Bullard St	I-220	Industrial Drive	1.031	J	U
Mississippi	Beasley Road	Industrial Park Road	Watkins Drive	2.382	J	U
Mississippi	Watkins Drive	I-220	Beasley Road		J	U
Mississippi	WooDriveow Wilson Drive	N. Mill Street	I-55	1.673	J	U
Mississippi	N. State St	Old Canton Road	Woodrow Wilson Drive	1.325	K	U
Mississippi	Old Canton Road	Lakeland Drive	N. State Street		K	U

State	Route No.	Start Point	End Point	Length (miles)	CUFC and CRFC ID Codification	CUFC = U CRFC = R
Mississippi	Lakeland Drive	Old Canton Road	I-55		K	U
Mississippi	I-20 Frontage Road	Continental Plant	St. Thomas Pkwy	0.855	J	U
Mississippi	St. Thomas Pkwy	I-20 Frontage Road	I-20		J	U
Mississippi	US 49	Gary Drive	I-220	1.518	K	U
Mississippi	MS 857	Nissan Parkway	W Sowell Road	4.208	J	U
Mississippi	W Sowell Road	I-55	MS 857		J	U
Mississippi	Commercial Parkway	Waterford Parkway	Curbview Cove	1.087	J	U
Mississippi	Curbview Cove	MS 22	Commercial Parkway		J	U
Mississippi	MS 22	Curbview Cove	I-55		J	U
Mississippi	Gluckstadt Road	I-55	Industrial Drive	0.366	J	U
Mississippi	Gluckstadt Road	Distribution Drive	I-55	0.43	J	U
Mississippi	MS 475	I-20	Allen Stuart Drive	2.56	J	U
Mississippi	Allen Stuart Drive	Forensic Science Drive	MS 475		J	U
Mississippi	Forensic Science Drive	Old Whitfield Road	Allen Stuart Drive		J	U
Mississippi	MS 475	North Fox Hall Road	I-20	3.037	H	U
Mississippi	MS 468	I-20	S. Pearson Road	1.819	H	U
Mississippi	S. Pearson Road	MS 468	Chidre Street		H	U
Mississippi	Chidre Street	Weems St	S. Pearson Road		H	U
Mississippi	Interstate Drive	US 49	Industrial Park Drive	1.599	J	U
Mississippi	Industrial Park Drive	Interstate Drive	Weems St		J	U
Mississippi	MS 18	I-20	Marquette Road	1.738	J	U
Mississippi	Marquette Road	MS 18	East Metro Pkwy		J	U
Mississippi	MS 25	I-55	MS 475	6.108	H	U
Mississippi	MS 475	MS 25	North Fox Hall Road		H	U
Mississippi	County Farm Road	Landon Road	I-10	1.635	J	U
Mississippi	County Farm Road	I-10	Beatline Road	5.598	J	U
Mississippi	Beatline Road	County Farm Road	Railroad Street		J	U
Mississippi	Beatline Road (proposed)	Railroad Street	US 90	0.58	K	U
Mississippi	Canal Road	I-10	28th Street	2.844	H	U
Mississippi	28th St	Canal Road	30th Avenue	2.308	H	U
Mississippi	US 49	Orange Grove Road	Airport Road	2.353	J	U
Mississippi	MS 605	Lorraine Road	I-10	0.828	J	U
Mississippi	MS 605	I-10	Seaway Road	0.732	J	U
Mississippi	MS 53	Canal Road	US 49	1.841	K	U
Mississippi	US 90	MS 611	Moss Point East urban limits	2.498	J	U
Mississippi	MS 609	Seaman Road	Big Ridge Road	0.533	K	U
Mississippi	MS 57	I-10	Sunplex Drive	1.155	J	U
Mississippi	Church Road W	US 51	Airways Blvd.	1.424	J	U
Mississippi	Pepper Chase Drive (new construction)	Turman Drive	Star Landing Road	1.795	J	U

State	Route No.	Start Point	End Point	Length (miles)	CUFC and CRFC ID Codification	CUFC = U CRFC = R
Mississippi	Star Landing Road W	US 51	Airways Road	0.389	J	U
Mississippi	Star Landing Road E	Airways Road	Swinnea Road	1.033	K	U
Mississippi	Hacks Cross Road	Stateline Road	MS 302/Goodman Road	2.26	J	U
Mississippi	Stateline Road	Alexander Road	Forest Hill Irene Road	3.078	J	U
Mississippi	Polk Ln	Stateline Road	MS 302/Goodman Road	2.249	J	U
Mississippi	McCracken Road	W Commerce Street	Vaiden Drive	0.633	J	U
Mississippi	JM Tatum Industrial Drive	US 49	Old Hwy 49/James Street	2.568	J	U
Mississippi	WL Runnels Industrial Drive	JM Tatum Industrial Drive	US 98	1.633	J	U
Mississippi	Old Hwy 49/James St	Faulkner St	JM Tatum Industrial Drive	3.388	J	U
Mississippi	L.E. Barry Road	River Terminal Road	Government Fleet Road	2.5	D	R
Mississippi	Government Fleet Road	L.E. Barry Road	US 425		D	R
Mississippi	Russel Crutcher Road	Port of Rosedale	MS 8	25.6	D	R
Mississippi	MS 8	Russell Crutcher Road	US 61		D	R
Mississippi	US 90	MS 607	Lower Bay Road	11.1	D	R
Mississippi	Lower Bay Road	US 90	Port and Harbor Drive		D	R
Mississippi	Port and Harbor Drive	Lower Bay Road	Port Bienville		D	R
Mississippi	Access Road	Port of Itawamba	Adams Road	1.1	C	R
Mississippi	Adams Street	Access Road	I-22/US 78		C	R
Mississippi	MS 182	US 82	Port Access Road	3.3	D	R
Mississippi	Port Access Road	MS 182	Port of Columbus		D	R
Mississippi	MS 182	US 45	Old Macon Road	3.8	D	R
Mississippi	Old Macon Road	MS 182	Charlie Smith Road		D	R
Mississippi	US 278	US 45	Waterway Drive	9.4	D	R
Mississippi	Waterway Drive	Port Access Road	US 278		D	R
Mississippi	Norm Connell Drive	US 45	Port of Aberdeen	1.1	D	R
Mississippi	MS 19	Philadelphia Urban Limit	MS 492	10.71	D	R
Mississippi	MS 16	MS 15	MS 19	3.31	D	R
Mississippi	County Road 351	County Road 370	County Road 370	18.5	D	R
Mississippi	County Road 370	MS 25	County Road 351		D	R
Mississippi	MS 25	County Road 370	US 72		D	R
Mississippi	MS 365	US 72	County Road 219	3.8	D	R
Mississippi	County Road 219	MS 365	Port Facility		D	R
Mississippi	Industrial Drive	Port of Vicksburg	County Road 370	9	D	R
Mississippi	Haining Road	Industrial Drive	County Road 351		D	R
Mississippi	N. Washington Street	Haining Road	US 72		D	R
Mississippi	N. Washington Street	Haining Road	Levee Street	6.5	C	R

State	Route No.	Start Point	End Point	Length (miles)	CUFC and CRFC ID Codification	CUFC = U CRFC = R
Mississippi	Levee Street	N. Washington St	Depot Street		C	R
Mississippi	Depot Street	Levee	Washington Street		C	R
Mississippi	Washington Street	Depot St	I-20		C	R
Mississippi	MS 809	Port of Greenville	US 82	2.9	D	R
Mississippi	MS 3	US 49W	Rialto Road	6.8	D	R
Mississippi	Rialto Road	Levee Road	MS 3		D	R
Mississippi	Levee Road	Old River Road	Rialto Road		D	R
Mississippi	Old River Road	Levee Road	MS 3		D	R
Mississippi Subtotal				**197.923**		
Missouri						
Montana						
Nebraska	S79H/South Beltline Highway	Stable Club Road	N92	2.07		R
Nebraska	N92	US 26	Stable Club Road	1.78		R
Nebraska	US 26	790139 County Road 20	1060 Highland Road	3.77		R
Nebraska	US 385	L62A	Club Road/West Road	24.28		R
Nebraska	US 30	Young Street	US 83	7.02		R
Nebraska	US 83	US 30	I-80	2.59		R
Nebraska	N44	I-80	Railroad Street	1.69		R
Nebraska	US 34	West 33rd Street	US 6/West J Street	2.66		R
Nebraska	US 6/ US 34	BNSF Rail (between S. Marian Road and Summit Avenue)	BNSF Rail (between N. Showboat Blvd. and N. Blaine Avenue)	1		R
Nebraska	S. Bell Street/Old US. 275 Reichmuth Road	Cumming Street	N36	5.2		R
Nebraska	N36	Reichmuth Road	Old US 275	0.3		R
Nebraska	Cloverly Road	US 77	Old US 275	1.5		R
Nebraska	US 30	33rd Avenue	East 40th Avenue	5.17		R
Nebraska	US 81	33rd Avenue	53rd Avenue	1.7		R
Nebraska	US 81	US 34	N64	41.04		R
Nebraska	E. 29th Avenue	US 30	8th Street	1		R
Nebraska	US 275	S. 20th Street	S. Chestnut Street	2.75		R
Nebraska	US 275	Oak Street/56th Avenue	16th Road/N. Mill Street	28.9		R
Nebraska	Omaha Avenue	S. 25th Street	US 275	0.8		R
Nebraska	US 81	US 275	Monroe Avenue	0.59		R
Nebraska	US 75	N66	Oak Hill Road	0.67		R
Nebraska	US 34	Murray Road	N66	6.37		R
Nebraska	Lincoln South Beltway	S. 84th Street	N2	2.7		R
Nebraska	US 30	Between Johnstown Road and Claude Road	N. Grant Street	1.53		U
Nebraska	US 30	E. 2nd Street/E. 1st Street split	Capital Avenue	2.11		U
Nebraska	Relocated US 281	US 281	US 34	7.08		U

State	Route No.	Start Point	End Point	Length (miles)	CUFC and CRFC ID Codification	CUFC = U CRFC = R
Nebraska	Lincoln South Beltway	US 77	S. 84th Street	5.2		U
Nebraska	US 77 (includes Lincoln West Beltway)	Start of Lincoln South Beltway	I-80	9.68		U
Nebraska	SR 2	US 77	S. 96th Street	8.92		U
Nebraska	US 77	I-80	US 6	0.22		U
Nebraska	US 6	US 77	Roundhouse Road	1.4		U
Nebraska	US 6	L55X/Old US 77	N. 84th Street	2.52		U
Nebraska	L55X/Old US	US 6	I-80	2.67		U
Nebraska	NW 12th Street	W. Cornhusker Highway	W. Highland Blvd.	1.3		U
Nebraska	Dakota Avenue	I-129	Pine Street	1.9		U
Nebraska Subtotal				**190.08**		
Nevada	US95	Sr157/Kyle Canyon Road	7.5 miles south of NY/ES County line	139.4	G	R
Nevada	SR439	I-80/USA Parkway	US 50	10.6	F	R
Nevada	US395	I-80	Lemmon Drive	6.4	H	U
Nevada	CC215	US95	L-15n	12.9	I	U
Nevada	US95	CC215	Sr157/Kyle Canyon Road	4.3	K	U
Nevada	CC215	I-215	Rainbow	2.93	K	U
Nevada	US395	Lemmon Drive	Red Rock Road	3.6	K	U
Nevada	SR573	Craig/Losee	Las Vegas Blvd.	3.5	H	U
Nevada	Greg Street	I-80	Mill Street	4.5	H	U
Nevada	KOVAL	E. Reno Avenue	Sands	1.8	I	U
Nevada	US50	I-580 Carson	SR341	6.2	K	U
Nevada	SR612/NELLIS	Washington	Las Vegas Blvd.	3.8	I	U
Nevada	SR468/SR659	Glendale Avenue	McCarran Blvd.	4.6	I	U
Nevada	SR593	I-15 Tropicana	I-515	5.7	I	U
Nevada	SR610	Lamb Blvd	I-15	2.37	I	U
Nevada	SR445	I-80 Pyramid	SR659 McCarran	1.6	I	U
Nevada	SR562/SUNSET	Las Vegas Blvd.	Eastern Avenue	3	I	U
Nevada	TERMINAL	Mill	Gentry	1.7	I	U
Nevada	US395/I-580	Virginia Street	Kietzke Interchange	6.1	I	U
Nevada Subtotal				**225**		
New Hampshire						
New Jersey	Mercer CR 539 (Old York Road - East Windsor)	49.42	49.9	0.48	F	R
New Jersey	Monmouth CR 524 (Main Street - Farmingdale)	30.27	31.18	0.91	F	R
New Jersey	Monmouth CR 526	10.14	12.8	2.66	F	R
New Jersey	Monmouth CR 539	45.5	49.9	4.4	F	R
New Jersey	Monmouth CR 539 SPUR (Sharon Station Road)	0	2.3	2.3	F	R
New Jersey	Cape May CR 621 (Ocean Drive – Lower Twp)	1.5	2	0.5	F	R

State	Route No.	Start Point	End Point	Length (miles)	CUFC and CRFC ID Codification	CUFC = U CRFC = R
New Jersey	NJ 49	5.37	8.3	2.93	F	R
New Jersey	Hunterdon CR 519	14.9	16.6	1.7	G	R
New Jersey	NJ 122	2.07	2.42	0.35	G	R
New Jersey	NJ 55	27.7	27.9	0.2	G	R
New Jersey	US 40	9.91	10.02	0.11	G	R
New Jersey	US 40	11.67	16.5	4.83	G	R
New Jersey	NJ 173	0.32	1.5	1.18	G	R
New Jersey	NJ 173	4.33	11	6.67	G	R
New Jersey	Atlantic Avenue (Camden)	0.09	0.75	0.66	J	U
New Jersey	Hudson CR 501	30.85	31.11	0.26	K	U
New Jersey	Hudson CR 501	33.94	34.22	0.28	K	U
New Jersey	Hudson CR 508	12.53	13.06	0.53	K	U
New Jersey	Essex CR 510	29.27	29.58	0.31	K	U
New Jersey	Morris CR 510W	0.3	0.7	0.4	K	U
New Jersey	Middlesex CR 514	28.8	29.24	0.44	K	U
New Jersey	Union CR 514	40	40.29	0.29	K	U
New Jersey	Middlesex CR 527	42.84	42.92	0.08	K	U
New Jersey	Somerset CR 527	53	53.12	0.12	K	U
New Jersey	Middlesex CR 535	17.02	17.69	0.67	J	U
New Jersey	Monmouth CR 547	20	20.79	0.79	K	U
New Jersey	Mercer CR 571	41.96	42.5	0.54	K	U
New Jersey	Camden CR 603 (Ferry Avenue – Camden)	0	0.36	0.36	J	U
New Jersey	Union CR 615 (Stiles Street - Linden)	0	1.37	1.37	K	U
New Jersey	Hudson CR 659 (Central Avenue – Kearny)	1.7	1.8	0.1	K	U
New Jersey	Cumberland CR 674 (Garden Road – Vineland)	0.7	0.8	0.1	J	U
New Jersey	Delancy Street (Newark)	0	1	1	J	U
New Jersey	Morgan Blvd. (Camden)	0.21	1.09	0.88	J	U
New Jersey	NJ 124	0	0.39	0.39	K	U
New Jersey	NJ 130	45.3	46.46	1.16	K	U
New Jersey	NJ 139	0	0.47	0.47	K	U
New Jersey	NJ 140	0	0.99	0.99	K	U
New Jersey	NJ 168	6.6	7.42	0.82	K	U
New Jersey	NJ 173	0	0.32	0.32	K	U
New Jersey	NJ 173	1.5	4.33	2.83	K	U
New Jersey	NJ 173	11	11.6	0.6	K	U
New Jersey	NJ 18	39.56	40.9	1.34	K	U
New Jersey	NJ 24	0	1.2	1.2	K	U

State	Route No.	Start Point	End Point	Length (miles)	CUFC and CRFC ID Codification	CUFC = U CRFC = R
New Jersey	NJ 24	9.6	10.42	0.82	K	U
New Jersey	NJ 27	35.28	35.35	0.07	K	U
New Jersey	NJ 28	7.86	8.09	0.23	K	U
New Jersey	NJ 28	2	2.66	0.66	K	U
New Jersey	NJ 31	4.84	7.7	2.86	K	U
New Jersey	NJ 32	0	1.18	1.18	J	U
New Jersey	NJ 33	35.86	36.15	0.29	K	U
New Jersey	NJ 35	49.2	49.36	0.16	K	U
New Jersey	NJ 35	33.84	34	0.16	K	U
New Jersey	NJ 38	0	0.4	0.4	K	U
New Jersey	NJ 4	2.9	3.54	0.64	K	U
New Jersey	NJ 4	10.1	10.59	0.49	K	U
New Jersey	NJ 413	0.4	0.75	0.35	K	U
New Jersey	NJ 42	13.82	14.28	0.46	K	U
New Jersey	NJ 439	0.34	1	0.66	J	U
New Jersey	NJ 439	1.71	2.16	0.45	J	U
New Jersey	NJ 44	2.2	5.5	3.3	K	U
New Jersey	NJ 45	26.3	26.6	0.3	K	U
New Jersey	NJ 49	0	5.37	5.37	J	U
New Jersey	NJ 49	8.3	8.5	0.2	J	U
New Jersey	NJ 495	0.9	1.33	0.43	J	U
New Jersey	NJ 495	2	2.5	0.5	K	U
New Jersey	NJ 495 ramp	ramp	ramp	0.1	J	U
New Jersey	NJ 55	24.5	24.7	0.2	K	U
New Jersey	NJ 56	7.65	9.18	1.53	K	U
New Jersey	NJ 56	8.1	8.3	0.2	K	U
New Jersey	NJ 7	0	0.73	0.73	J	U
New Jersey	NJ 73	27	27.68	0.68	K	U
New Jersey	NJ 82	0	0.29	0.29	K	U
New Jersey	NJ 93	0	0.2	0.2	K	U
New Jersey	NJ 93	0.56	0.92	0.36	K	U
New Jersey	S. 2nd Street (Camden)	0	0.6	0.6	J	U
New Jersey	US 1	0.1	2.5	2.4	K	U
New Jersey	US 1	5.98	14	8.02	I	U
New Jersey	US 130	41.5	41.7	0.2	K	U
New Jersey	US 130	34.06	34.16	0.1	K	U
New Jersey	US 130	50.06	50.25	0.19	K	U
New Jersey	US 130	54.9	55.8	0.9	K	U
New Jersey	US 130	33.08	33.15	0.07	J	U
New Jersey	US 130	71.6	72.09	0.49	J	U
New Jersey	US 130	74.1	74.6	0.5	J	U
New Jersey	US 130	50.8	50.9	0.1	K	U
New Jersey	US 130	50.05	50.15	0.1	K	U

State	Route No.	Start Point	End Point	Length (miles)	CUFC and CRFC ID Codification	CUFC = U CRFC = R
New Jersey	US 130	49.5	49.6	0.1	K	U
New Jersey	US 130	48.9	49	0.1	K	U
New Jersey	US 130	47.1	47.2	0.1	K	U
New Jersey	US 130	41.55	41.65	0.1	K	U
New Jersey	US 202	11.44	11.91	0.47	K	U
New Jersey	US 202/206	23.9	25.2	1.3	K	U
New Jersey	US 206	33.6	34	0.4	K	U
New Jersey	US 206	66.36	68.6	2.24	K	U
New Jersey	US 206	108.97	109.49	0.52	K	U
New Jersey	US 22	33.88	37.14	3.26	K	U
New Jersey	US 22	57.2	57.3	0.1	K	U
New Jersey	US 22	4.02	4.89	0.87	K	U
New Jersey	US 30/US 130	3	3.3	0.3	K	U
New Jersey	US 40	10.02	11.67	1.65	K	U
New Jersey	US 46	69.52	70.42	0.9	K	U
New Jersey	US 46	55	56	1	K	U
New Jersey	US 46	71.52	72.09	0.57	K	U
New Jersey	US 46	56	56.5	0.5	K	U
New Jersey	US 9	129.57	130.46	0.89	K	U
New Jersey	US 9	129.7	130.2	0.5	K	U
New Jersey	US 9	132.5	133.36	0.86	K	U
New Jersey	US 9	136.06	136.38	0.32	K	U
New Jersey	US 9	101.4	102	0.6	K	U
New Jersey Subtotal				**104.11**		
New Mexico						
New York						
North Carolina	US 19	I-26	I-240	13.78	I	U
North Carolina	I-40 BUS	US 52	I-40	12.95	I	U
North Carolina	US 29	NC150	Hicone Road (SR2565)/NHFN PHFS designated US 29	5.48	I	U
North Carolina	US 64	NC 751	I-440	8.82	I	U
North Carolina	US 421	I-85	Company Mill Road (SR3394)	3.69	K	U
North Carolina	US 64	I-540	NC 39	16.32	K	U
North Carolina	US 74	Lanvalle Road (SR1438)	US 17	3.87	K	U
North Carolina	US 64	I-95	Thomas Road (SR1233)	9.45	H	U
North Carolina	US 70	US 17 ramp	SR 1121	2.45	K	U
North Carolina	US 321	I-40	Alex Lee Blvd.	5.43	K	U
North Carolina	US 74	I-485	US-601	12.95	K	U
North Carolina	US 64	US 64 ALT	I-95	6.9	K	U
North Carolina	US 29	NC State line	NC150	27.32	C	R
North Carolina	US 64	US 421	NC 751	28.78	C	R

State	Route No.	Start Point	End Point	Length (miles)	CUFC and CRFC ID Codification	CUFC = U CRFC = R
North Carolina	US 421	Company Mill Road (SR3394)	US 421 BUS	22.62	C	R
North Carolina	US 64	NC 39	US 64 ALT	17.65	C	R
North Carolina	US 74	I-95	Lanvalle Road (SR1438)	70.47	E	R
North Carolina	US 421	US 1	I-95	39.51	C	R
North Carolina Subtotal				**308.44**		
North Dakota						
Ohio						
Oklahoma	US 69	2.2 mi north of SH 91	Main Street, Durant, Old US-70	10.29	A, D, F, G	R
Oklahoma	US 69	Bryan/Atoka C/L	Pittsburgh/Atoka C/L	41.48	A, D, F, G	R
Oklahoma	US 69	Pittsburgh/Atoka C/L	US 69/US 69B Jct. N of McAlester	26.43	A, D, F, G	R
Oklahoma	US 69	10.2 mi N. of Muskogee/McIntosh C/L	Arkansas River	9.01	A, C, D, F, G	R
Oklahoma	US 69	Muskogee/Wagoner C/L	Mayes/Wagoner C/L	19.22	A, C, F, G	R
Oklahoma	US 69	Mayes/Wagoner C/L	US-69/OK-20 Junction (Pryor)	16.54	A, C, F, G	R
Oklahoma	US 81	1.5 mi S. of US 81/SH 19 Jct.	.85 miles N. of US 62/US 81 Jct.	8.65	A, B, F, G	R
Oklahoma	US 54	US 54 from 4.8 mi N. of Jct.US 54/US 64E	Jct. of US 54 & Okla/Kansas SL	14.82	A, B, D, F, G	R
Oklahoma	SH-51/ US-64	IDL/US-75	US 169	7.7	K	U
Oklahoma	US-169	US-64/ Memorial Drive	Pine Street	11.7	K	U
Oklahoma	SH-167	I-44	OK-266	4.8	J	U
Oklahoma	US-75	SH-364/ Creek Tpike	I-244	7	K	U
Oklahoma	N. 10th Street	Cemetery Road (Garth Brooks Blvd)	Mustang Road	2.02	I, J, K	U
Oklahoma	Reno Avenue	Morgan Road	Western Avenue	9	I, J, K	U
Oklahoma	N. 36th Street	Santa Fe Avenue	Lincoln Blvd.	0.49	H, J, K	U
Oklahoma	N. 122nd Street	Santa Fe Avenue	I-235/SH-77	0.45	H, J, K	U
Oklahoma	Memorial Road	Santa Fe Avenue	Kelley Avenue	1.01	H, J, K	U
Oklahoma	Reno Avenue	I-235	Eastern Avenue	1.24	H, I, J, K	U
Oklahoma	S. 149th Street (S. 19th Street)	Telephone Road/Kelly Avenue	Eastern Avenue	0.76	I, J, K	U
Oklahoma	Eastern Avenue (24th Avenue SW)	SH-9	S. 209th Street (Tecumseh Road)	4.86	I, J, K	U
Oklahoma	Flood Avenue	S. 239th Street (Robinson Street)	I-35	3.87	I, J, K	U
Oklahoma	Council Road	SH-152	I-40	3.24	H, I, J, K	U
Oklahoma	MacArthur Blvd	S. 44th Street	N. 16th Street	4.5	H, I, J, K	U
Oklahoma	Douglas Boulevard	I-40	US-62 (N. 23rd Street)	4.22	H, I, J, K	U
Oklahoma	Sunnylane Road	I-40	N. 4th Street	1.13	H, I, J, K	U
Oklahoma	Santa Fe Avenue	N. 114th Street	N. 150th Street	2.6	J, K	U
Oklahoma Subtotal				**217.03**		
Oregon						
Pennsylvania						
Rhode Island	US-6	Connecticut/Rhode Island line	RI-116	11.4	G	R

State	Route No.	Start Point	End Point	Length (miles)	CUFC and CRFC ID Codification	CUFC = U CRFC = R
Rhode Island	RI-102	Lapham Farm Road	RI-44	2.1	G	R
Rhode Island	RI-102	RI-44	I-95	23.1	G	R
Rhode Island	RI-138	I-95	RI-2	7.2	F, G	R
Rhode Island	RI-44	Connecticut/Rhode line	Cooper Road	11.6	G	R
Rhode Island	RI-102	RI-146	Lapham Farm Road	7.4	K	U
Rhode Island	RI-146	Rhode Island/Massachusetts line	I-95	15.8	J, K	U
Rhode Island	US-6	RI-116	I-295	3.5	K	U
Rhode Island	US-6	I-295	I-95	5	K	U
Rhode Island	RI-99	RI-122	RI-146	2.7	J, K	U
Rhode Island	US-IA	Henderson Street	Ernest Street	1.2	H, J, K	U
Rhode Island	Oxford Street	US-1A	Eddy Street	0.3	H, J, K	U
Rhode Island	Eddy Street	Oxford Street	Ernest Street	0.6	H, J, K	U
Rhode Island	Ernest Street	Eddy Street	US-1A	0.3	H, J, K	U
Rhode Island	Thurbers Avenue	Eddy St	US-1A	0.3	H, J, K	U
Rhode Island	RI-37	I-295, Exit 3A	US-1	2.5	J, K	U
Rhode Island	US-1	RI-37, Exit SB	T.F. Green Airport Connector Road	1.3	H, J, K	U
Rhode Island	Airport Road	US-1	Commerce Drive	0.8	H, J, K	U
Rhode Island	RI-2	I-95	RI-401	0.3	H, J, K	U
Rhode Island	RI-104	RI-2	RI-4	0.4	H, J, K	U
Rhode Island	RI-4	RI-402	US-1	6.7	H, J, K	U
Rhode Island	RI-403	US-1	Commerce Park Road	1	H, J, K	U
Rhode Island	US-1	RI-4	RI-108	7.6	H, J, K	U
Rhode Island	RI-138	US-1	Newport	8.7	K	U
Rhode Island	RI-138	RI-2	US-1	6.6	K	U
Rhode Island	Davisville	RI-403	Thompson Road	1.7	H, J, K	U
Rhode Island Subtotal				**130.1**		
South Carolina	US 25	40.502	43.22	2.718	G	R
South Carolina	US 25	43.22	46.88	3.66	G	R
South Carolina	US 25	46.88	53.89	7.01	G	R
South Carolina	US 76	33.295	33.66	0.365	G	R
South Carolina	US 76	33.66	43.261	9.601	G	R
South Carolina	US 76	43.261	43.69	0.429	G	R
South Carolina	US 76	43.69	46.62	2.93	G	R
South Carolina	US 76	0	6.05	6.05	G	R
South Carolina	US 76	6.05	7.76	1.71	G	R
South Carolina	US 76	7.76	7.798	0.038	G	R
South Carolina	US 521	15	15.51	0.51	G	R
South Carolina	US 521	15.51	15.69	0.18	G	R
South Carolina	US 521	15.69	16.21	0.52	G	R
South Carolina	US 521	16.21	17.32	1.11	G	R
South Carolina	US 521	17.32	17.34	0.02	G	R

State	Route No.	Start Point	End Point	Length (miles)	CUFC and CRFC ID Codification	CUFC = U CRFC = R
South Carolina	US 521	17.34	18.19	0.85	G	R
South Carolina	US 521	18.19	20.2	2.01	G	R
South Carolina	US 521	0	3.9	3.9	G	R
South Carolina	US 521	3.9	6.006	2.106	G	R
South Carolina	SC 38	0.011	0.429	0.418	G	R
South Carolina	SC 38	0.429	0.59	0.161	G	R
South Carolina	SC 38	0.59	0.93	0.34	G	R
South Carolina	SC 38	0.93	0.935	0.005	G	R
South Carolina	SC 38	0.935	2.71	1.775	G	R
South Carolina	SC 38	2.71	3.923	1.213	G	R
South Carolina	SC 38	3.923	4.01	0.087	G	R
South Carolina	SC 38	4.01	4.59	0.58	G	R
South Carolina	SC 38	4.95	6.12	1.17	G	R
South Carolina	SC 38	0	0.97	0.97	G	R
South Carolina	SC 38	0.97	1.06	0.09	G	R
South Carolina	US 501	0	0.18	0.18	G	R
South Carolina	US 501	0.18	0.38	0.2	G	R
South Carolina	US 501	0.38	4.188	3.808	G	R
South Carolina	US 501	4.188	4.81	0.622	G	R
South Carolina	US 501	4.81	4.93	0.12	G	R
South Carolina	US 501	4.93	5.05	0.12	G	R
South Carolina	US 501	5.05	5.171	0.121	G	R
South Carolina	US 501	5.171	5.2	0.029	G	R
South Carolina	US 501	5.2	5.34	0.14	G	R
South Carolina	US 501	5.34	5.36	0.02	G	R
South Carolina	US 501	5.36	5.61	0.25	G	R
South Carolina	US 501	5.61	6.63	1.02	G	R
South Carolina	US 501	6.63	7.42	0.79	G	R
South Carolina	US 501	7.42	7.81	0.39	G	R
South Carolina	US 501	7.81	10.6	2.79	G	R
South Carolina	US 501	10.6	10.68	0.08	G	R
South Carolina	US 501	10.68	10.88	0.2	G	R
South Carolina	US 501	10.88	11.253	0.373	G	R
South Carolina	US 501	11.253	12.4	1.147	G	R
South Carolina	US 501	12.4	12.63	0.23	G	R
South Carolina	US 501	12.63	12.885	0.255	G	R
South Carolina	US 501	0.72	2.088	1.368	G	R
South Carolina	US 501	2.11	4.33	2.22	G	R
South Carolina	US 501	4.33	5.22	0.89	G	R
South Carolina	US 501	5.22	9.232	4.012	G	R
South Carolina	US 501	10.061	12.27	2.209	G	R
South Carolina	US 501	12.27	13.594	1.324	G	R
South Carolina	US 501	13.594	14	0.406	G	R

State	Route No.	Start Point	End Point	Length (miles)	CUFC and CRFC ID Codification	CUFC = U CRFC = R
South Carolina	US 501	14	14.108	0.108	G	R
South Carolina	US 501	14.108	20.07	5.962	G	R
South Carolina	US 501	20.07	21.195	1.125	G	R
South Carolina	US 501	21.195	23.552	2.357	G	R
South Carolina	US 17	0	0.3	0.3	G	R
South Carolina	US 17	0.3	4.42	4.12	G	R
South Carolina	US 17	4.42	6.58	2.16	G	R
South Carolina	US 17	6.58	7.01	0.43	G	R
South Carolina	US 17	7.01	7.791	0.781	G	R
South Carolina	US 17	7.81	12.65	4.84	G	R
South Carolina	US 17	0	5.92	5.92	G	R
South Carolina	US 17	5.92	13.4	7.48	G	R
South Carolina	US 17	13.4	13.61	0.21	G	R
South Carolina	US 17	13.61	17.518	3.908	G	R
South Carolina	US 17	0	16.242	16.242	G	R
South Carolina	US 17	16.242	17.31	1.068	G	R
South Carolina	US 17	0	4.1	4.1	H, I, J, K	R
South Carolina	US 17	4.1	6.61	2.51	H, I, J, K	R
South Carolina	US 17	6.61	9.22	2.61	H, I, J, K	R
South Carolina	US 17	9.22	12.469	3.249	H, I, J, K	R
South Carolina	US 17	12.469	12.91	0.441	H, I, J, K	R
South Carolina	US 17	12.91	13.05	0.14	H, I, J, K	R
South Carolina	US 17	40.56	42.299	1.739	G	R
South Carolina	SC 101	17.382	20.772	3.39	K	U
South Carolina	SC 80	1.48	3.53	2.05	K	U
South Carolina	Secondary 12	0	0.66	0.66	H, I, J, K	U
South Carolina	Secondary 12	0.66	1.088	0.428	H, I, J, K	U
South Carolina	US 176	20.237	21.77	1.533	H, I, J, K	U
South Carolina	US 25	24.93	25.73	0.8	K	U
South Carolina	US 25	25.73	27.142	1.412	K	U
South Carolina	US 25	27.142	27.64	0.498	K	U
South Carolina	US 25	27.64	31.49	3.85	K	U
South Carolina	US 25	31.49	33.3	1.81	K	U
South Carolina	US 25	33.3	36.12	2.82	K	U
South Carolina	US 25	36.12	36.604	0.484	K	U
South Carolina	US 25	36.604	38.04	1.436	K	U
South Carolina	US 25	38.04	38.13	0.09	K	U
South Carolina	US 25	38.113	38.27	0.14	K	U
South Carolina	US 25	38.27	40.502	2.232	K	U
South Carolina	US 76	7.798	9.17	1.372	K	U
South Carolina	US 76	9.17	12.44	3.27	K	U
South Carolina	US 76	12.44	14.56	2.12	K	U
South Carolina	US 76	14.56	14.78	0.22	K	U

State	Route No.	Start Point	End Point	Length (miles)	CUFC and CRFC ID Codification	CUFC = U CRFC = R
South Carolina	US 76	14.78	15	0.22	K	U
South Carolina	US 76 Business	0	1.1	1.1	K	U
South Carolina	US 521	6.006	6.659	0.653	K	U
South Carolina	US 521	6.659	7.18	0.521	K	U
South Carolina	US 521	7.18	8.07	0.89	K	U
South Carolina	US 521	8.07	8.19	0.12	K	U
South Carolina	US 521	8.19	8.99	0.8	K	U
South Carolina	US 521	8.99	10.06	1.07	K	U
South Carolina	US 521	10.06	10.38	0.32	K	U
South Carolina	US 521	10.38	10.75	0.37	K	U
South Carolina	US 521	10.75	11.25	0.5	K	U
South Carolina	US 521	11.25	11.81	0.56	K	U
South Carolina	US 521	11.81	11.98	0.17	K	U
South Carolina	US 521	11.98	12.32	0.34	K	U
South Carolina	US 521	12.32	12.7	0.38	K	U
South Carolina	US 501	12.885	14.24	1.355	K	U
South Carolina	US 501	14.24	15.018	0.778	K	U
South Carolina	US 501	15.018	15.103	0.085	K	U
South Carolina	US 501	15.103	15.33	0.227	K	U
South Carolina	US 501	15.33	16.45	1.12	K	U
South Carolina	US 501	16.45	17.7	1.25	K	U
South Carolina	US 501	17.7	17.76	0.06	K	U
South Carolina	US 501	17.76	17.83	0.07	K	U
South Carolina	US 501	17.83	18.055	0.225	K	U
South Carolina	US 501	18.055	18.46	0.405	K	U
South Carolina	US 501	18.46	18.5	0.04	K	U
South Carolina	US 501	18.5	18.58	0.08	K	U
South Carolina	US 501	18.58	18.67	0.09	K	U
South Carolina	US 501	18.67	18.719	0.049	K	U
South Carolina	US 501	18.719	18.77	0.051	K	U
South Carolina	US 501	18.77	18.94	0.17	K	U
South Carolina	US 501	18.94	19.01	0.07	K	U
South Carolina	US 501	19.01	19.083	0.073	K	U
South Carolina	US 501	19.083	19.155	0.072	K	U
South Carolina	US 501	19.155	19.204	0.049	K	U
South Carolina	US 501	19.204	19.251	0.047	K	U
South Carolina	US 501	19.251	19.31	0.059	K	U
South Carolina	US 501	19.31	19.36	0.05	K	U
South Carolina	US 501	19.36	19.5	0.14	K	U
South Carolina	US 501	19.5	20.735	1.235	K	U
South Carolina	US 501	20.735	20.98	0.245	K	U
South Carolina	US 501	20.98	21.593	0.613	K	U
South Carolina	US 501	21.593	21.76	0.167	K	U

State	Route No.	Start Point	End Point	Length (miles)	CUFC and CRFC ID Codification	CUFC = U CRFC = R
South Carolina	US 501	21.76	21.95	0.19	K	U
South Carolina	US 501	21.95	22.58	0.63	K	U
South Carolina	US 501	31.58	22.88	0.3	K	U
South Carolina	US 501	22.88	23.09	0.21	K	U
South Carolina	US 501	23.09	23.58	0.49	K	U
South Carolina	US 501	23.58	23.765	0.185	K	U
South Carolina	US 501	23.765	25.582	1.817	K	U
South Carolina	US 501	25.582	28.18	2.598	K	U
South Carolina	US 501	28.18	28.42	0.24	K	U
South Carolina	US 501	28.42	29.59	1.17	K	U
South Carolina	US 501	29.59	31.53	1.94	K	U
South Carolina	US 501	9.231	9.502	0.27	K	U
South Carolina	US 501	9.502	10.061	0.559	K	U
South Carolina	US 17	17.518	17.79	0.272	K	U
South Carolina	US 17	17.79	19.95	2.16	K	U
South Carolina	US 17	19.95	20.63	0.68	K	U
South Carolina	US 17	20.63	24.04	3.41	K	U
South Carolina	US 17	24.04	2438	0.54	K	U
South Carolina	US 17	24.58	25.19	0.71	K	U
South Carolina	Port Access Road	0	1.2	1.2	K	U
South Carolina	US 76	26.09	26.74	0.65	K	U
South Carolina	US 76	26.74	27.04	0.3	K	U
South Carolina	US 76	27.04	28.2	1.16	K	U
South Carolina	US 76	28.2	28.68	0.48	K	U
South Carolina	US 76	28.68	29.9	1.22	K	U
South Carolina	US 76	29.9	31.72	1.82	K	U
South Carolina	US 76	31.72	33.295	1.575	K	U
South Carolina Subtotal				**223.92**		
South Dakota						
Tennessee	SR317	0	4.78000021	4.78	J, K	U
Tennessee	SR076	13.28999996	14.43000031	1.14	K	U
Tennessee	SR013	26.56999969	28.88299942	2.313	K	U
Tennessee	SR308	4.147999763	7.489999771	3.342	K	U
Tennessee	SR018	7.346000195	9.829999924	2.484	J, K	U
Tennessee	I0026	8.909999847	9.300000191	0.39	J, K	U
Tennessee	I0026	10.01000023	10.60000038	0.59	J, K	U
Tennessee	I0026	13.17000008	15.14000034	1.97	J, K	U
Tennessee	I0026	5.789999962	7.849999905	2.06	J, K	U
Tennessee	SR036	6.989999771	7.579999924	0.59	I, K	U
Tennessee	SR036	0	2.93	2.93	I, K	U
Tennessee	SR009	7.24	8.18	0.94	I, K	U
Tennessee	5289	0.5	1.51	1.01	J, K	U
Tennessee	SR324	0.645	2.175	1.53	H, K	U

State	Route No.	Start Point	End Point	Length (miles)	CUFC and CRFC ID Codification	CUFC = U CRFC = R
Tennessee	SR169	6.48	8.31	1.83	J, K	U
Tennessee	SR162	0	5.89	5.89	J, K	U
Tennessee	1124	5.22	8.64	3.42	J, K	U
Tennessee	SR034	11.13000011	14.90999985	3.78	K	U
Tennessee	1450	12.35	13.543	1.193	J, K	U
Tennessee	2247	0.781	1.83	1.049	J, K	U
Tennessee	2807	0	1.145	1.145	K	U
Tennessee	2813	5	8.68	3.68	J, K	U
Tennessee	2831	1.803	4.27	2.467	I, K	U
Tennessee	2842	8.33	9.5071	1.177	J, K	U
Tennessee	2861	8.7541	9.7	0.946	J, K	U
Tennessee	2869	2.46	3.62	1.16	J, K	U
Tennessee	2870	4.1	5.31	1.21	K	U
Tennessee	4191	0.87	4.71	3.84	I, J, K	U
Tennessee	5427	1.31	1.873	0.563	J, K	U
Tennessee	5428	0	1.44	1.44	K	U
Tennessee	SR004	0	2.0971	2.097	J, K	U
Tennessee	SR014	7.4597	7.98	0.52	H, K	U
Tennessee	SR057	0	1.25	1.25	J, K	U
Tennessee	SR086	0	1.885	1.885	K	U
Tennessee	SR176	2.9	4.0117	1.112	J, K	U
Tennessee	SR109	13.696	15.0116	1.32	K	U
Tennessee	SR076	14.80500031	16.28000069	1.475	K	U
Tennessee	SR102	7.659999847	13.06000042	5.388	J, K	U
Tennessee	SR266	0	6.737999916	6.748	J, K	U
Tennessee	SR109	0.052999999	7.96999979	7.934	K	U
Tennessee	SR109	0	9.045	9.05	K	U
Tennessee	SR136	0	2.309999943	2.31	C, D, G	R
Tennessee	SR028	17.77000046	30.52000046	12.75	C, G	R
Tennessee	SR028	0	4.96999979	4.97	C, G	R
Tennessee	SR028	21.39999962	33.58000183	12.18	A, C, D, G	R
Tennessee	SR028	0	7.152999878	7.153	A, C, D, G	R
Tennessee	SR063	2.078999996	4.09499979	2.016	C, G	R
Tennessee	SR029	2.743000031	6.519000053	3.776	C, D, G	R
Tennessee	SR324	0	0.644999981	0.645	C, G	R
Tennessee	SR034	0	2.559999943	2.56	C, G	R
Tennessee	SR034	12.38700008	22.875	10.488	C, G	R
Tennessee	SR035	0	3.779999971	3.78	C, G	R
Tennessee	SR034	0	2.160000086	2.16	C, G	R
Tennessee	0D930	0	0.660000026	0.66	F, G	R
Tennessee	0D944	0.736000001	0.947000027	0.211	F, G	R
Tennessee	0D889	7.946000099	8.612000465	0.666	F, G	R
Tennessee	SR840	0	2	2	G	R

State	Route No.	Start Point	End Point	Length (miles)	CUFC and CRFC ID Codification	CUFC = U CRFC = R
Tennessee	SR052	6.800000191	7.25	0.45	C, D, G	R
Tennessee	SR010	23.0170002	24.96999931	1.953	C, D, G	R
Tennessee	SR096	0	3.266000032	3.266	C, D, G	R
Tennessee	SR266	6.737999916	8.751999855	2.014	C, G	R
Tennessee	SR052	0	4.566999912	4.567	C, D, G	R
Tennessee	SR096	15.99400043	26.94000053	10.946	C, D, G	R
Tennessee	SR010	0	8.878000259	8.878	C, D, G	R
Tennessee	SR109	7.97	23.65	15.68	C, D, G	R
Tennessee	SR109	9.045	13.696	4.651	C, D, G	R
Tennessee	SR211	3.99000001	10.31000042	6.32	C, F, G	R
Tennessee	SR002	16.77000046	19.56999969	2.8	C, G	R
Tennessee	SR002	11.4090004	14.68099976	3.272	C, D, G	R
Tennessee	SR040	0.360000014	26.25	25.89	A, C, D, G	R
Tennessee	SR128	0	10.00199986	10.002	C, G	R
Tennessee	SR001	15.05000019	28.11000061	13.06	C, D, G	R
Tennessee	SR019	0	13.02999973	13.03	C, D, G	R
Tennessee	SR001	0	8.170000076	8.17	C, D, G	R
Tennessee	SR019	22.49099922	26.13999939	3.649	C, G	R
Tennessee Subtotal				**306.561**		
Texas						
Utah	US-6	Milepost 178.85	Milepost 258.88	80.03	D	R
Utah	US-191	Milepost 157.19	Milepost 71.86	85.33	A	R
Utah	US-491	Milepost 0.00	Milepost 17.04	17.04	C	R
Utah	SR-252	Milepost 0.00	Milepost 6.80	6.8	K	U
Utah	SR-134	Milepost 11.30	Milepost 12.40	1.1	J	U
Utah	Rulon White Boulevard	SR-134	1975 North	1.05	J	U
Utah	400 North	I-15	1200 West	0.98	J	U
Utah	SR-39	Milepost 4.00	Milepost 6.00	2	J	U
Utah	SR-193	Milepost 1.00	Milepost 3.50	2.5	J	U
Utah	SR-108	Milepost 0.10	Milepost 3.00	2.9	J	U
Utah	SR-68	Milepost 62.58	Milepost 69.00	6.42	H	U
Utah	1100 North/2600 South	SR-68	I-15	1.5	J	U
Utah	I-215	Milepost 26.70	Milepost 28.93	2.23	K	U
Utah	SR-172	Milepost 5.40	Milepost 9.20	3.8	H	U
Utah	SR-154	Milepost 20.06	Milepost 23.80	3.74	J	U
Utah	SR-68	Milepost 56.19	Milepost 59.46	3.27	J	U
Utah	700 South	SR-172	SR-68 at 400 South	4.62	J	U
Utah	California Avenue	SR-172	SR-68	4.59	J	U
Utah	2100 South	SR-68	900West	1.16	J	U
Utah	SR-201	Milepost 0.00	Milepost 18.10	18.1	K	U
Utah	I-215	Milepost 11.51	Milepost 20.56	9.05	K	U
Utah	900 West	1700 South	3300 South	2.36	H	U

State	Route No.	Start Point	End Point	Length (miles)	CUFC and CRFC ID Codification	CUFC = U CRFC = R
Utah	SR-171	Milepost 9.22	Milepost 10.00	0.78	H	U
Utah	US-6	Milepost 173.42	Milepost 178.85	5.43	K	U
Utah	River Road	3500 South	SR-7	3.37	J	U
Utah	SR-7	Milepost 0.00	Milepost 3.45	3.45	J	U
Utah Subtotal				**273.6**		
Vermont						
Virginia						
Washington	US 395	North boundary of Urbanized Area	0.5 mile south of Foster Welles Road	1	J, K	U
Washington	US 395	I-182	I-82	7.54	H, K	U
Washington	US 12	A Street	Tank Farm Road	0.93	J, K	U
Washington	Fleshman Way	SR129 underpass	Idaho State line	0.15	K	U
Washington	US 12	2nd Street	Idaho State line	0.2	K	U
Washington	SR 432	I-5	SR 433	4.51	H, J, K	U
Washington	Henderson Blvd	I-5	Plum Street SE	0.43	H, J, K	U
Washington	Plum Street SE	Henderson Blvd.	State Avenue	0.63	H, J, K	U
Washington	East Bay Drive NE	Plum Street SE	Olympia Avenue NE	0.06	H, J, K	U
Washington	Olympia Avenue NE	East Bay Drive NE	Marine Drive NE	0.13	H, J, K	U
Washington	US 101	Black Lake Blvd SW	Kaiser Road	1.08	K	U
Washington	N. Freya St	E Empire Avenue	E. Francis Avenue	1.53	J, K	U
Washington	N. Market St	N. Greene Street	N. Haven Place	0.83	J, K	U
Washington	N. Greene St	E Illinois Avenue	E. Mission +E908:E966 Avenue	0.9	J, K	U
Washington	N. Freya Way	E Mission Avenue	N. Freya Street	0.34	J, K	U
Washington	N. Freya St	N. Freya Way	Sprague Avenue	0.74	J, K	U
Washington	S. Freya St	Sprague Avenue	I-90	0.26	J, K	U
Washington	S. Thor Pl/ S Thor St	Sprague Avenue	I-90	0.31	J, K	U
Washington	N. Argonne Road	North of E Empire Avenue	SR 290	0.57	J, K	U
Washington	Argonne Road	SR 290	Mullan Road	0.38	J, K	U
Washington	Argonne Road	Mullan Road	I-90	0.2	J, K	U
Washington	Mullan Road	Argonne Road	I-90	0.21	J, K	U
Washington	Sullivan Road	BNSF grade crossing south of SR 290	North City Limit of Spokane Valley	0.63	J, K	U
Washington	Sullivan Road (planned route)	Forker Road	North City limit of Spokane Valley	0.81	J, K	U
Washington	Appleway Avenue	Liberty Lake Road	Molter Road	0.84	K	U
Washington	Airport Drive	Spotted Road	Airport Drive (loop)	0.25	H, K	U
Washington	Spotted Road	Airport Drive WB	Airport Drive EB	0.14	H, K	U
Washington	Spotted Road	Airport Drive EB	Flightline Blvd.	0.77	H, K	U
Washington	Flightline Blvd	Spotted Road	Grove Road	0.44	H, K	U
Washington	Grove Road	Flightline Blvd.	I-90	0.22	H, K	U
Washington	Barker Road	SR 290	Flora Road	0.07	K	U
Washington	SR 290	0.4 mile west of Starr Road	Starr Road	0.39	K	U
Washington	SR 14	I-205 (Vancouver)	SE 164th Avenue	2.45	J, K	U

State	Route No.	Start Point	End Point	Length (miles)	CUFC and CRFC ID Codification	CUFC = U CRFC = R
Washington	SR 14	Port Street	32nd Street (Washougal)	2.04	J, K	U
Washington	SR 501	I-5 (Vancouver)	Fourth Plain Blvd.	1.94	H, I, J, K	U
Washington	501 Couplet	Franklin Street	I-5 on ramp	0.55	H, I, J, K	U
Washington	SR 285	N. Miller Street	US 2	1.99	J, K	U
Washington	N. 1st St	US 12	I Street	0.81	J, K	U
Washington	I St	1st Street	5th Avenue	0.32	J, K	U
Washington	I St	5th Avenue	6th Avenue	0.06		U
Washington	6th Avenue	I Street	River Road	0.25	J, K	U
Washington	South Union Gap Beltway/Westside Connector (planned route)	W. Ahtanum Road	I-82 ramp	1.98	J, K	U
Washington	US 12	Eschbach Road	Old Naches Highway	3.26	J, K	U
Washington	SR 17	North of W. Rankin Road	Adams/Grant County line	1.33	D, G	R
Washington	US97	National Forest Development Road 7200	Kittitas/Chelan County line	15.79	A, D, G	R
Washington	US97	US 2	National Forest Development Road 7200	5.18	D, G	R
Washington	SR 17	North of SR 260	South of Adam/Franklin County line	3.97	A, D, G	R
Washington	0 NE	I-90	3 NE	2.58	D, G	R
Washington	3 NE	3 NE	E. Wheeler Road	1	D, G	R
Washington	SR 17	1.3 mile south of Road 3 SE	1 mile north of Road 6 SE	1.55	D, G	R
Washington	SR 281	I-90	SR 28	10.55	D, F, G	R
Washington	US 101	SR 105 (Aberdeen)	Aberdeen Couplet	3.87	D, F, G	R
Washington	US 101 Couplet	S H Street	US 101 in Hoquiam	3.99	D, F, G	R
Washington	US 101 Couplet	S G Street	E. Wishkah Street	0.13	D, F, G	R
Washington	U S12	US 101	S. Fleet Street	0.6	D, F, G	R
Washington	US 12 Couplet	S G Street	US 12	0.35	D, F, G	R
Washington	SR18	South of Issaquah Hobart Road S.	I-90	8.11	A, F, G	R
Washington	US 97	SR 970	Kittitas/Chelan County line	14.29	A, D, G	R
Washington	Hood River Bridge	SR 14 (Milepost 65.06)	Oregon State line	0.45	D, F, G	R
Washington	The Dales Bridge on US197	US 197	Oregon State line	0.21	D, G	R
Washington	US 97 Sam Hill Memorial Bridge	US 197 (Milepost 0)	Oregon State line	0.24	A, G	R
Washington	SR 3	SR 302	Manson/Kitsap County line	4.97	F, G	R
Washington	Cook Road	I-5	Green Road	0.22	G	R
Washington	Bridge ot the Gods	SR 14 (Milepost 41.55)	Oregon State line	0.23	G	R
Washington	Bigelow Gulch Road	Jensen Road	Forker Road	3.76	G	R
Washington	Bigelow Gulch Road (planned route)	West of Palmer Road	Bradley Road	1.18	G	R

State	Route No.	Start Point	End Point	Length (miles)	CUFC and CRFC ID Codification	CUFC = U CRFC = R
Washington	Bigelow Gulch Road (realignment)	Bradley Road	Jensen Road	0.85	G	R
Washington	Forker Road	Bigelow Gulch Road	Proposed Sullivan Road	0.76	G	R
Washington	SR 290	Starr Road	0.36 mile east of Starr Road	0.36	G	R
Washington	US 395	0.3 mile north of Crawford St	0.45 mile south of Burroughs Road	2.5	D, G	R
Washington	US 395	Williams Lake Road	Vanasse Road	5.42	D, E, G	R
Washington	US 12	Boise Cascade Road	US 730	2.93	A, D, F, G	R
Washington	US 12	US 730	Nine Mile Hill	9.75	D, F, G	R
Washington	SR 539	SR 546	Canadian border	2.62	D, E, G	R
Washington	SR 9	W Garfield St	Canadian border	0.17	E, G	R
Washington	SR 26	Adams/Whitman County line	SR 127	20.04	D, G	R
Washington	SR 26	SR 127	Penawawa Road	5.08	A, D, G	R
Washington	US 195	Colfax	Pullman	12.19	D, G	R
Washington	LaRue Road	US 97	SR 22	0.93	D, G	R
Washington	LaRue Road (planned route)	SR 22	Meyers Road	0.62	D, G	R
Washington	Meyers Road	L St	I-82	1.92	D, G	R
Washington	L St	Meyers Road	Meyers Road	0.3	D, G	R
Washington	Meyers Road	S Track Road	L St	0.46	D, G	R
Washington	US 97	LaRue Road	SR 22	0.67	A, D, G	R
Washington	US 97	SR 22	South of Yakima UA boundary	11.15	D, G	R
Washington Subtotal				**206.41**		
West Virginia						
Wisconsin						
Wyoming	US 30	0	100.03	98.732	A, B, C, D, G	R
Wyoming	US 20-26	11.733	59.455	47.73	A, B, C, E, F, G	R
Wyoming	Greeley Highway	0	3.538	3.538	A, B, C, G	R
Wyoming	Casper-Future	0	4.987	4.987	H, I, J, K	U
Wyoming	Cheyenne-Future Christensen	0	0.68	0.68	H, I, J, K	U
Wyoming	Burlington Trail	101.35	101.794	0.444	I, J, K	U
Wyoming	I-80 Service Road	0	1.068	1.068	I, J, K	U
Wyoming	I-80 Service Road	1.003	1.382	0.379	H, I, J, K	U
Wyoming	Campstool Way	0	0.265	0.265	H, I, J, K	U
Wyoming	5th Street	100.848	101.146	0.298	H, I, J, K	U
Wyoming	Morrie Avenue	99.661	100.499	0.835	H, I, J, K	U
Wyoming	Venture Drive	105.986	107.074	1.088	H, I, J, K	U
Wyoming	Greeley Highway	3.538	8.472	4.926	H, I, J, K	U
Wyoming	Waterford	98.664	99.549	0.885	H, I, J, K	U
Wyoming	College Drive	0	6.873	6.873	H, I, K	U
Wyoming	WY 220	113.36	117.21	3.591	H, I, J, K	U
Wyoming	Fox Farm Road	0	1.84	1.84	H, I, K	U
Wyoming	Round Top Road	0	1.81	1.81	H, I, J, K	U

State	Route No.	Start Point	End Point	Length (miles)	CUFC and CRFC ID Codification	CUFC = U CRFC = R
Wyoming	WY 253	0	0.56	0.56	H, I, J, K	U
Wyoming	Christensen Road	0.416	0.926	0.51	H, I, J, K	U
Wyoming	WY 254	1.336	4.06	2.754	H, I, J, K	U
Wyoming	WY 258	7.85	18.289	10.439	H, I, K	U
Wyoming	WY 258	18.289	18.44	0.151	H, I, K	U
Wyoming	US 20-26	0	0.087	0.087	H, I, J, K	U
Wyoming	US 20-26	0.087	2.34	2.313	H, I, J, K	U
Wyoming	US 20-26	4.518	11.733	7.223	H, I, J, K	U
Wyoming	Nationway	101.19	103.186	1.996	H, I, J, K	U
Wyoming	Logan Avenue	100.309	100.71	0.401	H, I, J, K	U
Wyoming	US 20-26	0	2.9	2.88	H, I, K	U
Wyoming	WY 505	186.881	187.889	1.008	H, I, J, K	U
Wyoming	Lincolnway	358.01	361.446	3.436	H, I, K	U
Wyoming	A-209-2	5.02	5.087	0.067	H, I, J, K	U
Wyoming	Campstool Road	0.08	5.02	4.94	H, I, J, K	U
Wyoming	High Plains	100	103.14	3.14	H, I, J, K	U
Wyoming	WY 220	0	0.04	0.04	H, I, J, K	U
Wyoming	Christensen Road	0	0.3	0.3	H, I, J, K	U
Wyoming	CR 927	0	0.214	0.214	H, I, J, K	U
Wyoming Subtotal				**222.428**		

A = Refer to 23 U.S.C. 167(e)(1)(A): Rural principal arterial roadway with a minimum of 25 percent of the annual average daily traffic of the road measured in passenger vehicle equivalent units from trucks.

B = Refer to 23 U.S.C. 167(e)(1)(B): Provides access to energy exploration, development, installation, or production areas.

C = Refer to 23 U.S.C. 167(e)(1)(C): Connects the Primary Highway Freight System, a roadway described in subparagraph (A) or (B), or the Interstate System to facilities that handle more than: 1) 50,000 20-foot equivalent units per year; or 2) 500,000 tons per year of bulk commodities.

D = Refer to 23 U.S.C. 167(e)(1)(D): Provides access to a grain elevator, an agricultural facility, a mining facility, a forestry facility, or an intermodal facility.

E = Refer to 23 U.S.C. 167(e)(1)(E): Connects to an international port of entry.

F = Refer to 23 U.S.C. 167(e)(1)(F): Provides access to significant air, rail, water, or other freight facilities in the State.

G = Refer to 23 U.S.C. 167(e)(1)(G): Corridor that is, in the determination of the State, vital to improving the efficient movement of freight of importance to the economy of the State.

H = Refer to 23 U.S.C. 167(f)(3)(B)(i): Connects an intermodal facility to the Primary Highway Freight System, the Interstate System, or an intermodal freight facility.

I = Refer to 23 U.S.C. 167(f)(3)(B)(ii): Located within a corridor of a route on the Primary Highway Freight System and provides an alternative highway option important to goods movement.

J = Refer to 23 U.S.C. 167(f)(3)(B)(iii): Serves a major freight generator, logistic center, or manufacturing and warehouse industrial land.

K = Refer to 23 U.S.C. 167(f)(3)(B)(iv): Corridor that is important to the movement of freight within the region, as determined by the metropolitan planning organization or the State.

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

Conditions and Performance

24th Edition

REPORT TO CONGRESS

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