U.S. Department of Transportation
Federal Highway Administration
Federal Transit Administration

25th Edition | Report to Congress

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

Conditions and Performance

U.S. Department
of Transportation

Federal Highway
Administration

Federal Transit
Administration

Office of the Administrator

1200 New Jersey Ave., SE
Washington, D.C. 20590

The Honorable Mike Johnson
Speaker of the House of Representatives
Washington, DC 20515

Dear Mr. Speaker:

Enclosed is the 25th edition of the biennial "Status of the Nation's Highways, Bridges and Transit: Conditions and Performance" Report to Congress (C&P Report), in accordance with the requirements of 23 U.S.C. §503(b)(8) and 49 U.S.C. §308(e). The report provides an overview of physical conditions, operational performance, and investment trends.

This edition outlines the state of our highway and transit systems from 2008–2018 and documents the Nation's backlog of unmet highway, bridge, and transit investment needs. The Bipartisan Infrastructure Law (BIL), enacted as the Infrastructure Investment and Jobs Act (IIJA), provides the resources needed to begin reducing this backlog.

The 25th C&P Report projects that an average annual investment level of $151.1 billion (in constant 2018 dollars) would be sufficient to fund all potential highway capital investments estimated to be cost-beneficial at some point over the period from 2018 to 2038. From 2014 through 2018, highway capital spending by all levels of government averaged $115.1 billion in 2018 dollars. The report also estimates an annual investment level of $20.3 billion (in constant 2018 dollars) that would eliminate the transit State of Good Repair backlog by 2038.

Projected Federal Highway Administration (FHWA) funding obligations from 2022 through 2026 under BIL are 28 percent higher in inflation-adjusted dollars than actual FHWA funding obligations from 2014 through 2018. If Federal funding levels were to remain constant in inflation-adjusted terms, at current BIL levels through 2038, and if State and local highway investment were to remain constant at recent levels, this would result in a combined national annual highway expenditure level of $123.3 billion in constant 2018 dollars for the 20-year period ending in 2038.

BIL also supports transit agencies and communities as they modernize and expand to attract new passengers and create more opportunities. With $108 billion dollars in funding obligated by the Federal Transit Administration (FTA) over 5 years, the legislation both expands existing transit programs and adds four new ones, making it possible for us to support safer, faster, and more reliable service to everyone and ensure equitable access for all. The All Stations Accessibility Program provides support to upgrade legacy rail transit stations that remain inaccessible to individuals with disabilities.

Rail Vehicle Replacement Grants will replace railcars past their useful life and significantly modernize America's transit infrastructure. Two new ferry programs—Ferry Service for Rural Communities and Electric or Low-Emitting Ferry Pilot Program—will expand passenger ferry service and support the transition to low- or zero-emission propulsion technologies.

These additional Federal investments, based on BIL funding levels, combined with State, and local investments, would be sufficient to significantly improve the state of the Nation's highways and bridges. In summary, BIL moves us closer to our infrastructure investment goals.

BIL also advances other critical priorities. These priorities include reducing the number of deaths and injuries on our Nation's roadways, creating communities of opportunity through equitable access to transportation alternatives, undoing the harm caused by historical Federal policies that have segregated and displaced disadvantaged communities, achieving net-zero emissions, and fortifying our infrastructure to sustain a safe and equitable system.

The next, 26th, edition of the C&P Report will be based on data from 2022 instead of 2020. This adjustment will provide some insight on the early impacts of the BIL while also providing a more useful baseline for analysis and forecasting, given the effects of the pandemic on travel in 2020. This report will be developed and submitted to Congress in late 2024.

A similar letter has been sent to the President of the Senate; the Chairman and Ranking Member of the Senate Committee on Environment and Public Works; the Chairman and Ranking Member of the Senate Committee on Banking, Housing, and Urban Affairs; and the Chairman and Ranking Member of the House Committee on Transportation and Infrastructure.

Sincerely,

Shailen P. Bhatt
FHWA Administrator

Nuria I. Fernandez
FTA Administrator

Enclosure

U.S. Department of Transportation
Federal Highway Administration
Federal Transit Administration

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Highways, Bridges, and Transit

Conditions and Performance

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Abbreviations

AADT	Annual average daily traffic
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
ADT	Average Daily Traffic
APTA	American Public Transit Association
APTL	Average passenger trip lengths
ARNOLD	All Road Network of Linear Referenced Data
ATRI	American Transportation Research Institute
ATU	Amalgamated Transit Union
BAC	Blood alcohol content
BART	Bay Area Rapid Transit
BCA	Benefit-cost analysis
BCR	Benefit-cost ratio
BEA	Bureau of Economic Analysis
BIL	Bipartisan Infrastructure Law
BLS	Bureau of Labor Statistics
BRT	Bus rapid transit
BTS	Bureau of Transportation Statistics
C&P	Conditions and performance
CAFE	Corporate Average Fuel Economy
CAGR	Compound annual growth rate
CAMPO	Capital Area Metropolitan Planning Organization
CAPTI	Climate Action Plan for Transportation Infrastructure
CARES	Coronavirus Aid, Relief and Economic Security
CDC	Centers for Disease Control and Prevention
CDOT	Colorado Department of Transportation
CFR	Code of Federal Regulations
CGE	Computable general equilibrium
CIG	Capital Investment Grants
CMAQ	Congestion Mitigation and Air Quality
CMV	Commercial motor vehicle
CNG	Compressed natural gas
COG	Council of governments
COVID	Coronavirus disease
CRCP	Continuously reinforced concrete pavement
CRFC	Critical Rural Freight Corridor

CRRSA	Coronavirus Response and Relief Supplemental Appropriations
CRSS	Crash Report Sampling System
CUFC	Critical Urban Freight Corridor
CVS	Commercial vehicle safety
DDSA	Data-Driven Safety Analysis
DOT	Department of Transportation
EDC	Every Day Counts
EPA	Environmental Protection Agency
EV	Electric vehicle
FAF	Freight Analysis Framework
FAH	Federal-aid Highway
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
FMT	Freight Mobility Trends
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
FTOT	Fuel Transportation Optimization Tool
GDP	Gross domestic product
GHG	Greenhouse gas
GIS	Geographic information system
GTFS	General Transit Feed Specification
HD	High definition
HERS	Highway Economic Requirements System
HMA	Hot Mix Asphalt
HOV	High-occupancy vehicle
HPMS	Highway Performance Monitoring System
HSIP	Highway Safety Improvement Program
HSIS	Highway Safety Information System
HSM	Highway Safety Manual
HTF	Highway Trust Fund
IBCR	Incremental benefit-cost ratio
IIJA	Infrastructure Investment and Jobs Act
INFRA	Infrastructure for Rebuilding America
IPCC	Intergovernmental Panel on Climate Change
IRI	International Roughness Index
IRS	Internal Revenue Service
ITI	Intelligent transportation infrastructure
ITS	Intelligent transportation systems

JCP	Jointed concrete pavement
LRSP	Local road safety plan
MAIS	Maximum Abbreviated Injury Scale
MBTA	Massachusetts Bay Transportation Authority
MCDM	Multi-criteria decision method
MIRE	Model Inventory of Roadway Elements
MOE	Measures of effectiveness
MPO	Metropolitan planning organization
MR&R	Maintenance, repair, and rehabilitation
MTA	Mass Transit Account
MVMT	Million vehicle miles traveled
NBI	National Bridge Inventory
NBIAS	National Bridge Investment Analysis System
NBIS	National Bridge Inspection Standards
NCFO	National Census of Ferry Operators
NCTP	National Coalition on Truck Parking
NDC	Nationally determined contribution
NEVI	National Electric Vehicle Infrastructure
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
NPMRDS	National Performance Management Research Data Set
NTD	National Transit Database
NTI	National Tunnel Inventory
NTIS	National Tunnel Inspection Standards
O&M	Operations and maintenance
OMB	Office of Management and Budget
P&R	Preservation and repair
PCC	Portland cement concrete
PHED	Peak Hour Excessive Delay
PHFS	Primary Highway Freight System
PM	Performance measures
PMA	Polymer-modified asphalt
PMT	Passenger miles traveled
PSR	Present Serviceability Rating
PTI	Planning Time Index

Pub. L.	Public law
RAIRS	Rail Accident/Incident Reporting System
RAISE	Rebuilding American Infrastructure with Sustainability and Equity
SGR	State of good repair
SHA	State Highway Administration
SHSP	Strategic Highway Safety Plan
SMA	Stone-matrix asphalt
SNBIBE	Specification for National Bridge Inventory Bridge Elements
SOV	Single-occupancy vehicle
SQC	Synthesis, Quantity, and Condition
STBG	Surface Transportation Block Grant
STEP	Safe Transportation for Every Pedestrian
STIC	Small Transit Intensive Cities
TAM	Transit asset management
TERM	Transit Economic Requirements Model
TMC	Traffic Message Channel
TNC	Transportation network company
TOD	Transit Oriented Development
TOPS	Table of Potential Samples
TPM	Transportation Performance Management
TREDIS	Transportation Economic Development Impact System
TRI	Truck Reliability Index
TSI	Transportation Services Index
TTI	Travel Time Index
TTR	Travel Time Reliability
TTTR	Truck Travel Time Reliability
TWC	Transit Workforce Center
UHPC	Ultra-high performance concrete
UPT	Unlinked passenger trips
UZA	Urbanized area
VMT	Vehicle miles traveled
VNTSC	Volpe National Transportation Systems Center
VOMS	Vehicle operated in maximum service
VRH	Vehicle revenue hours
VRM	Vehicle revenue miles
VOC	Volatile organic compound
VRM	Vehicle revenue mile
VSL	Value of statistical life
ZEV	Zero-emission vehicle

Foreword: The Bipartisan Infrastructure Law

The data analysis supporting the 25th edition of the C&P Report predates the Bipartisan Infrastructure Law (BIL), enacted as the Infrastructure Investment and Jobs Act (IIJA) (Pub. L. 117-58) and signed into law by President Biden on November 15, 2021. BIL represents the largest long-term investment in our infrastructure and economy in the Nation's history to help build a safe, resilient, and equitable transportation future.

This report describes the state of our highway and transit systems from 2008 to 2018 and documents the Nation's backlog of unmet highway, bridge, and transit investment needs prior to BIL being enacted. Building upon findings presented in the 24th edition, performance targets were established to reduce the highway repair backlog of $830 billion by 50 percent by 2040. The 2018 highway repair backlog of $852 billion is 2.6 percent higher, but in constant-dollar terms it is 4.6 percent lower than the previously reported value. This edition also presents a transit state of good repair (SGR) backlog of $101 billion.

BIL provides the resources needed to begin reducing this backlog while advancing other critical priorities. These resources include the largest dedicated bridge investment since construction of the Interstate Highway System, along with new programs that focus on key infrastructure priorities (including rehabilitating bridges in critical need of repair and modernizing the Nation's subway, light rail, and bus systems), reducing carbon emissions, increasing system resilience, forging new connections in communities, and improving mobility and access to economic opportunity.

As required by Congress, the C&P Report provides decision makers with an appraisal of the physical condition and operational performance of the Nation's highways, bridges, and transit systems. It continues to fulfill that intent. As BIL moves us closer to a better transportation system for all travelers, the 25th edition of the C&P Report reaffirms that only continued and sustained investments in transportation into the future—including investments beyond those in BIL—can help us reach our goals as a Nation.

BIL Highlights

With regard to **infrastructure investment**, the 25th C&P Report projects that an average annual investment level of $151.1 billion (in constant 2018 dollars) would be sufficient to fund all potential highway capital investments estimated to be cost-beneficial at some point over the period from 2018 to 2038. From 2014 through 2018, highway capital spending by all levels of government averaged $115.1 billion in 2018 dollars. Projected FHWA funding obligations from 2022 through 2026 under BIL are 28 percent higher in inflation-adjusted dollars than FHWA funding obligations from 2014 through 2018. If Federal funding levels were to remain constant in inflation-adjusted terms at current BIL levels through 2038, and State and local highway investment were to remain constant at recent levels, this would result in a combined national annual highway expenditure level of $123.3 billion in constant 2018 dollars for the 20-year period ending in 2038. **This additional Federal investment, based on BIL funding levels, combined with State and local investment, would be sufficient to significantly improve the state of the Nation's highways and bridges.**

BIL promotes **safety** by continuing the Highway Safety Improvement Program (HSIP) to achieve a significant reduction in traffic fatalities and serious injuries on all public roads, including non-State-owned public roads and roads on Tribal lands. The HSIP requires a data-driven, performance-focused strategic approach to improving highway safety on all public roads.

BIL establishes the new Safe Streets and Roads for All (SS4A) discretionary grant program, which supports local initiatives to prevent death and serious injury on roads and streets, commonly referred to as "Vision Zero" or "Toward Zero Deaths" initiatives. The SS4A program supports the U.S. Department of Transportation's (DOT) National Roadway Safety Strategy and a goal of zero deaths and serious injuries on our Nation's roadways.

To provide **congestion relief** and improve mobility and travel reliability, BIL establishes a Congestion Relief Program to provide competitive grants to States, local governments, and metropolitan planning organizations for projects in large urbanized areas to advance innovative, integrated, and multimodal solutions in the most congested metropolitan areas of the United States. The goals of the Congestion Relief Program are to reduce highway congestion and its associated economic and environmental costs, and to optimize existing highway capacity and use of transit systems that provide alternatives to highways.

As **freight movement** and **truck parking** remain national concerns, BIL continues the National Highway Freight Program (NHFP) to improve the efficient movement of freight on the National Highway Freight Network (NHFN) and support several goals, including:

- Investing in infrastructure and operational improvements that strengthen economic competitiveness, reduce congestion, reduce the cost of freight transportation, improve reliability, and increase productivity;
- Improving the safety, security, efficiency, and resiliency of freight transportation in rural and urban areas;
- Improving the state of good repair of the NHFN;
- Using innovation and advanced technology to improve NHFN safety, efficiency, and reliability;
- Improving the efficiency and productivity of the NHFN;
- Improving State flexibility to support multi-State corridor planning and address highway freight connectivity; and
- Reducing the environmental impacts of freight movement on the NHFN.

BIL requires States to include an assessment of the adequacy of commercial motor vehicle parking in their State Freight Plans and increases the required frequency of plan updates.

Equity is a priority in BIL. To increase our Nation's capacity and ability to address transportation equity, DOT is collaborating with internal partners; researching and documenting noteworthy practices among States, regions, and localities; and creating grant programs that incorporate racial equity and environmental justice as focus areas. The Reconnecting Communities Pilot (RCP) discretionary grant program authorized by BIL will provide $1 billion over the next 5 years to support reconnecting communities that were previously cut off from economic opportunities by transportation infrastructure through planning grants and capital construction grants to restore community connectivity.

BIL also supports transit agencies and communities as they modernize and expand to attract new people and create more opportunities. With $108 billion in funding obligated by the Federal Transit Administration (FTA) over 5 years, the legislation both expands existing transit programs and adds four new ones, making it possible for us to support safer, faster, and more reliable service to everyone and ensure equitable access for all. BIL authorized four new grant programs, including the All Stations Accessibility Program, which provides support to upgrade legacy rail transit stations that remain inaccessible to individuals with disabilities. The Rail Vehicle Replacement Grants Program will replace railcars past their useful life and significantly modernize America's transit infrastructure.

Two new ferry programs—Ferry Service for Rural Communities and the Electric or Low-Emitting Ferry Pilot Program—will expand passenger ferry service and support the transition to low- or zero-emission propulsion technologies.

To **combat climate change**, BIL provides significant investments to support a more equitable and climate-friendly transportation system, including a $7.5 billion grant program to strategically deploy publicly accessible EV charging and alternative fueling infrastructure along highway corridors. In addition to investments, BIL establishes a carbon reduction program that requires States, in coordination with MPOs, to develop strategies to reduce greenhouse gas (GHG) emissions from the transportation sector. Several States are also pursuing programs that reduce GHG emissions and provide funding for transportation projects and programs that support climate and equity goals. FHWA provides technical assistance, resources, and tools to support State, regional, and local agencies in incorporating climate change considerations into transportation planning and investment decisions. Resources are available at https://www.fhwa.dot.gov/environment/sustainability/energy.

Introduction

The U.S. Department of Transportation (DOT) has prepared this report—the 25th 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). The statutory due dates specified in these sections differ; this 25th edition is intended to address the requirements for reports due:

- July 31, 2021, under 23 U.S.C. §503(b)(8); and
- March 31, 2022, 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 2018 data. In assessing historical trends, many of the exhibits presented in this report provide statistics for the 10 years from 2008 to 2018. 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 2038.

Since this report draws primarily on 2018 data, the effects of the coronavirus 2019 (COVID-19) pandemic are not reflected in the analyses presented in Part I or Part II. However, the discussions presented in Parts III and Part IV include the impacts of the COVID-19 pandemic on highway passenger travel, freight transportation, and transit service, and the resulting implications for highway funding, transit ridership trends, and operating revenues.

None of the data or analyses presented in this edition reflect the impacts of increased Federal investment under the Bipartisan Infrastructure Law (BIL), enacted as the Infrastructure Investment and Jobs Act (IIJA), Pub. L. 117-58 (Nov. 15, 2021).

Section 13006(a)(2)(F) of BIL expanded the required scope of this report to include new elements. Specifically, 23 U.S.C. §503(b)(8) now requires the report to provide estimates of the current conditions, needs, and backlog for tunnels; the conditions and needs for intelligent transportation systems; and resilience needs. Multi-year research efforts have been initiated to address these requirements; details on this research and its results will be incorporated into future editions of the report. The BIL also repealed 23 U.S.C. §167(h), folding its requirement for an assessment of the conditions and performance of the highway network for freight movement into 23 U.S.C. §503(b)(8). This edition is written as responding to the 23 U.S.C. §167(h) requirement.

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 (Pub. L. 114-94).
- 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 describes the 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 2014–2018 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 and the investment backlog to findings in previous reports and discussing scenario implications.
- Chapter 9 discusses how changing some of the underlying technical assumptions would affect the future highway and transit investment scenarios.
- Chapter 10 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, *Additional Information,* explores related issues not fully covered in the core analyses.

- Chapter 11 discusses impacts of COVID-19 on the highway and transit transportation system.
- Chapter 12 examines issues relating to greenhouse gas mitigation.

Part IV, *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 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 IV and the macroeconomic impact modeling results presented in Chapter 11.

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 (MAP-21) Act (Pub. L. 112-141) 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 (NTI) 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. Information available in the NTI, and summarized in Chapter 1 of this report, include physical characteristics, location, traffic loads, and ownership by level of government.

Beginning with this version of the report, information on the Nation's ferries will be included. Information on ferry operations is based on data in the 2016 National Census of Ferry Operators (NCFO). The 2016 NCFO collected responses from 163 ferry operators or 74.1 percent of all the known 220 eligible ferry operators. The data presented in the NCFO report represent only data provided by the respondents.

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 900 urban and 1,300 rural transit agencies. NTD also provides data on the composition and age of transit fleets.

This edition of the C&P Report is the first to use asset inventory data obtained primarily from the National Transit Database's Asset Inventory Module (NTD AIM). Prior to this improvement, most transit asset inventory data had been obtained through asset inventory data requests made by FTA to a sample of the Nation's larger rail and bus operators. Given the nature of these requests, the data submitted by local agencies lacked consistency in terms of level of asset detail and the age of the inventory data. With the introduction of NTD AIM, FTA now obtains consistently reported asset inventory data for a large proportion of the nation's transit asset types, including revenue and service vehicles, stations and maintenance facilities, and guideway structures. AIM data are also reported annually, assuring the data used for C&P Report analyses better reflect actual transit asset conditions and reinvestment requirements for the analysis period covered by the report.

Although NTD AIM data represent a significant improvement, data supplied through direct agency requests are still used for asset types that are not currently represented in NTD AIM (including communications, subway ventilation, or maintenance equipment) or where agencies do not currently report year-built data for some asset types (including track, tunnels, bridges, switches, and crossings). For this reason, data supplied through direct agency requests are still required to support the assessment of transit asset capital reinvestment needs.

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 identifies the investments needed to replace and rehabilitate existing assets, improve operating performance, and expand transit systems to address the growth in travel demand.

This edition of the C&P Report introduces significant changes to the estimation of transit expansion needs compared with prior reports. Specifically, whereas recent C&P editions focused solely on levels of expansion investment required to support future rider growth, this edition introduces several new analysis components designed to estimate the level of investment to attain service performance and service coverage objectives. This includes components to assess investment levels to introduce service to “transit deserts” (areas not currently served by fixed-route transit that have the density to potentially support transit service), to increase service on low-frequency routes, to reduce crowding for high-utilization operators, and to increase operating speeds in urbanized areas with speeds below the national average.

Changes to C&P Report Scenarios from the 24th Edition

The 24th C&P Report included Low Growth and High Growth scenarios for transit, which together identified system expansion needs for a range of potential annual trend-line ridership growth projections. These two transit scenarios have been replaced in this edition by an Expansion scenario and an Expansion with Growth scenario. The former of these two new scenarios preserves the existing assets and expands the asset base to improve system performance, but assumes no growth in transit ridership. The latter of these two scenarios adds additional assets required to support limited transit growth.

The Maintain Conditions and Performance scenario for highways and bridges presented in the 24th C&P Report used the percentage of deck area on bridges classified as poor, average pavement roughness, and average delay per vehicle mile traveled (VMT) as primary indicators. This edition retains the first of these measures, but substitutes the share of travel on pavements with poor ride quality and the share of travel projected to occur under severely congested conditions for the second and third of these measures. This change in metrics places the focus on the impacts of poor rather than average conditions and performance.

The remaining 20-year highway and transit scenarios presented in this edition are consistent with those presented in the 24th edition. Although the total investment backlogs for highways and transit presented in the two editions are also conceptually consistent, this edition introduces a new Highway Repair backlog estimate, which excludes system expansion needs.

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 objective 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 highway and bridge 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.

The types of capital investment alternatives that are modeled do not reflect the full range of potential transportation investments. Current data sources and modeling capabilities severely limit the ability to identify investment needs associated with resiliency or equity, or Complete Streets (streets designed with safety for all users).

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 long-term growth rates are uncertain, particularly in light of recent declines in transit ridership due to the COVID-19 pandemic. Neither the transit nor highway travel forecasts reflect the potential impacts of the COVID-19 pandemic or emerging transportation technology options such as carshare, scooters, and automated 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.

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

Highlights

This edition of the C&P Report is based primarily on data through 2018. In assessing recent trends, it generally focuses on the 10-year period from 2008 to 2018. The prospective analyses generally cover the 20-year period from 2018 to 2038; the investment levels associated with these scenarios are stated in constant 2018 dollars. This section presents the key findings of the overall C&P 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 4,195,274 miles of public roadways and 616,096 bridges in 2018. This network carried 3.255 trillion vehicle miles traveled (VMT) and 5.591 trillion person miles traveled, up from 2.993 trillion VMT and up from 4.931 trillion person miles traveled in 2008.
- The 1,028,217 miles of Federal-aid highways (25 percent of total mileage) carried 2.772 trillion VMT (85 percent of total travel) in 2018.
- Although the 220,169 miles on the National Highway System (NHS) comprise only 5 percent of total mileage, the NHS carried 1.779 trillion VMT in 2018, approximately 55 percent of total travel.
- The 48,741 miles of the Interstate System carried 0.834 trillion VMT in 2018, slightly more than 1 percent of total mileage and close to 26 percent of total VMT. The Interstate System has grown since 2008, when it consisted of 46,892 miles that carried 0.741 trillion VMT.
- The Nation's 503 tunnels had a combined length of 666,858 feet. The annual average daily traffic (AADT) for tunnels was approximately 14.2 million vehicles, and the annual average daily truck traffic was 0.84 million.

Highway System Terminology

Federal-aid highways are roads that generally are eligible for Federal funding assistance under current law. (Certain Federal programs allow the use of Federal funds for other roads as well.)

The NHS includes 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).

Highway Funding—2018

- All levels of government spent a combined $244.5 billion for highway-related purposes in 2018. Just less than half (48 percent) of total highway spending ($117.0 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 $117.0 billion spent on highway capital improvements in 2018, $27.4 billion (23 percent) was spent on the Interstate

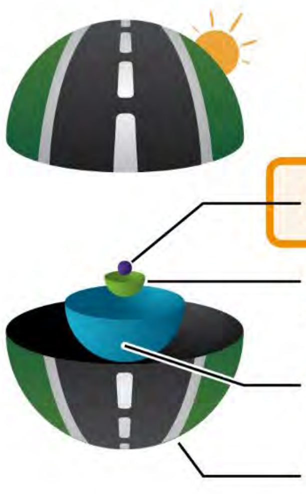
Constant-dollar Conversions for Highway Expenditures

This report uses the Federal Highway Administration's National Highway Construction Cost Index (NHCCI) 2.0 for inflation adjustments to highway capital expenditures, and the Consumer Price Index (CPI) for adjustments to other types of highway expenditures. From 2008 to 2018, the CPI increased by 16.6 percent (1.6 percent per year), whereas the NHCCI 2.0 increased by only 7.9 percent (0.8 percent per year).

System, $59.0 billion (50 percent) was spent on the NHS (including the Interstate System), and $93.6 billion (80 percent) was spent on Federal-aid highways (including the NHS).

- Revenues raised for use on highways, by all levels of government combined, totaled $237.8 billion in 2018. The $6.7 billion difference between highway revenues and highway expenditures ($244.5 billion) comes from funds drawn from reserves. This difference represents the net decrease during 2018 of the cash balances of the Federal Highway Trust Fund and comparable dedicated accounts at the State and local levels.
- Of the $237.8 billion of revenues raised in 2018 for use on highways, $121.3 billion (51 percent) was collected from user charges, including fuel taxes ($66.9 billion), tolls ($17.6 billion), and vehicle taxes and fees ($36.8 billion).
- During 2018, $116.5 billion was raised for use on highways from nonuser sources, including general fund appropriations ($39.4 billion), bond issue proceeds ($21.7 billion), investment income and other receipts ($22.0 billion), property taxes ($11.6 billion), and other taxes and fees ($21.8 billion).

2018 Highway System Statistics



United States Road System	Miles (Miles per System)	VMT (Vehicle Miles Traveled)	Capital Spending ($ Billions)
Interstate System	1% 48,741 miles	26% 0.834 trillion VMT	23% $27.4 billion
National Highway System	5% 220,169 miles	55% 1.779 trillion VMT	50% $59.0 billion
Federal-aid Highways	25% 1,028,217 miles	85% 2.772 trillion VMT	80% $93.6 billion
Systemwide (All Roads)	100% 4,195,274 miles	100% 3.255 trillion VMT	100% $117.0 billion

The Interstate System accounts for 1% of road mileage, but carries 26% of highway travel.

Highway Spending Trends

- In nominal dollar terms, highway spending increased by 29.7 percent (2.6 percent per year) from 2008 to 2018; after adjusting for inflation, this equates to a 15.4-percent increase (1.4 percent per year).
- Highway capital expenditures rose from $90.4 billion in 2008 to $117.0 billion in 2018, a 29.5-percent increase (2.6 percent per year) in nominal dollar terms; after adjusting for inflation, this equates to a 20.0-percent increase (1.8 percent per year).
- The portion of total highway capital spending funded by the Federal government decreased from 41.6 percent in 2008 to 40.1 percent in 2018. Federally funded highway capital outlay grew by 2.3 percent per year over this period, compared with a 2.9-percent annual increase in capital spending funded by State and local governments.

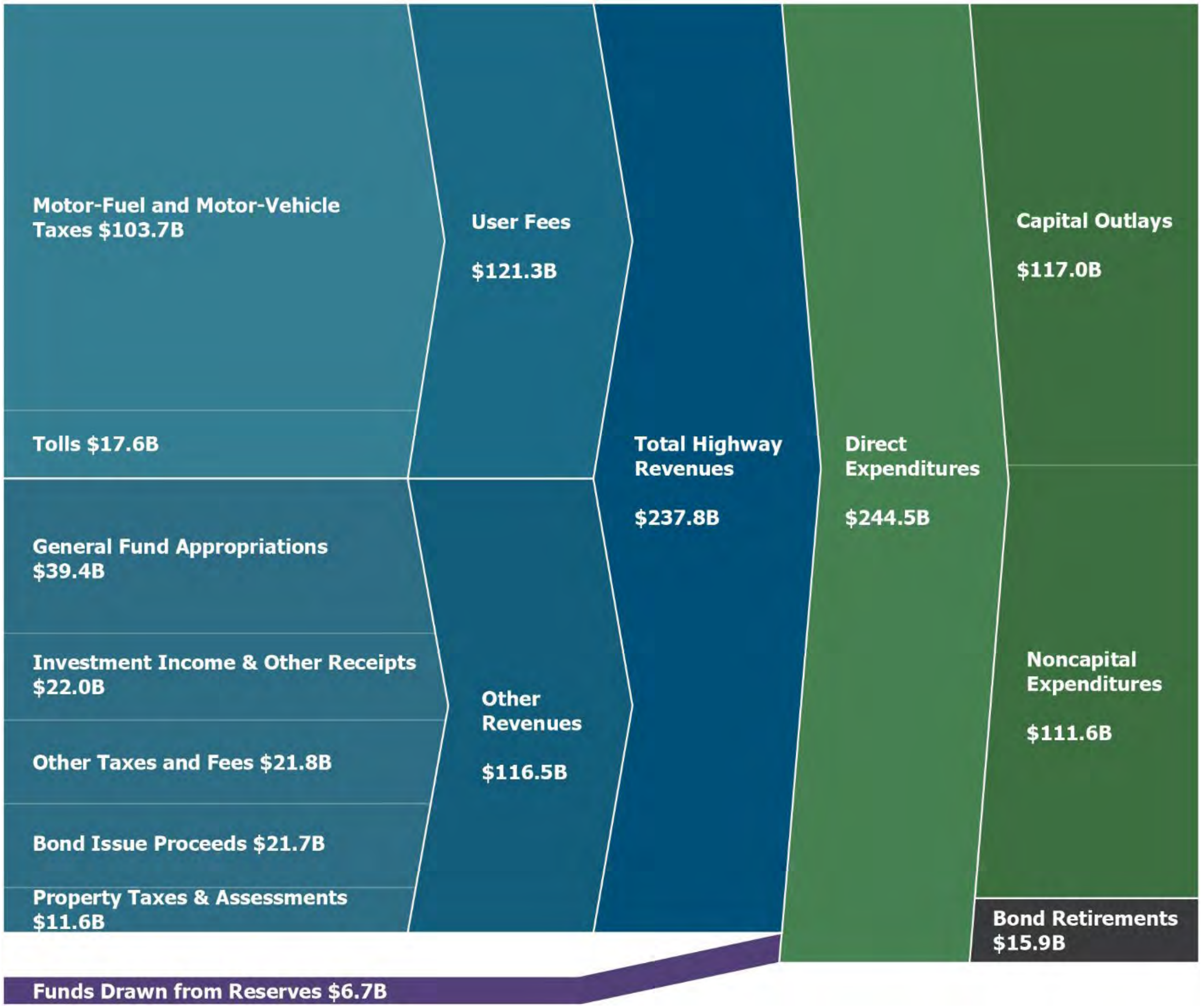
- The composition of highway capital spending shifted during the 2008–2018 period. The percentage of highway capital spending directed to system rehabilitation rose from 51.1 percent in 2008 to 66.1 percent in 2018. For the same period, the percentage of spending directed to system enhancement rose from 12.0 percent to 14.1 percent, whereas the percentage of spending directed to system expansion fell from 36.9 percent to 19.8 percent.

Highway Capital Spending Terminology

This report splits highway capital spending into three categories:

- **System rehabilitation—**resurfacing, rehabilitation, or reconstruction of existing highway lanes and bridges.
- **System expansion—**the construction of new highways and bridges and the addition of lanes to existing highways.
- **System enhancement—**safety enhancements, traffic operation improvements such as the installation of intelligent transportation systems, environmental enhancements, and other enhancements such as bicycle and pedestrian facilities.

2018 Highway Revenues and Expenditures



Conditions and Performance of the System

Bridge Conditions Have Improved

- Based on unweighted bridge count, the share of bridges classified as poor has improved, dropping from 10.1 percent in 2008 to 7.6 percent in 2018. The share of bridges classified as good rose from 46.0 percent to 47.8 percent during this decade.
- Weighted by deck area, the share of bridges classified as poor improved, declining from 8.8 percent in 2008 to 5.4 percent in 2018. The deck area–weighted share of poor NHS bridges dropped from 8.0 percent to 4.5 percent during the period.
- Weighted by deck area, the share of bridges classified as good declined slightly, from 45.8 percent in 2008 to 45.3 percent in 2018. The deck area–weighted share of good NHS bridges improved from 43.1 percent to 43.4 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."

Classifications are often weighted by bridge deck area, because in general, larger bridges are costlier to rehabilitate or replace than smaller bridges. Classifications are also sometimes weighted by annual daily traffic because more heavily traveled bridges have a greater effect on highway user costs.

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

Highway Safety Performance Has Been Mixed as Pedestrian and Bicyclist Fatalities Have Risen

- The annual number of traffic fatalities decreased by 2.3 percent from 2008 to 2018, dropping from 37,423 to 36,560, as reported in the Fatality Analysis Reporting System (FARS) Annual Report file. (More recent data shows a final count of 36,835 fatalities in 2018, 36,355 fatalities in 2019, 38,824 fatalities in 2020, and an estimated 42,915 fatalities in 2021.)
- From 2008 to 2018 the number of nonmotorists (pedestrians, bicyclists, etc.) killed by motor vehicles increased by 38.2 percent, from 5,320 to 7,354 (20.1 percent of all traffic fatalities). From 2008 to 2009, nonmotorist fatalities declined 8.1 percent, but beginning in 2009 that trend began to shift, and by 2018, nonmotorist fatalities had increased 50.5 percent.
- Fatalities related to roadway departure decreased by 6.8 percent from 2008 to 2018, but roadway departure remains a factor in over half (50.7 percent) of all traffic fatalities. Intersection-related fatalities increased 20.7 percent from 2008 to 2018, and more than one-fourth (27.4 percent) of traffic fatalities in 2018 occurred at intersections.
- The fatality rate per 100 million VMT declined from 1.26 in 2008 to 1.13 in 2018 but has increased since reaching a low of 1.08 in 2014.

Pavement Condition Trends Have Been Mixed

- The share of Federal-aid highway pavements with good ride quality improved during the 2008–2018 period, as measured on both a VMT-weighted basis (rising from 46.4 percent to 53.0 percent) and a mileage basis (rising from 40.7 percent to 47.2 percent).
- The share of Federal-aid highway pavements with poor ride quality measured on a mileage basis worsened more significantly during the 2008–2018 period (rising from 15.8 percent to 22.6 percent) than ride quality measured on a VMT-weighted basis (rising from 14.6 percent to 15.2 percent). Weighted by lane miles, the share of pavement with poor ride quality

improved, decreasing from 19.8 percent to 18.5 percent over this period. This divergence may be due to States focusing improvements on major roads that are more heavily traveled.

- The share of VMT on NHS pavements with good ride quality rose from 57.0 percent in 2008 to 61.7 percent in 2018. 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 of VMT on pavements with good ride quality rose from 57 percent in 2008 to 60 percent in 2010 based on the pre-expansion NHS, and from an estimated 54.7 percent in 2010 to 61.7 percent in 2018 based on the post-expansion NHS.

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 VMT on NHS pavements with poor ride quality decreased from 8 percent in 2008 to 7 percent in 2010; since the expansion of the NHS under MAP-21 this share has remained relatively constant at about 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 freeways and expressways averaged 1.33 in 2018 in the Nation's 52 largest metropolitan areas. This means that the average peak-period trip took 33 percent longer than did the same trip under free-flow traffic conditions. The comparable TTI value for 2012 was 1.24.

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).

- For the Nation's 52 largest metropolitan areas, the Planning Time Index (PTI) as computed based on the NPMRDS averaged 2.12 for freeways and expressways in 2018, meaning that ensuring on-time arrival 95 percent of the time required planning for 2.12 times the travel time under free-flow traffic conditions. The comparable PTI value for 2012 was 2.17. On average, urban freeways and expressways in these areas were congested for 4.3 hours per day in 2018, up from 3.6 hours in 2012.
- The Texas Transportation Institute 2021 Urban Mobility Report estimates that the average commuter in 494 urbanized areas experienced a total of 54 hours of delay resulting from congestion in 2018, up from 42 hours in 2008. Total delay reached 8.6 billion hours and fuel wasted reached 3.4 billion gallons in 2018, leading to a total cost of $188 billion.

2008–2018 Highway System Trends

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

Future Capital Investment Scenarios

The scenarios that follow pertain to spending by all levels of government combined for the 20-year period from 2018 to 2038 (reflecting the impacts of spending from 2019 through 2038); the funding levels associated with these analyses are stated in constant 2018 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.

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.

Both the Sustain 2014–2018 Spending scenario and the Maintain Conditions and Performance scenario 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 is directed to projects with the largest benefit-cost ratios.

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

Sustain 2014–2018 Spending Scenario

- The Sustain 2014–2018 Spending scenario assumes that capital spending by all levels of government is sustained through 2038 at the average annual level from 2014 to 2018 ($115.1 billion), and that all spending supports only cost-beneficial projects. Under these assumptions, the share of travel on pavements with poor ride quality is projected to improve (i.e., be reduced) by 6.2 percentage points, and the share of bridges classified as poor would also be projected to improve, declining from 5.4 percent in 2018 to 2.7 percent in 2038.

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 conditions and performance in 2038 are maintained at 2018 levels. The average annual level of investment associated with this scenario is $79.0 billion, 31.4 percent lower than the level of the Sustain 2014–2018 Spending scenario.
- Under the Maintain Conditions and Performance scenario, $44.7 billion per year would be directed to system rehabilitation, $23.5 billion to system expansion, and $10.8 billion to system enhancement. The share of travel on severely congested roads and the share of bridges classified as poor in 2038 would match their 2018 levels.

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 $151.1 billion, 31.3 percent higher than the level of the Sustain 2014–2018 Spending scenario.
- About 36.1 percent of the capital investment under the Improve Conditions and Performance scenario would go to addressing a backlog of cost-beneficial investments of $1.1 trillion. The rest would address new needs arising from 2019 through 2038.
- The $1.1 trillion backlog includes $237 billion for system expansion and $852 billion for existing assets. This $852 billion Highway Repair Backlog includes $511 billion for the pavement component of system rehabilitation investments, $191 billion for the bridge component of system rehabilitation investments, and $150 billion for system enhancement.
- The Improve Conditions and Performance scenario includes average annual spending of $87.0 billion (57.6 percent) for the $151.1 billion for system rehabilitation, $20.8 billion (13.7 percent) for system enhancement, and $43.3 billion (28.7 percent) for system expansion.
- Under the Improve Conditions and Performance scenario, the share of travel on pavements with poor ride quality is projected to improve (i.e., to be reduced) from 15.8 percent to 6.2 percent; the share of travel on severely congested roads is projected to improve from 11.2 percent to 7.5 percent. The share of bridges classified as poor is also projected to improve, decreasing from 5.4 percent in 2018 to 1.2 percent in 2038.

Why Poor Pavements and Bridges Are Reduced but Not Eliminated

The Improve Conditions and Performance scenario would not eliminate all poor pavements and bridges because in some cases improving assets becomes cost-beneficial only after assets have declined into poor condition, and in others improving assets before they reach poor condition is cost-beneficial. Therefore, at the end of any given year, some portion of the pavement and bridge population would remain in poor condition. Moreover, severely congested roads would also not be eliminated completely, because system users impose costs on other users and society at large that they do not pay for, which leads to overconsumption of travel and to congestion. Congestion would not be eliminated even by expanding road capacity because of the generated induced travel demand, which in turn would fill the additional capacity.

Changes in Improve Scenario and Highway Repair Backlog Estimates

- The average annual investment level in the 25th C&P Report for the Improve Conditions and Performance scenario ($151.1 billion) is 15.3 percent lower than in the 24th C&P report ($178.4 billion) when adjusted to the same dollar-year.
- The Department of Transportation has established a performance target to reduce the backlog of $830 billion [2016 dollars] in highway repairs by 50 percent by 2040. Although the 2018 Highway Repair backlog of $852 billion is 2.6 percent higher, in constant dollar terms, it has decreased from the 24th C&P Report to the 25th C&P Report by 4.6 percent.

2018–2038 Future Highway Capital Investment Scenarios

	Average Annual Investment	System Rehabilitation & Enhancement	Expansion	Share of Travel on Severely Congested Roads	Share of Travel on Pavements with Poor Ride Quality	Share of Deck Area on Poor Bridges
Maintain Conditions and Performance at 2018 Levels	$79.0	70.3% $55.5	29.7% $23.5	No Change 11.2%	Reduce to 15.7%	No Change 5.4%
Sustain Spending at 2014–2018 Levels, Adjusted for Inflation	$115.1	70.4% $81.0	29.6% $34.1	Reduce to 8.8%	Reduce to 9.6%	Reduce to 2.7%
Improve Conditions and Performance	$151.1	71.3% $107.7	28.7% $43.3	Reduce to 7.5%	Reduce to 6.2%	Reduce to 1.2%

Note: Billions of 2018 dollars. Includes all public and private investment.

Modeled vs. Nonmodeled Investment

The highway investment scenarios include 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. Of 2014 to 2018 average annual capital spending on all U.S. roads, 13.7 percent was used for system enhancements (safety enhancements, traffic control facilities, and environmental enhancements) that neither model analyzes directly. An additional 14.5 percent was used for pavement and capacity improvements on non-Federal-aid highways; FHWA does not collect the data that would be necessary to support analysis for such roads using HERS. (FHWA does collect enough data for the Nation's bridges to support analysis using NBIAS.)

Combining these percentages yields about 28.2 percent; each scenario for the road system was scaled up so that nonmodeled investment would make up this share of its total investment level. For example, of the $151.1 billion average annual investment in the Improve Conditions and Performance scenario, $42.6 billion represents nonmodeled investment.

Highlights: Transit

Spending on the System

- All levels of government spent a combined $73.3 billion in 2018 to provide public transportation and maintain transit infrastructure.
- Public transportation operating expenditures (wages, salaries, fuel, spare parts, preventive maintenance, support services, and leased transit services) totaled $51.8 billion in 2018, a 37.9 percent increase from 2008. Of this total cost, 35.6 percent was funded by system-generated revenue, most of which came from passenger fares. The Federal government provided a further 8.5 percent of revenues, and the remaining funds came from State and local sources.
- Expenditures for transit capital investments, excluding directly generated sources, totaled $18.7 billion in 2018, a 16.4-percent increase from 2008. Capital investments are used for the acquisition, renovation, and repair of transit vehicles, such as buses and railcars, and fixed assets, such as stations and rail guideway elements. Federal funding made up 40.3 percent of these capital expenditures, while the remaining funds came from State and local sources.
- In 2018, $15.0 billion, or 70.1 percent, of total transit capital expenditures was invested in rail modes, and $6.0 billion, or 28.2 percent, was invested in nonrail modes. In 2018, $18.2 billion, or 39 percent, of total transit operating expenditures was invested in rail modes, and $28.0 billion, or 61 percent, was invested in nonrail modes. Guideway investments in at-grade rail, elevated structures, tunnels, bridges, track and power systems totaled $7.3 billion in 2018. Investments in vehicles, stations, and maintenance facilities totaled $10.1 billion.
- Between 2008 and 2018, after adjusting for inflation (constant dollars), public funding for transit increased at an average annual rate of 1.4 percent. Federal funding increased at an average annual rate of 1.4 percent, and State and local funding increased at an average annual rate of 1.5 percent.
- Farebox recovery ratios, representing the share of operating expenses that come from passenger fares, were about 43.9 percent for the top 10 transit agencies in 2018, down slightly from 44.1 percent in 2008. For all agencies, the 33.8 percent recovery ratio in 2018 is down slightly from 34.2 percent in 2008, reflecting an annual average change of -0.1 percent.

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 and the 2010 census. Each large UZA (more than 200,000 people) has a designated recipient—a metropolitan planning organization or large transit agency—that 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 formula funds directly. When obligated, funds become available on a reimbursement basis.

Unlinked Passenger Trips, Passenger Miles, and Revenue Miles

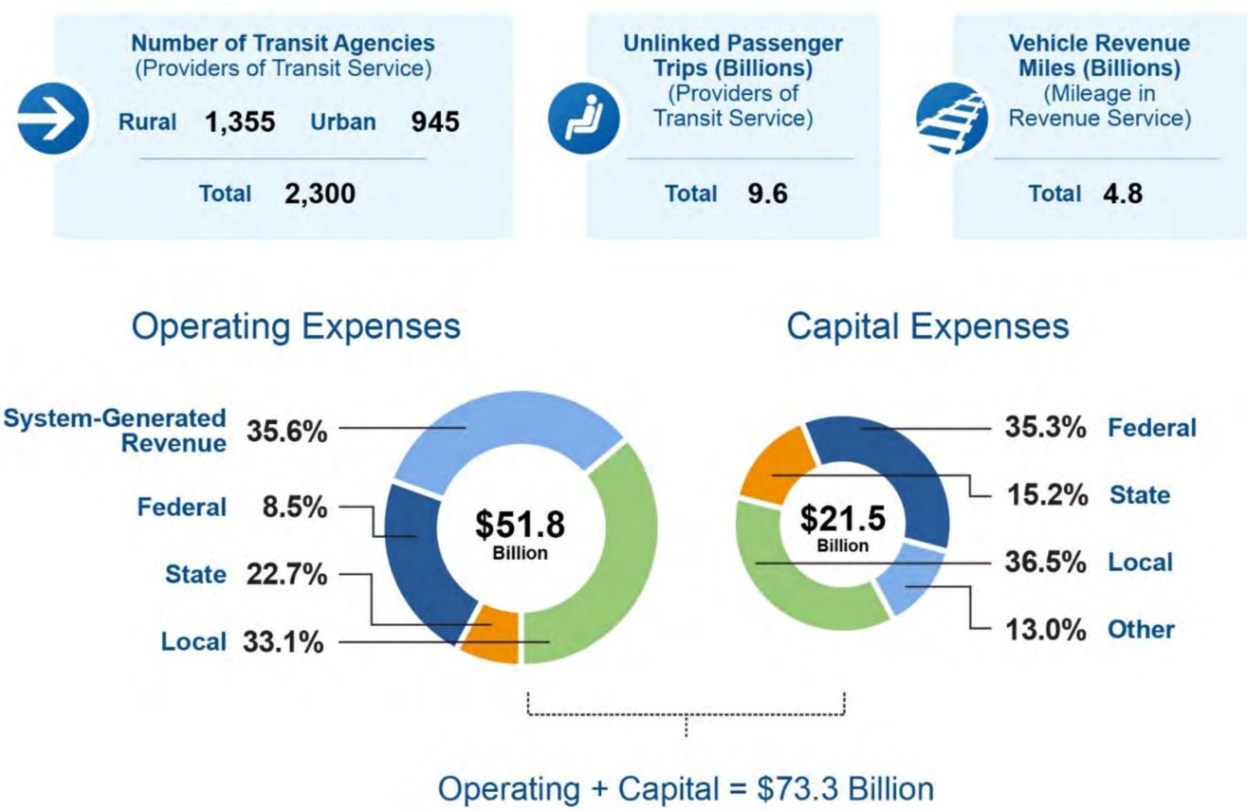
Unlinked passenger trips (UPT), also called boardings, count every time a person gets on an in-service transit vehicle. Each transfer to a new vehicle or route is considered another unlinked trip, so a person's commute to work may count as more than one trip if that person transferred between routes.

- Passenger miles traveled (PMT) count how many miles a person travels. UPT and PMT are common measures of transit service consumed.
- Vehicle revenue miles (VRM) count the miles of revenue service.

Extent of the System

- Of the transit agencies in the United States that report to the National Transit Database (NTD), in 2018, 945 agencies provided service primarily to urbanized areas and 1,355 provided service to rural areas. Of the 945 urban agencies, 278 agencies (about 30 percent) operated only one mode and the remaining agencies operated two to eight modes. Among the 1,355 rural agencies, about 71 percent operated only one transit mode, and the remaining agencies operated two to four modes.
- Transit is provided through 18 distinct modes in two major categories, rail and non-rail. In 2018, there were transit providers operated 1,174 regular fixed-route bus modes operated, 180 commuter bus modes operated, and 12 bus rapid transit modes operated. Rail modes include heavy rail (15), light rail (22), streetcar (19), hybrid rail (six), commuter rail (21), and other less common rail modes that run on fixed tracks. Demand-response service was provided by 1,906 operators. Open-to-the-public vanpool service was provided by 101 operators. Other modes include ferryboat (32) and trolleybus (five), as well as other less common modes
- Bus and heavy rail continue to be the largest segments of the industry, providing 47.6 percent and 37.8 percent of all transit trips, respectively. Demand-response systems are the second-largest transit supplier, generating 25.0 percent of vehicle revenue miles, yet carry only 1.1 percent of passenger trips. In 2018, light rail and commuter rail generated 5.1 percent and 5.5 percent of unlinked passenger trips, respectively.
- Transit operators reported 9.6 billion unlinked passenger trips on 4.8 billion vehicle revenue miles in 2018.

2018 Transit System Extent and Spending



Transit Modes

Public transportation is provided by different types of vehicles in different operating modes:

- Fixed-route bus service uses rubber-tire 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 of the following kinds of fixed-guideway (rail) transit service:

- Heavy rail (often running in subway tunnels), which is characterized primarily by third-rail electric power and an exclusive dedicated guideway.
- Commuter rail, which often shares track with freight trains and usually uses overhead electric power (but may use diesel power or third rail), is typically found in extended urban areas.
- Light rail systems are common in large and medium-sized urban areas; they feature overhead electric power.
- Streetcars are small light rail systems, usually with only one or two cars per train, that often run in mixed traffic.
- Hybrid rail, previously classified as light rail or commuter rail, shares the characteristics of these two modes but has higher average station density (stations per track mile) than commuter rail and lower density than light rail; it has a smaller peak-to-base ratio than 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 used mostly to provide paratransit service, as required by the Americans with Disabilities Act. These vehicles do not follow a fixed schedule or route.

2018 Top Transit Modes Operated in the United States

	% of Transit Systems	% Vehicle Revenue Miles	% of Passenger Miles Traveled	No. of Transit Systems
Fixed-route Bus Systems	39.0%	45.1%	34.6%	1,366
Heavy Rail Systems	0.4%	14.3%	31.4%	15
Light Rail Systems (includes street cars)	1.2%	2.6%	5.1%	41
Commuter Rail Systems	0.6%	7.3%	23.4%	21
Demand-response Systems (includes taxi cabs)	54.4%	25.1%	1.8%	1,906
Other Systems (Rail)	0.5%	0.2%	0.1%	18
Other Systems (Nonrail)	4.0%	5.4%	3.6%	139
TOTAL	100.0%	100.0%	100.0%	3,506

Notes: 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, and ferryboat.

Conditions and Performance of the System

Increases in Fatalities

- The number of transit fatalities increased from 192 fatalities in 2008 to 260 fatalities in 2018. In 2018, 85 fatalities, or 32.7 percent, were classified as suicides. Collisions accounted for 84 percent of fatalities in 2018, generally at intersections and grade crossings.

Some Improvement in System Performance

- Between 2008 and 2018, the service offered by transit agencies grew significantly. The annual rate of growth in VRM ranged from 0.5 percent per year for heavy rail to 4.0 percent per year for light rail. This has resulted in 0.2 percent more route miles available to the public.
- In 2018, agencies reported 212,002 transit vehicles serving urban and rural areas, 5,162 passenger stations, and 2,393 maintenance facilities. Rail systems operated on 13,086 miles of track, and fixed-route buses operated on 226,782 mixed traffic route miles.
- The average fleet age for buses was 7.4 years in 2018, up from 7.0 years in 2008, but the percentage of vehicles below the replacement threshold increased from 11.8 percent in 2008 to 15.1 percent in 2018.
- Between 2008 and 2018, 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 supplied was nearly in accordance with growth in service consumed. From 2008 to 2018, average passenger loads were either flat or they decreased, with the exception of Other Rail, while passenger miles traveled and unlinked passenger trips both decreased

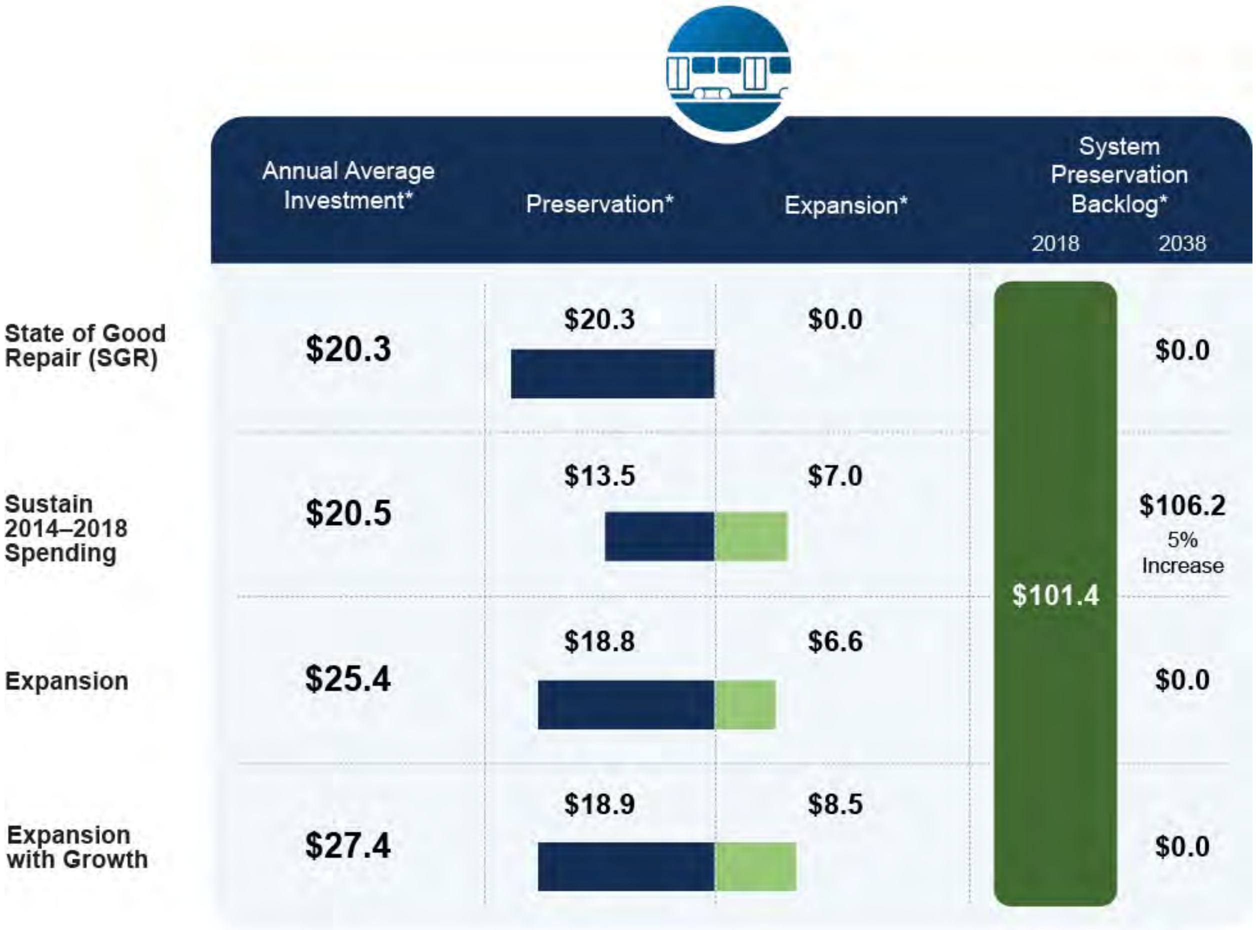
slightly. Vehicle occupancy decreased by 20 percent on fixed-route buses, the third largest decrease across all modes, following Demand Response and Other Nonrail modes.

Future Capital Investment Scenarios, Systemwide

As in the highway discussion, the transit investment scenarios that follow pertain to spending by all levels of government combined for the 20-year period from 2018 to 2038; the funding levels associated with all these analyses are stated in constant 2018 dollars. Unlike the highway scenarios, the 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.

2018–2038 Future Transit Capital Investment Scenarios



*Billions of 2018 Dollars

- For this report, the 20-year investment levels for transit capital assets have been estimated using the SGR Benchmark analysis and three investment scenarios that build on expansion investment components. The SGR Benchmark analysis found that the level of expenditure required to immediately attain and maintain SGR for the next 20 years, $20.3 billion per year, is roughly 50 percent higher than current asset preservation expenditures of $13.5 billion per year. Unlike the three capital investment scenarios which, with minor exceptions, apply a cost-benefit test to all investment needs, SGR Benchmark investments are not subject to any cost-benefit tests.

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 general construct allows FTA to estimate system preservation needs. The SGR 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 an estimate of total reinvestment needs. Some assets continue to provide reliable service past the average replacement age and others do not; the differences average out over the large number of assets nationally. 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. Expansion needs address a range of objectives, including improving service coverage and frequency, and increasing operating speeds. The Expansion with Growth scenario includes investment to support long-term ridership increases (assuming a return to 2018 ridership levels after 2030).

Sustain 2014–2018 Spending Scenario

- The Sustain 2014–2018 Spending scenario assesses the expected impact on asset conditions and system performance if annual reinvestment expenditures are sustained at their 2014–2018 5-year average over the next 20 years. For this report, the 2014–2018 preservation and expansion expenditure levels are roughly in line with the estimated level of investment required to maintain the deferred investment backlog and system performance at 2018 levels. Note that annual investment levels are expected to exceed 2014–2018 levels under the BIL.
- Under the Sustain 2014–2018 Spending scenario, total preservation spending of $13.5 billion per year is well below that of the SGR Benchmark and other scenarios. Sustaining 2014–2018 spending levels is marginally less than that required to maintain the current size of the SGR backlog, but therefore significantly less than the $19.5 billion required to eliminate the backlog over 20 years. Total expansion spending of $7.0 billion per year is slightly more than that required to address the expansion investment levels identified in the Expansion scenario, but less than the amount estimated for the Expansion with Growth scenario. In this report, 2014–2018 spending levels are based on the inflation-adjusted annual average preservation and expansion spending for the most recent 5-year period reported to the NTD (2014–2018). This 5-year annual average

Expansion Investment in the Sustain 2014–2018 Spending Scenario

The Sustain 2014–2018 Spending scenario includes all the expansion investment types in the Expansion with Growth Scenario (including the investment components for transit deserts, frequency improvements, operating speeds and crowding reduction improvements, planned New Starts investments, and ridership growth analysis). TERM's benefit-cost analysis is then used to "constrain" these investment needs to include only investments with the highest benefit-cost ratios, such that the expansion investment needs equal the 2014–2018 $7.0 billion expansion investment average. (Note: New and Small Starts investments with Full Funding Grant Agreements are excluded from the cost-benefit test.)

helps smooth year-to-year variations in spending while limiting the analysis to more recent program funding levels.

Expansion Scenario

- The Expansion scenario estimates the total combined 20-year investment levels for both transit expansion and transit asset preservation. The expansion investments were driven by the level of investment required to (1) support planned New Starts/Small Starts investments, (2) attain specific service targets for areas currently unserved or underserved by transit, (3) attain specific service performance targets for urban areas with low average operating speeds, and (4) reduce crowding for transit agencies with high-capacity utilization, all relative to 2018 levels.
- Total preservation investment levels under the Expansion scenario are estimated to be $18.8 billion per year. This is less than the needed spending under the SGR benchmark because TERM's cost-benefit test projects that the Nation would not need to reinvest in certain transit assets that do not pass the test. Total expansion investments are estimated to be $6.6 billion per year.

Expansion with Growth Scenario

- The Expansion with Growth scenario builds on the needs identified in the Expansion scenario, including estimated expansion investment levels required to support projected growth in passenger miles traveled (PMT), taking into account the decline and expected slow recovery of ridership following the COVID-19 pandemic. Under these assumptions, investment in expansion assets does not occur until ridership reaches pre-pandemic levels in individual submarkets.
- Total preservation investment levels under the Expansion with Growth scenario are estimated to be $18.9 billion per year. This is slightly more than in the Expansion scenario because of the 20-year reinvestment levels for the additional assets required to support ridership growth. Total expansion levels are estimated to be $8.5 billion per year. This is about 22 percent higher than 2014–2018 spending.

Executive Summary

Part I: Moving a Nation

Part I includes six chapters; each describes the existing transportation system from a different perspective:

1. Chapter 1, **System Assets**, describes the extent of highways, bridges and transit systems based primarily on data from the Highway Performance Monitoring System (HPMS), the National Bridge Inventory (NBI), the National Tunnel Inventory (NTI), and the National Transit Database (NTD).
2. 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.
3. Chapter 3, **People and Their Travel**, uses data from the National Household Travel Survey (NHTS) and U.S. Census Bureau to show how changes in population and population demographics influence travel demand.
4. Chapter 4, **Mobility,** covers highway congestion and reliability in the Nation's urban areas, as well as transit ridership, average speed, vehicle utilization, and maintenance reliability.
5. Chapter 5, **Safety**, presents statistics on highway safety and transit performance, focusing on common roadway factors that contribute to fatalities and injuries, as well as transit safety and security data by mode and type of service.
6. Chapter 6, **Infrastructure Conditions**, presents data on the 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 to achieve national performance goals. FHWA has finalized six related rulemakings to implement the TPM framework:

- 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 and Freight 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 report performance data and targets for each of 17 performance measures (https://www.fhwa.dot.gov/tpm/reporting/index.cfm).

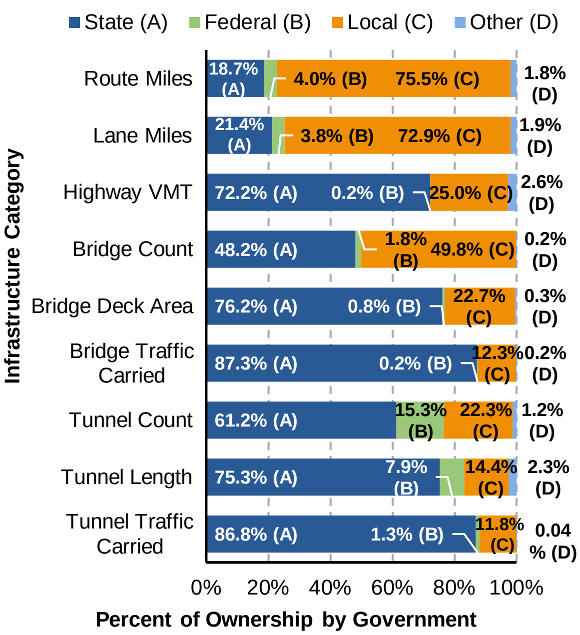
Chapter 1: System Assets – Highways

In 2018, local governments owned 75.5 percent of the Nation's 4,195,274 public road route miles and 72.9 percent of its lane miles (computed as roadway length times the number of lanes). However, State-owned roads carried a disproportionate share of the Nation's travel in motorized vehicles, accounting for 72.2 percent of the 3.255 trillion vehicle miles traveled (VMT) in 2018.

Ownership of bridges is more evenly split, as local governments owned slightly more (49.8 percent) of the Nation's 616,096 bridges in 2018 than did State governments (48.2 percent). State-owned bridges made up 76.2 percent of the Nation's bridge deck area and carried 87.3 percent of total bridge traffic.

State governments owned 61.2 percent of the Nation's 503 tunnels in 2018, and 75.3 percent of their combined length of 126.3 miles.

Highway, Bridge, Tunnel Ownership by Level of Government, 2018



Note: "Other" category represents private, railroad, and unknown.

Sources: HPMS; NBI; NTI.

Although the Federal government provides significant financial support for the Nation's highways and bridges, it owns only 4.0 percent of public road route miles. The Federal government owns 10,976 bridges and 77 tunnels.

Highway functional classifications are based on the degree to which roads provide access relative to mobility. Roads classified as local provide the most access to adjacent land. In 2018, 48.4 percent of route miles were classified as rural local and 20.7 percent were classified as urban local. Roads classified as arterials serve the longest distances with the fewest access points. Collectors funnel traffic from local roads to arterials.

Highway, Bridge and Tunnel Extent, 2018

Area	Functional System	Route Miles	Bridge Count	Tunnel Count
Rural	Interstate	0.7%	4.1%	6.4%
	Other Principal Arterial	2.2%	6.0%	8.2%
	Minor Arterial	3.2%	6.2%	5.0%
	Collector	16.1%	22.5%	16.3%
	Local	48.4%	32.9%	8.0%
	Subtotal Rural	**70.7%**	**71.7%**	**43.7%**
Urban	Interstate	0.5%	5.3%	20.7%
	Other Principal Arterial	1.9%	8.3%	22.5%
	Minor Arterial	2.7%	5.2%	5.2%
	Collector	3.5%	3.9%	1.6%
	Local	20.7%	5.6%	6.4%
	Subtotal Urban	**29.3%**	**28.3%**	**56.3%**
Total		**100.0%**	**100.0%**	**100.0%**

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

Sources: HPMS; NBI; NTI.

In general, the 1,028,217 route miles of public roads that were functionally classified as arterials, urban collectors, or rural major collectors in 2018 are eligible for Federal-aid highway funding and are described as "Federal-aid highways."

The National Highway System (NHS) includes almost all principal arterials as well as collector and local roads that connect the principal arterials to other transportation modes and defense installations. The total length was 220,169 miles in 2018, which includes 48,741 miles on the Interstate Highway System. State governments own more than 89.4 percent of the NHS, and over 99.9 percent of the Interstate System.

Chapter 1: System Assets – Transit

Most transit systems in the United States report to the National Transit Database (NTD). In 2018, 945 systems served urbanized areas that had populations greater than 50,000. In rural areas, 1,355 systems were operating. In total, 2,300 transit systems reported data to NTD in 2018.

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, commuter bus, bus rapid transit, demand response, vanpools, ferryboats, and other modes. In 2018, transit agencies operated 1,174 regular fixed-route bus modes, 180 commuter bus modes, and 12 bus rapid transit modes. Rail modes include heavy rail (15), light rail (22), streetcar (19), hybrid rail (six), commuter rail (21). Agencies operated 1,906 demand-response services (including demand-response taxi).

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 486 urbanized areas combined is 2,528 people per square mile. Areas with higher population density are able to attract more discretionary transit riders.

Organizational Structure of Urban and Rural Agencies

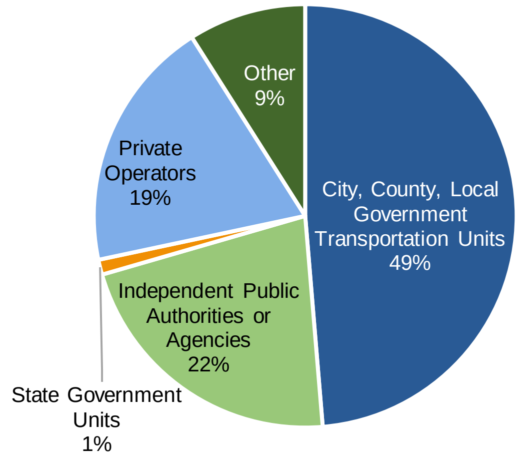
Approximately 50 percent of transit agencies in the United States are transportation units or departments of cities, counties, or other local governments. Independent public authorities or agencies account for 20 percent of transit agencies; 19 percent are private operators and the remaining 12 percent are other organizational structures such as State governments, area agencies on aging, municipal planning organizations, planning agencies, Tribes, and universities.

Agencies in rural and urban areas differ in several respects. Nearly one-third of urban transit agencies are independent public authorities or agencies; less than one-fifth of rural agencies fall into those categories. More than 25 percent of rural agencies are private operators, compared with less than 10 percent of urban operators.

National Transit Assets

- Of the 140,563 vehicles in urban and rural areas, 118,691 are nonrail vehicles (buses, demand response, and vanpool), whereas 21,014 are rail passenger cars.
- Rail systems operate on 13,086 miles of track; bus systems operate over 226,782 directional route miles.
- Urban and rural areas have 5,162 stations and 2,393 maintenance facilities.

Transit Agency Type



Source: NTD.

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.

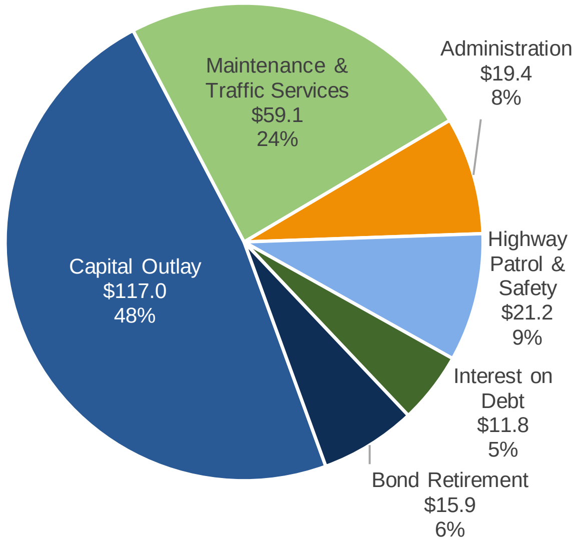
Chapter 2: Funding – Highways

Revenues and expenditures across the different levels of government are closely intertwined. Revenues are raised through fees and taxes collected from highway users and other sources at all levels of government—Federal, State, and local. Expenditures cover costs in construction, replacement, rehabilitation, maintenance, and other capital outlay for highways and bridges. In 2018, revenues raised for highways and bridges by all levels of government totaled $237.8 billion, and expenditure totaled $244.5 billion. When revenues fall below expenditures (such as in 2018), the difference is drawn from highway reserve accounts for current use at the Federal, State, and local levels. Total highway capital outlay on all systems reached $117.0 billion in 2018.

Total revenue increased by 2.1 percent per year from 2008 to 2018. Revenues from user charges, including motor fuel taxes, motor vehicle taxes and fees, and tolls generated $121.3 billion. The largest revenue increase was generated from tolls during this period. Toll revenues grew from $9.1 billion to $17.6 billion at an annual average rate of 6.8 percent. User charges accounted for about half of total revenue, including 44 percent of total revenues from motor fuel and motor vehicle taxes, and the 7 percent of tolls. The remaining $116.5 billion was generated from a variety of other sources, including property taxes and assessment, General Fund appropriations, other taxes and fees, investment income, and debt financing.

Total expenditures grew by 2.6 percent per year from 2008 to 2018. Federal, State, and local governments funded 20.4, 50.7, and 28.9 percent of total expenditures in 2018, respectively. Capital outlay represented nearly half (48 percent) of total expenditures, followed by maintenance and traffic services, which made up 24 percent. Administration, highway patrol and safety, bond retirement, and interest on debt each comprised between 9 and 6 percent of total government expenditures on highways in 2018.

Highway Expenditures by Type, 2018



Note: Dollar values are in billions.
Source: Highway Statistics 2018.

Total capital outlay increased at an annual average rate of 2.6 percent between 2008 and 2018. Federal spending increased by 2.3 percent and State and local spending by 2.9 percent during this same period. In 2018, the Federal government funded 40.1 percent of capital outlay but only 20.4 percent of highway expenditures.

About two-thirds (66.1 percent) of capital outlay was directed toward system rehabilitation, including $61.2 billion for highways and $16.2 billion for bridges. A fifth (19.8 percent) of capital outlay went to system expansion, mainly in the form of additions to highways.

Capital Outlay by Improvement Category, 2018

Improvement Type		Capital Outlay Funding in 2018		
System Rehabilitation	Highway	$61.2	52.3%	66.1%
	Bridge	$16.2	13.8%	
System Expansion	Additions to Existing Roadways	$13.3	11.3%	19.8%
	New Routes	$8.8	7.5%	
	New Bridges	$1.1	1.0%	
System Enhancement	All	$16.5	14.1%	14.1%
Total		**$117.0**	**100.0%**	**100.0%**

Note: Dollar values are in billions.
Source: Highway Statistics 2018.

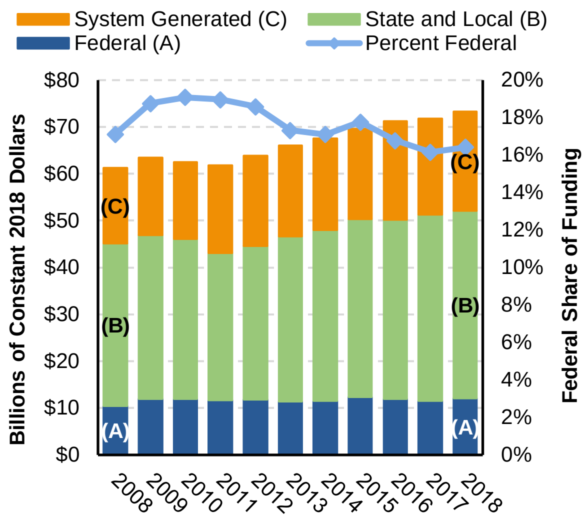
Chapter 2: Funding – Transit

Funding Sources

In 2018, $73.3 billion was generated from all sources to fund urban and rural transit. Transit funding comes from public funds allocated by Federal, State, and local governments and from system-generated revenues that transit agencies earn from the provision of transit services. Of the funds generated in 2018, 71 percent came from public sources and 29 percent came from system-generated funds (passenger fares and other system-generated revenue sources). The Federal share was $12.0 billion (23 percent of total public funding and 16 percent of all funding).

Between 2008 and 2018, all sources of public funding for transit increased by 1.4 percent per year. The Federal share remained relatively stable, varying in the range of 16 to 19 percent.

Funding for Urban Transit by Government Jurisdiction, 2008–2018



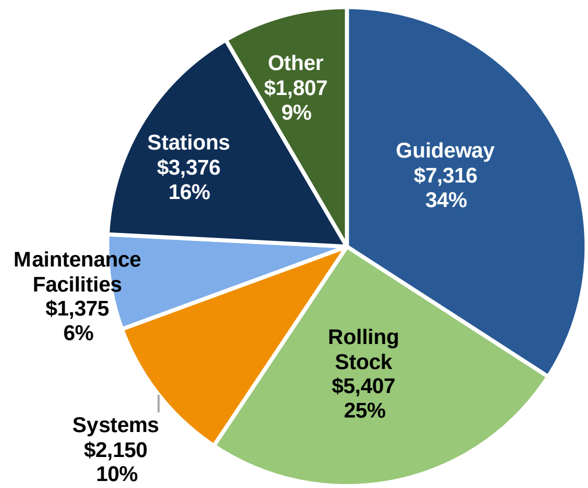
Source: NTD.

Expenditures

In 2018, operating expenses consumed $51.8 billion of all funding devoted to transit whereas capital expenditures consumed $21.5 billion of all funding.

The largest share of capital expenditures—34.7 percent ($7.3 billion)—was used for expansion or rehabilitation of guideway assets. Investments in vehicles, stations, and maintenance facilities totaled $10.1 billion or 48.2 percent.

Urban Capital Expenditures by Asset Type, 2018

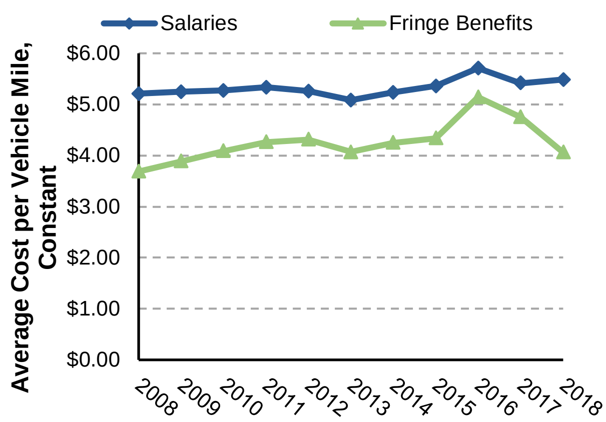


Note: In millions of dollars
Source: NTD.

Salaries and Fringe Benefits

From 2008 to 2018, fringe benefits at the top 10 transit agencies increased at the highest rate of any operating cost category on a per-mile basis. Over this period, fringe benefits increased at an annual compound average rate of 1.0 percent with a total accumulated increase of 10.2 percent. Fringe benefits can include many different components, but medical insurance usually plays a key role in the total cost. Meanwhile, salaries and wages increased by 5.3 percent.

Salaries/Wages and Fringe Benefits, Average Cost per Mile, Top 10 Transit Agencies, 2008–2018



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

Chapter 3: People and Their Travel

The U.S. population has grown significantly since 2000, according to the U.S. Census Bureau, experiencing a 16.3-percent increase from 282 million people to 332 million in 2020. The size of the population affects the total number of trips and miles traveled each day. Average annual person miles traveled increased by 4.2 percent—from 13,651 miles per person to 14,228 miles—between 2001 and 2017. The growth in person miles traveled, which accounts for travel on all modes of transportation, has outpaced the growth in vehicle miles traveled (VMT). Average annual VMT per person decreased from 8,206 to 7,698 miles between 2001 and 2017.

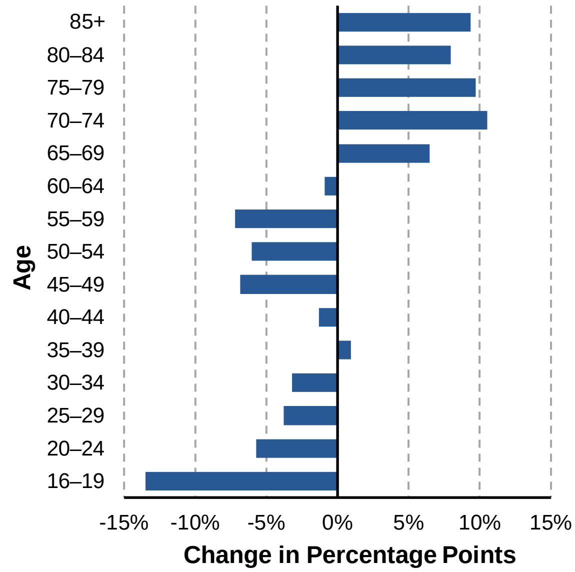
Age distribution of the population, population diversity, and income influence travel demand as well as characteristics of travel demand such as mode, distance, and purpose.

Population Age Distribution

The proportion of 35- to 54-year-olds in the total population declined from 29.5 percent in 2000 to 25.4 percent in 2020. Despite this decline, this age cohort makes the most trips, an average of 1,388 trips per year. The highest population growth has been among ages 55 and older, which increased from 21.1 percent of the population in 2000 to over 29.4 percent in 2019.

Overall, the proportion of total licensed drivers (ages 16 and older) in the United States changed from 86.5 percent of the population in this age range in 2001 to 83.9 percent in 2020. The percentage of licensed drivers decreased for all age groups below 60 years of age. In contrast, the percentage of licensed drivers among people ages 60 and older has grown. For example, the percentage of people ages 85 and older with a driver's license grew from 50 percent in 2001 to 59 percent in 2020, an increase of 9 percent. Given that there were 6.7 million Americans ages 85 and older in 2020, that equates to 4.0 million drivers ages 85 and older. Driver's license rates are lowest for people ages 16 to 19 years old, and declined from 47 percent of the 16- to 19-year-old population in 2001 to 33 percent in 2020.

Change in Percentage of Licensed Drivers by Age Cohort, 2001 vs. 2020



Source: FHWA Table DL-20.

Population Diversity

The U.S. population is not only aging, but also becoming more diverse. In 2000, 28.7 percent of the Nation's population comprised people of color: 12.8 percent Black or African American, 11.9 percent Hispanic or Latino (of any race), and 4.1 percent Asian, Native Hawaiian, and other Pacific Islander. By 2020, people of color accounted for 39.9 percent of the Nation's population.

Increased diversity brings changes in how people travel. The average trip rate is lower for minority population groups at 3.0 to 3.2 trips per day, compared with White and non-Hispanic travelers at 3.5 and 3.4 trips per day, respectively. On average, higher-income households make more trips and travel more miles compared with lower-income households. Similarly, for most racial and ethnic groups, the average number of daily trips increases as income increases.

Black households are an exception, where the highest number of average daily trips is made by households with incomes between $50,000 and $74,999.

Average Daily Trip Rate by Household Income and Race or Ethnicity, 2017

Household Income	Asian and Pacific Islander	Black	White	Hispanic (of any race)
$0-$24,999	2.6	3.0	3.0	3.1
$25,000-$49,999	3.1	3.3	3.4	3.2
$50,000-$74,999	3.0	3.4	3.4	3.2
$75,000-$99,000	3.2	3.2	3.5	3.1
$100,000+	3.2	3.1	3.7	3.5

Source: National Household Travel Survey, 2017.

Work Travel

Trends in work influence travel demand. The 2017 National Household Travel Survey (NHTS) shows that travel to work makes up about 19 percent of all trips. Full-time workers make more trips, at 3.8 to 3.9 trips per day per person, compared with nonworkers, who averaged 2.9 to 3.2 trips. According to the 2019 American Community Survey and the U.S. Census Bureau, driving to work continues to be the predominant choice for almost 85 percent of all workers, followed by working from home (6 percent), and using transit (5 percent). About 3 percent of workers walk or bike to work.

Household Travel

The number of households in the United States grew from 108.2 million in 2001 to 128.5 million in 2020. Many travel activities serve the entire household, such as grocery shopping, trips to places of worship, or dining out. Although personal vehicles are used for most trips across all incomes, both lower- and higher-income households are more likely to use public transit or walk. For example, households with annual incomes of $50,000 to $74,999 used a vehicle an average of 85 percent of the time and walked or used transit about 10 percent of the time, whereas households with annual incomes of $15,000 to $24,999 and those earning $150,000 to $199,999 used a vehicle less often (about 80 percent of the time) and walked more often (over 10 percent of the time). The lowest-income households, under $10,000 per year, walked for the largest percentage of total trips (21.2 percent) and had the highest level of transit use at 9.1 percent of all trips.

Percentage of Trips by Household Income and Mode of Travel, 2017

Household Income	Walk	Bicycle	Auto	Transit
<$10K	21.2%	2.1%	61.5%	9.1%
$10K–$14.9K	14.8%	1.2%	75.1%	5.0%
$15K–$24.9K	11.4%	1.1%	80.0%	3.6%
$25K–$34.9K	10.3%	0.8%	84.1%	2.3%
$35K–$49.9K	8.4%	0.7%	85.9%	1.9%
$50K–$74.9K	8.8%	0.9%	85.0%	1.8%
$75K–$99.9K	8.8%	0.8%	85.5%	1.8%
$100K–$124.9K	9.4%	0.8%	84.8%	1.8%
$125K–$149.9K	9.1%	0.6%	84.4%	2.1%
$150K–$199.9K	11.3%	1.5%	81.0%	2.5%
>$200K	12.3%	1.1%	79.9%	2.7%

Source: FHWA, 2018. Summary of Travel Trends: 2017 National Household Travel Survey.

The average number of vehicles per household in 2017 was the same as in 2001—about two vehicles (1.88)—despite the increases in population and number of households. This lack of change may be attributable to the decline in the number of people per household (from 2.62 in 2000 to 2.53 in 2020) or the increase in single-person households (from 25.5 percent in 2000 to 28.2 percent in 2020). According to the 2020 American Community Survey, 8.5 percent of U.S. households do not have access to a vehicle, either by choice or by circumstance. The slow growth in the number of vehicles per household could also be attributable to access to alternative transportation modes, such as on-demand transportation and shared modes. Households without a vehicle are more likely to be renters, single-person-households, and/or have annual incomes under $25,000 compared with households with one vehicle, according to the 2017 NHTS.

Personal vehicles are still the preferred mode of travel, but preference for them is declining—particularly among people under 60 years of age. This decline is likely being offset by other transportation modes, such as transit, on-demand services, and shared modes. In addition, advances in communication technology—particularly the increasing availability of high-speed internet—have supported online shopping trends and virtual meeting platforms, providing an alternative to personal travel.

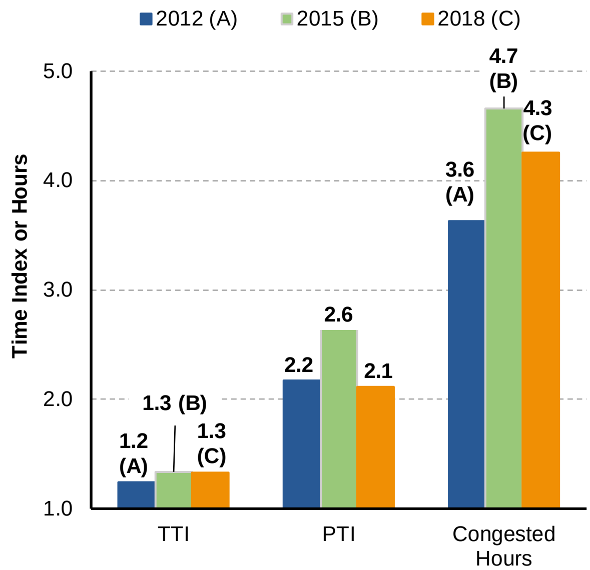
Chapter 4: Mobility – Highways

The Texas Transportation Institute's 2021 Urban Mobility Report estimates that the average commuter in 494 urbanized areas experienced a total of 54 hours of delay resulting from congestion in 2018, up from 42 hours in 2008. Total delay reached 8.6 billion hours and fuel wasted reached 3.4 billion gallons in 2018, leading to a total cost of $188 billion.

Congestion

The National Performance Management Research Data Set (NPMRDS) indicates that the Travel Time Index (TTI) for Interstate and other limited-access highways averaged 1.33 in 2018 in the Nation's 52 largest metropolitan areas. This means that the average peak-period trip took 33 percent longer than did the same trip under free-flow traffic conditions. The comparable TTI value for 2012 was 1.24.

Mobility on Limited-Access Highways in the 52 Largest Metropolitan Areas, 2012–2018



Source: FHWA staff calculation from the NPMRDS.

The average planning time index (PTI) was 2.12 for freeways and expressways in these 52 metropolitan areas in 2018. This means that drivers who wanted to arrive on time 95 percent of the time would need to leave early enough to account for their trip taking 2.12 times longer than it would under free-flow traffic conditions. The comparable PTI value for 2012 was 2.17.

On average, freeways and expressways in these 52 metropolitan areas were congested for 4.3 hours per day in 2018, up from 3.6 hours in 2012.

Road congestion varies over the course of a year. The TTI tended to be stable in the first half of 2018, but worsened substantially between July and October. The PTI generally worsened in fall and winter. High-congestion hours were concentrated in winter months and shorter periods of congestion tended to occur in warmer months.

Speed and Reliability

More than half (73 percent) of NHS travel in 2018 occurred near or at congestion-free conditions with median speeds above 45 mph. During weekday morning peak hours, travelers experienced heavily congested travel conditions with median travel speeds below 30 mph on 8 percent of the NHS and below 20 mph on 2 percent of the NHS. Trucks operated at lower median speeds compared with all vehicles combined. About 3 percent of NHS travel occurred at speeds below 20 mph, and 9 percent occurred at speeds between 20 and 30 mph.

Median speeds differed slightly between morning and afternoon peaks. However, a higher percentage of NHS roads were congested and less reliable during the afternoon peak compared with the morning peak.

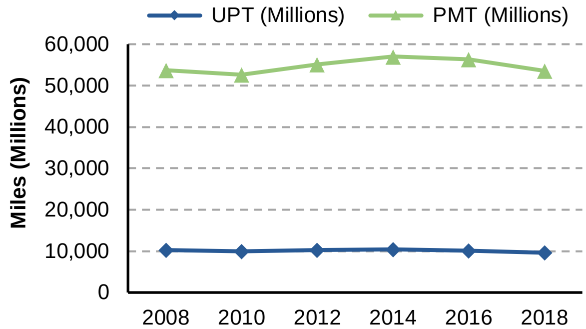
Most (80 percent) NHS segments were considered to be relatively reliable in 2018 for general traffic. However, during daylight hours on weekdays 38–40 percent of NHS road segments did not meet the more particular reliability needs for on-time truck deliveries. Truck travel appeared to be more reliable over weekends, when 44 percent of roads were reliable and 36 percent highly unreliable. Similarly, evening truck travel between 8 p.m. and 6 a.m. was more desirable with 43 percent of roads considered reliable and 32 percent highly unreliable.

Chapter 4: Mobility – Transit

Transit Ridership

After rising from 2008 to 2014, transit ridership declined through 2018. Over the 10-year period from 2008 to 2018, passenger miles traveled (PMT) were relatively flat, declining by 0.4 percent, whereas unlinked passenger trips (UPT) declined by 6.3 percent.

Passenger Miles Traveled and Unlinked Passenger Trips, 2008–2018

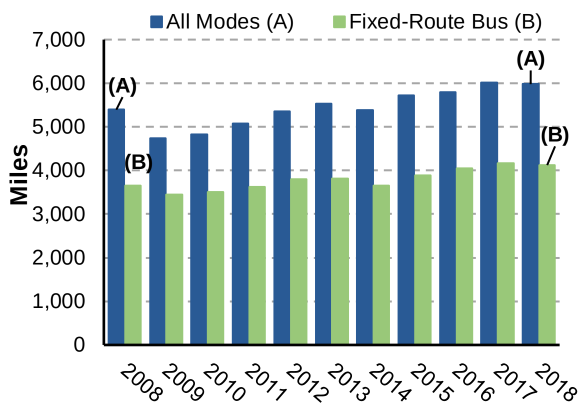


Note: PMT is passenger miles traveled, UPT is unlinked passenger trips.
Source: NTD.

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 2008 and 2018, the number of miles between failures increased by an average of 1.0 percent annually.

Mean Distance Between Urban Vehicle Failures, 2008–2018



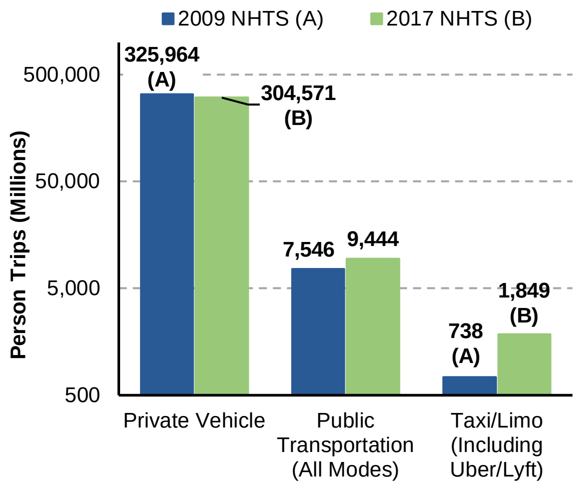
Note: Only directly operated vehicle data were used to calculate mean distance between failures. 2014 data do not include agencies that qualified and opted to use the small systems waiver of the National Transit Database.
Source: National Transit Database.

Miles between failures for all modes increased in seven of the 10 years from 2008 to 2018, decreasing in 2009, 2014, and 2018. The overall increase from 2008 to 2018 was 10.8 percent.

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. The New York City UZA had the highest market share of public transit work trips, with nearly 33 percent of work trips taken on transit. The Chicago, Washington (DC), San Francisco, Boston, Philadelphia, and Seattle UZAs also had a greater than 10 percent market share for work trips taken on transit.

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



Notes: NHTS is National Household Travel Survey. Vertical axis is portrayed using a logarithmic scale.
Source: NHTS, FHWA, 2017.

ADA Accessibility

In 2018, the overall level of ADA accessibility was 94.8 percent. The most significant increases in ADA accessibility were in commuter rail passenger and self-propelled cars, which saw increases from approximately 22.7 percent and 5.4 percent in 2008 to 83.0 percent and 86.3 percent in 2018. In 2018, vans and all other rail vehicles were nearly tied for the smallest share of ADA-accessible vehicles at 78 and 77 percent, respectively.

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 roadway safety. This balance of coordinated efforts, coupled with a comprehensive focus on shared, reliable safety data, enables these DOT administrations to concentrate on their areas of expertise while working together toward the Nation's safety goal.

The data below come from NHTSA's Fatality Analysis Reporting System (FARS):

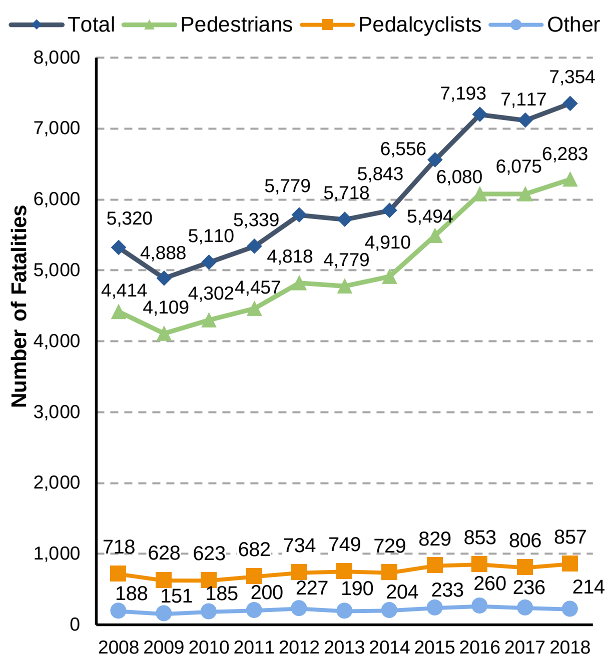
- From 2008 to 2018, highway fatalities decreased by 2.3 percent, from 37,423 to 36,560.
- Motor vehicle fatalities declined by 13 percent from 2008 to 2011. The number of fatalities changed little from 2011 through 2014, but increased by 12 percent from 2014 to 2018.
- From 2008 to 2018, fatality rates per 100 million vehicle miles traveled (VMT) decreased by 10 percent.
- From 2008 to 2010, the fatality rate per 100 million VMT dropped from 1.26 to 1.11 and varied little from 2010 through 2014. The rate rose from 1.08 in 2014 to 1.19 in 2016 and dropped to 1.13 in 2018.

Although progress was made in reducing overall highway fatalities from 2008 to 2018, certain types of fatal crashes increased. Three focus areas established by FHWA, based on the most common crash types relating to roadway characteristics, are roadway departure, intersection, and pedestrian/pedalcyclist fatalities, which accounted for 51 percent, 27 percent, and 20 percent, respectively, of total fatalities in 2018.

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 2008 to 2018, roadway departure fatalities decreased by 6.8 percent.
- From 2008 to 2018, intersection-related fatalities increased by 20.7 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 2018, 29.9 percent of fatalities related to intersections occurred in rural areas and 70.1 percent occurred in urban areas.
- From 2008 to 2018, pedestrian/bicyclist fatalities increased by 38.2 percent.
- From 2008 to 2009, nonmotorist fatalities declined by 8.1 percent. Beginning in 2009, that trend shifted and resulted in a 50.4-percent increase by 2018. Pedestrian fatalities rose from 4,109 in 2009 to 6,283 in 2018, an increase of 52.9 percent. Pedalcyclist (primarily bicyclist) fatalities rose from 628 in 2009 to 857 in 2018, an increase of 36.5 percent.

Pedestrian, Pedalcyclist, and Other Nonmotorist Traffic Fatalities, 2008–2018



Source: Fatality Analysis Reporting System, National Center for Statistics and Analysis, National Highway Traffic Safety Administration.

More recent data show an increase in overall highway fatalities since 2018; these trends are discussed in Chapter 11.

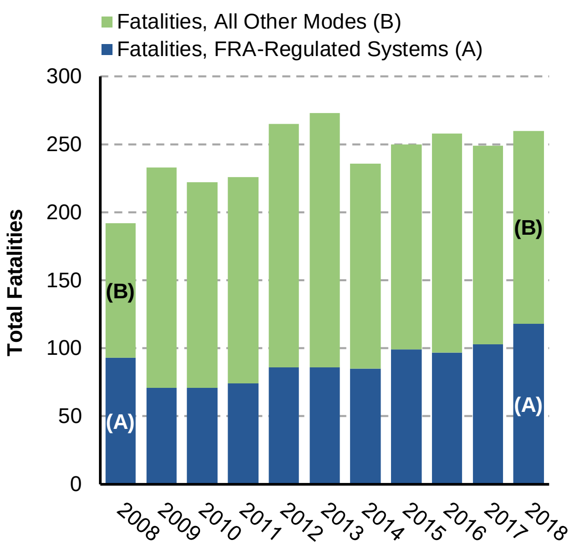
Chapter 5: Safety – Transit

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 who have just disembarked from transit vehicles. Passengers are individuals boarding, traveling, or alighting a transit vehicle.

Transit fatalities, including FRA-regulated systems, rose from 285 in 2008 to 378 in 2018. Two significant contributors to this increase were growth in the number of suicides in transit, from 45 in 2008 to 85 in 2018, and growth in FRA-regulated rail system fatalities, from 93 in 2008 to 118 in 2018.

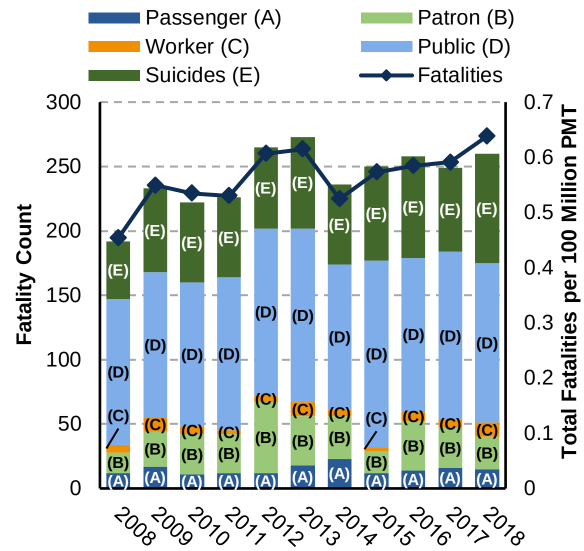
Fatalities, for All Modes, 2008–2018 (Including FRA-Regulated Rail Systems)



Sources: NTD; FRA.

Of the 260 transit-related fatalities in 2018 (excluding FRA-regulated rail systems), 15 were passengers, 25 were patrons, 11 were workers, and 124 (48 percent) were other members of the public. The remaining 85 were suicides. The number of fatalities per 100 million passenger miles travelled increased from 0.5 in 2008 to 0.7 in 2018.

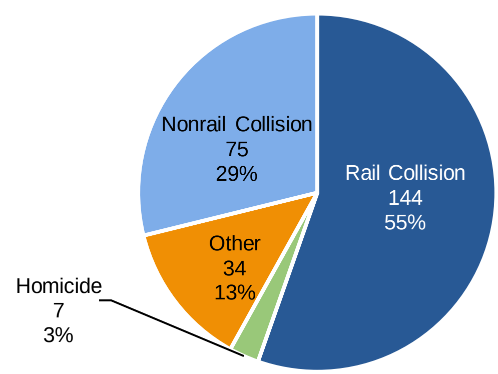
Annual Transit Fatalities, by Victim Type, 2008–2018 (Excluding FRA-Regulated Systems)



Source: NTD.

Between 2008 and 2018, rail transit fatalities increased by 35 percent. Collisions are the most common type of fatal incident in rail transit. In 2018, 219 people, or 84 percent of all fatalities (excluding FRA-regulated systems), died in collision incidents. Rail collisions make up nearly two-thirds of these fatalities. Within rail modes, fatality rates differ considerably. In every year from 2008 to 2018, the fatality rate for light rail was higher than that for heavy rail.

Transit Fatality Event Types, 2018 (Excluding FRA-Regulated Rail Systems)



Source: NTD.

FRA-regulated rail systems fatalities rose by 26.9 percent from 2008 to 2018, from 93 to 118. In this same period, injuries on FRA-regulated systems rose by 5.2 percent and incidents rose by 18.6 percent.

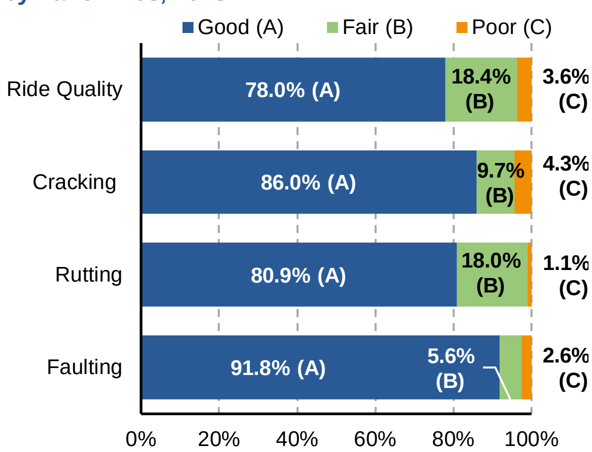
Chapter 6: Infrastructure Conditions – Highways

FHWA measures pavement and bridge conditions based on categorical ratings of good, fair, and poor. Condition data presented by raw counts are simplest to compute, but weighting by VMT or bridge traffic provides a metric for the extent to which pavement or bridge conditions are affecting the traveling public.

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 (distresses occurring on the surface of pavements), pavement rutting (surface depressions in the vehicle wheel path of asphalt surface pavements), and pavement faulting (the vertical displacement between adjacent jointed sections on concrete surface pavements).

Weighted by lane miles, 3.6 percent of pavements on Interstate highways for which data were available had poor ride quality in 2018; the comparable shares for cracking, rutting, and faulting were 4.3 percent, 1.1 percent, and 2.6 percent, respectively.

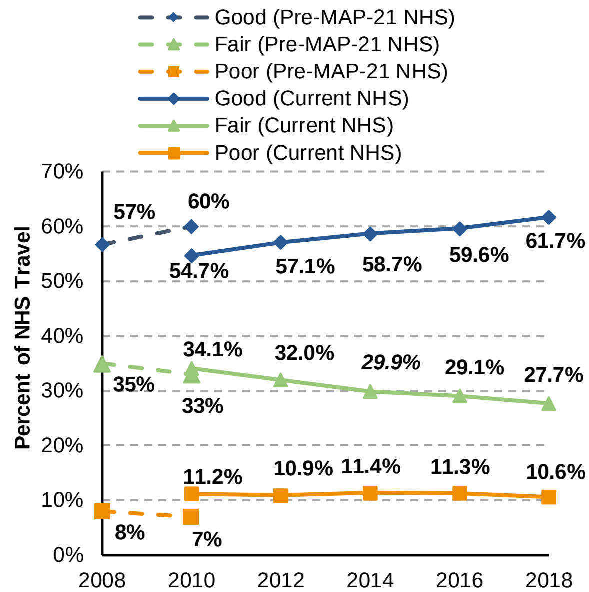
Interstate Highway Pavement Condition, Weighted by Lane Miles, 2018



Source: HPMS.

FHWA 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 2008 to 60 percent in 2010 on the pre-expansion NHS, and from an estimated 54.7 percent in 2010 to 61.7 percent in 2018 on the expanded NHS.

NHS Pavement Ride Quality, Weighted by VMT, 2008–2018



Notes: Data for odd-numbered years are omitted.
Source: HPMS.

The NBI contains data on bridge decks, superstructures, and substructures that combined form an overall bridge condition rating. The unweighted share of bridges rated poor was reduced from 10.1 percent in 2008 to 7.6 percent in 2018. Poor bridge condition ratings were further reduced from 8.8 percent to 5.4 percent in the deck-area-weighted share and from 7.1 percent to 3.8 percent in the traffic-weighted share over this period. A poor condition rating does not mean that a bridge is unsafe.

Systemwide Bridge Conditions, 2008–2018

Condition	Measurement Type	2008	2018
Good	By Bridge Count	47.8%	46.0%
	Weighted by Deck Area	45.8%	45.3%
	Weighted by ADT	44.7%	46.4%
Fair	By Bridge Count	41.9%	46.4%
	Weighted by Deck Area	45.3%	49.2%
	Weighted by ADT	48.2%	49.8%
Poor	By Bridge Count	10.1%	7.6%
	Weighted by Deck Area	8.8%	5.4%
	Weighted by ADT	7.1%	3.8%

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, ballast, tunnels, elevated structures, and bus guideways
Maintenance Facilities	Bus and rail maintenance buildings, bus and rail maintenance equipment, and storage yards
Stations	Rail and bus stations, platforms, walkways, and shelters
Systems	Systems for train control, electrification, communication, and revenue collection; also includes utilities, signals, train, centralized vehicle/train control, and substations
Vehicles	Large buses, vans, heavy rail, light rail, commuter rail passenger cars, nonrevenue vehicles

Source: TERM.

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 $1,161 billion in 2018.

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 $101-billion investment required to replace them (referred to as the reinvestment backlog), represent major challenges to the rail transit industry.

Guideway elements and stations represent more than 63 percent of the total value of transit assets in the United States. However, both categories represent a very small portion of assets categorized as below SGR, with each category having only 3 percent and 6 percent of assets not in a state of good repair. The asset category with the highest percentage of assets not in a state of good repair is systems: 25 percent of systems assets are not in a state of good repair, with 18 percent of assets categorized as in poor condition.

Assets that support rail service account for more than 84 percent of the total value of transit assets. In contrast, assets that support nonrail services—including bus, paratransit, ferry, and other modes—account for 15 percent of the total value of transit assets. A remaining 0.3 percent of transit assets support both rail and nonrail services at larger multimodal agencies.

Asset Categories Rated Below SGR, 2018

Asset Category	Percentage Below SGR
Guideway Elements	2.9%
Systems	25.3%
Facilities	16.7%
Stations	5.7%
Vehicles	13.8%

Source: TERM.

Trends in Urban Bus and Rail Transit Fleet not in SGR

The average condition rating for bus and rail fleets did not change much between 2008 and 2018, ranging between 3.3 and 3.6 for buses and ranging between 3.2 and 3.5 for rail. The percentage of the bus fleet not in SGR rose from 11.1 percent in 2008 to 14.6 percent in 2018. For rail, the percentage not in SGR increased between 2008 and 2018 from 4.2 percent to 9.2 percent, after declining to a low of 2.8 percent in 2012.

The average fleet age of all buses was 7.1 years in 2018, up from 6.1 years in 2008. The average fleet age of rail vehicles increased from 20.1 years in 2008 to 24.4years in 2018.

Introduction to 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.

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.

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.

These four chapters measure investment levels in constant 2018 dollars except where noted otherwise. The chapters consider scenarios for investment from 2019 through 2038 that are geared toward maintaining some indicator of physical condition or operational performance at its 2018 level, sustaining investment at recent levels, or achieving some objective linked to benefits versus costs.

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.

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.

Analytical Tools and Uncertainty

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 models used for the analysis are the Highway Economic Requirements System (HERS), the Transit Economic Requirements Model (TERM), and the National Bridge Investment Analysis System (NBIAS). Each of these tools incorporates benefit-cost analysis (BCA) within its analytical framework. However, each of the scenarios presented in this report includes components that were not computed via BCA.

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 analysis. 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.

The investment models 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. Specific information about overall confidence intervals cannot be determined as the component variables used are not independent. Each input data and componenet variable has a unique level of uncertainty or confidence.

For example, HPMS data are collected with sampling precision requirements to ensure the samples are an accurate representation of the population. If a sample is designed at the 90-10 confidence interval and precision rate, the resultant sample estimate will be within 10 percent of the true value, 90 percent of the time.

HPMS Sample Selection Precision Level

Confidence Interval and Precision Rate	Functional Classes
90-5	Interstate (Rural; Small Urban)
	Other Freeway and Expressway (Rural; Small Urban)
	Other Principal Arterial (Rural; Small Urban)
90-10	Interstate (Urbanized > 200,000)
	Other Freeway and Expressway (Urbanized > 200,000)
	Other Principal Arterial (Urbanized > 200,000)
	Minor Arterial (Rural; Small Urban; Urbanized > 200,000)
80-10	Interstate (Urbanized < 200,000)
	Other Freeway and Expressway (Urbanized < 200,000)
	Other Principal Arterial (Urbanized < 200,000)
	Major Collector (Rural; Small Urban; Urbanized > 200,000)
	Minor Collector (Small Urban; Urbanized > 200,000)
80-10 (Or 70-15 if a State has three or more urbanized areas with a population < 200,000)	Minor Arterial (Urbanized < 200,000)
	Major Collector (Urbanized < 200,000)
	Minor Collector (Urbanized < 200,000)

Source: HPMS Field Manual.

Within HPMS, lower precision rates are defined for lower-level functional roads and lower population densities because of the limited resources of the communities managing those systems.

Supplemental analysis on alternative modeling strategies and sensitivity analysis on alternative parameter values are presented in Chapters 8 and 9, respectively, to assess the impacts and significance of these uncertainties on future investment levels and future highway performance estimates.

Sustain 2014–2018 Spending Scenario

Although some earlier C&P editions included analyses showing the impacts of sustaining spending at base-year levels, this edition follows the approach of the 24th C&P Report in using a 5-year average for the base period. This approach is expected to smooth out annual variations and make the scenarios more consistent between editions of this report. The Sustain Spending scenario for this edition is based on average annual spending over 2014–2018.

Constant-dollar conversions for the Highway Sustain 2014–2018 Spending scenario were performed using the National Highway Construction Cost Index (NHCCI), resulting in an average annual capital spending level from 2014 to 2018 of $115.1 billion.

Derivation of Highway Sustain 2014–2018 Spending Scenario

Year	National Highway Construction Cost Index	Total Highway Capital Spending (Billions of $)	
		Current Dollars	Constant 2018 Dollars
2014	1.6816	$105.4	$112.0
2015	1.6984	$109.3	$115.0
2016	1.6606	$104.5	$112.4
2017	1.6745	$111.5	$119.0
2018	1.7861	$117.0	$117.0
5-Year Average		**$109.6**	**$115.1**

Sources: FHWA: Highway Statistics, Various Years, Tables HF-10A and PT-1.

Constant-dollar conversions for the Transit Sustain 2014–2018 Spending scenario were performed using the RS Means Construction Index, resulting in an average annual capital spending level from 2014 to 2018 of $20.5 billion.

Derivation of Transit Sustain 2014–2018 Spending Scenario

Year	RS Means Construction Index (2018 = 100)	Total Transit Capital Spending (Billions of Dollars)	
		Current Dollars	Constant 2018 Dollars
2014	90.77	$17.4	$19.2
2015	92.44	$19.3	$20.8
2016	93.03	$19.4	$20.9
2017	95.82	$19.6	$20.5
2018	100.00	$21.1	$21.1
5-Year Average		**$19.4**	**$20.5**

Note: Excludes reduced reporter agencies.

Source: NTD.

Chapter 7: Capital Investment Scenarios – Highways

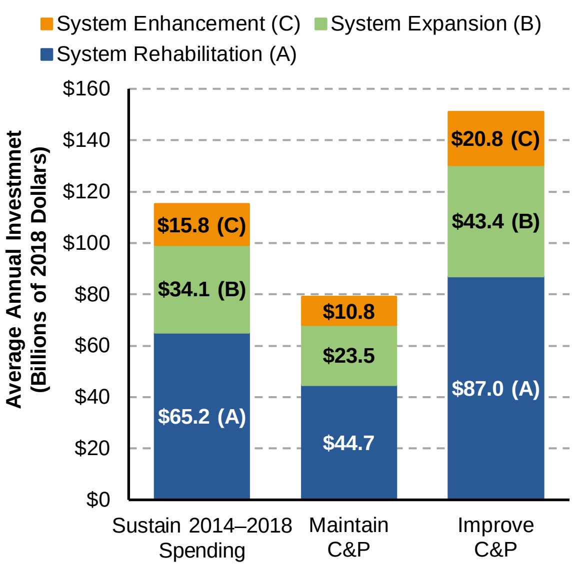
This report presents a set of illustrative 20-year highway capital investment scenarios based on simulations developed using HERS and NBIAS, with scaling factors applied to account for types of capital spending that are not currently modeled. All scenario investment levels are stated in constant 2018 dollars.

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 $79.0 billion.

The Sustain 2014–2018 Spending scenario assumes that annual capital spending is sustained over the next 20 years at the average level from 2014–2018 ($115.1 billion), in constant-dollar terms. In other words, spending would rise by exactly the rate of inflation during that period.

Since the level of 2014–2018 spending has been significantly higher than that of the Maintain Conditions and Performance scenario, the Sustain 2014–2018 Spending scenario should result in improved overall conditions and performance in 2038 relative to 2018.

Highway Capital Investment Scenarios

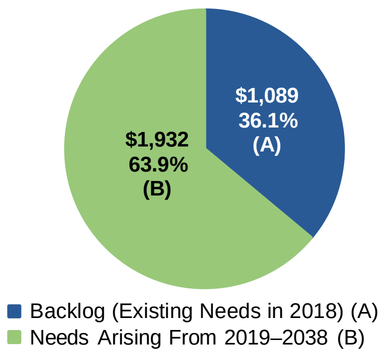


Sources: HERS and NBIAS.

The Improve Conditions and Performance scenario seeks to identify the level of investment needed to implement all potential investments estimated to be cost-beneficial. This scenario can be viewed as an "investment ceiling," above which it would not be cost-beneficial to invest. Of the $151.1 billion average annual investment level under the Improve Conditions and Performance scenario, $87.0 billion would be directed to system rehabilitation, $20.8 billion to system enhancement and $43.3 billion to system expansion.

Cumulative 20-year investment under the Improve Conditions and Performance scenario would total more than $3.0 trillion. This includes an estimated $1.1 trillion (36.1 percent), as of 2018, 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 Improve Conditions and Performance Scenario, Investment Backlog vs. Emerging Needs



Note: Values are in billions of 2018 dollars.
Source: HERS and NBIAS.

The estimated Highway Repair Backlog (a subset of the total backlog that excludes system expansion needs) is $143.0 billion for the Interstate System, $361.2 billion for the NHS, $641.0 billion for Federal-aid highways, and $852.0 billion for all public roads.

The Improve Conditions and Performance Scenario investment estimate and its backlog component both include projects off the Federal-aid highways and enhancement projects regardless of whether they are cost-beneficial, due to data limitations.

Chapter 7: Capital Investment Scenarios – Transit

This chapter provides an analysis of the State of Good Repair (SGR) Benchmark and three investment scenarios—the Sustain 2014–2018 Spending, Expansion, and Expansion with Growth scenarios.

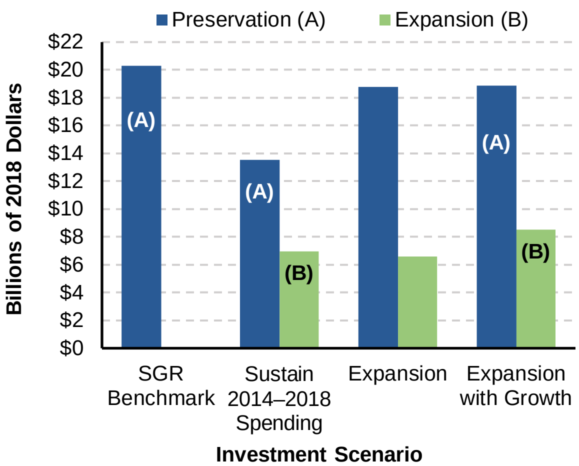
SGR Benchmark

The SGR Benchmark estimates the level of investment required to eliminate the SGR backlog by 2038. Unlike the investment scenarios, the benchmark does not include investment in expansion assets and is not subject to a benefit-cost screen.

Expenditures: An estimated $20.3 billion in annual investment is required to eliminate the SGR backlog by 2038. This is 50 percent higher than the 2014–2018 annual spending of $13.5 billion. (Funding levels are expected to increase under BIL.)

Asset Conditions: The SGR Benchmark projects improvement in average asset condition ratings, from 3.4 in 2018 to 3.5 by 2038.

Scenario Investment Summary



Source: TERM.

Sustain 2014–2018 Spending Scenario

In this scenario, for the period 2016–2018, the average annual investments in transit asset preservation and expansion are maintained at $13.5 billion and $7.0 billion, respectively, for the next 20 years.

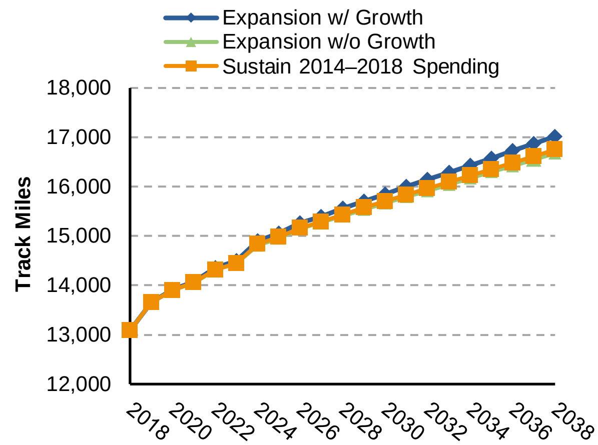
Backlog and Conditions: The recent rate of investment is not enough to maintain the current size of the SGR backlog, with the backlog growing from $101.4 billion in 2018 to $106.2 billion in 2038. At this level of underinvestment, average asset conditions decline from 3.4 in 2018 to 3.3 in 2038.

Transit Capacity: The $7.0 billion in average annual expansion investment is sufficient to increase rail transit route miles by 28 percent by 2038.

Expansion Scenarios

Expansion scenarios address a range of objectives, such as funding planned New Starts investments, improving bus service coverage and frequency, increasing operating speeds, and expanding the fleets of high-occupancy operators, all relative to 2018 levels. The Expansion with Growth scenario includes investment for long-term ridership increases (primarily after 2030).

Rail Expansion



Source: TERM.

Backlog and Conditions: Reinvestment levels are unconstrained for these scenarios, which results in elimination of the backlog by 2038 (subject to a benefit-cost test). With the backlog eliminated and significant investment in expansion, average asset conditions improve from 3.4 in 2018 to roughly 3.5 by 2038 (and slightly higher when growth in ridership is included).

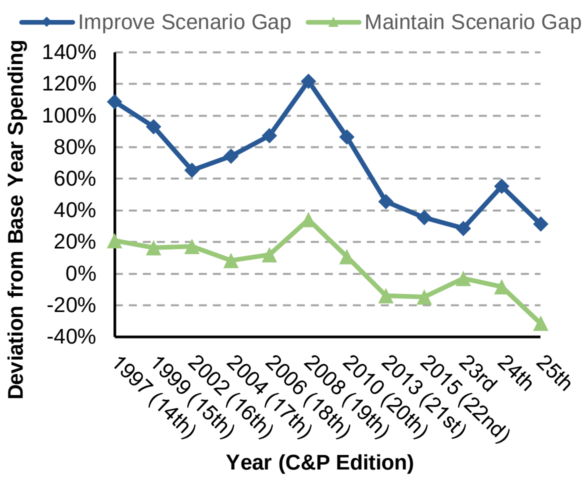
Transit Capacity: The average annual expansion investment of $6.6 billion to $8.5 billion in the expansion scenarios is sufficient to increase rail transit route miles by 27 percent to 30 percent by 2038.

Chapter 8: Supplemental Analysis – Highways

The 24th C&P Report estimated the average annual investment level for the Improve Conditions and Performance scenario as $165.9 billion in 2016 dollars, or $178.4 billion in 2018 dollars (after adjusting for inflation, using the National Highway Construction Cost Index 2.0). The 25th C&P Report estimates the comparable value at $151.1 billion in 2018 dollars, approximately 15.3 percent lower than the adjusted 24th C&P Report estimate.

The implied **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 gap between base-year spending and the average annual investment level for the primary Maintain and Improve scenarios presented in each C&P edition has varied, reaching the highest level in the 2008 C&P Report. The gaps between the average annual investment levels for both the Maintain and Improve scenarios decreased between the 24th and 25th editions.

Comparison of Implied Funding Gaps



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

The Department of Transportation has established a performance target to **reduce the backlog** of $830 billion in highway repairs by 50 percent by 2040. This figure represents the combination of the System Rehabilitation and System Enhancement portions of the 2016 backlog presented in the 24th C&P Report. Although the 2018 highway repair backlog of $852 billion is 2.6 percent higher in nominal dollar terms, when computed in constant dollar terms the backlog has decreased from the 24th C&P Report to the 25th C&P Report by 4.6 percent.

Externalities represent the uncompensated impact of one person's actions on the wellbeing of a bystander. Congestion is a common example of a negative externality that drivers have on other drivers. Similarly, emissions and noise pollution are negative externalities imposed by drivers on society. The existence of externalities means that highway use is underpriced from the individual driver's perspective, leading to overconsumption in the form of higher VMT. This in turn may result in higher investments in system expansion. If externalities were internalized in some manner by drivers on severely congested roads during peak periods (be it through altruism or through some sort of pricing scheme), HERS estimates that the level of cost-beneficial highway capacity investments would be 44.9 percent lower than that reflected in the Improve scenario.

Examining the implications of **alternative investment allocations**, such as a Mixed Spending strategy allocating resources to both system rehabilitation and system expansion compared to a Rehabilitation First strategy that includes system rehabilitation only, can yield a better understanding of the modeling framework underlying the C&P Report. As should be expected, the HERS and NBIAS models predict a Rehabilitation First strategy would lead to better overall physical conditions and worse operational performance relative to the Mixed Spending strategy. An exception to this trend is on urban Interstates, where HERS predicted worse pavement conditions under the Rehabilitation First strategy relative to the Mixed Spending strategy. This appears as a result of some potential projects featuring both rehabilitation and expansion elements being deferred by HERS to a later date outside the 20-year analysis window once the system expansion elements were removed from consideration.

Chapter 8: Supplemental Analysis – Transit

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

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.

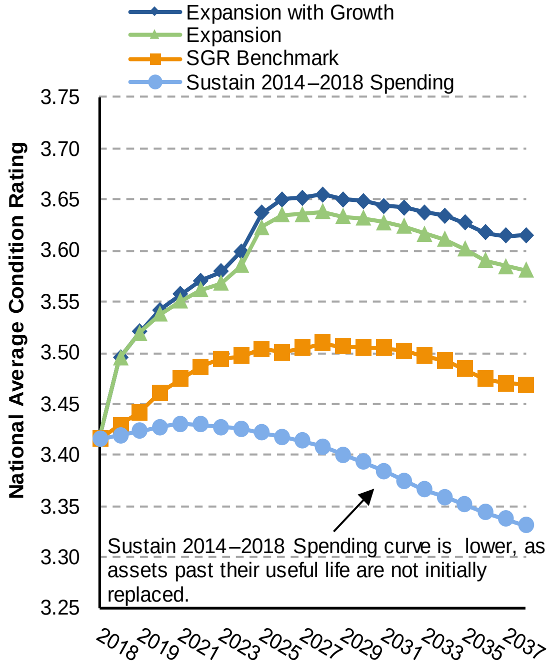
The national condition level of transit assets in 2018 stood at 3.41 (on a scale from 1 to 5), which is in roughly the mid-range of the adequate condition (3.0–3.9).

Asset Conditions under Investment Scenarios

Under the Expansion and Expansion with Growth Investment scenarios, there is an initial jump in the average condition over the first 10 years of the forecast period, driven by significant investments in new expansion assets. The increase in average conditions for these scenarios begins to slow in the later years of the forecast period and then average conditions start to decline, with the average condition in 2038 projected to be in the 3.6 range.

Under the Sustain 2014–2018 Spending scenario, the average condition is predicted to decrease consistently from the 2018 level (3.4) toward 3.3, in the bottom of the adequate condition range (3.0–3.9). The two main reasons for this result are: (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.

Asset Condition Forecast for All Existing and Expansion Transit Assets

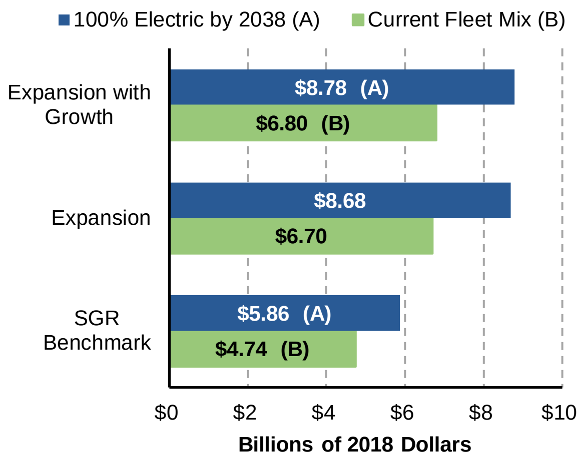


Source: TERM.

Electric Bus Fleet Costs

Assuming broad adoption of electric buses in place of existing diesel and CNG models by 2038, total bus fleet investment costs can be expected to increase by roughly 25 to 30 percent over this period.

Impact of Electric Vehicles on Scenario Average Annual Needs by Scenario



Source: TERM.

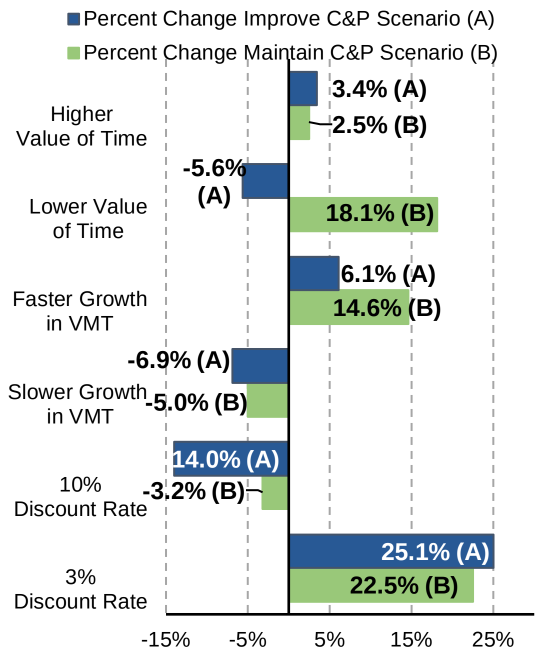
This equates to a roughly $2.2 billion increase in annual funding through 2038 to cover the transition to 100-percent electric fleets.

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 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.

Investments are sensitive to the discount rate, a value used in benefit-cost analyses to scale down benefits and costs arising in the future relative to those arising sooner. Substituting a 3-percent discount rate for the baseline rate of 7 percent would increase the average annual investment requirements for the Improve Conditions and Performance scenario (Improve) by 25.1 percent (from $151.1 billion to $188.9 billion). Investments under the Maintain Conditions and Performance scenario (Maintain) would increase by 22.5 percent, assuming a 3-percent discount rate. A 10-percent discount rate would decrease average annual investment requirements by 14.0 percent for the Improve scenario, and 3.2 percent for the Maintain scenario.

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



Sources: HERS and NBIAS.

The overall impact of different estimates of growth in VMT was similar for both scenarios. Applying a 1.3-percent VMT growth per year (an optimistic forecast), instead of 1.1 percent, increases the Improve scenario funding level by 6.1 percent and the Maintain scenario level by 14.6 percent. Applying a forecast of 0.9-percent growth in VMT per year (a pessimistic forecast) reduces the Improve scenario funding level by 6.9 percent and the Maintain scenario by 5.0 percent.

Assuming lower values of time (35 percent of median hourly household income instead of 50 percent for personal travel time) reduces that average annual investment level for the Improve scenario by 5.6 percent while increasing investment levels for the Maintain scenario by 18.1 percent. Conversely, assuming higher values of time (60 percent of median hourly household income for personal travel time) increases the average annual investment level for the Improve scenario by 3.4 percent and the Maintain scenario by 2.5 percent.

Impact of Alternative Assumptions on Highway Scenario Investment Levels

Test	Maintain C&P Scenario	Improve C&P Scenario
Baseline	$79.0	$151.1
Lower Value of Time	$93.3	$142.5
Higher Value of Time	$80.9	$156.2
Slower Growth in VMT	$75.0	$140.6
Faster Growth in VMT	$90.5	$160.3
Lower Discount Rate of 3%	$96.8	$188.9
Higher Discount Rate of 10%	$76.4	$129.9

Note: Amounts are in billions of dollars.

Sources: HERS and NBIAS.

DOT's guidance on the value of a statistical life saved in 2018 to be assumed for benefit-cost analysis recommends a base value of $10.5 million and alternative values of $6.3 million and $14.7 million. Applying the recommended alternatives in HERS and NBIAS would increase both scenarios by less than 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.

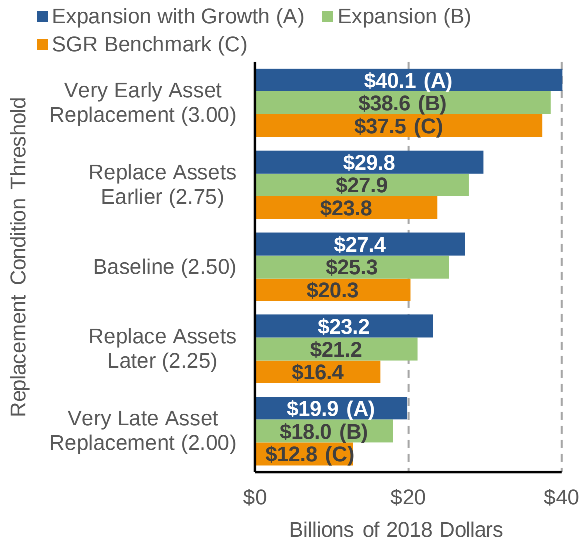
Chapter 9: Sensitivity Analysis – Transit

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

Replacement Thresholds

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

Sensitivity to Replacement Threshold



Source: TERM.

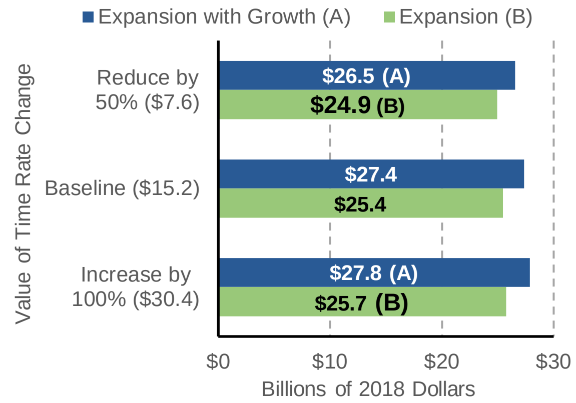
Capital Costs

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 report) would lead to proportional growth in the SGR Benchmark but would be only partially realized (a 14- to 15-percent increase) under the Expansion or Expansion with 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.

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. However, preservation expenditures have low sensitivity to variations in the value of time. Doubling the $15.20 current hourly rate from DOT's benefit-cost analysis guidance increases overall investment by 1–3 percent.

Sensitivity to Value of Time



Source: TERM.

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. TERM is relatively insensitive to changes in the discount rate. Decreasing the discount rate from 7 percent to 3 percent leads to an increase of only 1 percent in investment levels.

Service Coverage and Frequency

Sensitivity analyses were conducted to understand how changes in the density and service parameters would affect estimated investment levels for the Expansion scenario. For transit coverage, the change to a density threshold of three dwelling units per acre would result in a 71-percent increase in the Expansion costs relative to the transit coverage component of the baseline Expansion scenario. For transit frequency, changing the density thresholds for peak-period service would result in a 42-percent increase in the Expansion costs relative to the transit frequency component of the baseline Expansion scenario. These significant percentage increases in coverage and frequency improvement costs reflect the large number of block groups that benefit from each of the threshold reductions.

Chapter 10: Impacts of Investment – Highways

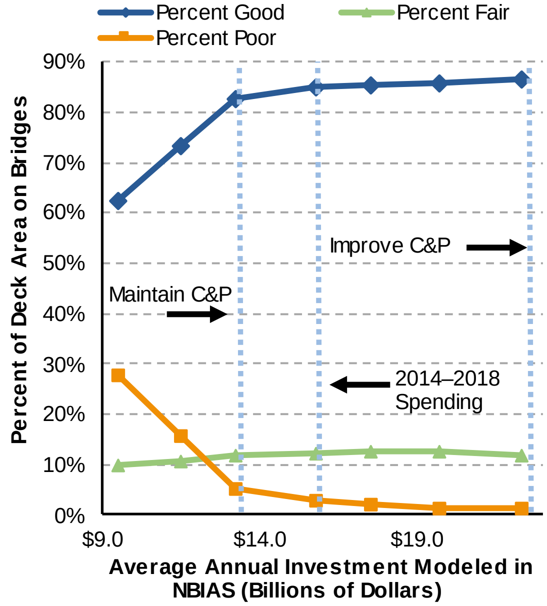
Of the $151.1 billion average annual investment level for all public roads under the Improve Conditions and Performance scenario presented in Chapter 7, 14.8 percent ($22.3 billion) was derived from NBIAS estimates of rehabilitation and replacement needs for all bridges. HERS evaluates needs on Federal-aid highways for pavement resurfacing or reconstruction and widening, including those associated with bridges; 57.0 percent ($86.1 billion) of this scenario was derived from HERS. The remaining 28.2 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 2014 to 2018 spending.

Sustaining NBIAS-modeled investment at $15.8 billion (the portion of 2014 to 2018 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 84.9 percent good, 12.2 percent fair, and 2.7 percent poor. Increasing annual investment to $22.3 billion would increase the deck area-weighted share rated as good to 86.7 percent and reduce the share rated as poor to 1.2 percent.

Sustaining HERS-modeled investment at $66.8 billion (the portion of 2014 to 2018 spending directed toward improvement types modeled in HERS) in constant-dollar terms over 20 years is projected to result in 70.6 percent of VMT in 2038 occurring on Federal-aid highway pavements with good ride quality, 19.8 percent on pavements with fair ride quality, and 9.6 percent on pavements with poor ride quality. Increasing annual investment to $86.1 billion would increase the VMT-weighted share rated as good to 76.2 percent and reduce the share rated as poor to 6.2 percent.

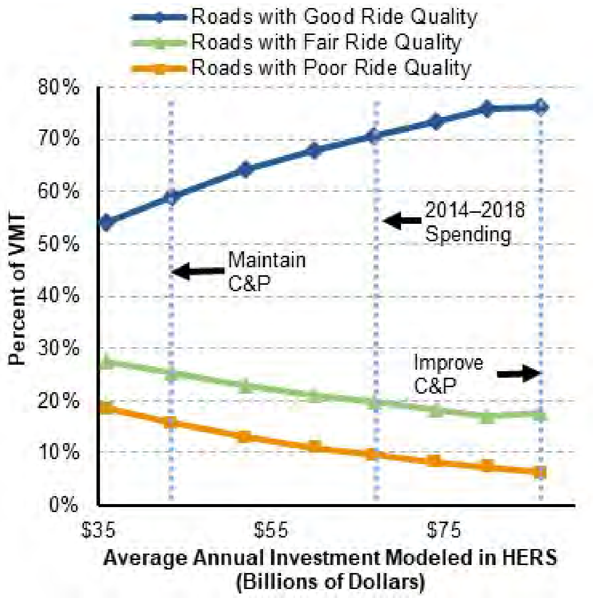
Other projected impacts of investing at the Improve scenario level include reducing VMT-weighted average pavement roughness on Federal-aid highways by 18.7 percent in 2038 relative to 2018 and reducing the percentage of VMT on congested roads from 11.2 percent to 7.5 percent. Average total user costs (including travel time costs, vehicle operating costs, and crash costs) are projected to decrease by 6.6 percent, from $1.449 per VMT in 2018 to $1.373 per VMT in 2038.

Projected Impact of Future Investment Levels on 2038 Bridge Condition Indicators for All Bridges



Source: NBIAS.

Projected Impact of Alternative Investment Levels on 2038 Pavement Ride Quality Indicators for Federal-aid Highways



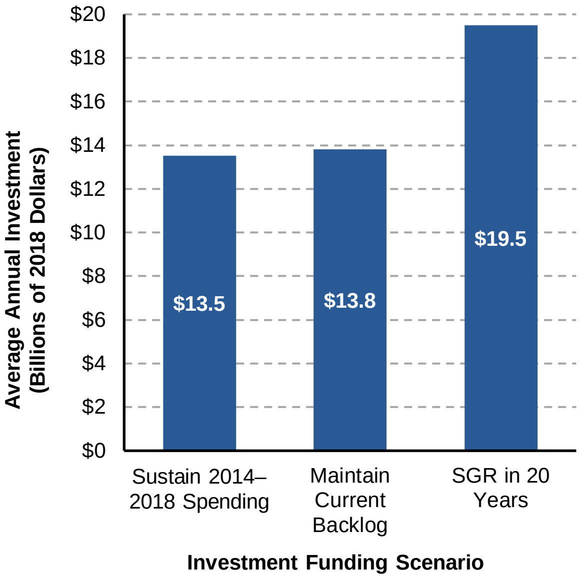
Source: NBIAS.

Chapter 10: Impacts of Investment – Transit

Impact of Preservation Investments on Transit Backlog and Conditions

TERM analysis suggests that the 2014–2018 average annual rate of capital reinvestment of $13.5 billion is marginally lower than that required to maintain the SGR backlog and, if sustained over the next 20 years, would result in a reinvestment backlog of roughly $106.2 billion by 2038. In contrast, increasing the annual rate of reinvestment to an average of $20.3 billion would fully eliminate the backlog by 2038. Finally, an annual level of reinvestment of roughly $13.8 billion is required to maintain the backlog at its current level.

Impact of Preservation Investment on 2038 Transit State of Good Repair Backlog



Source: TERM.

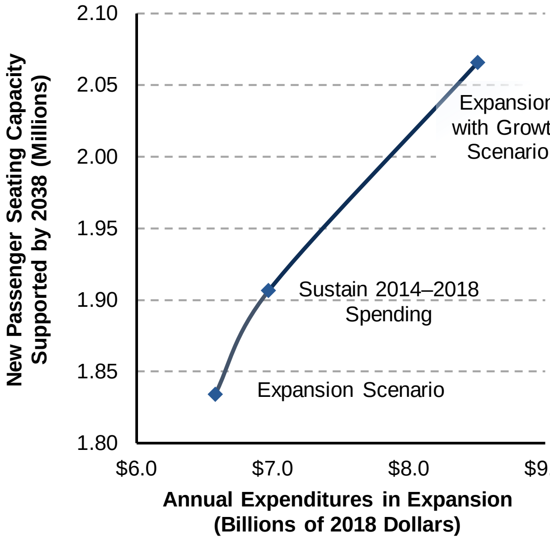
Sustained 2014–2018 spending at the recent average annual level of $13.5 billion is sufficient to maintain average condition of *existing* assets at roughly their estimated 2018 level (3.4). In contrast, unconstrained average annual replacement of $20.3 billion increases the average condition rating of the nation's transit assets to 3.5 by 2038, but with much higher conditions during the early years of the 20-year forecast period (followed by a slow decline in conditions).

Impact of Expansion Investments on Transit Capacity

Although capital spending on preservation primarily benefits the condition of existing transit assets, expansion investments are typically undertaken to expand the asset base to expand transit capacity and potentially to improve service performance for existing transit system users. The recent rate of investment in asset expansion ($7.0 billion in 2018 dollars) could support an increase in U.S. transit seating capacity by roughly 1.9 million additional seats by 2038 (approximately a 1.6-percent annual growth in seating capacity). This might result in less-crowded conditions in stations and vehicles, along with increased operating speeds.

Under the Expansion with Growth scenario, an additional $1.5 billion in annual expansion investment (an annual total of $8.5 billion) is required to deliver the seating capacity required to support that scenario's capacity increase of 2.1 million seats by 2038 (without increasing vehicle crowding).

New Passenger Seating Capacity in 2038 Supported by Expansion Investments in All Urbanized and Rural Areas



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 well below the national average for that mode.

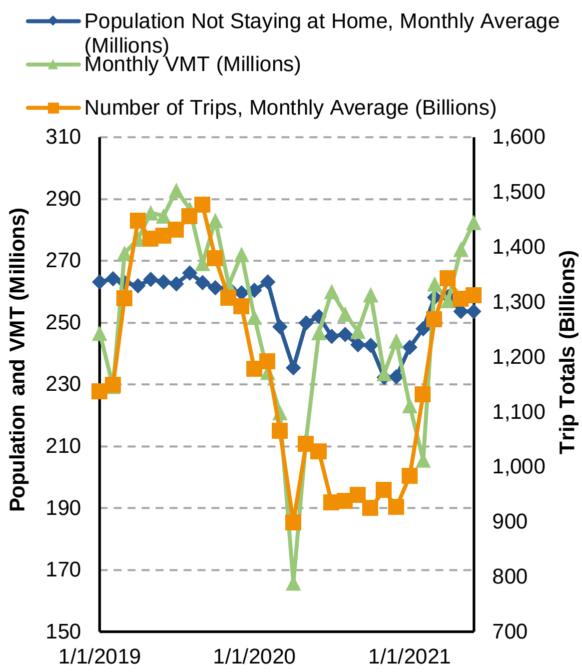
Source: TERM.

Chapter 11: Impacts of the COVID-19 Pandemic on Transportation – Highways

The declaration of Coronavirus Disease 2019 (COVID-19) as a pandemic in March 2020 caused many people to stay at home, except to access essential services, to contain the disease. This resulted in drastic declines in traffic volume and trips that are proportionate to the change in the number of people who opted to stay, or not stay, at home.

In 2019, an average of 63.4 million people opted to stay home, and 262.8 million people opted to leave home for work, school, healthcare, goods and services, or other reasons. By March 15, 2020, the number of people staying at home sharply increased by 37 percent compared with the 2019 average. The number of people staying at home peaked on April 12, 2020, at over 110 million people, nearly 73.5 percent higher than the 2019 annual average, compared with 216.9 million people who did not stay home.

Population Not Staying Home, VMT and Trip Totals



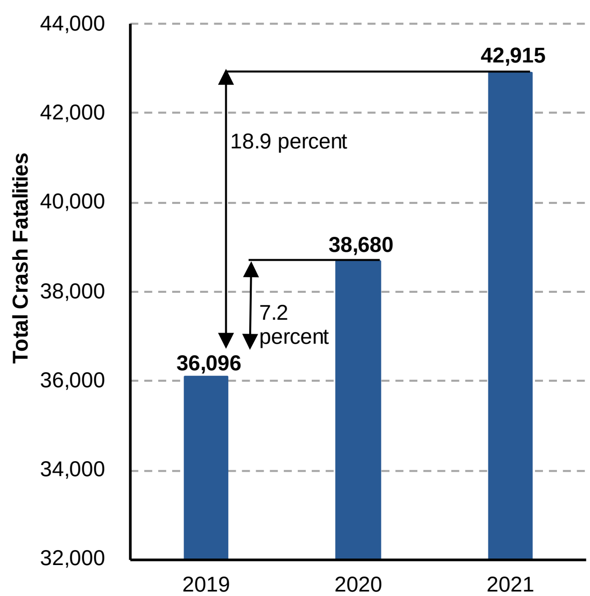
Sources: Bureau of Transportation Statistics; FHWA.

VMT declined by 19 percent in March 2020 and by 40 percent in April 2020 compared with 2019 totals. By 2021, VMT remained below traffic volumes encountered before COVID-19 and did not increase to pre-pandemic levels until September of 2021. Patterns in passenger vehicle and truck VMT differ, however. Passenger vehicle VMT was 13 percent lower than 2019 levels in October 2020, whereas truck VMT was 14 percent higher. Truck VMT has been higher than 2019 values since June 2020.

The total number of trips by all modes of roadway travel declined by as much as 38 percent in 2020 compared with 2019 totals, but rebounded to near pre-pandemic levels in early 2021. Since the start of the COVID-19 pandemic, all trip totals have been below 2019 totals except for trips less than one mile, which have continued to exceed 2019 levels since February 2021.

Despite declines in traffic volumes, roadway fatalities increased. By the end of 2020, a total of 38,680 fatalities occurred due to roadway crashes, a 7.2-percent increase from 2019, or 2,584 more fatalities. The total number of annual fatalities increased to 42,915 at the end of 2021, almost 19 percent (18.9 percent) higher than 2019 totals or 6,819 more deaths.

Total Crash Fatality Trends



Source: NHTSA.

The decline in travel led to a $3.86 billion reduction in the amount of fuel taxes collected and deposited into the Highway Trust Fund in 2020 compared with 2019 quarterly trust fund certifications.

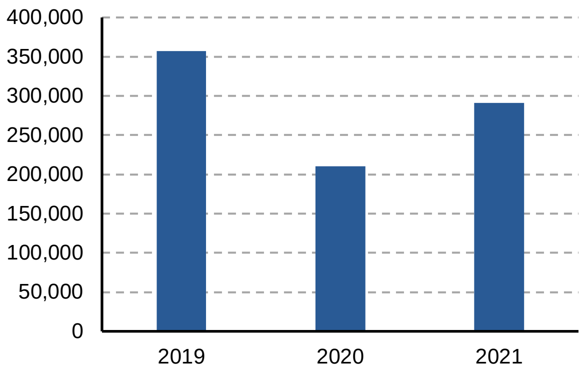
Chapter 11: Impacts of the COVID-19 Pandemic on Transportation – Transit

The COVID-19 pandemic greatly affected all areas of life including work, school, and social activities. As a result of people staying home, travel volumes decreased, and travel patterns shifted. Between April 2019 and April 2020, transit ridership decreased by 81 percent.

Ridership. Not all transit modes were affected at the same rate. The two hardest-hit modes were commuter rail and commuter bus. Ridership on these modes decreased by 93 percent between April 2019 and April 2020. The least affected mode was local bus service, which experienced only a 71 percent decrease in ridership during the same period. Overall, ridership on rail modes was more affected than on nonrail modes. Ridership began to rebound in 2021, but not to pre-pandemic levels.

Among the top 10 transit agencies, BART in the Bay Area experienced the most significant ridership decrease between January 2020 and May 2021, with 81 percent fewer trips. During the same period, transit ridership for Los Angeles Metro decreased by only 42 percent.

Vehicle Revenue Miles Throughout the Pandemic

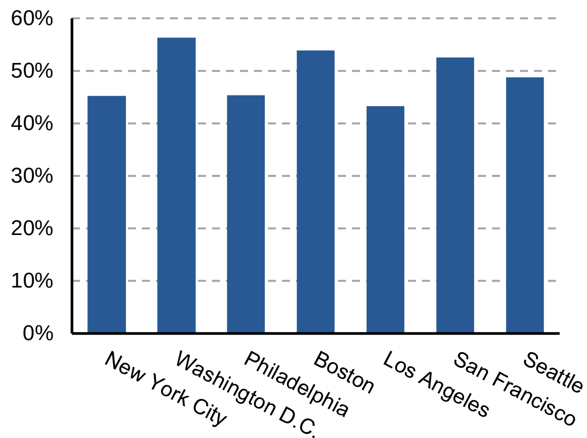


Source: NTD.

Service. Vehicles Revenue Hours (VRH) and Vehicle Revenue Miles (VRM) decreased by 38 percent and 41 percent, respectively, between April 2019 and April 2020. These figures are much lower than the ridership decreases experienced in the same period. Although declines in ridership affected rail modes at a higher rate, service reductions were higher for nonrail modes, with VRM decreasing by 42 percent for nonrail modes and 38 percent for rail modes. VRM increased between April 2020 and April 2021, but not to pre-pandemic levels.

Fare Revenues. As a result of the pandemic, many transit agencies temporarily suspended fares. Suspended fares, coupled with ridership decreases, caused fare revenue to decrease anywhere from 19 to 70 percent between 2019 and 2020 among the top 10 transit agencies. In 2020, the top 10 transit agencies suspended fare collection, although suspension varied in length and by mode. Fare revenue decreases between 2019 and 2020 varied from 70 percent for King County Metro in Washington State to 19 percent for the Massachusetts Bay Transportation Authority. The New York MTA experienced a 59-percent decrease in fare revenue in 2020, equivalent to $3.7 billion.

Households with Teleworkers, August 2020



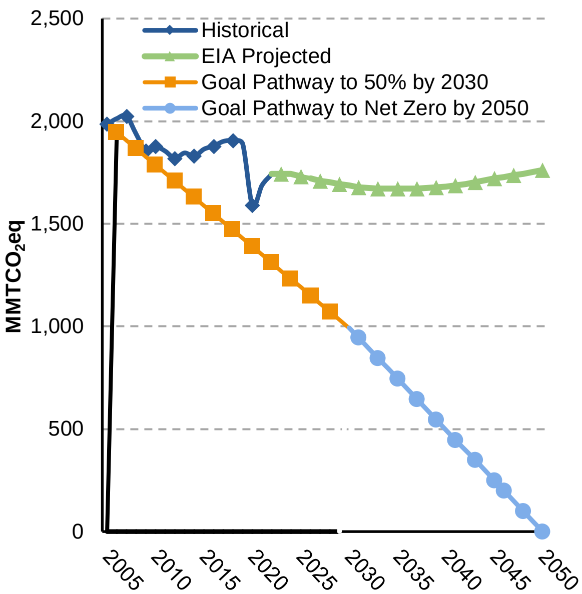
Note: Telework numbers represent people who answered yes to the following question: "Some adult in household substituted some or all of their typical in-person work for telework because of the coronavirus pandemic?"
Source: BTS.

Telework. Teleworking increased during the pandemic, leading to fewer people commuting and decreases in transit ridership. In major metropolitan areas across the country, between 42 percent and 56 percent of households reported having at least one teleworker due to COVID-19. According to the 2019 American Community Survey, less than 10 percent of workers in these same metropolitan areas were working from home.

Chapter 12: Greenhouse Gas Mitigation – Highways

Transportation is the largest source of greenhouse gas (GHG) emissions in the United States, having surpassed emissions from electricity generation in 2016. Transportation accounted for 28.5 percent of total U.S. GHG emissions as of 2019. On-road vehicles are the heaviest contributors to U.S. transportation GHG emissions, accounting for over 83.1 percent of the sector's total in 2019. Light-duty vehicles (LDVs) represent 69.7 percent, and medium- and heavy-duty vehicles account for 23.7 percent. Accounting for GHG reduction policies in place at the end of 2020, the transportation sector is expected to remain the largest source of U.S. CO_2 emissions through 2050, increasing at an average annual rate of 0.3 percent despite gains in energy efficiency.

Projected Transportation Sector Energy-related CO2 Emissions Compared with Net Zero Goal



Sources: U.S. Energy Information Administration, Annual Energy Outlook 2006 through 2021, Reference Case Table 18: Carbon Dioxide Emissions by Sector and Source; Projections: EIA, AEO2021 National Energy Modeling System run ref 2021.d113020a.

Reducing the sector's CO_2 emissions by 50–52 percent below 2005 levels is the nationally determined contribution (NDC) that U.S. targeted starting in April 2021. Meeting this target would require yearly reductions of almost 6 percent starting in 2022. This rate of improvement would be approximately seven times greater than what was achieved in reducing on-road vehicle GHG emissions between 2005 and 2015. Four primary routes are available to reduce GHGs from transportation:

1. Increase vehicle fuel efficiency.
2. Transition to lower-carbon transportation energy sources, including electric and alternative fuel vehicles.
3. Shift travel and goods movement to more efficient and low- or no-emission modes.
4. Reduce travel distances through more efficient land-use patterns such as increased density and mixed-use development.

Federal programs and policies to mitigate GHG emissions from the transportation sector have evolved over recent years, including new Corporate Average Fuel Economy (CAFE) standards, established by DOT, that regulate fuel economy standards for LDVs and for medium- and heavy-duty trucks. State and local transportation planning, as well as land use policy, can be used to improve the convenience and efficiency of the transportation system by better connecting origins and destinations, reducing travel distances, and increasing access to less emission-intensive modes (such as biking and transit), resulting in reduced GHG emissions.

The Infrastructure Investment and Jobs Act, referred to as the "Bipartisan Infrastructure Law," (BIL) provides investments supporting a more equitable and climate-friendly transportation system, including a $7.5 billion grant program to strategically deploy publicly accessible EV charging and alternative fueling infrastructure along highway corridors. In addition to investments, BIL establishes a carbon reduction program that requires States, in coordination with MPOs, to develop carbon reduction strategies to reduce transportation emissions. Several States are also pursuing programs that reduce GHG emissions and provide funding for transportation projects and programs that support climate and equity goals.

Related FHWA resources are available at https://www.fhwa.dot.gov/environment/sustainability/energy/.

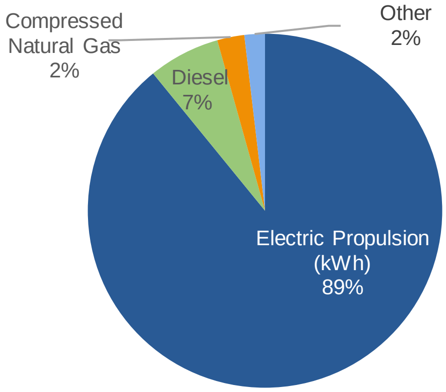
Chapter 12: Greenhouse Gas Mitigation – Transit

Public transit has an important role to play in reducing emissions. By converting personal vehicle trips into transit trips that are less energy-intensive per capita, public transit can help to lower GHG emissions. Transit can also reduce road congestion and create land-use efficiencies that encourage shorter and fewer driving trips that further reduce GHG emissions. In 2018, the use of public transportation avoided 75 million metric tons of GHG emissions while producing only 12 million metric tons.

Fuel Type

Public transit vehicles are powered by a variety of fuel sources including electric (propulsion and battery), diesel, compressed natural gas, gasoline, liquefied petroleum, and biodiesel. All rail modes are powered primarily by electric propulsion, with a few using biodiesel and diesel. In 2018, rail modes used more than 6 billion kilowatt-hours of electricity.

Transit Fuel Type Use



Notes: Electric includes propulsion and battery. Other includes gasoline, liquefied petroleum, biodiesel, and other fuel.

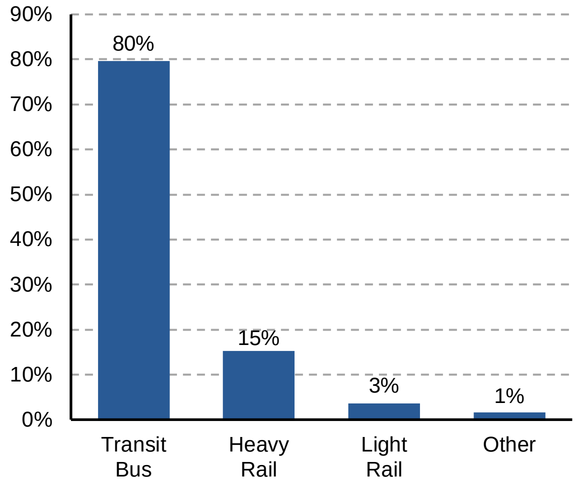
Source: NTD.

Bus modes are powered primarily by diesel and compressed natural gas, although buses use every type of fuel source. In 2018, buses used more than 305 million gallons of diesel and nearly 166 million gallons of compressed natural gas. Demand-response vehicles use every type of fuel except electric propulsion. Gasoline is the most common fuel for these vehicles. In 2018, demand-response vehicles used more than 65,000 gallons of gasoline. Ferryboats rely on diesel and biodiesel. In 2018, ferryboats used more than 40,000 gallons of diesel and biodiesel.

Number of Vehicles

In 2018, there were 76,164 transit vehicles. Most vehicles were buses, while nearly one-fifth of vehicles were rail vehicles. These vehicles were used on heavy rail, light rail, automated guideway/monorail, historic trolley, aerial tramway, and cable car modes. Additional vehicles included 234 ferry boats and 68 other vehicles. Bus vehicles include articulated, trolley, and double-decker buses.

Share of Transit Vehicles by Mode



Note: Transit bus includes bus, articulated bus, and double-decker bus. Any mode that accounts for less than 1 percent has been combined into Other.

Source: NTD.

Emissions

All transit modes produce greenhouse gas (GHG) emissions. The U.S. Energy Information Administration develops an Annual Energy Outlook that forecasts GHG emissions by transit mode and fuel type for bus modes. Between 2020 and 2050, GHG emissions are expected to increase for both rail and bus. For bus, all fuel types are expected to produce more emissions by 2050, with electric expected to see a nearly 2,000-percent increase in emissions. Overall, bus emissions are expected to increase by 35 percent. For rail, the Annual Energy Outlook only forecasts electricity emissions. Between 2020 and 2050, GHG emissions from electricity for rail modes are expected to increase by 118 percent.

Part IV: Highway Freight Conditions and Performance Report

The Fixing America's Surface Transportation (FAST) Act required FHWA to establish a National Highway Freight Network (NHFN) to help strategically direct Federal resources and policies toward improved performance along that network. Projects for improving freight movement on the NHFN are eligible for National Highway Freight Program (NHFP) obligations. The NHFN comprises 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 analysis included in this *Highway Freight Conditions and Performance Report to Congress* (third edition) supports improved decision-making that will result in a safer, more reliable, and more efficient freight transportation system. This edition builds on and enhances the analysis included in the previous two editions by:

- Updating all condition and performance indicators using the latest data available at the time of writing;
- Providing an enhanced NHFN performance analysis based on the FHWA Freight Mobility Trends tool, a freight performance analysis tool released in 2020;
- Updating and expanding the analysis of CRFCs/CUFCs and State Freight Plans;
- Updating and expanding the discussion of Federal, State, and other freight industry efforts that address NHFN conditions and performance-related needs or issues; and
- Discussing several special topics including supply chains, freight transportation equity, and climate impacts from freight movement.

Freight Demand Overview

In 2018, the Nation's freight transportation system moved a daily average of about 51 million tons of freight worth more than $51.8 billion. From 2000 to 2018, total freight ton-miles grew by 3.7 percent, from 5,065,648 to 5,250,670.

Performance Analyses

Performance Analysis: Safety

Safety is a top U.S. Department of Transportation (DOT) priority, a major NHFP goal, and a key element of freight performance. There is a strong public interest in ensuring the safe movement of freight along the NHFN as well as the full extent of the Nation's freight transportation system. Between 2014 and 2019 the number of fatal crashes and fatalities on the NHFN increased by 17 percent, peaking in 2016.

Performance Analysis: Mobility

Freight mobility pertains to how efficiently freight moves. Approximately 82 percent of the most congested NHFN corridors in 2019 (based on 2019 truck hours of delay per mile) were located in coastal metropolitan areas. On 30 of the 50 most congested NHFN corridors, truck hours of delay per mile increased in 2019 compared with 2017.

Performance Analysis: Reliability

Reliability measures the impacts of non-recurring congestion on trip consistency. Reliability was assessed through an evaluation of the peak period Planning Time Index (PTI) and Truck Travel Time Reliability (TTTR) index for the top 50 most congested freight corridors on the NHFN (based on 2019 truck hours of delay per mile):

- The highest PTI (representing the least reliable corridor) was on I-95/I-295 in New York, New York (with a PTI value of 10.56); the lowest PTI (representing the most reliable corridor) was on I-15 in Salt Lake City, Utah (with a PTI value of 1.74).
- Compared with 2017, the TTTR index on the Interstate system increased from 1.36 to 1.39 in 2019, indicating overall reliability was worse in 2019.

Performance Analysis: Freight Demand

Truck volumes provide indicators of freight demand. Expected growth in freight over the next 25 to 30 years will translate to higher volumes of freight vehicles on the Nation's freight transportation network, particularly on its highways.

CRFC/CUFC

CRFCs/CUFCs provide States and eligible metropolitan planning organizations (MPOs) an opportunity to designate high-priority connectors leading to the NHFN from freight generators or other freight facilities. As of January 1, 2021, States and MPOs had designated 5,681 CRFC and CUFC miles, about 10 percent of the total 2021 NHFN roadway mileage. As of this date, 29 States and the District of Columbia had submitted CRFC/CUFC designations to FHWA.

Program Highlights

Program Highlights: State Freight Plans

BIL added new requirements for the State Freight Plans that each State receiving NHFP funding must develop. Now plans should be updated every four years and must address an eight-year forecast period. Most States have updated their plans accordingly. The plans address a wide array of conditions and performance-related issues, including infrastructure conditions, truck parking, and funding.

Program Highlights: Truck Parking

Jason's Law requires DOT to conduct a survey assessing States' capabilities to provide adequate commercial motor vehicle parking and rest facilities. First conducted in 2015, this survey was updated in 2019. The 2019 survey documented the locations of approximately 313,000 truck parking spaces, including 40,000 spaces at public rest areas and toll service plazas, and 273,000 spaces at private truck stops. Compared with the 2015 survey, the 2019 survey found an 11-percent increase in the number of private parking spaces and a 6-percent increase in the number of public parking spaces.

Conditions Analyses

The International Roughness Index (IRI) assesses pavement ride quality as experienced by a driver. In 2018, the IRI for 76 percent of NHFN pavement mileage was rated good, 19 percent was rated fair, and 5 percent was rated poor. Overall pavement condition is a combination indicator that incorporates IRI and an assessment of individual pavement distresses. In 2018, the overall pavement condition for 57 percent of NHFN mileage was rated good, 42 percent was rated fair, and 1 percent was rated poor.

In 2019, 37 percent of the total NHFN bridge mileage was in good condition, 58 percent was in fair condition, and 5 percent was in poor condition.

Special Topics

Special Topic: Supply Chain

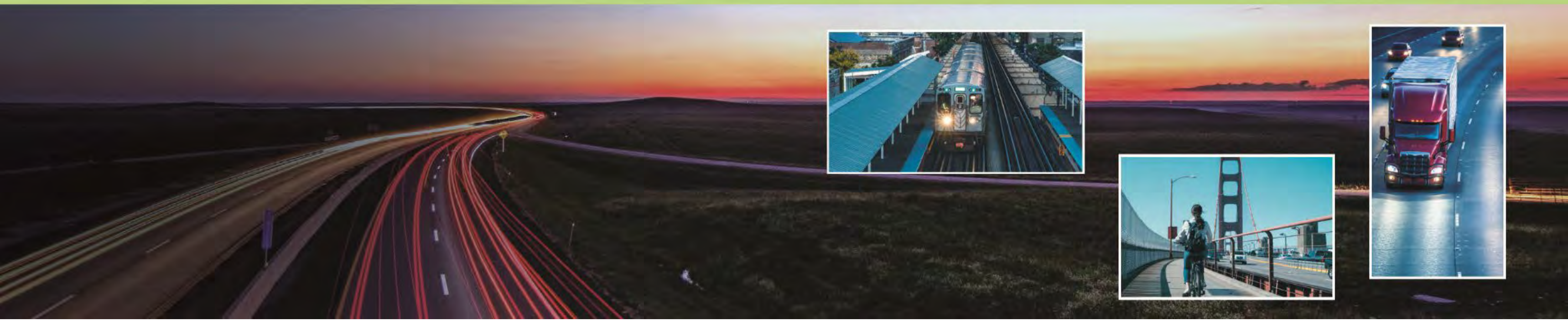
Widespread impacts from unexpected supply chain disruptions can upset freight movement in the short term with potentially lasting economic implications. These impacts underscore the need for public investment to improve freight movement safety, resilience, mobility, and reliability. DOT invests in research and innovation delivery to improve the understanding of national supply chains for better investment decisions in freight transporation improvements.

Special Topic: Freight Transportation Equity

Freight transportation equity refers to how costs and benefits of freight transportation are distributed to users. To increase Federal agencies' capacity and ability to address freight transportation equity, DOT is collaborating with internal partners; researching and documenting noteworthy practices among States, regions, and localities; and creating grant programs that incorporate racial equity and environmental justice as focus areas.

Special Topic: Climate Impacts

Freight transportation contributes to negative climate impacts and is also vulnerable to the impacts of climate change. FHWA is researching strategies and tools to assist public sector transportation professionals in considering climate change as part of freight planning and analysis, as well as addressing climate change through freight planning programs, activities, and project development.



Part I: Moving a Nation

Introduction

Part I of this 25th C&P Report includes six chapters, each of which describes the existing system from a different perspective:

- Chapter 1, **System Assets**, describes the extent of highways, bridges, tunnels, and transit systems. Information on ferries is also included. 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 transit 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.
- Chapter 3, **People and Their Travel**, analyzes travel patterns associated with various household characteristics and population demographics.
- Chapter 4, **Mobility,** covers highway congestion and reliability in the Nation's urban areas, the economic costs of congestion, and speed and reliability on the National Highway System (NHS). 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 physical conditions of the Nation's highways, bridges, tunnels, 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).

The Federal Highway Administration (FHWA) defines TPM as a strategic approach that uses system information to make investment and policy decisions to achieve 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 of the 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.

The national performance goals specified in 23 United States Code § 150(b) for the Federal-aid Highway Program are:

> (1) SAFETY.-To achieve a significant reduction in traffic fatalities and serious injuries on all public roads.
>
> (2) INFRASTRUCTURE CONDITION.-To maintain the highway infrastructure asset system in a state of good repair.
>
> (3) CONGESTION REDUCTION.-To achieve a significant reduction in congestion on the National Highway System.
>
> (4) SYSTEM RELIABILITY.-To improve the efficiency of the surface transportation system.
>
> (5) 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.
>
> (6) ENVIRONMENTAL SUSTAINABILITY.-To enhance the performance of the transportation system while protecting and enhancing the natural environment.
>
> (7) 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.

Under 23 Code of Federal Regulations (CFR) part 490, FHWA established 17 national performance measures for the Federal-aid Highway Program in support of six of the seven goals. To meet the new statutory requirements, FHWA pursued a number of significant rulemakings.

Collectively, the regulations establish performance management requirements that address safety (five measures), pavements (four measures), bridges (two measures), travel time reliability (two measures), freight movement (one measure), traffic congestion (two measures), and on-road mobile source emissions performance measure (one measure). The requirements encourage effective investment of Federal transportation funds. Performance management increases the accountability and transparency of the Federal-aid Highway Program and provides a framework to support improved investment decision making through a focus on performance outcomes.

Exhibits I-1 and *I-2* provide specific information about the performance measures as well as the related three published performance measure rulemakings, effective dates, and regulatory references.

Exhibit I-1: Performance Measure Rules

Kind of Measure	Rule	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
Congestion Mitigation and Air Quality (CMAQ) Program[4]	**Measures for Assessing the CMAQ Program – Traffic Congestion** Rule Effective Date: May 20, 2017 Regulatory Part: 23 CFR 490 (Subparts A, H)	• 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.

Exhibit I-2: 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 and minimum standards

Implementation of MAP-21/FAST Act Performance Requirements

State DOTs first reported safety data in 2017. Beginning with the 2018 reporting year, all 52 State DOTs reported performance data and targets for each of the 17 performance measures. The first full set of performance data submitted to FHWA is available online at the State Performance Dashboard and Reports website.[1] 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.

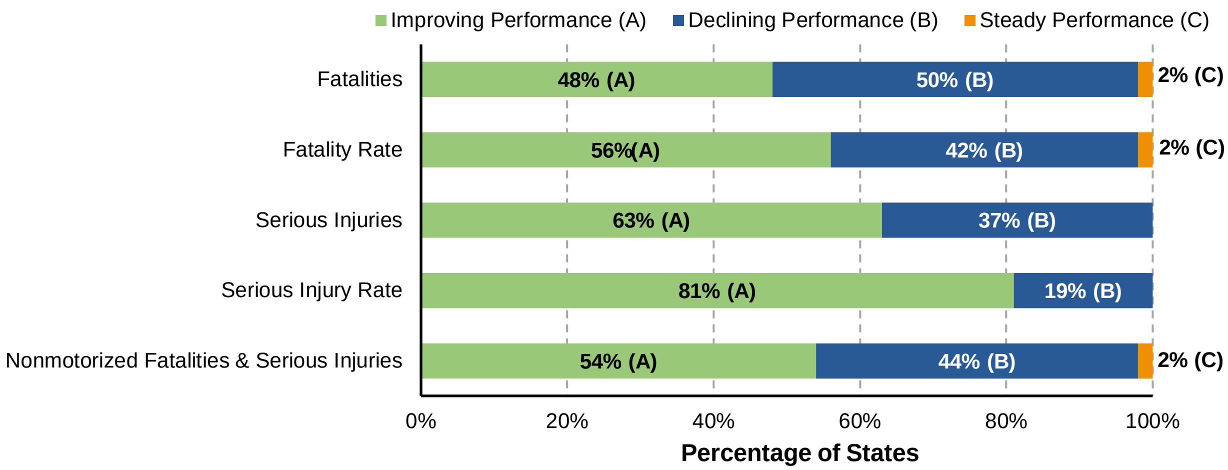
Comparison of Baseline Performance to Target

State DOTs set targets for all applicable measures, with some indicating improving performance, declining performance, or steady performance in the future years compared with the baseline.

For the safety performance measures, States DOTs used a baseline period of 2013–2017 and the next performance period of 2015–2019. The annual safety targets are set using a five-year rolling average. For most other measures, States DOTs set both two-year and four-year targets for the upcoming performance period (2018–2021); the targets are set relative to the 2017 baseline value.

Exhibit I-3 provides detail on the expected trends, comparing baseline performance to targets from investments and policy decisions across the State DOTs for the safety performance measures. Improving performance would indicate a reduction in the number or rate of fatalities or serious injuries, and declining performance would indicate an increase in the number or rate of fatalities or serious injuries.

Exhibit I-3: Safety Performance Measures, State Expected Trend – Baseline (2013–2017) to Target (2015–2019)

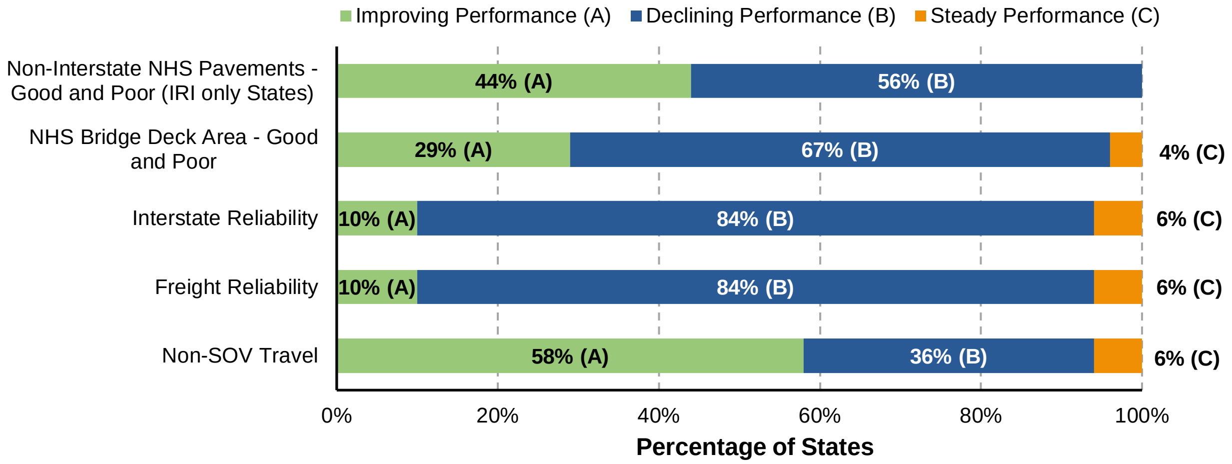


Source: FHWA Transportation Performance Management (TPM) 2018 Data Report. https://www.fhwa.dot.gov/tpm/reporting/national/

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

Exhibit I-4 provides detail on the expected trends, comparing baseline performance to targets from investments and policy decisions across the State DOTs for the infrastructure condition and system performance measures. For example, 58 percent of States set targets for the percentage of non-single-occupancy vehicle (SOV) travel that are higher than the actual share in the baseline. For each of the other conditions and performance measures, a majority of States set targets reflecting declining performance relative to the baseline. *Exhibit I-4* includes information only for the measures for which State DOTs reported both 2018 baseline value and four-year target information; it does not include other measure areas with phased reporting.

Exhibit I-4: Infrastructure Condition and System Performance Measures, State-Expected Trend – 2018 Baseline to 4-Year Target by Percentage of States



Note: Non-interstate NHS pavement and NHS bridge (weighted by deck area) performance measures are based on changes in structures classified as being in good and poor condition. FHWA computation procedures for the condition measures can be found at https://www.fhwa.dot.gov.tpm/guidance/

Source: FHWA Transportation Performance Management (TPM) 2018 Data Report. https://www.fhwa.dot.gov/tpm/reporting/national/

Chapter 1: System Assets

System Assets – Highways

The Nation's extensive network of roadways, bridges, tunnels, and ferries 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 open to public travel. Although most public roads carry a mix of vehicular users and nonvehicular uses, this section focuses on vehicular use. Chapter 3 includes information on a broader range of transportation modes. (See Chapter 11 of the 2015 C&P Report for greater detail on pedestrian and bicycle transportation.)

The terms "rural" and "urban" as used in this section are in 23 USC 101(a), which defines rural and urban as follows:

- The term "urban area" means an urbanized area or, in the case of an urbanized area encompassing more than one State, that part of the urbanized area in each such State, or urban place as designated by the Bureau of the Census having a population of 5,000 or more and not within any urbanized area, within boundaries to be fixed by responsible State and local officials in cooperation with each other, subject to approval by the Secretary. Such boundaries shall encompass, at a minimum, the entire urban place designated by the Bureau of the Census, except in the case of cities in the State of Maine and in the State of New Hampshire.
- The term "rural areas" means all areas of a State not included in urban areas.

SECTION SUMMARY

- The Nation's highway assets included 4.2 million miles of public roadways (route miles) and 8.8 million lane miles in 2018. Considering motorized vehicles only, these roads carried about 3.3 trillion miles of vehicular travel and 5.6 trillion miles of person travel in 2018.
- Local governmental agencies own 75.5 percent of the Nation's route miles, which carried 25.0 percent of vehicular travel in 2018. State governments own 18.7 percent of route miles, which carried 72.2 percent of vehicular travel.
- Local governments own 49.8 percent of the Nation's bridges, but these carried only 12.3 percent of bridge traffic in 2018. State governments own 48.2 percent of bridges, which carried 87.3 percent of bridge traffic.
- Federal-aid highways are a subset of public roads eligible for Federal-aid highway assistance. These include 24.5 percent of route miles, which carried 85.2 percent of vehicle miles traveled (VMT) in 2018.
- The National Highway System (NHS), a subset of Federal-aid highways, included 5.2 percent of the Nation's route miles and carried 54.7 percent of VMT in 2018.
- The Interstate System, a subset of the NHS, constituted just 1.2 percent of route miles but carried 25.6 percent of the Nation's VMT in 2018.

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. Vehicle Miles Traveled (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. In the transit section of this report, data presented on passenger miles traveled 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 2018, the NBI contained records for 616,096 bridges. Data for input to the NBI are collected regularly from the States as set forth in the National Bridge Inspection Standards (NBIS).

KEY TAKEAWAY

The Nation's road network included 4,195,274 miles of public roadways and 616,096 bridges in 2018. This network carried 3.255 trillion vehicle miles traveled (VMT) and 5.591 trillion person miles traveled, up from 2.993 trillion VMT and up from 4.931 trillion person miles traveled in 2008.

Beginning with this version of the Status of the Nation's Highways, Bridges, and Transit: Conditions and Performance Report to Congress (C&P Report), information on the Nation's tunnels and ferries will be included. The statistics for tunnels reported in this section draw from the data submitted by States to the National Tunnel Inventory (NTI). Information available in the NTI includes physical characteristics, location, traffic loads, and owners for each of the 503 tunnels on the Nation's highways in 2018. Data for input to the NTI are collected regularly from the States as set forth in the National Tunnel Inspection Standards (NTIS).

Tunnels

A tunnel is an enclosed roadway for motor vehicle traffic with vehicle access limited to portals, regardless of type of structure or method of construction. Tunnels fall into two general categories: complex and noncomplex. A complex tunnel is characterized by advanced or unique structural elements or functional systems. These may include lighting, emergency egress capacity, and mechanical or fire suppression equipment to ventilate exhaust from the tunnel or provide protection against tunnel fires. A noncomplex tunnel in contrast is typically of a shorter length, not requiring any ventilation, and may or may not have lighting installed.

The majority of road tunnels in the United States were constructed during two distinct periods of highway system expansion. The first period was during the 1930s and 1940s as part of public works programs associated with recovery from the Great Depression. The second period was during the construction of the Interstate Highway System in the 1950s and 1960s.

The Nation's 503 tunnels represent 666,858 linear feet or 126.3 miles of Interstates, State routes, and local routes. In 2018, 26 States and the District of Columbia contained at least one tunnel. Nine States and the District of Columbia combined contained 348 of the Nation's 503 tunnels or 69.2 percent. These were California (90), Washington (57), Massachusetts (44), Colorado (41), North Carolina (29), Pennsylvania (26), the District of Columbia (17), Virginia (17), Oregon (14), and Tennessee (13).

Of the Nation's tunnels, 182 or 36.2 percent were complex tunnels. Of these, 152 (83.5 percent) were located in nine States and the District of Columbia. All 44 tunnels in Massachusetts are complex tunnels. California has the second-highest number of complex tunnels (37) followed by Pennsylvania (20), Virginia (12), New York (9), Washington (9), Colorado (6), Michigan (6), New Jersey (5), and the District of Columbia.

Source: https://www.fhwa.dot.gov/bridge/inspection/tunnel/inventory.cfm

Information on ferry operations is based on data in the 2016 National Census of Ferry Operators (NCFO). The 2016 NCFO collected responses from 163 ferry operators or 74.1 percent of all the known 220 eligible ferry operators. The data presented in the NCFO report represent only data provided by the respondents.

KEY TAKEAWAY

The Nation's 503 tunnels had a combined length of 666,858 feet. The annual average daily traffic (AADT) for tunnels was approximately 14.2 million vehicles, and the annual average daily truck traffic was 0.84 million.

As shown in *Exhibit 1-1*, highway mileage and its accompanying lane mileage have each increased between 2008 and 2018, at an average annual rate of 0.3 percent. Highway VMT grew at an average annual rate of 0.4 percent between 2008 and 2018. Person miles traveled grew at an average annual rate of 0.8 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, Bridge and Tunnel Extent and Travel, 2008–2018

Category	2008	2010	2012	2014	2016	2018	Average Annual Rate of Change 2018/2008
Route Miles	4,059,352	4,083,768	4,109,421	4,194,257	4,157,292	4,195,274	0.3%
Lane Miles	8,518,776	8,616,206	8,641,051	8,830,511	8,775,538	8,833,083	0.4%
VMT (trillions)	2.993	2.986	2.988	3.040	3.189	3.255	0.8%
Person Miles Traveled (trillions)	4.931	5.063	5.100	5.205	5.458	5.591	1.3%
Bridges	601,506	604,493	607,380	610,749	614,387	616,096	0.2%
Bridge Deck Area (millions of sq. meters)	343.5	351.5	358.5	365.5	371.5	390.4	1.3%
Bridge ADT (millions)	4,432	4,439	4,485	4,504	4,627	4,738	0.7%
Bridge Truck ADT (millions)	417.0	413.1	405.2	408.4	430.6	445.3	0.7%
Tunnels						503	
Tunnel Length (ft)						666,858	
Tunnel AADT (millions)						14.2	
Tunnel Truck AADT (millions)						0.840	

Notes: The passenger miles traveled value for 2008 was estimated based on vehicle occupancy data from the 2001 NHTS; the values for 2010, 2012, 2014, and 2016 were derived in a comparable manner based on data from the 2009 NHTS. The value for 2018 was estimated using data from the 2017 NHTS. Includes estimated values for Puerto Rico PMT. Average Daily Traffic (ADT) is estimated by dividing the total daily volumes during a specified short time period (often 7 days or less) by the number of days in the period. Truck ADT is determined by multiplying ADT by an estimated percentage of the average number of trucks that travel through the same specific point of a road over the same time period. Annual Average Daily Traffic (AADT) estimates the mean traffic volume across all days for a year for a given location along a roadway. AADT is different from ADT because it represents data for the entire year. Truck AADT is the average daily volume of truck traffic on a road segment for a year.

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

Exhibit 1-1 also shows that the number of bridges cataloged in the NBI increased at an annual rate of 0.2 percent between 2008 and 2018, from 601,506 to 616,096. Total bridge deck area grew at an average annual rate of 1.3 percent, whereas bridge crossings (measured as annual daily traffic) increased at an average annual rate of 0.7 percent.

The tunnel data in *Exhibit 1-1* shows a total of 503 tunnels with a combined length of 666,858 feet were reported in the NTI for 2018. The annual average daily traffic

VMT Trends Since 2018

Based on data from Table VM-2 of the annual FHWA *Highway Statistics* publication, VMT grew by 0.7 percent in 2019.

More recent trends are discussed in Chapter 11, "Impacts and Implications of COVID-19 Pandemic on Transportation."

(AADT) for tunnels was approximately 14.2 million vehicles, whereas the annual average daily truck traffic was 0.840 million.

Definition of Traffic Volume Terms Used in the 25th Conditions & Performance Report

Vehicle Miles Traveled (VMT): VMT is the total miles traveled by vehicles in a specific area (e.g., a route, a functional road classification, or geographic area) over a period of one year.

Annual Average Daily Traffic (AADT): AADT estimates, with as little bias as possible, the mean traffic volume across all days for a year for a given location along a roadway. AADT is different from Average Daily Traffic (ADT) because it represents data for the entire year.

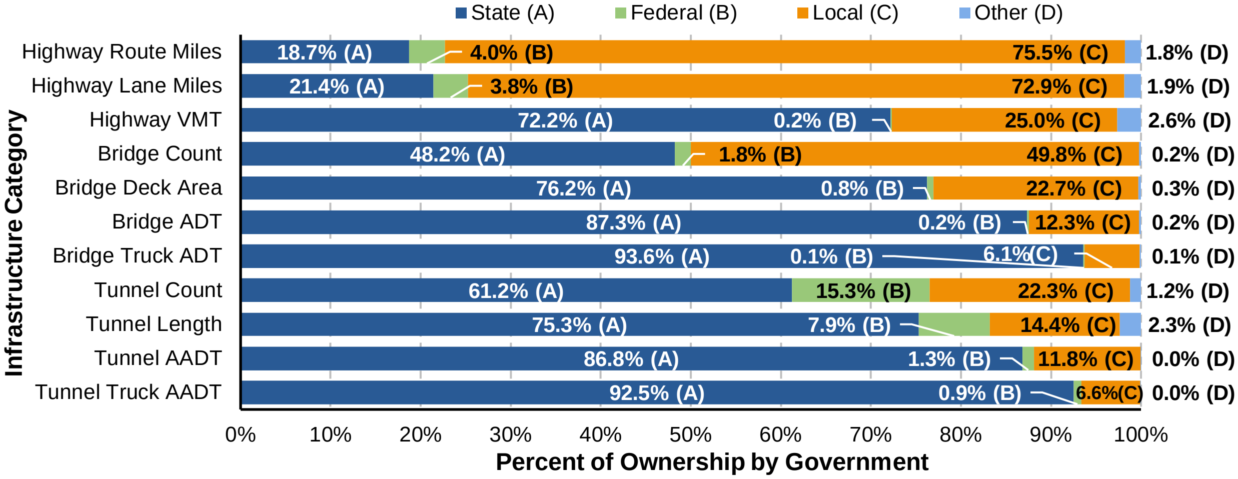
Average Daily Traffic (ADT): ADT, also referred to as mean daily traffic, is the average number of vehicles that travel through a specific point of a road over a short-duration time period (often 7 days or less). It is estimated by dividing the total daily volumes during a specified time period by the number of days in the period.

Source: Federal Highway Administration (FHWA), Office of Highway Policy Information, "Traffic Data Computation Method Pocket Guide." https://www.fhwa.dot.gov/policyinformation/pubs/pl18027_traffic_data_pocket_guide.pdf

Roads, Bridges, and Tunnels by Ownership

State and local governments own the vast majority of public roads and the bridges and tunnels located on these roads. As shown in *Exhibit 1-2*, local governments own 75.5 percent of the Nation's public route mileage, 49.8 percent of all bridges, and 22.3 percent of the tunnels. State governments own 18.7 percent of public route mileage, 48.2 percent of the Nation's bridges, and 61.2 percent of tunnels.

Exhibit 1-2: Highway, Bridge, Tunnel Ownership by Level of Government, 2018



Note: "Other" category represents private and railroad.

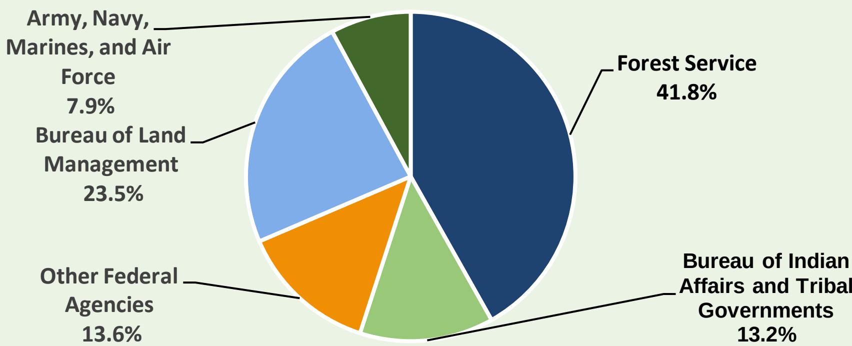
Sources: Highway Performance Monitoring System; National Bridge Inventory; National Tunnel Inventory.

Although many roads, bridges, and tunnels 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 1.8 percent of the Nation's bridges and 15.3 percent of the tunnels. The relatively small share of the Nation's route miles (4.0 percent) owned by the Federal government are located primarily in military installations, Tribal lands, National Forests, and National Parks. These roads carry only 0.2 percent of total VMT.

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 2018. *Exhibit 1-3* shows that of these route miles, the U.S. Forest Service owned the largest share, approximately 41.8 percent. Approximately 23.5 percent was owned by the Bureau of Land Management; the Bureau of Indian Affairs and Tribal governments owned a combined 13.2 percent of federally owned route miles. Roads on military installations (owned by the Army, Navy, Marines, and Air Force) comprise 7.9 percent. The remaining 13.6 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, 2018



Source: Highway Performance Monitoring System.

Roads, Bridges, and Tunnels 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 of highways is discussed in the portion of the section titled "Roads, Bridges, and Tunnels by Purpose."

The National Highway System (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 greater detail later in this section.

Exhibit 1-4 compares the relative magnitudes of these subsets to the total extent of the Nation's highways, bridges, and tunnels. 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.

Although Federal-aid highways constitute just 24.5 percent of the Nation's route mileage, they carry 85.2 percent of the Nation's VMT. The NHS includes 5.2 percent of the Nation's route mileage but carries 54.7 percent of highway traffic. The Interstate System makes up only 1.2 percent of the Nation's roads but carries 25.6 percent of VMT.

Federal-aid highways include 53.8 percent of the Nation's bridges, compared with 23.6 percent for the NHS and 9.4 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.

Exhibit 1-4: Interstate, NHS, and Federal-aid Highway, Bridge, Tunnel Extent, and Travel, 2018

Category	Interstate	NHS	FAH	All Public Roads	Share of Total		
					Interstate	NHS	FAH
Highway Route Miles	48,741	220,169	1,028,217	4,195,274	1.2%	5.2%	24.5%
Lane Miles	227,992	769,296	2,499,005	8,833,083	2.6%	8.7%	28.3%
VMT (trillions)	0.834	1.779	2.772	3.255	25.6%	54.7%	85.2%
Bridge Count	57,886	145,290	331,256	616,096	9.4%	23.6%	53.8%
Bridge Deck Area (millions of sq. meters)	103.0	225.7	329.0	390.4	26.4%	57.8%	84.3%
Bridge ADT (millions)	2,156	3,760	4,548	4,738	45.5%	79.3%	96.0%
Bridge Truck ADT (millions)	267.4	385.7	436.2	445.3	60.1%	86.6%	98.0%
Tunnel Count	136	283	374	503	27.0%	56.3%	74.4%
Tunnel Length (ft.)	323,690	481,715	578,752	666,858	48.5%	72.2%	86.8%
Tunnel AADT (millions)	7.5	12.7	13.5	14.2	52.8%	89.7%	95.4%
Tunnel Truck AADT (millions)	0.599	0.707	0.803	0.840	71.4%	84.2%	95.6%

Notes: FAH is Federal-aid Highway; NHS is National Highway System.

Sources: Highway Performance Monitoring System; National Bridge Inventory; National Tunnel Inventory.

Of the Nation's tunnels, 74.4 percent are located on Federal-aid highways, with the NHS having 56.3 percent and the Interstate System having 27.0 percent. The tunnels located on the Federal-aid highway system carried 95.6 percent of the Nation's tunnel traffic; those on the NHS carried 89.7 percent, whereas the tunnels on the Interstate System carried 52.8 percent.

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 55.4 percent of Federal-aid highway route miles, whereas local governments own 44.4 percent.

State governments owned 58.6 percent of Federal-aid highway lane miles in 2018, whereas 40.9 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 over 89.4 percent of the NHS. In contrast, the Federal government owns less than 0.1 percent of the 220,169 NHS route mileage, and local governments owned 10.5 percent. State governments own more than 99.9 percent of the 48,741 Interstate System mileage; the Federal government owns none of the Interstate System.

Sources: 2018 Highway Statistics, Table HM-16; Custom Query of 2018 HPMS Data.

Federal-aid Highways

Federal-aid highways comprised approximately 1.03 million route miles in 2018 and facilitated approximately 2.77 trillion VMT. As shown in *Exhibit 1-5*, highway route mileage on Federal-aid highways increased by 33,859 miles between 2008 and 2018. Lane mileage increased by 110,196 miles to almost 2.50 million lane miles in 2018 and VMT increased from 2.53 trillion in 2008 to 2.77 trillion VMT in 2018, an increase of more than 110 billion VMT. The number of bridges on Federal-aid highways increased from 316,012 in 2008 to 331,256 in 2018. This is an annual rate of change of approximately 0.5 percent. In 2018, there were 374 tunnels on Federal-aid highways, with a combined length of 578,752 feet or approximately 109.6 miles. Tunnel AADT was 13.525 million and the average annual daily truck traffic was 0.803 million.

KEY TAKEAWAY

The 1,028,217 miles of Federal-aid highways (25 percent of total mileage) carried 2.772 trillion VMT (85 percent of total travel) in 2018.

Exhibit 1-5: Federal-aid Highway Extent and Travel, 2008–2018

Category	2008	2010	2012	2014	2016	2018	Average Annual Rate of Change 2018/2008
Highway Route Miles	994,358	1,007,777	1,005,378	1,020,461	1,026,319	1,028,217	0.3%
Lane Miles	2,388,809	2,451,140	2,433,012	2,445,667	2,485,190	2,499,005	0.5%
VMT (trillions)	2.534	2.525	2.527	2.572	2.710	2.772	0.9%
Bridges	316,012	319,108	321,724	325,467	329,324	331,256	0.5%
Bridge Deck Area (millions of sq. meters)	285.8	293.5	299.7	307.3	313.3	329.0	1.4%
Bridge ADT (millions)	4,234.6	4,235.9	4,277.1	4,308.5	4,436.5	4,547.9	0.7%
Bridge Truck ADT (millions)	406.8	403.0	394.9	398.8	421.0	436.2	0.7%
Tunnels						374	
Tunnel Length (ft.)						578,752	
Tunnel AADT (millions)						13.5	
Tunnel Truck AADT (millions)						0.803	

Sources: Highway Performance Monitoring System; National Bridge Inventory; National Tunnel 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 (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.[2]

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

[2] 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.

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 throughout the year (see https://www.fhwa.dot.gov/planning/national_highway_system/nhs_maps/).

The modifications approved by FHWA from 2014 to 2018 resulted in decreases in highway miles and lane miles to 220,169 and 769,296 respectively. VMT on the NHS increased to 1.779 trillion in 2018 from 1.661 trillion in 2014. However, the number of bridges and the total bridge deck area on the NHS increased during the same period.

Exhibit 1-6 shows the changes in the NHS from 2008 to 2018. Route miles, lane miles, and VMT increased at an average annual rate change of 3.0 percent. The number of bridges increased at an average annual rate of 2.2 percent.

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.

KEY TAKEAWAY

Although the 220,169 miles on the National Highway System (NHS) comprise only 5 percent of total mileage, the NHS carried 1.779 trillion VMT in 2018, approximately 55 percent of total travel.

Exhibit 1-6: NHS Extent and Travel, 2008–2018

Category	2008	2010	2012	2014	2016	2018	Average Annual Rate of Change 2018/2008
Route Miles	164,108	159,326	223,357	226,767	222,331	220,169	3.0%
Lane Miles	574,011	575,546	771,184	771,245	769,508	769,296	3.0%
VMT (trillions)	1.327	1.311	1.644	1.661	1.749	1.779	3.0%
Bridge Count	116,523	116,669	117,485	143,165	144,610	145,290	2.2%
Bridge Deck Area (millions of sq. meters)	168.4	172.2	175.3	211.7	215.6	225.7	3.0%
Bridge ADT (millions)	3,132.1	3,138.8	3,153.4	3,555.7	3,669.6	3,759.5	1.8%
Bridge Truck ADT (millions)	336.0	335.0	326.2	351.6	373.0	385.7	1.4%
Tunnel Count						283	
Tunnel Length (ft.)						481,715	
Tunnel AADT (millions)						12.7	
Tunnel Truck AADT (millions)						0.707	

Note: MAP-21 expanded the size of the NHS in 2012.

Sources: Highway Performance Monitoring System; National Bridge Inventory; National Tunnel Inventory.

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). Freight transportation is discussed in greater detail in Part III of this report.

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" was essential to the national interest. The Act committed the Nation to completing the Interstate System within the Federal-State partnership of the Federal-aid Highway Program, with the States responsible for construction according to approved standards 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.

KEY TAKEAWAY

The 48,741 miles of the Interstate System carried 0.834 trillion VMT in 2018, slightly more than 1 percent of total mileage and close to 26 percent of total VMT. The Interstate System has grown since 2008, when it consisted of 46,892 miles that carried 0.741 trillion VMT.

As shown in *Exhibit 1-7*, there were small increases in the size of the Interstate System from 2008 to 2018. The total number of route miles increased from 46,892 route miles in 2008 to 48,474 route miles in 2018. Lane miles increased from 213,542 lane miles in 2008 to 227,992 lane miles in 2018. The number of bridges increased from 55,626 bridges in 2008 to 57,886 bridges in 2018. There were 136 tunnels with a total length of 323,690 feet or 61.3 miles located on the Interstate System in 2018.

Exhibit 1-7: Interstate System Extent and Travel, 2008–2018

Category	2008	2010	2012	2014	2016	2018	Annual Rate of Change 2018/2008
Route Miles	46,892	47,019	47,182	47,714	48,474	48,741	0.4%
Lane Miles	213,542	214,880	217,165	220,124	225,481	227,992	0.7%
VMT (trillions)	0.741	0.725	0.731	0.736	0.811	0.834	1.2%
Truck VMT (trillions)	0.336	0.325	0.257	0.297	0.318	0.348	2.2%
Bridges	55,626	55,339	55,959	56,553	57,309	57,886	0.4%
Bridge Deck Area (millions of sq. meters)	90.6	92.7	94.2	95.9	98.4	103.0	1.3%
Bridge ADT (millions)	2,000.0	1,992.4	2,006.7	2,008.7	2,094.1	2,155.5	0.8%
Bridge Truck ADT (millions)	244.3	240.9	234.6	238.2	256.2	267.4	0.9%
Tunnels						136	
Tunnel Length (ft.)						323,690	
Tunnel AADT (millions)						7.5	
Tunnel Truck AADT (millions)						0.599	

Sources: Highway Performance Monitoring System; National Bridge Inventory; National Tunnel Inventory.

Roads, Bridges, and Tunnels by Purpose

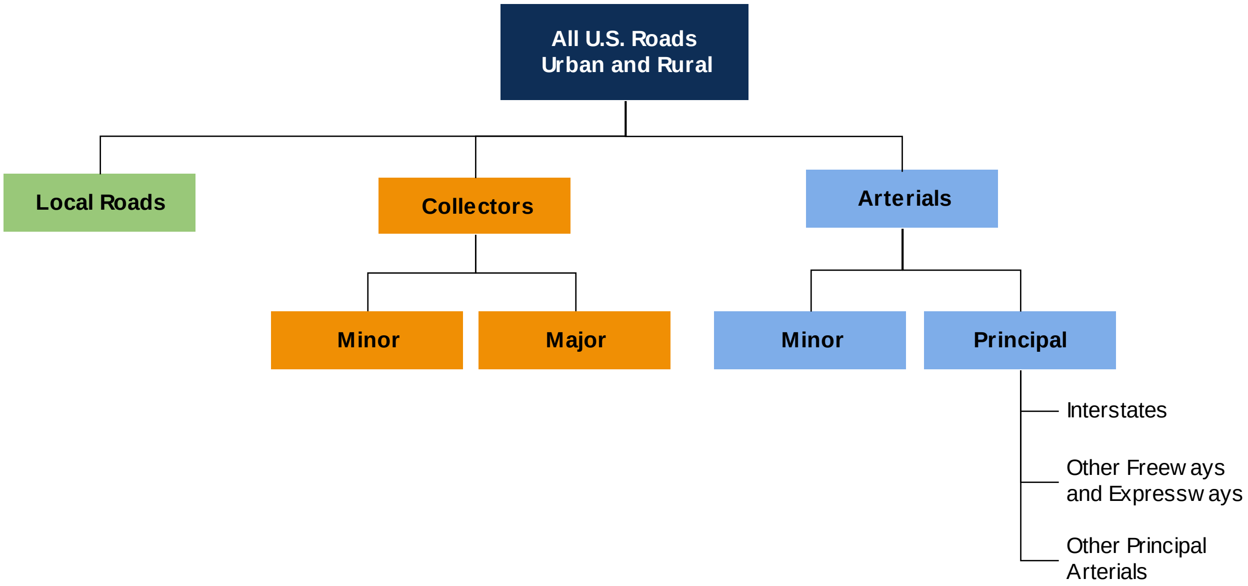
The Nation's roadway system serves movements from long-distance freight needs to neighborhood travel. Because of the diverse needs for vehicular travel, the network is categorized under the Highway Functional Classification System. Each functional classification defines the role an element of the network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

Classification of Roadways as Rural Versus 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 1-8 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.

Exhibit 1-8: 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 to support high levels of demand for vehicular traffic, whereas a rural setting will have fewer lanes supporting lower traffic levels.

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.

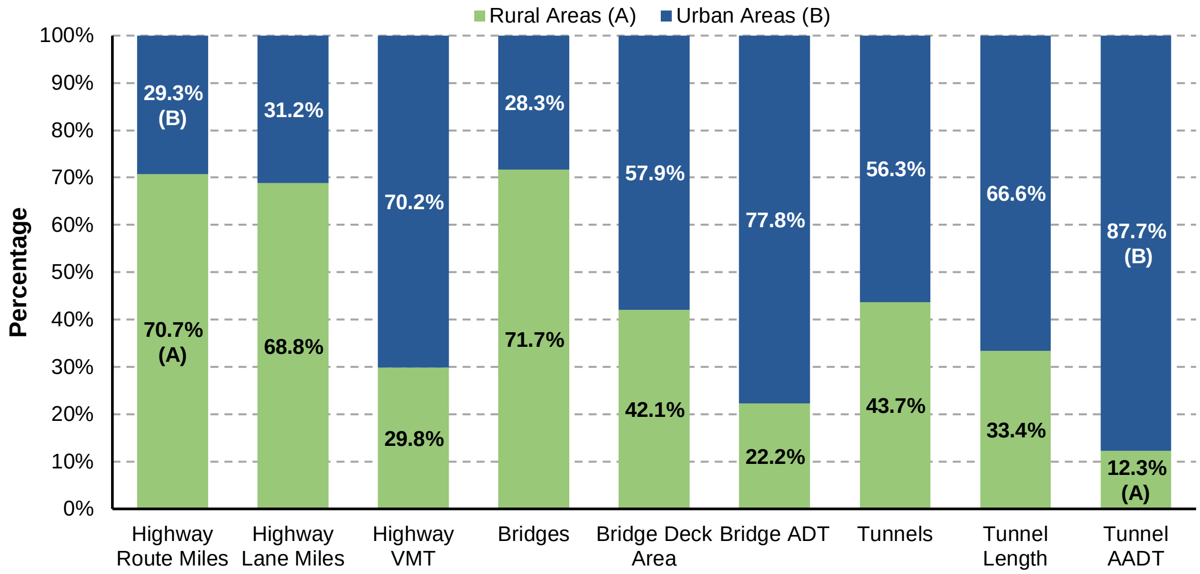
There are exceptions to the general rules limiting Federal-aid funding to Federal-aid highways. States may use funding from their Surface Transportation Block Grant (STBG) Program apportionments to fund safety projects on any public road. STBG funds may also be used on existing bridges and tunnels that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

As shown in *Exhibit 1-9*, almost half (48.4 percent) of the Nation's highway mileage was classified as rural local in 2018. Urban local roads comprised an additional 20.7 percent of total highway miles.

Exhibit 1-9 also details the breakdown of travel occurring in rural and urban settings. Urban areas have a higher share of VMT and lower highway 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. In contrast, 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.

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 carried the highest share of bridge traffic volume by classification with 36.3 percent, whereas tunnels on urban Interstates received the highest percent of tunnel traffic volume with 46.9 percent of the Nation's total tunnel traffic volume in 2018.

Exhibit 1-9: Highway, Bridge, and Tunnel Extent and Travel by Functional System and Area, 2018



Functional System	Highway Route Miles	Highway Lane Miles	Highway VMT	Bridges	Bridge Deck Area	Bridge ADT	Tunnels	Tunnel Length	Tunnel AADT
Rural Areas (less than 5,000 in population)									
Interstate	0.7%	1.4%	7.8%	4.1%	6.9%	9.2%	6.4%	14.0%	5.9%
Other Freeway and Expressway	0.2%	0.3%	1.1%				2.6%	2.8%	2.0%
Other Principal Arterial	2.2%	2.7%	6.0%				5.6%	2.9%	1.0%
Other Principal Arterial				6.0%	8.7%	5.6%			
Minor Arterial	3.2%	3.2%	4.5%	6.2%	5.8%	2.8%	5.0%	3.2%	0.3%
Major Collector	9.8%	9.4%	5.0%	14.8%	8.6%	2.7%	5.0%	2.7%	0.4%
Minor Collector	6.2%	5.9%	1.5%	7.7%	3.1%	0.7%	11.3%	5.7%	1.1%
Local	48.4%	46.0%	4.0%	32.9%	8.9%	1.2%	8.0%	2.2%	1.5%
Subtotal Rural Areas	**70.7%**	**68.8%**	**29.8%**	**71.7%**	**42.1%**	**22.2%**	**43.7%**	**33.4%**	**12.3%**
Urban Areas (5,000 or more in population)									
Interstate	0.5%	1.2%	17.7%	5.3%	19.4%	36.3%	20.7%	34.5%	46.9%
Other Freeway and Expressway	0.3%	0.7%	7.8%	3.5%	11.0%	16.7%	10.1%	11.3%	23.0%
Other Principal Arterial	1.6%	2.7%	15.1%	4.9%	11.8%	12.3%	12.3%	12.3%	12.7%
Minor Arterial	2.7%	3.4%	12.9%	5.2%	8.1%	7.6%	5.2%	2.6%	2.0%
Collector				3.9%	3.8%	2.9%			
Major Collector	3.1%	3.2%	6.5%				1.2%	0.4%	1.0%
Minor Collector	0.4%	0.4%	0.5%				0.4%	0.1%	0.1%
Local	20.7%	19.7%	9.6%	5.6%	3.7%	2.1%	6.4%	5.3%	2.0%
Subtotal Urban Areas	**29.3%**	**31.2%**	**70.2%**	**28.3%**	**57.9%**	**77.8%**	**56.3%**	**66.6%**	**87.7%**
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**

Note: 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; National Tunnel Inventory.

Approximately 70.7 percent of the Nation's highway route mileage was located in rural areas, as was 68.7 percent of lane mileage. Local roads in rural and urban settings had the highest share of the Nation's lane mileage at 46.0 percent and 19.7 percent, respectively. Bridges in urban areas accounted for 57.9 percent of the bridge deck area in the Nation, compared with 42.1 percent for rural areas. Approximately 77.8 percent of bridge traffic volume was carried on the 28.3 percent of the Nation's bridges in urban areas. Of the Nation's tunnel traffic volume, 87.7 percent was in urban areas. In addition, 56.3 percent of the Nation's tunnels was located in urban areas compared with 43.7 percent in rural areas. In addition, urban area tunnels accounted for 66.6 percent of the Nation's total tunnel length compared to 33.4 percent in rural areas or two times the amount in 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 1-9* between the functional classes reported under the highway portion of the exhibit and the bridge and tunnel portions is due to the NBI and the NTI databases 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.

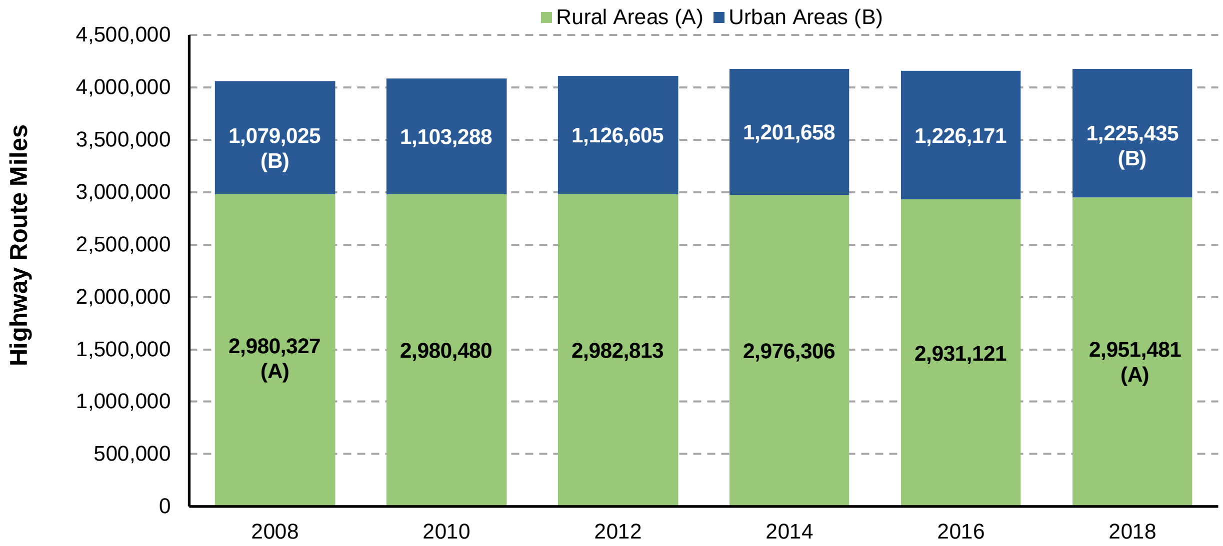
Exhibit 1-10 shows the highway route miles in the Nation based on functional system. The Nation's public highways comprised approximately 4.18 million route miles in 2018, up from 4.06 million route miles in 2008. Total route mileage in urban areas grew from slightly less than 1.08 million route miles in 2008 to approximately 1.23 million route miles in 2018. Highway route miles in rural areas, however, decreased from approximately 2.98 million route miles in 2008 to slightly more than 2.95 million route miles in 2018. The largest decrease in route mileage, from approximately 2.04 million miles to slightly more than 2.02 million miles, was seen in rural local roadways.

The Nation's public highways comprised approximately 4.18 million route miles in 2018, up from 4.06 million route miles in 2008. Total route mileage in urban areas grew from 1,079,025 route miles in 2008 to 1,225,435 route miles in 2018. Total highway route miles in rural areas, however, decreased from approximately 2.98 million route miles in 2008 to approximately 2.95 million route miles in 2018. 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.

Exhibit 1-11 shows the change in highway lane miles from 2008 to 2018 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 2.42 million in 2008 to slightly more than 2.75 million in 2018. The largest decrease in lane miles occurred on rural local roadways, a loss of 28,749 lane miles of roadway, whereas urban local roadways experienced the largest increase in lane miles, at 209,405 lane miles.

Exhibit 1-10: Highway Route Miles by Functional System and Area, 2008–2018

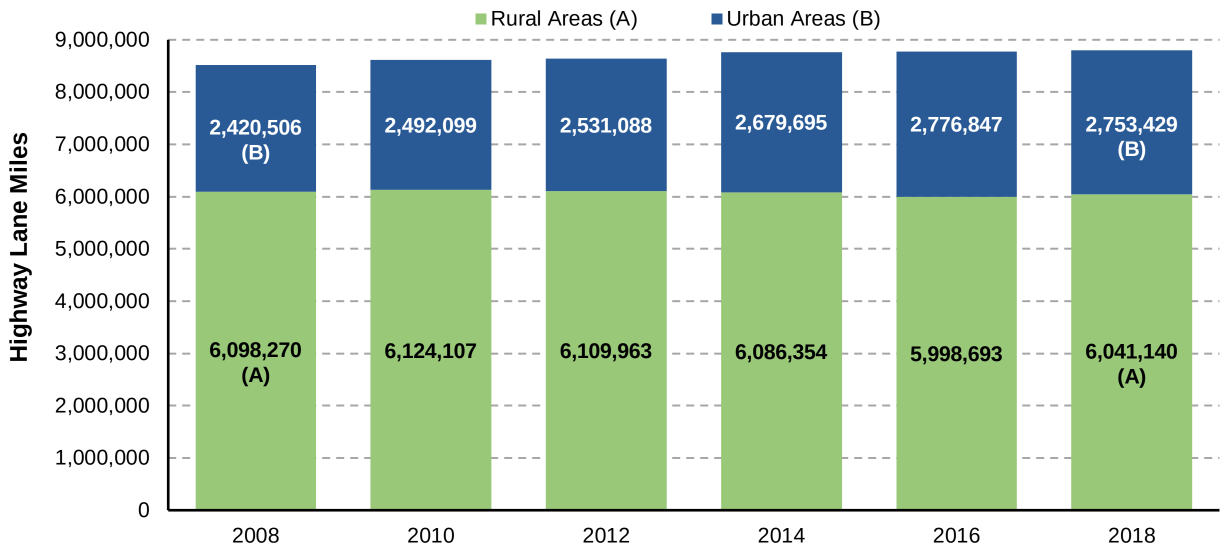


Functional System	Highway Route Miles						Annual Rate of Change 2018/2008
	2008	2010	2012	2014	2016	2018	
Rural Areas (less than 5,000 in population)							
Interstate	30,22	30,260	30,564	29,095	29,177	29,280	-0.3%
Other Freeway & Expressway		3,299	4,395	3,299	6,378	6,504	
Other Principal Arterial		92,131	91,462	92,131	89,772	90,161	
Other Principal Arterial	95,002						0.2%
Minor Arterial	135,256	135,681	135,328	132,672	134,034	133,746	-0.1%
Major Collector	418,473	418,848	419,353	418,848	407,870	407,859	-0.3%
Minor Collector	262,852	263,271	262,435	263,271	258,719	259,789	-0.1%
Local	2,038,517	2,036,990	2,039,276	2,036,990	2,005,171	2,024,142	-0.1%
Subtotal Rural Areas	2,980,327	2,980,480	2,982,813	2,976,306	2,931,121	2,951,481	-0.1%
Urban Areas (5,000 or more in population)							
Interstate	16,789	16,922	17,150	18,567	19,312	19,160	1.3%
Other Freeway & Expressway	11,401	11,371	11,521	11,784	12,302	12,100	0.6%
Other Principal Arterial	64,948	65,505	65,593	66,761	66,517	66,453	0.2%
Minor Arterial	107,182	108,375	109,337	112,228	113,316	112,468	0.5%
Collector	115,087						-4.6%
Major Collector		115,538	116,943	127,809	130,294	129,085	
Minor Collector		3,303	3,588	11,754	16,961	17,852	
Local	763,618	782,273	802,473	852,755	867,469	868,317	1.3%
Subtotal Urban Areas	**1,079,025**	**1,103,288**	**1,126,605**	**1,201,658**	**1,226,171**	**1,225,435**	1.3%
Total Highway Route Miles	**4,059,352**	**4,083,768**	**4,109,418**	**4,177,964**	**4,157,292**	**4,176,916**	0.3%

Note: 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. 2018 PR excluded.

Source: Highway Performance Monitoring System.

Exhibit 1-11: Highway Lane Miles by Functional System and Area, 2008–2018



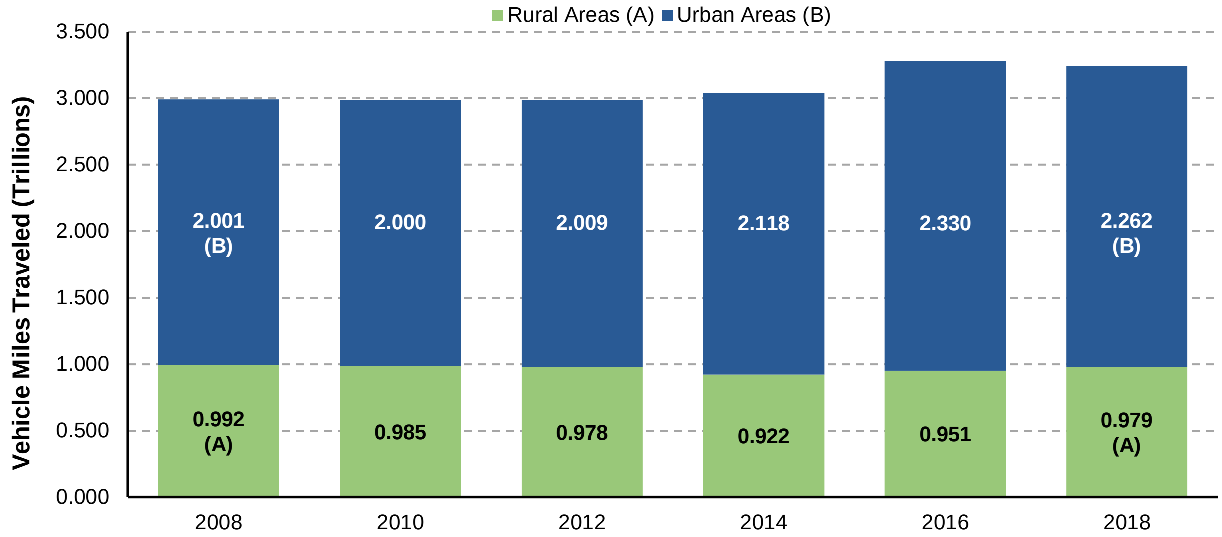
Functional System	Highway Lane Miles 2008	2010	2012	2014	2016	2018	Annual Rate of Change 2018/2008
Rural Areas (less than 5,000 in population)							
Interstate	122,956	123,762	124,927	118,688	119,159	119,885	-0.3%
Other Freeway & Expressway		11,907	16,593	20,677	24,542	25,071	
Other Principal Arterial		243,065	240,639	233,985	231,532	233,261	
Other Principal Arterial	250,153						0.3%
Minor Arterial	281,071	287,761	281,660	274,271	276,685	276,150	-0.2%
Major Collector	841,353	857,091	842,722	823,609	818,994	818,911	-0.3%
Minor Collector	525,705	526,540	524,870	517,026	517,439	519,579	-0.1%
Local	4,077,032	4,073,980	4,078,552	4,098,098	4,010,342	4,048,283	-0.1%
Subtotal Rural Areas	**6,098,270**	**6,124,107**	**6,109,963**	**6,086,354**	**5,998,693**	**6,041,140**	**-0.1%**
Urban Areas (5,000 or more in population)							
Interstate	91,924	93,403	95,197	102,541	105,457	106,741	1.5%
Other Freeway & Expressway	53,073	53,231	54,160	55,385	58,943	57,356	0.8%
Other Principal Arterial	228,792	235,127	234,469	231,099	237,381	240,389	0.5%
Minor Arterial	274,225	285,954	283,608	287,061	296,203	296,734	0.8%
Collector	245,262						2.6%
Major Collector		252,435	250,760	272,931	278,414	277,564	
Minor Collector		7,404	7,948	25,168	58,584	38,010	
Local	1,527,230	1,564,546	1,604,946	1,705,510	1,741,865	1,736,635	1.3%
Subtotal Urban Areas	**2,420,506**	**2,492,099**	**2,531,088**	**2,679,695**	**2,776,847**	**2,753,429**	**1.3%**
Total Highway Lane Miles	**8,518,776**	**8,616,206**	**8,641,051**	**8,766,049**	**8,775,540**	**8,794,569**	**0.3%**

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

Source: Highway Performance Monitoring System.

Exhibit 1-12 shows VMT in trillions of miles by functional class from 2008 to 2018. VMT in rural areas decreased slightly from 0.99 trillion miles in 2008 to 0.98 trillion miles in 2018. Urban VMT increased from 2.0 trillion to 2.62 trillion during the same period. *Exhibit 1-12* also shows the largest average annual decrease of 2.3 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 2.6 percent. Overall, VMT on rural roadways declined by an average annual rate of 0.1 percent and VMT on urban roadways increased by an average annual rate of 1.2 percent between 2008 and 2018.

Exhibit 1-12: VMT by Functional System and Area, 2008–2018



Functional System	Annual Travel Distance (Trillions of Miles)						Annual Rate of Change 2018/2008
	2008	2010	2012	2014	2016	2018	
Rural Areas (less than 5,000 in population)							
Interstate	0.244	0.246	0.246	0.232	0.247	0.257	0.5%
Other Freeway & Expressway		0.020	0.020	0.026	0.034	0.037	
Other Principal Arterial		0.206	0.203	0.188	0.190	0.196	
Other Principal Arterial	0.223						0.5%
Minor Arterial	0.152	0.151	0.149	0.141	0.144	0.146	-0.4%
Major Collector	0.186	0.176	0.176	0.159	0.160	0.165	-1.2%
Minor Collector	0.055	0.053	0.053	0.050	0.048	0.044	-2.3%
Local	0.132	0.133	0.130	0.126	0.128	0.134	0.2%
Subtotal Rural Areas	**0.992**	**0.985**	**0.978**	**0.922**	**0.951**	**0.979**	-0.1%
Urban Areas (5,000 or more in population)							
Interstate	0.482	0.483	0.490	0.525	0.563	0.571	1.7%
Other Freeway & Expressway	0.224	0.222	0.225	0.228	0.250	0.254	1.3%
Other Principal Arterial	0.466	0.461	0.460	0.471	0.483	0.484	0.4%
Minor Arterial	0.381	0.378	0.375	0.393	0.412	0.416	0.9%
Collector	0.178						2.6%
Major Collector		0.179	0.177	0.195	0.207	0.212	
Minor Collector		0.004	0.004	0.012	0.207	0.018	
Local	0.271	0.273	0.278	0.295	0.207	0.306	1.2%
Subtotal Urban Areas	**2.001**	**2.000**	**2.009**	**2.118**	**2.330**	**2.262**	**1.2%**
Total VMT	**2.993**	**2.985**	**2.987**	**3.040**	**3.281**	**3.240**	**0.8%**

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

Source: Highway Performance Monitoring System.

Exhibit 1-13 shows an analysis of the types of vehicles comprising the Nation's VMT between 2008 and 2018. 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 90.5 percent of total VMT in 2018, combination trucks accounted for more than 5.8 percent, and single-unit trucks accounted for 3.8 percent.

Exhibit 1-13: Highway Travel by Functional System and Vehicle Type, 2008–2018

Functional System Vehicle Type	Annual Travel Distance (Trillions of Miles)						Annual Rate of Change 2018/2008
	2008	2010	2012	2014	2016	2018	
Rural							
Interstate							
Passenger Vehicles	0.181	0.185	0.188	0.175	0.184	0.193	0.6%
Single-unit Trucks	0.012	0.011	0.009	0.009	0.010	0.010	-1.4%
Combination Trucks	0.050	0.049	0.049	0.047	0.050	0.051	0.1%
Other Arterial							
Passenger Vehicles	0.322	0.324	0.325	0.309	0.318	0.327	0.1%
Single-unit Trucks	0.020	0.019	0.017	0.016	0.016	0.018	-1.3%
Combination Trucks	0.032	0.033	0.030	0.029	0.029	0.030	-0.5%
Other Rural							
Passenger Vehicles	0.335	0.328	0.327	0.304	0.302	0.306	-0.9%
Single-unit Trucks	0.019	0.018	0.018	0.017	0.016	0.017	-1.1%
Combination Trucks	0.016	0.016	0.014	0.013	0.012	0.014	-1.3%
Total Rural							
Passenger Vehicles	0.839	0.837	0.840	0.789	0.804	0.825	-0.2%
Single-unit Trucks	0.051	0.048	0.044	0.043	0.042	0.045	-1.2%
Combination Trucks	0.098	0.099	0.093	0.089	0.091	0.095	-0.3%
Urban							
Interstate							
Passenger Vehicles	0.424	0.427	0.434	0.463	0.492	0.499	1.7%
Single-unit Trucks	0.017	0.014	0.015	0.016	0.019	0.019	1.5%
Combination Trucks	0.036	0.036	0.036	0.041	0.042	0.047	2.9%
Other Urban							
Passenger Vehicles	1.403	1.415	1.427	1.495	1.554	1.572	1.1%
Single-unit Trucks	0.059	0.048	0.046	0.050	0.053	0.056	-0.5%
Combination Trucks	0.050	0.042	0.035	0.039	0.041	0.042	-1.8%
Total Urban							
Passenger Vehicles	1.827	1.842	1.861	1.958	2.046	2.072	1.3%
Single-unit Trucks	0.075	0.062	0.061	0.067	0.072	0.075	0.0%
Combination Trucks	0.086	0.077	0.071	0.080	0.083	0.089	0.4%
Total Passenger Vehicles	**2.666**	**2.680**	**2.700**	**2.747**	**2.850**	**2.897**	**0.8%**
Total Single-unit Trucks	**0.127**	**0.111**	**0.105**	**0.109**	**0.114**	**0.121**	**-0.5%**
Total Combination Trucks	**0.184**	**0.176**	**0.163**	**0.170**	**0.174**	**0.184**	**0.0%**

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.

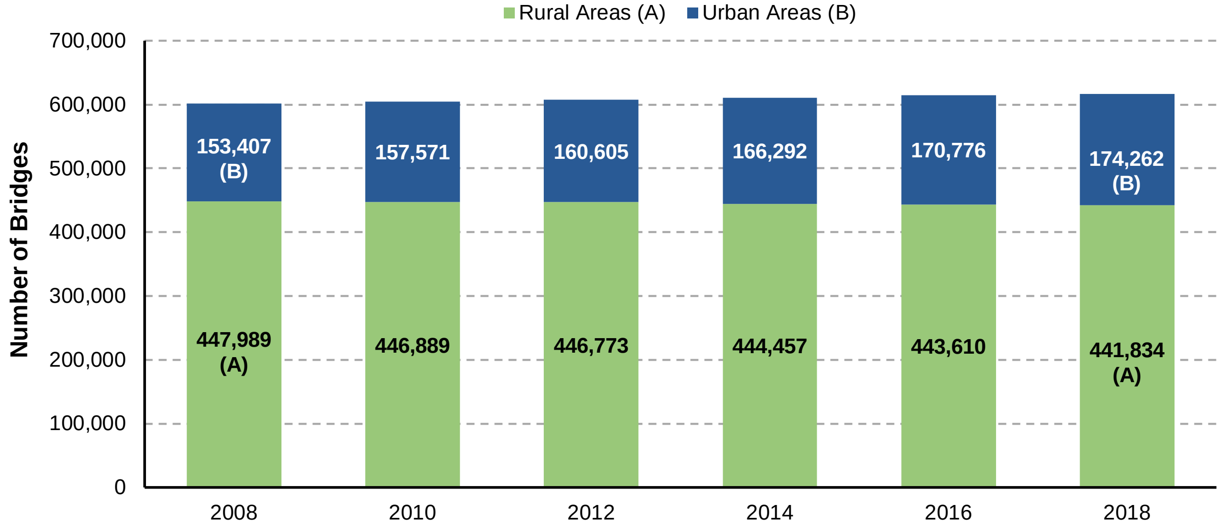
Source: Highway Statistics, various years, Table VM-1.

Passenger vehicle travel grew at an average annual rate of 0.8 percent from 2008 to 2018. During the same period, combination truck traffic remained constant and single-unit truck traffic declined at an average annual rate of 0.5 percent. Household travel is discussed in greater detail in Chapter 3; highway freight transportation is discussed in Chapter 11.

The change in the number of bridges by functional system from 2008 to 2018 is shown in *Exhibit 1-14*. The number of bridges in the Nation has increased from 601,506 in 2008 to 616,096 in 2018, an annual rate of change of approximately 0.2 percent. Bridges on rural other principal arterials increased at an annual rate of 0.4 percent during this period, whereas bridges on the remaining rural roadways experienced a decrease in their annual rate of change. The largest decrease in annual rate of change was rural Interstate bridges at an annual rate of 0.3 percent from 2008 to 2018, whereas the number of bridges on urban collectors had the largest average annual increase at 2.4 percent.

The number of bridges on rural local roadways decreased by the largest amount, from 205,959 bridges in 2008 to 202,824 in 2018, a reduction of 3,135 bridges. During the same period the number of bridges increased by the largest amount—5,002 bridges—on urban collector roadways.

Exhibit 1-14: Number of Bridges by Functional System and Area, 2008–2018



Functional System	Bridges 2008	2010	2012	2014	2016	2018	Annual Rate of Change 2018/2008
Rural							
Interstate	25,997	25,223	25,201	25,057	25,176	25,105	-0.3%
Other Principal Arterial	35,594	36,084	36,460	36,711	37,236	36,962	0.4%
Minor Arterial	39,079	39,048	39,123	38,159	37,942	38,165	-0.2%
Major Collector	93,118	93,059	92,875	92,777	92,142	91,167	-0.2%
Minor Collector	48,242	47,866	47,922	47,758	47,721	47,611	-0.1%
Local	205,959	205,609	205,192	203,995	203,393	202,824	-0.2%
Subtotal Rural	**447,989**	**446,889**	**446,773**	**444,457**	**443,610**	**441,834**	**-0.1%**
Urban							
Interstate	29,629	30,116	30,758	31,496	32,133	32,781	1.0%
Other Freeway and Expressway	19,168	19,791	20,139	20,821	20,695	21,311	1.1%
Other Principal Arterial	26,934	27,373	28,141	28,669	29,478	29,967	1.1%
Minor Arterial	27,561	28,103	28,437	29,943	31,515	31,864	1.5%
Collectors	18,932	20,311	20,590	21,834	23,007	23,934	2.4%
Local	31,183	31,877	32,540	33,529	33,948	34,405	1.0%
Subtotal Urban	**153,407**	**157,571**	**160,605**	**166,292**	**170,776**	**174,262**	**1.3%**
Unclassified	**110**	**33**	**2**	**0**	**1**	**0**	**-100.0%**
Total	**601,506**	**604,493**	**607,380**	**610,749**	**614,387**	**616,096**	**0.2%**

Source: National Bridge Inventory.

Ferries

A ferry is a vessel that carries passengers and/or vehicles and/or freight over a body of water and may include hovercraft, hydrofoil, or other high-speed vessels. It is limited in its use to the carriage of deck passengers, vehicles, freight, or combinations of all three. It operates on a short run on a frequent schedule between two points over the most direct water routes other than in ocean or coastwise service, and is offered as a public service of a type normally attributed to a bridge or tunnel.

Ferries are used: (a) to cross water in rural areas where there is not a bridge, (b) to commute to work in coastal cities, (c) to receive services in island regions, and (d) for recreation or tourism in parks, among other reasons. A resurgence of ferry use has prompted the construction of new ferry vessels and terminals and the addition of route segments to create additional transportation options in areas where roadways and other public transportation options are overcrowded, or where there previously was no other accessible public transportation.

A total of 118.9 million passengers and 25.0 million vehicles were transported by ferry in 2015. New York and Washington, the top two States for total passenger boardings, together reported transporting almost 70 million passengers in 2015 (43.6 and 26.1 million passengers, respectively). Washington and Texas, the top two States for total vehicle boardings, transported a reported 11.1 and 2.3 million vehicles, respectively, in 2015.

A total of 652 vessels were reported by those operators responding to the 2016 NCFO; of these, 609 (93.3 percent) were reported to be in service in 2015. New York and California had the largest reported fleets in 2015 with 56 and 55 vessels, respectively. The average age of the reported vessels was 27 years. The oldest vessel was 102 years old.

Of the 652 reported vessels, 46.8 percent were privately owned and operated, and 37.3 percent were publicly owned and operated. Some of the vessels were reported as either publicly or privately owned, but did not report how they were operated (1.7 and 6.3 percent, respectively). A relatively small number were publicly owned and privately operated (6.1 percent); even fewer were privately owned and publicly operated (0.9 percent).

Of the reported vessels, 93.3 percent carried passengers, 42.8 percent carried vehicles, and 19.9 percent carried freight. Of the reported vessels, 313 carried only passengers, seven only carried vehicles, and five were freight-only vessels. There were 170 vessels (26.1 percent) that carried both passengers and vehicles, 23 (3.5 percent) that carried both passengers and freight, and 102 (15.6 percent) that carried passengers, vehicles, and freight.

A total of 560 terminals were reported in 2015. The top five States were New York (60), California (47), Alaska (41), Washington (40), and Maine (32). These States accounted for 220 terminals or 39.3 percent of total terminals. Of these, 57.7 percent were publicly owned and operated (57.7 percent), 17.7 percent were privately owned and operated, and 11.3 percent were publicly owned and privately operated.

Ferry route segments are defined as the direct travel between two terminals with no intermediate stops, where the associated State of the route segment is the State of the origin terminal. The highest numbers of reported route segments were concentrated in the Northeast, the West Coast, and in Alaska. The top five States with the largest number of reported segments were California (98), New York (95), Washington (78), Michigan (53), and Maine (46). These five States accounted for 370 segments (42.0 percent) of the 880 reported segments.

The 880 total reported route segments served a combined total of 20,042.4 nautical miles. The highest total number of reported State route miles was in Alaska with 12,492.5 nautical miles or over 62.3 percent of the reported U.S. route miles. Ferry routes in the United States ranged from 0.1 miles to 595.0 miles with the majority of routes being less than 1 mile (26.0 percent). The longest reported route segment is 595 nautical miles in length and extends from Ketchikan, AK, to Bellingham, WA.

Intrastate route segments (segments that do not cross State lines) accounted for 87.7 percent of all route segments. The largest percentage of interstate segments (segments that cross State lines) was reported in the Northeast. Of those northeastern States, New York and New Jersey had a relatively large proportion of these interstate segments, 25 and 19, respectively. There were 10 international segments. These are defined as either starting or ending at a terminal in a non-U.S. State or territory.[3]

[3] U.S. Department of Transportation, Bureau of Transportation Statistics, National Census of Ferry Operators 2016. https://www.bts.gov/

System Assets – Transit

System History

The first transit agencies in the United States date to the 19th century. These agencies were privately owned, for-profit businesses helped define the urban communities of that time. By the postwar period, competition from the private automobile was limiting the ability of transit businesses to operate at a profit. As transit businesses started to fail, local, State, and national government leaders began to realize the importance of sustaining transit services.

In 1964, Congress passed the Urban Mass Transportation Act of 1964, which established a program to provide Federal funding for transit agencies. The requirement for Federal funds for transit be given to public agencies rather than to private firms accelerated the transition from private to public ownership and operation of transit agencies. 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 and operation of transit services. Maryland and Massachusetts directly own and operate multimodal transit agencies in their largest cities. Delaware and the U.S. Virgin Islands directly provide regular fixed-route bus service, and Georgia directly provides commuter bus service. New Jersey and Rhode Island have both set up Statewide public transit corporations to operate transit services within their States. Connecticut directly provides transit service Statewide, and separately also operates rail systems.

Federal legislation in 1962 instituted the first requirement for transportation planning in urban areas with a population of more than 50,000. Twenty-seven years later, the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) made metropolitan planning organization (MPO) coordination a prerequisite for Federal funding of transit projects in urban areas. MPOs are

SECTION SUMMARY

Agencies/Reporters

- Most transit agencies in the United States report to the National Transit Database (NTD). In 2018, 945 agencies serving almost all 486 urbanized areas and 1,355 rural agencies reported to the NTD.

Modal Service

- Transit is provided through 18 distinct modes, which belong to two major categories: rail and nonrail. There were 1,174 regular fixed-route bus modes operated, 180 commuter bus modes operated, and 12 bus rapid transit modes operated in 2018.
- 1,822 demand response modes were operated in 2018.
- Open-to-the-public vanpool service was provided by 101 agencies.
- Other modes include ferryboat (32 agencies), trolleybus (five agencies), and other less common modes.
- Rail modes include heavy rail (15), light rail (22), streetcar (19), hybrid rail (six), commuter rail (21), and other less common rail modes that run on fixed tracks.

Assets

- Agencies reported 212,002 vehicles in urban and rural areas.
- Rail agencies were operated on 13,086 miles of track.
- Fixed-route bus, commuter bus, and bus rapid transit agencies operated on more than 226,782 mixed-traffic route miles.
- Agencies reported 5,162 passenger stations and 2,393 maintenance facilities.

composed of State and local officials who work to address transportation planning needs of urbanized areas at a regional level. 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. TEA-21 also created the Jobs Access and Reverse Commute program to address the challenges face by welfare recipients and low-income persons seeking to obtain and maintain employment.

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, it added a new formula allocation for Small Transit Intensive Cities (STIC). In the Capital Investment Grants (CIG), it created a Small Starts project eligibility category with a streamlined review process for lower-cost alternative approaches to transit projects such as bus rapid transit. It greatly increased funding for rural transit providers, made intercity fixed-route bus transportation eligible for rural funds, and set aside funds for Tribal transit by federal-recognized American Indian Tribes.

The Moving Ahead for Progress in the 21st Century (MAP21) Act was enacted on July 6, 2012. MAP21 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. MAP-21 enhanced FTA's safety oversight authority and directed FTA to issue a new rule requiring transit asset management plans 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 Fixing America's Surface Transportation (FAST) Act (Pub. L. 114-94) was enacted into law on December 4, 2015. The FAST Act retained the basic structure of the urban formula program, but increased the STIC formula funding and allowed certain smaller agencies (100 demand-response vehicles or fewer) in large urban areas to use some formula funds for operating expenses.

System Infrastructure

State and local transit agencies have evolved into several different institutional models. A transit provider can be 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.

Urban and Rural Transit Agencies

As summarized in *Exhibit 1-15*, 945 transit agencies in urbanized areas (UZAs) and 1,355 transit agencies in rural areas submitted data to the NTD in 2018. *Exhibit 1-16* identifies the population sizes and population density 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.)

Of the 945 urban reporters, 283 were independent public authorities or agencies; 507 were city, county, or local government transportation units or departments; 22 were State government units or departments of transportation; and 75 were private operators. The remaining 58 agencies were either private operators or independent agencies, such as MPOs, COGs, or other planning agencies, and universities.

KEY TAKEAWAY

Transit is provided through 18 distinct modes in two major categories, rail and nonrail. In 2018, transit providers operated 1,174 regular fixed-route bus modes, 180 commuter bus modes, and 12 bus rapid transit modes. Rail modes include heavy rail (15), light rail (22), streetcar (19), hybrid rail (six), commuter rail (21), and other less common rail modes that run on fixed tracks. Demand-response service was provided by 1,906 operators. Open-to-the-public vanpool service was provided by 101 operators. Other modes include ferryboat (32) and trolleybus (five), as well as other less common modes.

Similarly, of the 1,355 rural reporters, 179 were independent public authorities or agencies; 623 were city, county, or local government transportation units or departments; four were State government units or departments of transportation; and 355 were private operators. The remaining 194 agencies were either private operators or independent agencies (e.g., MPOs, COGs or other planning agencies, universities, and Tribes).

All transit providers that receive or benefit from either urban formula or rural formula funds from FTA must report to the NTD. Reduced reporting requirements apply to transit providers in rural areas that do not receive or benefit from urbanized area formula funds. The reduced reporting requirements also apply to urbanized are transit systems with fewer than 30 vehicles in maximum service and not operating fixed-guideway service. In 2018, 529 transit agencies were full reporters and 1,624 transit agencies filed with reduced reporting requirements.

Exhibit 1-15: Number of Urban and Rural Agencies by Organizational Structure, 2018

Organizational Structure	City, County, Local Government Transportation Units	Independent Public Authorities or Agencies	State Government Unit	Private Operators	Other	Total
Urban	507	283	22	75	58	945
Rural	623	179	4	355	194	1,355
Total	**1,130**	**462**	**26**	**430**	**252**	**2,300**

Note: Tribes are included with rural agencies. Independent Public Authorities includes subsidiary unit of a transit agency. Private Operators includes private providers reporting on behalf of a public entity, private-for-profit corporation, and private-nonprofit corporation. Other includes area agency on aging, MPO, council of governments (COG), or other planning agency, other publicly owned or privately chartered corporation, Tribe, and university.

Source: National Transit Database.

Some transit providers only receive funds from the Section 5310 program. This program (49 U.S.C. §5310) provides formula funding to States and urban areas 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 2018, 945 urban agencies reported providing transit service. Of these, 278 agencies, or about 30 percent, operated only one mode. About half (464 agencies) operated two modes, usually both fixed-route bus and demand response. The remaining 183 operated from three to eight modes.

Transit service frequency and mode depend on land use and population density. *Exhibit 1-16* lists the population and population density of UZAs with a population over 1 million. The UZAs with the highest population density among this group are Los Angeles, San Francisco, San Jose, and New York-Newark. The UZAs with the lowest population density among this group are Charlotte, Atlanta, and Pittsburgh. The difference in population density between Los Angeles and Charlotte is more than 5,300 people per square mile. While Los Angeles may be the densest UZA overall, the New York-Newark UZA includes almost all of Long Island and large areas of central New Jersey with lower population density compared with its core area.

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

UZA Rank	UZA Name	2010 Population (Millions)	Population Density (people/square mile)
1	New York-Newark, NY-NJ-CT	18.4	5,319
2	Los Angeles-Long Beach-Anaheim, CA	12.2	6,999
3	Chicago, IL-IN	8.6	3,524
4	Miami, FL	5.5	4,442
5	Philadelphia, PA-NJ-DE-MD	5.4	2,746
6	Dallas-Fort Worth-Arlington, TX	5.1	2,879
7	Houston, TX	4.9	2,978
8	Washington, DC-VA-MD	4.6	3,470
9	Atlanta, GA	4.5	1,707
10	Boston, MA-NH-RI	4.2	2,232
11	Detroit, MI	3.7	2,793
12	Phoenix-Mesa, AZ	3.6	3,165
13	San Francisco-Oakland, CA	3.3	6,266
14	Seattle, WA	3.1	3,028
15	San Diego, CA	3.0	4,037
16	Minneapolis-St. Paul, MN-WI	2.7	2,594
17	Tampa-St. Petersburg, FL	2.4	2,552
18	Denver-Aurora, CO	2.4	3,554
19	Baltimore, MD	2.2	3,073
20	St. Louis, MO-IL	2.2	2,329
21	San Juan, PR	2.1	2,479
22	Riverside-San Bernardino, CA	1.9	3,546
23	Las Vegas-Henderson, NV	1.9	4,525
24	Portland, OR-WA	1.8	3,528
25	Cleveland, OH	1.8	2,307
26	San Antonio, TX	1.8	2,945
27	Pittsburgh, PA	1.7	1,915
28	Sacramento, CA	1.5	3,660
29	San Jose, CA	1.7	5,820
30	Cincinnati, OH-KY-IN	1.6	2,063
31	Kansas City, MO-KS	1.5	2,242
32	Orlando, FL	1.5	2,527
33	Indianapolis, IN	1.5	2,108
34	Virginia Beach, VA	1.4	2,793
35	Milwaukee, WI	1.4	2,523
36	Columbus, OH	1.4	2,680
37	Austin, TX	1.4	2,605
38	Charlotte, NC-SC	1.2	1,685
39	Providence, RI-MA	1.2	2,185
40	Jacksonville, FL	1.1	2,008
41	Memphis, TN-MS-AR	1.1	2,132
42	Salt Lake City-West Valley City, UT	1.0	3,675

Note: UZA is urbanized area.

Sources: Census Bureau.

In 2018, an additional 1,355 agencies served rural areas. Roughly 71 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 agencies are much more extensive than the rail transit system. Bus fixed-route service includes three distinct modes: regular fixed-route bus, commuter bus, and bus rapid transit.

As summarized in *Exhibit 1-17,* 1,366 agencies reported fixed-route bus service in 2018, including 1,174 regular bus agencies, 180 commuter bus agencies, and 12 bus rapid transit agencies. These fixed-route buses operated on 226,782 mixed traffic route miles. In addition, 1,906 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 1-17: Number of Agencies by Mode, 2018

Rail Type	Mode Type	Urban	Rural
Nonrail	Regular Bus	767	407
	Commuter Bus	116	64
	Bus Rapid Transit	11	1
	Demand Response/Taxi	835	1,071
	Vanpool	84	17
	Ferryboat	26	6
	Trolleybus	5	0
	Público	1	0
Rail	Heavy Rail	15	0
	Light Rail	22	0
	Streetcar	19	0
	Commuter Rail	21	0
	Hybrid Rail	6	0
	Monorail/Automated Guideway	6	0
	Inclined Plane	3	0
	Aerial Tramway	1	1
	Cable Car	1	0
Total		**1,939**	1,567

Note: Tribes are included in rural agencies.
Source: National Transit Database.

KEY TAKEAWAY

Of the transit agencies in the United States that report to the National Transit Database (NTD), in 2018, 945 provided service primarily to urbanized areas and 1,355 provided service to rural areas. Of the 945 urban agencies, 278 agencies (about 30 percent) operated only one mode and the remaining agencies operated two to eight modes. Among the 1,355 rural agencies, about 71 percent operated only one transit mode and the remaining agencies operated two to four modes.

On the rail side, agencies reported operating 15 heavy rail agencies, 22 light rail agencies, 19 streetcar agencies, 21 commuter rail agencies, and six hybrid rail agencies. Hybrid rail agencies 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.

In addition to fixed-route bus service, demand-response service, and rail service, transit agencies reported operating 101 vanpool systems, 32 ferryboat systems, five trolleybus systems, six monorail/automated guideway systems, three inclined plane systems, one cable car system, and one público in 2018.

Exhibit 1-18 shows a breakdown of vehicle revenue miles for rail modes in urbanized areas. Although every major urbanized area in the United States has fixed-route bus and demand-response agencies, 50 urbanized areas were also served by at least one of the rail modes, including 21 by commuter rail, 22 by light rail, 12 by heavy rail, 18 by streetcar vehicles, six by hybrid rail vehicle, and nine by the other rail modes.

Exhibit 1-18: Vehicle Revenue Miles for Rail Modes Serving Urbanized Areas, 2018

UZA Rank	Urbanized Area	Commuter Rail	Heavy Rail	Light Rail	Streetcar	Hybrid Rail	Other	Total Rail
1	New York-Newark, NY-NJ-CT	196,489,271	364,018,847	2,588,419		1,259,015		564,355,552
2	Los Angeles-Long Beach-Anaheim, CA	13,513,335	6,976,333	17,999,250				38,488,918
3	Chicago, IL-IN	47,886,176	73,461,555					121,347,731
4	Miami, FL	3,607,386	7,384,249				1,108,496	12,100,131
5	Philadelphia, PA-NJ-DE-MD	24,348,413	21,560,570		3,096,378			49,005,361
6	Dallas-Fort Worth-Arlington, TX	1,627,050		10,236,821	150,786			12,014,657
7	Houston, TX			3,535,806				3,535,806
8	Washington, DC-VA-MD	2,416,319	81,751,483		131,715			84,299,517
9	Atlanta, GA		22,334,099		58,080			22,392,179
10	Boston, MA-NH-RI	24,565,346	23,313,396	5,986,849				53,865,591
11	Detroit, MI				183,644		566,926	750,570
12	Phoenix-Mesa, AZ			3,297,498				3,297,498
13	San Francisco-Oakland, CA	7,202,308	77,291,768	5,324,769	457,759	63,934	691,565	91,032,103
14	Seattle, WA	2,233,332		5,429,764	283,548		209,229	8,155,873
15	San Diego, CA	1,376,954		8,656,486		710,981		10,744,421
16	Minneapolis-St. Paul, MN-WI	599,814		5,336,357				5,936,171
17	Tampa-St. Petersburg, FL				65,410			65,410
18	Denver-Aurora, CO	2,563,181		11,758,421				14,321,602
19	Baltimore, MD	6,508,708	4,633,205	2,988,892				14,130,805
20	St. Louis, MO-IL			6,210,574				6,210,574
21	San Juan, PR		1,321,004					1,321,004
24	Portland, OR-WA			8,932,446	427,910	161,503	34,000	9,555,859
25	Cleveland, OH		2,113,189	682,556				2,795,745
27	Pittsburgh, PA			2,184,781			14,586	2,199,367
28	Sacramento, CA			4,418,237				4,418,237
29	San Jose, CA			3,314,903				3,314,903
30	Cincinnati, OH-KY-IN				92,052			92,052
31	Kansas City, MO-KS				131,103			131,103
32	Orlando, FL	608,544						608,544
34	Virginia Beach, VA			387,609				387,609
35	Milwaukee, WI				14,129			14,129
37	Austin, TX					310,272		310,272
38	Charlotte, NC-SC			1,420,469	47,265			1,467,734
40	Jacksonville, FL						148,197	148,197
41	Memphis, TN-MS-AR				11,912			11,912
42	Salt Lake City-West Valley City, UT	5,429,232		6,655,535				12,084,767
44	Nashville-Davidson, TN	203,195						203,195
46	Buffalo, NY			926,900				926,900
47	Hartford, CT	1,542,400						1,542,400
49	New Orleans, LA				1,219,212			1,219,212
52	Tucson, AZ				201,796			201,796
56	Albuquerque, NM	1,348,618						1,348,618
88	Little Rock, AR				53,112			53,112
100	Chattanooga, TN-GA						19,625	19,625
102	Stockton, CA	1,102,574						1,102,574
104	Denton-Lewisville, TX					328,658		328,658
177	Portland, ME	2,340,372						2,340,372
256	Kenosha, WI-IL				17,242			17,242
393	Morgantown, WV						632,104	632,104
400	Johnstown, PA						1,988	1,988

Note: Other rail modes include cable car, inclined plane, and monorail. 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. Gray cells indicate that the area is not served.

Source: National Transit Database.

Transit agencies mostly expanded their service from 2008 to 2018. This is reflected in growing counts for most categories of transit assets.

Transit Fleet and Stations

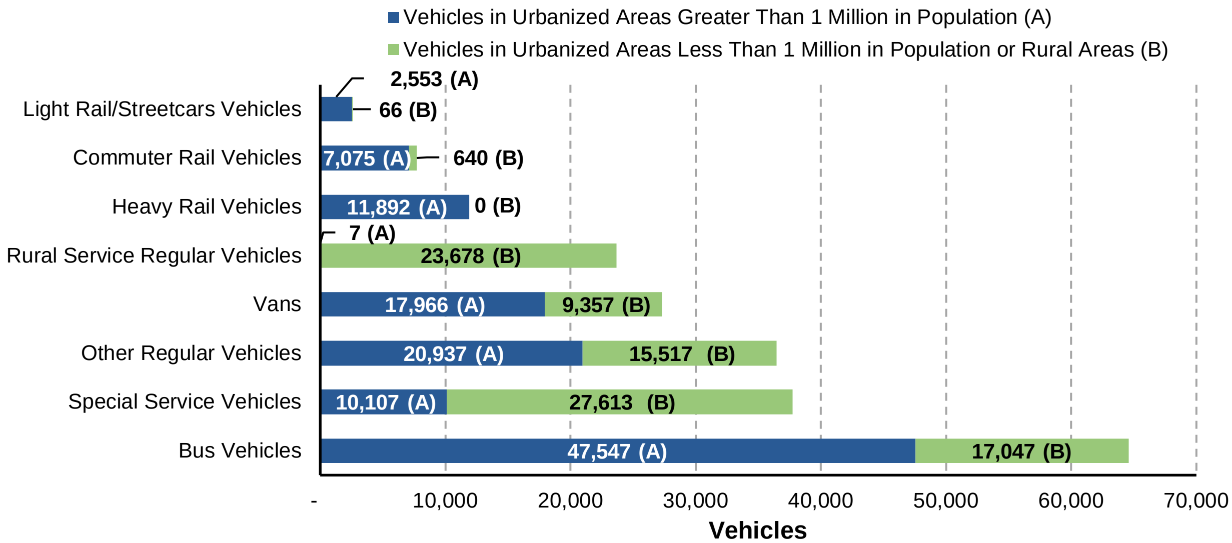
Exhibit 1-19 provides an overview of the Nation's fleet of 212,002 transit vehicles as of 2018, segmented by related vehicle type, type of service, and size of urbanized area served. Note that rail vehicles represent only a small proportion of the Nation's total transit fleet (roughly 10 percent) and 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 in population.

Exhibit 1-20 shows the composition of the Nation's rubber-tire transit vehicle fleet as of 2018. 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 6.

Demand Response

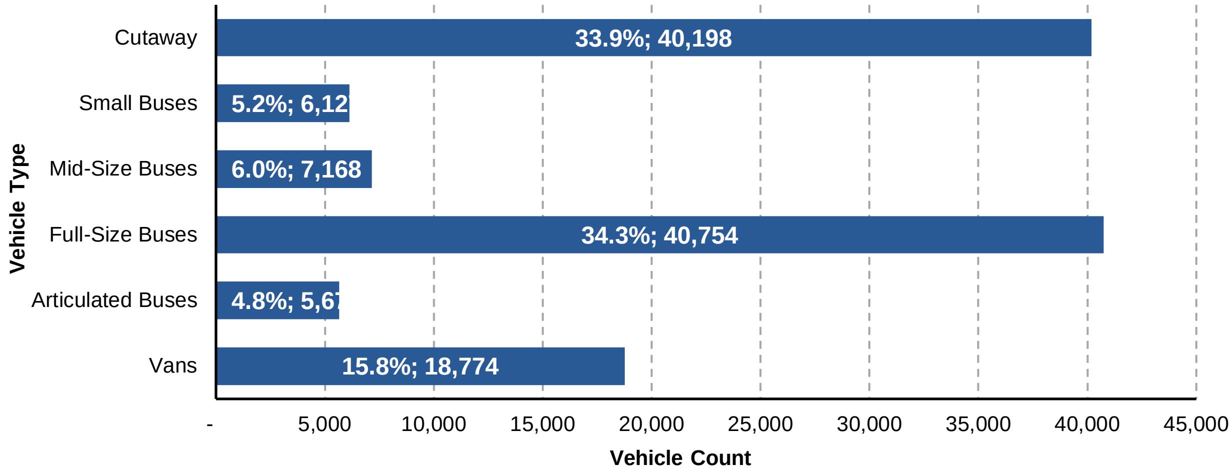
The demand-response mode operates without fixed routes or schedules, but groups together people with similar trips for a shared ride service. Transit agencies are required by the Americans with Disabilities Act (ADA) of 1990 to provide demand-response service within their fixed-route service area to persons with disabilities who are unable to use the fixed-route system. Demand-response service is sometimes provided more broadly to areas without fixed-route service as a public service to the elderly and people with disabilities. In some cases, demand-response service is provided to the general public as a more-efficient alternative to fixed-route service in lower-density areas where demand for transit is relatively low.

Exhibit 1-19: Transit Active Fleet by Vehicle Type, 2018



Source: National Transit Database.

Exhibit 1-20: Composition of Transit Road Vehicle Fleet, 2018



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); National Transit Database.

Exhibit 1-21 presents the number of stations by rail and nonrail mode between 2008 and 2018. In 2018, heavy rail, commuter rail, light rail, and fixed-route bus accounted 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 accounted for only a small share of the station total in 2018. Between 2008 and 2018, the number of stations increased by 14 percent. The only modes to see a decrease in stations between 2008 and 2018 were inclined plane, Alaska railroad, and bus. During this period, ferryboat saw a 91-percent increase in stations, more than any other mode. Between 2016 and 2018, bus stations decreased by 19 percent. This decrease is spread out across 133 agencies or 28 percent of agencies with bus stations. During this period, only one agency reported an increase in bus stations.

Exhibit 1-21: Stations by Mode, 2008–2018

Rail Type	Transit Mode	Total Stations						
		2008	2010	2012	2014	2016	2018	% Change
Rail	Heavy Rail	1,041	1,041	1,044	1,130	1,051	1,054	1%
	Commuter Rail	1,189	1,225	1,234	1,245	1,261	1,280	8%
	Light Rail	787	848	794	828	871	923	17%
	Streetcar Rail	0	0	85	86	132	125	47%
	Monorail/Automated Guideway	43	43	57	58	60	51	19%
	Alaska Railroad	10	10	10	11	11	8	-20%
	Hybrid Rail	0	0	49	55	55	58	18%
	Inclined Plane	8	8	8	6	6	6	-25%
	Aerial Tramway	0	0	0	2	2	2	0%
	Total Rail	**3,078**	**3,175**	**3,281**	**3,421**	**3,449**	**3,507**	**14%**
Nonrail	Bus	1,346	1,462	1,355	1,476	1,514	1,229	-9%
	Commuter Bus	0	0	195	234	235	234	20%
	Trolleybus	5	5	5	5	5	5	0%
	Bus Rapid Transit	0	0	7	27	31	32	357%
	Ferryboat	81	82	94	101	132	155	91%
	Total Nonrail	**1,432**	**1,549**	**1,656**	**1,843**	**1,917**	**1,655**	**16%**
Total All Modes		**4,510**	**4,724**	**4,937**	**5,264**	**5,366**	**5,162**	**14%**

Note: Streetcar Rail, Hybrid Rail, Bus Rapid Transit, and Commuter Bus were created as new modes in 2012. For those modes, the percent change column represents the change between 2012 and 2018. For Aerial Tramway, the first agency reported this mode in 2014. The percent change column represents the change between 2014 and 2018.

Source: National Transit Database.

Several modes (commuter bus, streetcar, and hybrid rail) were added to NTD during this period, so they appear to have no stations in 2008 and 2010. Aerial tramway shows no stations until 2014, when the Portland (Oregon) Aerial Tramway opened. (The Roosevelt Island aerial tramway in New York does not take FTA funding and does not report to the NTD.) Information on ADA stations is presented in Chapter 4.

KEY TAKEAWAY

In 2018, agencies reported 212,002 transit vehicles serving urban and rural areas, 5,162 passenger stations, and 2,393 maintenance facilities. Rail systems operated on 13,086 miles of track and fixed-route buses operated on more than 226,782 mixed traffic route miles.

Whereas *Exhibit 1-19* 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 more than 22,000 rail vehicles (passenger cars) and over 151,000 nonrail vehicles, excluding special service vehicles. The bus fleet, which includes bus, commuter bus, and bus rapid transit, accounts for 41 percent of the national fleet, and demand response for 33 percent of the national fleet. The number of active fleet vehicles increased by 31 percent from 2008 to 2018. Five modes— Alaska railroad, cable car, inclined plane, público, and trolleybus—saw a decrease in active vehicles between 2008 and 2018.

Exhibit 1-22: Fleet by Mode, 2008–2018

Rail Type	Transit Mode	Active Vehicles						% Change
		2008	2010	2012	2014	2016	2018	
Rail	Heavy Rail	11,367	11,434	11,422	11,623	11,841	11,892	5%
	Commuter Rail	6,792	6,976	7,263	7,305	7,211	7,131	5%
	Light Rail	1,957	2,155	1,981	2,071	2,129	2,282	17%
	Streetcar Rail	0	0	316	321	361	378	20%
	Monorail/Automated Guideway	54	59	156	159	163	124	100%
	Alaska Railroad	101	96	63	95	95	96	-5%
	Hybrid Rail	0	0	44	53	55	67	52%
	Cable Car	40	39	38	39	39	36	-10%
	Inclined Plane	8	8	8	6	6	6	-25%
	Aerial Tramway	0	0	0	2	61	70	3400%
	Total Rail	**20,327**	**20,767**	**21,291**	**21,674**	**21,961**	**22,082**	**8%**
Nonrail	Bus	64,647	64,552	62,204	61,386	68,345	65,094	1%
	Demand Response	32,248	30,512	30,846	32,384	52,393	57,091	77%
	Vanpool	10,970	11,711	13,537	14,714	15,395	14,733	34%
	Demand-Response Taxi	0	5,715	6,142	6,846	6,534	5,490	-4%
	Commuter Bus	0	0	1,994	5,491	6,553	5,774	190%
	Público	3,718	5,620	2,873	2,310	2,310	2,310	-38%
	Trolleybus	601	571	572	544	761	596	-1%
	Bus Rapid Transit	0	0	90	470	655	367	308%
	Ferryboat	151	131	145	149	179	196	30%
	Total Nonrail	**112,335**	**118,812**	**118,403**	**124,294**	**153,125**	**151,651**	**35%**
Total All Modes		**132,662**	**139,579**	**139,694**	**145,968**	**175,086**	**173,733**	**31%**

Note: Streetcar Rail, Hybrid Rail, Bus Rapid Transit, and Commuter Bus were created as new modes in 2012. For those modes, the percent change column represents the change between 2012 and 2018. For Aerial Tramway, the first agency reported this mode in 2014. The percent change column represents the change between 2014 and 2018. For Demand Response – Taxi, the first year vehicles were reported was 2010, the percent change column represents the change between 2010 and 2018.

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 13,086 miles of track in 2018. 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, 2018

Maintenance Facility Type	Over 1 Million	Under 1 Million and Rural Areas	Total
Fixed-Route Bus	475	377	853
Rural Transit	1	639	640
Demand Response	254	236	490
Commuter Rail	97	11	108
Commuter Bus	67	30	97
Heavy Rail	69	0	69
Light Rail	54	1	55
Streetcar Rail	19	5	24
Ferryboat	19	3	22
Vanpool	6	6	11
Other Rail	6	5	11
Hybrid Rail	5	1	6
Trolleybus	4	1	5
Bus Rapid Transit	2	1	2
Aerial Tramway	1	0	1
Total Maintenance Facilities	**1,078**	**1,315**	**2,393**

Note: Directly operated service only. Includes owned and leased facilities. Other Rail includes Alaska Railroad, Cable Car, Inclined Plane, Monorail/Automated Guideway.

Source: National Transit Database.

Exhibit 1-24: Transit Rail Mileage and Stations, 2018

Transit Type	Urbanized Area Track Mileage	Urbanized Area Transit Rail Stations Count
Heavy Rail	2,235	1,054
Commuter Rail	7,917	1,280
Light Rail	1,735	923
Hybrid Rail	226	58
Streetcar Rail	361	125
Other Rail and Tramway	611	65
Total	**13,086**	**3,505**

Note: Other Rail includes Alaska Railroad, Cable Car, Inclined Plane, Monorail/Automated Guideway.

Source: National Transit Database.

Chapter 2: Funding

Funding – Highways

This chapter presents data and analyses on revenue and expenditure 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 highway expenditures and, more specifically, highway capital outlay. A separate section presents data on transit system funding, highlighting trends in revenues, capital outlay, and operating expenditures.

The classification of the revenue and expenditure types 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 annual *Highway Statistics* publication.

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.

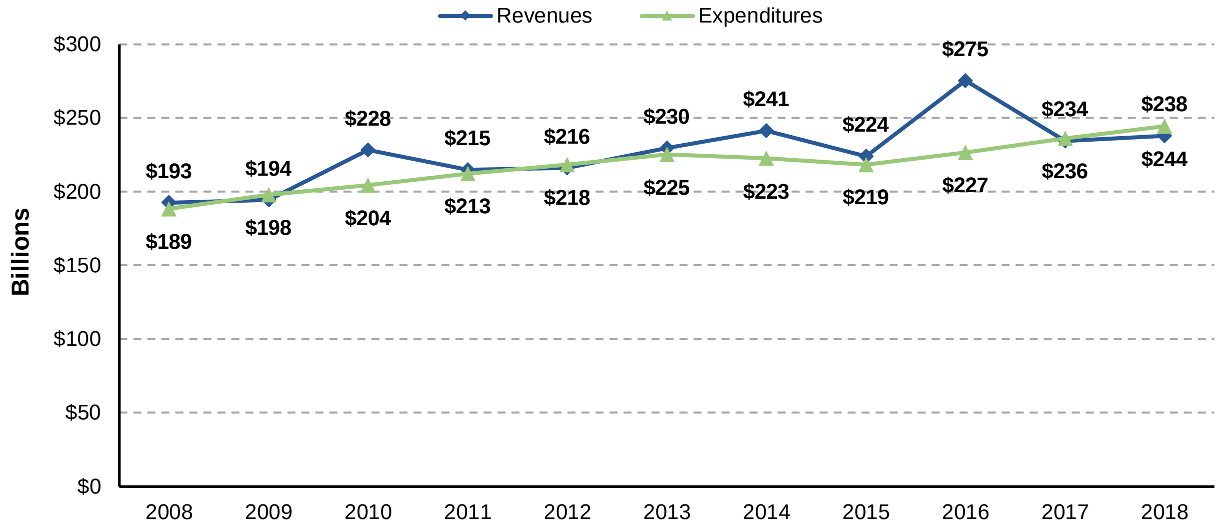
SECTION SUMMARY

- Combined highway expenditures at the Federal, State, and local government levels totaled $244.5 billion in 2018.
- States funded 50.7 percent of total highway expenditures in 2018, whereas local governments funded 28.9 percent.
- Total highway capital outlay on all systems reached $117.0 billion in 2018.
- The composition of highway capital outlay shifted from 2008 to 2018. The share directed toward system expansion fell from 36.9 percent to 19.8 percent, whereas the share directed toward system rehabilitation rose from 51.1 percent to 66.1 percent.
- The Federal government funded 40.1 percent of highway capital outlay and 20.4 percent of total highway expenditures in 2018.
- From 2008 to 2018, federally funded highway capital outlay grew by 2.3 percent per year. Capital outlay funded by State and local governments grew by 2.9 percent.

Revenues and expenditures across the different levels of government are closely intertwined. Revenues are raised through fees and taxes collected from highway users and other sources at all three levels of government—Federal, State, and local. Expenditures cover costs in construction, replacement, rehabilitation, maintenance, and other needed activities for highways and bridges. Most highway revenues raised at the Federal level support the Federal-aid Highway Program, a federally funded, State-administrated program through which Federal funds are transferred primarily based on statutory formulas. Other Federal revenues are transferred to States or local governments via different 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).

Exhibit 2-1 presents the 10-year trend of total revenues and expenditures in highways and bridges between 2008 and 2018 from all government sources. The difference between revenues and expenditures corresponds to the cumulative changes in cash balances of dedicated highway funds, including the Highway Account of the Federal Highway Trust Fund (HTF) and comparable dedicated accounts at the State and local levels. When revenues exceed expenditures (such as in 2016), the difference is placed in highway reserve accounts at different levels of government for future use. When revenues fall below expenditures (such as in 2018), the difference is drawn from highway reserve accounts for current use at the Federal, State, and local levels.

Exhibit 2-1: Government Revenues and Expenditures for Highways, 2008–2018



Note: Dollar values are in billions.
Source: Highway Statistics, various years, Tables HF-10A and HF-10.

Total revenues for highways decreased from 2010 to 2012, then increased to the decade's high of $275 billion in 2016 before declining again in 2018. The noticeable boost in revenues in 2016 is attributable to a large General Fund appropriation in the first year of the Fixing America's Surface Transportation (FAST) Act authorization. Expenditures, on the other hand, grew more steadily over time.

Exhibit 2-2 summarizes revenue sources and expenditure types for highways and bridges in 2018. Total direct expenditures for highways and bridges in 2018 reached $244.5 billion, whereas total revenues from all government sources were $237.8 billion in the same year. The $6.7 billion difference between total revenues and total expenditures represents cash amounts drawn from or placed in reserve accounts at different levels of government, including $8.8 billion drawn from the balance of the Federal HTF, $2.6 billion placed into comparable accounts at the State level, and $0.4 billion drawn from comparable accounts at the local level.

> **KEY TAKEAWAY**
>
> Revenues raised for use on highways, by all levels of government combined, totaled $237.8 billion in 2018. The $6.7 billion difference between highway revenues and highway expenditures ($244.5 billion) comes from funds drawn from reserves. This difference represents the net decrease during 2018 of the cash balances of the Federal Highway Trust Fund and comparable dedicated accounts at the State and local levels.

Exhibit 2-2: Summary of Government Revenue Sources and Direct Expenditures for Highways, 2018

Category	Federal	State	Local	Total
User Charges	$35.8	$78.4	$7.1	$121.3
Other	$5.2	$48.3	$63.0	$116.5
Total Revenues	**$41.0**	**$126.7**	**$70.1**	**$237.8**
Net Intergovernmental Transfers from (to) Other Levels of Government	-$46.5	$26.4	$20.1	
Funds Drawn From (or Placed in) Reserves	$8.8	-$2.6	$0.4	$6.7
Total Transfers and Reserve Deposits/Withdrawals	**-$37.7**	**$23.8**	**$20.5**	**$6.7**
Capital Outlay	$0.5	$83.6	$33.0	$117.0
Noncapital Expenditures	$0.2	$27.5	$31.4	$59.1
Bond Retirement	$2.6	$39.4	$26.3	$68.3
Total, All Direct Expenditures	**$3.3**	**$150.5**	**$90.7**	**$244.5**

Note: Dollar values are in billions. User charges shown represent only the portions of user charges that are used to fund highway spending; a portion of the revenues 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 $160.5 billion in 2016.

Source: *Highway Statistics* 2018, Table HF-10.

Highway Revenues

Highway Revenue and Transfer Terminology

Revenue source and transfer terms used in this chapter include:

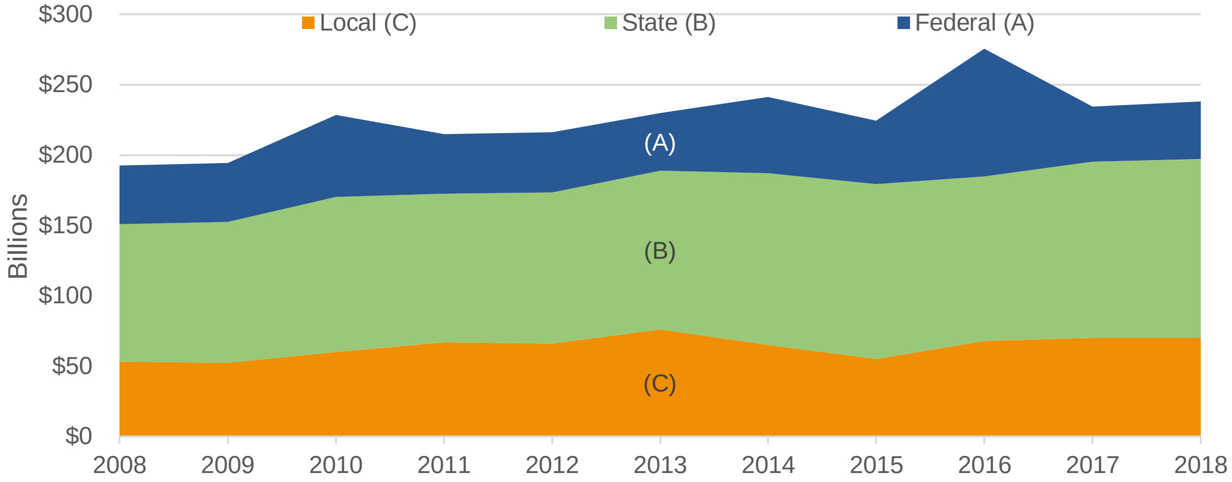
- **User Charges:** Taxes and fees imposed on the owners and operators of motor vehicles for their use of public highways, including motor fuel taxes, tolls, motor vehicle taxes, certificate of title fees, driver license fees, weight-distance taxes, oversize-overweight permits, and trip permits.
- **General Fund:** The chief operating fund of a State, local, or the Federal government. 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.
- **Investment income and other receipts:** Development fees, special district assessments, and private-sector investment in highways, to the extent that such investment is captured in State and local accounting systems.
- **Intergovernmental transfers:** Transfers of funds from one government entity (e.g., State, local government, or a 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 HTF intended for use over multiple years.

Revenues refer to 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. Amounts generated from user charges that are used for non-highway purposes are not included as part of highway revenues.

Revenues by Level of Government

The stacked areas at the top of *Exhibit 2-3* represent revenues received from all levels of government between 2008 and 2018. In 2018, State governments generated 53.3 percent of total revenues at $126.7 billion, followed by local governments at $70.1 billion (29.5 percent) and the Federal government at $41.0 billion (17.2 percent).

Exhibit 2-3: Highway Revenues by Level of Government, 2008–2018



Level of Government	2008	2010	2012	2014	2016	2018	Share in 2018	Annual Rate of Change 2018/2008
Federal	$41.7	$57.9	$42.7	$54.3	$90.6	$41.0	17.2%	-0.2%
State	$97.7	$110.2	$107.5	$122.1	$117.1	$126.7	53.3%	2.6%
Local	$53.2	$60.2	$65.8	$64.8	$67.8	$70.1	29.5%	2.8%
Total Revenues	**$192.6**	**$228.3**	**$216.1**	**$241.3**	**$275.5**	**$237.8**	**100%**	**2.1%**
Net Intergovernmental Transfers from (to) Other Levels of Government								
Federal	-$36.9	-$42.5	-$44.1	-$43.6	-$43.2	-$46.5		
State	$21.6	$28.4	$27.4	$29.9	$28.3	$26.4		
Local	$15.2	$14.1	$16.7	$13.7	$14.9	$20.1		

Note: Dollar values are in billions.

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

In 2018, a total of $237.8 billion in highway revenues was received by Federal, State, and local governments combined. From 2008 to 2018, total revenues for highways across all levels of government increased from $192.6 billion to $237.8 billion, at an annual rate of 2.1 percent (lower part of *Exhibit 2-3*). Annual revenues from the Federal government fluctuated, with a minor overall 10-year decline of 0.2 percent per year. In contrast, revenues generated from State and local governments grew steadily at 2.6 and 2.8 percent per year, respectively. The sharp increase in 2016 was due to a large one-time transfer of Federal government funds from the General Fund to the Highway Account of the HTF under the FAST Act ($51.9 billion). Although the FAST Act authorized Federal highway and public transportation programs through September 30, 2020, the entire amount specified for the Highway Account was transferred at one time.

Exhibit 2-3 also identifies transfers between different levels of governments. In 2018, the Federal government provided $46.5 billion to State and local governments for use on highways and bridges. Net transfers from other levels of government to State governments (transfers from Federal and local governments less transfers to local governments) totaled $26.4 billion, whereas net transfers from other levels of government to local governments (transfers from Federal and State governments less transfers to State government) totaled $20.1 billion. By definition, transfers net out to zero for all levels of government combined.

Revenues by Source

Revenues intended for highway and bridge construction, operations, and maintenance are raised at the Federal, State, and local levels of government. Revenues from user charges, including motor fuel taxes, motor vehicle taxes and fees, and tolls, from all levels of government were $121.3 billion in 2018 (*Exhibit 2-4*). The remaining $116.5 billion was generated from a variety of other sources, including property taxes and assessments, General Fund appropriations, other taxes and fees, investment income, and debt financing. Between 2016 and 2018, total revenues dropped from $275.5 billion to $237.8 billion, driven mainly by a decrease in General Fund appropriations from $90.4 billion to $39.4 billion. The amount of other revenues increased or remained steady during 2016–2018 in each category except for a minor decrease in property taxes and assessment.

KEY TAKEAWAY

Of the $237.8 billion of revenues raised in 2018 for use on highways, $121.3 billion (51 percent) was collected from user charges, including fuel taxes ($66.9 billion), tolls ($17.6 billion), and vehicle taxes and fees ($36.8 billion).

The graph at the top of *Exhibit 2-4* shows the share of each funding source by year for 2008–2018. It demonstrates that a relatively steady percentage of revenues came from property taxes/assessments and other taxes and fees during that time, whereas the portion of revenues coming from General Fund appropriations and motor fuel and motor vehicle taxes varied significantly.

Motor fuel and motor vehicle taxes have been the largest source of revenue, representing 43.6 percent of total revenues in 2018. Combined with tolls, these user charges accounted for slightly above half of total revenue. In addition to General Fund appropriations ($39.4 billion, or 16.6 percent of total revenue), other sources of revenues included investment income and other receipts (9.2 percent), other taxes and fees (9.2 percent), and property taxes and assessments (4.9 percent). Bond issuance served as a bridging mechanism to provide an additional 9.1 percent of revenues ($21.7 billion).

Following the 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 the majority of total revenues raised for highway and bridge programs by all levels of government for many years. However, beginning in 2008, due to relatively flat user revenues and transfers from the general fund to keep the Federal HTF solvent, the share of user revenues subsequently stayed in a range between 40.7 and 48.7 percent before rising to 51.0 percent in 2018.

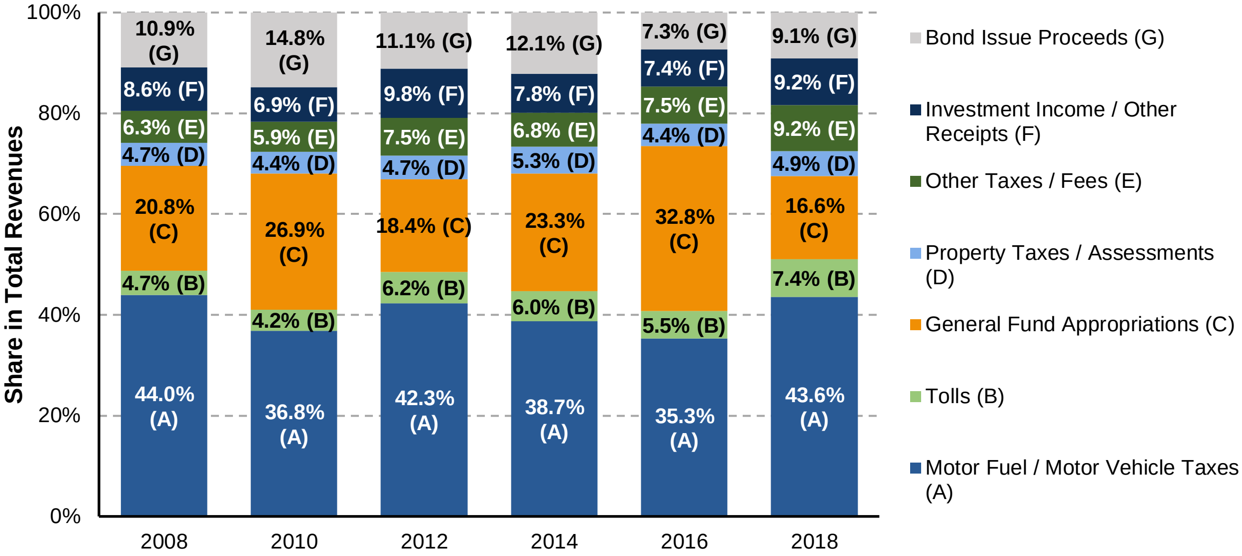
KEY TAKEAWAY

During 2018, $116.5 billion was raised for use on highways and bridges from non-user sources, including general fund appropriations ($39.4 billion), bond issue proceeds ($21.7 billion), investment income and other receipts ($22.0 billion), property taxes ($11.6 billion), and other taxes and fees ($21.8 billion).

The top chart of *Exhibit 2-4* demonstrates the share of General Fund of total revenues dropped by 4 percentage points and that of bond issue proceeds fell by 2 percentage points from 2008 to 2018, despite fluctuations over time. These decreases were offset by the increased shares of tolls and other taxes and fees. The shares of revenues raised from property taxes and assessments and from investment income and other receipts remained steady.

The lower half of *Exhibit 2-4* summarizes the trends in revenues over the past 10 years, with the largest rate of increase from toll collection. During this period, toll revenues grew from $9.1 billion to $17.6 billion at an annual average rate of 6.8 percent. The much larger component of user fees, motor fuel and motor vehicle taxes, increased at a much lower rate of 2.0 percent per year. Meanwhile, revenues from other taxes and fees expanded rapidly at 6.0 percent annually, followed by modest increases in investment income (2.9 percent) and property taxes and assessments (2.6 percent). In contrast, revenues raised from General Fund appropriation declined by 0.1 percent per year. Bond issue proceeds grew at a comparatively slow pace of 0.4 percent per year.

Exhibit 2-4: Government Highway Revenues by Source, 2008–2018



Revenue Source	2008	2010	2012	2014	2016	2018	Annual Rate of Change 2018/2008
Motor Fuel and Motor Vehicle Taxes	$84.7	$84.1	$91.5	$93.4	$97.2	$103.7	2.0%
Tolls	$9.1	$9.7	$13.5	$14.4	$15.1	$17.6	6.8%
Subtotal: User Fees	**$93.8**	**$93.8**	**$104.9**	**$107.8**	**$112.3**	**$121.3**	**2.6%**
Property Taxes and Assessments	$9.0	$10.1	$10.1	$12.8	$12.0	$11.6	2.6%
General Fund Appropriations	$40.0	$61.5	$39.8	$56.3	$90.4	$39.4	-0.1%
Other Taxes and Fees	$12.2	$13.5	$16.1	$16.4	$20.5	$21.8	6.0%
Investment Income and Other Receipts	$16.6	$15.8	$21.1	$18.7	$20.3	$22.0	2.9%
Bond Issue Proceeds	$20.9	$33.7	$24.0	$29.2	$20.0	$21.7	0.4%
Total Revenues	**$192.6**	**$228.3**	**$216.1**	**$241.3**	**$275.5**	**$237.8**	**2.1%**

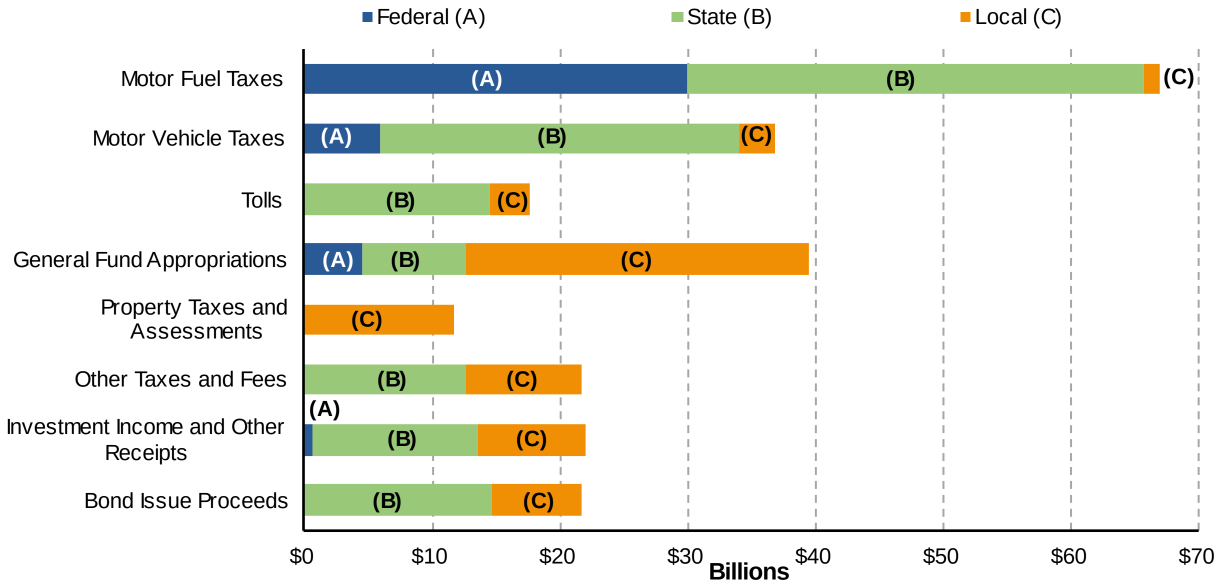
Notes: Dollar values are in billions. Motor fuel taxes, motor vehicle taxes and fees, and tolls refer to the portion of user charges that are used to fund highway spending, which excludes user fees used for mass transit and other nonhighway purposes. Gross receipts generated by user charges totaled $147.2 billion in 2016.

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

Revenues by Source and Level of Government

Exhibit 2-5 shows that the types and proportions of revenues used to fund highways varied significantly by level of government. Federal revenues in 2018 came mainly from motor fuel taxes, motor vehicle taxes, and General Fund appropriations. States generated most of their revenues via dedicated user charges ($78.4 billion out of a total of $125.4 billion). Local governments received a large portion of their revenues from annual General Fund appropriations, supplemented by property taxes and other taxes and fees.

Exhibit 2-5: Highway Revenues by Source and Level of Government, Billions of Dollars in 2018



Revenue Source	Federal	State	Local	Total	Federal Share of Total	State Share of Total
Motor Fuel Taxes	$29.9	$35.7	$1.2	$66.9	44.7%	53.4%
Motor Vehicle Taxes	$5.9	$28.1	$2.8	$36.8	16.0%	76.3%
Tolls	$0.0	$14.6	$3.1	$17.6	0.0%	82.6%
Subtotal: User Fees	**$35.8**	**$78.4**	**$7.1**	**$121.3**	**29.5%**	**64.6%**
Property Taxes and Assessments			$11.6	$11.6		
General Fund Appropriations	$4.5	$8.1	$26.9	$39.4	11.4%	20.5%
Other Taxes and Fees	$0.0	$12.7	$9.0	$21.8	0.0%	58.2%
Investment Income and Other Receipts	$0.7	$12.9	$8.4	$22.0	3.0%	58.6%
Bond Issue Proceeds	$0.0	$14.7	$7.0	$21.7	0.0%	67.6%
Total Revenues	**$40.9**	**$126.7**	**$70.1**	**$237.8**	**17.2%**	**53.3%**

Notes: Dollar values are in billions. Motor fuel taxes, motor vehicle taxes and fees, and tolls refers to the portion of user charges that are used to fund highway spending, which excludes user fees used for mass transit and other nonhighway purposes. Gross receipts generated by user charges totaled $160.5 billion in 2018, of which $121.3 billion was used for highways. The $4 billion General Fund Appropriation shown for Federal includes expenditures by the FHWA and other Federal agencies that were not paid for from the Highway Trust Fund.

Sources: *Highway Statistics 2018*, Table HF-10, and FHWA estimates.

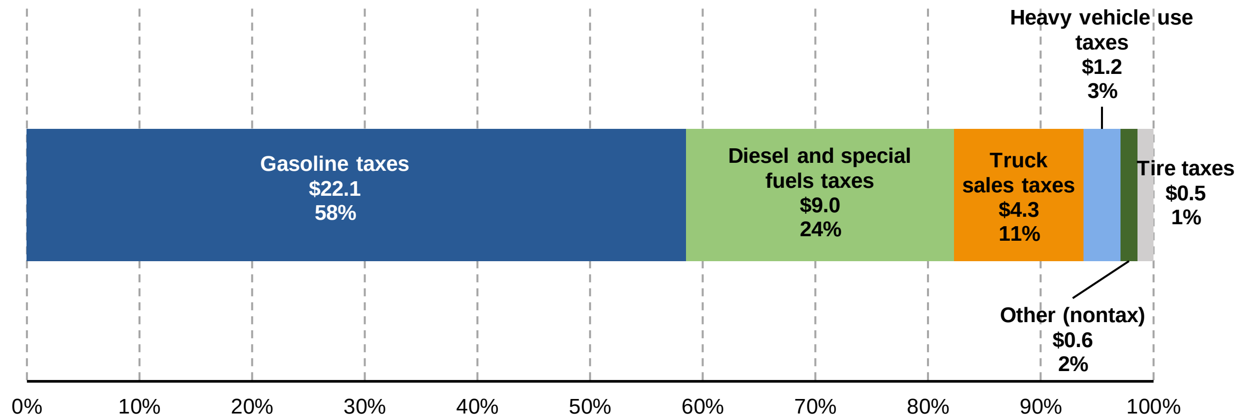
Of the $66.9 billion motor fuel taxes used for highways, $35.9 billion was attributable to States, whereas the Federal government raised $29.9 billion and local government $1.2 billion. Motor vehicle taxes were collected predominantly by State governments, supplemented by Federal and local sources. State governments were the main collectors of toll revenues used for highways ($14.6 billion), and local governments collected an additional $3.1 billion.

Local government revenues constituted a significant share of non-user fee revenues in 2018. For example, the largest portion of General Fund appropriations of $34.9 billion was derived from local governments ($26.9 billion), followed by State governments ($8.1 billion) and the Federal government ($4.5 billion). Local governments were the exclusive source of highway revenues supported by property taxes and assessments. The Federal government barely contributed to other taxes and fees and investment income and other receipts, as nearly three-fifths of these revenues were raised by State governments and two-fifths by local governments. Similarly, State and local governments were responsible for the entirety of bond issue proceeds, with approximately two-thirds from States and one-third from local governments.

Federal HTF Highway Account Excise Tax Receipts and Expenditures

In Fiscal Year 2018, total HTF Highway Account net receipts reached $37.8 billion. The account was largely funded by fuel taxes, with 58 percent coming from gasoline sales taxes and 24 percent from diesel and special fuels taxes (*Exhibit 2-6*). The remaining revenues were collected from truck sales taxes (11 percent), heavy vehicle use taxes (3 percent), nontax revenues (2 percent), and tire taxes (1 percent). It should be noted that States have the ability to "flex" certain Federal-aid Highway Program funds from the HTF Highway Account to the Transit Account for use on transit projects. In 2018, such "flex" amounts are reflected in the HTF Highway Account net receipts ($37.8 billion in *Exhibit 2-6*), but are not included in the Federal revenues for highways ($35.8 billion in *Exhibit 2-5*). The $2.0 billion difference came from three sources: $0.6 billion of HTF receipts, shown as miscellaneous revenues in *Exhibit 2-5* (investment income and other receipts); $1.3 billion flexed from the Highway Account of HTF to the Transit Account; and $0.1 billion used for highways in U.S. territories.

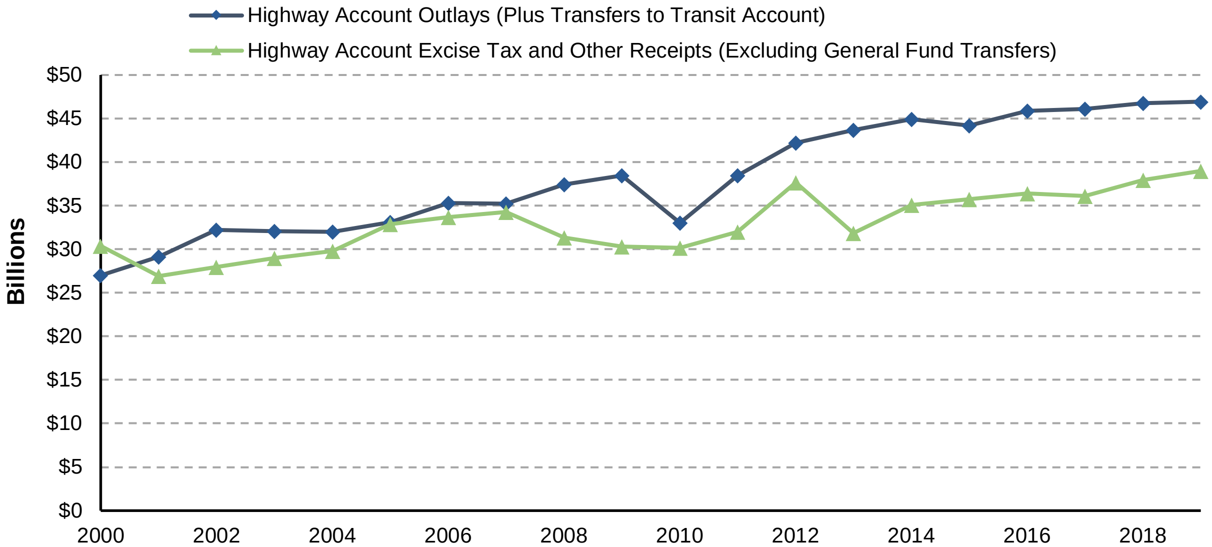
Exhibit 2-6: HTF Highway Account Net Receipts by Source, Fiscal Year 2018



Note: Dollar values are in billions.
Source: *Highway Statistics* 2018, Table FE-210.

The last time that annual net highway excise taxes and related receipts credited to the Highway Account of the HTF exceeded annual expenditures from the Highway Account was in 2000. For each year since 2000, as shown in *Exhibit 2-7*, 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 Trust Account (including amounts transferred from the Highway Account to the Transit Account). (The HTF Highway Account receipts and expenditures shown in *Exhibit 2-7* 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 equaled annual expenditures. The growth of expenditures then quickly outpaced increases in revenues, and in Fiscal Year 2019 net receipts were equivalent to approximately 83 percent of expenditures in that year ($39.0 billion of revenues vs. $46.9 billion of expenditures).

Exhibit 2-7: Highway Trust Fund Highway Account Receipts and Expenditures, Fiscal Years 2000–2019



Note: Values are measured in fiscal years.

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

Exhibit 2-8: Transfers from General Fund to HTF, Fiscal Years 2008–2021

Fiscal Year	Authorization Period	To Highway Account	To Mass Transit Account
2008–2010	SAFETEA-LU & extensions	$29.7	$4.8
2012–2015	MAP-21 & extensions	$32.8	$6.0
2016	FAST Act	$52.0	$18.1
2017	FAST Act	$0.1	
2018	FAST Act	$0.1	
2021	Continuing Appropriations Act, 2021, and Other Extensions Act	$10.4	$3.2
Total		**$125.1**	**$32.1**

Note: Dollar values are in billions.

Source: Congressional Appropriations by Fiscal Year (https://www.congress.gov/help/appropriations-and-budget).

To help maintain a positive cash balance in the HTF, transfers from the General Fund to the HTF were legislatively mandated in Fiscal Years 2008–2021 under several consecutive authorizations, with the exception of Fiscal Years 2011 and 2019–2020 (*Exhibit 2-8*). In Fiscal Years 2012, 2014, and 2016–2018, 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 (See Highway Statistics Tables FE-10 for greater detail).

Highway Expenditures

Highway expenditures includes the construction, operation, improvement, and maintenance of highways, bridges, sidewalks, and other related structures. Expenditures identified in this report represent cash outlays, not authorizations or obligations of funds. (The terms “expenditures,” “spending,” and “outlay” are used interchangeably in this report.)

Highway Expenditure Terminology

Definitions for expenditure 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 preservation 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, 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).
- **Direct expenditures:** Funds spent directly on roads and bridges by an entity, excluding amounts transferred to another entity or placed in reserve. Direct expenditures at one level of government plus net intergovernmental transfers into it equal the amount of expenditures funded by the same level of the government.

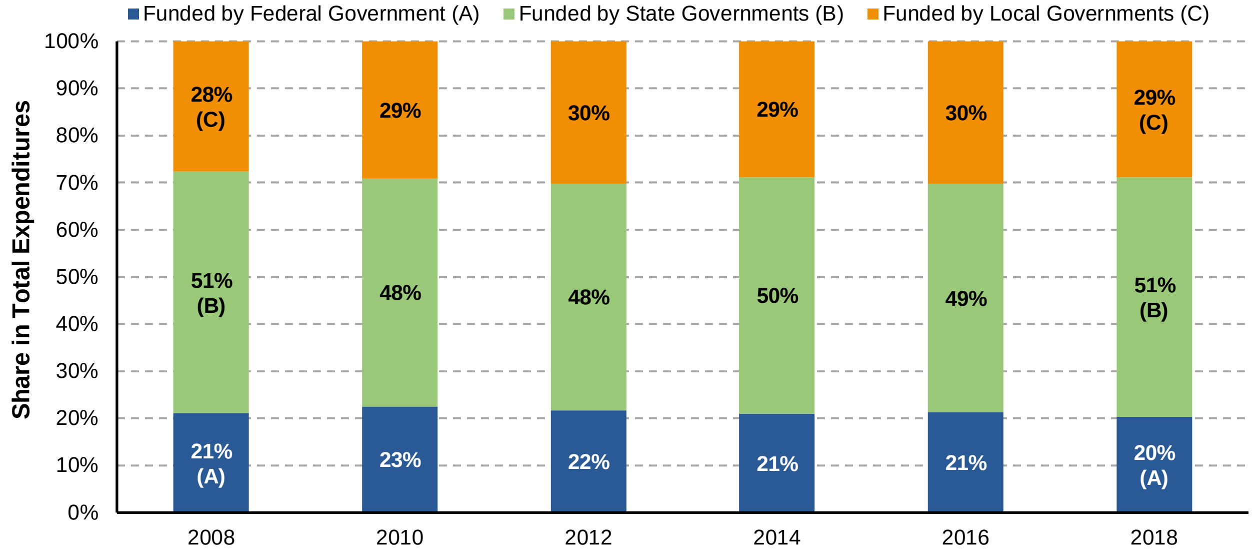
Expenditures by Level of Government

Exhibit 2-9 breaks down the total expenditures by Federal, State, and local governments. The numbers in the table indicate the level of government that provided the funding for those expenditures.

In 2018, the Federal government funded $49.8 billion, or about one-fifth, of total expenditures. More than half of total expenditures were funded by States ($124.1 billion) and 28.9 percent by local governments ($70.6 billion). Compared with 2008, the shares of expenditures funded by each level of government remained relatively stable.

Total expenditures increased from $188.5 billion in 2008 to $244.5 billion in 2018, growing at an average rate of 2.6 percent per year. (Note that this represents growth in nominal-dollar terms; see the Constant-dollar Expenditures section for a discussion of inflation-adjusted expenditure trends.) This growth was driven by an expansion of locally funded expenditures, which rose by 3.1 percent annually. The annual growth rate of expenditures funded by the Federal government and local governments was 2.3 and 2.5 percent per year, respectively.

Exhibit 2-9: Highway Expenditures by Level of Government, 2008–2018



Level of Government	2008	2010	2012	2014	2016	2018	Share in 2018	Annual Rate of Change 2018/2008
Funded by Federal Government	$39.8	$46.1	$47.3	$46.7	$48.2	$49.8	20.4%	2.3%
Funded by State Governments	$96.6	$98.7	$105.2	$111.8	$110.1	$124.1	50.7%	2.5%
Funded by Local Governments	$52.2	$59.5	$65.8	$64.1	$68.5	$70.6	28.9%	3.1%
Total	**$188.5**	**$204.3**	**$218.4**	**$222.6**	**$226.7**	**$244.5**	**100.0%**	**2.6%**
Net Intergovernmental Transfers from (to) Other Levels of Government								
Federal	($36.9)	($42.5)	($44.1)	($43.6)	($43.2)	($46.5)		
State	$21.6	$28.4	$27.4	$29.9	$28.3	$26.4		
Local	$15.2	$14.1	$16.7	$13.7	$14.9	$20.1		
Direct Expenditure								
Federal	$2.9	$3.6	$3.2	$3.2	$5.0	$3.3	1.4%	1.4%
State	$118.2	$127.1	$132.6	$141.6	$138.4	$150.5	61.6%	2.4%
Local	$67.4	$73.6	$82.6	$77.7	$83.4	$90.7	37.1%	3.0%
Total	**$188.5**	**$204.3**	**$218.4**	**$222.6**	**$226.7**	**$244.5**	**100.0%**	**2.6%**

Note: Dollar values are in billions.

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

Exhibit 2-9 also presents intergovernmental transfers and direct expenditures by level of government, excluding any funds transferred to another entity or placed in reserve. Direct expenditures at one level of government plus net intergovernmental transfers from it equal the amount of expenditures funded by the same level of the government (a negative value of net intergovernmental transfer means funds are transferred out to other units of governments). For example, the Federal government funded $49.8 billion of highway expenditures in 2018 (upper part of table in *Exhibit 2-9*), but only $3.3 billion was direct Federal spending (lower part of table), primarily on Federally owned roads. The majority of federally funded government expenditures were in the form of transfers from the Federal government to State and local governments ($46.5 billion). In other words, the direct expenditures at the Federal level ($3.3 billion) are the combination of the federally funded expenditure ($49.8 billion) plus net intergovernmental transfers into it ($46.5 billion). Similarly,

KEY TAKEAWAY

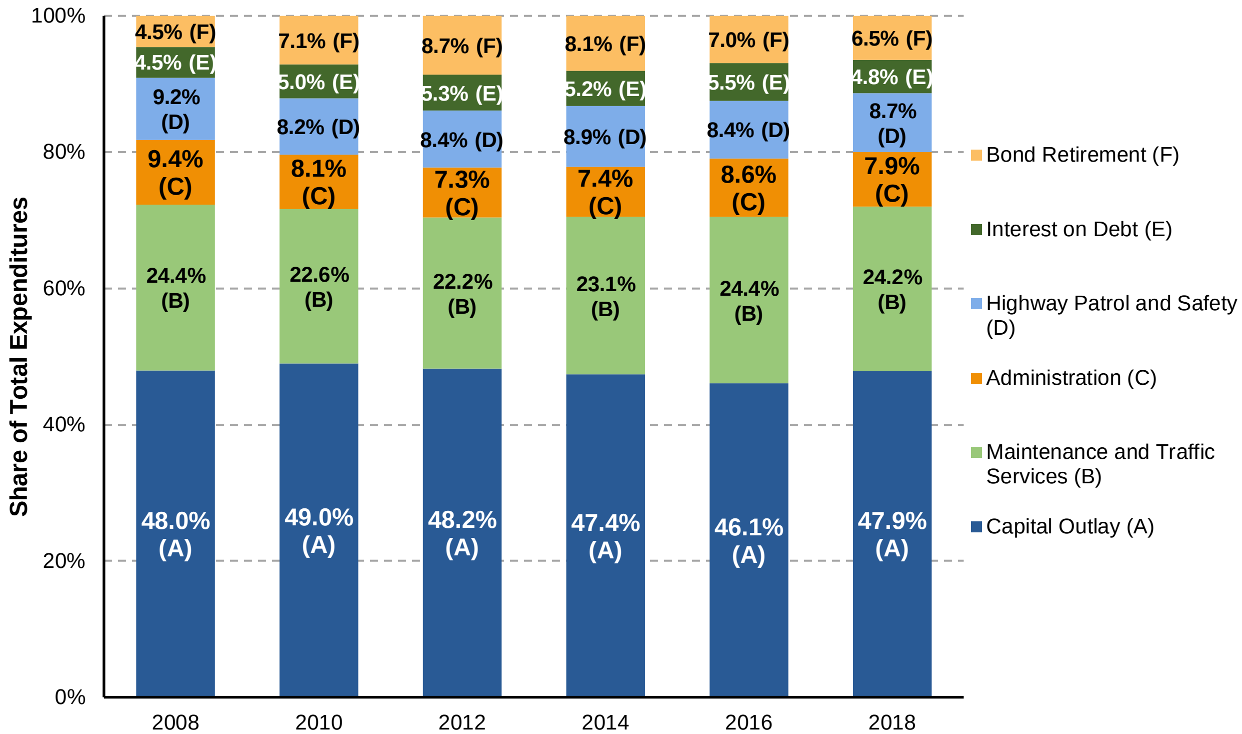
All levels of government spent a combined $244.5 billion for highway-related purposes in 2018. Just less than half (48 percent) of total highway spending ($117.0 billion) was for capital improvements to highways and bridges; the remainder included expenditures for physical maintenance, highway and traffic services, administration, highway safety, bond interest, and bond retirement.

State direct expenditures were $150.5 billion, far exceeding the State-funded expenditures of $124.1 billion, with the difference supported mostly by Federal-to-State transfers. Inbound transfers also explain the difference between expenditures that were locally funded ($70.6 billion) and local direct expenditures ($90.7 billion).

Expenditures by Type

Exhibit 2-10 breaks down highway and bridge expenditures by type. Current expenditures accounted for about 93.5 percent of total government expenditures on highways in 2018, with the remaining 6.5 percent coming from bond retirement. Total current expenditures included $228.6 billion of highway capital expenditures; more than half was dedicated to capital outlay ($117.0 billion), representing 47.9 percent of total expenditures (top bar chart of *Exhibit 2-10*).

Exhibit 2-10: Highway Expenditures by Type, 2008–2018



Expenditure Type	2008	2010	2012	2014	2016	2018	Annual Rate of Change 2018/2008
Capital Outlay (A)	$90.4	$100.0	$105.3	$105.4	$104.5	$117.0	2.6%
Maintenance and Traffic Services (B)	$45.9	$46.3	$48.5	$51.4	$55.3	$59.1	2.6%
Administration (C)	$17.8	$16.5	$16.0	$16.4	$19.5	$19.4	0.9%
Highway Patrol and Safety (D)	$17.3	$16.8	$18.3	$19.8	$19.1	$21.2	2.0%
Interest on Debt (E)	$8.5	$10.1	$11.5	$11.5	$12.5	$11.8	3.3%
Subtotal: Current Expenditures	**$180.0**	**$189.7**	**$199.5**	**$204.6**	**$211.0**	**$228.6**	**2.4%**
Bond Retirement	$8.6	$14.6	$18.9	$17.9	$15.8	$15.9	6.4%
Total Expenditures	**$188.5**	**$204.3**	**$218.4**	**$222.6**	**$226.7**	**$244.5**	**2.6%**

Note: Dollar values are in billions.

Sources: *Highway Statistics*, various years, Tables HF-10A; Highway Statistics 2018, Table HF-10.

Approximately $111.6 billion was spent on noncapital expenditures, including maintenance and traffic services, administration, highway patrol and safety, and bond interest. The highest noncapital expenditure type was maintenance and traffic services, which amounted to $59.1 billion (24.2 percent of total expenditures), followed by highway patrol and safety at $21.2 billion (8.7 percent), administration at $19.4 billion (7.9 percent), and interest on debt at $11.8 billion (4.8 percent). The proportion of each expenditure type barely changed during the 2008–2018 period, with a small increase in the share of capital outlay and a small decrease in the share of administration.

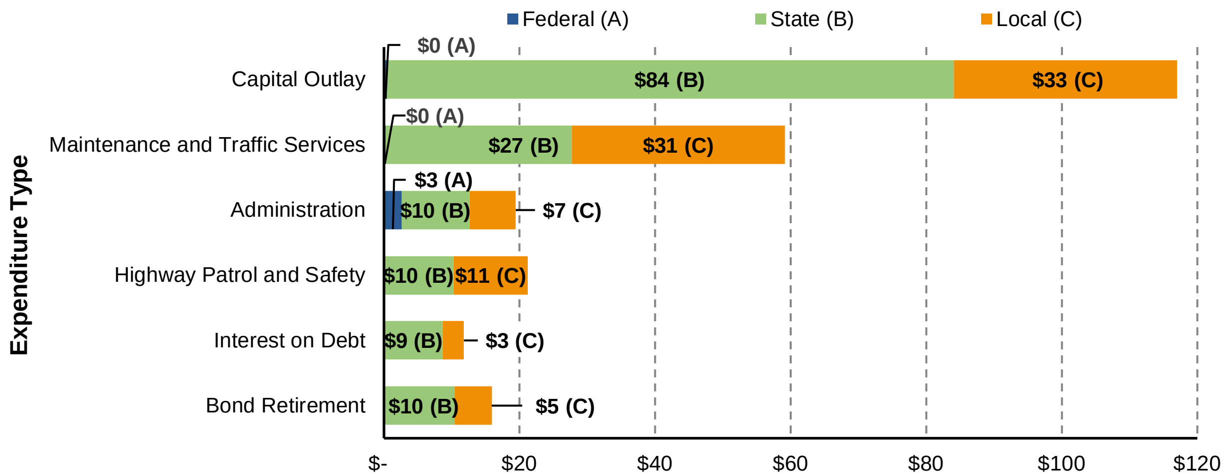
Total highway expenditures have grown at an annualized rate of 2.6 percent, and current expenditures grew at 2.4 percent in the 10-year period from 2008 to 2018 (lower part of *Exhibit 2-10*). The top two expenditure types, capital outlay and maintenance and traffic control, increased at similar rates over the course of that time. Expenditures related to debt service increased at higher annual rates: expenditures directed to bond retirement increased by 6.6 percent yearly and payments for interest on debt increased by 3.3 percent annually between 2008 and 2018. Administration expenditures increased at a much slower pace of 0.9 percent per year, whereas expenditures for highway patrol and safety increased at a rate of 2.0 percent annually.

Direct Expenditures by Type and Level of Government

Non-Federal spending was the main form of direct expenditures, especially in the form of State direct expenditures (*Exhibit 2-11*). In 2018, State and local governments represented $150.5 billion and $90.7 billion of direct expenditures, respectively, whereas Federal direct expenditures were only $3.3 billion.

States were the major spending entity in several expenditure types. They accounted for 71.4 percent ($83.6 billion) of total capital outlay, 73.7 percent of interest on debt, and 65.7 percent of bond retirement. States also directly supported about half of other expenditure types. More than half of maintenance and traffic services, as well as highway patrol and safety, were directly supported by local governments (53.1 percent and 51.5 percent, respectively). Local governments provided more than one-third of direct highway expenditures for administration and bond retirement, and were an important player in providing more than a quarter of expenditures spent directly on capital outlay and debt service.

Exhibit 2-11: Direct Highway Expenditures by Type and Level of Government, 2018



Expenditure Type	Federal	State	Local	Total	Share of State	Share of Local
Capital Outlay	$0.5	$83.6	$33.0	$117.0	71.4%	28.2%
Maintenance and Traffic Services	$0.2	$27.5	$31.4	$59.1	46.5%	53.1%
Administration	$2.6	$10.0	$6.8	$19.4	51.5%	35.0%
Highway Patrol and Safety		$10.3	$10.9	$21.2	48.5%	51.5%
Interest on Debt		$8.7	$3.1	$11.8	73.7%	26.3%
Subtotal: Current Expenditures	**$3.3**	**$140.1**	**$85.2**	**$228.6**	**61.3%**	**37.3%**
Bond Retirement		$10.4	$5.5	$15.9	65.7%	34.3%
Total, All Expenditures	**$3.3**	**$150.5**	**$90.7**	**$244.5**	**61.6%**	**37.1%**

Note: Dollar values are in billions.

Source: *Highway Statistics* 2018, Table HF-10.

Highway Capital Outlay

Capital outlay maintains and expands the functions of highways and bridges. Highways, streets, and roads are common types of capital projects, including repairs, resurfacing, reconstruction, and expansion of highway systems. Bridges are also an important part of highway capital investment, including rehabilitation of bridges as well as new bridge construction.

Capital Outlay by Level of Government

In 2018, State and local governments funded $70.0 billion of capital outlay, 59.9 percent of total capital investment of $117.0 billion (*Exhibit 2-12*). The remaining $47.0 billion, or 40.1 percent, was funded by the Federal government. This is a sharp contrast to the breakdown in *Exhibit 2-9*, where the Federal government funded 20.4 percent of total expenditures. This contrast underscores the fact that Federal funds are used primarily for capital investment.

KEY TAKEAWAY

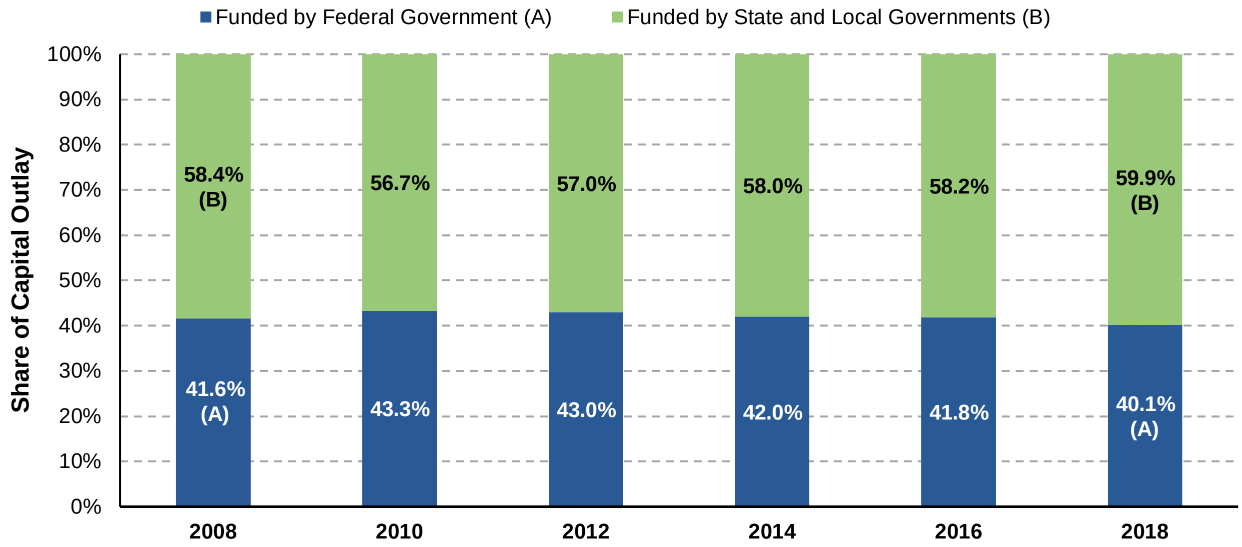
The portion of total highway capital spending funded by the Federal government decreased from 41.6 percent in 2008 to 40.1 percent in 2018. Federally funded highway capital outlay grew by 2.3 percent per year over this period, compared with a 2.9-percent annual increase in capital spending funded by State and local governments.

Total capital outlay increased at an annual average rate of 2.6 percent between 2008 and 2018, supported by 2.3-percent growth in Federal spending and 2.9-percent growth in State and local spending. The strong growth in non-Federal capital outlay resulted in the capital outlay funded by State and local governments increasing from $52.8 billion to $70.0 billion over 10 years, and the portion funded by the Federal government increased from $37.6 billion to $47.0 billion.

Although State and local governments implemented most construction projects, many were actually funded by the Federal government through intergovernmental transfers. In 2018, the Federal government provided $47.0 billion in funds, most of which went to State and local governments as intergovernmental transfers ($46.5 billion).[4] Direct capital outlay by the Federal government—the money spent directly on roads and not transferred to States or placed in reserves—was only $0.5 billion (0.4 percent of capital outlay). On the other hand, State and local governments directly spent $116.6 billion in capital expenditures, but only 60 percent ($70.0 billion) was sourced from State and local origins; the other 40 percent ($46.5 billion) was funded through receipts of transfers from the Federal government.

[4] In the computation of capital spending by the Federal government, the C&P report has traditionally made a simplifying assumption all transfers were for capital outlay. However, the same general assumption doesn't necessarily hold at the State and local governments level, as the State to local and local to State transfers often cover non-capital expenditures such as routine maintenance costs. Hence, C&P reports have traditionally presented a combined State and locally funded portion of capital outlay.

Exhibit 2-12: Highway Capital Outlay by Level of Government, 2008–2018



Level of Government	2008	2010	2012	2014	2016	2018	Share in 2018	Annual Rate of Change 2018/2008
Funded by Federal Government	$37.6	$43.3	$45.3	$44.2	$43.7	$47.0	40.1%	2.3%
Funded by State and Local Governments	$52.8	$56.7	$60.0	$61.2	$60.8	$70.0	59.9%	2.9%
Total	**$90.4**	**$100.0**	**$105.3**	**$105.4**	**$104.5**	**$117.0**	**100.0%**	**2.6%**
Net Intergovernmental Transfers from (to) Other Levels of Government								
Federal	($36.9)	($42.5)	($44.1)	($43.6)	($43.2)	($46.5)		
State and Local	$36.9	$42.5	$44.1	$43.6	$43.2	$46.5		
Direct Capital Outlay								
Federal	$0.7	$0.8	$1.1	$0.7	$0.5	$0.5	0.4%	-4.6%
State and Local	$89.7	$99.2	$104.1	$104.7	$104.0	$116.6	99.6%	2.7%
Total	**$90.4**	**$100.0**	**$105.3**	**$105.4**	**$104.5**	**$117.0**	**100.0%**	**2.6%**

Note: Dollar values are in billions.
Source: *Highway Statistics* various years, Tables HF-10A and HF-10.

Capital Outlay by Type and Category

States provide FHWA with detailed data on what they spend on arterials and collectors, classifying highway capital outlay into 17 improvement types. The improvement types fall in three broad categories: system rehabilitation, system expansion, and system enhancement[5] (*Exhibit 2-13*). These broad categories, which are also used in Part II of this report to discuss the components of future capital investment scenarios, 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.

[5] The definitions of capital outlay and maintenance come from "A Guide to Reporting Highway Statistics," available at: https://www.fhwa.dot.gov/policyinformation/hss/guide/ch8.cfm

- **System enhancement:** Safety improvements, traffic management and engineering, and environmental improvements, as well as other improvements that are not directly related to the physical structure or condition of roads and bridges.

Exhibit 2-13: Direct State Highway Capital Outlay on Arterials and Collectors by Improvement Type, 2018

Improvement Type	System Rehabilitation	System Expansion: New Roads and Bridges	System Expansion: Existing Roads	System Enhancement	Total Outlay
Right-of-Way		$1.4	$2.0		$3.4
Engineering	$7.1	$0.9	$1.1	$1.4	$10.5
New Construction		$4.4			$4.4
Relocation			$0.6		$0.6
Reconstruction—Added Capacity	$3.4		$5.1		$8.5
Reconstruction—No Added Capacity	$5.1				$5.1
Major Widening	$0.5		$2.1		$2.7
Minor Widening	$1.3				$1.3
Restoration, Rehabilitation, and Resurfacing	$25.0				$25.0
New Bridge		$0.9			$0.9
Bridge Replacement	$6.0				$6.0
Major Bridge Rehabilitation	$0.3				$0.3
Minor Bridge Work	$4.4				$4.4
Safety				$3.6	$3.6
Traffic Management/Engineering				$1.5	$1.5
Environmental and Other				$2.7	$2.7
Total, State Arterials and Collectors	**$53.1**	**$7.5**	**$11.0**	**$9.2**	**$80.7**

Note: Dollar values are in billions.

Source: Highway Statistics 2018, Tables SF-12 and SF-12A.

Direct State expenditures on arterials and collectors totaled $80.7 billion in 2018, drawing on a combination of State revenues and transfers from the Federal government and local governments (*Exhibit 2-13*). Restoration and rehabilitation is the improvement type with the largest direct State expenditures at $25.0 billion (31 percent of the total), followed by $10.5 billion for engineering (13 percent) and $8.5 billion for reconstruction-with-added-capacity (11 percent).

Exhibit 2-13 reports direct State expenditures on arterials and collectors only. 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 NHS. *Exhibit 2-14* summarizes an estimated distribution by broad categories of improvement types in 2018 on all systems by extrapolating from the available detailed data of direct State expenditures on arterials and collectors ($80.7 billion in *Exhibit 2-13*) to the total highway system from all levels of government ($117.0 billion in *Exhibit 2-12*).

Of the $117.0 billion in total highway capital outlay on all systems, an estimated 66.1 percent ($77.3 billion) was used for system rehabilitation, 8.5 percent ($9.9 billion) for new roads and bridges, 11.3 percent ($13.3 billion) for existing roads expansion, and 14.1 percent ($16.5 billion) for system enhancement. Expenditures on arterials and collectors from all levels of government reached $97.5 billion in 2018, mostly contributed by direct State spending ($80.7 billion).

System Enhancement

System enhancement includes several components:

- **Safety Improvements.** Expenditures for a project or a significant portion of a project that provides features or devices to enhance safety.
- **Traffic management/traffic engineering.** Expenditures for traffic operation improvements that are designed to reduce traffic congestion and to facilitate the flow of traffic of people and vehicles on existing systems or to conserve motor fuels, or that are designed to reduce vehicle use or to improve transit service. Expenditures for the following types of systems would be included: intelligent transportation infrastructure (ITI), traffic signal controls, freeway management, incident management, road and bridge surveillance and control, electronic message boards, video monitoring, motorist information radio, and freeway ramp control.
- **Environmental Improvements.** Expenditures for improvements in the quality of the natural environment. Includes improvements that do not provide any increase in the level of service, in the condition of the facility, or in safety features. Typical environmental improvements include reduction in highway-related pollution and noise, protecting and enhancing ecosystems, beautification, and other environmentally related features not built as a part of the above identified improvement types.
- **Other Enhancements.** Expenditures for improvements that are not categorized above, such as construction of bicycle and pedestrian facilities such as bike paths, bicycle rest areas, and pedestrian overpasses.

Exhibit 2-14: Estimated Highway Capital Outlay by Improvement Category, 2018

Category	System Rehabilitation	System Expansion		System Enhancement	Total Outlay
		New Roads and Bridges	Existing Roads		
Direct State Expenditures on Arterials and Collectors					
Highways and Other	$42.4	$6.6	$11.0	$9.2	$69.2
Bridges	$10.7	$0.9			$11.6
Total, Arterials and Collectors	$53.1	$7.5	$11.0	$9.2	$80.7
Total, Arterials and Collectors, All Jurisdictions (Estimated)[1]					
Highways and Other	$50.7	$7.8	$12.8	$11.9	$83.3
Bridges	$13.1	$1.1			$14.2
Total, Arterials and Collectors	$63.8	$8.9	$12.8	$11.9	$97.5
Total Capital Outlay on All Systems (Estimated)[2]					
Highways and Other	$61.2	$8.8	$13.3	$16.5	$99.7
Bridges	$16.2	$1.1			$17.3
Total, All Systems	**$77.3**	**$9.9**	**$13.3**	**$16.5**	**$117.0**
Percent of Total	66.1%	8.5%	11.3%	14.1%	100.0%

Note: Dollar values are in billions.

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

[2] Improvement type distribution for Rural Local and Urban Local functional classes was estimated based on *Highway Statistics* Table SF-12A, using both the partial State data reported for these functional classes and State arterial and collector data.

Sources: *Highway Statistics* 2018, Table SF-12A, and FHWA estimates.

Estimation Procedures for *Exhibit 2-14*

Exhibit 2-14 reflects a combination of three types of estimates by functional class in 2018: one for direct State government capital expenditures on arterials and collectors, one for local government capital expenditures, and one for Federal government capital expenditures. *Exhibit 2-12* reports that direct capital expenditures in 2018 totaled $0.5 billion from the Federal government, $83.6 billion from State governments, and $33.0 billion from local governments, based on data from *Highway Statistics* Table HF-10.

At the State level, a distribution by functional class has been reported in *Highway Statistics* Table SF-12. The difference between the sum of arterials and collectors spending and total State spending is assumed to represent State capital outlay on roads functionally classified as local. At the local level, the total local government expenditures of $33.0 billion is assigned to each functional class, based on its share in State level spending adjusted for mileage and traffic volume. Similarly, the total Federal government expenditures of $0.5 billion is split by functional class, based on State level spending share adjusted for mileage and traffic volume. Spending from the Federal government, State governments, and local governments together produced a total capital outlay of $117.0 billion as in *Exhibit 2-12*.

Next, the capital outlay needs to be allocated to each of the 17 improvement types listed in *Exhibit 2-13*. *Highway Statistics* Table SF-12A shows aggregate spending by improvement type in Federal Highway Form FHWA-534 across States, reporting capital outlay by improvement type and functional class for roads on and off the NHS in 2018. The expenditures are split between system preservation and system expansion for two improvement types, as noted in *Exhibit 2-13*. The 17 improvement types are then grouped into three broad categories: system rehabilitation, system expansion, and system enhancement.

Most highway capital improvement types reported by States are easily assigned to one of the three broad categories. However, engineering is split among the three categories, and reconstruction-with-added-capacity and major widening are divided between system rehabilitation and system expansion. Based on historical outputs from the Highway Economic Requirements System (HERS), it is assumed that 40 percent of expenditures on reconstruction-with-added-capacity goes to system preservation and 60 percent to system expansion. It is also assumed that 20 percent of expenditures on major widening is used for system preservation and 80 percent for system expansion. Engineering spending is assumed to be distributed across all three categories based on the relative size of each category in total capital outlay.

The shares of each of these broad categories are multiplied by total capital outlay to produce the estimated outlay for each functional class across all levels of government shown in *Exhibit 2-14*.

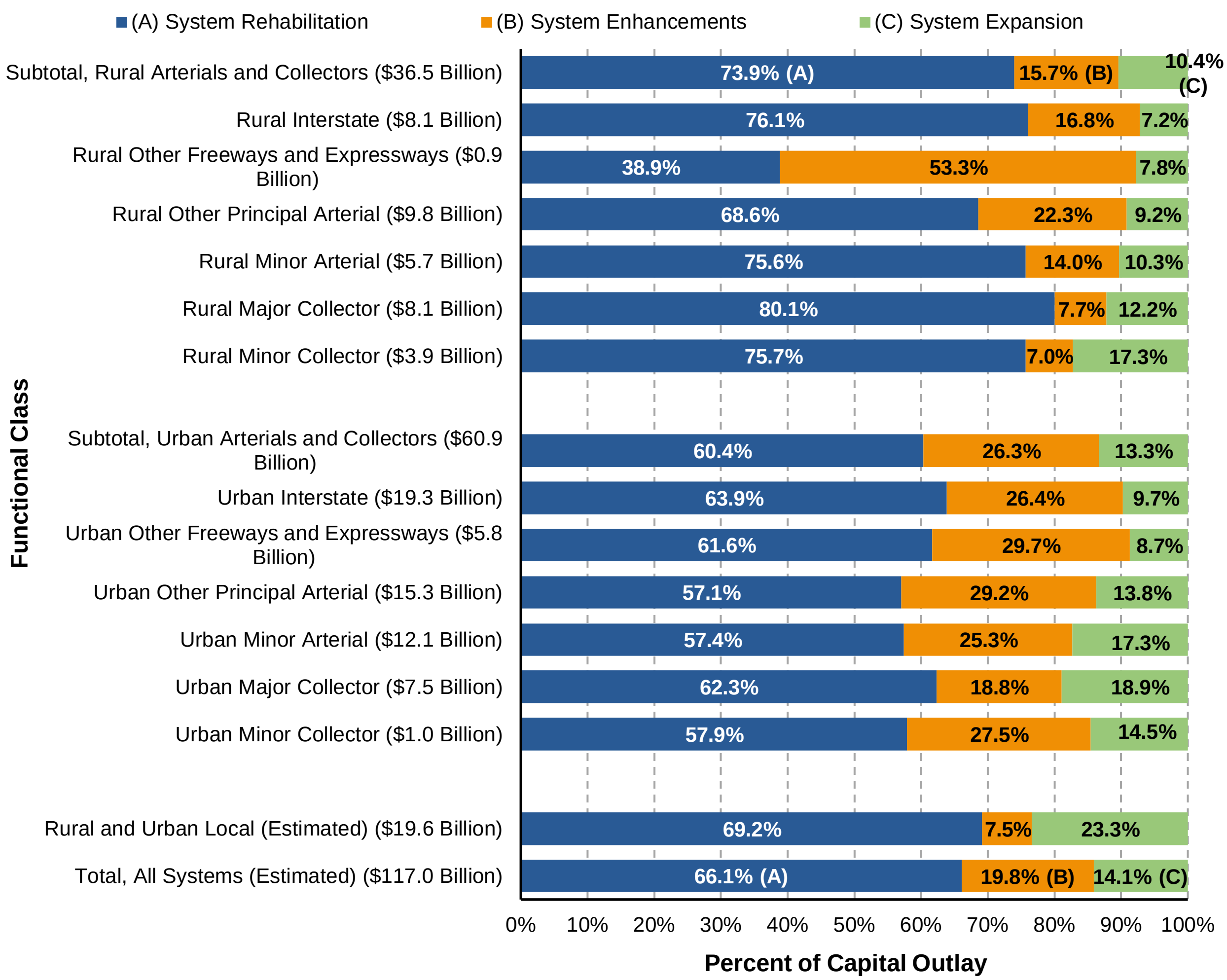
Capital Outlay by Category and Functional Class

Exhibit 2-15 shows the distribution of capital expenditures by improvement category and functional class. In 2018, $36.5 billion was invested on rural arterials and collectors, with 73.9 percent of those funds directed to system rehabilitation, 15.7 percent to expansion, and the remaining 10.4 percent to system enhancement. Capital outlay on urban arterials and collectors totaled $60.9 billion, of which 60.4 percent was for system rehabilitation and 26.3 percent was for system expansion.

> **KEY TAKEAWAY**
>
> Of the $117.0 billion spent on highway capital improvements in 2018, $27.4 billion (23 percent) was spent on the Interstate System, $59.0 billion (50 percent) was spent on the NHS (including the Interstate System), and $93.6 billion (80 percent) was spent on Federal-aid highways (including the NHS).

The proportion of funds for system rehabilitation vs. system expansion varied the most across rural arterials and collectors. Among the individual functional systems, rural major collectors had the highest percentage of highway capital outlay directed to system rehabilitation (80.1 percent), whereas rural other freeways and expressways had the lowest percentage directed for that purpose (38.9 percent). The largest portion of capital outlay for expansion occurred on rural other freeways and expressways (53.3 percent); the smallest amount occurred on rural minor collectors (7.0 percent).

Exhibit 2-15: Distribution of Capital Outlay by Improvement Category and Functional Class, 2018

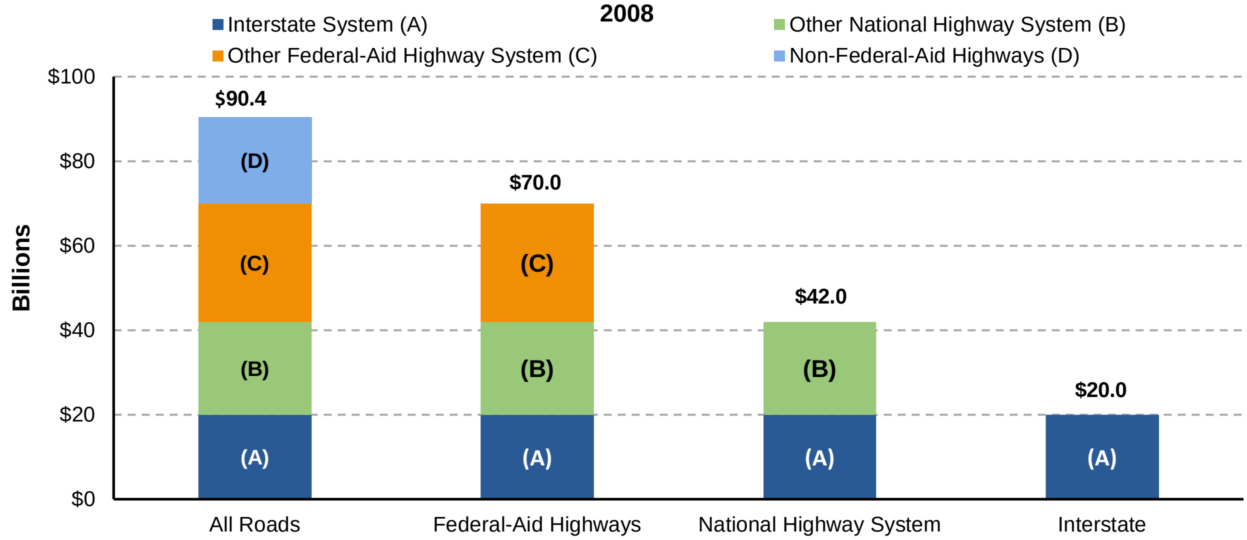


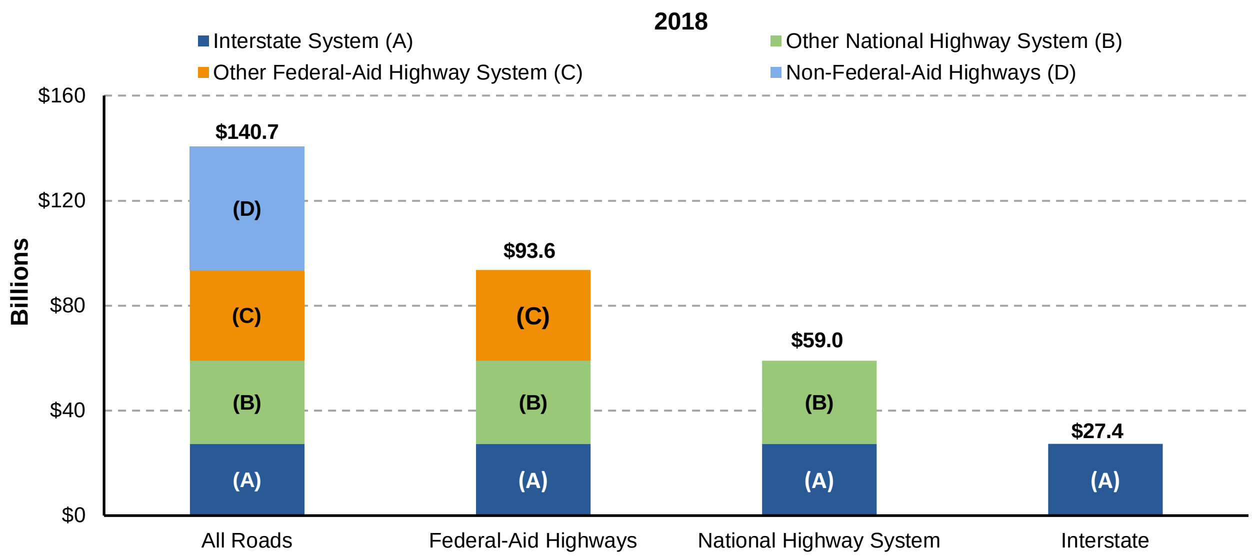
Sources: *Highway Statistics* 2018, Table SF-12A, and FHWA estimates.

Capital Outlay by Category and Highway System

Exhibit 2-16 compares the size and allocation of capital outlay by nesting highway systems between 2008 and 2018. In 2018, $93.6 billion of $117.0 billion total capital outlay for all roads was used to build, expand, or improve Federal-aid highways. Of this amount, more than half ($59.0 billion) was directed at the NHS, a part of Federal-aid highways. As a subset of the NHS, Interstates represented $27.4 billion of capital outlay.

Exhibit 2-16: Distribution of Capital Outlay by System, 2008 vs. 2018





Road System	Capital Outlay, Billions of Dollars		Share of Capital Outlay in All Roads	
	2008	2018	2008	2018
All Roads	$90.4	$117.0	100%	100%
Federal-Aid Highways	$70.0	$93.6	77.4%	80.0%
National Highway System	$42.0	$59.0	46.4%	50.4%
Interstate	$20.0	$27.4	22.1%	23.4%

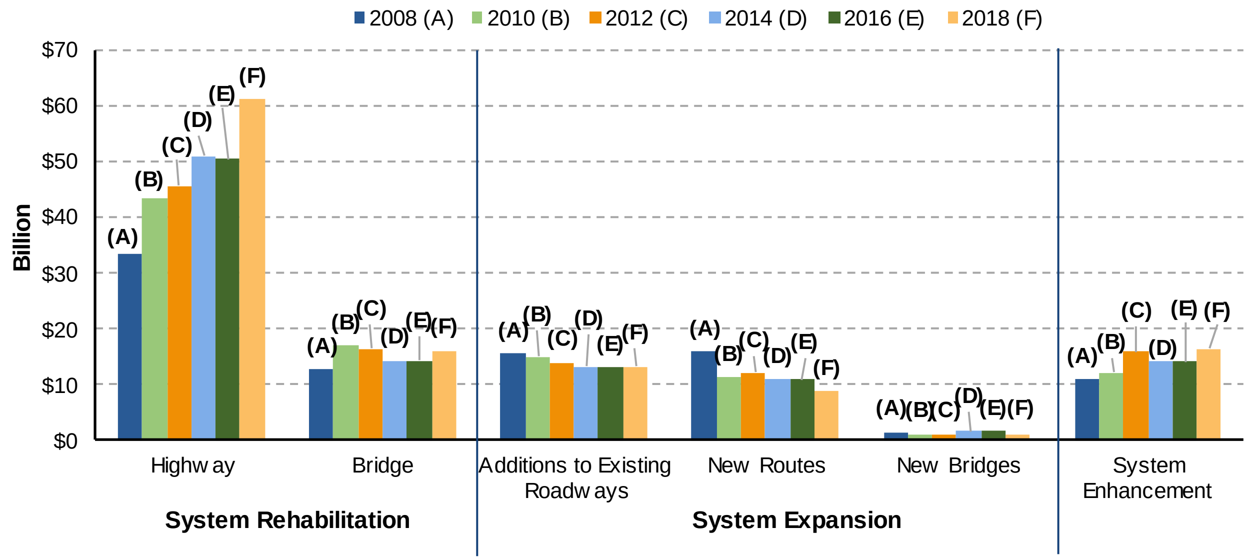
Note: Dollar values are in billions.
Sources: *Highway Statistics*, Table SF-12A, and FHWA estimates.

Total capital outlay rose from $90.4 billion in 2008 to $117.0 billion in 2018, an increase of 29 percent. The shares of total capital outlay dedicated to defined road systems increased over time. Capital expenditure on Federal-aid highways accounted for 77.4 percent of total capital outlay in 2008, and it represented a larger portion of total capital outlay in 2018 at 80.0 percent. Similarly, the NHS portion of total capital outlay on all roads rose from 46.4 percent to 50.4 percent. This increase can be attributed to the expansion of NHS in 2012, as discussed in Chapter 1. The capital share of Interstates rose from 22.1 percent to 23.4 percent.

Capital Outlay on All Roads

Exhibit 2-17 shows the allocation by improvement categories on all roads. In 2018, system rehabilitation represented about two-thirds of total capital outlay, mainly for the restoration and repair of highways (52.3 percent of total capital outlay). The second largest spending category was system expansion: 7.5 percent of total capital outlay was used for adding new routes and 11.3 percent for adding to existing roadways. About 14 percent of total capital outlay was used for system enhancement.

Exhibit 2-17: Capital Outlay on All Roads by Improvement Category, 2008–2018



Improvement Category	2008	2010	2012	2014	2016	2018	Share in 2018	Annual Rate of Change 2018/2008
System Rehabilitation								
Highway	$33.5	$43.4	$45.8	$51.0	$50.5	$61.2	52.3%	6.2%
Bridge	$12.7	$17.0	$16.4	$14.4	$14.3	$16.2	13.8%	2.5%
Subtotal	$46.2	$60.5	$62.2	$65.4	$64.8	$77.3	66.1%	5.3%
System Expansion								
Additions to Existing Roadways	$15.7	$15.0	$14.0	$13.2	$13.0	$13.3	11.3%	-1.7%
New Routes	$16.1	$11.4	$12.1	$11.0	$11.0	$8.8	7.5%	-5.8%
New Bridges	$1.5	$0.9	$1.1	$1.6	$1.6	$1.1	1.0%	-2.9%
Subtotal	$33.3	$27.4	$27.2	$25.9	$25.6	$23.2	19.8%	-3.6%
System Enhancement	$10.9	$12.2	$15.9	$14.2	$14.2	$16.5	14.1%	4.3%
Total	**$90.4**	**$100.0**	**$105.3**	**$105.4**	**$104.5**	**$117.0**	**100.0%**	**2.6%**
Percent of Total Capital Outlay								
System Rehabilitation	51.1%	60.5%	59.0%	62.0%	62.0%	66.1%		
System Expansion	36.9%	27.4%	25.8%	24.5%	24.5%	19.8%		
System Enhancement	12.0%	12.2%	15.1%	13.5%	13.6%	14.1%		

Note: Dollar values are in billions.

Sources: *Highway Statistics*, various years, Table SF-12A, and FHWA estimates.

A noticeable trend from 2008 to 2018 was that more resources were shifted to system rehabilitation at the expense of system expansion. Total expenditures increased by 2.6 percent per year during the 10-year period, driven by strong growth in expenditures on system rehabilitation at an annual average growth rate of 5.3 percent. The largest capital expenditures within system rehabilitation was for highway rehabilitation, which almost doubled from $33.5 billion in 2008 to $61.2 billion in 2018.

Meanwhile, expenditures on system expansion declined by an annual rate of 3.6 percent. This decline was due mostly to a nearly 50 percent decline in expenditures for new routes, from $16.1 billion in 2008 to $8.8 billion in 2018. Expenditures on system enhancement increased by 4.3 percent annually, but the overall dollar values remained comparatively low ($16.5 billion in 2018).

As a result, the share of capital outlay dedicated to system rehabilitation grew from 51.1 percent to 66.1 percent between 2008 and 2018, reflecting the need to preserve an aging system. At the same time, the share directed to system expansion was more than halved, plummeting from 36.9 percent to 19.8 percent. These trends further illustrate the shifting priorities toward improving and enhancing the existing highway network.

KEY TAKEAWAY

The composition of highway capital spending shifted during the 2008–2018 period. The percentage of highway capital spending directed to system rehabilitation rose from 51.1 percent in 2008 to 66.1 percent in 2018. For the same period, the percentage of spending directed to system enhancement rose from 12.0 percent to 14.1 percent, whereas the percentage of spending directed toward system expansion fell from 36.9 percent to 19.8 percent.

Capital Outlay on Federal-aid Highways

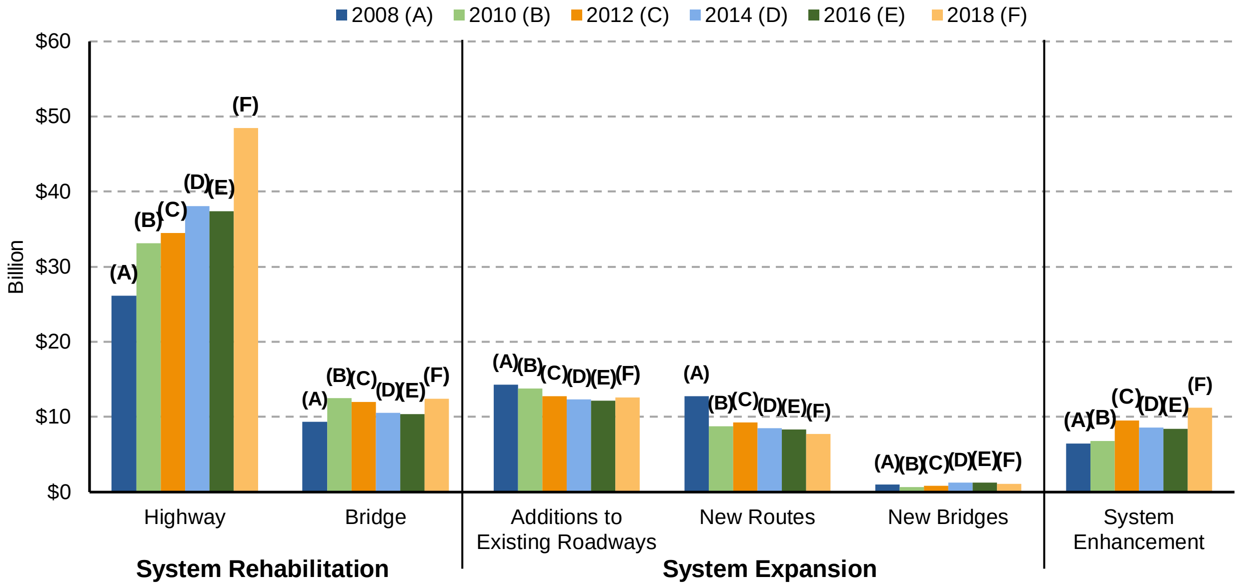
As discussed in Chapter 1, “Federal-aid highways” include all roads except those in functional classes that are generally ineligible for Federal funding: rural minor collector, rural local, or urban local. *Exhibit 2-18* shows that total capital outlay on Federal-aid highways reached $93.6 billion in 2018, increasing at an average annual rate of 3.0 percent from 2008 to 2018, slightly above the 2.6 percent annual growth for all roads. The largest increases in dollar amounts were in the later portions of this period, as total capital outlay on Federal-aid highways increased by $15.7 billion between 2016 and 2018 ($77.9 billion to $93.6 billion).

The allocations and trends for expenditures on Federal-aid highways generally mirror those for all roads in *Exhibit 2-17*, allocating slightly more resources to system expansion. The funding levels and shares for system rehabilitation and enhancement on Federal-aid highways increased between 2008 and 2018, but these increases were offset by a reduction in system expansion spending.

The share of capital outlay on Federal-aid highways directed to system rehabilitation in 2018 was 65.0 percent, below the comparable percentage for all roads of 66.1 percent. The share of system expansion on Federal-aid highways was 22.9 percent, higher than its share on all roads of 19.8 percent.

Expenditures for system rehabilitation on Federal-aid highways grew at an annual rate of 5.6 percent, comparable to that of all roads at 5.3 percent. Capital outlay on system expansion declined by 2.7 percent per year, less alarming than the 3.6 percent annual decrease on all roads. System enhancement expanded by 5.8 percent, faster than the 4.3 percent on all roads.

Exhibit 2-18: Capital Outlay on Federal-aid Highways by Improvement Category, 2008–2018



Improvement Type	2008	2010	2012	2014	2016	2018	Share in 2018	Annual Rate of Change 2018/2008
System Rehabilitation								
Highway	$26.1	$33.1	$34.5	$38.1	$37.4	$48.4	51.8%	6.4%
Bridge	$9.3	$12.5	$12.0	$10.5	$10.4	$12.4	13.3%	2.9%
Subtotal	$35.5	$45.6	$46.5	$48.6	$47.7	$60.9	65.0%	5.6%
System Expansion								
Additions to Existing Roadways	$14.3	$13.8	$12.8	$12.3	$12.1	$12.6	13.5%	-1.2%
New Routes	$12.8	$8.8	$9.3	$8.5	$8.3	$7.7	8.3%	-4.9%
New Bridges	$1.0	$0.7	$0.8	$1.2	$1.2	$1.1	1.2%	1.1%
Subtotal	$28.1	$23.3	$22.9	$22.1	$21.7	$21.5	22.9%	-2.7%
System Enhancement	$6.4	$6.8	$9.6	$8.6	$8.5	$11.3	12.0%	5.8%
Total	**$70.0**	**$75.7**	**$79.0**	**$79.3**	**$77.9**	**$93.6**	**100.0%**	**3.0%**
Percent of Total Capital Outlay								
System Rehabilitation	50.7%	60.3%	58.9%	61.4%	61.3%	65.0%		
System Expansion	40.1%	30.8%	29.0%	27.8%	27.9%	22.9%		
System Enhancement	9.2%	9.0%	12.1%	10.8%	10.9%	12.0%		

Note: Dollar values are in billions.

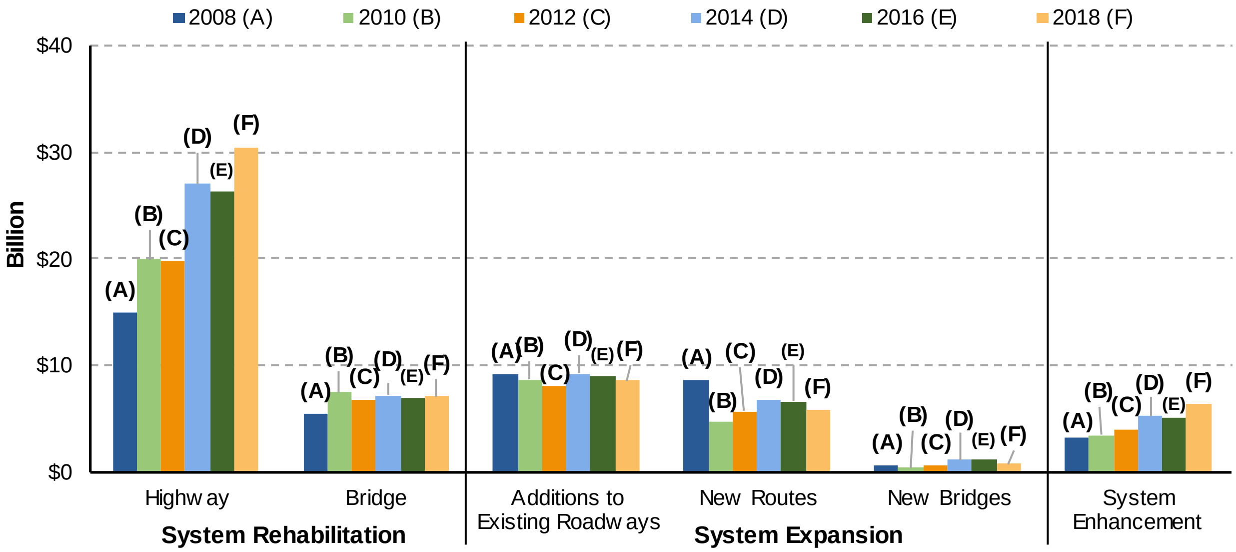
Sources: *Highway Statistics*, various years, Table SF-12A, and FHWA estimates.

Capital Outlay 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 2-19* shows that capital outlay on the NHS amounted to $59.0 billion in 2018. System rehabilitation expenditures of $37.5 billion accounted for the greatest share (63.5 percent), followed by system expansion at $15.1 billion (25.6 percent) and system enhancement at $6.3 billion (10.8 percent).

Over the 10-year period beginning in 2008, the share of system rehabilitation on the NHS climbed quickly from 48.5 percent to 63.6 percent, at the expense of system expansion. The share of capital outlay spent on system expansion declined from 43.7 percent to 25.6 percent of total capital outlay on the NHS. During the same period, the share of system enhancement on the NHS increased slightly from 7.8 percent to 10.8 percent.

Exhibit 2-19: Capital Outlay on the National Highway System by Improvement Category, 2008–2018



Improvement Type	2008	2010	2012	2014	2016	2018	Share in 2018	Annual Rate of Change 2018/2008
System Rehabilitation								
Highway	$14.9	$19.9	$19.7	$27.0	$26.3	$30.5	51.7%	7.4%
Bridge	$5.4	$7.4	$6.7	$7.1	$6.9	$7.0	11.9%	2.6%
Subtotal	$20.4	$27.3	$26.4	$34.1	$33.2	$37.5	63.6%	6.3%
System Expansion								
Additions to Existing Roadways	$9.2	$8.6	$8.0	$9.2	$9.0	$8.5	14.5%	-0.7%
New Routes	$8.6	$4.7	$5.6	$6.7	$6.6	$5.8	9.9%	-3.8%
New Bridges	$0.6	$0.3	$0.5	$1.1	$1.1	$0.8	1.3%	3.1%
Subtotal	$18.3	$13.7	$14.1	$17.0	$16.6	$15.1	25.6%	-1.9%
System Enhancement	**$3.3**	**$3.4**	**$4.0**	**$5.2**	**$5.1**	**$6.3**	**10.8%**	**6.8%**
Total	**$42.0**	**$44.4**	**$44.6**	**$56.3**	**$54.9**	**$59.0**	**100.0%**	**3.5%**
Percent of Total Capital Outlay								
System Rehabilitation	48.5%	61.6%	59.3%	60.6%	60.5%	63.6%		
System Expansion	43.7%	30.8%	31.7%	30.2%	30.3%	25.6%		
System Enhancement	7.8%	7.6%	9.0%	9.2%	9.2%	10.8%		

Notes: Dollar values are in billions.

The NHS was expanded under MAP-21 from 4.0 percent of the Nation's highway mileage to approximately 5.4 percent. For 2014 and 2016, all spending on principal arterials was assumed to have occurred on the NHS.

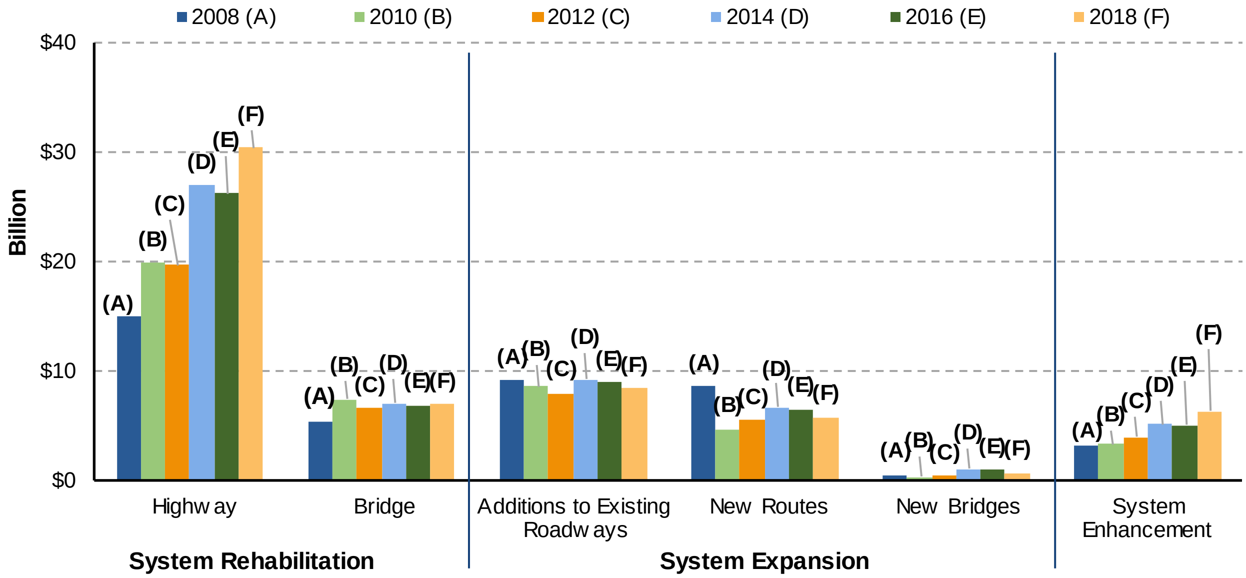
Sources: *Highway Statistics*, various years, Table SF-12A, and FHWA estimates.

Compared with capital outlay on all roads or Federal-aid highways, the share of system expansion tends to be higher: 25.6 percent versus 19.8 percent on all highways or 22.9 percent on Federal-aid highways. The trend of moving funds from system expansion to system rehabilitation remains the same, although the annual rate of decline of 1.9 percent is not as deep as the decrease on all roads (3.6 percent) or Federal-aid highways (2.9 percent).

Capital Outlay on the Interstate System

Exhibit 2-20 shows that the share of Interstate capital outlay directed to system rehabilitation in 2018 was 67.5 percent, higher than the comparable percentages for the NHS (63.6 percent), Federal-aid highways (65.0 percent), or all roads (66.1 percent). This pattern has been largely consistent since 2008; 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 expansion was 23.6 percent in 2018, higher than comparable percentages for all roads (19.8 percent) or Federal-aid highways (22.9 percent), but lower than that for the NHS (25.6 percent).

Exhibit 2-20: Capital Outlay on the Interstate System by Improvement Category, 2008–2018



Improvement Type	2008	2010	2012	2014	2016	2018	Share in 2018	Annual Rate of Change 2018/2008
System Rehabilitation								
Highway	$7.5	$9.4	$8.9	$14.4	$14.0	$15.4	56.1%	7.4%
Bridge	$3.3	$4.1	$3.8	$3.2	$3.1	$3.1	11.4%	-0.5%
Subtotal	$10.8	$13.5	$12.7	$17.6	$17.1	$18.5	67.5%	5.5%
System Expansion								
Additions to Existing Roadways	$4.5	$3.5	$3.4	$3.8	$3.6	$4.6	16.7%	0.2%
New Routes	$3.0	$1.7	$2.7	$1.7	$1.6	$1.6	5.9%	-6.0%
New Bridges	$0.3	$0.1	$0.2	$0.4	$0.4	$0.3	1.0%	-0.6%
Subtotal	$7.8	$5.3	$6.3	$5.9	$5.7	$6.5	23.6%	-1.9%
System Enhancement	**$1.4**	**$1.4**	**$1.5**	**$1.8**	**$1.8**	**$2.5**	**9.0%**	**5.6%**
Total	**$20.0**	**$20.2**	**$20.5**	**$25.3**	**$24.5**	**$27.4**	**100.0%**	**3.2%**
Percent of Total Capital Outlay								
System Rehabilitation	53.9%	66.7%	62.1%	69.6%	69.6%	67.5%		
System Expansion	38.9%	26.3%	30.5%	23.2%	23.2%	23.6%		
System Enhancement	7.1%	6.9%	7.3%	7.2%	7.2%	9.0%		

Notes: Dollar values are in billions.

Sources: *Highway Statistics*, various years, Table SF-12A, and FHWA estimates.

From 2008 to 2018, capital outlay on the Interstate System increased annually by an average of 3.2 percent to $27.4 billion in 2018, above the 2.6-percent annual increase observed for all roads or 3.0 percent for all Federal-aid highways, but below the 3.5 percent for the NHS.

The portion of expenditures going to system rehabilitation on the Interstate System increased by 13.6 percentage points from 53.9 percent in 2008 to 67.5 percent in 2018. In contrast, the portion expended on system expansion fell by 15.4 percentage points, from 38.9 percent in 2008 to 23.6 percent in 2018.

KEY TAKEAWAY

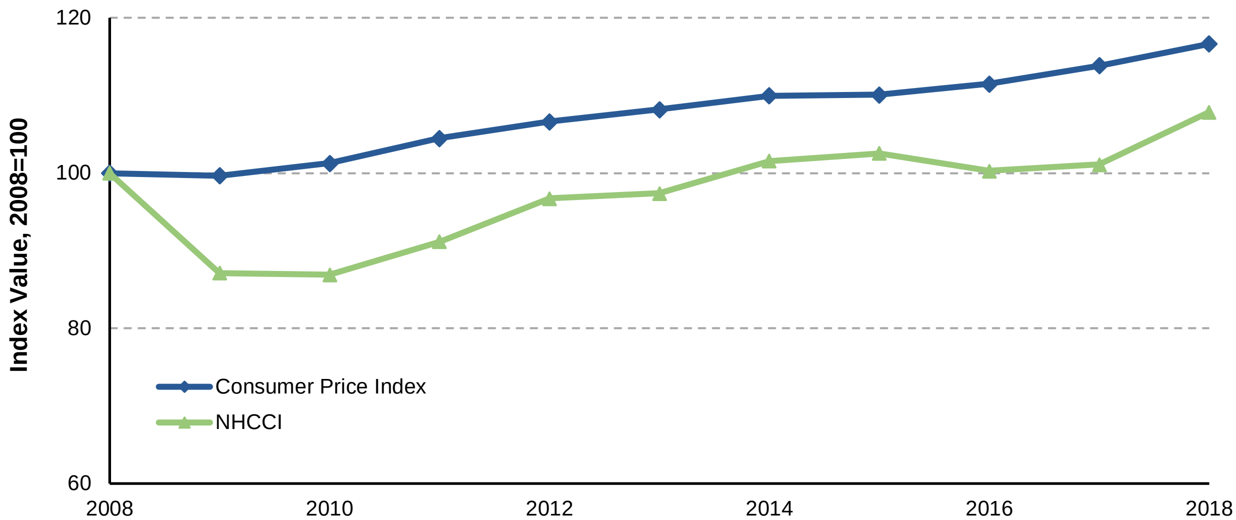
Highway capital expenditures rose from $90.4 billion in 2008 to $117.0 billion in 2018, a 29.5-percent increase (2.6 percent per year) in nominal dollar terms; after adjusting for inflation this equates to a 20.0-percent increase (1.8 percent per year).

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 (same base year) 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 compared with highway construction activities. The FHWA National Highway Construction Cost Index (NHCCI) version 2.0 provides constant-dollar conversions for highway capital outlay. Constant-dollar conversions for other types of highway expenditures are based on the Bureau of Labor Statistics' Consumer Price Index.

Exhibit 2-21 illustrates the trends in cost indices used in the report, converted to a common base year of 2008. Over the 10-year period from 2008 to 2018, the Consumer Price Index increased by 16.6 percent from the 2008 base index of 100, significantly higher than the 7.9-percent increase in the NHCCI.

Exhibit 2-21: Comparison of Inflation Indices (Converted to a 2008 Base Year), 2008–2018



Note: To facilitate comparisons of trends from 2008 to 2018, each index was mathematically converted so that its value for the year 2008 would be equal to 100.

Sources: *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 over the 10-year study period, the NHCCI fluctuated significantly. Highway construction prices as measured by the NHCCI declined dramatically from 2008 to 2009 by 12.9 percent, remained fairly flat in 2010, and then resumed an upward trend. The value of the NHCCI didn't fully recover to its 2008 level until 2014.

Exhibit 2-22 displays time-series data on highway expenditures from all levels of government in both current (nominal) and constant (real) 2018 dollars. Capital outlay is converted from current to constant 2018 dollars using NHCCI, whereas noncapital expenditures are converted using the Consumer Price Index.

KEY TAKEAWAY

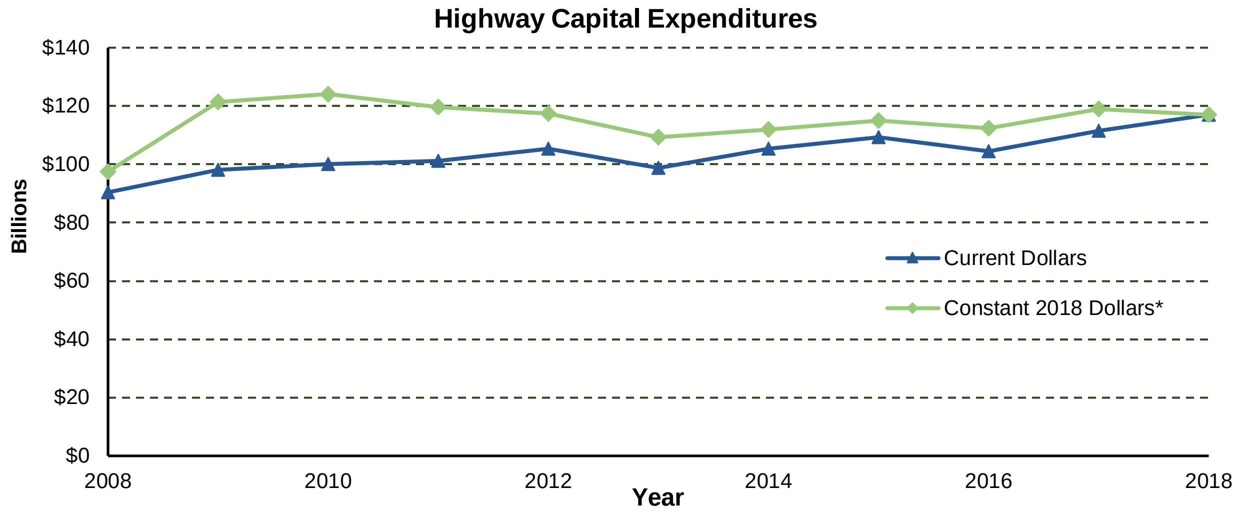
In nominal-dollar terms, highway spending increased by 29.7 percent (2.6 percent per year) from 2008 to 2018; after adjusting for inflation this equates to a 15.4-percent increase (1.4 percent per year).

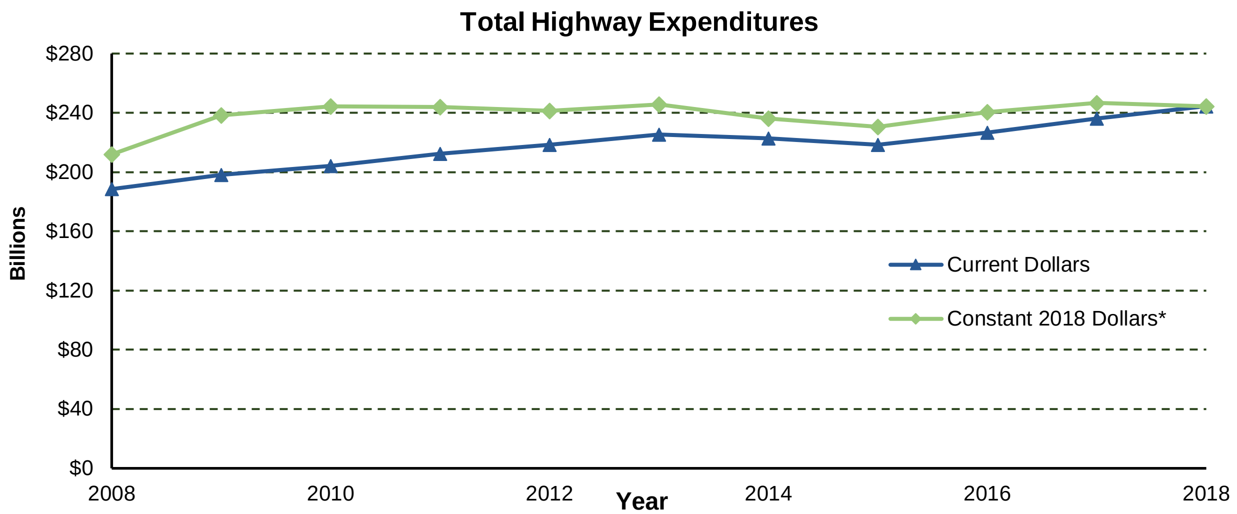
The differences between current and constant values are noticeable over a decade. Measured in current terms, highway capital outlay grew by approximately 29.5 percent from $90.4 billion in 2008 to $117.0 billion in 2018, or at annualized rate of 2.6 percent. When expressed in constant 2018 dollars, the cumulative growth dropped to 20.0 percent from $97.5 billion to $117.0 billion, or at a more modest rate of 1.8 percent per year. The current and constant series converge in 2018, as the constant series is measured in 2018 dollars. Capital outlay expressed in constant 2018 dollars exhibited a bump between 2008 and 2011, reflecting the sharp drop of NHCCI values during the period (*Exhibit 2-21*).

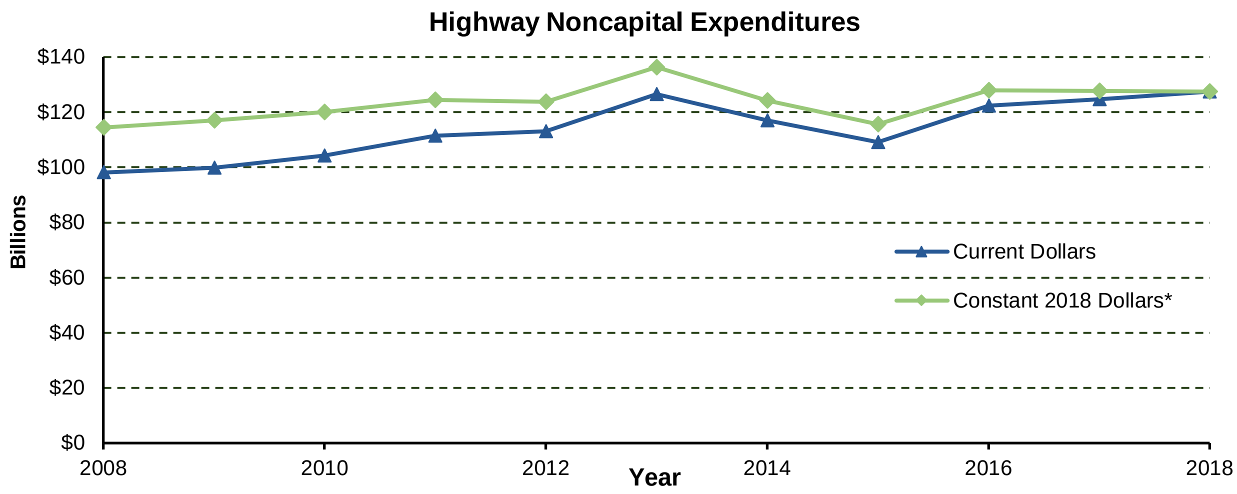
Nominal noncapital expenditures grew by 29.9 percent in the period of 2008–2018, from $98.1 billion to $127.5 billion. However, in constant 2018 dollar terms, other highway expenditures grew 11.4 percent over the same period of time, from $114.4 billion in 2008 to $127.5 billion in 2018.

Total highway expenditures are the sum of capital and noncapital expenditures. Current-value total expenditures rose from $188.5 billion in 2008 to $244.5 billion in 2018. This is a 29.7-percent increase over a decade at an annual growth rate of 2.6 percent per year. When expressed in constant 2018 dollars, total highway expenditures increased by 15.4 percent, from $211.9 billion to $244.5 billion. This increase translates into a much lower growth rate of 1.4 percent per year.

Exhibit 2-22: Highway Capital, Noncapital, and Total Expenditures in Current and Constant 2018 Dollars, All Units of Government, 2008–2018







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/).

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 *Exhibits 2-23 and 2-24,* $73.3 billion was available for transit funding in 2018. 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. Since some FTA grant programs include a mix of funds from the Mass Transit Account and from the General Fund, the NTD—which collects data by grant program—cannot distinguish the two types of funds. Additionally, the Mass Transit Account has received a number of transfers from the General Fund in recent years.

State and local governments also provide funding for transit from their General Fund appropriations, from tolls and from fuel, income, sales, property, and other taxes.

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.

In 2018, public funds of $52.0 billion were available for transit, accounting for 71 percent of total transit funding. *Exhibit 2-24* breaks down the sources of the $73.3 billion in transit funding for all areas. Of this amount, Federal funding was $12.0 billion and 17 percent of all transit funding. State funding was $15.6 billion, accounting for 21 percent of all transit funding. Local jurisdictions provided $18.5 billion in 2018, or 33 percent of all transit funding. System-generated revenues were $28.4 billion, or 29 percent of all transit funding.

SECTION SUMMARY

- Passenger fares contributed $15.9 billion, or 23 percent of all transit funds. Other directly generated funds such as parking revenues, concessions, and other sources contributed $12.5 billion, or 16 percent.
- Public assistance accounted for 63 percent of all funds, of which Federal funds accounted for 30 percent, State for 32 percent, and local for 38 percent.
- Capital investment increased from $16.1 billion in 2008 to $18.7 billion in 2018, excluding directly generated sources; all capital investments totaled $21.5 billion in 2018.
- Capital investments in rehabilitation of existing assets and expansion in 2018 were $15 billion and $6 billion, respectively, a 70/30-percent split.

Financial Indicators of the Top 10 Transit Agencies

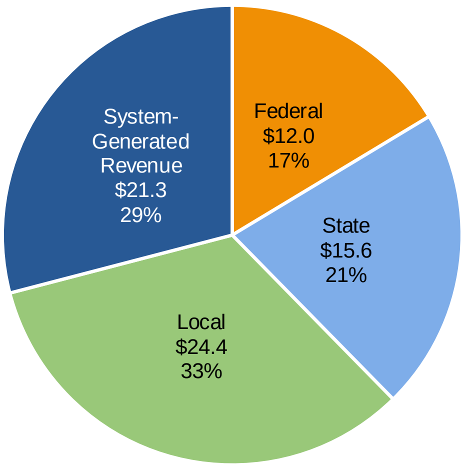
- The average recovery ratio (fare revenues per total operating expenses) of the top 10 transit agencies ranged between 42 percent and 46 percent from 2008 to 2018.
- Average fare revenues per mile increased by 35 percent, from $4.80 per mile in 2008 to $6.50 per mile in 2018 (constant dollars).
- Operating cost per mile increased for the top 10 transit operators by 17.1 percent, from $12.60 per mile in 2008 to $14.80 per mile in 2018. Average labor costs for the top 10 transit agencies increased by 7.3 percent, from $8.89 per mile in 2008 to $9.55 per mile in 2018.

Exhibit 2-23: Revenue Sources for Transit Funding, 2018

Fund Source	Revenue Sources					Percent
	Directly Generated Funds	Federal	State	Local	Total	
Public Funds		$12,032	$15,558	$24,450	$52,040	71%
General Fund		$1,925	$4,648	$6,176	$12,750	17%
State Transportation Funds			$10,451		$10,451	14%
Fuel Tax		$10,107		$218	$10,325	14%
Income Tax				$214	$214	0.3%
Sales Tax				$13,171	$13,171	18%
Property Tax				$2,061	$2,061	3%
Other Dedicated Taxes				$97	$97	0.1%
Other Public Funds				$1,774	$1,774	2%
Reduced Reporter Fed/State/Local		$680	$458	$738	$1,876	3%
System-Generated Revenue	$21,255				$21,255	29%
Passenger Fares	$15,891				$15,891	22%
Other Revenue	$5,365				$5,365	7%
Total All Sources					**$73,295**	**100%**

Note: Dollar values are in millions.
Source: National Transit Database.

Exhibit 2-24: Public Transit Revenue Sources, 2018



Note: Dollar values are in billions; total is $73.3 billion.
Source: National Transit Database.

Federal Funding

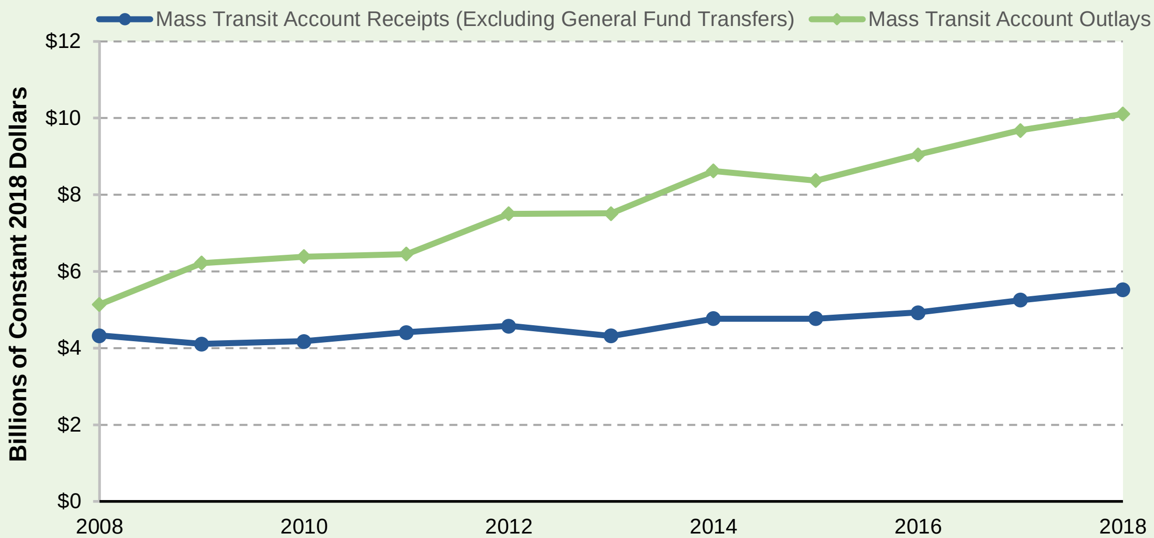
Federal funding for transit comes from two sources: the general revenues of the U.S. government and revenues generated from fuel taxes credited to the Highway Trust Fund's MTA. The Transit Account is generally the largest source of Federal funding for transit. Of the funds authorized for transit grants in the Federal Transit Administration's (FTA's) 2018 budget, 72 percent were derived from the Transit Account. Much of the transit funding from the Highway Trust Fund is distributed to States and urbanized areas by legislatively defined formulas. A smaller part is distributed by FTA competitively.

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. In recent years, Congress has used general revenues on a number of occasions to top up the balances of the Mass Transit Account. Additionally, Congress in recent years has often made additional general fund appropriations to supplement funds from the Mass Transit Account for a number of FTA programs. Finally, it is worth noting that FTA's largest discretionary program, the Capital Investment Grants Program, has historically been funded from the General Fund, rather than the Highway Trust Fund.

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

As shown in *Exhibit 2-25*, for each of the 10 years since 2008 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 2-25: Mass Transit Account Receipts and Outlays, Fiscal Years 2008–2018



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/2015/fe10.cfm).

Since 1973, Federal statutes authorizing surface transportation have contained flexible funding provisions that enable transfers from certain highway funds to transit programs and vice versa. Transfers are subject to State and regional/local discretion, and priorities are established through Statewide transportation planning processes. Forty-seven States and the District of Columbia participate in the flexible funding program. The U.S. Territories do not participate. Flexible funding transferred from highways to transit fluctuates from year to year and is drawn from several different sources.

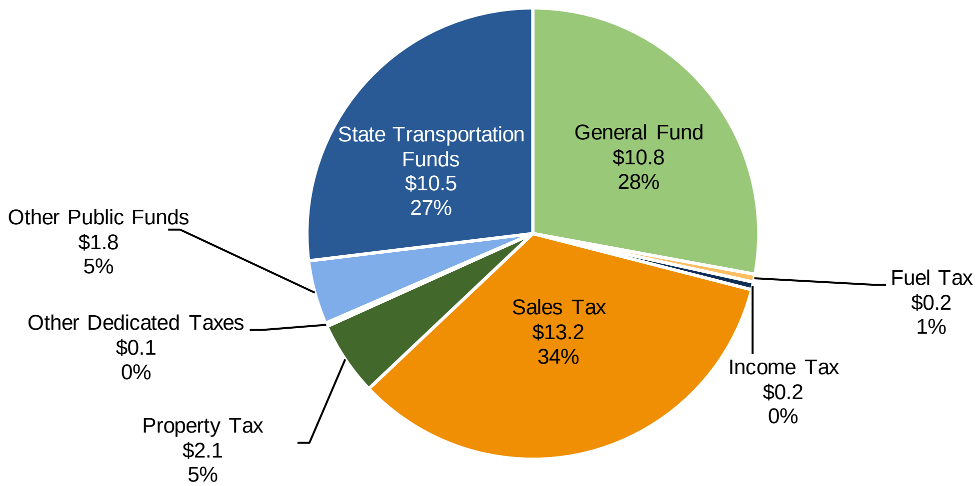
The Surface Transportation Block Grant Program is the primary source of FHWA funds that are "flexed" to FTA to pay for transit projects. Funding may be used for up to 80 percent of the eligible project costs. All capital and maintenance projects eligible for funds under current FTA programs are eligible 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

State and local 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 2-26*. Taxes—including fuel, sales, income, property, and other dedicated taxes—provide 29 percent of public funds for State and local sources. General funds provide 28 percent of transit funding, other public funds provide 5 percent, and State transportation funds provide the remaining 30 percent. Urban full reporters received $38.8 billion in State and local funds out of the $40.0 billion State and local funds received by all reporters.

Exhibit 2-26: State and Local Sources of Urban Transit Funding



Note: Dollar values are in billions.
Source: National Transit Database.

System-generated Funds

System-generated funds totaled $21.3 billion in 2018, providing 37 percent of total transit funding. Passenger fares contributed $15.9 billion, accounting for 21 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

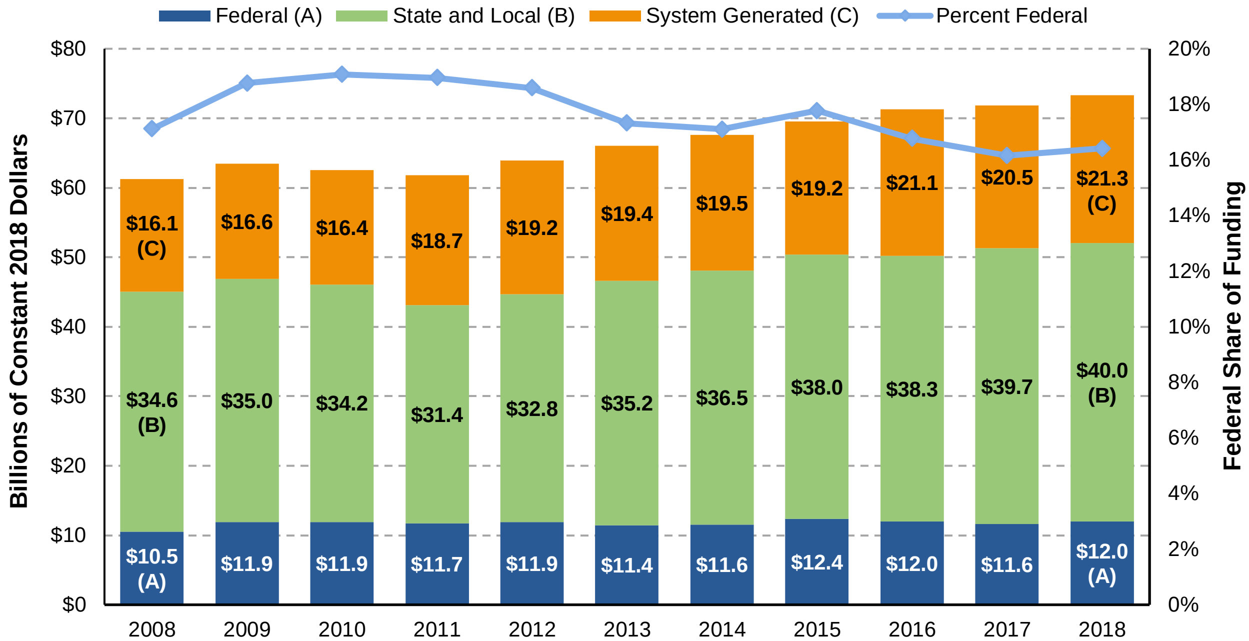
Between 2008 and 2018, public funding for transit increased at an average annual rate of 1.4 percent in constant dollars. These trends are shown in *Exhibit 2-27*.

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 2-27* shows that since 2008, the Federal government has provided between 16 and 19 percent of total funding for transit (including system-generated funds). In 2018, it provided 16 percent.

KEY TAKEAWAY

Between 2008 and 2018, after adjusting for inflation (constant dollars), public funding for transit increased at an average annual rate of 1.4 percent. Federal funding increased at an average annual rate of 1.4 percent, and State and local funding increased at an average annual rate of 1.5 percent.

Exhibit 2-27: Funding for Urban Transit by Government Jurisdiction, 2008–2018

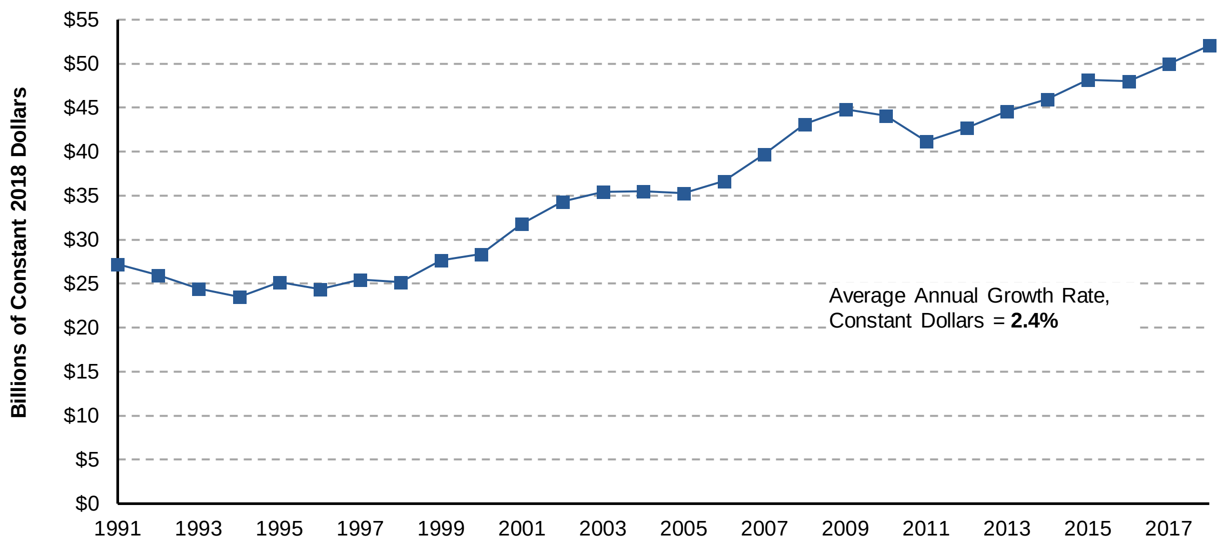


Note: Dollar values are in billions.
Source: National Transit Database.

Funding in Constant Dollars

Public funding for transit in constant (adjusted for inflation) dollars since 1991 is presented in *Exhibit 2-28*. Total public funding for transit was $52.1 billion in 2018. The growth in total funding accelerated between 2005 and 2009, then slowed and turned negative between 2009 and 2011, 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.

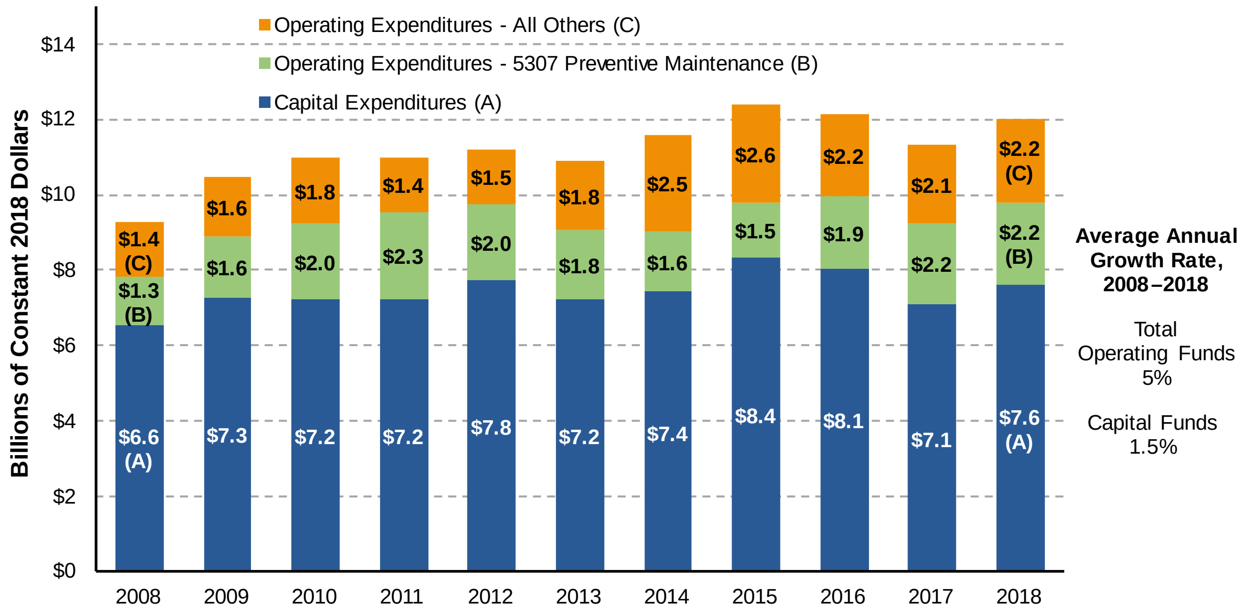
Exhibit 2-28: Public Funding for Public Transportation, 1991–2018 (All Sources)



Source: National Transit Database.

Much of the increase in Federal funds over this period went to operating expenses. In constant dollars, Federal funds directed to capital expenditures increased at an average annual rate of 1.5 percent from 2008 to 2018, whereas capital funds applied to operating expenditures increased much more rapidly by 4.5 percent per year during the same period, albeit from a much smaller base. As indicated in *Exhibit 2-29*, in 2018 $4.4 billion, or 37 percent of all Federal funds, was applied to operating expenditures and $7.6 billion (63 percent) of Federal funds was applied to capital expenditures. Half of the operating expenditures were for preventive maintenance, which is reimbursed as a capital expense under some of FTA's grant programs.

Exhibit 2-29: Application of Federal Funds for Transit Operating and Capital Expenditures, 2008–2018



Note: Dollar values are in billions.
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).

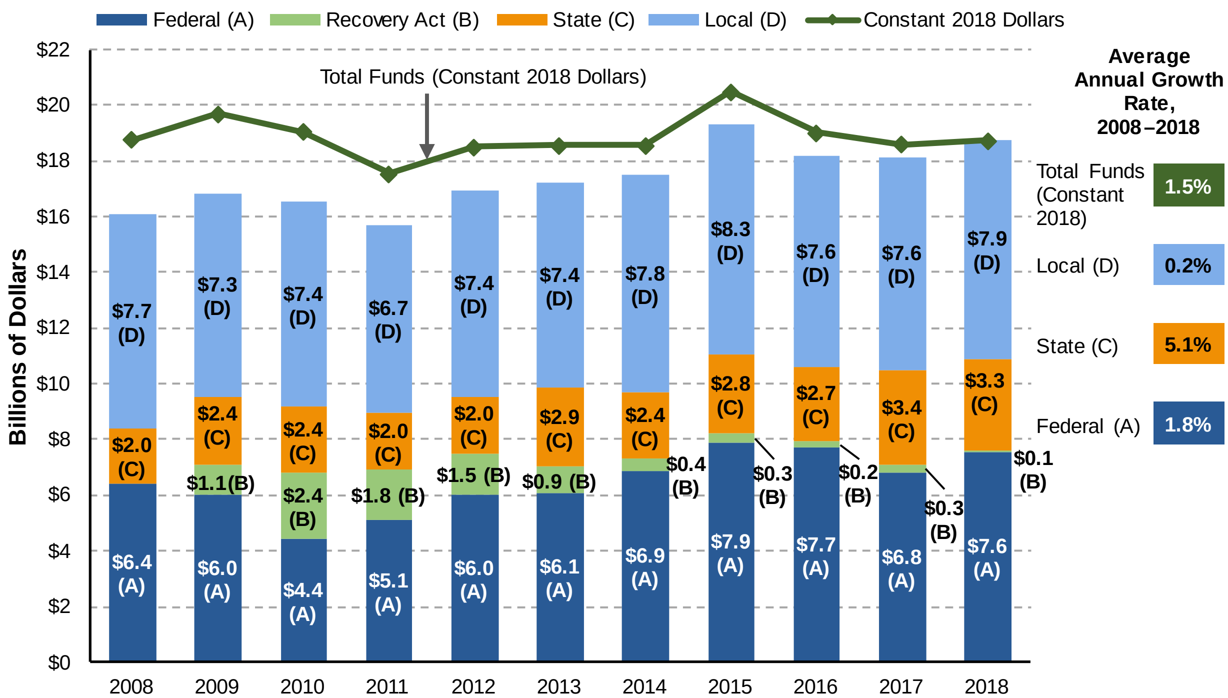
As shown in *Exhibit 2-30*, total public transit agency expenditures for capital investment were $18.7 billion in 2018, excluding directly-generated sources and other funds not from Federal, State, or Local sources. Federal funds provided $7.6 billion in 2018, accounting for 40.3 percent of total transit agency capital expenditures. State funds provided 17.5 percent and local funds provided 41.9 percent of total transit funding. Over the period 2008 to 2018, State funding for transit capital investments grew at a faster rate (5.1 percent) than did Federal or local funding (1.8 and 0.2 percent, respectively). Transit capital expenditures increased by 16.4

KEY TAKEAWAY

Expenditures for transit capital investments, excluding directly generated sources, totaled $18.7 billion in 2018, a 16.4-percent increase from 2008. Capital investments are used for the acquisition, renovation, and repair of transit vehicles, such as buses and railcars, and fixed assets, such as stations and rail guideway elements. Federal funding made up 40.7 percent of revenues for capital spending. The remaining funds came from State and local sources.

percent from 2008 to 2018. Investments from the American Recovery and Reinvestment Act of 2009 ("Recovery Act") provided as much as $2.4 billion in capital funds in 2010, but dwindled to just $0.1 billion in 2018. With directly generated sources added, the total amount of capital investment in 2018 was $21.5 billion. This expenditure accounted for 29.4 percent of total available funds for transit.

Exhibit 2-30: Sources of Funds for Urban Transit Capital Expenditures, 2008–2018



Note: Dollar values are in billions.
Source: National Transit Database.

As shown in *Exhibit 2-31*, rail modes account for approximately three-quarters of transit capital expenditures. This high percentage 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 2018, $15 billion, or 70.1 percent of total transit capital expenditures, was invested in rail modes of transportation, compared with the $6.4 billion, or 29.9 percent of the total, invested in nonrail modes. The $6.4 billion nonrail mode total includes the $354 million spent by agencies with fewer than 30 peak vehicles. This investment distribution has been consistent over the past decade.

Total guideway investment was $7.3 billion in 2018, and total investment in systems was $2.2 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 25.2 percent of total transit capital investment.

Most, but not all, major transit fixed-guideway expansion projects are constructed using Capital Investment Grant program funds. In 2018, total investment in vehicles, stations, and maintenance facilities was $5.4 billion, $3.4 billion, and $1.3 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.

Exhibit 2-31: Urban Transit Capital Expenditures by Mode and Type, 2018

Rail Capital Expenditures in Millions

Type	Commuter Rail	Heavy Rail	Light Rail	Hybrid Rail	Streetcar Rail	Other Rail[1]	Total Rail
Guideway	$2,016	$2,885	$2,013	$43	$125	$34	**$7,116**
Rolling Stock	$452	$803	$396	$4	$55	$3	**$1,713**
Systems	$487	$1,163	$127	$40	$16	$14	**$1,848**
Maintenance Facilities	$226	$313	$145	$1	$8	$3	**$695**
Stations	$471	$1,914	$470	$2	$3	$3	**$2,863**
Fare Revenue Collection Equipment	$26	$72	$26	$0	$1	$0	**$125**
Administrative Buildings	$18	$29	$8	$0	$0	$0	**$56**
Other Vehicles	$17	$34	$7	$0	$0	$2	**$61**
Other Capital Expenditures[2]	$77	$458	$4	$0	$12	$0	**$552**
Total	**$3,791**	**$7,671**	**$3,195**	**$91**	**$222**	**$60**	**$15,029**
Percentage of Total	**17.7%**	**35.8%**	**14.9%**	**0.4%**	**1.0%**	**0.3%**	**70.1%**

Nonrail Capital Expenditures in Millions

Type	Fixed-Route Bus	Bus Rapid Transit	Commuter Bus	Demand Response	Ferryboat	Trolley Bus	Vanpool	Total Nonrail
Guideway	$65	$116	$16	$0	$0	$3	$0	$200
Rolling Stock	$3,022	$8	$131	$242	$173	$91	$28	$3,694
Systems	$279	$0	$0	$11	$3	$1	$9	$302
Maintenance Facilities	$594	$6	$18	$18	$45	$0	$0	$680
Stations	$311	$3	$3	$0	$196	$0	$0	$513
Fare Revenue Collection Equipment	$94	$0	$0	$1	$1	$0	$0	$97
Administrative Buildings	$212	$0	$0	$11	$1	$2	$0	$226
Other Vehicles	$54	$0	$0	$1	$0	$0	$0	$56
Other Capital Expenditures[2]	$229	$0	$5	$5	$40	$0	$0	$281
Total	**$4,858**	**$134**	**$175**	**$289**	**$458**	**$97**	**$37**	**$6,048**
Percentage of Total	**22.7%**	**0.6%**	**0.8%**	**1.3%**	**2.1%**	**0.5%**	**0.2%**	**28.2%**

Total Expenditures for Rail and Nonrail Modes

Type	Total Rail and Nonrail	Percent of Total
Guideway	$7,316	34.1%
Rolling Stock	$5,407	25.2%
Systems	$2,150	10.0%
Maintenance Facilities	$1,375	6.4%
Stations	$3,376	15.8%
Fare Revenue Collection Equipment	$222	1.0%
Administrative Buildings	$282	1.3%
Other Vehicles	$116	0.5%
Other Capital Expenditures[2]	$833	3.9%
Agencies operating fewer than 30 peak vehicles[3]	$354	1.7%
Total	**$21,431**	**100.0%**

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

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

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

Notes: Dollar values are in millions.

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

Source: National Transit Database.

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

"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 2-32 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.

After adjusting for inflation (constant dollars), total capital expenditures from 2008 to 2018 increased by an annual average of 1.2 percent. Rehabilitation and expansion expenses increased at nearly identical rates. Average annual expenses for nonrail rehabilitation had the largest increase over this time, with an average annual increase in expansion expenses of 3.3 percent. Although nonrail spending increased at a higher rate than rail spending, total rail assets still exceed nonrail assets.

KEY TAKEAWAY

In 2018, $15.0 billion, or 71.1 percent of total transit capital expenditures, was invested in rail modes and $6.0 billion, or 28.2 percent, was invested in nonrail modes. In 2018, $18.2 billion, or 39 percent, of total transit operating expenditures was invested in rail modes, and $28.0 billion, or 61 percent, was invested in nonrail modes. Guideway investments, including at-grade rail, elevated structures, tunnels, bridges, track, and power systems, totaled $7.3 billion in 2018. Investments in vehicles, stations, and maintenance facilities totaled $10.1 billion.

Exhibit 2-32: Urban Capital Expenditures Applied by Rehabilitation or Expansion by Mode, 2008–2018

Expenditure Category	Expenditures											Average Annual Rate of Change 2018/2008
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	
Rail Rehabilitation	$9,075	$8,755	$7,149	$6,528	$6,041	$7,281	$7,128	$7,773	$8,318	$8,627	$9,233	**0.2%**
Rail Expansion	$5,256	$5,916	$6,577	$5,756	$7,216	$6,301	$6,419	$6,817	$6,469	$5,735	$5,800	**1.0%**
Rail Total	**$14,331**	**$14,671**	**$13,726**	**$12,284**	**$13,257**	**$13,581**	**$13,546**	**$14,589**	**$14,786**	**$14,363**	**$15,032**	**0.5%**
Nonrail Rehabilitation	$3,770	$4,496	$4,757	$4,570	$4,547	$4,323	$4,531	$5,320	$4,974	$5,125	$5,235	**3.3%**
Nonrail Expansion	$655	$527	$580	$601	$595	$564	$366	$478	$556	$603	$874	**2.9%**
Nonrail Total	**$4,426**	**$5,023**	**$5,337**	**$5,171**	**$5,141**	**$4,887**	**$4,897**	**$5,799**	**$5,529**	**$5,728**	**$6,109**	**3.3%**
Rehabilitation Total	$12,846	$13,250	$11,906	$11,098	$10,587	$11,603	$11,659	$13,093	$13,291	$13,752	$14,467	**1.2%**
Expansion Total	$5,911	$6,444	$7,157	$6,357	$7,811	$6,865	$6,785	$7,295	$7,024	$6,338	$6,674	**1.2%**
Grand Total	**$18,757**	**$19,694**	**$19,063**	**$17,455**	**$18,398**	**$18,468**	**$18,444**	**$20,388**	**$20,316**	**$20,090**	**$21,141**	**1.2%**

Note: Dollar values are in millions (constant dollars).

Source: National Transit Database.

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. §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. 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.

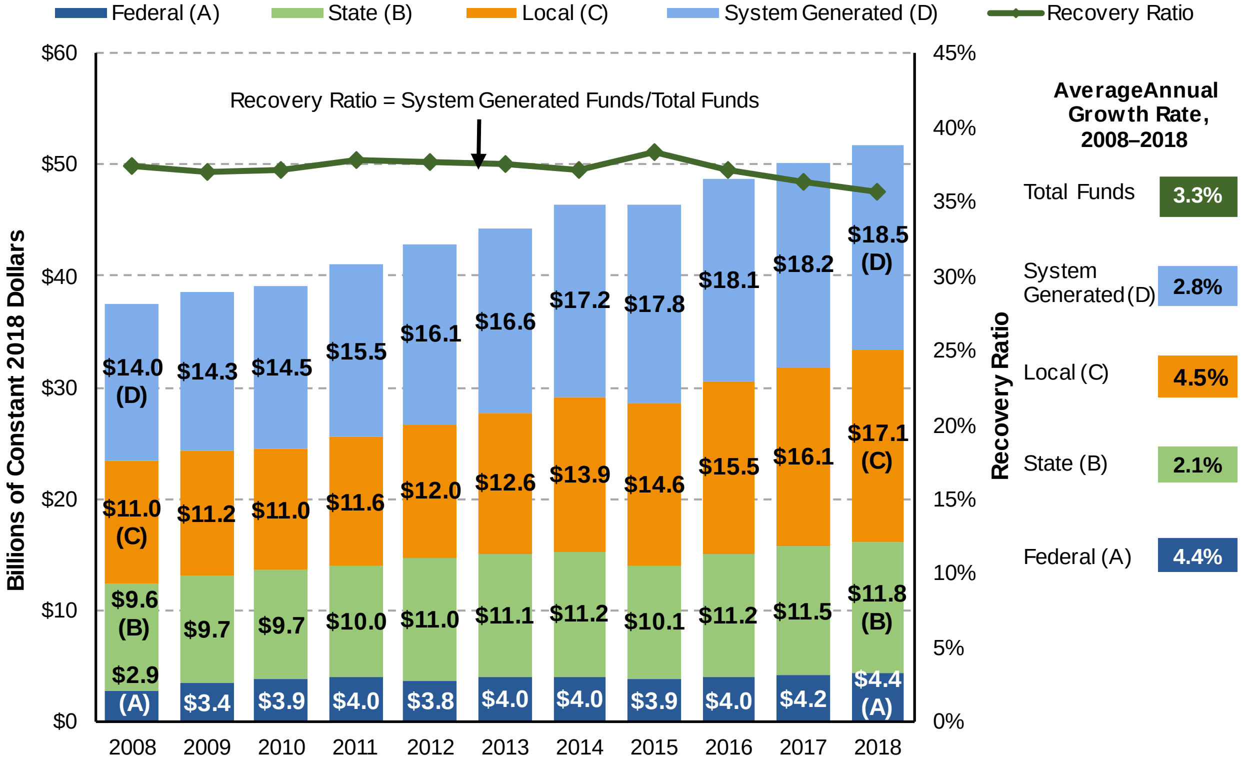
Operating Expenditures

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 2-33*, $51.8 billion was available for operating expenses in 2018. This is a 37.9-percent increase from 2008. The Federal share of operating expenses increased slightly from 7.6 percent in 2008 to 8.5 percent in 2018. The share generated from system revenues decreased slightly from 37.7 percent in 2012 to 35.6 percent in 2018. The State share also dropped, decreasing from 25.1 percent in 2013 to 22.7 percent in 2018. The local share of operating expenditures increased from 28.0 percent in 2012 to 33.1 percent in 2018.

KEY TAKEAWAY

Public transportation operating expenditures (wages, salaries, fuel, spare parts, preventive maintenance, support services, and leased transit services) totaled $51.8 billion in 2018, a 37.9-percent increase from 2008. Of this total cost, 35.6 percent was funded by system-generated revenue, of which most came from passenger fares. The Federal government provided a further 8.5 percent of revenues and the remaining funds came from State and local sources.

Exhibit 2-33: Urban Sources of Funds for Transit Operating Expenditures, 2008–2018



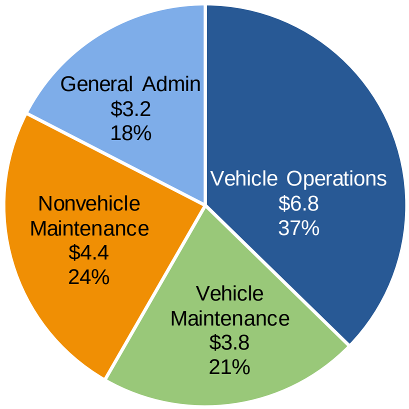
Note: Dollar values are in billions.

Sources: Transit Economic Requirements Model (TERM); National Transit Database.

Operating Expenditures by Type of Cost

Exhibits 2-34 and *2-35* illustrate how rail and non-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 2-34: Rail Operating Expenditures by Type of Cost, 2018

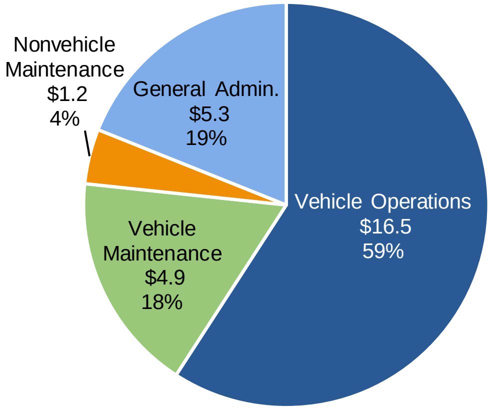


Note: Dollar values are in billions.

Note: Total rail operating expenditures were $18.2 B.

Source: National Transit Database.

Exhibit 2-35: Nonrail Operating Expenditures by Type of Cost, 2018



Notes: Dollar values are in billions.

Note: Total nonrail operating expenditures were $28.0 B.

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 2-36*, operating expenditures per VRM for all transit modes combined were $10.94 in 2018. The average annual increase in operating expenditures per VRM for all modes combined between 2008 and 2018 was 0.8 percent in constant dollars.

Exhibit 2-36: Urban Operating Expenditures per Vehicle Revenue Mile, 2008–2018

Mode	Expenditures						
	Heavy Rail	Commuter Rail	Light Rail[1]	Fixed-Route Bus[2]	Demand Response[3]	Other[4]	Total
2008	$10.90	$16.21	$16.99	$10.77	$4.85	$5.74	$10.06
2009	$11.08	$17.02	$18.49	$10.96	$4.94	$5.36	$10.21
2010	$11.33	$16.87	$19.14	$11.12	$5.09	$5.21	$10.35
2011	$11.71	$16.80	$18.75	$11.05	$4.84	$4.92	$10.24
2012	$11.97	$17.01	$18.92	$11.08	$4.83	$5.02	$10.31
2013	$13.46	$17.46	$18.52	$11.14	$4.75	$4.87	$10.58
2014	$13.94	$17.75	$19.08	$11.28	$4.75	$4.85	$10.76
2015	$14.02	$17.80	$19.50	$11.32	$4.73	$5.17	$10.82
2016	$14.68	$18.15	$20.32	$11.43	$4.68	$5.21	$11.02
2017	$13.07	$17.86	$19.69	$11.48	$5.00	$5.11	$10.83
2018	$13.23	$18.31	$20.70	$11.40	$5.03	$5.75	$10.94
Average Annual Rate of Change 2018/2008	**2.0%**	**1.2%**	**2.0%**	**0.6%**	**0.4%**	**0.0%**	**0.8%**

[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.

Notes: Values are in constant 2018 dollars.

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

Source: National Transit Database.

As illustrated in *Exhibit 2-37*, 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.

Exhibit 2-37: Transit Operating Expenditures per Capacity-Equivalent Vehicle Revenue Mile by Mode, 2008–2018

Mode	Expenditures						
	Heavy Rail	Commuter Rail	Light Rail[1]	Fixed-Route Bus[2]	Demand Response[3]	Other[4]	Total
2008	$3.24	$4.36	$4.60	$7.61	$15.44	$9.75	$5.78
2009	$3.26	$4.52	$4.85	$7.67	$15.77	$9.71	$5.85
2010	$3.46	$4.64	$5.17	$8.00	$15.60	$9.71	$6.12
2011	$3.79	$4.90	$5.09	$8.47	$17.15	$9.60	$6.50
2012	$4.04	$5.08	$5.43	$8.93	$17.38	$10.59	$6.85
2013	$4.99	$5.28	$5.27	$9.32	$17.83	$10.99	$7.37
2014	$5.16	$5.36	$5.40	$9.82	$19.93	$11.22	$7.74
2015	$5.16	$5.36	$5.46	$9.84	$20.02	$11.58	$7.75
2016	$5.57	$5.59	$5.79	$10.14	$20.42	$12.31	$8.10
2017	$5.17	$5.75	$5.98	$10.27	$17.86	$12.45	$7.96
2018	$5.50	$6.20	$6.61	$10.72	$18.90	$14.75	$8.44
Average Annual Rate of Change 2018/2008	**5.4%**	**3.6%**	**3.7%**	**3.5%**	**2.0%**	**4.2%**	**3.9%**

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

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

[3] Includes demand response and demand response taxi.

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

Note: Values are in constant 2018 dollars.

Source: National Transit Database.

Exhibit 2-38 provides a range of service efficiency and effectiveness measures for two groups of aggregate data: Top 10 agencies (by ridership) as of 2018, 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 vehicle 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 vehicle per revenue 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 increased by as much as 17 percent over the period 2008 to 2018, whether assessed on a per-mile or per-trip basis.

As shown in *Exhibit 2-39*, the growth in operating expenses among the top 10 transit agencies is led by the cost of fringe benefits, which have been increasing at a rate of 1 percent per year above inflation (constant dollars) since 2008. By comparison, average salaries at these 10 agencies decreased at an inflation-adjusted rate of 0.5 percent per year from 2008–2018. 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.

Exhibit 2-38: Top 10 Agencies versus All Urban and Rural Agencies in the United States, 2008–2018

Scope	Mode	Fare and Cost per Vehicle Mile											Percent Increase 2008–2018	Average Annual Percent Increase
		2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018		
Top 10 Agencies	Average Fare per Mile	$5.6	$5.6	$5.8	$6.3	$6.3	$6.6	$6.6	$6.8	$6.7	$6.6	$6.5	16.4%	1.5%
	Average Cost per Mile	$12.6	$12.8	$13.0	$13.2	$13.6	$13.7	$14.0	$14.1	$14.7	$14.6	$14.8	17.1%	1.6%
	Average Recovery Ratio	44.1%	43.7%	44.7%	47.6%	46.6%	48.0%	47.4%	48.0%	45.8%	45.3%	43.9%	-0.6%	-0.1%
National (All Rural and Urban Agencies)	Average Fare per Mile	$3.1	$3.1	$3.1	$3.3	$3.3	$3.5	$3.5	$3.6	$3.5	$3.4	$3.3	8.7%	0.8%
	Average Cost per Mile	$9.0	$9.0	$9.0	$9.0	$9.2	$9.2	$9.4	$9.8	$10.0	$10.0	$10.1	12.8%	1.2%
	Average Recovery Ratio	34.1%	34.3%	34.7%	36.7%	36.6%	37.5%	36.8%	36.3%	35.0%	34.1%	32.9%	-3.6%	-0.4%

Notes: Values are shown in constant 2018 dollars.

The 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 Railway, King County Metro, and San Francisco Bay Area Rapid Transit District.

Source: National Transit Database.

Exhibit 2-39: Top 10 Agencies—Urban Growth in Labor Costs, 2008–2018

Cost Component	Average Cost per Vehicle Mile											% Growth Since 2008	Average Annual Rate of Change
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018		
Salaries	$5.2	$5.2	$5.3	$5.3	$5.3	$5.1	$5.2	$5.4	$5.7	$5.4	$5.5	5.3%	0.5%
Fringe Benefits	$3.7	$3.9	$4.1	$4.3	$4.3	$4.1	$4.2	$4.3	$5.1	$4.8	$4.1	10.2%	1.0%
Total Labor Cost	$8.89	$9.13	$9.36	$9.60	$9.58	$9.16	$9.48	$9.69	$10.85	$10.17	$9.55	7.3%	0.7%

Notes: Costs are in constant 2018 dollars.

The 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 Railway, King County Metro, Bay Area Rapid Transit District.

Source: National Transit Database.

Average Fares and Operating Costs, on a per-mile Basis, for the Nation’s 10 Largest Transit Agencies

After adjusting for inflation, fares per mile increased by 3.1 percent yearly from 2008 to 2018, whereas the average cost per mile increased by 3.2 percent yearly. The result is a 0.1-percent yearly decrease in the “fare recovery ratio,” which is the percentage of operating costs covered by passenger fares. The 2018 fare recovery ratio for these 10 agencies, which are all rail, was 43.9 percent. These agencies are more cost- and service-effective than the national average, which means that ridership grows at a rate greater than the rate of increase in service miles or operating expenses.

Operating Expenditures per 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 1.8 percent between 2008 and 2018 when adjusted for constant dollars (from $0.73 to $0.87). Demand response has the highest operating cost per passenger mile, whereas heavy rail and commuter rail have the lowest operating cost per passenger mile. Between 2008 and 2018 light rail operating expenditures per passenger mile increased by 37 percent, or an annual average increase of 3.2 percent. This was the highest increase among the modes. These data are shown in *Exhibit 2-40*.

KEY TAKEAWAY

Farebox recovery ratios, representing the share of operating expenses that come from passenger fares, were about 43.9 percent for the top 10 transit agencies in 2018, down slightly from 44.1 percent in 2008. For all agencies, the 33.8 percent recovery ratio in 2018 was down slightly from 34.2 percent in 2008, reflecting an annual average change of - 0.1 percent.

Exhibit 2-40:   Urban Operating Expenditures per Passenger Mile, 2008–2018

Mode	Expenditures						
	Heavy Rail	Commuter Rail	Light Rail[1]	Fixed-Route Bus[2]	Demand Response[3]	Other[4]	Total
2008	$0.42	$0.45	$0.71	$0.99	$3.96	$0.67	$0.73
2009	$0.44	$0.48	$0.75	$1.02	$4.06	$0.68	$0.76
2010	$0.45	$0.49	$0.81	$1.04	$4.18	$0.66	$0.77
2011	$0.43	$0.46	$0.75	$1.01	$4.08	$0.64	$0.74
2012	$0.44	$0.49	$0.75	$0.99	$4.14	$0.64	$0.74
2013	$0.49	$0.49	$0.77	$1.00	$4.17	$0.62	$0.76
2014	$0.50	$0.52	$0.80	$1.02	$4.17	$0.63	$0.78
2015	$0.52	$0.52	$0.85	$1.10	$4.21	$0.66	$0.81
2016	$0.54	$0.53	$0.89	$1.12	$4.14	$0.67	$0.83
2017	$0.51	$0.51	$0.90	$1.20	$4.44	$0.66	$0.84
2018	$0.54	$0.51	$0.97	$1.24	$4.51	$0.73	$0.87
Average Annual Rate of Change 2018/2008	**2.4%**	**1.1%**	**3.2%**	**2.3%**	**1.3%**	**0.8%**	**1.8%**

[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: Values are in constant 2018 dollars.
Source: National Transit Database.

Farebox Recovery Ratios

The farebox recovery ratio presents farebox revenues as a percentage of total transit operating costs.[6] This metric captures users' relative contributions to the cost of providing transit services and is a function of several factors. Farebox recovery ratios tend to be higher where transit service is closely linked with transit travel demand, such as on services that operate only or largely during peak periods, and on more capital-intensive modes that tend to have lower operating costs. Importantly, however, the farebox recovery ratio also depends on fare structures and choices about operating hours and routes that may be set to help achieve other public policy goals, such as providing affordable transportation options to disadvantaged members of the

[6] Net of reconciling cash expenses.

community to help improve their access to opportunity and encouraging the use of more environmentally sustainable modes of travel.

Average farebox recovery ratios for U.S. transit services from 2008 to 2018 are provided in *Exhibit 2-41*. The average farebox recovery ratio over this period for all transit modes combined was 33.8 percent in 2018. Heavy rail had the highest average farebox recovery ratio at 60.7 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 capital costs. Farebox recovery ratios also vary widely within each mode. The ratio for heavy rail, for example, ranged from 13 percent to 78 percent in 2016 across the 15 reporting agencies. Other modes, such as fixed-route bus, had an even larger range: from 0 percent to over 100 percent in 2016 across the more than 1,200 reporting agencies. The vast majority of fixed-route bus systems, however, reported a farebox recovery ratio between 0 and 50 percent.

Exhibit 2-41: Average Urban Farebox Recovery Ratio by Mode, 2008–2018

Mode	Heavy Rail	Commuter Rail	Light Rail[1]	Fixed-Route Bus[2]	Demand Response[3]	Other[4]	Total
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%
2017	63.3%	52.9%	24.9%	24.9%	9.1%	40.6%	35.1%
2018	60.7%	50.7%	23.0%	24.0%	9.4%	39.9%	33.8%
Average Annual Rate of Change 2018/2008	**0.2%**	**0.1%**	**-2.4%**	**-0.9%**	**2.2%**	**1.9%**	**-0.1%**

[1] Includes light rail, hybrid rail, and streetcar rail.
[2] Includes bus, bus rapid transit, and commuter bus.
[3] Includes demand response and demand-response taxi.
[4] Includes aerial tramway, Alaska railroad, cable car, ferryboat, inclined plane, monorail/automated guideway, público, trolleybus, and vanpool.
Source: National Transit Database.

Combined Capital and Operating Expenditures

As noted above, transit capital expenditures totaled $21.5 billion in 2018 (including $2.8 billion from directly generated sources), and transit operating expenditures totaled $51.8 billion. Adding these figures yields a combined capital and operating expenditure total of $73.3 billion.

KEY TAKEAWAY

All levels of government spent a combined $73.3 billion in 2018 to provide public transportation and maintain transit infrastructure.

Chapter 3: People and Their Travel

Introduction

People use the U.S. transportation system every day to go to work or school, shop, visit loved ones, ship goods, make service calls, go on vacation, and more. Virtually every activity outside the home or business involves some form of transportation.

Many factors influence transportation demand and in different ways. Characteristics about the household and the people living in the household matter when it comes to travel. Different types of households travel differently. As their characteristics, needs, and preferences change, so too does the way they use transportation.

Changes in demographics, such as household size, income, and age, drive changes in transportation demand. Geographic changes, such as urban expansion, can shift transportation demand or change transportation needs. Social changes influence preferences and expectations, and technological innovations change what is possible, including how activities are completed, the transportation services available, and the ways in which goods and services are provided.

This chapter presents trends in travel behavior, with an emphasis on the characteristics of people and households that influence transportation demand.

SECTION SUMMARY

- The number of households grew from 108.2 million in 2001 to 128.5 million in 2020.
- In 2020, 35–54-year-olds comprised 25.4 percent of the U.S. population, a decrease from 29.5 percent in 2000. This age cohort makes the most trips, with an average of 1,388 trips per year.
- In 2020, 8.0 percent of U.S. households did not have access to a vehicle either by choice or by circumstance.
- The proportion of licensed drivers in the United States declined slightly from 86.5 percent in 2001 to 83.9 percent in 2020.
- The percentage of people ages 85 and older with a driver's license grew from 50 percent in 2001 to 59 percent in 2020; this equates to 4.0 million drivers ages 85 and older.
- Nearly 30 million Americans did not have access to internet-enabled alternatives to transportation, such as e-commerce and remote learning, in 2018.
- Total person miles traveled (PMT) in 2017 was 4,291,150 miles. The growth in PMT outpaced the growth in vehicle miles traveled (VMT), which totaled 2,321,820 miles in 2017.

Population

As the Nation's population continues to grow, so does overall transportation demand. How and where the population is growing and changing directly affect the type and distribution of travel. Population growth results from two factors: natural increase (births and deaths) and immigration.

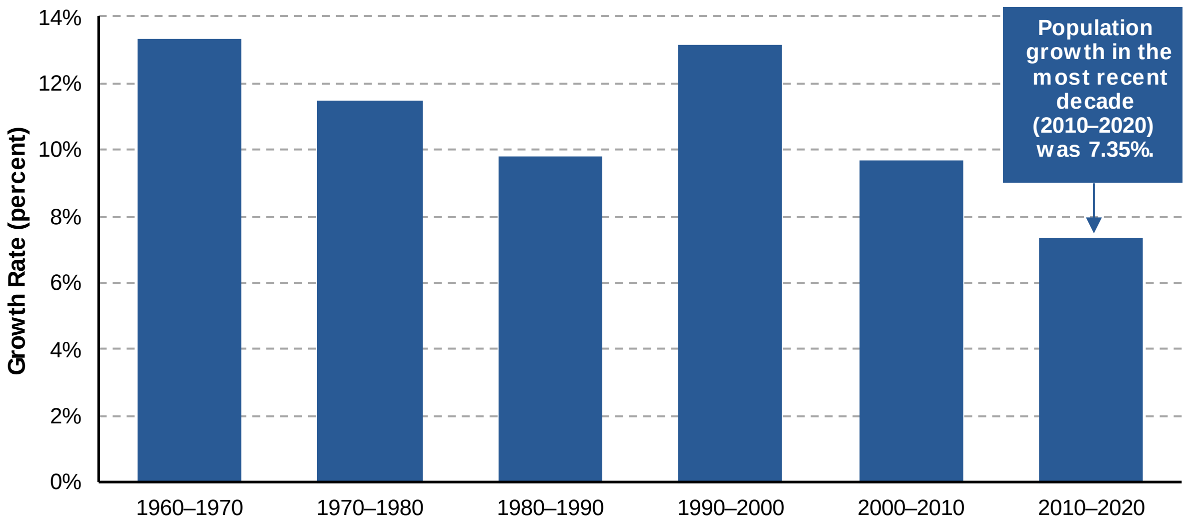
The U.S. population has grown significantly over the past two decades, experiencing a 16.3 percent increase from 282 million people in 2000 to 332 million people in 2020.[7] However, the annual rate of population growth has been declining in the United States since 2015. In 2017, a year that aligns with travel data from the National Household Travel Survey (NHTS), the size of the U.S. population was 290.1 million.

The past decade (i.e., 2010–2020) experienced an average annual growth rate of 0.66 percent. The average annual growth rate in the previous decade was 0.97 percent. Population growth

[7] U.S. Census Bureau (2021). Table NA-EST2021-POP. https://www.census.gov/data/tables/time-series/demo/popest/2020s-national-total.html

between 2019 and 2020 was the slowest in 120 years at 0.35 percent. This is important because the size of the population is directly related to the total number of trips and miles traveled each day. Even with declining growth rates, the U.S. population is still expected to grow to 404.5 million people by 2060.[8] The rate of population growth is an important consideration when forecasting demand. *Exhibit 3-1* provides an overview of U.S. population growth rate by decade from 1960 to 2020.

Exhibit 3-1: Estimated U.S. Population Growth by Decade, 1960–2020



Source: U.S. Census Bureau (2021). Historical Population Change Data (1910–2020). https://www.census.gov/data/tables/time-series/dec/popchange-data-text.html

As with the size of the population, the number of households in the United States grew from 104.7 million in 2000 to 128.5 million in 2020. However, the average number of people per household declined from 2.62 in 2000 to 2.53 in 2020 (see *Exhibit 3-2*). This decline may be due in part to lower birth rates, the size of the older population, or patterns of immigration, marriage, employment, and housing costs. However, the percentage of single-person households also increased: from 25.5 percent of all households in 2000 to 28.2 percent in 2020.[9] This increase is important because many travel activities serve the entire household, such as grocery shopping, trips to places of worship, or dining out. Therefore, transportation demand increases overall where there are more households for the same population size.[10,11,12]

[8] U.S. Census Bureau (2018). Demographic Turning Points for the United States: Population Projections for 2020 to 2026. https://www.census.gov/content/dam/Census/library/publications/2020/demo/p25-1144.pdf

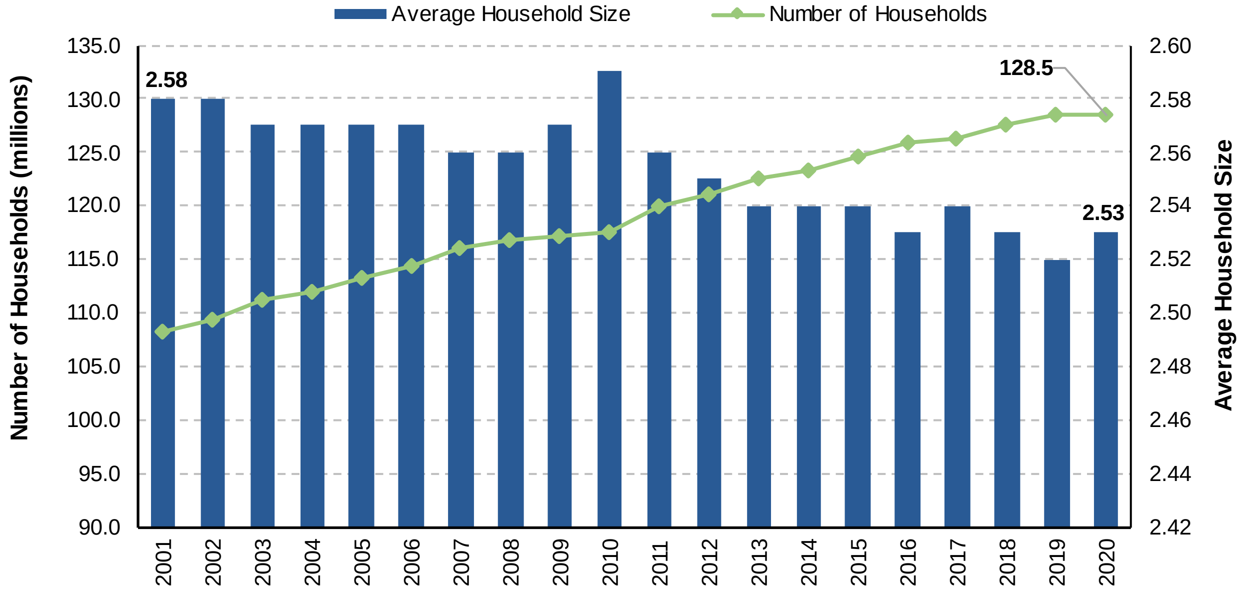
[9] https://www.census.gov/data/tables/time-series/demo/families/households.html

[10] https://www.fhwa.dot.gov/policy/otps/TPS_2020_Trends_Report.pdf

[11] https://onlinepubs.trb.org/onlinepubs/trnews/trnews264TravelDemand.pdf

[12] https://significance.nl/wp-content/uploads/2019/03/2004-GDJ-Drivers-of-passenger-transport-demand-worldwide.pdf

Exhibit 3-2: Number of Households and Average Household Size, 2001–2020

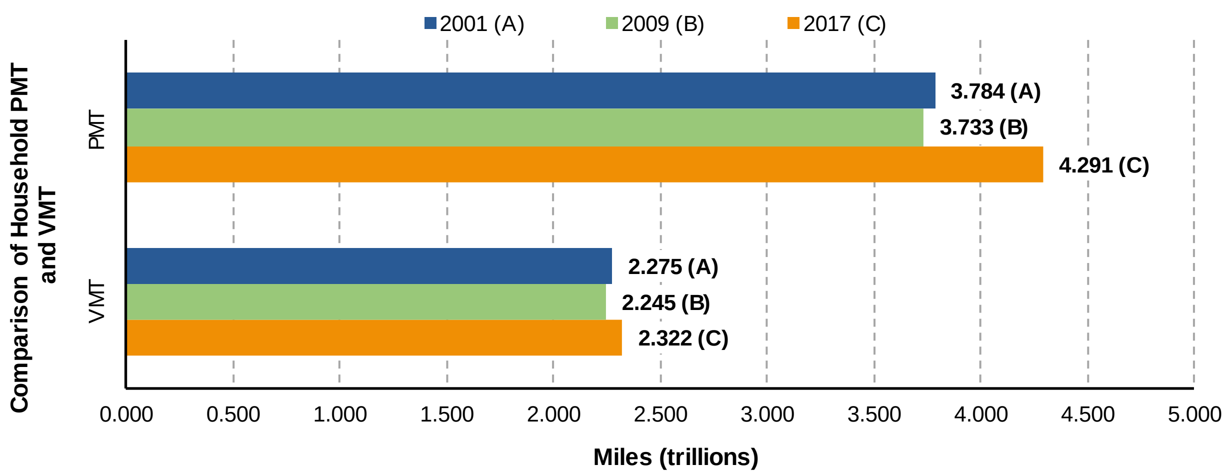


Source: U.S. Census Bureau (2020). Historical Household Tables. https://www.census.gov/data/tables/time-series/demo/families/households.html

Population and Travel Demand

Over the past five decades, household travel demand has consistently outpaced population growth. It is measured in PMT, which accounts for travel on all modes of transportation, and VMT, which accounts for travel by personal vehicle. *Exhibit 3-3* compares trends in PMT and VMT in 2001, 2009, and 2017. These years are chosen because they align with travel data from the NHTS. As shown in *Exhibit 3-3*, the growth in PMT has outpaced the growth in VMT. This means that travel via other modes has grown faster than travel by personal vehicle.

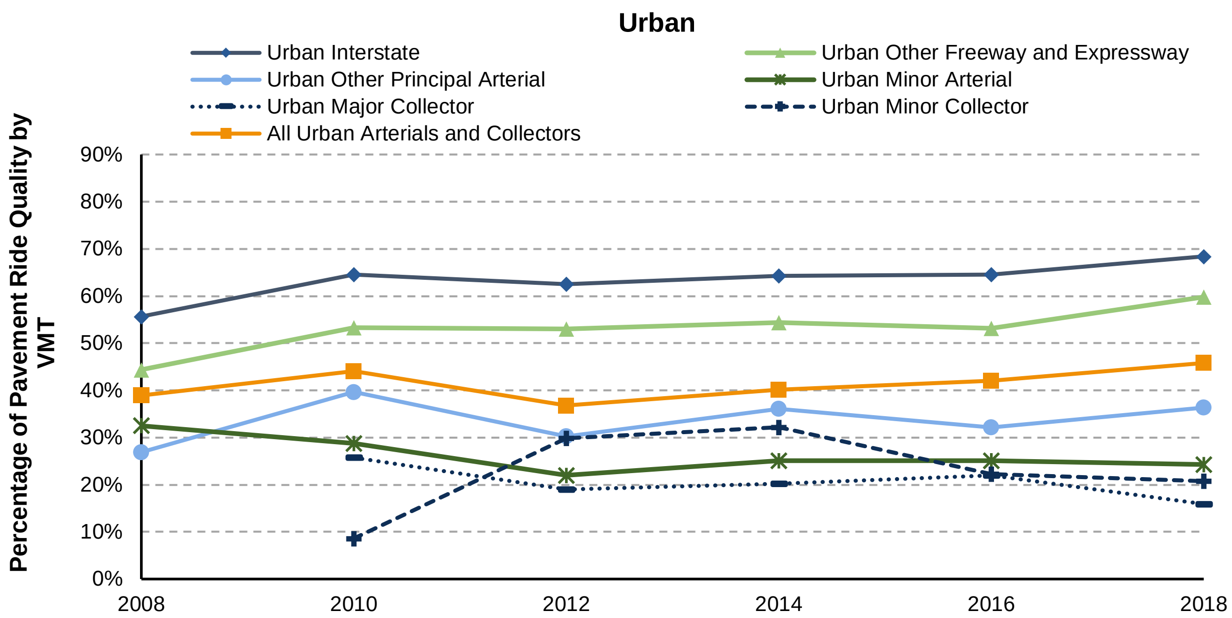
Exhibit 3-3 Total Annual Household PMT and VMT, 2001–2017



Source: McGuckin, N. and Fucci, A. (2017). Summary of Travel Trends: 2017 National Household Travel Survey, Report No. FHWA-PL-18-019. https://nhts.ornl.gov/assets/2017_nhts_summary_travel_trends.pdf

Exhibit 3-4 shows trends in PMT and VMT per person. Although PMT (all travel modes) has increased, VMT per person has decreased. VMT per person was 7,698 miles in 2017, down from 8,206 miles per person in 2001.

Exhibit 3-4: Total Annual PMT and VMT per Person and per Household, 2001–2017



Source: McGuckin, N. and Fucci, A. (2017). Summary of Travel Trends: 2017 National Household Travel Survey, Report No. FHWA-PL-18-019. https://nhts.ornl.gov/assets/2017_nhts_summary_travel_trends.pdf

Factors That Influence Travel Demand

Many factors beyond population and household size influence travel demand. These factors include, but are not limited to, the age distribution of the population, population diversity, vehicle ownership, licensure rates, worker status, and income. All of these factors influence travel demand; travel demand characteristics such as mode, distance, and purpose; and travel demand distribution across population groups and geographic areas.

Age

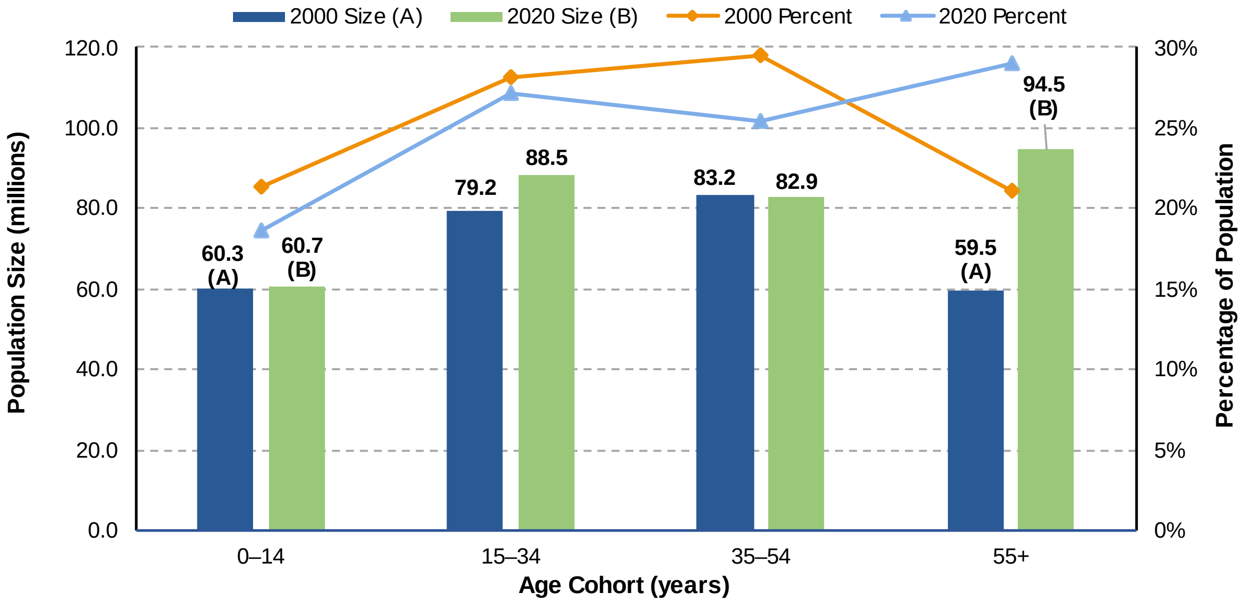
The characteristics of people and households helps us to understand how, why, how much, and when people travel, and to predict future transportation needs. The average age of Americans has continued to shift older, with the proportion of people ages 65+ growing faster than those younger than 30, resulting in the median age increasing from 32.9 years in 1990 to 38.2 years in 2020.[13]

The highest population growth rates have been among seniors (e.g., people ages 65 and older). This is a continuing trend in the United States—there are more older drivers on roads, and there are more seniors who may require transportation services. This is especially true in suburban areas, where the size of the senior population is growing and fewer travel options are available.[14]

[13] U.S. Census Bureau (2020). American Community Survey 2020 5-year estimates.

[14] Parker, K., Horowitz, J.M., Brown, A., Fry, R., Cohn, D., and Igielnik, R. (2018). Chapter 1. "Demographic and Economic Trends in Urban, Suburban and Rural Communities." *What Unites and Divides Urban, Suburban, and Rural Communities*. Pew Research Center, Washington, DC. https://www.pewresearch.org/social-trends/2018/05/22/what-unites-and-divides-urban-suburban-and-rural-communities/

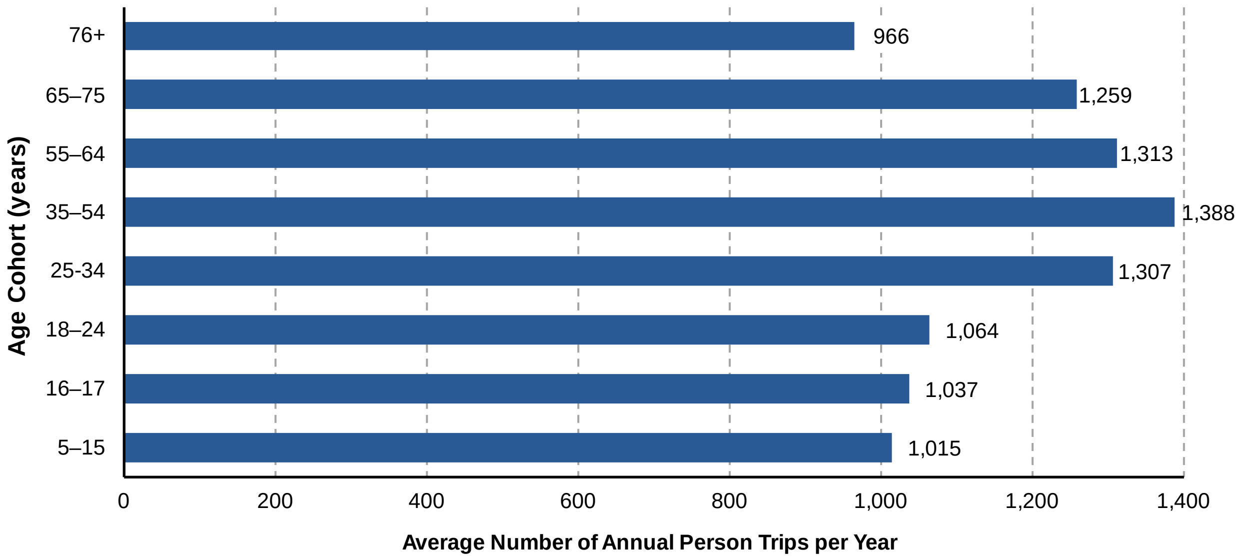
Exhibit 3-5: Population Size and Percentage of the Population by Age Cohort, 2000 vs. 2020



Sources: U.S. Census Bureau (2016). State Intercensal Tables: 2000–2010. https://www.census.gov/data/tables/time-series/demo/popest/intercensal-2000-2010-state.html; U.S. Census Bureau (2020). National Population by Characteristics 2010–2019. https://www.census.gov/data/tables/time-series/demo/popest/2010s-national-detail.html

Since 2000, the 35- to 54-year-old age cohort has declined as a percentage of the total population. In 2020, 35- to 54-year-olds comprised 25.4 percent of the U.S. population—a decrease from 29.5 percent in 2000. This is noteworthy because this age cohort comprises people who make the most trips (i.e., workers and households with children), with an average of almost 1,400 trips per year in 2017 (see *Exhibit 3-6*).

Exhibit 3-6: Average Number of Trips per Year by Age, 2017



Source: National Household Travel Survey.

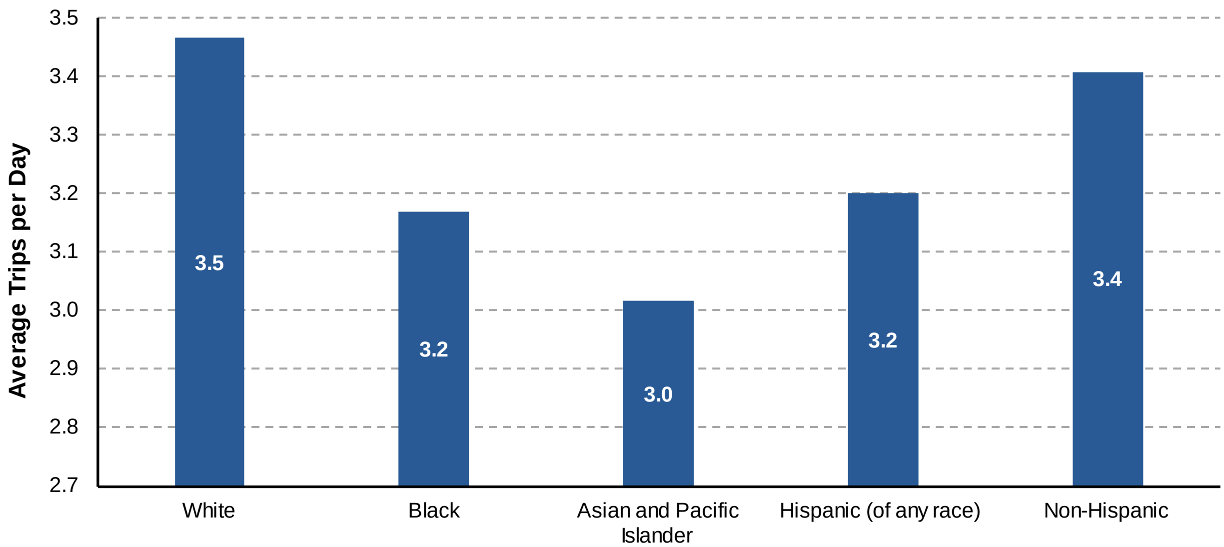
Both men and women are delaying marriage, and women are delaying motherhood. By 2018, just under half of Millennials ages 25 to 37 were married (46 percent), which was a significant decrease from 83 percent of the Silent Generation (people born from 1928–1945) who were married between the ages of 25 and 37. Marriage rates have dropped steadily with each subsequent generation. These lifestyle changes are important because income, employment status, marriage, and children all affect travel demand. High-income, employed, married people with children travel the most. Conversely, low-income, unemployed, single people without children travel the least.

Diversity

The U.S. population is not only aging, but also becoming more diverse. In 2000, 28.7 percent of the Nation's population comprised people of color: 12.8 percent Black or African American, 11.9 percent Hispanic or Latino (of any race), 9 percent American Indian and Alaska Native, and 4.1 percent Asian, Native Hawaiian, and other Pacific Islander.[15] In 2017, a year that aligns with travel data in the NHTS, 38.5 percent of the Nation's population comprised people of color: 13.9 percent Black or African American; 17.6 percent Hispanic or Latino (of any race); 1.7 percent American Indian and Alaska Native; 6.7 percent Asian, Native Hawaiian, and other Pacific Islander; and 5.4 percent some other race.[16] In 2020, people of color accounted for 39.9 percent of the U.S. population, or 130.3 million people.[17] By 2060, 56 percent of the U.S. population is forecast to be people of color.[18]

Increased diversity brings changes in the level and distribution of travel demand in the United States. For example, as highlighted in *Exhibit 3-7*, the average daily trip rate is lower for minority population groups compared with White and non-Hispanic travelers.

Exhibit 3-7: Average Number of Trips per Day by Race and Ethnicity, 2017



Source: National Household Travel Survey.

Many of the racial and ethnic differences in travel demand are minimized when controlling for income. For most racial and ethnic groups, the average number of daily trips increases as income increases. One exception is Black or African American households, where the highest numbers of average daily trips are made by households with incomes between $50,000 and $74,999.

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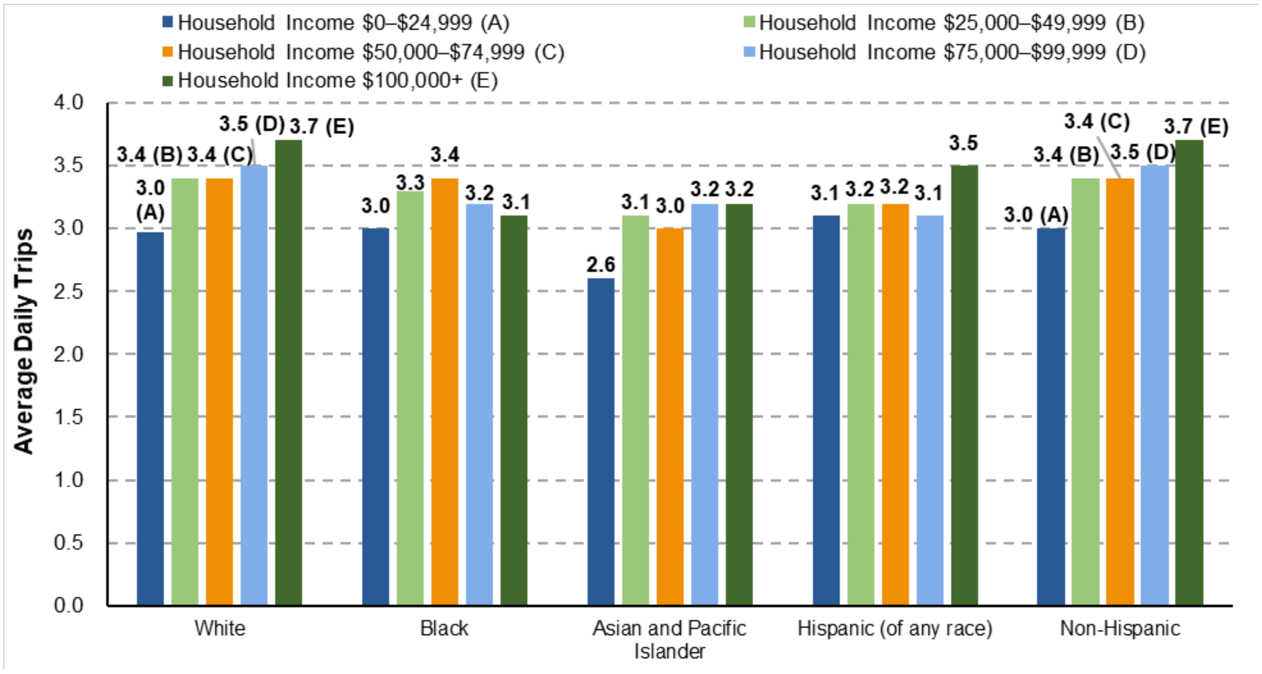
[15] https://www2.census.gov/programs-surveys/popest/tables/1990-2000/national/totals/nat-srh.txt

[16] U.S. Census Bureau (2017). American Community Survey 2017 5-Year Estimates Data Profiles. Table DP05. https://data.census.gov/cedsci/table?q=DP05&tid=ACSDP5Y2017.DP05

[17] U.S. Census Bureau (2020). American Community Survey 2020 5-Year Estimates Data Profiles. Table DP05. https://data.census.gov/cedsci/table?q=DP05&tid=ACSDP5Y2020.DP05

[18] U.S. Census Bureau (2018). Demographic Turning Points for the United States: Population Projections for 2020 to 2026. https://www.census.gov/content/dam/Census/library/publications/2020/demo/p25-1144.pdf

Exhibit 3-8: Average Daily Trip Rate by Household Income and Race and Ethnicity, 2017



Source: National Household Travel Survey.

Income

Income affects the number of trips individuals take and the distance traveled in each trip. *Exhibit 3-9* shows the average number of trips by household income per day and the average length of those trips.

Higher-income households made substantially more trips and traveled more miles on average compared with lower-income households. Households with incomes of $100,000 or more made 22 percent more trips than those with incomes under $25,000, and those trips were 71 percent longer on average.

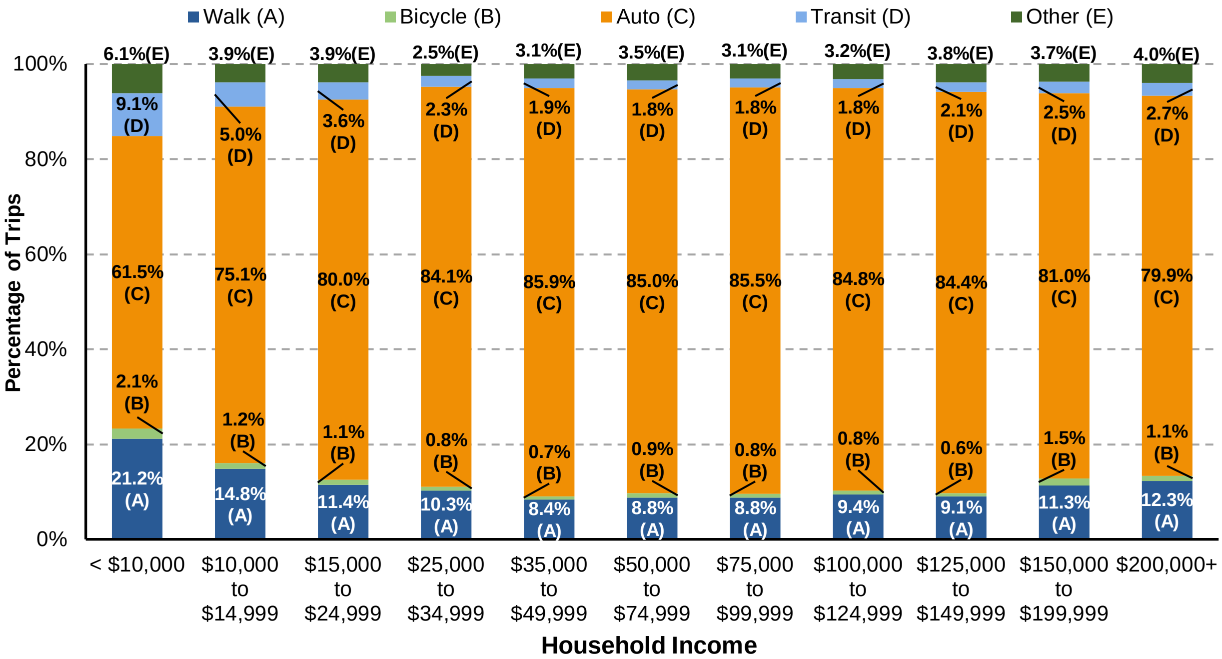
Exhibit 3-9: Number of Person Trips and Average Trip Length by Income, 2017

Household Income	Average Number of Trips per Day	Average Trip Length (mile)
$0–$24,999	3.0	8.1
$25,000–$49,999	3.4	9.7
$50,000–$74,999	3.4	11.3
$75,000–$99,999	3.5	12.7
$100,000+	3.6	13.9
Total	**3.4**	**11.6**

Source: National Household Travel Survey.

Although personal vehicles were used for the majority of trips across all incomes in 2017, lower-income households were more likely to use public transit, walk, and bicycle for their travel (see *Exhibit 3-10*). The lowest-income households (under $10,000 per year), for example, walked for a large percentage of their trips (21.2 percent) and had the highest level of transit use at 9.1 percent of all trips.

Exhibit 3-10: Percentage of Trips by Household Income and Mode of Travel, 2017

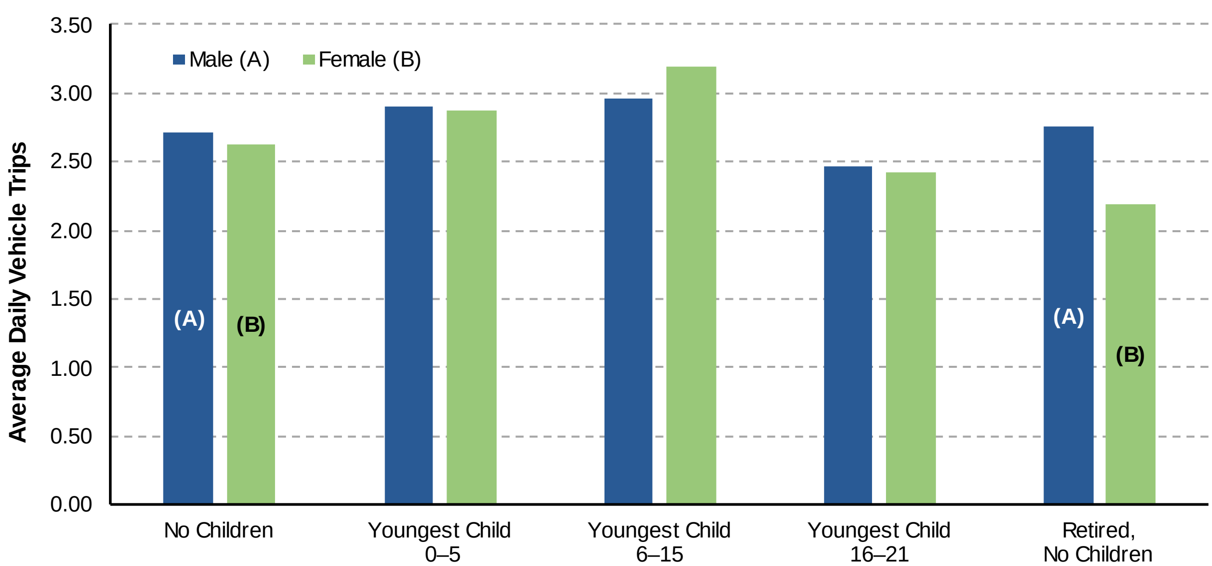


Source: McGuckin, N. and Fucci, A. (2017). Summary of Travel Trends: 2017 National Household Travel Survey, Report No. FHWA-PL-18-019. https://nhts.ornl.gov/assets/2017_nhts_summary_travel_trends.pdf

Gender

Historically, men and women have had strong differences in travel demand: differences in the types of trips, the number of trips, trip distances, and driver licensing. These differences have declined in recent years, which may reflect the changing roles of men and women in the household.[19]

Exhibit 3-11: Average Daily Vehicle Trip Count for Males and Females, by Age of Children in Household, 2017



Source: National Household Travel Survey.

[19] https://www.planning.org/planning/2020/feb/mind-the-gender-gap/

The largest difference in travel behavior between men and women is seen in retirement when no children are living in the household. This may be due, in part, to the traditional gender roles of older generations. Gender differences in travel are also seen in households with school-age children between 6 and 15 years of age. During this stage of life, women travel more compared with men for school trips and family errands.

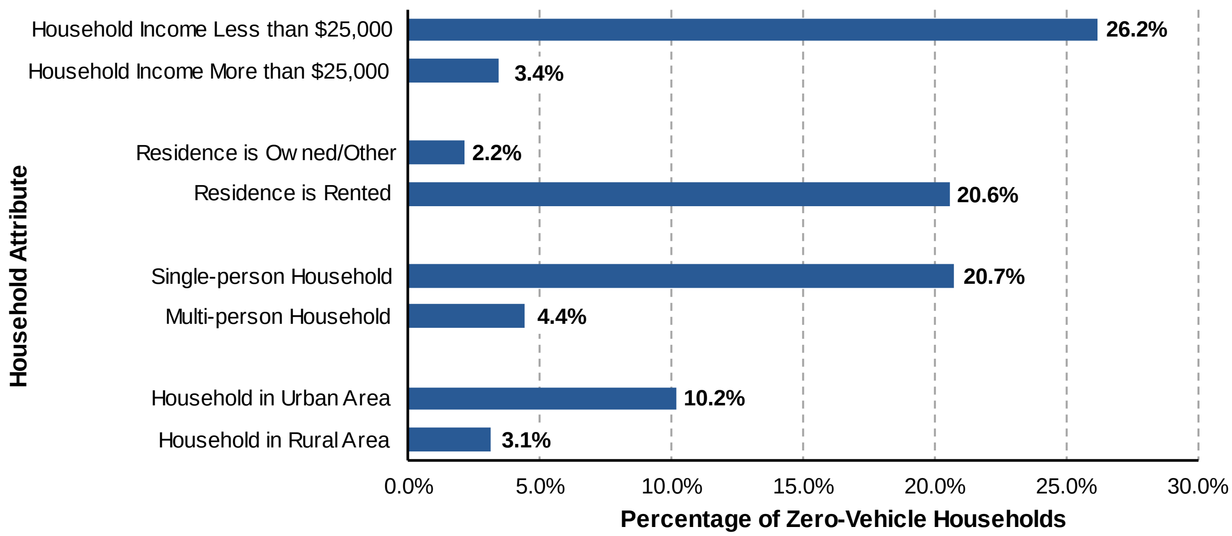
Vehicles and Licensing

Most U.S. households use a vehicle to make their daily trips such as to commute to work and school, run errands, access healthcare, and care for dependent family members. The U.S. Department of Transportation has been collecting data on travel and vehicle ownership since the 1960s. Vehicle ownership varies across the Nation. Overall, 8.5 percent of U.S. households do not have access to a vehicle (either by choice or by circumstance) according to the 2020 American Community Survey.[20]

Vehicle Ownership Trends

Not surprisingly, income is one of the major determinants of the number of vehicles in a household. *Exhibit 3-12* depicts the percentage of zero-vehicle households by household attributes in 2017. Households with no vehicles are more likely to live in urban areas, be renters, and have incomes under $25,000 compared with households with at least one vehicle.

Exhibit 3-12: Percentage of Zero-vehicle Households in the United States by Household Attribute, 2017



Source: U.S. Census Bureau (2019). American Community Survey, Table S2504. https://data.census.gov/cedsci/table?q=vehicle%20ownership&tid=ACSST1Y2019.S2504

However, the vehicle ownership model may be changing, as exemplified by the slowing growth in the average number of vehicles per household. *Exhibit 3-13* shows that the average number of vehicles per household has leveled off over the past two decades. This is likely due to changes in household size, labor force participation, and access to alternative transportation modes (such as on-demand transportation and shared modes). For example, as household size decreases, the number of vehicles per household also declines as there are fewer drivers.

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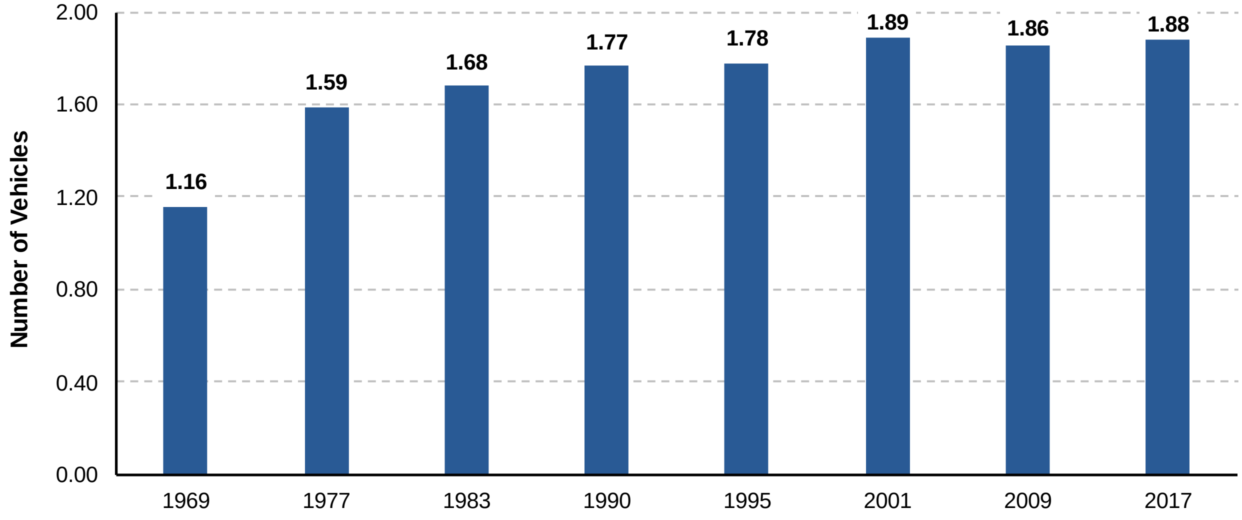
[20] U.S. Census Bureau (2020). American Community Survey, Table S2504. https://data.census.gov/cedsci/table?q=vehicle%20ownership&tid=ACSST1Y2020.S2504

Exhibit 3-13 Average Number of Vehicles per Household, 1969–2017

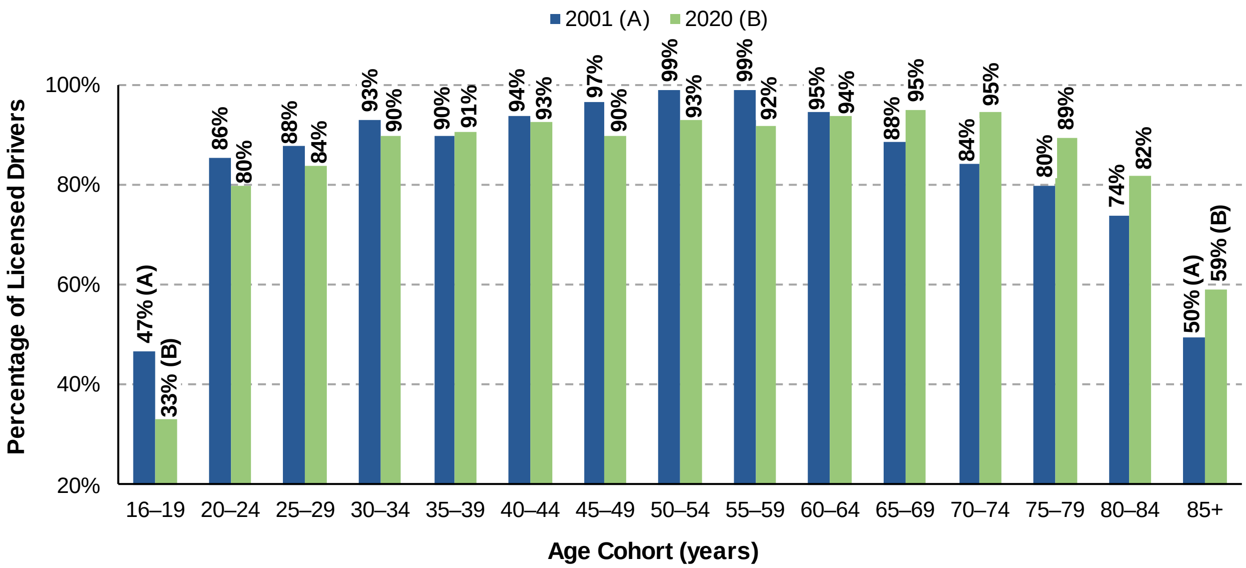


Source: McGuckin, N. and Fucci, A. (2017). Summary of Travel Trends: 2017 National Household Travel Survey, Report No. FHWA-PL-18-019. https://nhts.ornl.gov/assets/2017_nhts_summary_travel_trends.pdf

Driver's License Trends

Overall, the proportion of total licensed drivers (ages 16 and older) in the United States declined slightly from 86.5 percent in 2001 to 83.9 percent in 2020.[21] People ages 65 and older have experienced a growth in total population as well as in the number and percentage of licensed drivers. For example, the percentage of people ages 85 and older with a driver's license grew from 50 percent in 2001 to 59 percent in 2020 (see *Exhibit 3-14*). Given that there were 6.7 million Americans ages 85 and older in 2019, that equates to 4.0 million drivers ages 85 and older.

Exhibit 3-14: Percentage of Licensed Drivers by Age Cohort, 2001 vs. 2020



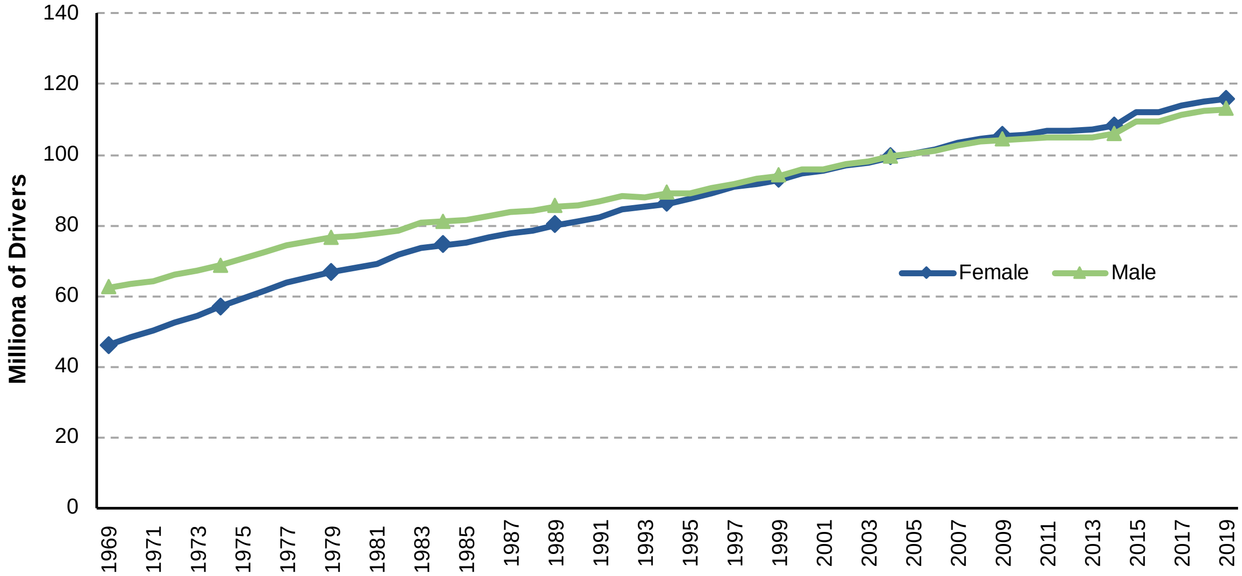
Source: Federal Highway Administration (2021). Table DL-20: Distribution of Licensed Drivers–2020 by Sex and Percentage in Each Age Group and Relation to Population. https://www.fhwa.dot.gov/policyinformation/statistics/2020/pdf/dl20.pdf

[21] Federal Highway Administration (2020). Table DL-20: Distribution of Licensed Drivers–2020 by Sex and Percentage in Each Age Group and Relation to Population. https://www.fhwa.dot.gov/policyinformation/statistics/2020/pdf/dl20.pdf

Driver's license rates are lowest for people ages 16 to 19 years. The percentage of licensed drivers has decreased for every age group below 65 years of age. Reasons for this decline may include increased graduated driver's licensing laws as well as the availability of new alternative travel modes and technologies. Researchers have also posited that rising internet use may reduce the need for some in-person interactions, and the cost of vehicle ownership (e.g., gas, insurance, maintenance) makes driving a less attractive mode option for travelers.

Historically, there was a large difference in licensure rates between men and women. In 1969, 60 percent of licensed drivers were men and 40 percent were women (see *Exhibit 3-15*). Many factors, including changes in social norms and growth in women's employment and income, have translated to greater licensing among women. In 2019, 49.4 percent of licensed drivers were men and 50.6 percent were women.

Exhibit 3-15: Licensed Drivers in the United States, Male and Female, 1969–2019



Source: National Household Travel Survey.

Work-Related Travel Trends

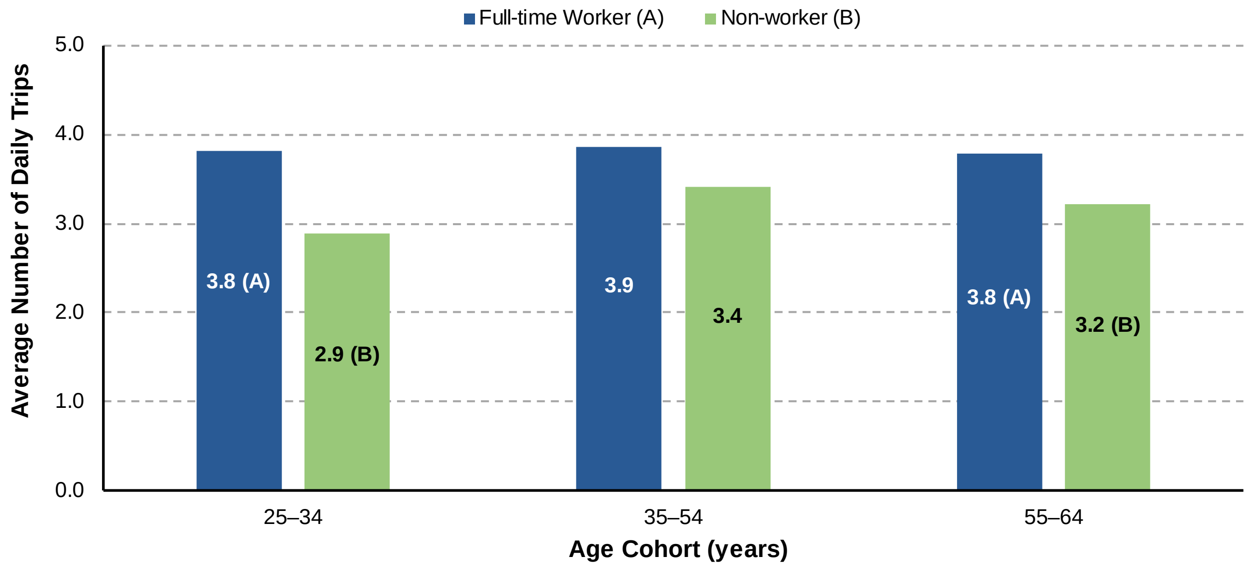
VMT is very closely related to participation in the labor force. Demographics and socioeconomic characteristics are closely related to occupations. Hence, trends in demographics and socioeconomic characteristics of the population can provide insight into future travel demand and transportation needs.

Full-time workers make more trips than nonworkers in every age cohort (see *Exhibit 3-16*). The greatest difference in average daily trips per person is between workers and nonworkers in the 25 to 34 years age cohort.

Although travel to work makes up only 19 percent of all trips,[22] most of these trips are made in peak travel periods when many people are traveling at the same time, which can lead to congestion on highways, buses, and subways.

[22] National Household Travel Survey.

Exhibit 3-16: Average Daily Trips per Person by Worker Status, 2017



Source: National Household Travel Survey.

Travel to Work

Changes in work travel, including mode, time of day, or teleworking, can disperse or concentrate travel demand on the transportation system. As shown in *Exhibit 3-17*, commuting to work by driving alone continues to be the predominant mode choice for workers.

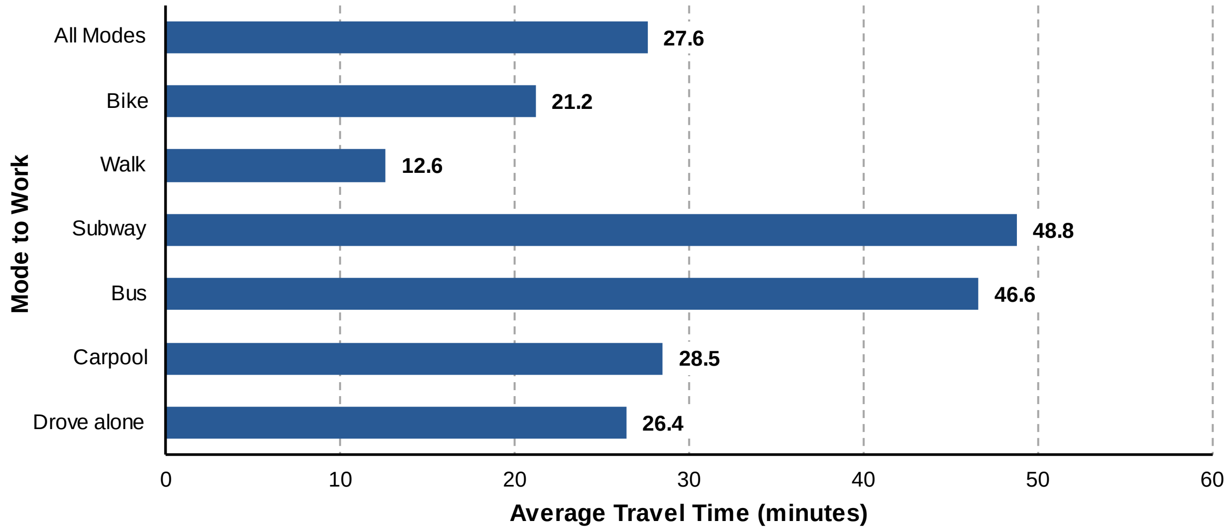
Exhibit 3-17: Typical Transportation Mode to Work, 2019

Mode to Work	Percent of Workers
Vehicle	**84.8%**
Drive Alone	75.9%
Carpool	8.9%
Public Transit	**5.0%**
Bus	2.3%
Subway	1.9%
Other	0.8%
Bike	**0.5%**
Walk	**2.6%**
Work from Home	**5.7%**
Other	**1.4%**
Total	**100.0%**

Source: U.S. Census Bureau, 2019 American Community Survey, 1-year estimates.

The most popular modes for commuting to work also have the shortest travel times. The average one-way travel time for all work trips is 27.6 minutes according to the 2019 American Community Survey. Driving alone (26.4 minutes), biking (21.2 minutes), and walking (12.6 minutes) have travel times under the average. The longest travel times are for subway (48.8 minutes) and bus (46.6 minutes), likely due in part to wait times and transfers for these transit modes.

Exhibit 3-18: Average Travel Time to Work in Minutes, 2019



Source: U.S. Census Bureau, 2019 American Community Survey, 1-year estimates.

Work Options

Job types often dictate people's work schedule and flexibility. Since 2010, management, production, transportation, and service occupations have grown, whereas jobs in sales, office occupations, natural resources, construction, maintenance, and farming have declined (see *Exhibit 3-19*).

Exhibit 3-19: Percentage of Workers Ages 16 and Older by Occupation, 2010 and 2020

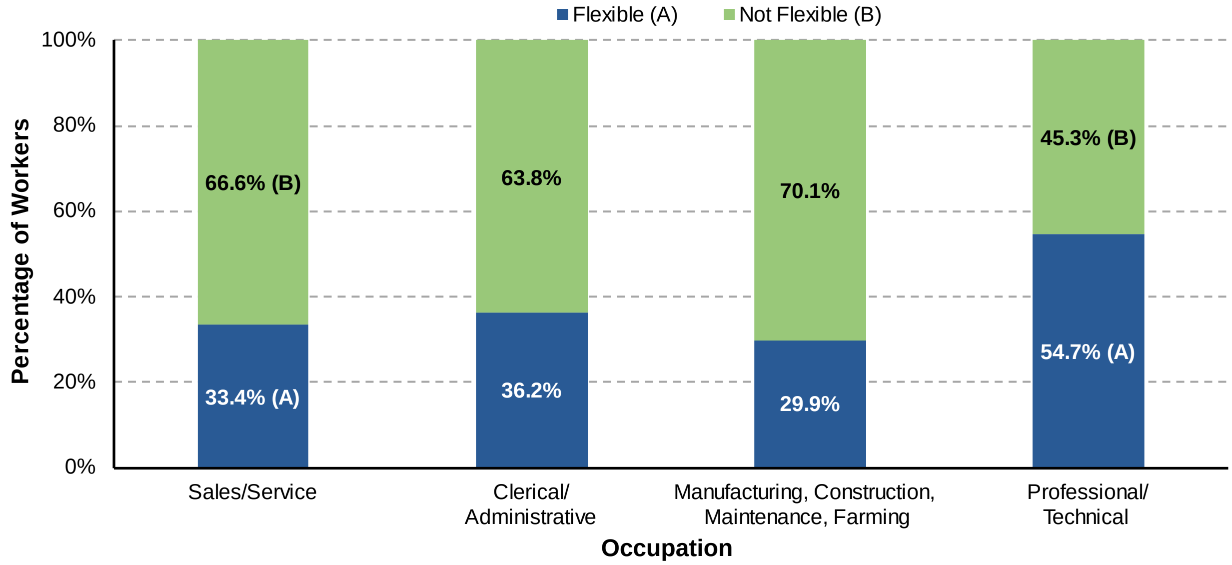
Occupation	2010	2020
Management, Business, Science, and Arts	35.3%	39.5%
Service	17.1%	17.4%
Sales and Office	25.4%	21.3%
Natural Resources, Construction, Maintenance, and Farming	9.8%	8.7%
Production, Transportation, and Material Moving	12.4%	13.1%

Source: U.S. Census Bureau (2019). Table S2401: Occupation by Sex for the Civilian Employed Population 16 Years and Over. https://data.census.gov/cedsci/table?q=S2401&tid=ACSST1Y2019.S2401

As shown in *Exhibit 3-20*, just over 33 percent of workers in sales and service occupations and just under 30 percent of those in natural resource, construction, and maintenance have flexibility in their work arrival time. In comparison, just under 55 percent of workers in professional and technical occupations have flexibility in their work start times.

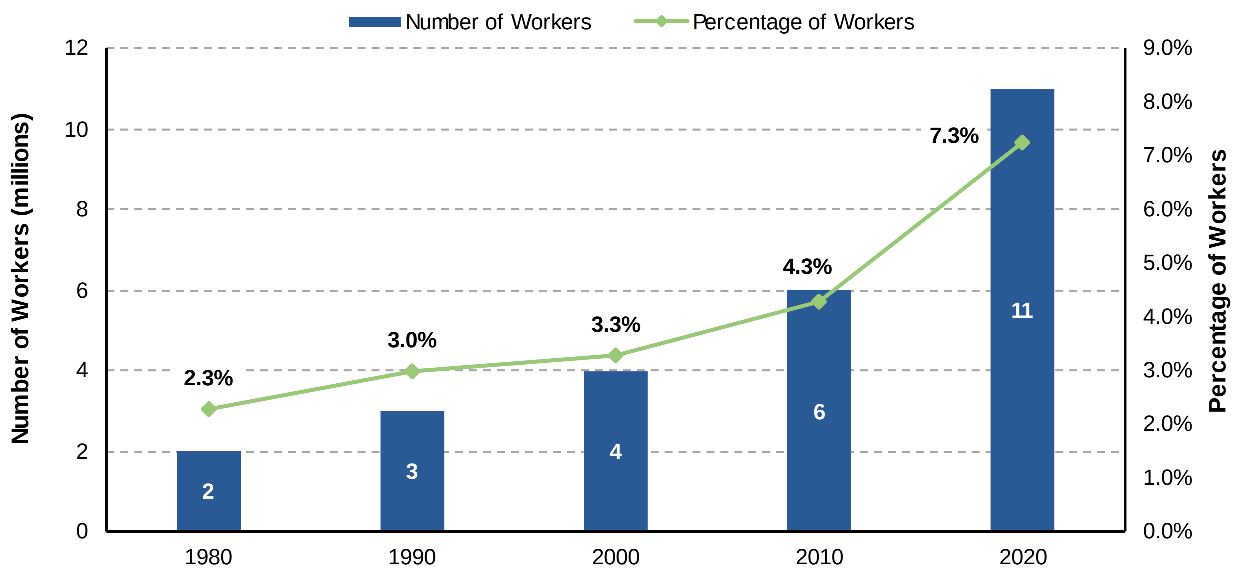
The U.S. workforce has seen tremendous growth in telework over the last few decades. The number of people who work from home grew from 2.3 million in 1980 to 11 million in 2020 (see *Exhibit 3-21*). Changes in occupation sectors and work culture as well as improvements in telecommunications speed, options, and security are likely contributors to this growth. Note that the 2020 numbers shown in *Exhibit 3-21* are from the American Community Survey (ACS) 2020 five-year estimates, which represent data collected over the 5-year period ending in 2020.

Exhibit 3-20 Work Arrival Time Flexibility by Occupation, 2017



Source: National Household Travel Survey.

Exhibit 3-21: Trends in Work from Home: Number and Share of Workers, 1980–2020



Source: U.S. Census Bureau (2020). TableB08301: Means of Transportation to Work. https://data.census.gov/cedsci/table?q=ACS%20means%20of%20transportation%20to%20work&tid=ACSDT5Y2020.B08301

The ability to work from home depends on occupation as well as the availability of internet service. According to the Federal Communications Commission (FCC), 98.8 percent of Americans in urban areas have access to broadband internet (see *Exhibit 3-22*). The FCC defines broadband as having a minimum of 25 Mbps download and 3 Mbps upload speeds. Broadband provides high-speed internet access via multiple types of technologies, including fiber optics, wireless, cable, DSL, and satellite.

In rural areas the number of Americans with access to broadband falls to 82.7 percent, dropping further to 79.1 percent on Tribal lands. Although 25/3 Mbps is the FCC-defined minimum broadband speed, FCC acknowledges that this minimum speed supports activities such as email, social media, and standard-definition video. The 25/3 Mbps minimum does not support file downloads, high-definition (HD) video streaming, HD video conferencing, or many core activities of students and teleworkers.[23]

In urban areas, 87.2 percent of Americans have access to the highest speed broadband, 250/25 Mbps. This number drops to 55.6 percent for rural areas and 49.6 percent on Tribal lands. This broadband speed supports all activities including streaming Ultra HD 4K video.[24]

Exhibit 3-22: Deployment (Millions) of Broadband Internet at Different Speed Tiers, 2017–2019

Internet Speed	Area	2017		2018		2019	
		Population	Percent	Population	Percent	Population	Percent
25/3 Mbps	United States	304.47	93.5%	309.00	94.4%	313.74	95.6%
	Rural Areas	46.98	73.7%	50.14	77.7%	53.83	82.7%
	Urban Areas	257.49	98.3%	258.85	98.5%	259.91	98.8%
	Tribal Lands	2.73	68.1%	2.92	72.3%	3.20	79.1%
250/25 Mbps	United States	190.04	58.3%	280.16	85.6%	286.18	87.2%
	Rural Areas	17.99	28.2%	33.26	51.6%	36.20	55.6%
	Urban Areas	172.05	65.7%	246.89	94.0%	249.97	95.0%
	Tribal Lands	1.60	39.9%	1.84	45.5%	2.01	49.6%
	Population Evaluated	**325.71**		**327.16**		**328.21**	

Source: Federal Communications Commission (2021). Fourteenth Broadband Deployment Report, Report No. FCC-21-18. https://www.fcc.gov/document/fcc-annual-broadband-report-shows-digital-divide-rapidly-closing

Communities without access to high-speed internet are more likely to have lower-than-average population size, lower population density, and lower per-capita and household income compared with communities that have access to broadband (see *Exhibit 3-23*).

Exhibit 3-23: Demographics for Communities with and without Access to Broadband, 2019

Region	Broadband Access	Population Size	Population Density	Per Capita Income (2018 Dollars)	Average Median Household Income (2018 Dollars)
United States	With	1,517.7	7,194.7	$33,336.42	$67,970.89
	Without	1,439.8	1,302.2	$27,441.02	$54,245.57
Rural Areas	With	1,407.7	172.9	$31,212.33	$63,254.26
	Without	1,385.0	78.1	$27,291.17	$54,067.27
Urban Areas	With	1,533.7	8,221.2	$33,646.93	$68,669.25
	Without	1,543.2	3,615.0	$27,728.41	$54,599.34

Note: Population density is the total population residing in the census block group as of 2019 divided by the square miles of land in the census block group; the estimate of land area is based on the 2010 Census.

Source: Federal Communications Commission (2020). 2020 Broadband Deployment Report, Report No. FCC-20-50. https://docs.fcc.gov/public/attachments/FCC-20-50A1.pdf

[23] https://www.fcc.gov/consumers/guides/broadband-speed-guide

[24] Ibid.

Chapter 4: Mobility

Mobility – 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 is often the biggest impediment to maintaining transportation mobility. Despite past capacity expansions on highways, the urban highway system has had difficulties keeping up with rising mobility demands and thus congestion has worsened over time. This deficiency in capacity and reliability can adversely affect the American economy and results in loss of time and fuel as well as missed opportunities.

This section focuses on highway mobility 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.

SECTION SUMMARY

- For the 52 largest metropolitan areas with population over 1 million, the Travel Time Index (TTI) for Interstate and other limited-access highways averaged 1.33 in 2018, meaning that the average peak-period trip took 33 percent longer than the same trip under free-flow traffic conditions.
- For limited-access highways in the same metropolitan areas, the Planning Time Index (PTI) averaged 2.12 in 2018, meaning that ensuring on-time arrival 95 percent of the time required planning for 2.12 times the travel time under free-flow traffic conditions. The median speed for all vehicles on the National Highway System was greater than 55 mph for 55 percent of all vehicles in 2018.
- Congestion grew persistently worse from 2008 to 2018. The average delay for an individual commuter rose from 42 hours in 2008 to 54 hours in 2018. Total delay reached 8.6 billion hours and fuel waste reached 3.4 billion gallons in 2018, leading to a total cost of $188 billion.

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 crashes, construction, inclement weather, and surging demand associated with special events. Such disruptions can make part of the roadway unusable and dramatically reduce the available capacity and reliability of the entire transportation system. About half of total highway congestion is recurring, and the other half nonrecurring.

A standard definition or measurement of what constitutes congestion has not 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), the Federal Highway Administration's (FHWA's) official data source for measuring congestion, 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, using INRIX® travel time data, covers all the National Highway System (NHS) roadways, as well as more than 25 key Canadian and Mexican border crossings. It includes more than 350,000 individual segments, known as Traffic Message Channels (TMCs), whose lengths range from 10 feet to 85.7 miles. The NPMRDS is a compilation of vehicle probe-based data on observed travel times, date/time, direction, average speed, and location for freight and passenger traffic in 5-minute intervals by segment. The data have a high geographical coverage and resolution, enabling localized and in-depth performance analysis.

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.) The data source of the NPMRDS changed in January 2017, based on a slightly different approach in data collection from that used in 2012–2016. This change of data source could lead to changes in mobility measures in 2017 and 2018, although it is impossible to assess the magnitude of the differences.

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, available at the FHWA website (https://ops.fhwa.dot.gov/perf_measurement/ucr/index.htm).

In the NPMRDS-based Urban Congestion Reports, the peak period includes the morning peak period (6 a.m. to 9 a.m.) and afternoon 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.

An alternative source of congestion measures is the Urban Mobility Report developed by the Texas Transportation Institute; the most recent edition released in June 2021 included data for 1982 through 2020. The 2021 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 on 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. The volume and roadway inventory data from FHWA's Highway Performance Monitoring System (HPMS) were used with the speeds to calculate travel delay statistics.

The 2021 Urban Mobility Report assigned peak hours as 6 a.m. to 10 a.m. (morning peak period) and 3 p.m. to 7 p.m. (evening peak period) on weekdays. Congestion occurs if traveling speed is below a congestion threshold, defined as the "reference speeds," as the comparison standard for travel delay. The reference speeds were calculated from the INRIX dataset, which took the lower value of either the low-volume speed (for example, during the period from 10 p.m. to 5 a.m.) or the speed limit (65 mph on the freeways) on each road section according to the roadway design characteristics. The reference speeds are generally slower than the speeds used in previous reports (called free-flow travel speed), resulting in lower delay estimates.

The Urban Congestion Report 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 and estimation methodology, and thus the values for these indicators vary between the two reports. For example, the boundaries of the 52 metropolitan areas used in the Urban Congestion Reports are based on metropolitan statistical areas with population above 1,000,000 in 2010. On the other hand, 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). The definition of free-flow speed or peak hours is also different, resulting in different interpretations of the same congestion indicators.

Travel Time Index

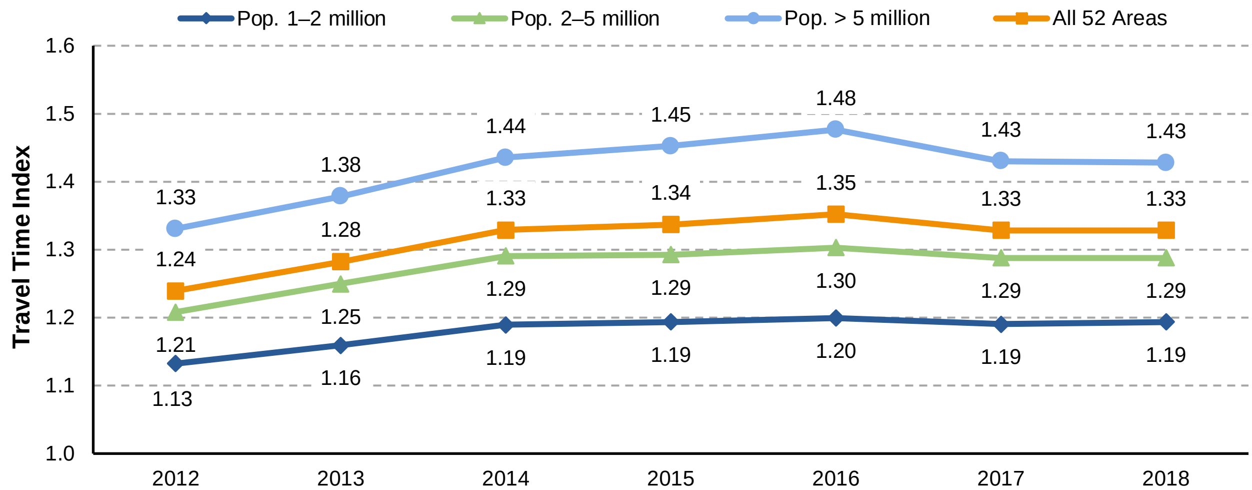
The TTI measures the average intensity of congestion. This index is calculated as the ratio of the travel time during the peak period (the morning and afternoon peak hours on weekdays) to the time required to make the same trip at free-flow speeds. The value of the TTI is always greater than or equal 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.

KEY TAKEAWAY

Based on the NPMRDS, the TTI for freeways and expressways averaged 1.33 in 2018 in the Nation's 52 largest metropolitan areas. This means that the average peak-period trip took 33 percent longer than did the same trip under free-flow traffic conditions. The comparable TTI value for 2012 was 1.24.

Based on the peak-period definition from the NPMRDS-based Urban Congestion Reports referenced above, *Exhibit 4-1* shows that the TTI for all 52 of the largest metropolitan areas was 1.33 in 2018, 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. TTI values are estimated on Interstate highways and other limited-access highways in the NPMRDS. The level of congestion rose continuously from 1.24 in 2012 to its peak of 1.35 in 2016, before dropping marginally to 1.33 in 2017 and 2018. A trip that would have taken 60 minutes during the off-peak period took an average of 74.4 minutes (24 percent longer) during the peak period in 2012, 81.1 minutes (35 percent longer) during the peak period in 2016, and 79.7 minutes (33 percent longer) in 2018.

Exhibit 4-1: Travel Time Index in the 52 Largest Metropolitan Areas by Population, 2012–2018



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 in the 52 largest metropolitan areas (population greater than 1 million). Data cover all Interstate highways and other limited-access highways in these areas. Data on Interstate highways start in 2012; data on other freeways and expressways start in July 2013. Population is from United States Census Bureau 2014 Metropolitan Statistical Areas Population Estimates for 2010. The provider of the NPMRDS changed in January 2017, using a slightly different approach in data collection from that used in 2012–2016.

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

Residents in the largest metropolitan areas tend to experience more severe congestion, and those with more moderate population usually report better mobility. In 2018, the average TTI was 1.43 for metropolitan areas with population over 5 million, meaning that a 60-minute off-peak trip took an average of 85.7 minutes during the peak period (60 minutes multiplied by 1.43). The average TTI for metropolitan areas with population between 2 and 5 million was 1.29, meaning that the same length of off-peak trip took 77.3 minutes during the peak. The TTI for metropolitan areas with population between 1 and 2 million was the lowest at 1.19, meaning that the same length of off-peak trip took 71.6 minutes during the peak.

METROPOLITAN POPULATION

Based on the United States Census Bureau (2014) report *Metropolitan Statistical Areas Population Estimates for 2010*, there are 21 metropolitan areas with population of 1–2 million: Austin, Birmingham, Buffalo, Columbus, Hartford, Indianapolis, Jacksonville, Las Vegas, Louisville, Memphis, Milwaukee, Nashville, New Orleans, Oklahoma City, Providence, Raleigh, Richmond, Rochester, Salt Lake City, and San Jose. There are 22 metropolitan areas with population of 2–5 million: Baltimore, Boston, Charlotte, Cincinnati, Cleveland, Denver, Detroit, Kansas City, Minneapolis, Orlando, Phoenix, Pittsburgh, Portland, Riverside, Sacramento, St Louis, San Antonio, San Diego, San Francisco, San Juan, Seattle, and Tampa. There are 9 metropolitan areas with population of more than 5 million: Atlanta, Chicago, Dallas/Ft Worth, Houston, Los Angeles, Miami, New York, Philadelphia, and Washington, DC.

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 could substantially influence travel decisions.

Travel time reliability measures typically compare high-delay days with average-delay days, which provides a different perspective on 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 be concentrated in the same month or week, such as a week with severe weather.) The planning time index (PTI), used to measure travel time reliability in this report, is defined as the ratio of the 95th percentile of travel time during the morning and afternoon 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).

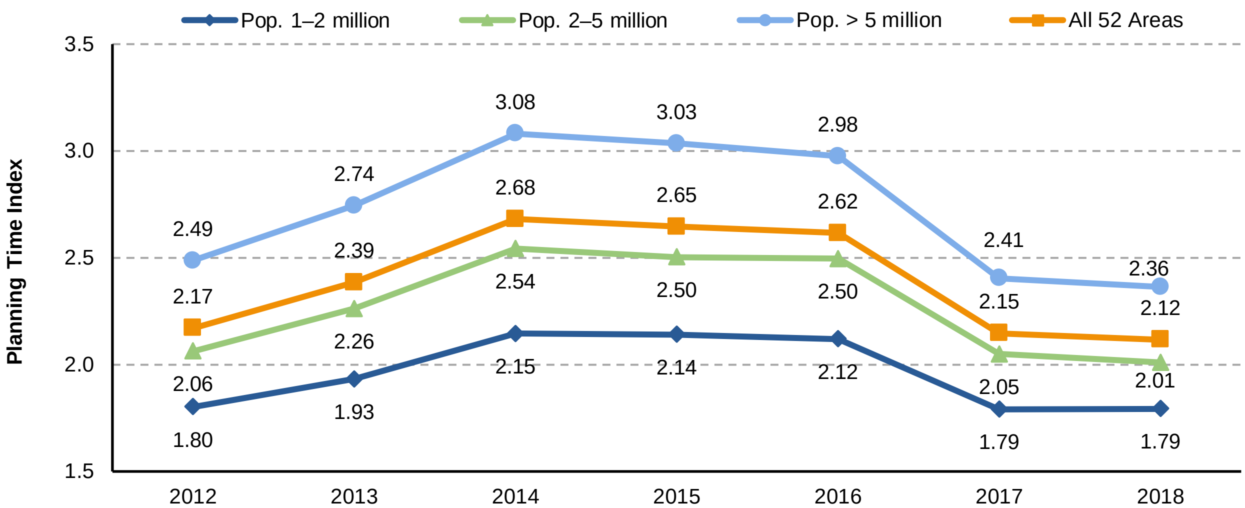
Transportation Performance Management (TPM) Travel Time Reliability Measures

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

- Percentage of the person-miles traveled on the Interstate that are reliable,
- Percentage of person-miles traveled on the non-Interstate NHS that are reliable, and
- Truck Travel Time Reliability Index.

Based on the peak period definition from the NPMRDS-based Urban Congestion Reports referenced above, *Exhibit 4-2* indicates the average PTI was 2.12 in the 52 largest metropolitan areas in 2018, meaning that travelers would need to plan on a 60-minute off-peak trip requiring up to 127.0 minutes (2.12 × 60 minutes) in the peak period to ensure on-time arrival 95 percent of the time. The value of the PTI was 2.17 in 2012, rose quickly to 2.68 in 2014, then declined steadily to a lower level of 2.12 in 2018. To ensure on-time arrival for a 60-minutes off-peak trip, an average traveler would have to allocate a total of 130 minutes in 2012; this budgeted time reached 161 minutes in 2014 then fell to its lowest level of 127 minutes in 2018.

Exhibit 4-2: Planning Time Index in the 52 Largest Metropolitan Areas by Population, 2012–2018



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 (population greater than 1 million). Data cover all Interstate highways and other limited-access highways in these areas. Data on Interstate highways start in 2012; data on other freeways and expressways start in July 2013. Population is from United States Census Bureau 2014 Metropolitan Statistical Areas Population Estimates for 2010. The provider of the NPMRDS changed in January 2017, using a slightly different approach in data collection from that used in 2012–2016.

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 2018, the average PTI was 2.36 on limited highways in metropolitan areas with more than 5 million residents, 18 percent higher than the PTI of 2.01 observed in areas with population between 2 million and 5 million, and 32 percent higher than the PTI of 1.79 in areas with population between 1 million and 2 million. The discrepancies across different sizes shrank over time, due mainly to improved travel time reliability in major metropolitan areas with large populations.

Congested Hours

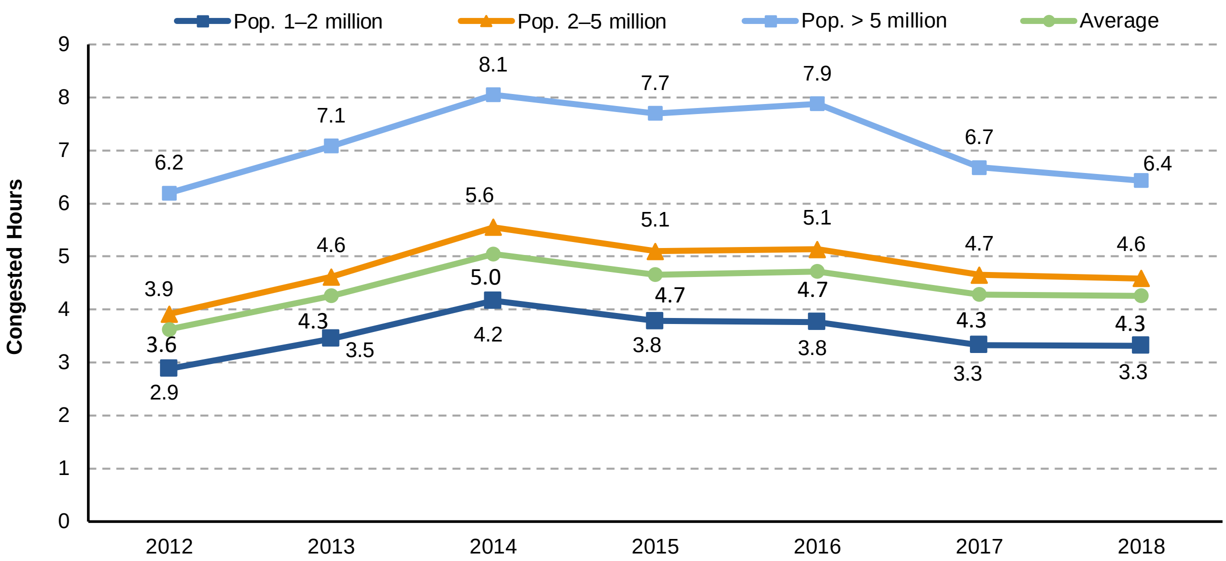
Congested hours are another performance indicator computed from NPMRDS for the 52 largest metropolitan areas in the United States. This indicator is calculated as the average number of hours when road sections are congested (speeds below 90 percent of free-flow speed) from 6 a.m. to 10 p.m. on weekdays. Averages are weighted across road sections and urban areas by VMT using volume estimates derived from FHWA's HPMS. As shown in *Exhibit 4-3*, highways were congested for 4.3 hours per day on average in 2018. For the 52 largest metropolitan areas combined, congested hours per day rose from 3.6 hours in 2012 to 5.0 hours in 2014, before tailing off to 4.3 hours in 2018.

KEY TAKEAWAY

For the Nation's 52 largest metropolitan areas, the PTI as computed based on the NPMRDS averaged 2.12 for freeways and expressways in 2018, meaning that ensuring on-time arrival 95 percent of the time required planning for 2.12 times the travel time under free-flow traffic conditions. The comparable PTI value for 2012 was 2.17. On average, freeways and expressways in these areas were congested for 4.3 hours per day in 2018, up from 3.6 hours in 2012.

Similar to the trend for the TTI and PTI, congestion duration has been higher on average in larger metropolitan areas. In areas with a population above 5 million, roads were congested for an average of 6.4 hours per day in 2018. Road congestion eased by 40 percent to 4.6 hours per day in metropolitan areas with population of 2–5 million. Residents in metropolitan areas with population between 1 and 2 million experienced the lowest number of congested hours, averaging 3.3 hours in 2018.

Exhibit 4-3: Congested Hours in the 52 Largest Metropolitan Areas, 2012–2018



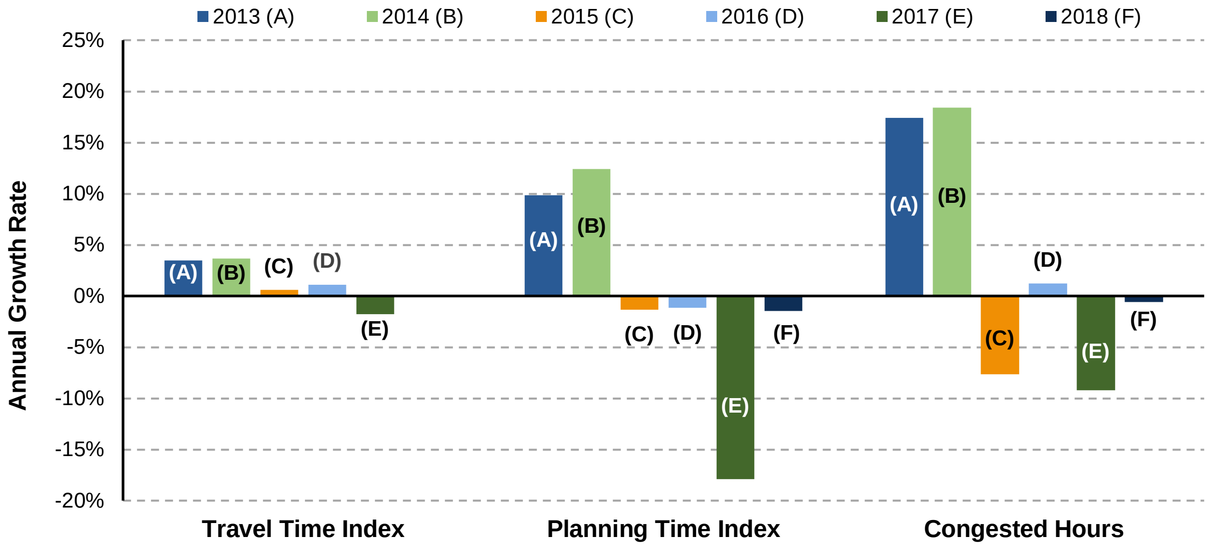
Note: Congested hours are averaged across metropolitan areas, road sections, and periods weighted by VMT using volume estimates derived from FHWA's Highway Performance Monitoring System over the 52 largest metropolitan areas (population greater than 1 million). Data cover all Interstate highways (Interstate functional class) and other limited-access highways (Other Freeway and Expressway functional class) in these areas. Data on Interstate highways start in 2012; data on other freeways and expressways start in July 2013. Population is from United States Census Bureau 2014 Metropolitan Statistical Areas Population Estimates for 2010. The provider of the NPMRDS changed in January 2017, using a slightly different approach in data collection from that used in 2012–2016.

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

Relationship Among Congestion Measures

TTI, PTI, and congested hours can be used to measure congestion intensity, volatility, and duration. *Exhibit 4-4* illustrates the evolution of congestion measures from 2012 to 2018. Travel time index showed relative stability compared to the other indicators, never rising or declining by more than 5 percent in any year. Planning time grew sharply in 2013 and 2014 by more than 10 percent. This was followed by four years of regression, with a 1-percent reduction in 2015 and 2016 and an 18-percent reduction in 2017 before declining by another 1 percent in 2018. (It should be noted that the large change in 2017 could be due in part to a change in the NPMRDS data provider in 2017.) Congested hours also grew sharply in 2013 and 2014, with percentage increases of 17 and 18 points respectively. From there congested hours dropped by 8 percent in 2015, 9 percent in 2017, and 1 percent in 2018. These indicators suggested that congestion worsened in 2013 and 2014, followed by flat growth or improved traffic conditions in the 2015–2018 period. Compared with TTI, both PTI and congested hours showed noticeable year-over-year variations. There were substantial drops in PTI and congested hours in 2017, suggesting improvement in both travel time reliability and the time that highways were congested, whereas congestion intensity (measured in TTI) shrank only modestly.

Exhibit 4-4: Annual Growth of Congestion Measures in the 52 Largest Metropolitan Areas, 2013–2018

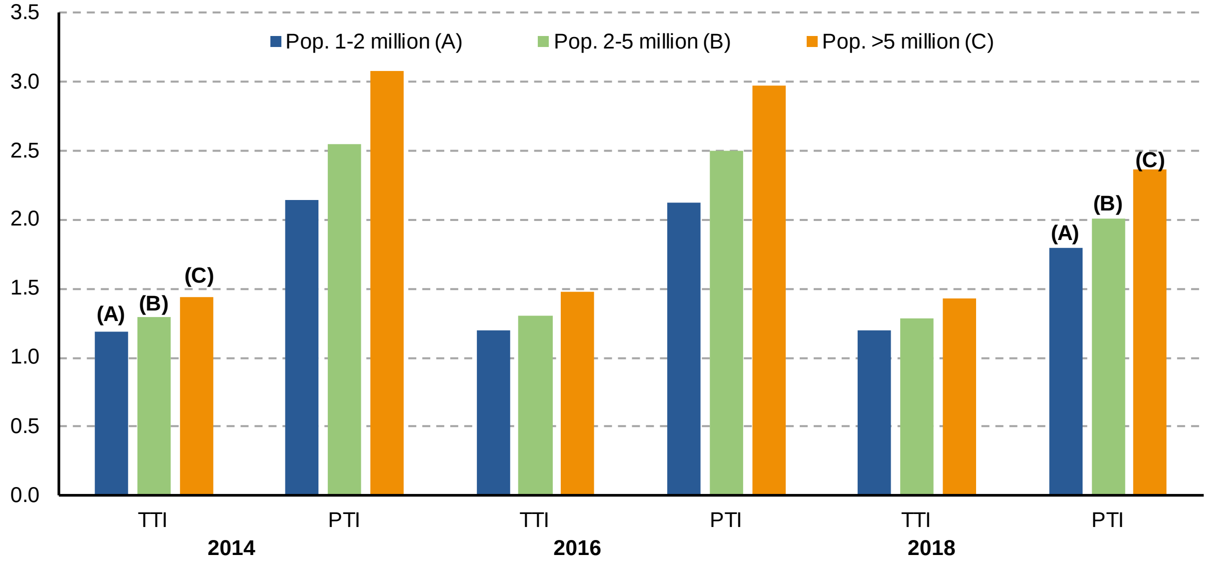


Note: Travel time index is averaged across metropolitan areas, road sections, and periods weighted by VMT using volume estimates derived from FHWA's Highway Performance Monitoring System over the 52 largest metropolitan areas (population greater than 1 million). Data cover all Interstate highways and other limited-access highways in these areas. Data on Interstate highways start in 2012; data on other freeways and expressways start in July 2013. Population is from United States Census Bureau 2014 Metropolitan Statistical Areas Population Estimates for 2010. The provider of the NPMRDS changed in January 2017, using a slightly different approach in data collection from that used in 2012–2016.

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

Exhibit 4-5 demonstrates that the average PTI has been consistently above the average TTI among the 52 largest metropolitan areas of different sizes covered in the NPMRDS. Drivers living in more populated urban areas tended to experience more severe congestion and low reliability during peak hours than those living in less populated urban areas. The reliability premium for smaller metropolitan areas was more pronounced, as the differences in PTI between areas of different sizes were much larger than the TTI difference. For example, PTI in metropolitan areas with population above 5 million was 18 percent higher than in metropolitan areas with population of 2–5 million and 32 percent higher than metropolitan areas with population of 1–2 million. The differences in TTI were only 20 and 11 percent higher for the same groups.

Exhibit 4-5: Travel Time Index and Planning Time Index in the 52 Largest Metropolitan Areas by Population, 2014, 2016, and 2018



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 (population greater than 1 million). Data cover all Interstate highways and other limited-access highways in these areas. Data on Interstate highways start in 2012; data on other freeways and expressways start in July 2013. Population is from United States Census Bureau 2014 Metropolitan Statistical Areas Population Estimates for 2010. The provider of the NPMRDS changed in January 2017, using a slightly different approach in data collection from that used in 2012–2016.

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

Seasonal Patterns in Congestion and Reliability

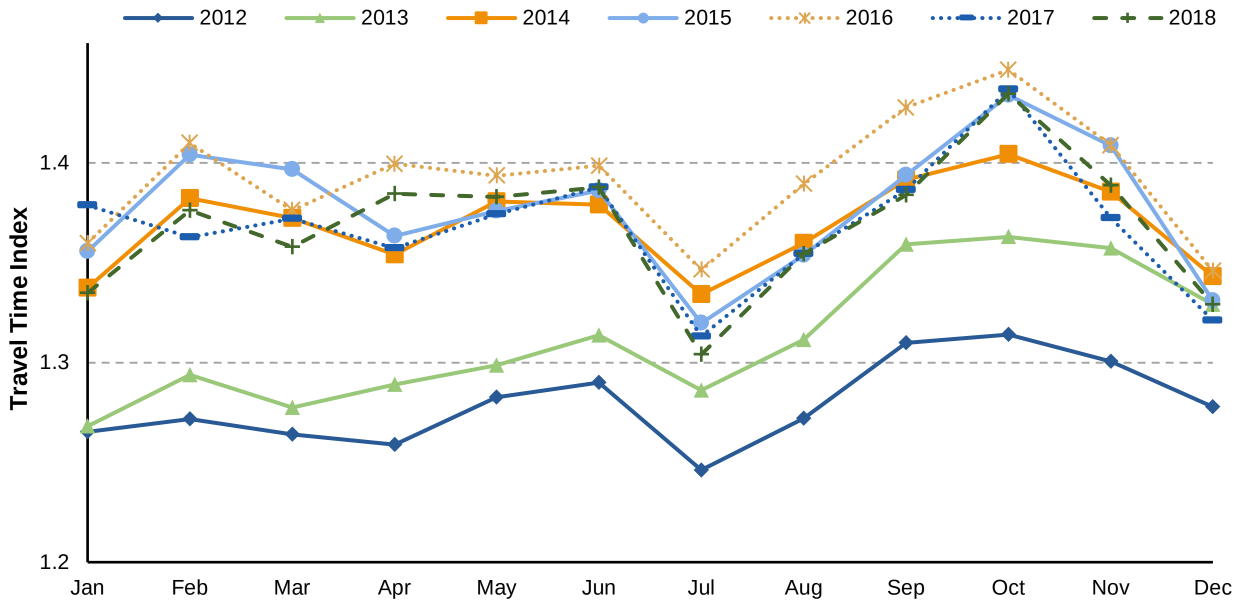
Road congestion varies over the course of a year. For each year from 2012 to 2018, travel conditions tended to be stable in the first half of the year, when the TTI stayed relatively flat (see *Exhibit 4-6*). TTI dropped to the lowest level in July, then quickly rose to the highest yearly value in October, and dropped again in the last two months of the year. Between July and October, peak-hour travel condition worsened substantially due to decreased speed and extended travel time. This observation is consistent with the public's perception of better travel conditions in summer during vacation season, with congestion rising in September as schools are again in session. TTI values were lower in 2012 and 2013 than other years, due to the limited data coverage of only Interstate in that year.

PTI generally fluctuated less in the first half of the year than in the second half (See *Exhibit 4-7*). The month with the lowest PTI on highways varied by year: it was in the summer months of July and August in 5 out of 7 years, and in the winter/spring months of February in 2014 and March in 2013. Highways were more congested in January of 2017, consistent with the trend observed in TTI in *Exhibit 4-6.*

The upward trend of PTI in the second half of the year implies that travel time reliability generally worsened in fall and winter. This seasonal pattern is more evident in the last quarter, where PTI consistently rose to a yearly high. Travelers experienced the highest monthly PTI values in wintertime: 4 years in November, October in 2013, December in 2014, and January in 2017.

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 January (2017), February (2014 and 2015), November (2018), and December (2012, 2013, and 2016) (see *Exhibit 4-8*). Limited-access highways tended to experience the shortest periods of congestion during the summer months of July (2015–2018) and September (2014). Congestion was low in April of 2012 and 2013.

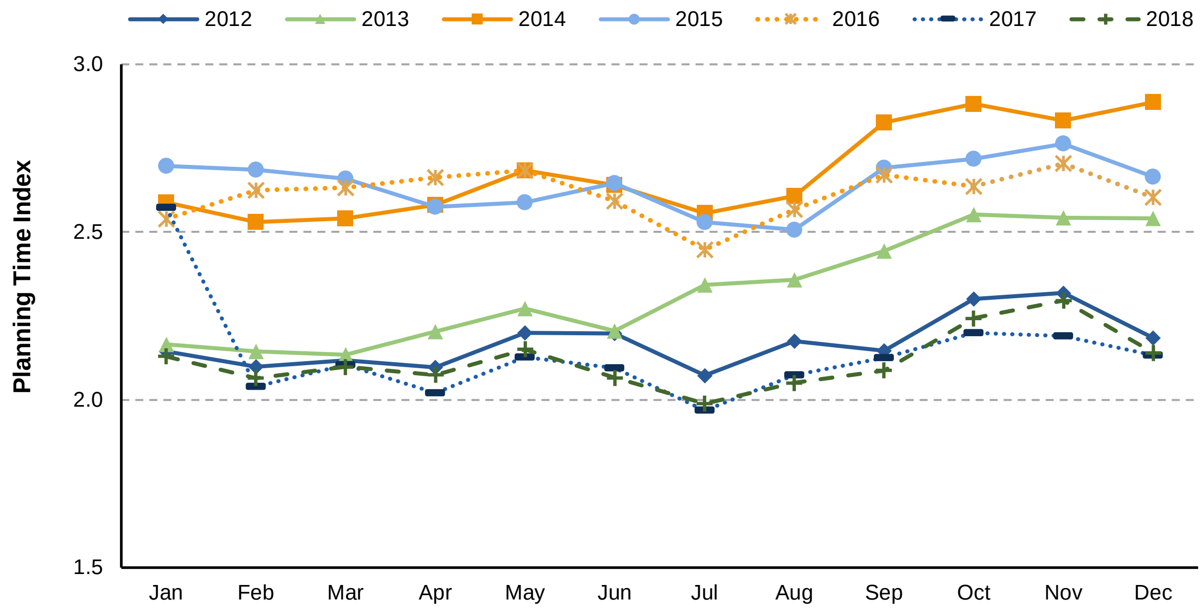
Exhibit 4-6: Monthly Travel Time Index in the 52 Largest Metropolitan Areas, 2012–2018



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 (population greater than 1 million). Data cover all Interstate highways and other limited-access highways in these areas. Data on Interstate highways start in 2012; data on other freeways and expressways start in July 2013. Population is from United States Census Bureau 2014 Metropolitan Statistical Areas Population Estimates for 2010. The provider of the NPMRDS changed in January 2017, using a slightly different approach in data collection from that used in 2012–2016.

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

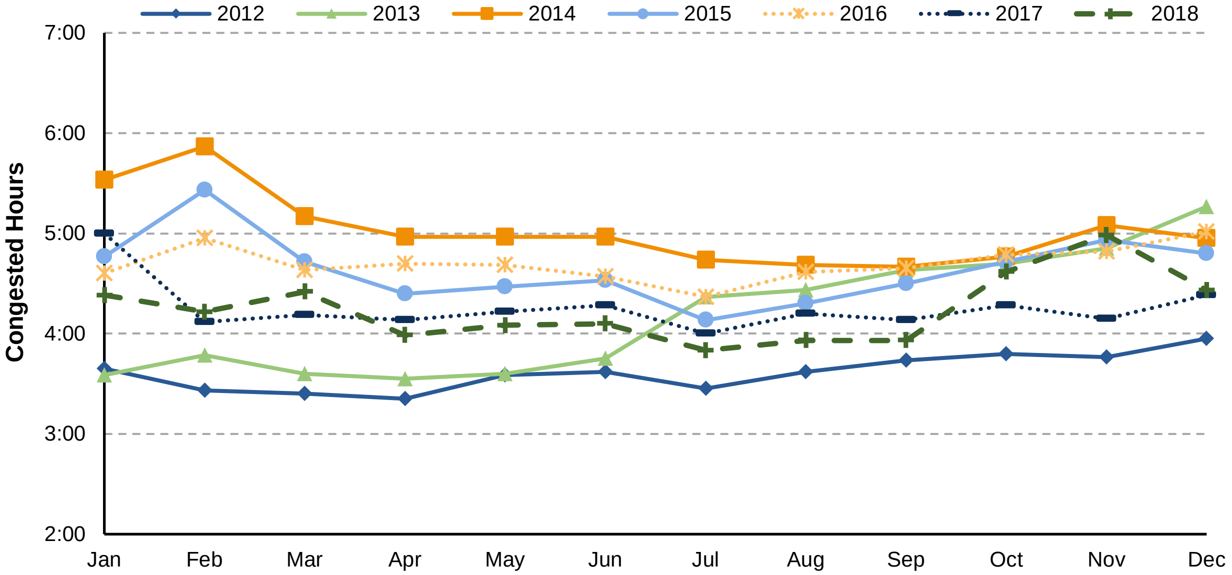
Exhibit 4-7: Monthly Planning Time Index in the 52 Largest Metropolitan Areas, 2012–2018



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 (population greater than 1 million). Data cover all Interstate highways and other limited-access highways in these areas. Data on Interstate highways start in 2012; data on other freeways and expressways start in July 2013. Population is from United States Census Bureau 2014 Metropolitan Statistical Areas Population Estimates for 2010. The provider of the NPMRDS changed in January 2017, using a slightly different approach in data collection from that used in 2012–2016.

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

Exhibit 4-8: Monthly Congested Hours in the 52 Largest Metropolitan Areas, 2012–2018



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 (population greater than 1 million). Data cover all Interstate highways and other limited-access highways in these areas. Data on Interstate highways start in 2012; data on other freeways and expressways start in July 2013. Population is from United States Census Bureau 2014 Metropolitan Statistical Areas Population Estimates for 2010. The provider of the NPMRDS changed in January 2017, using a slightly different approach in data collection from that used in 2012–2016.

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

Congestion Trends

This section focuses on examining congestion development from 2008 to 2018, based on the 2021 Urban Mobility Report. As noted earlier, the Urban Mobility Report uses some of the same metrics as those presented above, but the values were calculated using a different data source and methodology for a much larger number of urban areas. For example, the reference speed is now defined as the lower value of either the low-volume speed (such as the period from 10 p.m. to 5 a.m.) or the speed limit (65 mph on the freeways). Thus, the values presented in this section are not comparable with the values for the indicators reported above, although they represent similar concepts.

KEY TAKEAWAY

The Texas Transportation Institute's 2021 *Urban Mobility Report* estimates that the average commuter in 494 urbanized areas experienced a total of 54 hours of delay resulting from congestion in 2018, up from 42 hours in 2008. Total delay reached 8.6 billion hours and fuel wasted reached 3.4 billion gallons in 2018, leading to a total cost of $188 billion.

The average TTI first decreased during the economic downturn of 2009–2011, but subsequently rebounded and exceeded pre-recession levels in urbanized areas. The average TTI increased from 2011 to 2018 in 494 U.S. urbanized areas (*Exhibit 4-9*), 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 54 additional hours sitting in traffic during the peak traveling period in 2018, which is a substantial escalation from 42 hours in 2008. 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 30 percent over the 10 years and reached 8.6 billion hours in 2018.

Congestion wastes an enormous amount of fuel. Over the period of 2008–2018, the extra fuel consumed during congested travel increased from 3.1 billion to 3.4 billion gallons in 494 urbanized areas in the United States. Combining wasted fuel with travel time delay, the total cost of congestion was estimated to be $188 billion in 2018, $59 billion higher than 2008. (The average cost of time was assumed to be $20.17 per person-hour and $55.24 per truck-hour in 2020 constant dollars, which differ from the values used in the Part II analyses of this report. Fuel cost was aggregated using the average price in each State.)

Exhibit 4-9: National Congestion Measures in 494 Urbanized Areas, 2008–2018

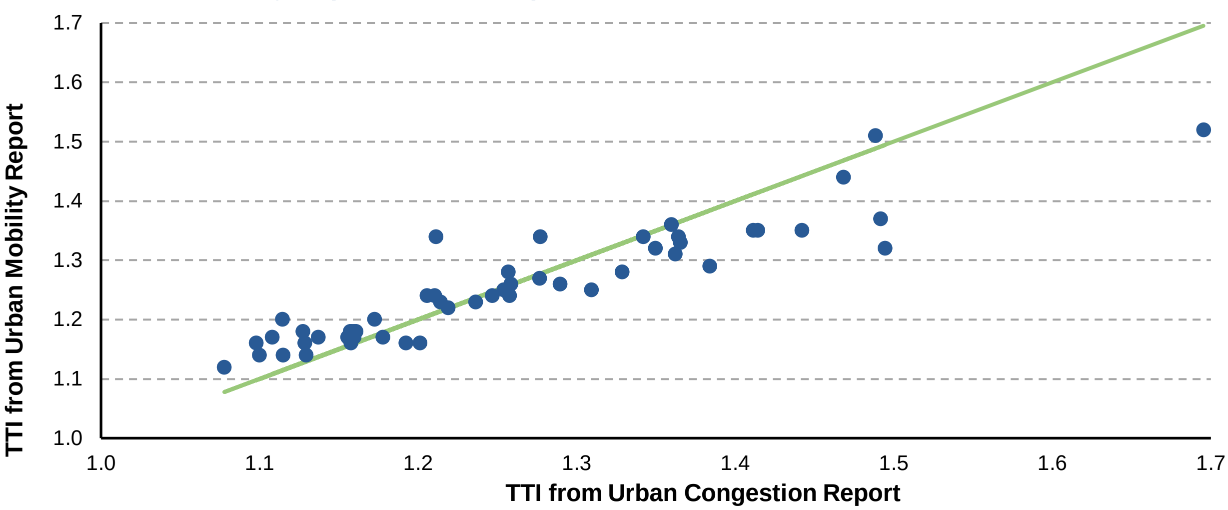
Year	Travel Time Index	Delay per Auto Commuter (Hours)	Total Delay (Billions of Hours)	Total Fuel Wasted (Billions of Gallons)	Total Cost
2008	1.21	42	6.6	3.1	$129
2009	1.21	43	6.7	3.0	$127
2010	1.21	44	6.9	3.0	$135
2011	1.21	45	7.2	3.1	$145
2012	1.22	46	7.4	3.1	$153
2013	1.22	48	7.7	3.2	$160
2014	1.22	49	7.9	3.2	$166
2015	1.22	51	8.1	3.3	$168
2016	1.23	52	8.3	3.3	$175
2017	1.23	53	8.5	3.3	$182
2018	1.23	54	8.6	3.4	$188

Note: Dollar values are in billions.

Source: Texas Transportation Institute (2021).

The Urban Congestion Report and the Urban Mobility Report used different definitions of peak period and free-flow or reference speed in calculation, hence they will produce different TTI estimates. *Exhibit 4-10* compares the 52 metropolitan areas in 2018 that were included in both reports. The solid line in the graph indicates that the two indicators take the same value. The scatterplot indicates that the calculated values of TTI from both reports are close and positively correlated in most cases (the correlation coefficient is 0.93).

Exhibit 4-10: Comparison of Travel Time Index from Urban Congestion Report and Urban Mobility Report in 52 Metropolitan Areas, 2018



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

The correlation is more manifest in metropolitan areas with less severe congestion. In metropolitan areas reporting low TTI values in the lower left part of *Exhibit 4-10*, the TTI presented in the Urban Congestion Report are consistently lower than the TTI presented in the Urban Mobility Report. In the graph, the dots are located close to and mostly above the solid line where TTI values are below 1.3. In metropolitan areas with heavier congestion of high TTI values, the pattern reverses. The values of TTI reported in the Urban Congestion Report tend to be consistently higher than the TTI presented in the Urban Mobility Report. The differences between the two TTI measures are larger as the dots deviate from the solid line. The noticeable outlier is Los Angeles, which has a TTI value of 1.70 in the Urban Congestion Report and 1.52 in the Urban Mobility Report. The difference could be attributable to the different data sources, assumptions, and estimation methods.

TPM Delay and Congestion Measures

TPM establishes national performance measures that use travel time specified in Title 23 Code of Federal Regulations Part 490, including:

- Two travel time reliability (TTR) measures to carry out the National Highway Performance Program:
  - Percent of the person-miles traveled on the Interstate that are reliable (referred to as the "Interstate Travel Time Reliability Measure"); and
  - Percent of person-miles traveled on the non-Interstate NHS that are reliable (referred to as the "Non-Interstate Travel Time Reliability Measure").
- One freight reliability measure to assess the freight movement on the Interstate System—the Truck Travel Time Reliability (Truck TTR) Index (referred to as the "Freight Reliability Measure").
- Two performance measures to assess traffic congestion to carry out the CMAQ program (referred to collectively as the "CMAQ Traffic Congestion Measures"):
  - Annual Hours of Peak Hour Excessive Delay (PHED) Per Capita (referred to as the "PHED Measure"); and
  - Percent of Non-SOV Travel (referred as the "Percent Non-SOV Travel Measure").

The level of TTR for all vehicles is defined as the ratio of the 80th-percentile travel time of a reporting segment to a "normal" travel time (50th percentile), using data from FHWA's NPMRDS or equivalent. The TTR is measured as the percent of person-miles traveled on the relevant NHS area that is reliable. TPM requires reporting in four periods: morning peak (6–10 a.m.), midday (10 a.m.–4 p.m.), and afternoon peak (4–8 p.m.) Mondays through Fridays; and weekends (6 a.m.–8 p.m.). The measures on the Interstate are different from those of the non-Interstate NHS. State DOTs were required to provide a Baseline Performance Period Report by October 1, 2018, including 2- and 4-year targets for the Interstate system, but only a 4-year target for the non-Interstate NHS.

The Truck TTR index is defined as the ratio between the 95th- and 50th-percentile truck travel times using FHWA's NPMRDS or equivalent data. In addition to the four periods required for TTR of all vehicles, TPM requires reporting a fifth period—overnights (8 p.m.–6 a.m.) for all days. The Truck TTR ratio is generated by dividing the 95th percentile time by the normal time (50th percentile) for each road segment. The Truck TTR Index is generated by multiplying each segment's largest ratio of the five periods by its length, then dividing the sum of all length-weighted segments by the total length of the road system. Truck TTR considers factors that are unique to this industry, such as the use of the system during all hours of the day and the importance of just-in-time delivery (95th percentile) to the freight industry.

FHWA describes detailed computation procedures for travel time-based measures. Beginning in 2018, State DOTs were required to submit travel time-related metric data by reporting segments by June 15th of each year for the previous year's measures. Metrics on the NHS are reported via HPMS.

National Travel Speed

In addition to estimating congestion in specific geographic areas, the NPMRDS can be used to examine travel time, speed, and reliability for the whole NHS. FHWA has conducted an in-depth analysis of multiple performance metrics to assess travel speed and reliability using the NPMRDS data in 2018. Instead of annual trends reported in the Urban Congestion Report or Urban Mobility Report, this analysis focuses on travel speed and reliability by different periods of the day for all vehicles and trucks in a single year for an in-depth understanding of mobility. The analysis provides a comprehensive perspective on the complexity of both data processing methods and overall travel reliability patterns and trends in computing these metrics.

Speed Metrics

Travel speed is a straightforward measure of the severity of congestion, with high speed associated with more favorable travel and low speed associated with different degrees of congestion. The speed metrics are based on information about each road segment (TMC) in NPMRDS: segment geospatial parameters, periods of the measurement, average speed, and vehicle travel time. Although the raw data are based on a 5-minute interval, the FHWA analysis used 15-minute intervals, same as in the TPM rule. The metrics used to measure speed include the 50th percentile travel time and travel speed. The 50th percentile (median) travel time is calculated for each group of TMCs based on year, period, and vehicle type (truck, passenger vehicle, or all vehicles). The median speed is calculated by dividing the length of the TMC by the 50th percentile travel time.

This report groups road segments on the NHS in a 5-category system based on average travel speed: below 20 miles per hour (mph), between 20 and 30 mph, between 30 and 45 mph, between 45 and 55 mph, and above 55 mph. Performance metrics of travel speed for all vehicles and trucks are computed in four periods, same as defined in the TPM regulations. Three periods of measurement are for weekdays: morning peak 6 a.m.–10 a.m., midday 10 a.m.–4 p.m., and afternoon peak 4 p.m.–8 p.m., and one for weekends: 6 a.m.–8 p.m. An additional period is used for every night 8 p.m.–6 a.m. for trucks only.

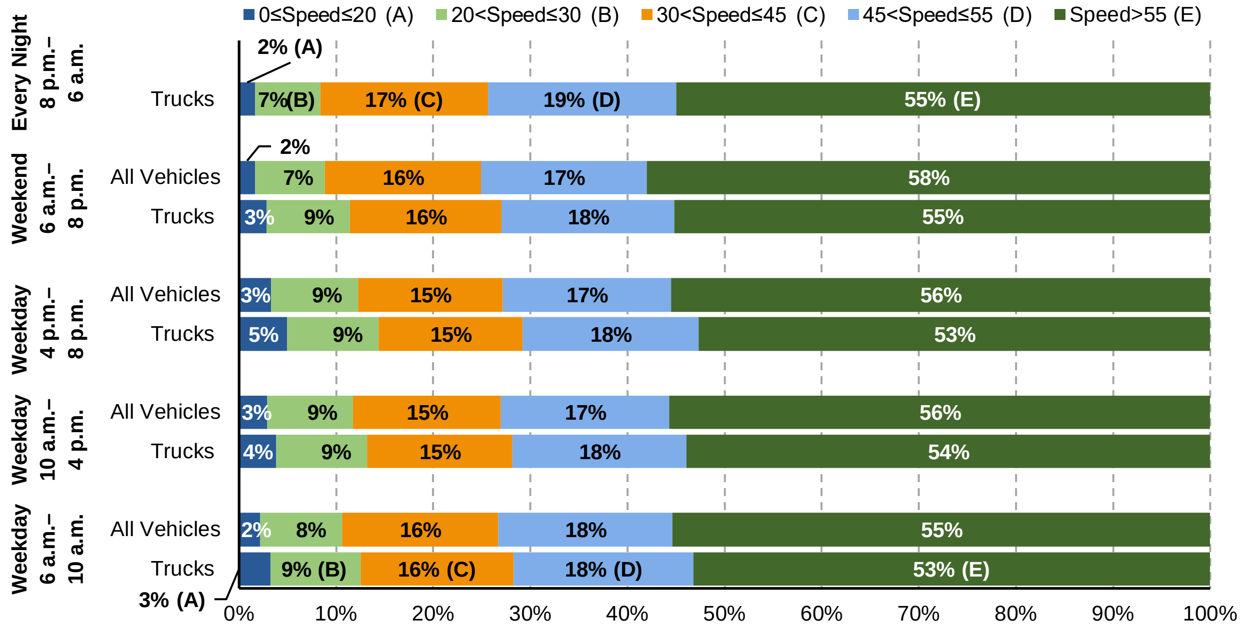
Each TMC in each period is assigned a speed category based on its calculated speed. The share of each speed category in a period is the ratio of aggregate TMC length in the speed category for the specific period and total TMC length for the same period. In the case of higher speed limits (for example at 75 mph), a median speed of 55 mph (50th percentile) usually suggests the 85th percentile speed would be over 60 mph. From a traffic operations standpoint, traffic is not considered congested when the 85th percentile speed is above 55 mph. (Traffic engineers use the 85th percentile speed to set the speed limit at a safe speed.)

Travel Speed

More than half of NHS roadways operated at congestion-free condition for all vehicles in 2018, with median speed above 55 mph from 6 a.m. to 8 p.m. every day (*Exhibit 4-11*). For example, 55 percent of NHS roadways experienced an average speed above 55 mph during the weekday morning peak, and 56 percent during the weekday afternoon peak. An additional 17–18 percent of NHS roadways reported an average speed between 45 and 55 mph during the same periods. Together, they indicated that 73 percent of NHS roads were near or at congestion-free status for all vehicles. On the other hand, a noticeable proportion of NHS roads were still heavily congested. During the weekday morning peak, vehicles traveled at below 20 mph on 2 percent of NHS roads and between 20 and 30 mph on 8 percent of roads.

Average travel speed of trucks was slightly lower than the speed of all vehicles. During the weekday morning peak, about 3 percent of NHS roads used by trucks were in undesirable condition at below 20 mph, and 9 percent were between 20 and 30 mph. Both shares were one percentage point higher than that of all vehicles. The same pattern of difference was repeated for weekday midday, weekday afternoon peak, and weekends, indicating persistent higher congestion for trucks.

Exhibit 4-11: Median Speed (MPH) on the National Highway System, 2018



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

Additionally, *Exhibit 4-11* presents the distribution of speed by trucks on the NHS in 2018, including every night from 8 p.m. to 6 a.m. A higher portion of truck drivers experienced lower median speed than all vehicles. Congestion tends to be alleviated in most segments of the NHS at nighttime compared with weekdays or weekend daytime. A smaller portion of NHS roads used by trucks were severely congested during the nights. The share of NHS roads that operated at a speed below 20 mph was 2 percent, lower than the shares of 3–5 percent reported in other times of the week. Only 7 percent of truck routes are identified with median night truck speed between 20 and 30 mph, also lower than 9 percent observed during daytime. On the other hand, more trucks traveled at almost congestion-free speed during nighttime. Nineteen percent of night truck traffic was close to congestion-free with median speed between 45 and 55 mph, and 55 percent of road length was free of congestion with median speed above 55 mph.

National Travel Reliability

Traffic congestion not only causes lower traveling speed, but also results in travel time unreliability and unpredictability.

Reliability Metrics

Two additional metrics are estimated using percentiles calculated from TMC segments in the NPMRDS: travel time reliability (TTR) and truck travel time reliability (Truck TTR). TTR for all vehicles is defined as the ratio of the 80th percentile travel time of a reporting segment to the 50th percentile. Truck TTR is defined as the ratio of the 95th percentile to the 50th percentile of driving time for trucks only. TTR and Truck TTR values are always equal to or greater than one, with higher TTR and Truck TTR values indicating higher congestion and lower reliability of travel. The Truck TTR is always higher than TTR because it uses a higher percentile threshold. The 80th percentile measures the worst day out of 5 days, or the worst days of a work week, whereas the 95th percentile measures the worst day out of 20 days which accounts for more traffic events that a truck will encounter over 4 weeks. The 95th percentile for Truck TTR reflects industry supply chain management, which is often based on 95 percent or better on-time freight delivery.

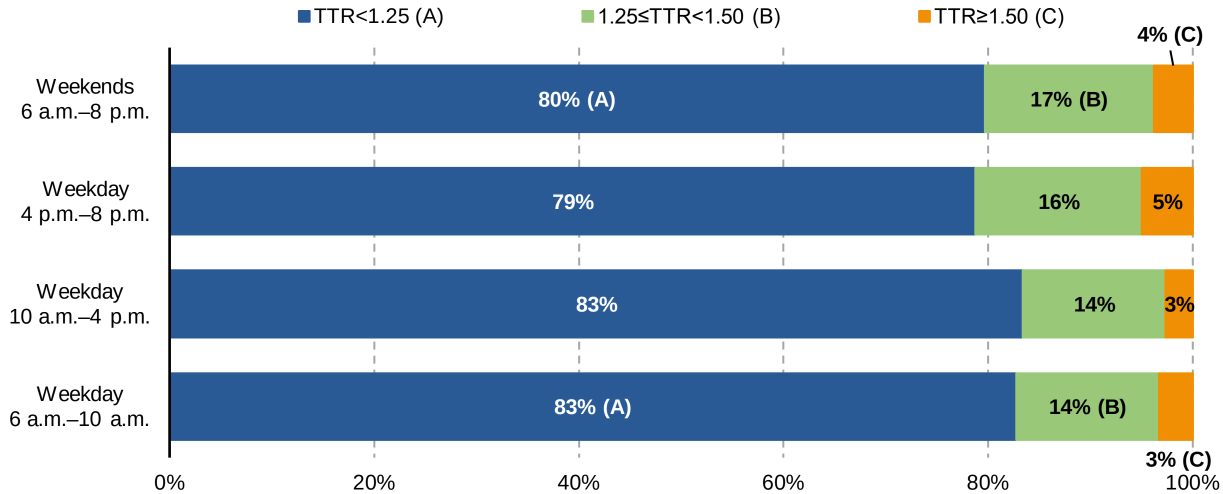
This report groups road segments in the NHS in a 3-category system based on TTR: below 1.25, between 1.25 and 1.50, and above 1.50. A TTR above 1.50 indicates heavy congestion, whereas a TTR value below 1.25 indicates reliable travel with few disruptions from congestion. The values of TTR and Truck TTR are computed in the same periods as those of median speed.

Each TMC in each period is assigned a TTR category based on its calculated TTR. The share of each TTR category in a period is the ratio of aggregate TMC length in the TTR category for the specific period and total TMC length for the same period.

Travel Time Reliability

Exhibit 4-12 shows the level of travel time reliability for different times of day for all vehicles. About 80 percent of NHS segments experienced no reliability issue at any time of day with TTR below 1.25. Travel reliability tended to be higher during weekdays before afternoon peak but deteriorated afterwards. Reliability during weekends was not optimal either; the share of highly reliable roads was similar to that of the weekday afternoon peak but lower than the weekday morning peak or midday. In 2018, approximately 3 percent of NHS roads were highly unreliable in the morning peak and midday hours, rising to 5 percent in weekday afternoon peaks. The poor driving condition from heavy congestion did not disappear on weekends, as 4 percent of roads still had a TTR value above 1.5.

Exhibit 4-12: All Vehicle Travel Time Reliability on the National Highway System, 2018

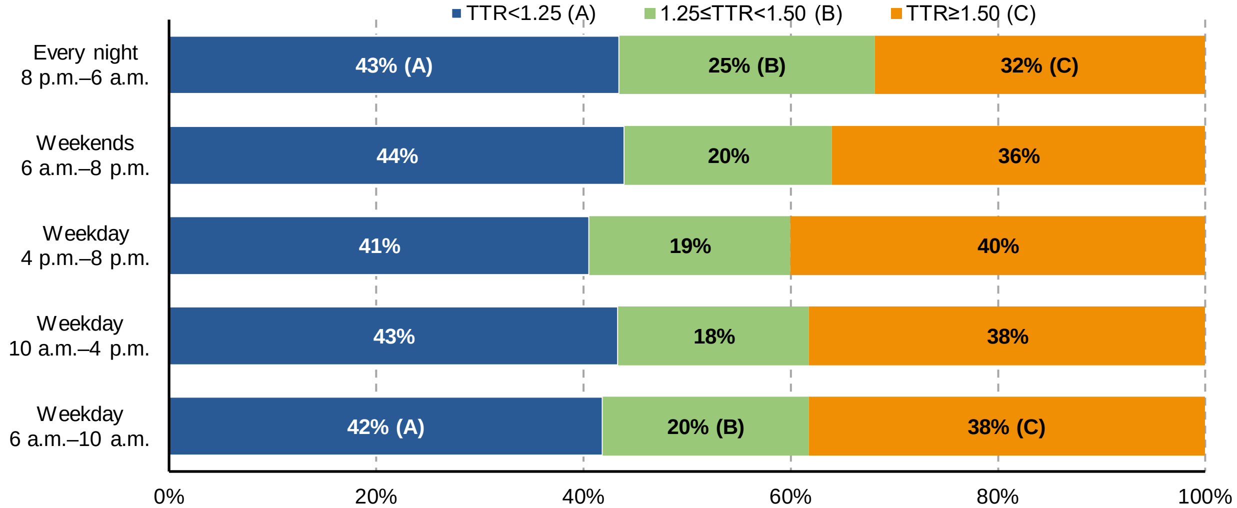


Source: FHWA staff calculation from the National Performance Management Research Data Set.

Truck TTR tells a different story because it measures the 95th percentile of travel time, instead of the 80th percentile. This results in a much lower share for roads falling in the category of Truck TTR less than 1.25, and a higher share of roads in the category of Truck TTR above 1.50, which makes on-time freight delivery more difficult for supply chain needs. Nationwide in 2018, about 41–43 percent of NHS roads used by trucks offered a reliable condition, with Truck TTR values below 1.25, for trucks to travel during various periods in weekdays (*Exhibit 4-13*). This share of reliable NHS roads was merely half of the share for all vehicles at 80 percent. At the same time, a substantial portion of road segments did not meet the reliability needs for on-time truck deliveries: 38–40 percent of road segments were classified very unreliable, with Truck TTR values above 1.50, whereas only less than 5 percent of roads were classified as unreliable for all vehicles. Truck travel appeared to be more reliable over weekends, when 44 percent of roads were reliable and 36 percent highly unreliable. Moreover, truck reliability was the most desirable during the night shift between 8 p.m. and 6 a.m., as many roads that were less reliable

(Truck TTR>1.50) during daylight hours became less congested and reported better Truck TTR values.

Exhibit 4-13: Truck Travel Time Reliability on the National Highway System, 2018



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

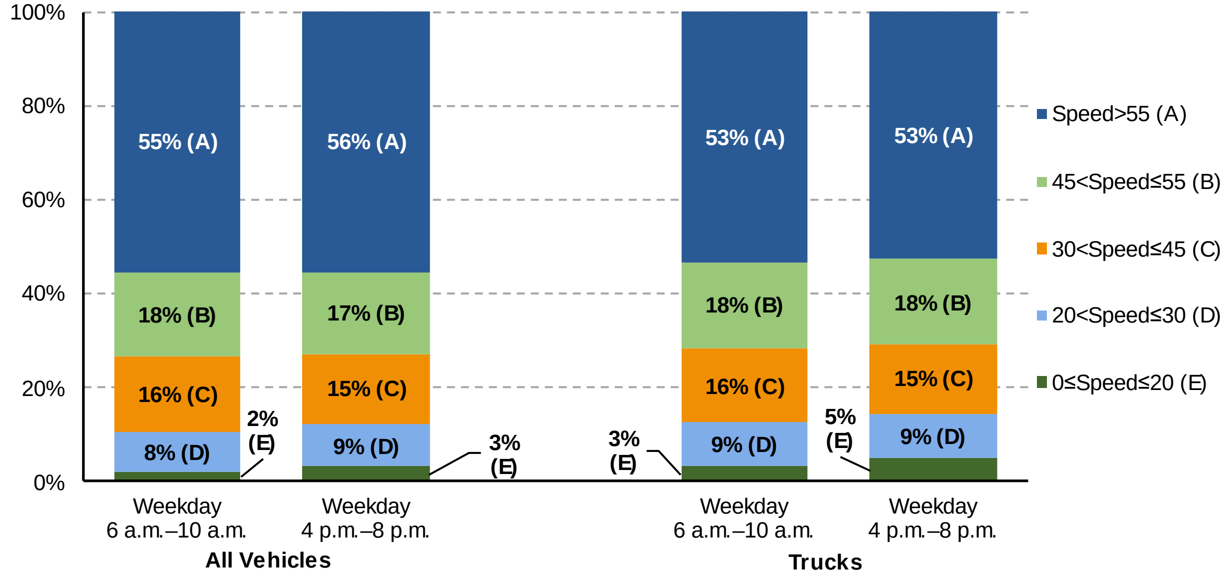
Comparison between Morning and Afternoon Peak Travel

Exhibit 4-14 compares the distribution of median speed during weekday morning and afternoon peaks, for all vehicles and for trucks only. Speed differences between morning and afternoon peaks across the five speed categories were small. However, the distribution of median speed appeared to be more polarized during afternoon peak hours compared with the morning peak. In 2018 the share of heavily congested roads (median speed lower than 20 mph) during afternoon peak was 3 percent, up from 2 percent during morning peak. The share of congested roads (median speed between 20 and 30 mph) also increased from 8 percent during the morning peak to 9 percent during the afternoon peak. Together, congested roads represented 12 percent of total NHS roads during the afternoon peak, a 2-percentage-point increase from the morning peak. Conversely, the share of congestion-free roads (median speed above 55 mph) expanded from 55 percent during the morning peak to 56 percent during the afternoon peak. These changes resulted in smaller shares of median speed between 30 and 55 mph: a decrease from 34 percent during the morning peak to 32 percent during the afternoon peak.

There was a pronounced drop in speed during the afternoon peak in NHS road segments reported by trucks in 2018. Congestion was observed more frequently in the afternoon peak hours: 3 percent of NHS roads were heavily congested during the morning peak in 2018, and this proportion increased to 5 percent during the afternoon peak. On the other hand, the share of roadways free of congestion (median speed above 55 mph) was 53.2 percent during the morning peak, dropping marginally to 52.7 percent during the afternoon peak in the same year.

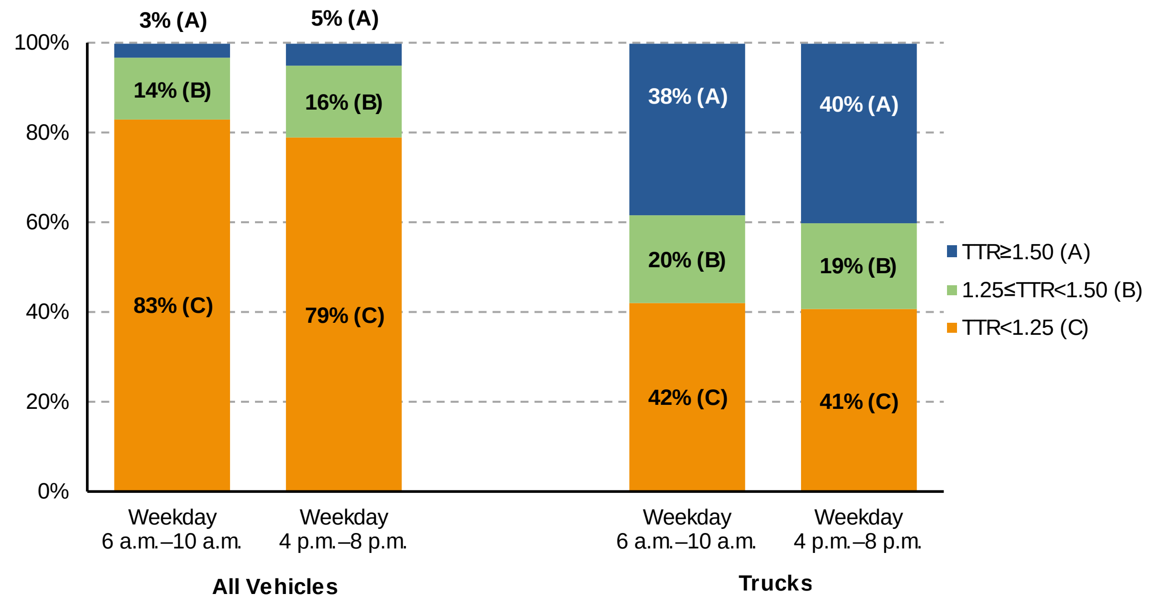
Exhibit 4-15 presents TTR and Truck TTR during weekday morning and afternoon peaks. Although the distribution of median travel speed did not change much, TTR deteriorated substantially. Clearly, travelers' experience was worse in the afternoon peak than in the morning as TTR distribution shifted adversely. In 2018, 83 percent of NHS roads offered reliable travel (TTR below 1.25) during the morning peak, whereas only 79 percent of roads met the criteria during the afternoon peak. The proportion of roads that were very unreliable (TTR above 1.50) also increased, from 3 percent during the morning peak to 5 percent during the afternoon peak.

Exhibit 4-14: Morning and Afternoon Peak Median Speed (MPH) on the National Highway System, 2018



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

Exhibit 4-15: Morning and Afternoon Peak Travel Time Reliability on the National Highway System, 2018



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

Travel condition for trucks declined over the course of the day, as more roadways became unreliable. The share of unreliable roads with Truck TTR above 1.50 rose from 38 percent during the morning peak to 40 percent during the afternoon peak. Although the share of roads that were unreliable increased, the share of reliable roads had decreased. Reliable highways represented 42 percent of NHS highway length during the morning peak and dropped to 41 percent during the afternoon peak.

Based on the median speed and TTR and Truck TTR of morning and afternoon peak hours, afternoon peak congestion was more severe than that of the morning peak. During the afternoon peak, some road segments that were congestion-free and reliable during the morning peak were reclassified as low-speed and unreliable.

Mobility and Access – Transit

SECTION SUMMARY

- Ridership in 2018 was 9.6 billion trips, a decrease of 6.3 percent compared with 10.3 billion in 2008.
- As of 2018, 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.
- Transit ridership declined from 2008 to 2010 during the Great Recession, ridership then increased to 2014, with a number of factors producing ridership decreases from 2014 to 2018.

The basic goal of all transit operators is to safely and efficiently connect people to the places they want to go. Transit operators seek to minimize travel time, 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.

This chapter presents data on ridership trends, travel trends, transit system coverage and frequency, system capacity, maintenance reliability, and compliance with the Americans with Disabilities Act (ADA). This chapter includes performance metrics that evaluate efficiency, effectiveness, and customer service. Financial efficiency metrics for transit, including operating expenditures per revenue mile or passenger mile, are discussed in Chapter 2.

The National Transit Database (NTD) includes urban data reported by mode and type of service. As of December 2018, NTD has 19 modes: 10 rail modes and nine nonrail modes.

Data from NTD are presented for each new mode for analyses specific to 2018. 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.

Ridership

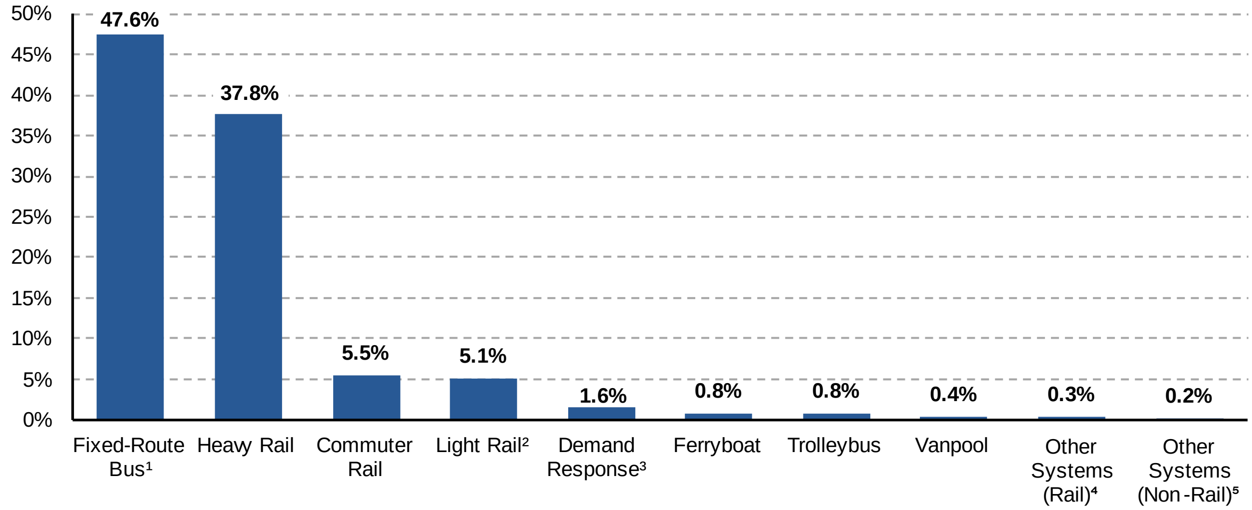
KEY TAKEAWAY

Bus and heavy rail continue to be the largest segments of the industry, providing 47.6 percent and 37.8 percent of all transit trips, respectively. Demand-response systems are the second-largest transit supplier, generating 25.0 percent of vehicle revenue miles, yet carry only 1.1 percent of passenger trips. In 2018, light rail and commuter rail generated 5.1 percent and 5.5 percent of unlinked passenger trips (UPTs), respectively.

The two primary measures of transit ridership are unlinked passenger trips (UPTs) and passenger miles traveled (PMT). An unlinked passenger trip, sometimes called a boarding, is defined as a journey on one transit vehicle. PMT is generally calculated based on UPTs and estimates of average trip length, although some systems are able to measure PMT directly, but rarely 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.

Fixed-route bus and heavy rail continue to be the largest segments of the transit industry, providing 47.6 percent and 37.8 percent of all UPTs, respectively, in 2018. Commuter rail and light rail were the next largest, providing 5.5 percent and 5.1 percent of UPTs, respectively, and demand response provided 1.1 percent. (See *Exhibit 4-16.*)

Exhibit 4-16: Share of Unlinked Passenger Trips by Mode, 2018



[1] Includes bus, commuter bus, and bus rapid transit.
[2] Includes light rail, hybrid rail, and streetcar rail.
[3] Includes demand response and demand response taxi.
[4] Includes Alaska railway, monorail/automated guideway, cable car, and inclined plane.
[5] Includes aerial tramway and público.
Source: National Transit Database.

Exhibit 4-17 provides total PMT for selected years between 2008 and 2018, showing steady growth across most modes. Fixed-route bus, trolleybus, and other nonrail decreased. Light rail, ferryboat, and vanpool modes each increased by roughly 30 percent. The other rail mode grew at the highest rate, whereas commuter rail had the largest increase in total passenger miles.

KEY TAKEAWAY

Transit operators reported 9.6 billion unlinked passenger trips on 4.8 billion vehicle revenue miles in 2018.

Exhibit 4-17: Transit Passenger Miles Traveled, 2008–2018

Mode	Passenger Miles (in Millions)						Average Annual Rate of Change 2018 to 2008
	2008	2010	2012	2014	2016	2018	
Rail	**29,989**	**29,380**	**31,176**	**32,672**	**32,944**	**32,305**	**0.7%**
Heavy Rail	16,850	16,407	17,516	18,339	18,357	16,914	0.0%
Commuter Rail	11,032	10,774	11,121	11,600	11,768	12,610	1.3%
Light Rail	2,081	2,173	2,489	2,675	2,756	2,728	2.7%
Other Rail	26	26	50	59	64	53	7.3%
Nonrail	**23,723**	**23,247**	**23,993**	**24,340**	**23,378**	**21,525**	**-1.0%**
Fixed-Route Bus	21,198	20,570	21,142	21,429	20,411	18,625	-1.3%
Demand Response	844	874	887	917	943	945	1.1%
Ferryboat	390	389	402	414	490	520	2.9%
Trolleybus	161	159	162	158	154	126	-2.4%
Vanpool	992	1,087	1,254	1,310	1,288	1,256	2.4%
Other Nonrail	138	169	145	112	92	54	-9.0%
Total	**53,712**	**52,627**	**55,169**	**57,012**	**56,322**	**53,830**	**0.0%**
Percent Rail	**55.8%**	**55.8%**	**56.5%**	**57.3%**	**58.5%**	**60.0%**	

Note: Light Rail includes light rail, hybrid rail, and streetcar rail. Other Rail includes Alaska railway, monorail/automated guideway, cable car, and inclined plane. Fixed-Route Bus includes bus, commuter bus, and bus rapid transit. Demand Response includes demand response and demand-response taxi. Other Nonrail includes aerial tramway and público.
Source: National Transit Database.

Light rail (ridership up 2.7 percent per year) enjoyed increased capacity during this period due to expansions and addition of new systems. Ferryboat (up 2.9 percent per year) increased through this period due to a 53-percent increase in revenue hours, which can be partially attributed to seven new agencies reporting passenger miles. Other rail (up 7.3 percent per year) also saw growth due to two new agencies reporting passenger miles.

Light Rail

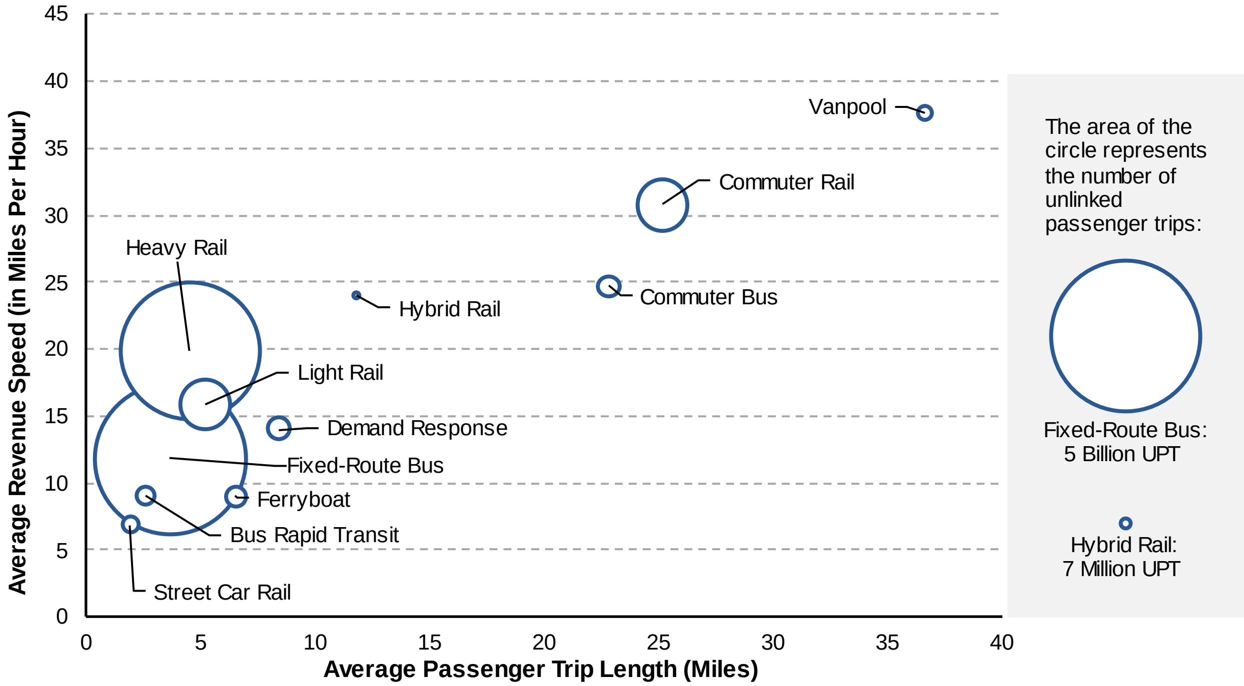
Light rail (including streetcars), like other rail services, offers higher average speeds compared to nonrail modes; however, average passenger trip length is consistent with that of bus and Bus Rapid Transit (BRT).

Commuter Rail

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 of approximately 25 miles.

Exhibit 4-18 depicts average passenger trip length (defined as PMT per UPT) versus revenue speed (defined as vehicle revenue miles per vehicle revenue hour), 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 travel, or active transportation modes such as bicycle and walking. Therefore, the average trip length of an individual mode in 2018 as depicted in *Exhibit 4-18* 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 4-18: Transit Urban Average Unlinked Passenger Trip Length vs. Average Revenue Speed for Selected Modes, 2018



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.

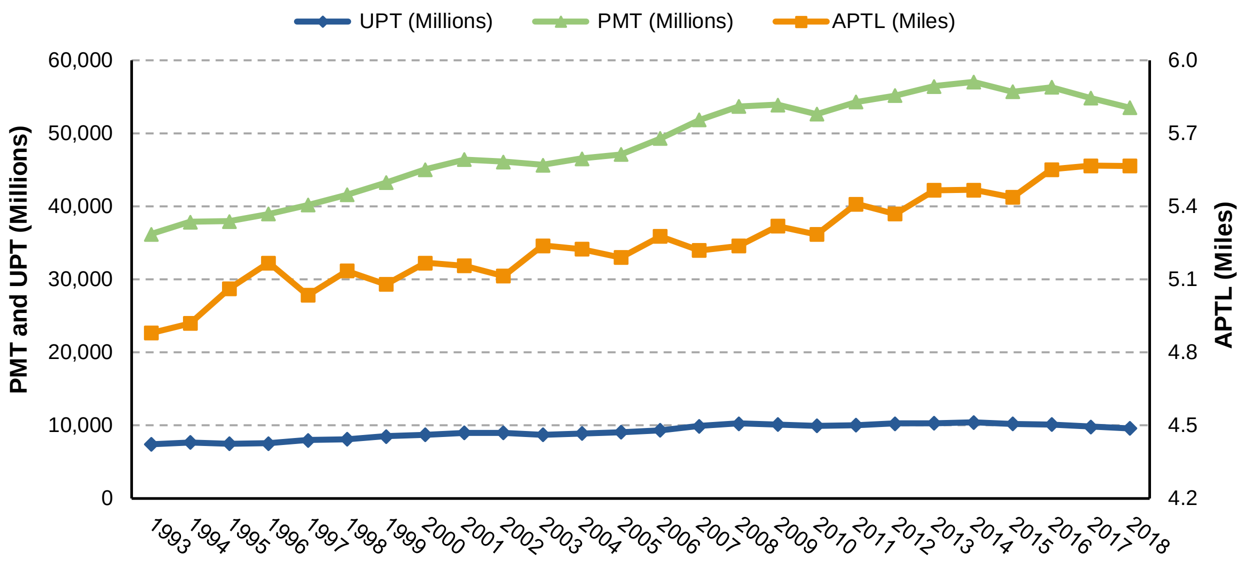
Commuter bus and commuter rail, on the other hand, are fixed-route modes, and a high percentage of commuters require other modes to reach their final destinations. Additionally, commuter bus and commuter rail are not as fast as vanpools due to more frequent stops near areas of attraction and generation 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 those for commuter rail and higher than those for 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. Hybrid rail systems frequently serve outlying areas, without entering a city center. Examples of hybrid rail include the Portland (Oregon) Westside Express, the Denton County A-Train north of the Dallas-Fort Worth urbanized area, the Sprinter Train between Escondido and Oceanside in the San Diego urbanized area, and the New Jersey Transit River Line between Trenton and Camden in the Philadelphia urbanized area.

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 (5 to 25 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 boardings and alightings per station or stop, which results in shorter average trip lengths than modes with a commuter orientation.

Transit Travel Trends

From 1993 to 2018, PMT increased on average by 1.6 percent annually, outpacing UPT, which grew by 1.0 percent per year. UPT peaked in 2014 at 10.4 billion and decreased slightly to 9.6 billion in 2018. This was reflected in an increase in average passenger trip lengths (APTL). In 1993, the average transit trip was 4.9 miles. By 2018, the average transit trip increased to 5.6 miles, a 14-percent increase. The increase is due in part to the growth of service areas as suburbs expanded out from city centers. UPT and PMT have decreased more recently, starting in 2013 and going through to 2018 and beyond. (See *Exhibit 4-19*).

Exhibit 4-19: PMT, UPT, and APTL, 1993–2018



Notes: PMT is passenger miles traveled, UPT is unlinked passenger trips, APTL is average passenger trip length.
Source: National Transit Database.

Exhibit 4-20 shows the largest urbanized areas (with greater than 1 million in population) with the highest transit market share of work trips according to American Community Survey (ACS) data. The ACS is an annual U.S. Census Bureau survey that asks a random and representative sample of the population for many details, including the transportation mode they use to get to work. The results of this journey-to-work question are used to estimate the share of the population that uses public transit to commute to work in each urbanized area. Seven of these urbanized areas have transit market shares that exceed 10 percent. The largest urbanized area with a transit market share below 10 percent is the Los Angeles-Long Beach-Anaheim urbanized area, which has the third-highest total ridership with more than 550 million trips due to its large size, but only a 5.2-percent market share.

Exhibit 4-20: Urbanized Areas of More than 1 Million Residents with Market Shares of Public Transit Work Trips Greater than 10 Percent, 2018

Geographic Area Name	Share of Public Transit	Total Population (Millions)	UPT (Millions)
New York–Newark, NY–NJ–CT Urbanized Area	32.7%	18.8	4,115
San Francisco–Oakland, CA Urbanized Area	19.6%	3.5	411
Washington, DC–VA–MD Urbanized Area	15.8%	5.0	417
Boston, MA–NH–RI Urbanized Area	14.4%	4.4	382
Chicago, IL–IN Urbanized Area	13.2%	8.7	574
Seattle, WA Urbanized Area	10.6%	3.4	219
Philadelphia, PA–NJ–DE–MD	10.3%	5.5	361

Note: Urbanized area refers to a Census-designated urban area with 50,000 residents or more.

Source: American Community Survey 2018 5-year Estimates, National Transit Database.

National Household Travel Survey and Key Public Transportation Characteristics 2009–2017

The National Household Travel Survey (NHTS) is a periodic national survey used to assist transportation planners and policy makers who need comprehensive data on travel and transportation patterns in the United States. The last NHTS, conducted in 2017, was based on data collected over a one-year period, starting in the second quarter of 2016 and ending in the first quarter of 2017.

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 4-21.*[25]

Exhibit 4-21: 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).

[25] Further information on these and other mode changes is available in the 2017 NHTS *Data User Guide* (https://nhts.ornl.gov/assets/2017UsersGuide.pdf).

Introduction to National Household Travel Survey (NHTS) Analyses

All analyses using the NHTS 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: This group, which includes public transportation modes and is designated as "PTRANS" (public transit), includes up to three subgroups:[1]

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.

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.

Market Share of Person Trips, All Modes and All Purposes, 2009 and 2017 NHTS

Exhibit 4-22 depicts the estimated public transportation 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 estimated number of person trips per day decreased from 1.4 trips per person per day in 2009 to 1.2 trips per person per day in 2017, a 17-percent decrease.

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 4-22* shows, this considerable increase was due to the rise in subway/elevated/light rail/streetcar trips which more than doubled in market share from 1.1 percent in 2009 to 2.8 percent in 2017. 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 and taxis increased dramatically, from 738 million trips in 2009 to 1.8 billion trips in 2017, but they only account for 0.4 percent of the total market share.

Exhibit 4-22: Market Share Change of Public Transportation, Private Vehicles, and Taxi Trips, 2009 and 2017

Mode to Work	Person-Trips (Millions)		Percent of Total	
	2009 NHTS	2017 NHTS	2009 NHTS	2017 NHTS
Private Vehicles	**325,964**	**304,571**	**83.3%**	**82.1%**
Public Transportation	**7,546**	**9,444**	**1.9%**	**2.5%**
Local or Commuter Bus	5,354	5,300	1.4%	1.4%
All Rail	2,260	4,144	0.6%	1.1%
Amtrak and Commuter Rail	561	794	0.1%	0.2%
Subway, Elevated, Light Rail, and Streetcar	1,604	3,350	0.4%	0.9%
Taxi and Limo (including Uber and Lyft)	**738**	**1,849**	**0.1%**	**0.5%**
Other	**57,045**	**55,281**	**14.7%**	**14.9%**
All Modes	**391,293**	**371,145**	**100.0%**	**100.0%**

Notes: 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: National Household Transit Survey, FHWA, 2017.

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.[26]

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 4-22*. “Workers” are a subset of the overall transportation market, and represent commuting work trips.

Public transportation has a higher share of the market when trip purposes are included, at 6.9 percent in the 2017 NHTS, divided nearly equally between rail and bus as shown in *Exhibit 4-23*.

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 gain 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 4-23: Market Share of Mode of Transportation to Work, 2009 and 2017

Mode to Work	Number of Persons (Thousands)		Percent of Total	
	2009 NHTS	2017 NHTS	2009 NHTS	2017 NHTS
Private Vehicles	**116,520**	**116,123**	**89.4%**	**87.1%**
Public Transportation	**6,681**	**9,146**	**5.1%**	**6.9%**
Local or Commuter Bus	3,980	4,033	3.1%	3.0%
Amtrak and Commuter Rail	1,302	1,338	1.0%	1.0%
Subway, Elevated, Light Rail, Streetcar	1,399	3,775	1.1%	2.8%
Taxi and Limo (including Uber and Lyft)	**106**	**479**	**0.1%**	**0.4%**
Other	**7,048**	**7,567**	**5.4%**	**5.7%**
All Modes	**130,355**	**133,315**	**100.0%**	**100.0%**

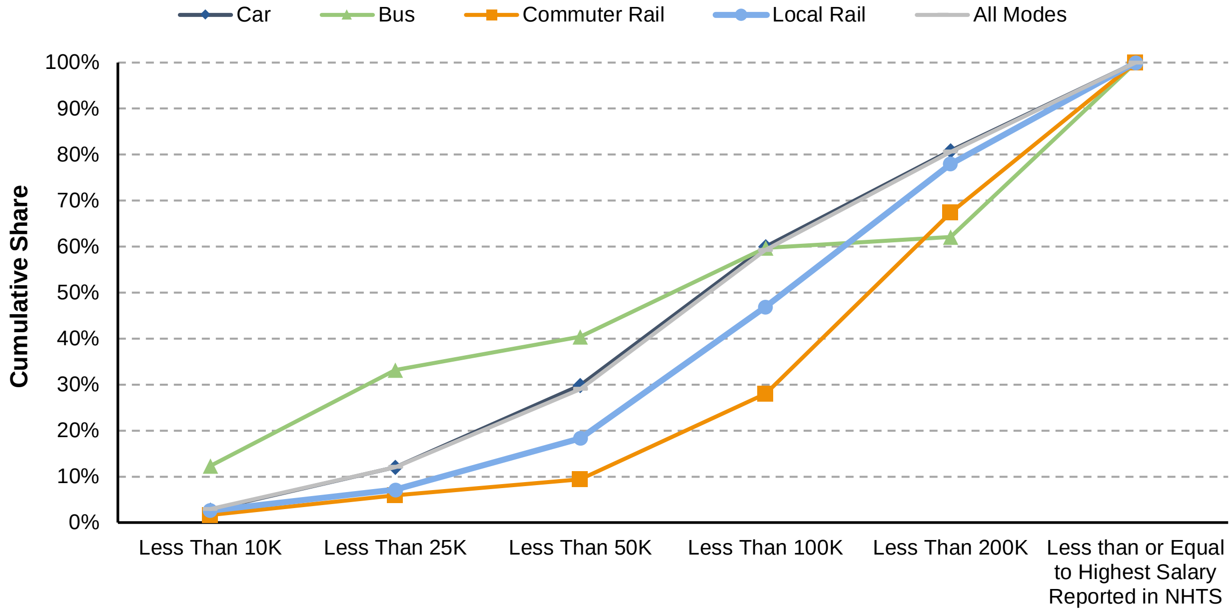
Notes: NHTS is National Household Travel Survey. Public or Commuter Bus, Amtrak/Commuter Rail, and Subway/Elevated/Light Rail/Streetcar are all subsets of Public Transportation.

Source: National Household Transit Survey, FHWA, 2017.

[26] Source: Summary of Travel Trends–2017 National Household Travel Survey (https://nhts.ornl.gov/assets/2017_nhts_summary_travel_trends.pdf).

Exhibit 4-24 shows the distribution of cumulative household income for work trips by mode. Private vehicles (the "Car" category 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 4-24: Distribution of Household Income for 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 for all modes 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 4-25*).

Exhibit 4-25: Public Transportation Commuting by Job Category, 2017

Job Category	Number of Commuters (Thousands)		Percent of Total	
	Public Transportation	National	Public Transportation	National
Professional, managerial, or technical	5,047	35,033	55.2%	47.5%
Sales and service	2,407	14,512	26.3%	26.3%
Clerical and administration support	1,135	20,141	12.4%	10.9%
Manufacturing, construction, maintenance, or farming	526	63,310	5.8%	15.1%
Other	29	217	0.3%	0.2%

Source: National Household Transit Survey, FHWA, 2017.

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.

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 is 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 Opportunity Report,[27] and also to eventually develop national performance measures for access to fixed-route transit. As of April 2021, the National Transit Map included route maps from 2,104 participating transit providers. The National Transit Map is available at: https://www.bts.gov/content/national-transit-map.

Exhibit 4-26 shows directional route miles by mode over the past 10 years. Growth in both rail (18 percent) and nonrail (2.0 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 4-26: Transit Directional Route Miles, 2008–2018

Mode	2008	2010	2012	2014	2016	2018	Average Annual Rate of Change 2018 to 2008
Rail	**11,317**	**11,720**	**12,067**	**12,298**	**12,573**	**12,742**	**1.2%**
Heavy Rail	1,617	1,617	1,622	1,622	1,646	1,661	**0.3%**
Commuter Rail	7,256	7,532	7,674	7,795	7,912	8,000	**1.0%**
Light Rail	1,446	1,581	1,766	1,877	2,004	2,079	**3.7%**
Other Rail	998	991	1,005	1,005	1,011	1,002	**0.0%**
Nonrail	**230,170**	**237,712**	**240,176**	**239,836**	**237,408**	**233,217**	**0.1%**
Fixed-Route Bus	229,113	236,615	238,903	238,388	235,876	231,784	**0.1%**
Ferryboat	601	641	817	990	1,074	974	**4.9%**
Trolleybus	456	456	456	458	458	458	**0.0%**
Total	**241,487**	**249,432**	**252,243**	**252,134**	**249,981**	**245,959**	**0.2%**
Percent Nonrail	**95.3%**	**95.3%**	**95.2%**	**95.1%**	**95.0%**	**94.8%**	

Notes: Light Rail includes light rail, hybrid rail, and streetcar rail. Other Rail includes Alaska railway, monorail/automated guideway, cable car, and inclined plane. Fixed-Route Bus includes bus, commuter bus, and bus rapid transit. 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.

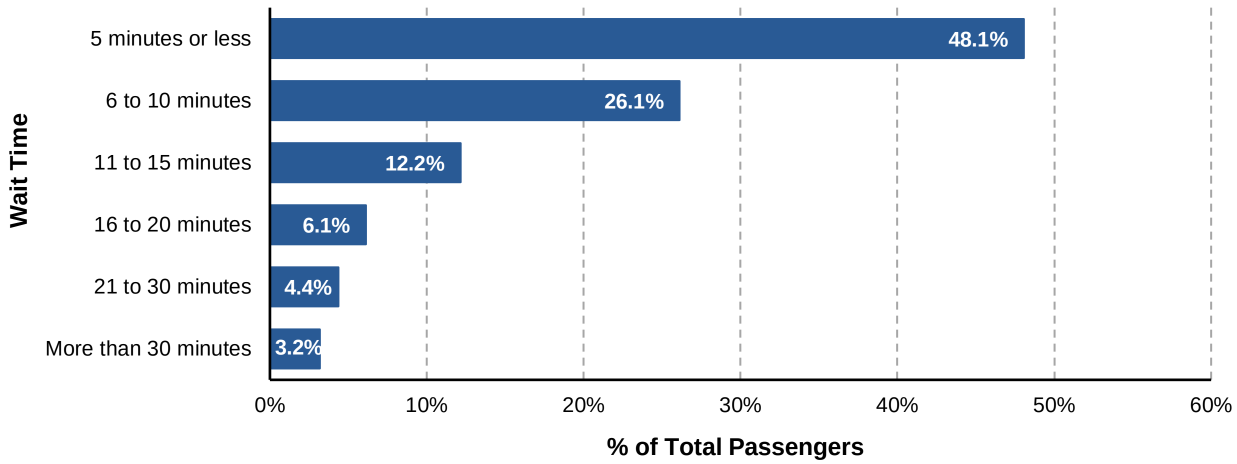
The frequency of transit service varies considerably based on location and time of day. Transit service is more frequent in urban areas and during rush hours, corresponding to the places and times with the highest demand for transit. Studies have found that transit passengers consider the time spent 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

[27] Tomer, Adie; Kneebone, Elizabeth; Puentes, Robert; and Berube, Alan, 2011. The Brookings Institute. "Missed Opportunity: Transit and Jobs in Metropolitan America." Available at: https://www.brookings.edu/wp-content/uploads/2016/06/0512_jobs_transit.pdf

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 4-27 shows findings on wait times from the 2017 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.

Exhibit 4-27: Distribution of Passengers by Wait Time, 2017



Source: National Household Travel Survey, FHWA.

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. Much transit infrastructure, however, has not yet been upgraded to address current or projected changes in climate. FTA does not collect systematic data on these upgrades, but significant grant money has been made available for transit systems to upgrade their structures and guideways to be more resistant to extreme precipitation events, sea level rise, storm surge, heat waves, and other environmental stressors. Efforts to improve resilience have been particularly evident in the aftermath of Superstorm Sandy and its impact on the Mid-Atlantic area, with a special grant program dedicated to that purpose.

System Capacity

> **Fixed Route Bus**
>
> 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 some rural areas of the country.

Exhibit 4-28 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 13.3 percent since 2008, with an average annual rate of change of 1.3 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 4-28: Rail and Nonrail Vehicle Revenue Miles, 2008–2018

Mode	Vehicle Revenue Miles (in Millions)						Average Annual Rate of Change 2018 to 2008
	2008	2010	2012	2014	2016	2018	
Rail	**1,053**	**1,056**	**1,056**	**1,109**	**1,143**	**1,167**	**1.0%**
Heavy Rail	655	647	638	657	676	686	0.5%
Commuter Rail	309	315	318	339	344	348	1.2%
Light Rail	86	92	99	112	121	128	4.0%
Other Rail	3	2	1	1	1	5	4.2%
Nonrail	**3,171**	**3,235**	**3,273**	**3,469**	**3,584**	**3,623**	**1.3%**
Fixed-Route Bus	2,026	1,996	1,978	2,047	2,126	2,161	0.6%
Demand Response	948	1,010	1,046	1,155	1,186	1,202	2.4%
Ferryboat	3	3	3	3	4	5	4.5%
Trolleybus	11	12	11	11	11	11	-0.5%
Vanpool	158	181	207	228	234	230	3.8%
Other Nonrail	25	32	27	25	23	16	-4.7%
Total	**4,224**	**4,291**	**4,329**	**4,578**	**4,727**	**4,790**	**1.3%**

Notes: Light Rail includes light rail, hybrid rail, and streetcar rail. Other Rail includes Alaska railway, monorail/automated guideway, cable car, and inclined plane. Fixed-Route Bus includes bus, commuter bus, and bus rapid transit. Demand Response includes demand response and demand-response taxi. Other Nonrail includes aerial tramway and público.

Source: National Transit Database.

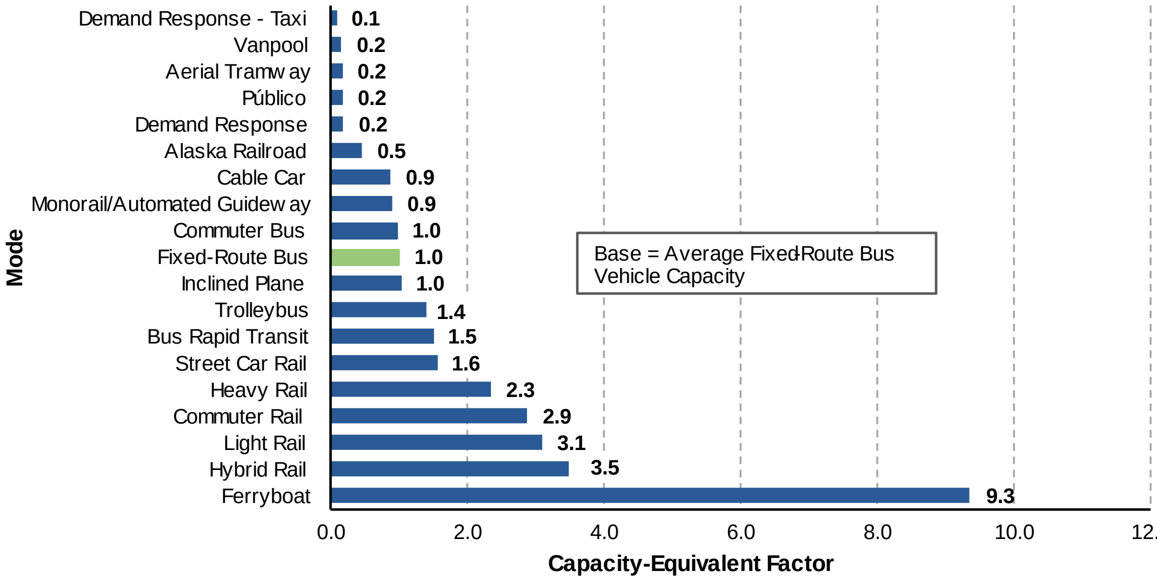
Exhibit 4-29 shows the 2018 capacity-equivalent factors for each mode. Unadjusted VRMs for each mode are multiplied by a capacity-equivalent factor to calculate capacity-equivalent VRMs. These factors are equal to the average full-seating and full-standing capacities of vehicles in active service for 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 33 seated and 16 standing, or 49 riders.

> **KEY TAKEAWAY**
>
> Between 2008 and 2018, the service offered by transit agencies grew steadily. The annual rate of growth in VRM ranged from 0.5 percent per year for heavy rail to 4.0 percent per year for light rail. This has resulted in 0.2 percent more route miles available to the public.

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 4-30 shows total capacity-equivalent VRMs. Light rail showed the most rapid expansion in capacity-equivalent VRMs from 2008 to 2018, followed by demand response, ferryboat, and vanpool. 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 4,970 million in 2008 to 5,484 million in 2018, an increase of 10 percent.

Exhibit 4-29: Capacity-Equivalent Factors by Mode, 2018



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 4-30: Capacity-Equivalent Vehicle Revenue Miles, 2008–2018

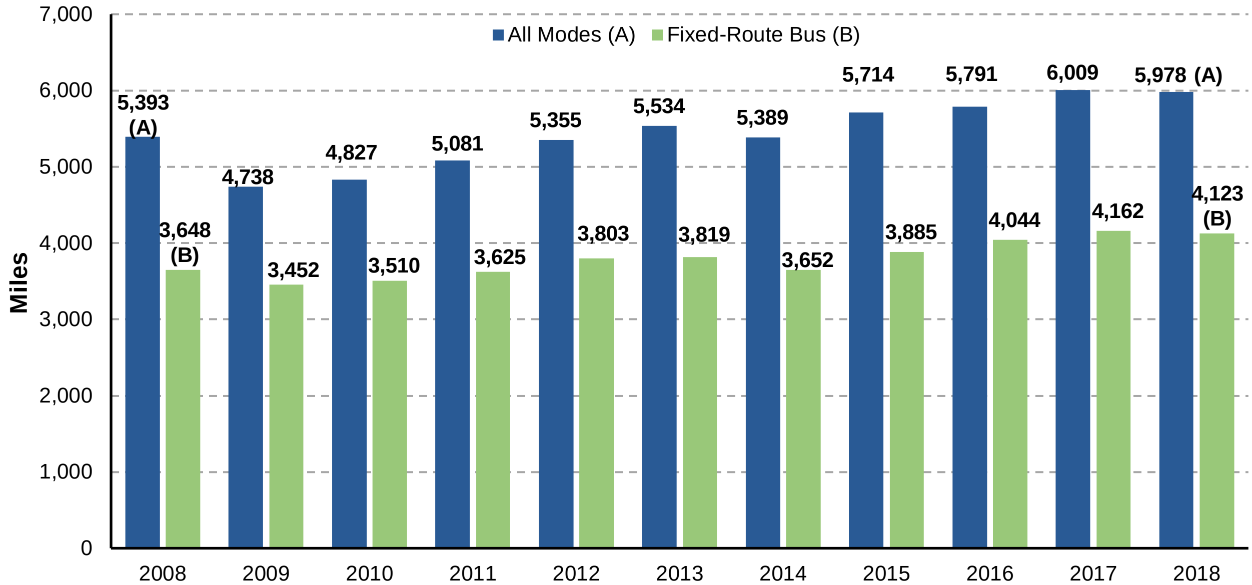
Mode	2008	2010	2012	2014	2016	2018	Average Annual Rate of Change 2018 to 2008
Rail	**2,703**	**2,714**	**2,760**	**2,932**	**3,030**	**2,999**	**1.0%**
Heavy Rail	1,621	1,599	1,580	1,582	1,625	1,608	-0.1%
Commuter Rail	844	860	888	996	1,018	1,002	1.7%
Light Rail	235	252	284	345	378	386	5.1%
Other Rail	4	3	9	9	9	4	-0.1%
Nonrail	2,267	2,262	2,255	2,352	2,446	2,474	0.9%
Fixed-Route Bus	**2,026**	**1,996**	**1,980**	**2,041**	**2,128**	**2,162**	**0.7%**
Demand Response	159	176	183	218	222	216	3.1%
Ferryboat	32	35	35	35	38	43	3.0%
Trolleybus	16	17	16	17	16	15	-1.1%
Vanpool	27	30	34	38	39	36	2.9%
Other Nonrail	6	8	7	4	4	3	-8.5%
Total	**4,970**	**4,976**	**5,015**	**5,284**	**5,476**	**5,474**	**1.0%**

Notes: Light Rail includes light rail, hybrid rail, and streetcar rail. Other Rail includes Alaska railway, monorail/automated guideway, cable car, and inclined plane. Fixed-Route Bus includes bus, commuter bus, and bus rapid transit. Demand Response includes demand-response and demand-response taxi. Other Nonrail includes 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.

Maintenance Reliability

Mean distance between failures, shown in *Exhibit 4-31*, 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. Miles between failures for all modes combined increased by 11 percent between 2008 and 2018, a 1.0-percent annual average increase. Miles between failures for all modes combined increased from 2009 to 2013, decreased in 2014, then increased steadily until 2017. The trend for fixed-route bus is similar to that of all modes combined. Miles between failures for fixed-route bus increased by 13 percent between 2008 and 2018.

Exhibit 4-31: Mean Distance Between Urban Vehicle Failures, 2008–2018



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 the 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 4-32 presents the change in the level of ADA accessibility of transit service vehicles from 2008 to 2018. The level of accessibility rose from 46.8 percent in 2008 to 83.2 percent in 2018. The most significant increases were in heavy rail passenger cars, commuter rail self-propelled passenger cars, and other rail vehicles. Heavy rail passenger cars increased in ADA accessibility from approximately 0 percent in 2008 to 96.9 percent in 2018. Commuter rail self-propelled passenger cars increased in ADA accessibility from 5.4 percent in 2008 to 81.0 percent in 2018. Other rail vehicles increased in ADA accessibility from approximately 0.9 percent in 2008 to 76.2 percent in 2018. Other rail vehicles include monorail vehicles, automated guideway vehicles, inclined plane vehicles, and cable cars. In 2018, vans and all other rail vehicles were nearly tied for the smallest share of ADA-accessible vehicles at 78 and 77 percent, respectively. Articulated buses had the largest share of ADA-accessible vehicles at 99 percent, a small decrease from 100 percent in 2008.

Heavy Rail

Heavy rail 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 39 percent of all public transportation trips, but only 14 percent of all miles and hours of service.

Exhibit 4-32: ADA Accessibility by Vehicle Type, 2008–2018

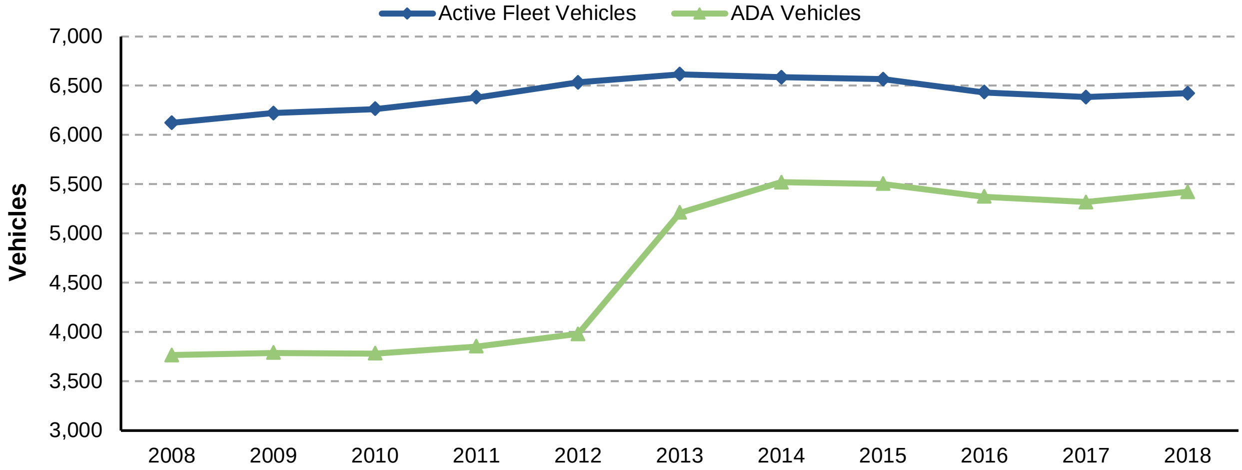
Vehicle Type	Active Fleet 2008	ADA Fleet 2008	ADA Fleet Share 2008	Active Fleet 2018	ADA Fleet 2018	ADA Fleet Share 2018	Change in Fleet	% Change in Share
Buses, Cutaways, and Over-the-road Buses	71,172	42,002	59.0%	55,929	54,964	98.3%	-21.4%	39.3%
Vans (Demand-Response Service)	29,833	12,153	40.7%	23,708	8,510	35.9%	-20.5%	-4.8%
Heavy Rail Passenger Cars	11,367	0	0.0%	11,892	11,520	96.9%	4.6%	96.9%
Articulated Buses	2,340	1,632	69.7%	5,670	5,609	98.9%	142.3%	29.2%
Commuter Rail Passenger Coaches	3,460	787	22.7%	3,666	3,043	83.0%	6.0%	60.3%
Commuter Rail Self-Propelled Passenger Cars	2,664	143	5.4%	2,756	2,379	86.3%	3.5%	81.0%
Light Rail Vehicles and Streetcars	1,919	484	25.2%	2,328	2,136	91.8%	21.3%	66.5%
All Other Rail Vehicles	110	1	0.9%	166	128	77.1%	50.9%	76.2%
All Other Nonrail Vehicles	945	730	77.2%	928	814	87.7%	-1.8%	10.5%
Total	123,810	57,932	46.8%	107,043	89,103	83.2%	-13.5%	36.4%

Notes: All Other Rail Vehicles includes monorail vehicles, automated guideway vehicles, inclined plane vehicles, and cable cars. All Other Nonrail Vehicles includes ferryboats, trolleybuses, school buses, and other vehicles.

Source: National Transit Database.

Exhibit 4-33 depicts the trends in the total active fleet and the ADA-accessible fleet for 2008–2018 for commuter rail. The data show that the ADA-accessible fleet increased steadily from 2008 to 2012 at an average rate of approximately 54 passenger cars per year, whereas the total fleet increased at an average of 103 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 between 2012 and 2014, 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 4-33: Total Active Fleet and ADA Fleet for Commuter Rail, 2008–2018



Source: National Transit Database.

KEY TAKEAWAY

Between 2008 and 2018, 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.

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 4-34* presents the changes between 2008 and 2018 in the number of urban transit ADA stations and the percentage of total ADA-compliant stations by mode. In 2018, 80.1 percent of total transit stations were either 100-percent accessible or self-certified as accessible, an increase from 74 percent in 2008. 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 26, 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, all are considered accessible and compliant.

Exhibit 4-34: ADA Accessibility of Stations, 2008 and 2018

Mode Category	2008 Stations	2008 ADA Stations	2008 ADA Stations Share	2018 Stations	2018 ADA Stations	2018 ADA Stations Share
Fixed-Route Bus	1,346	1,258	93.5%	1,495	1,453	97.2%
Other Nonrail	86	83	96.5%	162	137	84.6%
Commuter Rail	1,189	753	63.3%	1,280	900	70.3%
Heavy Rail	1,041	508	48.8%	1,054	588	55.8%
Light Rail	787	665	84.5%	923	863	93.5%
Other Rail	61	59	96.7%	248	195	78.6%
Total	**4,510**	**3,326**	**73.7%**	**5,162**	**4,136**	**80.1%**

Notes: Other Nonrail category includes ferryboat, aerial tramway, and trolleybus. Other Rail includes hybrid rail, automated guideway, monorail, street car rail, and inclined plane.

Source: National Transit Database.

Vehicle Occupancy

Exhibit 4-35 shows vehicle occupancy by mode for selected years from 2008 to 2018. Vehicle occupancy is calculated by dividing PMT by VRMs, resulting in the average passenger load in a transit vehicle. From 2008 to 2018, average passenger loads were either flat or decreased, with the exception of Other Rail. Vehicle occupancy decreased by 20 percent on fixed-route buses, the third largest decrease across all modes, following Demand Response and Other Nonrail modes.

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.

KEY TAKEAWAY

Growth in service supplied was nearly in accordance with growth in service consumed. From 2008 to 2018, average passenger loads were either flat or decreased, with the exception of Other Rail, while passenger miles traveled and unlinked passenger trips (UPT) both decreased slightly. Vehicle occupancy decreased by 20 percent on fixed-route buses, the third-largest decrease across all modes, following Demand Response and Other Nonrail modes.

Exhibit 4-35: Unadjusted Vehicle Occupancy: Passenger Miles per Vehicle Revenue Mile, 2008–2018

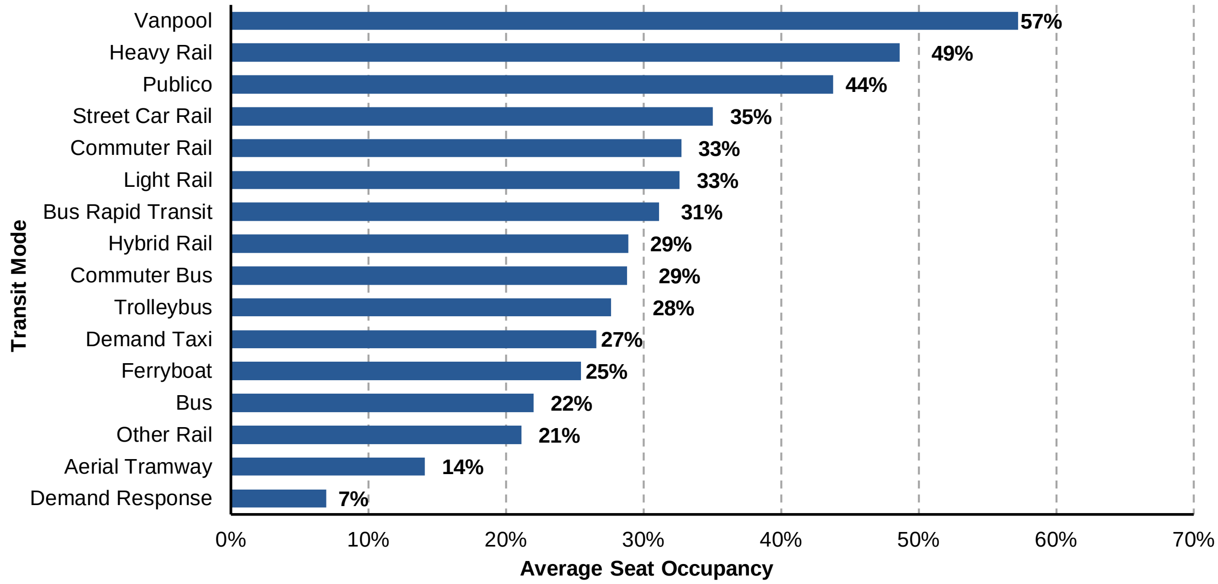
Rail or Nonrail	Mode	2008	2010	2012	2014	2016	2018	Average Annual Rate of Change 2008 to 2018	% Change
Rail	Heavy Rail	26	25	27	28	27	25	-0.4%	-4%
	Commuter Rail	36	34	35	34	34	36	0.0%	1%
	Light Rail	24	24	25	24	23	21	-1.3%	-11%
	Other Rail	9	11	8	9	10	12	2.9%	24%
Nonrail	Fixed-Route Bus	11	11	11	11	10	9	-2.0%	-20%
	Demand Response	1	1	1	1	1	1	0.0%	-36%
	Ferryboat	118	119	125	128	132	112	-0.5%	-5%
	Trolleybus	14	14	14	14	14	12	-1.5%	-16%
	Vanpool	6	6	6	6	6	5	-1.8%	-14%
	Other Nonrail	6	5	5	5	5	3	-6.7%	-37%

Note: Light Rail includes light rail, hybrid rail, and streetcar rail. Other Rail includes Alaska railway, monorail/automated guideway, cable car, and inclined plane. Fixed-Route Bus includes bus, commuter bus, and bus rapid transit. Demand Response includes demand response and demand-response taxi. Other Nonrail includes aerial tramway and público.

Source: National Transit Database.

As shown in *Exhibit 4-36*, 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 beginnings and ends of their routes.

Exhibit 4-36: Average Seat Occupancy Calculations for Passenger-carrying Transit Modes, 2018



Notes: Other Rail includes cable car, inclined plane, and monorail/automated guideway. 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 4-37* provides vehicle service use by mode for selected years from 2008 to 2018. 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 has fluctuated over the last 10 years, but increased by 19 percent between 2016 and 2018.

Exhibit 4-37: Vehicle Service Utilization: Average Annual Vehicle Revenue Miles per Active Vehicle by Mode, 2008–2018

Rail or Nonrail	Mode	2008	2010	2012	2014	2016	2018	Average Annual Rate of Change 2018 to 2008
Rail	Heavy Rail	58	57	56	57	57	58	0.0%
	Commuter Rail	45	45	44	46	48	49	0.7%
	Light Rail	44	43	42	46	47	47	0.6%
Nonrail	Fixed-Route Bus	31	31	31	28	28	30	-0.3%
	Demand Response	29	28	28	20	20	19	-4.2%
	Ferryboat	22	25	23	21	21	24	0.8%
	Trolleybus	19	20	20	20	15	18	-0.6%
	Vanpool	14	15	15	15	15	16	0.8%

Notes: Light Rail includes light rail, hybrid rail, and streetcar rail. Fixed-Route Bus includes bus, bus rapid transit, and commuter bus. Demand Response includes demand response and demand-response taxi. 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.

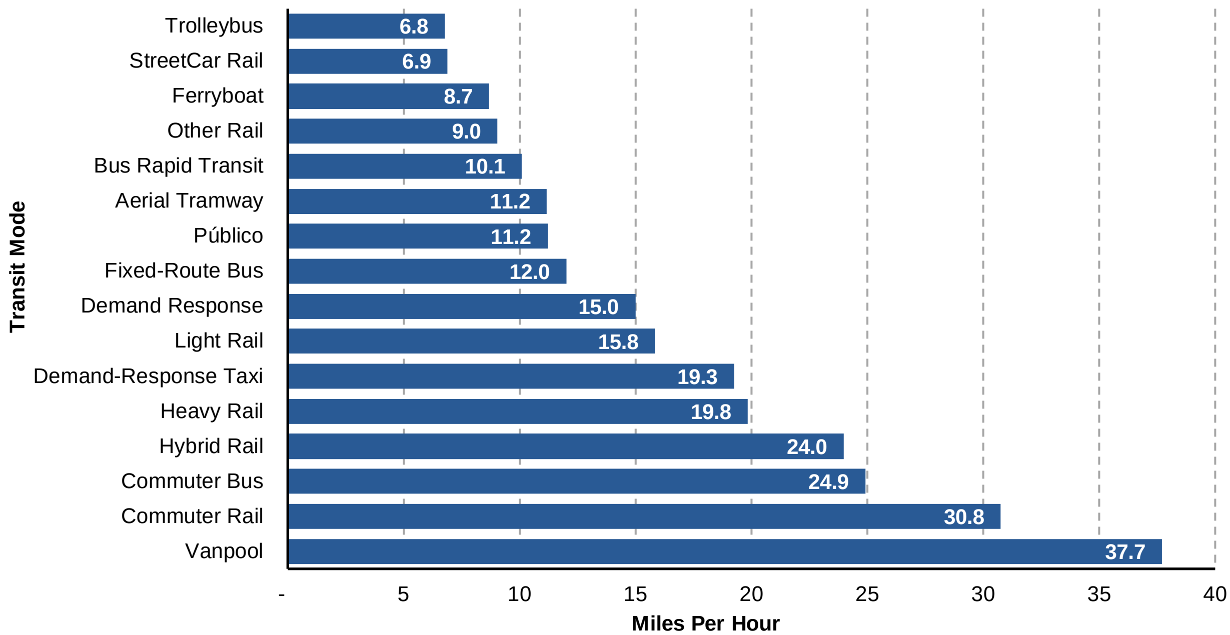
Source: National Transit Database.

Average Operating (Passenger-carrying) Speeds

Average vehicle operating speed is an approximate measure of the speed experienced by transit riders; it is not only a measure of the operating speed of transit vehicles between stops as it also includes the time spent loading and unloading passengers at stops as the vehicle becomes more crowded. Thus, 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 4-38* presents the results of these average speed calculations.

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.

Exhibit 4-38: Average Speeds for Passenger-Carrying Transit Modes, 2018



Notes: Other Rail includes Alaska railroad, monorail/automated guideway, cable car, and inclined plane. 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.

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.

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, enable these three DOT administrations to concentrate on their areas of expertise while working together toward the Nation's safety goal to reduce deaths and serious injuries on our Nation's roadways.

SECTION SUMMARY

- DOT's top priority is to make the U.S. transportation system the safest in the world.
- From 2008 to 2018, traffic fatalities have decreased by 2.3 percent.
- From 2009 to 2018, fatalities involving pedestrians, bicyclists, and other nonmotorists have increased 50.5 percent, up to 7,354 in 2018. This is following a decline that occurred from 2006 to 2009.
- As DOT moves toward the vision of zero deaths and serious injuries on our Nation's roadways, it will be essential to advance improvements in data and analysis, deploy safety infrastructure, and implement legislative and regulatory oversight.
- FHWA's Focused Approach to Safety addresses the most critical safety challenges surrounding roadway departures, intersections, and pedestrian/bicyclist-involved crashes, which account for nearly 90 percent of traffic fatalities.

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 also 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. The 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 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 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.

Overall Fatalities and Injuries

Statistics discussed in this section are drawn primarily from the Fatality Analysis Reporting System (FARS), a nationwide census of fatal crashes that provides DOT, Congress, and the American public with data on 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 produced annual estimate of total nonfatal injury crashes. It is important to note that nonfatal safety statistics in this section, compiled in early 2020 using FARS and CRSS data through 2018, 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 completed data and reports.

CRSS builds on the 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 2018, 6.7 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 the 6.7 million crashes in 2018, 33,654 were fatal, approximately 1.9 million crashes resulted in injuries that were not life-threatening, and 4.8 million crashes resulted in damage or harm to property alone. From 2008 to 2018, fatal crashes decreased by 1.5 percent. From 2008 to 2018, injury crashes increased by 16.1 percent, and property-damage-only crashes increased by 15.9 percent.

Traffic Incident Management Responder/Traveler Safety

Traffic incidents such as crashes, debris, or stalled vehicles on roadways put motorists' and responders' lives at risk, contribute to traffic delays, and strain the U.S. economy through unreliable travel times. Traffic Incident Management (TIM) is a planned and coordinated process to detect, respond to, and remove traffic incidents and restore traffic capacity as safely and quickly as possible. A TIM program engages human, institutional, mechanical, and technical resources to reduce the duration and impact of incidents, and improve the safety of travelers, crash victims, and responders.

Through the Every Day Counts program, the Second Strategic Highway Research Program (SHRP2) project, **Improving Traffic Incident Management**, now referred to as the **National Traffic Incident Management Responder Training**, provided a significant move forward in developing a coordinated, multidisciplinary training program for all emergency responders and those supporting TIM operations. The project resulted in a nationally recognized TIM training curriculum that provides responders with a common set of core competencies.

These competencies promote a shared understanding of the requirements for achieving the safety of responders and motorists, along with effective communications at traffic incident scenes. The total number of responders trained between 2012 and 2018 included more than 378,000 police, fire, emergency medical services, towing and recovery, and transportation/public works combined. All 50 States, the District of Columbia, and Puerto Rico are implementing the TIM training as well as the broader TIM program components of data collection, performance measures, data sharing, and technologies that enhance TIM.

Exhibit 5-1: Crashes by Severity, 2008–2018

Year	Fatal		Injury		Property Damage Only		Total Crashes[1]	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
2008	34,172	0.6	1,630,000	28.1	4,146,000	71.3	**5,811,000**	**100.0**
2009	30,862	0.6	1,517,000	27.6	3,957,000	71.9	**5,505,000**	**100.0**
2010	30,296	0.6	1,542,000	28.5	3,847,000	71.0	**5,419,000**	**100.0**
2011	29,867	0.6	1,530,000	28.7	3,778,000	70.8	**5,338,000**	**100.0**
2012	31,006	0.6	1,634,000	29.1	3,950,000	70.3	**5,615,000**	**100.0**
2013	30,202	0.5	1,591,000	28.0	4,066,000	71.5	**5,687,000**	**100.0**
2014	30,056	0.5	1,648,000	27.2	4,387,000	72.3	**6,064,000**	**100.0**
2015	32,538	0.5	1,715,000	27.2	4,548,000	72.2	**6,296,000**	**100.0**
2016	34,748	0.5	2,116,000	31.0	4,670,000	68.5	**6,821,000**	**100.0**
2017	34,560	0.5	1,889,000	29.3	4,530,000	70.2	**6,453,000**	**100.0**
2018	33,654	0.5	1,894,000	28.1	4,807,000	71.4	**6,734,000**	**100.0**

[1] Totals do not add across, as injury crashes, property crashes, and total crashes are estimated to the nearest thousand.

Source: Fatality Analysis Reporting System, National Automotive Sampling System General Estimates System, and Crash Report Sampling System, National Center for Statistics and Analysis, National Highway Traffic Safety Administration.

There were 36,560 fatalities on U.S. roadways in 2018. *Exhibit 5-2* displays trends in motor vehicle fatality counts and fatality rates from 1980 to 2018, as well as injury counts and injury rates from 1980 to 2018. The motor vehicle fatality count was above 51,000 in 1980 and then dropped to less than 44,000 in 1982, coinciding with the recession occurring in the early 1980s. 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 December 2007–June 2009 economic recession. The 37,806 fatalities in 2016 were the highest number reported since 2007. Fatalities decreased by 0.9 percent in 2017, and by 2.4 percent in 2018. The annual number of traffic fatalities decreased by 2.3 percent from 2008 to 2018. (More recent data through 2021 are available in the “Monthly Fatalities from Vehicle Crashes” section in Chapter 11.)

KEY TAKEAWAY

The annual number of traffic fatalities decreased by 2.3 percent from 2008 to 2018, dropping from 37,423 to 36,560, as reported in the FARS Annual Report file.

In addition to fatality counts, *Exhibit 5-2* shows fatality rates for two different measures of exposure: rates expressed in terms of population and rates in terms of VMT. To account for the amount of travel on the road, the fatality rate is most often expressed 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 population shown in *Exhibit 5-2* are often stratified to examine in more depth how demographic variables, such as male drivers aged 16–20 versus male drivers aged 21–44, influence fatality rates.

The fatality rate per 100,000 population was 22.48 in 1980, dropping to 17.88 in 1990 and to 14.87 in 2000. The rate dropped significantly from 14.72 in 2005 to 10.67 in 2010, then increased slightly to 11.17 in 2018.

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 then increased slightly to 1.13 in 2018 (*Exhibit 5-2*).

Exhibit 5-2: Summary of Fatality and Injury Rates, 1980–2018

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	1,720,629	2.57			
1986	46,087	240,133	19.19	1,834,872	2.51			
1988	47,087	244,499	19.26	2,025,962	2.32	3,427,000	1,402	169
1990	44,599	249,464	17.88	2,144,362	2.08	3,246,000	1,301	151
1992	39,250	255,030	15.39	2,247,151	1.75	3,079,000	1,207	137
1994	40,716	260,327	15.64	2,357,588	1.73	3,275,000	1,258	139
1996	42,065	265,229	15.86	2,484,080	1.69	3,480,000	1,312	140
1998	41,501	270,248	15.36	2,628,148	1.58	3,199,000	1,184	122
2000	41,945	282,162	14.87	2,746,925	1.53	3,194,000	1,132	116
2002	43,005	287,625	14.95	2,855,508	1.51	2,939,000	1,022	103
2003	42,884	290,108	14.78	2,890,221	1.48	2,902,000	1,000	100
2004	42,836	292,805	14.63	2,964,788	1.44	2,802,000	957	95
2005	43,510	295,517	14.72	2,989,430	1.46	2,709,000	917	91
2006	42,708	298,380	14.31	3,014,371	1.42	2,583,000	866	86
2007	41,259	301,231	13.70	3,031,124	1.36	2,449,000	813	81
2008	37,423	304,094	12.31	2,976,528	1.26	2,356,000	775	79
2009	33,883	306,772	11.05	2,956,764	1.15	2,224,000	725	75
2010	32,999	309,326	10.67	2,967,266	1.11	2,248,000	727	76
2011	32,479	311,580	10.42	2,950,402	1.10	2,227,000	715	75
2012	33,782	313,874	10.76	2,969,433	1.14	2,369,000	755	80
2013	32,893	316,058	10.41	2,988,280	1.10	2,319,000	734	78
2014	32,744	318,386	10.28	3,025,656	1.08	2,343,000	736	77
2015	35,484	320,743	11.06	3,095,373	1.15	2,455,000	765	79
2016	37,806	323,071	11.70	3,174,408	1.19	3,062,000	948	96
2017	37,473	325,147	11.52	3,212,347	1.17	2,745,000	844	85
2018	36,560	327,167	11.17	3,240,327	1.13	2,710,000	828	84

Sources: Fatality Analysis Reporting System, National Automotive Sampling System General Estimates System and Crash Report Sampling System, National Center for Statistics and Analysis, National Highway Traffic Safety Administration; U.S. Census Bureau for resident population data.

Also shown in *Exhibit 5-2* are the national estimates for people nonfatally injured in motor vehicle crashes from 1988 through 2018. Since 1988, a historic low of 2,224,000 injured was reached in 2009 with an injury rate of 75 per 100 million VMT. The injury count then rose 21.9 percent to 2,710,000 in 2018, and the rate rose 12.0 percent to 84 per 100 million VMT.

DOT suggests that multiple factors are related to the overall decline in roadway fatalities over the past decade, including roadway infrastructure improvements such as leading pedestrian intervals, median barriers, rumble strips, roundabouts, SafetyEdge℠, Innovative Intersection and Interchange Geometrics, High Friction Surface Treatments, and the use of data and analytical tools. Vehicle and behavioral improvements, such as increased seat belt use, child safety seats, more side air bags, and electronic stability control in vehicles, have also contributed to the decline. The improvements in infrastructure include some of the innovative technologies being deployed as part of FHWA's Every Day Counts (EDC) initiative. FHWA launched EDC in cooperation with the American Association of State Highway and

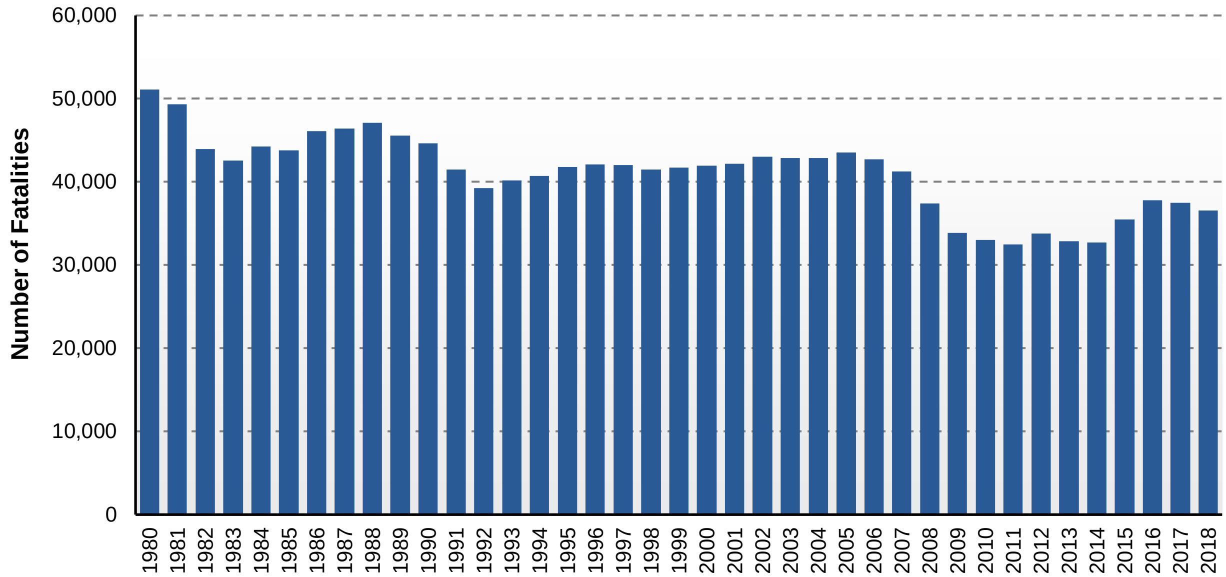
KEY TAKEAWAY

The fatality rate per 100 million VMT declined from 1.26 in 2008 to 1.13 in 2018 but has increased since reaching a low of 1.08 in 2014.

Transportation Officials (AASHTO) to expedite the delivery of highway projects and to address challenges presented by limited budgets.

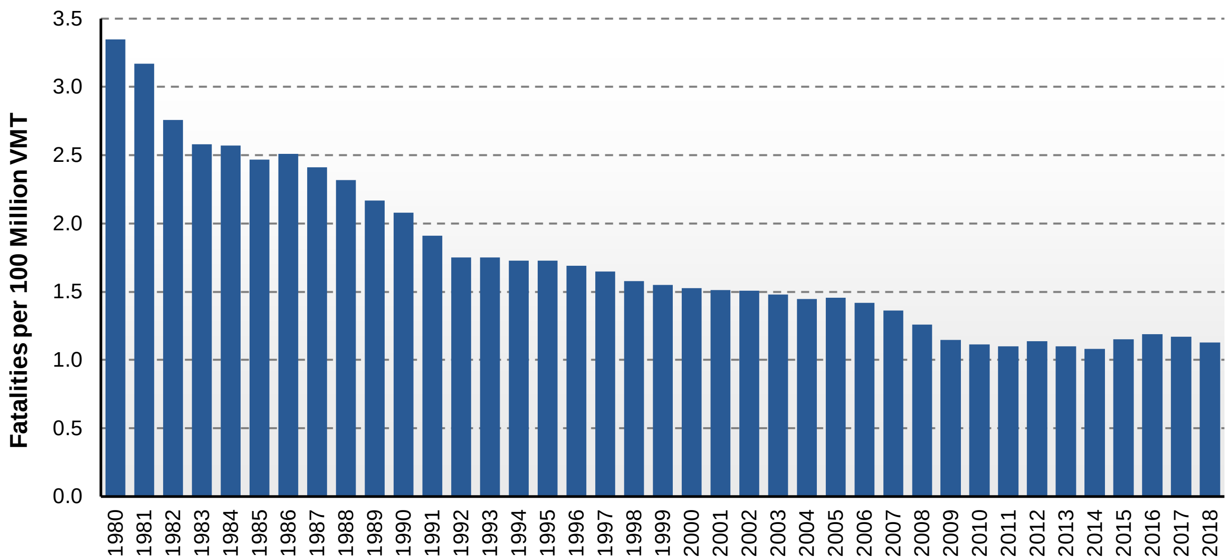
The trends since 1980 of the fatality counts and fatality rates per 100 million VMT, as discussed earlier and shown in *Exhibit 5-2*, are displayed graphically in *Exhibits 5-3* and *5-4*. *Exhibit 5-3* shows the number of motor vehicle fatalities from 1980 to 2018. *Exhibit 5-4* shows motor vehicle fatality rates per 100 million VMT from 1980 to 2018.

Exhibit 5-3: Fatalities, 1980–2018



Source: Fatality Analysis Reporting System/National Center for Statistics and Analysis, National Highway Traffic Safety Administration.

Exhibit 5-4: Fatality Rates per 100 Million VMT, 1980–2018



Source: Fatality Analysis Reporting System/National Center for Statistics and Analysis, National Highway Traffic Safety Administration.

Safety Data, Planning, and Performance

The DOT strategic goal on safety is to "reduce transportation-related fatalities and serious injuries across the transportation system." FHWA coordinates with States as they develop SHSPs. A major component and requirement of the HSIP, an SHSP is a Statewide coordinated safety plan, developed by a State department of transportation (State DOT) in cooperation with a broad range of safety stakeholders. An SHSP reflects a State's analyses of highway safety problems, identifies the 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 at least every 5 years to ensure States use current data to identify problems and to develop evidence-based strategies that have the most potential to save lives and prevent injuries.

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. Although 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 has developed several programs and projects to assist local agency practitioners and their stakeholders in improving safety on their roadways (https://safety.fhwa.dot.gov/local_rural/). For example, Road Safety 365: A Workshop for Local Governments, helps local practitioners routinely identify safety issues along their roadways and provides ideas on how to address them. A local road safety plan do-it-yourself website is also available for communities at: https://safety.fhwa.dot.gov/LRSPDIY/ .

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 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 data and analytic improvements that the Roadway Safety Data Program has begun addressing through the development of informational resources and the delivery of technical assistance, webinars, and peer exchanges. FHWA conducted a second Safety Data Capabilities Assessment in each State during 2017–2018. This assessment will be useful to States as they develop and implement plans for further safety data improvement and work to achieve performance goals.

Partnerships

FHWA continues to build effective partnerships with a wide range of stakeholders in both the public and private sectors. FHWA has spearheaded and participates in several programs aimed as facilitating such coordination. For instance, FHWA is a founding member of the Road to Zero (RTZ) Coalition, along with National Highway Traffic Safety Administration (NHTSA), Federal Motor Carrier Safety Administration (FMCSA), and dozens of other multidisciplinary-disciplinary organizations. The Coalition develops strategies to achieve the vision of zero traffic fatalities and facilitates widespread implementation of countermeasures to eliminate fatalities and serious injuries. FHWA is also an active participant on several American Association of State Transportation Officials (AASHTO) committees such as the Standing Committee on Highway Traffic Safety (SCOHTS) and the Safety Management Subcommittee, as well as several Transportation Research Board (TRB) committees. FHWA participates in informal discussions with national associations, practitioners, and private-sector groups that share mutual safety goals to strengthen those relationships and better leverage resources.

Improved Safety Analysis Tools

FHWA provides data and supports 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 the 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

FHWA's Role in Highway Safety Improvement

In 2018, vehicles traveled more than 3.2 trillion miles 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 crashes, (2) intersection crashes, and (3) pedestrian/bicycle crashes. These three focus areas encompass almost 90 percent 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. FHWA continues to expand the use of proven safety countermeasures and develop other methods to improve highway safety.

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.

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, TRB, and industry over the past two decades.

Safety Performance Management

Safety Performance Management (Safety PM) is part of the overall FHWA Transportation Performance Management program, which is a strategic approach that uses system information to make investment and policy decisions to achieve national performance goals.

Safety PM establishes five performance measures: the number and rate of fatalities, the number and rate of serious injuries, and the number of nonmotorized fatalities and serious injuries.

States set annual targets for each of the performance measures. NHTSA's Highway Safety Grants Program requests that States set identical targets for three common measures (number of fatalities, rate of fatalities, and number of serious injuries), which allows States to align safety performance targets and work collaboratively to achieve them.

FHWA assesses State safety performance target achievement annually to determine whether States have met or made significant progress toward meeting their safety performance targets. The State's safety performance targets help improve data, transparency, and accountability, and allow safety progress to be tracked at the national and State levels.

National Definition for Serious Injuries

As a means of standardizing serious injury data, the USDOT established a single national definition for reporting serious injuries. This action ensures a consistent, coordinated, and comparable serious injury data system. Law enforcement, engineers, safety specialists, researchers, planners, and others rely on accurate and consistent data to determine effective countermeasures. Prior to the national definition, States and law enforcement agencies used different definitions and coding conventions to report serious injuries, which led to inconsistent reporting. Inconsistent reporting results in poor data quality. The national definition results in data improvement at the State and national levels and assists stakeholders in addressing highway safety challenges.

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), driver behavior (VMT, speed, use of safety features, headway, fatigue, distraction), and interactions with nonoccupants, all affect the safety of the Nation's highway system. FHWA collaborates with other agencies to understand more clearly the relationships 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.

KEY TAKEAWAY

Fatalities related to roadway departure decreased by 6.8 percent from 2008 to 2018, but roadway departure remains a factor in over half (50.7 percent) of all traffic fatalities. Intersection-related fatalities increased 20.7 percent from 2008 to 2018, and more than one-fourth (27.4 percent) of traffic fatalities in 2018 occurred at intersections.

In 2018, roadway departure, intersection, and pedestrian/bicyclist fatalities accounted for 51 percent, 27 percent, and 20 percent, respectively, of the 36,560 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 greater detail below. Of the 36,560 fatalities in 2018, 13 percent do not involve a focus area.

Exhibit 5-5 shows how the number of fatalities for these crash types changed between 2008 and 2018. During this period, roadway departure fatalities decreased by 6.8 percent, intersection-related fatalities increased by 20.7 percent, and pedestrian/bicyclist-involved fatalities increased by 38.2 percent.

Exhibit 5-5: Fatalities by Crash Type, 2008–2018

Crash Type	2008	2010	2012	2014	2016	2018	Percent Change 2008 to 2018
Roadway Departures[1]	19,878	18,850	18,963	17,818	19,793	18,525	-6.8%
Intersection-related[1,2]	8,297	8,636	8,851	8,692	10,414	10,011	20.7%
Pedestrian/Bicycle-related[1,3]	5,320	5,110	5,779	5,483	7,193	7,354	38.2%

[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, National Highway Traffic Safety Administration.

Because a combination of factors can influence the fatalities shown in *Exhibit 5-5*, FHWA has developed targeted programs that include collaborative and comprehensive efforts to address all three areas. More information is available at: http://safety.fhwa.dot.gov/fas/.

In 2018, there were 18,525 roadway departure fatalities in the United States, accounting for 50.7 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 free technical assistance to these States, including crash data analysis and implementation plan development at either the Statewide or district level. Based on crash data and other risk factors provided by State DOTs, 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, other technical support, and training courses. The technical support is tailored to the needs of the focus State.

Four proven safety countermeasures for reducing roadway departure crashes are:

- Longitudinal rumble strips and stripes on two-lane rural roads. These are 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. This measure involves adding signs or markings to provide additional warning to drivers of a change in alignment and/or adding a pavement surface treatment using specific high-quality aggregate bonded to the surface with polymer resins to greatly reduce the risk of skidding in the curve.
- SafetyEdge^{SM} technology, which shapes the edge of a paved roadway in a way that eliminates tire scrubbing, a phenomenon that contributes to losing control of a vehicle when the driver attempts to return to the pavement following a roadway departure.
- Roadside design improvements at curves, such as improving the clear zone, flattening slopes, or adding barriers in curves to reduce risk or minimize the severity of crashes in curves.

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 2018, 27 percent of fatalities were related to intersections, with 30 percent of these intersection-related fatalities occurring in rural areas and 70 percent occurring in urban areas, as shown in *Exhibit 5-6*. From 2008 to 2018, intersection-related fatalities increased by 20.7 percent. The geometric design of an intersection and corresponding application of traffic control devices can substantially reduce the likelihood of crashes, resulting in fewer crashes, injuries, and fatalities.

Furthermore, when the speed of motor vehicles through intersections can be reduced, the severity of crashes that do occur will also be lessened.

Exhibit 5-6: Intersection-related Fatalities by Functional System, 2018

Rural/Urban	Functional System	Count	Percent of Total
Rural Areas (under 5,000 in population)	Principal Arterial	1,105	11.3%
	Minor Arterial	712	7.3%
	Collector (Major and Minor)	736	7.5%
	Local	361	3.7%
	Subtotal Rural	**2,914**	**29.9%**
Urban Areas (5,000 or more in population)	Principal Arterial	3,367	34.5%
	Minor Arterial	1,888	19.4%
	Collector (Major and Minor)	666	6.8%
	Local	914	9.4%
	Subtotal Urban	**6,835**	**70.1%**
Total Highway Fatalities[1]		**9,749**	**100.0%**

[1] Total excludes 262 intersection-related fatalities not identified by functional class.

Source: Fatality Analysis Reporting System, National Center for Statistics and Analysis, National Highway Traffic Safety Administration.

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.

Countermeasures associated specifically with intersection safety include:

- Leading pedestrian intervals, which give pedestrians the opportunity to enter an intersection 3–7 seconds before vehicles are given a green indication.
- Reduced left-turn conflict intersections, which use geometric designs that alter how left-turn movements occur to simplify decisions and minimize the potential for related crashes.
- Corridor access management, involving a set of techniques useful for managing access to highways, major arterials, and other roadways, which result in reduced crashes, fewer vehicle conflicts, and improved movement of traffic.
- Systemic application of multiple low-cost countermeasures at stop-controlled intersections, which involves deploying multiple low-cost measures (such as enhanced signing and pavement markings) at many stop-controlled intersections within a jurisdiction. This approach is designed to increase driver awareness and recognition of the intersections and potential conflicts.
- Road diets, defined as roadway reconfigurations that involve converting an undivided four-lane roadway into three lanes comprising two through-lanes and a center two-way left-turn lane.
- Roundabouts, which are circular intersections that feature channelized, curved approaches that reduce vehicle speed, entry yield control that gives right-of-way to circulating traffic, and counterclockwise flow around a central island that minimizes conflict points.

Pedestrians, Bicyclists, and Other Nonmotorists

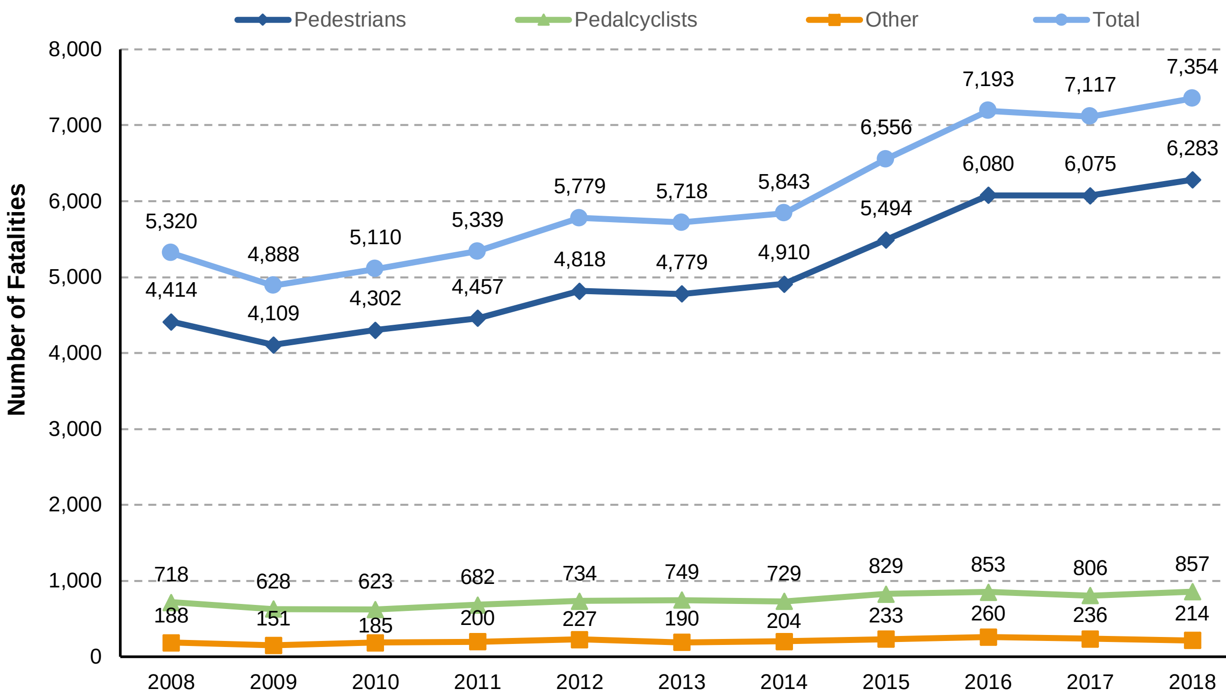
For this section, the Focused Approach to Safety definition is used to define nonmotorists.[28] This definition includes cases in which at least one person involved in a fatal motor vehicle crash was coded as either a pedestrian, bicyclist, or other nonmotorist. In 2018, 20.1 percent of the fatalities were nonmotorists. *Exhibit 5-7* shows that in 2018, 6,283 pedestrians, 857 pedalcyclists, and 214 other nonmotorists were killed, totaling 7,354 nonmotorist fatalities.

Overall, nonmotorist fatalities rose by 38.2 percent between 2008 and 2018. 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 50.4-percent increase up to 2018. Pedestrian fatalities rose from 4,120 in 2009 to 6,283 in 2018, an increase of 52.9 percent. Pedalcyclist fatalities rose from 623 in 2010 to 857 in 2018, an increase of 37.6 percent.

KEY TAKEAWAY

From 2008 to 2018, the number of nonmotorists (pedestrians, bicyclists, etc.) killed by motor vehicles increased by 38.2 percent, from 5,320 to 7,354 (20.1 percent of all traffic fatalities). From 2008 to 2009 nonmotorist fatalities declined by 8.1 percent between 2008 and 2009, but beginning in 2009 that trend began to shift, and by 2018, nonmotorist fatalities had increased by 50.5 percent.

Exhibit 5-7: Pedestrian, Bicyclist, and Other Nonmotorist Traffic Fatalities, 2008–2018



Source: Fatality Analysis Reporting System, National Center for Statistics and Analysis, National Highway Traffic Safety Administration.

[28] Nonmotorists are defined as 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 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.

Pedestrian and Bicyclist Safety Focus States and Cities and Countermeasures

In 2015 FHWA expanded its pedestrian focus area to include bicyclist and other nonmotorist fatalities. FHWA designates 16 States and 35 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 Focus States are California, Arizona, New Mexico, Texas, Louisiana, Florida, Georgia, North Carolina, Tennessee, Missouri, Illinois, Indiana, Michigan, Pennsylvania, New Jersey, and New York. The Focus Cities are distributed throughout the Focus States—seven in California, six in Florida, and five in Texas, as well as one or two in each of the other 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 them. 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.

Proven countermeasures associated specifically with pedestrian and bicyclist safety are:

- Walkways, including any type of defined space or pathway for use by a person traveling by foot or using a wheelchair, such as pedestrian walkways, shared-use paths, sidewalks, or roadway shoulders.
- Pedestrian crossing islands in urban and suburban areas, which are raised islands, located between opposing traffic lanes at intersection or midblock locations, that separate crossing pedestrians from motor vehicles.
- Leading pedestrian intervals, which give 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.

Through the EDC Program, Round 4 (2017–2018), the Safe Transportation for Every Pedestrian (STEP) initiative focused on improving pedestrian crossings and advancing cost-effective countermeasures to reduce crashes and save lives. Through STEP, FHWA provides free technical assistance, training, and educational products for stakeholders. FHWA promotes the following countermeasures through STEP:

- Road Diets can reduce vehicle speeds and the number of lanes pedestrians cross; they can also create space for new pedestrian facilities.
- Pedestrian hybrid beacons are a beneficial intermediate option between enhanced signing and a full pedestrian signal. They provide positive stop control in areas without the high pedestrian traffic volumes that typically warrant signal installation.
- Pedestrian refuge islands provide pedestrians a safe place to stop at the midpoint of the roadway before crossing the remaining distance. This is particularly helpful for older pedestrians or others with limited mobility.
- Raised crosswalks can reduce vehicle speeds.
- Crosswalk visibility enhancements, such as crosswalk lighting and enhanced signing and marking, help drivers detect pedestrians—particularly at night.

Pedestrian and Bicycle Exposure Data

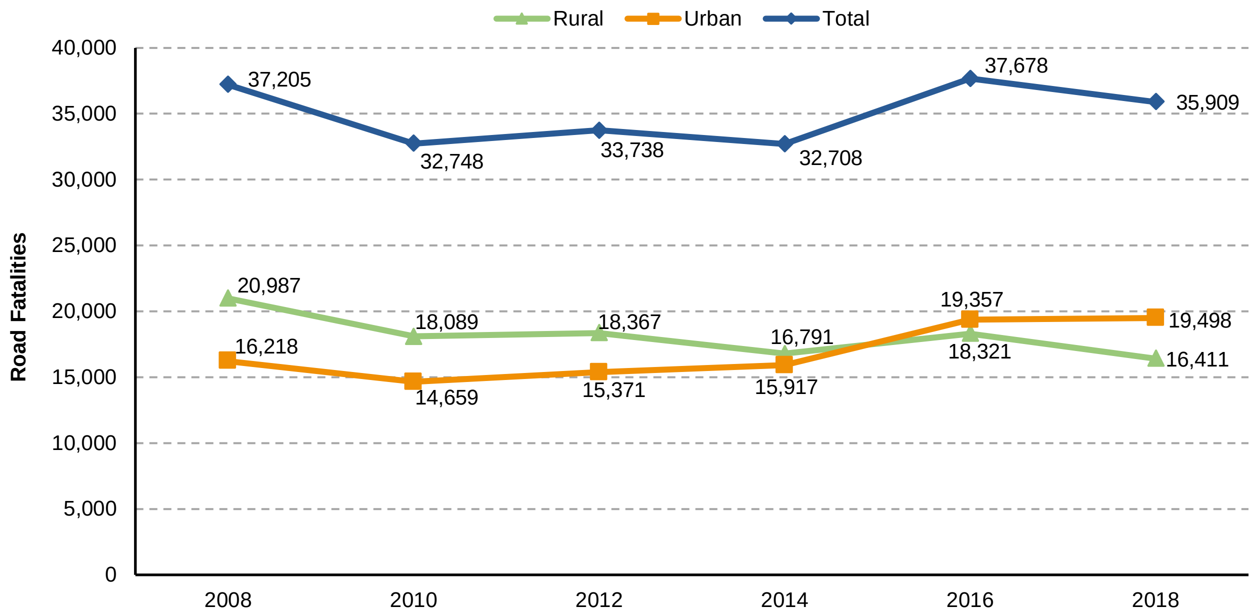
Bicycle and pedestrian safety can be analyzed and explored in many ways, including the total number of crashes, injuries, and fatalities during a given period. Although data on the absolute number of crash events provide important information for safety analyses, rates of events such as crashes, injuries, and/or fatalities per million trips or per million miles traveled offer additional insights on trends and potential causations.

The Travel Monitoring and Analysis System (TMAS), developed and managed by FHWA, has the capability to accept and process State-collected traffic volume data through traffic counting devices and programs. These data are collected continuously and are submitted to the TMAS by State highway agencies monthly. Submitting motorized traffic data by State highway agencies to TMAS is mandatory, per 23 U. S. C. § 150 and 23 U. S. C. § 315, but States' submission of pedestrian and bicycle travel data to TMAS is voluntary. FHWA has been working with States to provide paths for States to share their pedestrian and bicycle data, as many States collect bicycle and/or pedestrian exposure data for their state and local programs. FHWA will continue to work with States on pedestrian and bicycle data to gain a comprehensive understanding of national safety exposure.

Comparison of Rural and Urban Road Fatalities

The Concentration of Road Fatalities Has Shifted from Rural to Urban. In 2008, 56 percent of fatalities were rural and 44 percent urban, as shown in *Exhibit 5-8*. In 2016, for the first time since 1975, the number of urban fatalities was larger than the number of rural fatalities. By 2018, only 46 percent of fatalities were rural and 54 percent were urban. From 2008 to 2018, the annual number of rural fatalities declined by more than 4,500 and urban fatalities rose by more than 3,200.

Exhibit 5-8: Rural and Urban Road Fatalities, 2008–2018



Notes: Exhibit excludes fatalities for which rural/urban classification is unknown. Percentages are prorated based on the distribution of known rural/urban coding.

Source: NHTSA, 2020. Geospatial Summary of Crash Fatalities. https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812607.

Rural Fatality Rates Are Still Much Higher than Urban Fatality Rates. Although there has been a shift in the distribution of road fatalities, and the rural fatality rate declined from 1.82 per 100 million VMT in 2014 to 1.68 per 100 million VMT in 2018, the average rural fatality rate (1.83) during this five-year period (2014–2018) was still 2.2 times the average urban fatality rate (0.83).

Most Rural Fatalities Occur in Rural Areas that are Near Urban Areas. The majority of serious rural crashes took place in rural areas that were in close proximity to urban areas. In these rural areas, 59 percent of the total number of rural fatalities occurred in the subset of rural roadways that were within 5-mile buffers of urban areas.

Merging the urban portion of the United States with this 5-mile buffer reveals that 79 percent of national fatalities in 2018 occurred in this combined area. This 79 percent consists of the 50 percent of fatalities in urban areas, 21 percent of all fatalities in the "0- to 2.5-mile buffer" around urban areas, and 9 percent of all fatalities in the "2.5- to 5-mile buffer" around urban areas.

Most of the Nation's Road Miles Are Rural

As discussed in Chapter 1, based on the 2010 Census definitions of urban and rural areas, rural areas account for 71 percent of the Nation's public road miles, compared with 29 percent for urban areas.

Fatalities by Behavioral Factor (Speeding, Alcohol, and Restraint Use)

Although it is common to refer to the "cause" of a crash, most crashes are the result of a convergence of a series of events influenced by multiple contributing factors (driver attentiveness, speed, vehicle condition, road design, driver inexperience, etc.) rather than a single causal factor. For many years, three of the largest behavioral safety factors have been speeding, alcohol-impaired driving, and lack of restraint use.

In 2018, 26 percent of fatalities involved speeding, for a total of 9,378 fatalities. From 2014 to 2018, the percentage of fatalities involving speeding dropped slightly from 28 percent to 26 percent. The highest count for speeding-related fatalities (10,291) during this 5-year period occurred in 2016.

Alcohol-impaired fatalities, where one driver in the crash had a blood alcohol content (BAC) of 0.08 g/dL or higher (0.08+), totaled 10,511 in 2018. The percentage of fatalities that were in alcohol-impaired driving crashes dropped only slightly from 30 percent in 2014 to 29 percent in 2015 through 2018. Between 10,000 and 11,000 fatalities were in alcohol-impaired driving crashes each year from 2015 through 2018. The percentage of drivers involved in fatal crashes who had a BAC of 0.08+ was highest for motorcycles (25 percent), followed by passenger cars (21 percent), light trucks (19 percent), and large trucks (3 percent).

The percentage of drivers involved in fatal crashes where the driver had a BAC of 0.08+ was highest among those aged 21–24 years (27 percent), 25–34 years (25 percent), 35–44 years (21 percent) and 45–54 years (19 percent). This percentage was lower among drivers aged 16–20 years (15 percent), 55–64 years (15 percent), 65–74 years (10 percent), and 75 years and older (7 percent).

In 2018, a total of 2,283 fatally injured pedestrians had BACs of 0.01+, representing 38 percent of fatally injured pedestrians.

Restraint use among passenger vehicle occupants plays a large role in whether the occupant can survive a crash. Based on fatal crashes with known restraint use, the percentage of passenger vehicle fatalities where the occupant was unrestrained dropped slightly from

49 percent in 2014 to 47 percent in 2017 and 2018. Unrestrained passenger vehicle occupant fatalities averaged almost 10,000 each year from 2014 through 2018.

The number of fatally injured motorcycle riders averaged just over 5,000 per year from 2014 through 2018. Among these fatalities, riders were not wearing a helmet close to 40 percent of the time each year. Motorcyclists, like pedestrians and bicyclists, rely more heavily on safe infrastructure than do motor vehicle occupants, who have benefitted from many safety features such as seat belts, airbags, and electronic stability control.

In 2018, 344 children age less than 5 were fatally injured, consisting of 270 vehicle occupants and 74 nonoccupants (including pedestrians, bicyclists, and other nonoccupants).

Fatalities by Vehicle Type

In 2018, 22,697 passenger vehicle occupant fatalities occurred, distributed across passenger cars (12,775), SUVs (4,534), vans (1,077), pickups (4,253). Non-passenger vehicle types include large trucks (885 fatalities in 2018) and motorcycles (4,985).

Fatalities among occupants of large trucks totaled 885 in 2018, but there were 4,951 fatalities in crashes involving large trucks, including more than 4,000 fatalities of occupants of other vehicles or nonoccupants. By percentage, the 4,951 fatalities from crashes involving a large truck consisted of large truck occupants (18 percent), occupants of other vehicles (71 percent), and nonoccupants (11 percent).

The overall fatality rate per 100 million VMT was 1.13 in 2018. Fatality rates varied greatly across vehicle types, including passenger cars (0.91), light trucks (0.66), large trucks (0.29), and motorcycles (24.83). The fatality rate for motorcycles is more than 25 times that of the other vehicle types. Note that the definition of light trucks includes SUVs, vans, and pickups.

The national total VMT was more than 3.2 trillion in 2018, broken down as follows (in millions): 1,404,507 for passenger cars, 1,492,576 for light trucks, 304,864 for large trucks, and 20,076 for motorcycles.

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).

SECTION SUMMARY

- The total number of transit fatalities in 2018 (excluding FRA-regulated systems) was 260 people, of which 15 were transit passengers.
- Transit rail fatalities increased by 35 percent from 2008 to 2018.
- In 2018, 219 people died because of collisions, accounting for 84 percent of all transit fatalities.
- Transit stations are the most common location for transit fatalities. In 2018, 83 people died at transit stations, or 48 percent of all transit rail fatalities. These deaths were due primarily to suicides.
- Most bus fatalities occur on roadways at intersections. In 2018, 64 people died on roadways, or 77 percent of all bus fatalities.
- Together, rail modes accounted for 68 percent of noncommuter rail fatalities, and bus accounted for 32 percent. In contrast, rail accounted for 28 percent of injuries, whereas bus accounted for 72 percent.
- There were 22,730 noncommuter rail injuries in 2018. These injuries required medical assistance at facilities away from the scenes of the accidents.
- In 2018, 118 people died in commuter rail accidents, a 27-percent increase from 2008 (93 people). The total number of fatalities in transit, including commuter rail, increased by 33 percent between 2008 and 2018, from 285 in 2008 to 378 in 2018.

NTD compiles safety data for all transit modes, except for systems regulated by the Federal Railroad Administration (FRA). The FRA regulates all commuter rail systems, the Alaska Railroad, the PATH system in New York, and three other systems classified by the NTD as the *hybrid rail* mode. This section presents statistics and counts of basic aggregate data, such as injuries and fatalities from NTD and FRA. For 2018, 64 rail transit systems, 407 urban fixed-route bus providers, 262 urban demand response and vanpool providers, and 159 rural agencies reported at least one safety event. 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. However, the total aggregate data reported by these agencies account for a very small share of the Nation's transit safety events.

Incidents, Fatalities, and Injuries, Excluding FRA-Regulated Systems

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. 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 serious injury is reported when an injury requires hospitalization for more than 48 hours within 7 days of the event; results in a fracture of any bone; causes severe hemorrhages or nerve, muscle, or tendon damage; involves an internal organ; or involves second- or third-degree burns. 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

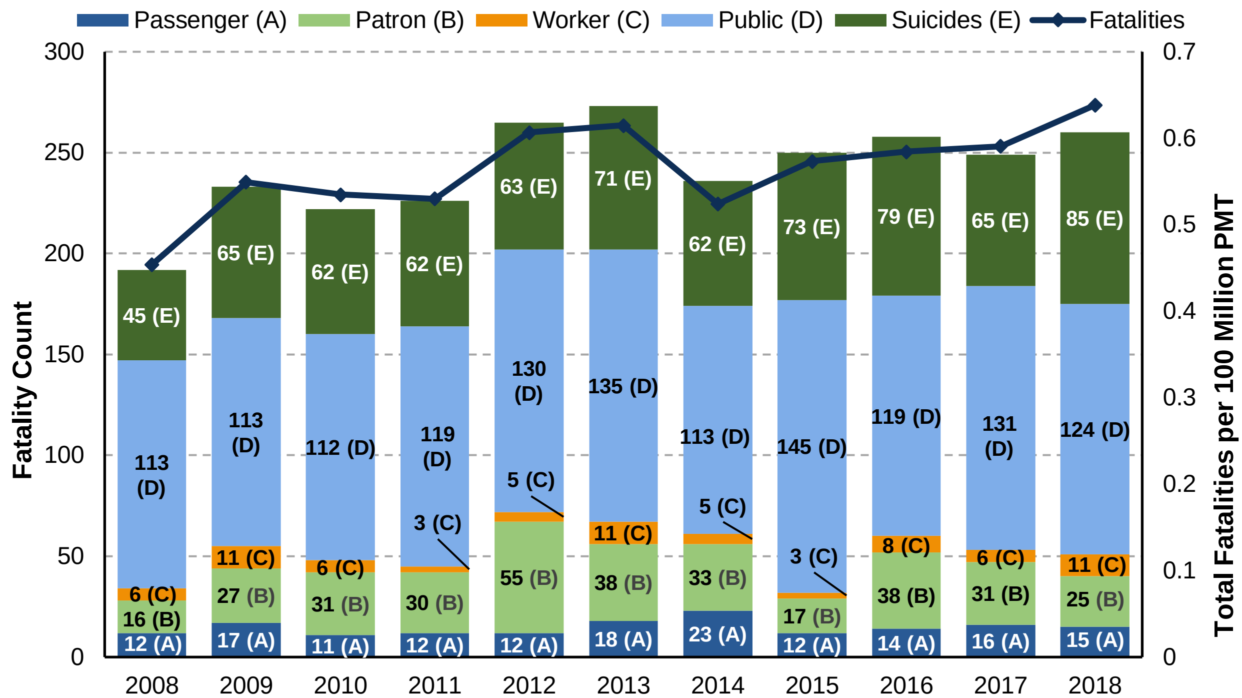
Despite a decline in 2014, fatality measures have exhibited a general upward trend over the past decade. *Exhibit 5-9* shows data on fatalities, both in total fatalities and fatalities per 100 million passenger miles traveled (PMT) for FTA-oversight systems. Suicides and fatalities involving station patrons have accounted for an increasing share of transit fatalities over this period. The interactions among 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, increasing from 45 suicides in 2008 to 85 in 2018. Pedestrian fatalities accounted for approximately 12 percent of all transit fatalities in 2018.

KEY TAKEAWAY

The number of transit fatalities increased from 192 fatalities in 2008 to 260 fatalities in 2018. In 2018, 85 fatalities, or 32.7 percent, were classified as suicides. Collisions accounted for 84 percent of fatalities in 2018, generally at intersections and grade crossings.

Exhibits 5-10 and *5-11* depict fatalities by event type in 2018. In 2018, there were 260 transit fatalities, 83 occurring on nonrail modes and 177 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 84 percent of all fatalities in 2018. Collisions are primarily with vehicles at grade crossings. The number of deaths due to homicide accounted for only 2 percent of fatalities on nonrail and 3 percent on rail, mostly involving nonusers of transit.

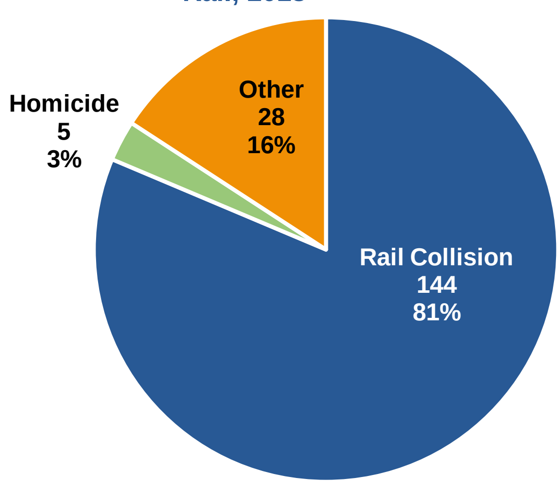
Exhibit 5-9: Annual Transit Fatalities, Including Suicides, 2008–2018



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

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

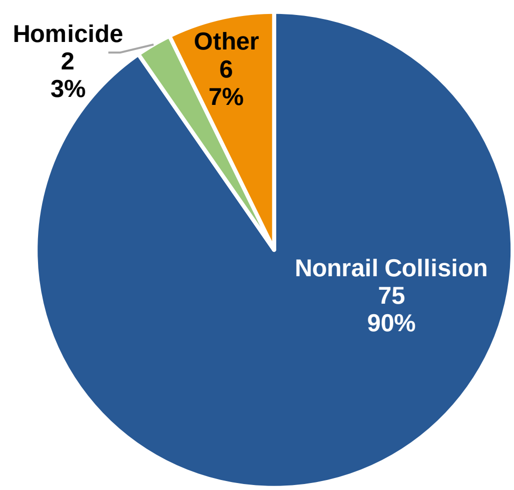
Exhibit 5-10: Transit Fatality Event Types, Rail, 2018



Notes: Exhibit includes data for rail transit modes, excluding commuter rail. Two NTD event type categories were updated in 2018.

Source: National Transit Database.

Exhibit 5-11: Transit Fatality Event Types, Nonrail, 2018

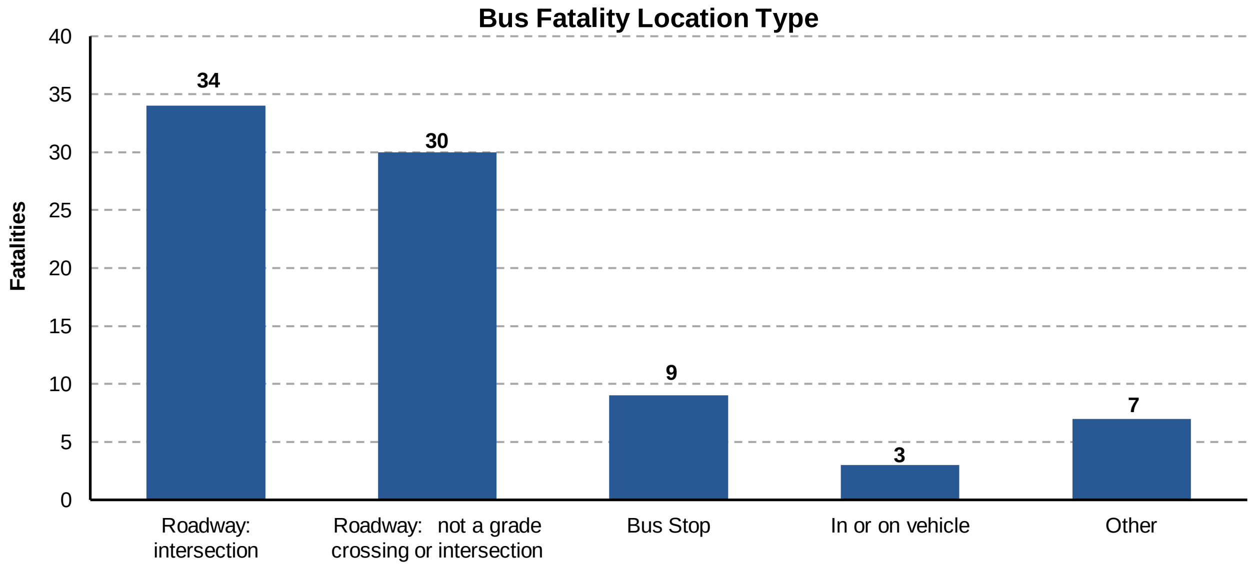


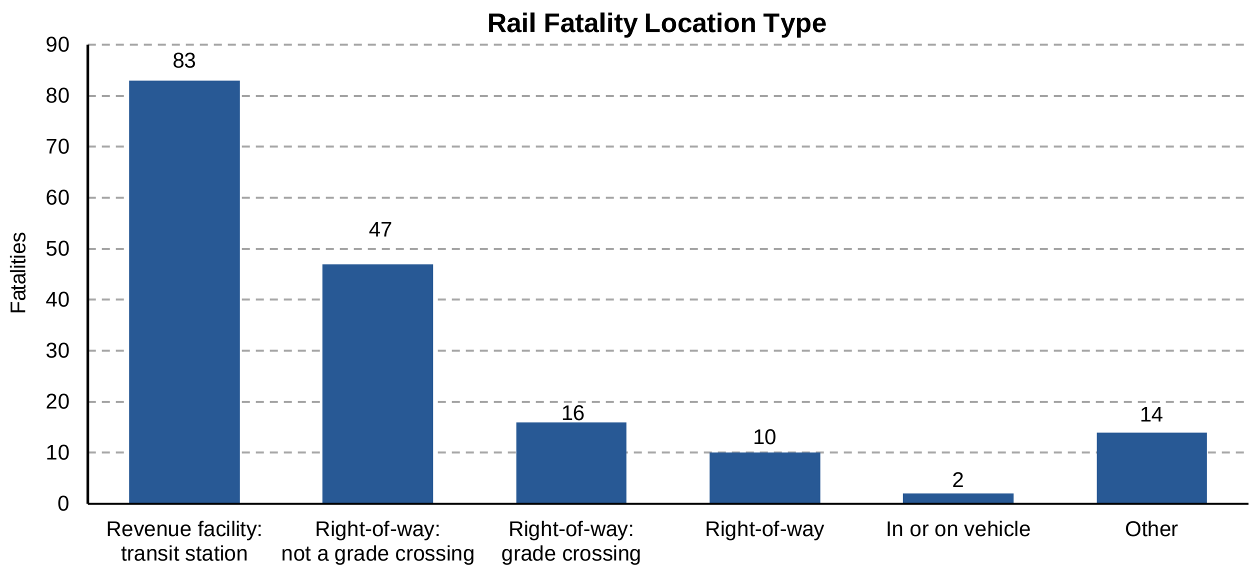
Notes: Exhibit includes data for nonrail transit modes. Two NTD event type categories were updated in 2018.

Source: National Transit Database.

Exhibit 5-12 shows fatalities by location type for bus and rail modes. More than 75 percent of bus fatalities occur on roadways, and most victims are members of the public (not riders). In contrast, nearly half of all rail fatalities occur at transit stations. In addition, 41 percent of bus fatalities occurred at roadway intersections and 9 percent of rail fatalities occurred at crossings. The interactions among transit, vehicles, pedestrians, cyclists, and motorists at rail grade crossings, pedestrian crosswalks, and intersections all influence overall transit safety performance.

Exhibit 5-12: Bus and Rail Fatality Types by Location, 2018





Note: National Transit Database event type categories were updated in 2018.
Source: National Transit Database.

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.[29]

Derailments

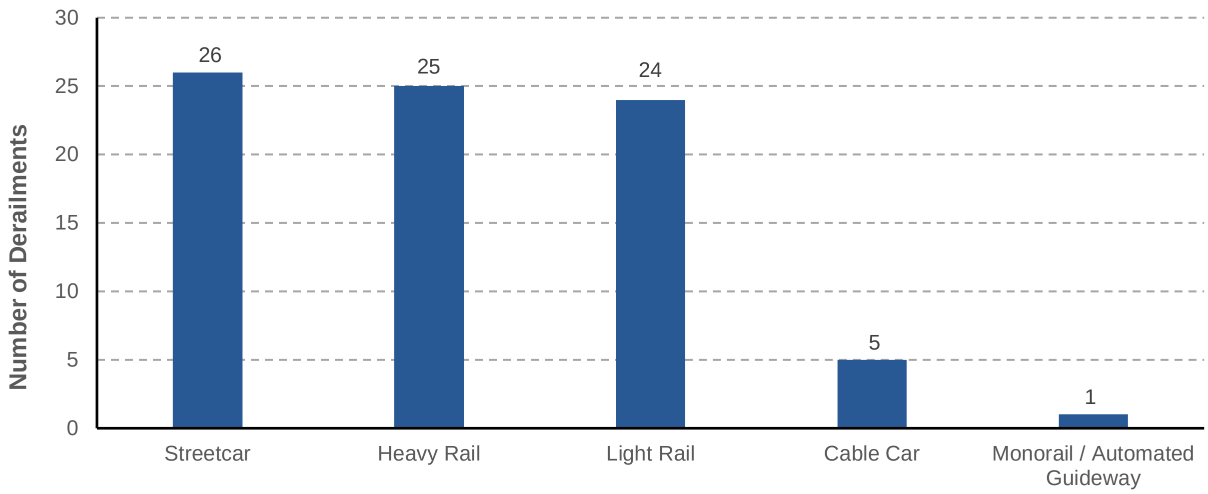
Exhibit 5-13 shows derailments by rail mode. Streetcar is the single mode with the highest number of derailments, followed by heavy rail and light rail. Heavy rail, which is a fast and high-capacity mode, had an average of 0.04 derailments per million vehicle revenue miles. Light rail, the second fastest mode, had an average of 0.20 derailments per million vehicle revenue miles; and streetcars, which operate in mixed traffic at low speeds, had 3.91 derailments per million vehicle revenue miles.

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.

Heavy rail systems are usually faster systems compared with light rail, and require very complex, diversified, and expensive asset types to operate. Heavy rail derailments are less frequent but severe when they happen in revenue service.

It should be noted that derailment events occur 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 5-13: Derailments by Rail Mode, 2018



Mode	Number of Derailments	Resulting Injuries	VRM	Derailments per Million VRM
Streetcar	26		6,643,053	3.91
Heavy Rail	25	1	673,218,384	0.04
Light Rail	24	1	118,273,342	0.20
Cable Car	5	3	298,274	16.76
Monorail / Automated Guideway	1		3,058,243	0.33

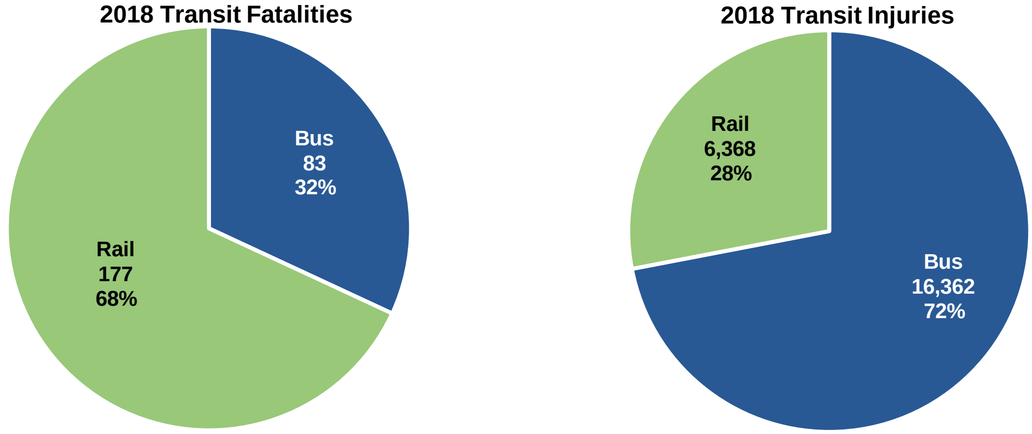
Source: National Transit Database Safety Analysis 2018.

[29] 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*.

Fatalities and Injuries by Mode

Rail accounts for the largest share of transit fatalities (68 percent), whereas bus accounts for the largest share of transit injuries (72 percent) as shown in *Exhibit 5-14*, which depicts the split of fatalities and injuries between rail modes and fixed-route bus. The most common type of rail incidents involve people walking along sidewalks by light rail and streetcar systems. Transit passengers account for a small share of fatalities and injuries. Common bus fatalities occur with other vehicle occupants (in collision accidents) and collisions with pedestrians near road crossings.

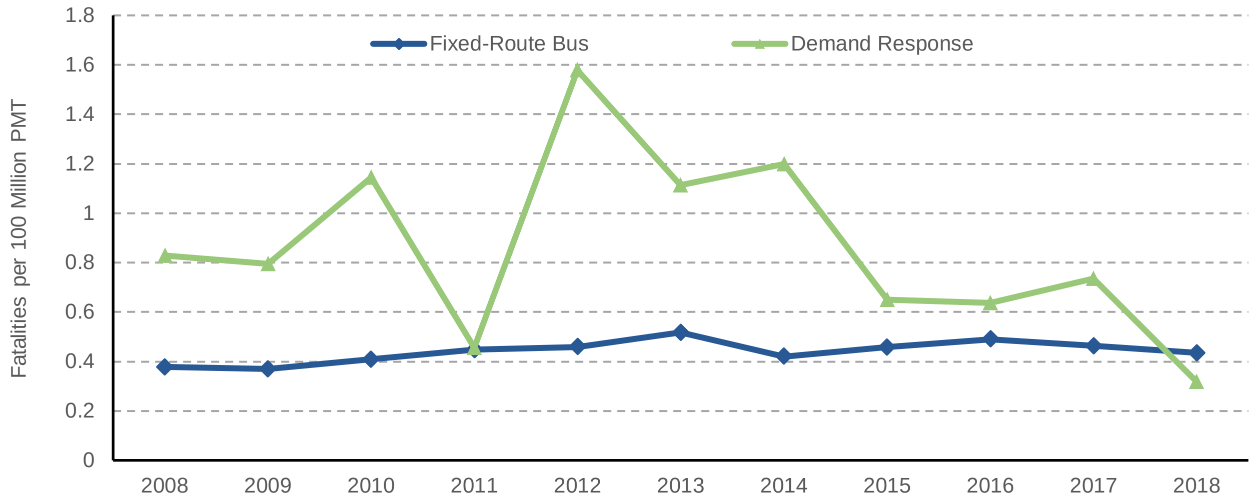
Exhibit 5-14: Transit Fatalities and Injuries by Mode, 2018



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

Exhibit 5-15 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.

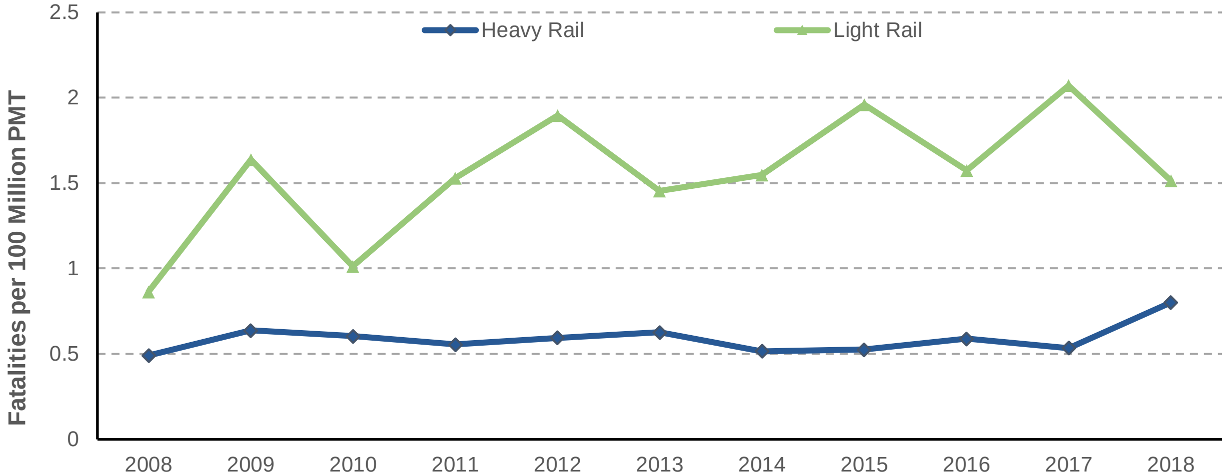
Exhibit 5-15: Annual Transit Fatality Rates by Highway Mode, 2008–2018



Note: Fatality totals include both directly operated and purchased transportation service types.
Source: National Transit Database.

Exhibit 5-16 shows fatalities (including suicides) per 100 million PMT for heavy rail and light rail. Heavy rail fatality rates remained relatively stable from 2008 through 2017. Suicides represent a large share of fatalities for heavy rail—approximately 51 percent in 2018. Light rail typically experiences more injuries and fatalities than does heavy rail, as many systems consist of streetcars operating in mixed traffic with both automobiles and pedestrians present.

Exhibit 5-16: Annual Transit Fatality Rates by Rail Mode, 2008–2018



Note: Fatality totals include both directly operated and purchased transportation service types.
Source: National Transit Database.

Fatality, Incident, and Injury Rates by Mode, Excluding Suicides

The analysis presented in *Exhibit 5-17* is by mode, which includes all major modes reported in the NTD except for FRA-regulated systems. Safety data for FRA-regulated systems 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 5-17 shows incidents and injuries per 100 million PMT reported in the NTD for the two main nonrail transit modes (fixed-route bus and demand-response transit) and the two main rail transit modes (heavy rail and light rail). Data for FRA-regulated systems are presented separately as those data were collected according to different definitions in RAIRS. Between 2008 and 2018, both demand response and heavy rail modes saw a decrease in incidents and injuries. Conversely, fixed-route bus saw an increase in incidents and injuries. Light rail saw an increase in incidents and a decrease in injuries.

Exhibit 5-17: Transit Incidents and Injuries per 100 Million PMT, by Mode, 2008–2018

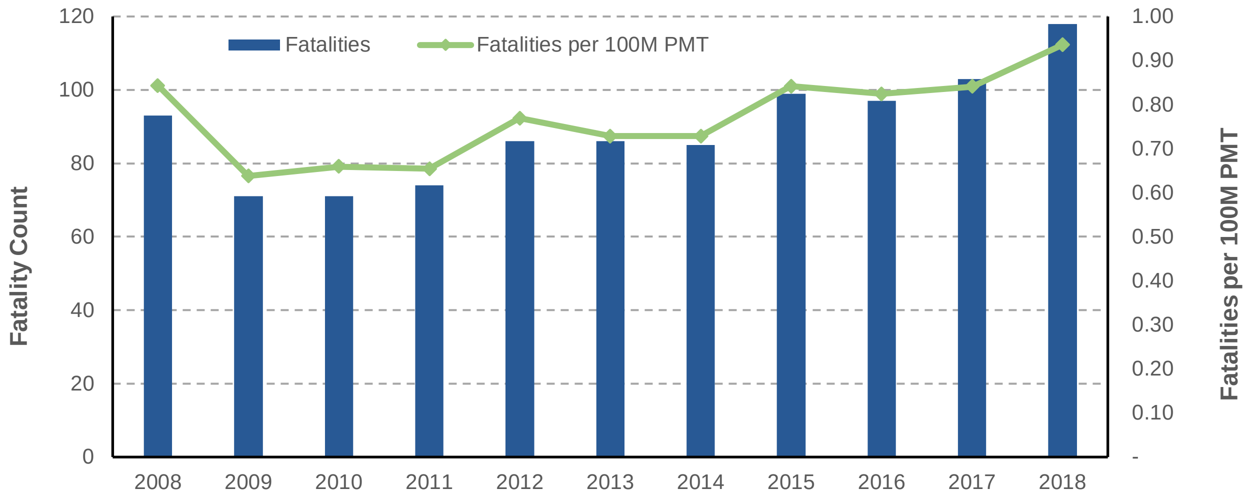
Category	Analysis Parameter	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Incidents	Fixed-Route Bus	54.15	58.28	55.28	46.26	45.20	47.63	48.81	59.72	59.80	63.76	66.82
	Heavy Rail	53.34	53.16	54.62	49.39	48.58	49.87	41.19	41.37	41.30	36.59	39.43
	Light Rail	48.58	45.76	40.09	39.68	36.94	40.67	41.85	67.43	69.72	57.71	55.23
	Demand Response	204.28	194.77	165.23	153.08	143.72	154.87	157.70	194.12	214.33	199.13	201.18
Injuries	Fixed-Route Bus	66.89	72.27	71.96	62.87	62.65	65.30	66.67	73.69	71.64	74.36	76.87
	Heavy Rail	43.94	45.85	47.08	42.14	42.07	43.55	34.98	34.04	33.25	28.39	31.07
	Light Rail	49.45	48.72	46.62	42.44	38.27	40.39	43.70	46.17	43.72	48.51	42.23
	Demand Response	234.50	215.20	188.69	177.32	172.36	183.95	190.85	200.29	226.41	198.18	194.93

Source: National Transit Database.

FRA-Regulated 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 5-18* 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 2018 was 118, with a fatality rate of 0.94.

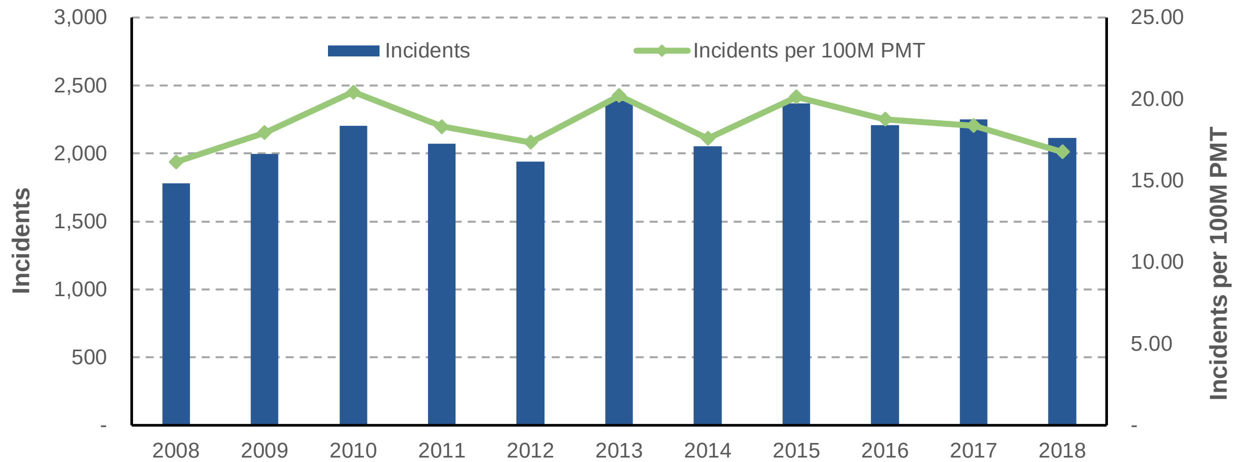
Exhibit 5-18: FRA-Regulated Rail System Fatalities, 2008–2018



Source: Federal Railroad Administration Rail Accident/Incident Reporting System.

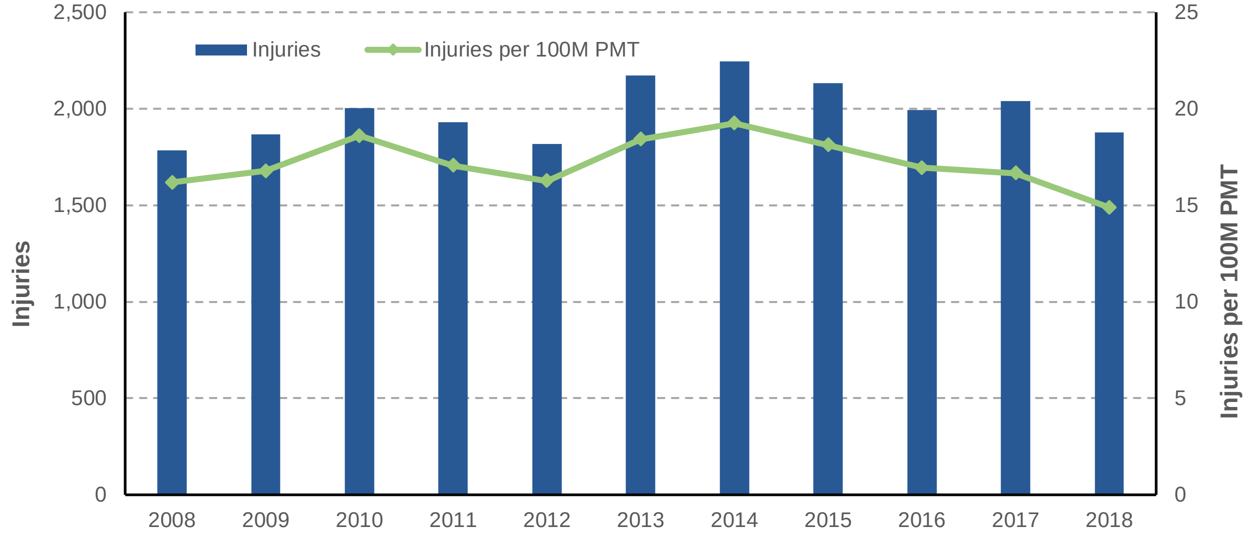
Exhibits 5-19 and *5-20* show the number of incidents on FRA-regulated rail systems and the number of injuries per 100 million PMT, respectively. Although FRA-regulated systems have a very low number of incidents per PMT, incidents are far more likely to result in fatalities than incidents occurring on any other mode. One contributing factor could be that the average speed of FRA-regulated rail system vehicles is considerably higher than the average speeds of other modes (except vanpools). The number of incidents peaked in 2013 at 2,385, followed closely by 2,367 in 2015. The number of injuries peaked in 2014 at 2,245, followed closely by 2,131 in 2015. The average rates of increase for FRA-regulated rail system fatalities, incidents, and injuries from 2008 to 2018 are 26.9 percent, 18.6 percent, and 5.2 percent, respectively.

Exhibit 5-19: FRA-Regulated Rail System Incidents, 2008–2018



Source: Federal Railroad Administration Rail Accident/Incident Reporting System.

Exhibit 5-20: FRA-Regulated Rail System Injuries, 2008–2018



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. The "roughness" of a pavement is an important roadway quality. Pavement roughness is generally defined as an expression of irregularities in the pavement surface that adversely affect the ride quality of a vehicle and that experienced by the passengers in the vehicle. A "smoother" ride is less stressful for the vehicle passengers, reduces trip delay by allowing travel at posted speed limits, and reduces costs related to delays, fuel consumption, and vehicle maintenance. Poor bridge conditions can lead to the imposition of weight limits, forcing trucks to seek alternative routes, which can increase travel time costs. If a bridge's condition deteriorates to the point where it must be closed, all traffic would need to use alternative routes—potentially 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.

SECTION SUMMARY

- The share of vehicle miles traveled (VMT) on Federal-aid highways on pavements with good ride quality rose from 46.4 percent in 2008 to 53.0 percent in 2018. In 2018, 61.7 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 declined from 45.8 percent in 2008 to 45.3 percent in 2018. During this period, the share of bridges weighted by average daily traffic (ADT) classified as in good condition rose from 44.7 percent to 46.4 percent.
- The deck area-weighted share of bridges classified as in poor condition decreased from 9.0 percent in 2008 to 5.4 percent in 2018. During this period, the share of bridges weighted by ADT classified as in poor condition declined from 7.1 percent to 3.8 percent.
- The shares of NHS bridges in 2018 weighted by deck area classified as in good, fair, and poor condition were 43.4 percent, 52.1 percent, and 4.5 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. 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.

Data Sources

Pavement condition data are reported to FHWA through the Highway Performance Monitoring System (HPMS). The HPMS requires reporting for Federal-aid highways only, which represent 24.5 percent of the Nation's road mileage but carry 85.2 percent 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. The HPMS includes information on the International Roughness Index (IRI), which is an indicator of the ride quality experienced by drivers. Other measures of pavement distress include pavement cracking (distresses that occur on the surface of pavements), 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). For the sections on the NHS where posted speed limit is less than 40 mph, States can report a general Present Serviceability Rating (PSR) value in place of an actual measurement of pavement roughness through the IRI[1,2].

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 2011—a number of highway sections still lacked these data as of 2018. In some cases, States provided an alternative PSR as permitted for certain types of roads; in others, no condition data were provided. *Exhibit 6-1* identifies the percentage of HPMS highway segments for which data were reported in 2018 for each distress type for Interstate highways, the National Highway System (NHS), and Federal-aid highways. In 2019, the 50 States, the District of Columbia, and Puerto Rico began reporting on pavement conditions per the requirements for National Performance Management measures. Under the new requirements, some data elements are to be reported every 0.1 mile (528 feet) for the full extent of the National Highway system and referred to as "Full Extent Data." 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 departments of transportation (DOTs) has improved since the last C&P Report. This increases the accuracy of the statistics reported in this chapter.

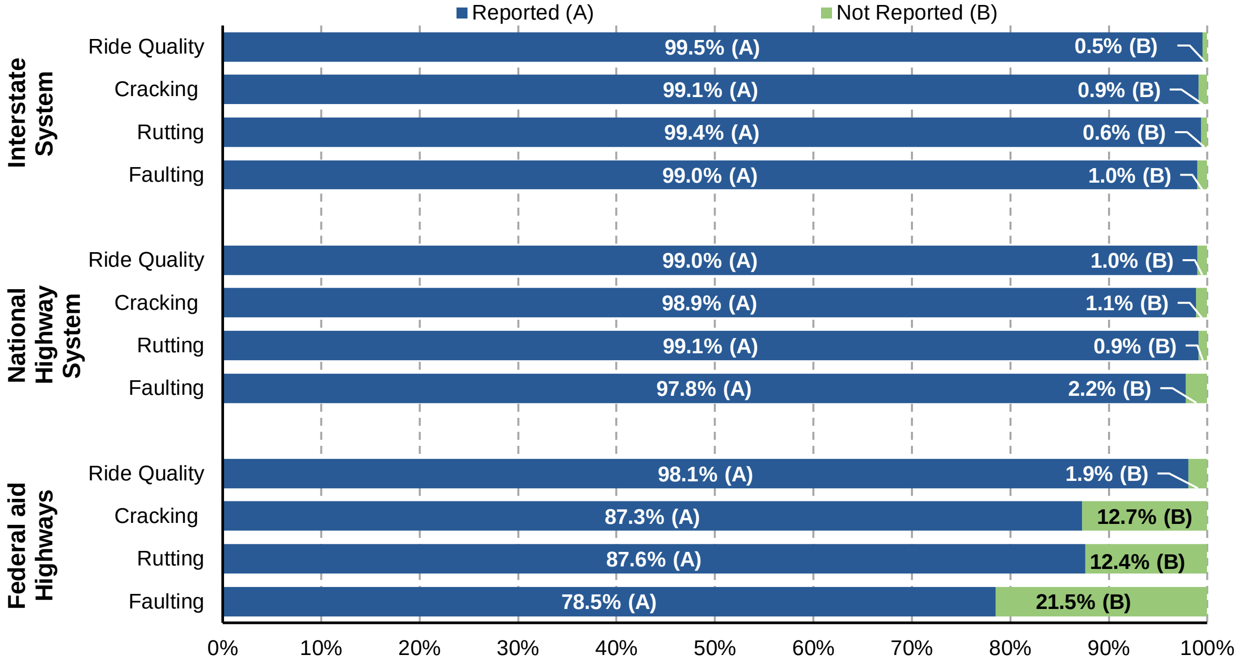
Exhibit 6-1 shows that States reported ride quality for 99.5 percent of the Interstate System. For cracking data, 99.1 percent of the Interstate was reported; 99.4 percent of rutting data was reported for the Interstate System; faulting data was reported for 99.0 percent. The percentages of data reported for the NHS for the same distresses were 99.0 percent, 98.9 percent, 99.1 percent, and 97.8 percent respectively. For Federal-aid highways, ride quality was reported for 98.1 percent of the sample sections, cracking was reported for 87.3 percent, rutting was reported for 87.6 percent, and faulting was reported for 78.5 percent.

For cracking and faulting, States reported a higher percentage of the requested data for Federal-aid highways than for the Interstate System or the NHS. This is likely attributable to the differences in the required data, as reporting on Federal-aid highways is based on random samples whereas data are requested for the full extent of the Interstate System and the NHS.

All 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.

Bridge condition data are reported to FHWA through the National Bridge Inventory (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.

Exhibit 6-1: Percentage of Pavement Data Reported, 2018



Source: Highway Performance Monitoring System.

The NBI database contains condition classifications on the three primary components of a bridge: deck, superstructure, and substructure. 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 the 135,810 bridge-class culverts represented in the NBI. 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. 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.

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 provides a metric for the extent to which pavement or bridge conditions are affecting the traveling public. Weighting by lane miles or deck area aligns 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). Some bridge data are presented based on actual bridge counts, whereas other data are weighted by bridge deck area or bridge traffic.

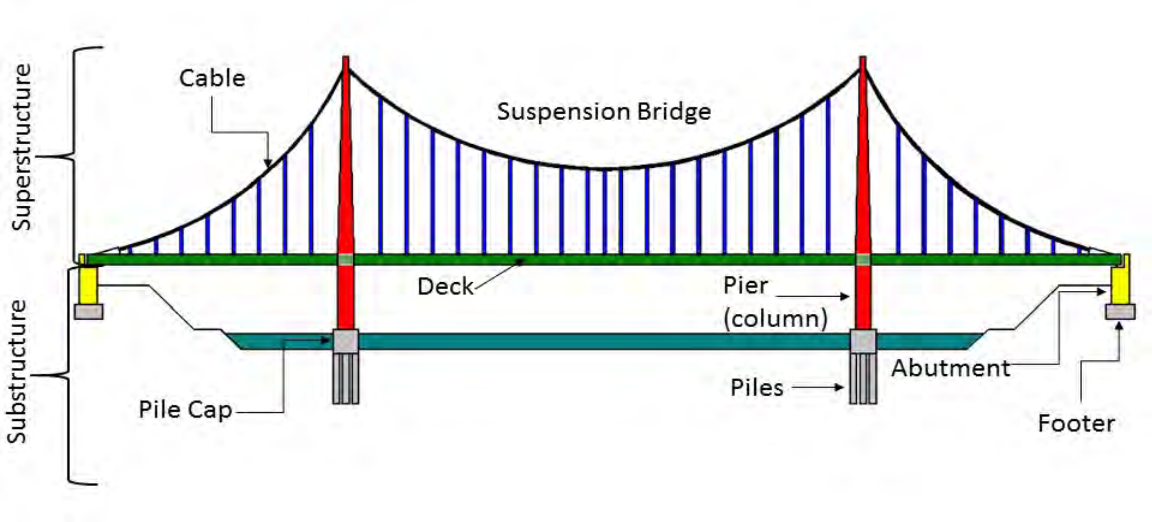
Bridge Element Data

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. In the case of culverts, a single numeric rating is assigned to the culvert. Although this rating system provided information that allowed FHWA to categorize the overall condition of a bridge and make high-level assessments of needs, it did not provide information on the extent and type of deterioration. Element condition data provide this information, which is valuable for refined conditions and needs assessments.

Bridges have just three primary components, but there are more than 100 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 their 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. Element data better quantify the severity, extent, and type of deterioration, and thus better 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 6-2*).

Many State and Federal agencies have been collecting element data since the 1990s. Recognizing the value of element data, the Moving Ahead for Progress in the 21st Century (MAP-21) Act included a requirement that element data are collected for bridges on the NHS. These data are now reported to FHWA.

Exhibit 6-2. Diagram of Selected Bridge Elements



Highway and Bridge Conditions—2018

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) in 23 U.S.C. §150, 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. 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.

Exhibit 6-3 identifies criteria for "good," "fair," and "poor" classifications for several individual pavement distresses and bridge components. This is consistent with the information laid out in the PM-2 rule, although the PM-2 rule requires only that targets be set for pavements and bridges on the NHS. This chapter applies the same criteria in classifying the conditions of other roads and bridges.

Exhibit 6-3: Condition Rating Classifications Used in the 25th 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 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
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

Notes: IRI is International Roughness Index; PSR is Present Serviceability Rating.

[1] Under the PM-2 rule, PSR can be reported in lieu of IRI, rutting, and faulting for any component of the NHS with a posted speed limit under 40 miles per hour (e.g., border crossings, toll plazas).

Source: FHWA (https://www.federalregister.gov/documents/2017/01/18/2017-00550/national-performance-management-measures-assessing-pavement-condition-for-the-national-highway).

The PM-2 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 relevant distresses (i.e., ride quality, cracking, and rutting for asphalt pavements; ride quality, cracking, and faulting for concrete pavements[30]) 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.

[30] For Continuously Reinforced Concrete Pavement (CRCP) only ride quality and cracking are relevant.

The PM-2 rule criteria for overall bridge ratings consider: (a) deck condition, (b) superstructure condition, (c) substructure condition, and (d) culvert condition.[31] If any one of these components is rated as poor, the bridge is classified as poor. The classification of a bridge as poor 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. Poor condition would indicate that some structural elements of the bridge have advanced deterioration. Typical needs of a bridge in poor condition would include condition-based maintenance activities, rehabilitation, or replacement. A bridge in poor condition may require more frequent inspections, closer monitoring, or weight restrictions to ensure it remains safe for public travel. If a bridge inspection determines a bridge to be unsafe, it is closed.

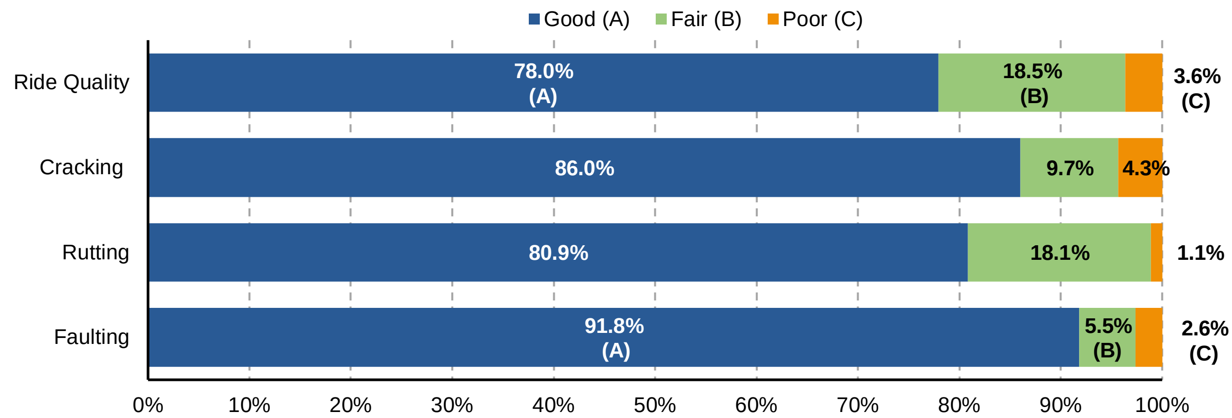
If all applicable components are rated as good, the bridge is classified as good. Good condition would indicate the structural elements of the bridge have no deterioration or some minor deterioration. A bridge in good condition may need preservation or cyclic maintenance activities.

Any bridges not rated as good or poor are classified as fair. Fair condition would indicate that some structural elements of the bridge have minor deterioration that could include section loss, cracking, spalling, scour, or other defects of similar significance. Typical needs of a bridge in fair condition would include preservation, cyclic maintenance activities, or condition-based maintenance activities.

Pavement Conditions - 2018

As shown in *Exhibit 6-4*, of the lane miles reported, approximately 78.0 percent of pavements on the Interstate System (weighted by lane miles) were rated as having good ride quality (roughness) in 2018, 18.5 percent had fair ride quality, and 3.6 percent had poor ride quality. The shares of pavement rated as good for cracking, rutting, and faulting were 86.0 percent, 80.9 percent, and 91.8 percent, respectively, whereas the shares rated as poor were 4.3 percent, 1.1 percent, and 2.6 percent, respectively.

Exhibit 6-4: Interstate Pavement Condition, Weighted by Lane Miles, 2018



Source: Highway Performance Monitoring System.

[31] Bridge components and condition rating descriptions are provided in the Federal Highway Administration Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges (NBI Coding Guide).

Interstate Overall Pavement Condition Ratings

The final rule on the "National Performance Management Measures; Assessing Pavement Condition for the National Highway Performance Program and Bridge Condition for the National Highway Performance Program" became effective February 17, 2017, establishing a set of performance measures for State DOTs and Metropolitan Planning Organizations (MPOs) to use as required by MAP-21 and the Fixing America's Surface Transportation (FAST) Act. All pavement data collected after January 1, 2018 for Interstate highways and January 1, 2020 for non-Interstate NHS routes shall meet the requirements of this section. Of the 17 measures, two are related to pavement condition: (1) Percentage of pavements in Good condition and (2) Percentage of pavements in Poor condition.

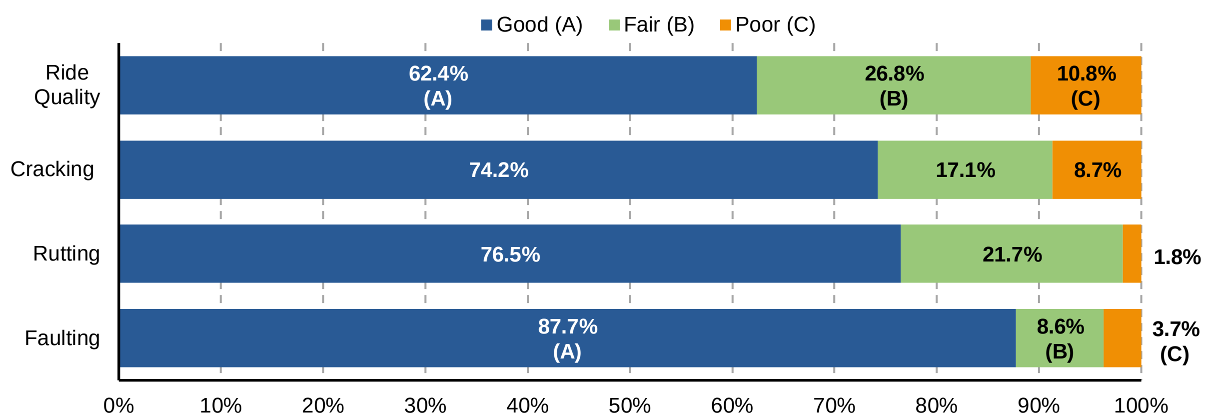
Based on the 2018 data submitted for the Interstate System by State DOTs, the national conditions[1] are:

- 61.4 percent[2] of the pavements of the Interstate System are in Good condition, and
- 0.9 percent[2] of the pavements of the Interstate System are in Poor condition.

Notes:
[1] Lane mile-based percentages computed based on the method described in 23 CFR Part 490 Subpart C.
[2] Values exclude data for States determined as having "insufficient" 2018 data (DC and WA).

For NHS pavements, *Exhibit 6-5* shows that, of the lane miles reported, 62.4 percent were rated as having good ride quality in 2018, 26.8 percent had fair ride quality, and 10.8 percent had poor ride quality. Comparing the results of *Exhibit 6-4* to those of *Exhibit 6-5* reveals that pavement ride quality on the Interstate portion of the NHS is better than on the non-Interstate portion of the NHS.

Exhibit 6-5: National Highway System Pavement Condition, Weighted by Lane Miles, 2018



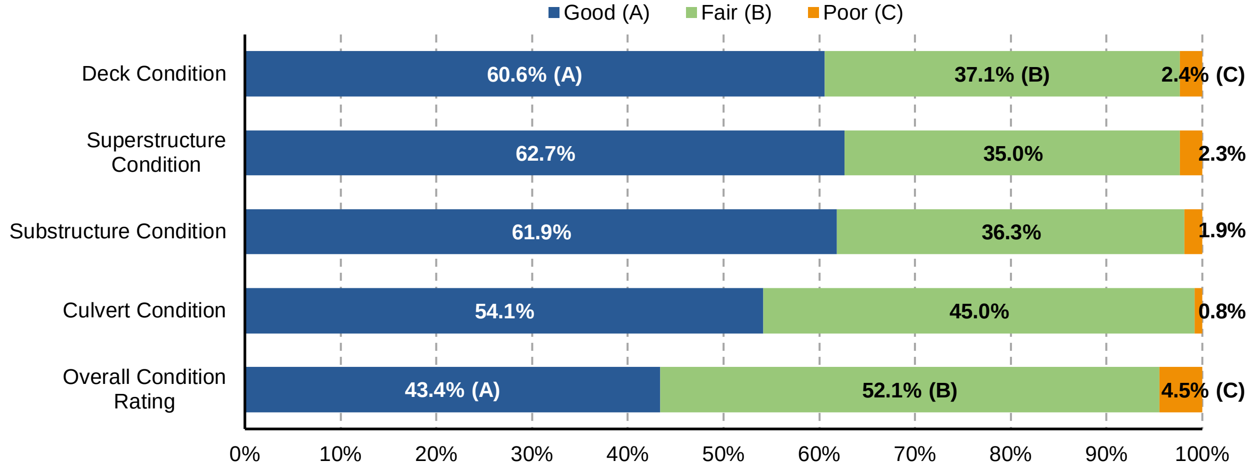
Source: Highway Performance Monitoring System.

In 2018, the lane mile-weighted shares of cracking, rutting, and faulting pavement rated as good for the NHS were 74.2 percent, 76.5 percent, and 87.7 percent, respectively—all of which are below the comparable values for Interstate highways. The share of NHS lane miles rated as poor in 2018 was 8.7 percent for cracking, 1.8 percent for rutting, and 3.7 percent for faulting pavement.

Bridge Conditions—2018

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 60.6 percent for 2018; the shares for superstructure and substructure were 62.7 percent and 61.9 percent, respectively. The share of NHS culverts in good condition was 54.1 percent in 2018. Applying the PM-2 classification rules (all individual bridge components rated as good) results in an overall share of 43.4 percent of NHS deck area rated as good.

Exhibit 6-6: National Highway System Bridge Conditions, Weighted by Deck Area, 2018

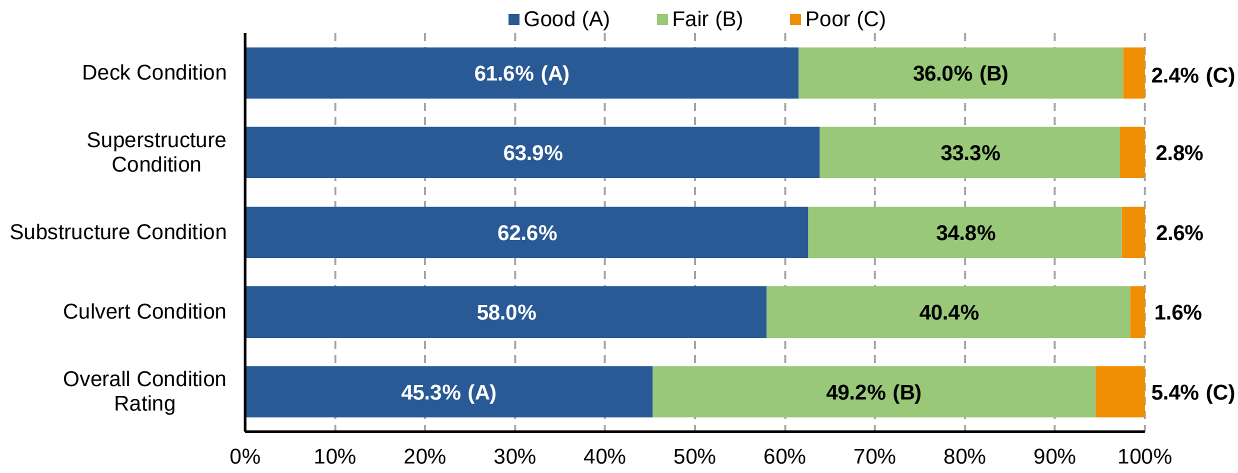


Source: National Bridge Inventory.

The deck area-weighted share of NHS bridges with decks in poor condition was 2.4 percent for 2018; the shares for superstructure and substructure were 2.3 percent and 1.9 percent, respectively; the share for culverts was 0.8 percent. Applying the PM-2 classification rules (any of the individual bridge components rated as poor) results in an overall share of 4.5 percent of NHS deck area rated as poor.

Exhibit 6-7 shows deck area-weighted condition data for all bridges on public roads. The shares of deck area rated as good for deck, superstructure, and substructure were 61.6 percent, 63.9 percent, and 62.6 percent, respectively. For all culverts for which data were reported, the share rated as good was 62.6 percent in 2018. Applying the PM-2 classification rules results in an overall share of 45.3 percent of all deck area rated as good.

Exhibit 6-7: Systemwide Bridge Conditions, Weighted by Deck Area, 2018



Source: National Bridge Inventory.

The deck area-weighted share of all bridges with decks in poor condition systemwide was 2.4 percent for 2018; the shares for superstructure, substructure, and culverts were 2.8 percent, 2.6 percent, and 1.6 percent, respectively. Applying the PM-2 classification rules results in an overall share of 5.4 percent of deck area rated as poor.

Historical Trends in Pavement and Bridge Conditions

Pavement ride quality data are available only for Federal-aid highways. This section presents data on changes in pavement ride quality on Federal-aid highways since 2008, as well as changes in the portion of bridges rated as 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, the Department of Transportation (DOT) began establishing annual targets for pavement ride quality. From 2006 through 2018, DOT used the share of VMT on the NHS on pavements with good ride quality as its performance metric.

KEY TAKEAWAY

The share of VMT on NHS pavements with poor ride quality decreased from 8 percent in 2008 to 7 percent in 2010; since the expansion of the NHS under MAP-21 this share has remained relatively constant at about 11 percent.

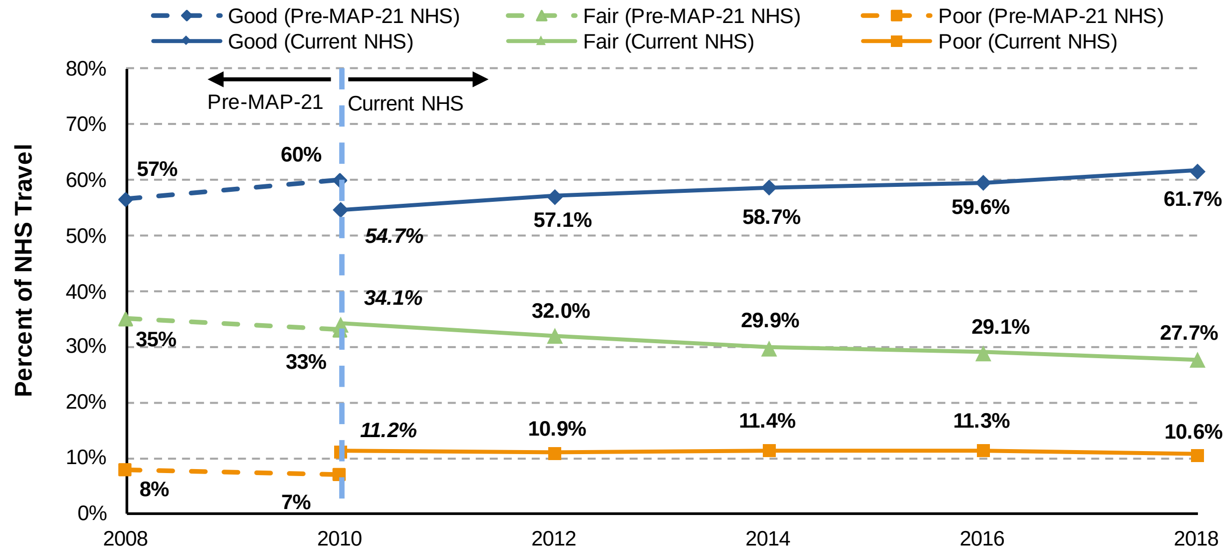
The Percentage of Interstate Pavements in Good or Fair Condition measure now serves as an indicator of trends for pavements on the Interstate System and replaces the previous indicator, Percentage of Vehicle Miles Traveled on the National Highway System in Good Condition. This new metric is based on a classification system of good, fair, and poor. MAP-21 expanded the definition 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 compared with the routes that were already defined as part of the NHS.

KEY TAKEAWAY

The share of VMT on NHS pavements with good ride quality rose from 57.0 percent in 2008 to 61.7 percent in 2018. 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 of VMT on pavements with good ride quality rose from 57 percent in 2008 to 60 percent in 2010 based on the pre-expansion NHS, and from an estimated 54.7 percent in 2010 to 61.7 percent in 2018 based on the post-expansion 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 2008 to 60 percent in 2010 based on the pre-expansion definition of the NHS, and from an estimated 54.7 percent in 2010 to 61.7 percent in 2018 based on the post-expansion NHS. From 2008 to 2010, the share of VMT on NHS pavements with poor ride quality decreased from 8 percent to 7 percent; this share decreased from an estimated 11.2 percent in 2010 to 10.6 percent in 2018.

Exhibit 6-8: National Highway System Pavement Ride Quality, Weighted by VMT, 2008–2018



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.

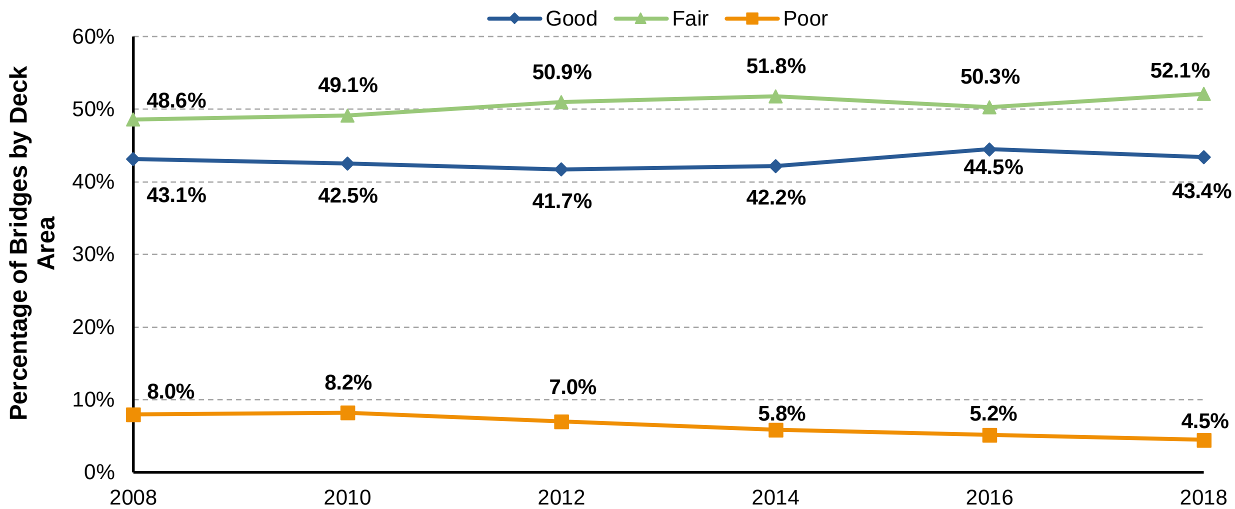
Source: Highway Performance Monitoring System.

Exhibit 6-9 shows an improved performance of bridges on the NHS from 2008 through 2018. The share of total deck area on bridges rated as poor declined from 8.0 percent in 2008 to 4.5 percent in 2018. The deck area on bridges in good condition increased slightly from 43.1 percent in 2008 to 43.4 percent in 2018; the share of deck area on bridges classified as fair (i.e., not good or poor) increased over this period from 48.6 percent in 2008 to 52.1 percent in 2018.

KEY TAKEAWAY

The share of Federal-aid highway pavements with “good” ride quality improved during the 2008–2018 period, as measured on both a VMT-weighted basis (rising from 46.4 percent to 53.0 percent) and a mileage basis (rising from 40.7 percent to 47.2 percent).

Exhibit 6-9: National Highway System Bridge Condition Ratings, Weighted by Deck Area, 2008–2018



Note: Odd-numbered years are omitted.

Source: National Bridge Inventory.

Federal-aid Highways Pavement Ride Quality Trends

Exhibit 6-10 details pavement ride quality on Federal-aid highways. The share of pavement mileage with good ride quality increased from 40.7 percent in 2008 to 47.2 percent in 2018. During the same period, the share of VMT on Federal-aid highways with good ride quality increased from 46.4 percent to 53.0 percent.

Exhibit 6-10: Pavement Ride Quality on Federal-aid Highways, 2008–2018

Weighting	Rating	2008	2010	2012	2014	2016	2018
Mileage	Good	40.7%	35.1%	36.4%	38.4%	40.2%	47.2%
	Fair	43.5%	44.9%	43.9%	39.4%	37.8%	30.2%
	Poor	15.8%	20.0%	19.7%	22.2%	22.0%	22.6%
Lane Miles	Good	40.6%	36.4%	35.6%	37.0%	38.2%	43.9%
	Fair	39.6%	48.7%	48.3%	46.7%	44.4%	37.6%
	Poor	19.8%	14.9%	16.1%	16.3%	17.4%	18.5%
VMT	Good	46.4%	50.6%	44.9%	47.0%	48.9%	53.0%
	Fair	39.0%	31.4%	38.4%	35.7%	34.0%	31.8%
	Poor	14.6%	18.0%	16.7%	17.3%	17.1%	15.2%

Note: Due to changes in data reporting instructions, data for 2010 and beyond are not fully comparable to data for 2008.
Source: Highway Performance Monitoring System.

From 2008 to 2018, the share of miles with pavement ride quality classified as poor worsened, increasing from 15.8 percent to 22.6 percent; over the same period, the share of Federal-aid highway VMT on pavements with poor ride quality increased much more slowly from 14.6 percent to 15.2 percent. However, when ride quality is analyzed by lane miles, the share of lane miles of poor pavement ride quality decreased from 19.8 percent in 2008 to 18.5 percent in 2018. The implication of these divergent findings is that pavement investment is likely being directed to parts of the system that are wider and serve the most travelers, but that some less-heavily traveled parts of the system are lagging behind.

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 6-11 shows that, based on unweighted bridge counts, the share of bridges rated as good fell from 47.8 percent in 2008 to 46.0 percent in 2018. The comparable shares weighted by deck area decreased slightly from 45.8 percent in 2008 to 45.3 percent in 2018. The shares by bridge traffic on good bridges increased from 44.7 percent in 2008 to 46.4 percent in 2018.

The share of bridges classified as poor dropped from 10.1 percent in 2008 to 7.6 percent in 2018. The share of bridges weighted by deck area rated as poor was lower (8.8 percent in 2008, dropping to 5.4 percent in 2018), suggesting that larger bridges are, on average, in better condition than smaller bridges. The share of bridges weighted by ADT rated as poor was even lower (7.0 percent in 2008, decreasing to 3.8 percent in 2018), suggesting that well-traveled bridges are in better shape on average than less traveled ones.

KEY TAKEAWAY

The share of Federal-aid highway pavements with "poor" ride quality worsened more significantly during the 2008–2018 period, measured on a mileage basis (rising from 15.8 percent to 22.6 percent) than on a VMT-weighted basis (rising from 14.6 percent to 15.2 percent). Weighted by lane miles, the share of pavements with poor ride quality improved, decreasing from 19.8 to 18.5 over this period. This divergence may be due to States focusing improvements on major roads that are more heavily traveled.

Exhibit 6-11: Systemwide Bridge Conditions, 2008–2018

Rating	Weighted By	2008	2010	2012	2014	2016	2018
Count	Total Bridges	600,536	604,116	607,121	610,340	614,277	616,096
	Bridges in Good Condition	287,317	286,534	287,194	287,701	291,412	283,316
	Bridges in Fair Condition	252,217	258,277	262,878	269,734	274,306	285,676
	Bridges in Poor Condition	61,002	59,305	57,049	52,905	48,559	47,054
Percent Good	By Bridge Count	47.8%	47.4%	47.3%	47.1%	47.4%	46.0%
	Weighted by Deck Area	45.8%	45.2%	44.7%	44.7%	46.5%	45.3%
	Weighted by ADT	44.7%	44.4%	44.0%	44.5%	48.1%	46.4%
Percent Fair	By Bridge Count	41.9%	42.7%	43.3%	44.2%	44.6%	46.4%
	Weighted by Deck Area	45.3%	46.0%	47.3%	48.3%	47.6%	49.2%
	Weighted by ADT	48.2%	48.9%	50.2%	50.6%	47.9%	49.8%
Percent Poor	By Bridge Count	10.1%	9.8%	9.4%	8.7%	7.9%	7.6%
	Weighted by Deck Area	8.8%	8.7%	7.8%	6.7%	5.9%	5.4%
	Weighted by ADT	7.1%	7.0%	6.5%	5.7%	3.9%	3.8%

Source: National Bridge Inventory.

Pavement and Bridge Condition Trends by Functional Class

Changes in HPMS reporting procedures in 2009 make identifying trends over the full 10-year period shown in *Exhibit 6-12* and *Exhibit 6-13* challenging, but it is possible to draw some significant conclusions from the data. Rural Interstates have the best ride quality of all functional systems, with 84.7 percent of VMT on pavements with good ride quality in 2018, up from 79.0 percent in 2008. The share of urban Interstate System VMT on pavements with good ride quality from 2008 to 2018 rose sharply from 55.7 percent to 68.4 percent.

KEY TAKEAWAY

Weighted by deck area, the share of bridges classified as good declined slightly, from 45.8 percent in 2008 to 45.3 percent in 2018. The deck area-weighted share of good NHS bridges improved from 43.1 percent to 43.4 percent over this period.

Pavements in rural areas are generally better than those in urban areas. The share of Rural Arterial and Major Collector VMT on pavements with good ride quality decreased from 62.5 percent in 2008 to 60.9 percent in 2018, whereas the comparable share of Urban Arterial and Collector VMT rose from

38.9 percent to 45.8 percent over the same period. 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 6-12 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 2018 ranged from 84.7 percent for Rural Interstates to 45.3 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 2018 ranged from 68.4 percent for Urban Interstates to 15.9 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 2018. 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.

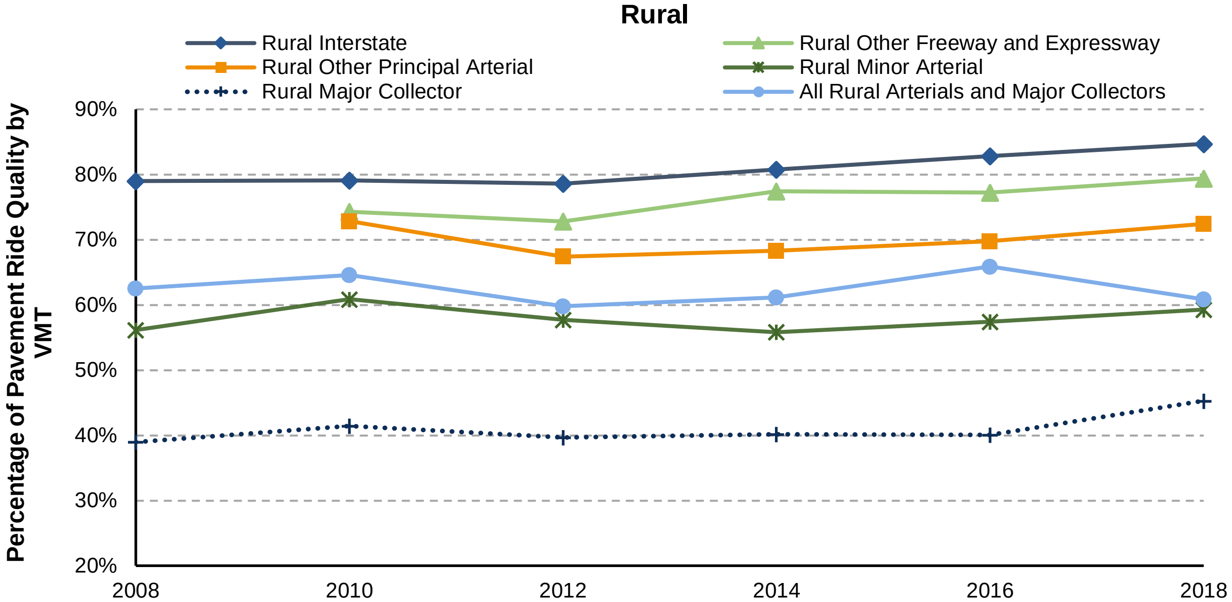
Exhibit 6-13 illustrates the share of pavements with poor ride quality by functional class. In 2018, Urban Major Collectors had the highest percentage of VMT on pavements with poor ride at 40.9 percent, up from 28.0 percent for Urban Major Collectors in 2008. Rural Other Freeway and Expressway had the lowest VMT-weighted share of pavements with poor ride quality in 2008 at 2.4 percent, which decreased slightly to 2.3 percent by 2018. The VMT-weighted share of VMT on all Rural Arterials and Major Collectors combined decreased from 5.2 percent in 2008 to 4.2 percent in 2018; the comparable share for All Urban Arterials and Collectors rose slightly from 19.0 percent to 19.3 percent over this period.

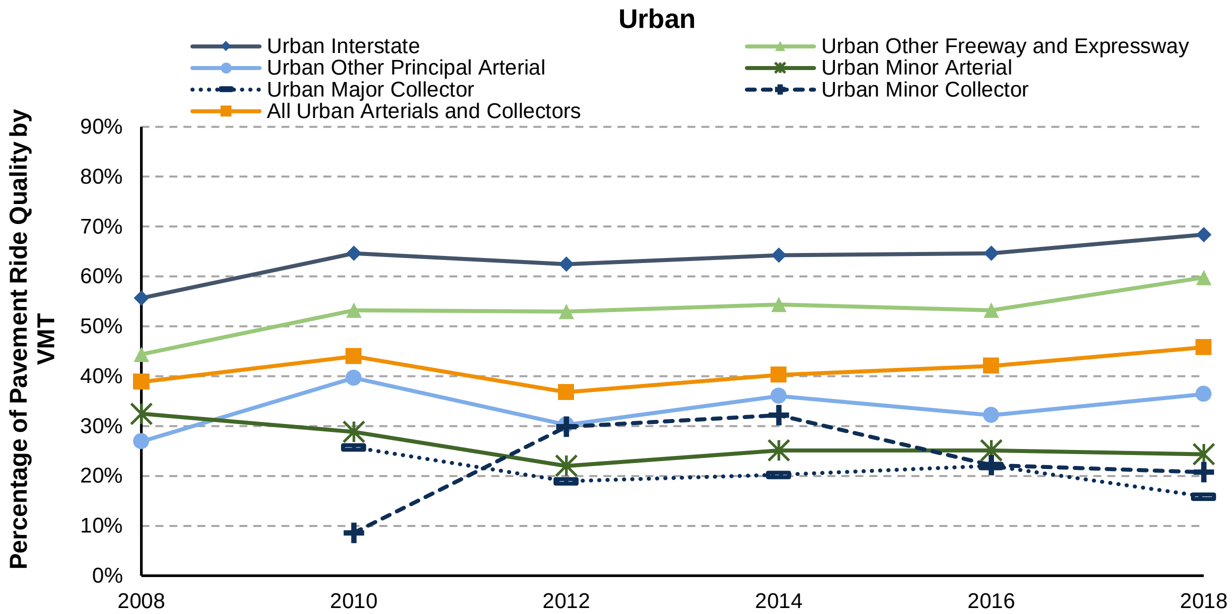
KEY TAKEAWAY

Based on unweighted bridge count, the share of bridges classified as poor has improved, dropping from 10.1 percent in 2008 to 7.6 percent in 2018. The share of bridges classified as good rose from 46.0 percent to 47.8 percent during this decade.

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 11.7 percent in 2008 to 14.9 percent in 2018. 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 34.2 percent in 2018, placing it at less than Urban Major Collectors at 40.9 percent. Among the Urban functional classes, Urban Interstate had the lowest share of VMT on pavements with poor ride quality, falling from 8.1 percent in 2008 to 5.8 percent in 2018.

Exhibit 6-12: Pavement Ride Quality Rated Good by Functional Class, Weighted by VMT, 2008–2018

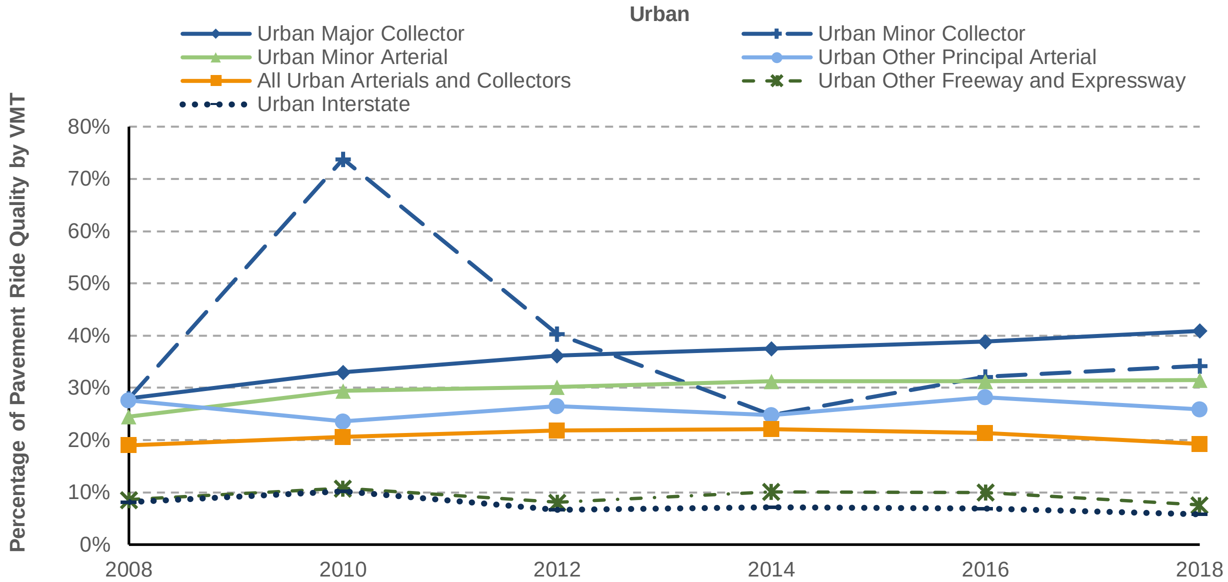


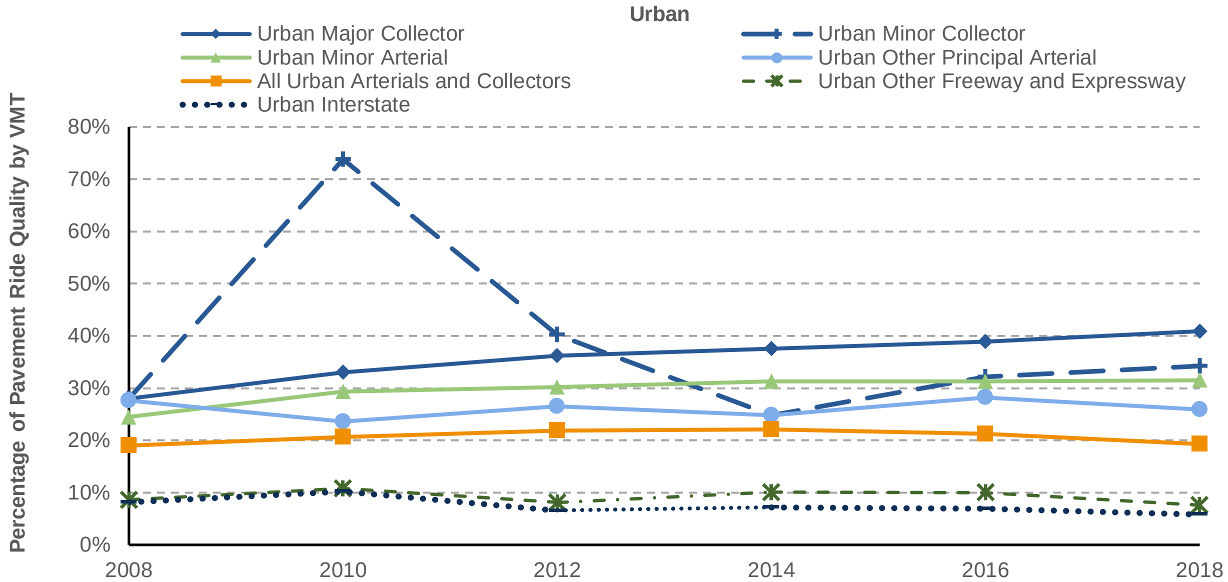


Note: VMT is vehicle miles traveled. Odd-numbered year data are omitted. Prior to 2010, the Rural Other Freeway and Expressway class was included as part of Rural Other Principal Arterial; the Urban Major Collector and Minor Collector classes were combined into a single category called Urban Collector.

Source: Highway Performance Monitoring System.

Exhibit 6-13: Pavement Ride Quality Rated Poor by Functional Class, Weighted by VMT, 2008–2018





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 6-14 shows that the highest share of bridge deck area rated as good condition was on Urban Other Freeways and Expressways, which increased from 48.8 percent in 2008 to 53.1 percent in 2018. The lowest share of rural bridge deck area rated as good condition in 2018 was 39.8 percent for Rural Interstates, down from 40.1 percent in 2008. The lowest share of urban bridge deck area in good condition in 2018 was 37.8 percent for Urban Interstates.

Exhibit 6-14: Bridges Rated Good, Weighted by Deck Area, by Functional Class, 2008–2018

Area	Functional Class	Percent Good Condition					
		2008	2010	2012	2014	2016	2018
Rural	Interstate	40.1%	39.3%	37.1%	39.0%	41.0%	39.8%
	Other Principal Arterial	53.9%	53.4%	53.7%	53.1%	52.6%	51.0%
	Minor Arterial	47.7%	46.9%	45.7%	46.1%	49.1%	47.1%
	Major Collector	48.1%	47.5%	47.9%	47.4%	47.2%	46.5%
	Minor Collector	49.4%	49.0%	49.0%	48.4%	48.4%	46.8%
	Local	54.0%	51.5%	51.5%	52.5%	52.4%	51.8%
	Subtotal Rural	**46.8%**	**46.1%**	**45.7%**	**45.8%**	**47.1%**	**47.6%**
Urban	Interstate	36.5%	36.3%	34.9%	35.6%	38.2%	37.8%
	Other Principal Arterial	48.8%	48.4%	49.3%	48.9%	54.8%	53.1%
	Minor Arterial	43.0%	42.8%	41.8%	41.3%	43.0%	41.6%
	Major Collector	44.6%	45.0%	44.0%	42.7%	45.0%	43.5%
	Minor Collector	47.9%	48.9%	47.9%	48.2%	49.6%	47.4%
	Local	51.0%	49.9%	50.2%	50.7%	50.7%	49.5%
	Subtotal Urban	**42.9%**	**42.8%**	**42.1%**	**42.1%**	**44.8%**	**43.7%**
Total Bridges Rated Good		**45.8%**	**45.2%**	**44.7%**	**44.7%**	**46.5%**	**45.3%**

Source: National Bridge Inventory. Source: National Bridge Inventory.

The overall percentages of rural and urban bridge deck area classified as good were 47.6 percent and 43.7 percent respectively. Overall, rural bridges have been consistently in better condition, when rated by deck area, since 2008. Urban bridge deck area in good condition increased from 42.9 percent in 2008 to 43.7 percent in 2018.

Exhibit 6-15 shows share of bridge deck area classified as poor, by functional class. As was the case for pavement ride quality in *Exhibit 6-13*, a clear pattern is discernable with the higher functional class generally having the lowest share of bridges rated as poor. The exceptions are that the share for Rural Other Principal Arterial (6.0 percent in 2008, dropping to 2.7 percent in 2018) has fallen below that for Rural Interstates (7.2 percent in 2008, dropping to 3.0 percent in 2018), and the share for Urban Other Freeway and Expressway (7.8 percent in 2008, dropping to 3.6 percent in 2018) has remained below that for Urban Interstates (8.9 percent in 2008, decreasing to 5.0 percent in 2018).

The share of bridge deck area rated as poor was generally lower in rural areas, decreasing from 8.5 percent in 2008 to 5.6 percent in 2018, compared with urban areas (9.0 percent in 2008, dropping to 6.0 percent in 2018). The exception was 2014, when 6.9 percent of rural bridge deck area was rated as poor versus 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. In rural areas the decrease was from 8.5 percent in 2008 to 5.6 percent in 2018, whereas in urban areas the percentage of bridge deck area rated as poor decreased from 9.0 percent in 2008 to 5.4 percent in 2018. Among all functional classes, the highest share of bridge deck area rated in poor condition was for Rural Local, although this was reduced from 10.6 percent in 2008 to 8.4 percent in 2018. Rural Other Principal Arterials had the lowest share of bridge deck area in poor condition in 2018 at 2.7 percent.

KEY TAKEAWAY

Weighted by deck area, the share of bridges classified as poor improved, declining from 8.8 percent in 2008 to 5.4 percent in 2018. The deck area-weighted share of poor NHS bridges dropped from 8.0 percent to 4.5 percent during the period.

Exhibit 6-15: Bridges Rated Poor, Weighted by Deck Area, by Functional Class, 2008–2018

Area	Functional Class	Percent Poor Condition					
		2008	2010	2012	2014	2016	2018
Rural	Interstate	7.2%	7.6%	5.9%	5.1%	3.6%	3.0%
	Other Principal Arterial	6.0%	5.6%	4.2%	3.6%	3.1%	2.7%
	Minor Arterial	9.2%	8.6%	7.9%	7.5%	6.0%	5.6%
	Major Collector	9.1%	8.9%	8.2%	8.0%	7.2%	7.0%
	Minor Collector	8.4%	8.3%	7.9%	7.5%	7.1%	6.8%
	Local	10.6%	10.2%	10.0%	9.8%	8.9%	8.4%
	Subtotal Rural	**8.5%**	**8.2%**	**7.4%**	**6.9%**	**5.9%**	**5.6%**
Urban	Interstate	8.9%	9.5%	7.8%	6.2%	6.1%	5.0%
	Other Freeway and Expressway	7.8%	7.5%	7.4%	5.0%	3.5%	3.6%
	Other Principal Arterial	10.4%	10.0%	9.3%	7.8%	6.9%	6.2%
	Minor Arterial	9.7%	9.0%	8.4%	7.9%	7.1%	6.8%
	Collector	9.3%	8.6%	7.9%	7.1%	6.0%	6.1%
	Local	7.8%	8.1%	7.7%	7.0%	6.6%	6.0%
	Subtotal Urban	**9.0%**	**9.0%**	**8.1%**	**6.6%**	**6.0%**	**5.4%**
Total Bridges Rated Poor		**8.8%**	**8.7%**	**7.8%**	**6.7%**	**5.9%**	5.4%

Source: National Bridge Inventory.

Pavement and Bridge Conditions by Owner

Exhibit 6-16 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 2018, 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 6-16: Federal-aid Highway Pavement Ride Quality by Owner, Weighted by Lane Miles, 2018

Category[1]	Federal	State Highway Agencies	Other
Percentage of Lane Miles Owned	**0.2%**	**89.5%**	**10.3%**
Classified as Good	72.7%	65.0%	26.5%
Classified as Fair	21.5%	28.1%	35.4%
Classified as Poor	5.9%	6.9%	38.0%

[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 2018; the comparable share for State highway agency-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 highway agency-owned Federal-aid highway lane miles had poor ride quality in 2018; 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 6-17*, federally owned bridges had a higher share rated as good (46.9 percent) than did bridges owned by local governments (46.7 percent) or those owned by States (45.2 percent).

Exhibit 6-17: Bridge Conditions by Owner, 2018

Category	Federal	State	Local	Private/Other[1]	Total
Percentages					
Percentage Owned	1.8%	48.2%	49.8%	0.2%	100.0%
Classified as Good	46.9%	45.2%	46.7%	33.2%	46.0%
Classified as Fair	45.4%	49.6%	43.3%	43.4%	46.4%
Classified as Poor	7.7%	5.2%	10.0%	23.4%	7.6%

[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 reported to the NBI.

Source: National Bridge Inventory.

Local governments had a higher share of bridges rated as poor (10.0 percent) than at the State (5.2 percent poor) or Federal (7.7 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 as good (33.2 percent) and higher shares rated as poor (23.4 percent) than do bridges owned by Federal, State, or local governments.

Bridge and Tunnel Conditions by Age

The age of a structure is just one indicator of its serviceability, or condition under which a structure 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.

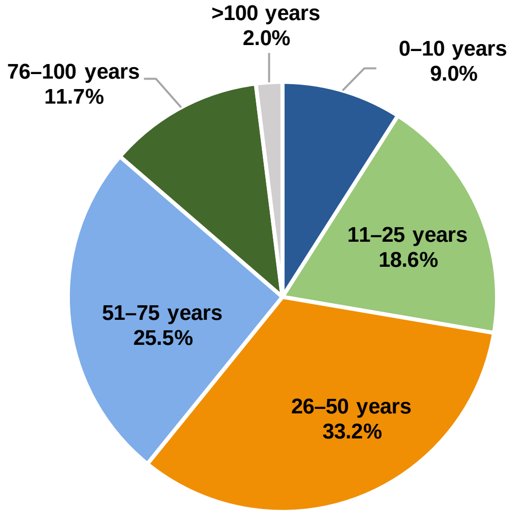
As an example, two bridges built at the same time using the same design standards and in the same climate can have very different serviceability levels. The first bridge might have had increased heavy truck traffic; lack of maintenance of the deck, superstructure, or the substructure; or lack of rehabilitation work. The second bridge 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 bridge would have a low serviceability level, whereas the second bridge would have a high serviceability level.

Bridge Conditions by Age

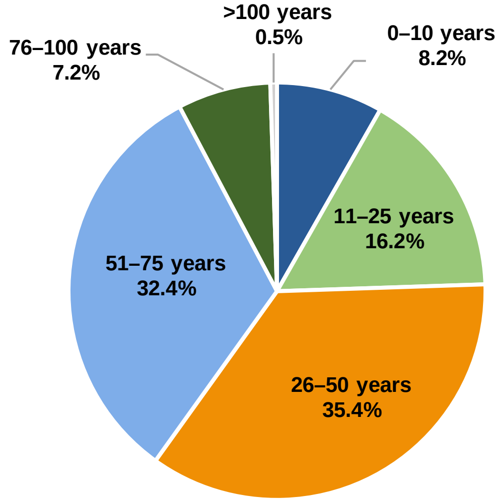
Exhibit 6-18 identifies the age composition of all highway bridges in the Nation. As of 2018, approximately 33.2 percent of the Nation's bridges were between 26 and 50 years old. For NHS bridges, 35.4 percent were in this age range, whereas 40.2 percent of the Interstate bridges fell into this age range. Approximately 25.5 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 32.4 percent, 7.2 percent, and 0.5 percent, respectively. Interstate bridges in these groups are 42.4 percent, 0.8 percent, and 0.03 percent, respectively.

Exhibit 6-18: Bridges by Age, 2018

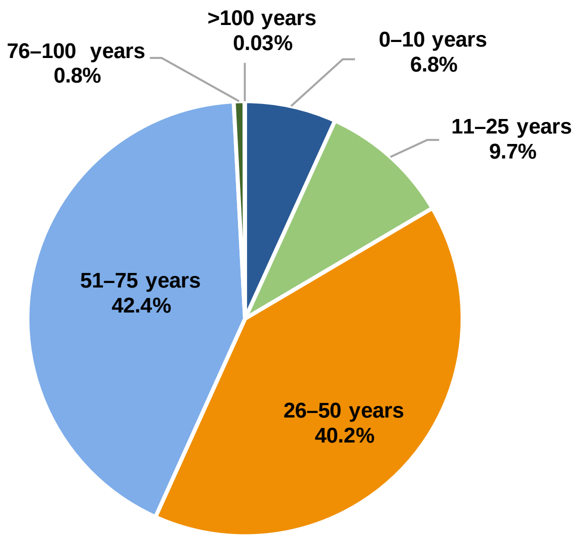
All Bridges



National Highway System Bridges



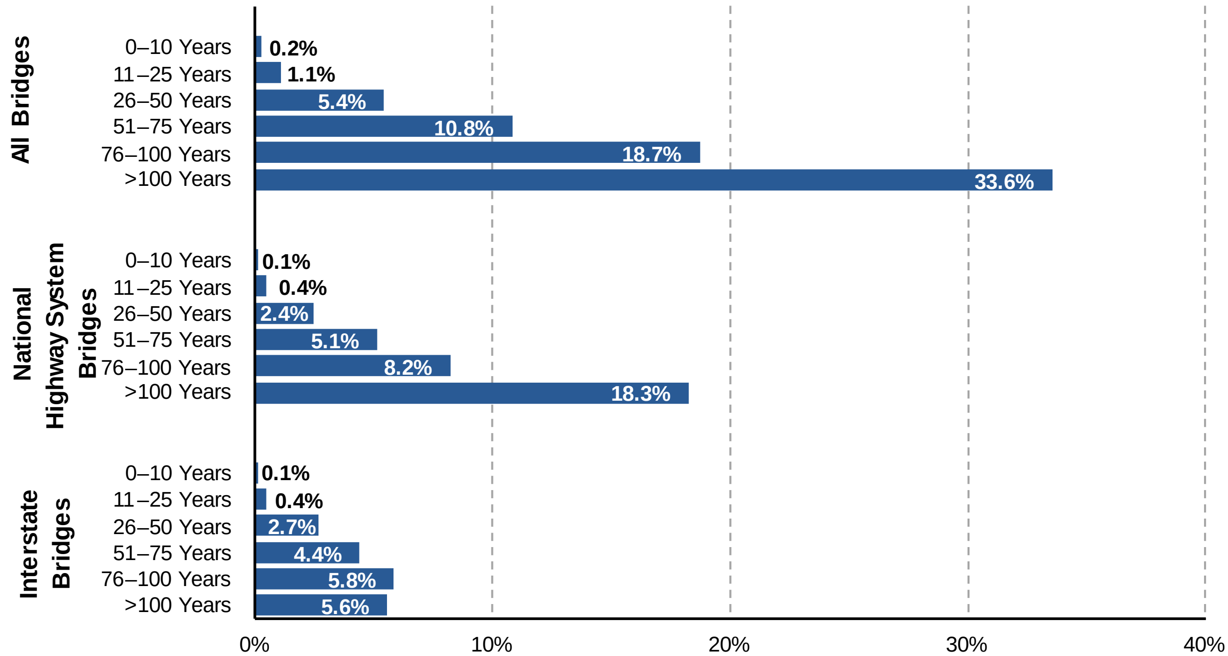
Interstate Bridges



Source: National Bridge Inventory.

Higher percentages of older bridges tend to have a higher rate/percentage of being classified as poor. *Exhibit 6-19* identifies the distribution of poor condition bridges within the age ranges presented in *Exhibit 6-18*. The percentage of bridges classified as poor generally tends to rise as bridges age. Although only 5.4 percent of bridges in the 26-to-50-year age group are rated as poor, the percentage is 10.8 percent for bridges 51 to 75 years of age, 18.7 percent for bridges 76 to 100 years of age, and 33.6 percent for bridges over 100 years old. Similar patterns are evident in the data for NHS and Interstate System bridges, but the overall percentage of poor bridges for these systems is lower than for the national bridge population.

Exhibit 6-19: Bridges Rated Poor by Age, 2018



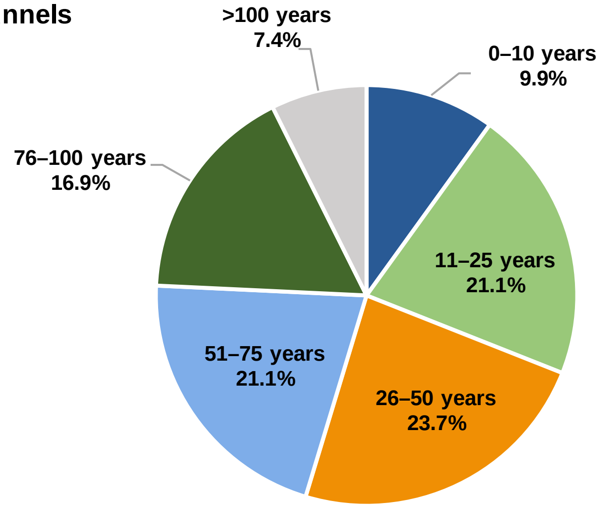
Source: National Bridge Inventory.

Tunnels by Age

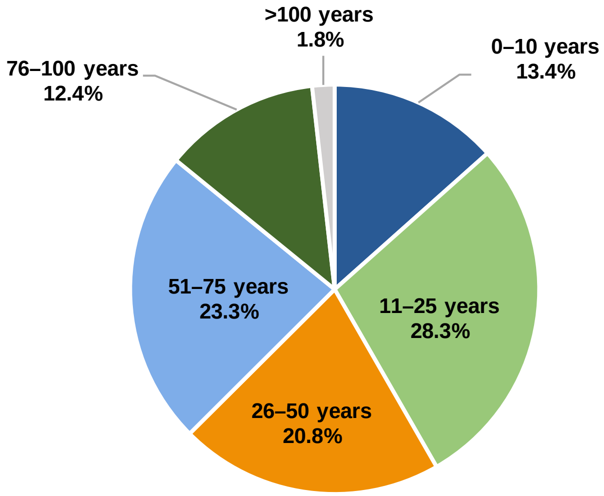
Exhibit 6-20 identifies the age composition of all highway tunnels in the Nation. As of 2018, approximately 23.7 percent of the Nation's tunnels were between 26 and 50 years old. For NHS tunnels, 20.8 percent were in this age range, whereas 30.1 percent of the Interstate tunnels fell into this age range. Approximately 21.1 percent of all tunnels are 51 years old to 75 years old, 16.9 percent are 76 to 100 years old, and 7.4 percent are more than 100 years old. The percentages of NHS tunnels in these groups are 23.3 percent, 12.4 percent, and 1.8 percent, respectively. The percentages of Interstate System tunnels in these groups are 18.4 percent and 6.6 percent, and 0.0 percent, respectively.

Exhibit 6-20: Tunnels by Age, 2018

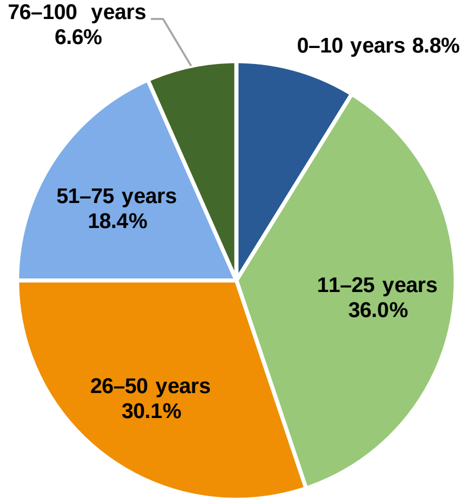
All Tunnels



National Highway System Tunnels



Interstate Tunnels



Source: National Tunnel Inventory.

Innovative Strategies

Targeted Overlay Pavement Solutions (TOPS)

Approximately half of all infrastructure dollars are invested in pavements, and more than half of that investment is in overlays. An overlay is any operation that consists of laying either Portland Cement Concrete (PCC) or Hot Mix Asphalt (HMA) over an existing pavement structure. By enhancing overlay performance, State and local highway agencies can maximize this investment and help ensure safer, longer-lasting roadways for the traveling public. Targeted Overlay Pavement Solutions (TOPS) are a collection of strategies using overlays on high-priority or high-maintenance locations such as primary Interstate pavements, intersections, bus lanes, ramps, and curves. TOPS integrate innovative overlay procedures into practices that can improve performance, lessen traffic impacts, and reduce the cost of pavement ownership.

Many of the pavements in the Nation's highway system have reached or are approaching the end of their design life. These roadways still carry daily traffic that often far exceeds their initial design criteria. Overlays are now available for both asphalt and concrete pavements that enable agencies to provide long-life performance under a wide range of traffic, environmental, and existing pavement conditions.

Concrete overlays now benefit from performance-engineered mixtures, including thinner-bonded and unbonded overlays with fiber reinforcement, interlayer materials, and new design procedures that improve durability and performance. Asphalt overlay mixtures have also advanced significantly with the use of stone-matrix asphalt (SMA), polymer-modified asphalt (PMA), and other materials and agents that reduce rutting, increase cracking resistance, and extend pavement life.

Several benefits are associated with the implementation of TOPS. Thousands of miles of rural and urban pavements need structural enhancement and improved surface characteristics, such as smoothness, friction, and noise. The use of TOPS can improve the pavement conditions of these highways significantly in a relatively short time, while also improving safety. Timely and well-designed overlay applications are cost-effective because less subsurface work is required. In urban areas, impacts to utilities and pedestrian facilities are minimized. Applying overlays to high-maintenance areas such as intersections, bus lanes, ramps, and curved alignments can pay immediate dividends in terms of reduced maintenance needs, fewer work zones, and improved safety.

Recent improvements to design methods, interlayer technology, slab geometry, and concrete mixtures have broadened concrete overlay surface treatment applicability, reliability, sustainability, and cost-effectiveness. A joint effort by Georgia, Iowa, Kansas, Michigan, Minnesota, Missouri, North Carolina, and Oklahoma resulted in the development of an improved design procedure for jointed unbonded concrete overlays on either existing concrete or composite pavements.

For asphalt overlays, several State DOTs have adopted SMA due to its increased service life and performance. The Maryland, Alabama, and Utah DOTs each used over 1 million tons of SMA during a 5-year period. DOTs in Florida, Georgia, New Jersey, New York City, Tennessee, and Virginia found highly modified asphalt in thin overlays is more resistant to reflective cracking. DOTs in Alabama and Oklahoma report that it has increased pavement life by two to four times.

UPHC for Bridge Preservation and Repair

Ultra-high performance concrete (UHPC) offers enhanced durability and improved life-cycle cost performance for bridge preservation and repair.

Keeping bridges in a state of good repair is essential to keeping the transportation system operating efficiently. Agencies at all levels can deploy UHPC for bridge preservation and repair to maintain or improve bridge conditions cost-effectively.

UHPC is a fiber-reinforced, cementitious composite material with mechanical and durability properties that far exceed those of conventional concrete materials. These qualities have made it popular for bridge construction, especially for field-cast connections between prefabricated bridge elements. Bridge infrastructure preservation and repair (P&R) is a new application of UHPC that offers enhanced performance and improved life-cycle cost over traditional methods. Because of its strength and durability, UHPC can be an optimum solution for some repairs. UHPC can be used in situations that normally use conventional concrete or repair mortars, and in some cases those that use structural steel. Some UHPC mixes gain strength rapidly, so bridges could be opened to traffic 24 hours after completing the necessary repairs. Additionally, UHPC repairs are long-lasting and resilient, requiring less maintenance and fewer follow-up repairs than conventional methods. In some cases, they can outlive and outperform their conventional counterparts: UHPC repairs could be the strongest and most durable part of the bridge.

Uses of UPHC include Preservation and Repair (P&R) bridge deck overlays, girder end repairs, expansion joint repairs, Performance-Based Engineering construction joint repairs, and column or pile jacketing. Some applications, such as bridge deck overlays and replacing expansion joints with UHPC link slabs, can extend the service life of bridges well beyond that of traditional repair strategies and are more cost-efficient than bridge replacement.

UHPC can generally be used anywhere other types of concrete would be used, and due to its strength and durability it can be the optimum material for many applications. UHPC-based repairs are long-lasting and require less maintenance and fewer follow-up repairs. The repairs can outlive and outperform their conventional counterparts, resulting in life-cycle cost savings. Use of UHPC for bridge deck overlays and link slabs can extend the service life of bridges well beyond that of traditional P&R strategies.

Examples of UPHC deployments as of 2019 include:

- Bridge Deck Overlays: Iowa DOT, Delaware DOT, New York State DOT.
- Link Slabs: New York State DOT, Maryland DOT, New Jersey DOT.
- Beam End or Girder Repair: Connecticut DOT, Rhode Island DOT, Florida DOT, St. Clair County (Michigan) Road Commission.

To see more examples of UHPC deployments, visit the interactive map on the Turner-Fairbank Highway Research Center website. (https://highways.dot.gov/research/structures/ultra-high-performance-concrete/deployments)

Resilience and Transportation Planning

The Nation's transportation system is essential to the economic prosperity and quality of life of communities. To play this critical role, infrastructure must be secure and resilient to a myriad of hazards. Resilience is the ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions. The Fixing America's Surface Transportation (FAST) Act, signed into law in December 2015, requires agencies to take resilience into consideration during transportation planning processes.

Following passage of the FAST Act, FHWA and the Federal Transit Administration updated the metropolitan and statewide transportation planning regulations to reflect these requirements. The transportation planning rule includes:

- A planning factor for States and metropolitan planning organizations (MPOs) to consider and implement improving the resilience and reliability of the transportation system (23 CFR 450.206(a)(9) and 23 CFR 450.306(b)(9)).
- A recommendation for MPOs to consult with agencies and officials responsible for natural disaster risk reduction when developing a metropolitan transportation plan and the transportation improvement program (23 CFR 450.316(b)).
- A requirement that the metropolitan transportation plan assess capital investment and other strategies that reduce the vulnerability of the existing transportation infrastructure to natural disasters (23 CFR 450.324(g)(7)).

The impacts of a changing climate and extreme weather events are among the hazards that threaten our Nation's transportation systems. Flooding, extreme heat, and severe storm events endanger the long-term investments that Federal, State, and local governments have made in transportation infrastructure. Changes in climate have intensified the magnitude, duration, and frequency of these events for many regions in the United States. As a result, transportation agencies across the country are assessing ways to protect, preserve, and improve their assets in the face of climate change and extreme weather events.

State DOTs and MPOs across the country are conducting vulnerability assessments to understand the vulnerability of their transportation systems to the impacts of climate change and extreme weather. The transportation planning process provides a key opportunity for transportation agencies to proactively identify projects and strategies to address the vulnerabilities identified through the assessments and to promote resilience at the systems level, thereby meeting the FAST Act resilience requirements outlined earlier. At each stage of the transportation planning process, agencies have opportunities to integrate resilience.

Tampa, Florida, provides an example of integrating resilience into long-range transportation plans. The Hillsborough MPO's long-range transportation plan includes an objective to increase the security and resilience of the multimodal transportation system, with an associated performance measure on reducing the recovery time and economic impact from a major storm. The plan also outlines an investment plan needed to achieve the objective of the vulnerability reduction program.

Information on resilience can be used to identify strategies and investment scenarios during development of Statewide and metropolitan long-range transportation plans. For example, the Capital Area Metropolitan Planning Organization (CAMPO) in Austin, Texas integrated the results of its vulnerability assessment into its 2040 Regional Transportation Plan. The plan summarizes the climate-related risks to the region's transportation system and identifies potential measures that the CAMPO region can implement to proactively increase the transportation system's climate resilience. Priority action items in the plan include increasing extreme weather resilience by evaluating the adequacy of potential wildfire and flood evacuation routes, identifying opportunities to increase system redundancy and alternate routes, and advancing best practices in addressing drought-related impacts on the transportation system.

The use of resilience metrics can guide the selection and prioritization of future projects. The Maryland Department of Transportation's State Highway Administration (SHA) is using the results of its vulnerability assessment to delineate coastal locations vulnerable to flooding. These data are intended to help the agency screen new project plans and designs for resilience to future climate impacts. The SHA will use the screening mechanism to inform its Highway Needs Inventory, a planning document that lists major capital construction projects.

Resilience can also be incorporated in the design and engineering phase of a project. The Massachusetts Department of Transportation developed the Highway Project Intake app, a web-based GIS application designed to improve agency coordination and expedite project delivery. It allows users to access more than 30 location-based transportation, safety, environmental, and vulnerability data layers, including an inventory of flood-prone areas. Project planners can use the tool to identify vulnerability issues and adaptation solutions early in the project planning process.

FHWA is developing resources to assist transportation agencies with integrating resilience into the transportation planning process. For more information, visit FHWA's Sustainability and Resilience website at http://www.fhwa.dot.gov/environment/sustainability/resilience/.

Promoting Resilient Operations for Transformative, Efficient, and Cost-Saving Transportation (PROTECT) Program

The PROTECT Program includes both formula funding distributed to States and competitive grants. The Infrastructure Investment and Jobs Act, Pub. L. 117-58 (Nov. 15, 2021), also known as the Bipartisan Infrastructure Law (BIL), established the PROTECT Program to help make surface transportation more resilient to natural hazards, including climate change, sea level rise, flooding, extreme weather events, and other natural disasters through support of:

- **Planning Activities** to develop a Resilience Improvement Plan: Resilience planning, predesign, design, or the development of data tools to simulate scenarios, including vulnerability assessments to assess the vulnerabilities of State surface transportation assets and community response strategies under current conditions and a range of potential future conditions, or evacuation planning and preparation;
- **Resilience Improvements** to improve the ability of an existing surface transportation asset to withstand one or more elements of a weather event or natural disaster, or to increase the resilience of surface transportation infrastructure from the impacts of changing conditions, such as sea level rise, flooding, wildfires, extreme weather events, and other natural disasters;
- **Community Resilience and Evacuation Routes** to strengthen and protect routes that are essential for providing and supporting evacuations caused by emergency events to ensure the ability of the evacuation route to provide safe passage during an evacuation and reduce the risk of damage to evacuation routes as a result of future emergency events; or
- **At-Risk Costal Infrastructure Activities** to strengthen, stabilize, harden, elevate, relocate or otherwise enhance the resilience of highway and non-rail infrastructure, including bridges, roads, and associated infrastructure, in order to improve transportation and public safety and to reduce costs by avoiding larger future maintenance or rebuilding costs.

For more information on BIL funded transportation programs, to include other programs in support of resiliency, visit https://www.fhwa.dot.gov/bipartisan-infrastructure-law/.

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.

The Federal Transit Administration (FTA) uses a numerical rating scale that ranges from 1 to 5 (see *Exhibit 6-21*) to describe the relative condition of transit assets. A rating of 4.8 to 5.0, or "excellent," indicates that the asset is in nearly new condition or lacks visible defects. The midpoint of the "marginal" rating (2.5) is the threshold below which the assets are considered 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.

SECTION SUMMARY

- The total replacement value of transit assets was $1,161 billion in 2018.
- The backlog in 2018 was $101 billion, comprising about 9 percent of all transit assets. Systems and stations accounted for 53 percent. Guideway elements accounted for only 16 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 2008, 11 percent of nonrail vehicles were not in SGR. In 2018, the share increased to 15 percent.
- The share of rail vehicles not in SGR increased from 4 percent in 2008 to 9 percent in 2018.
- The average fleet age of all buses was 7.1 years in 2018, up from 6.1 years in 2008.
- The average fleet age of rail vehicles increased from 20.1 years in 2008 to 24.4 years in 2018.

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 that would 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.

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 reference as part of ongoing oversight. In addition, each entity developing a TAM Plan must report annually to FTA's National Transit Database (NTD).

Exhibit 6-21: Definitions of Transit Asset Conditions

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

Source: Transit Economic Requirements Model (TERM).

FTA has estimated typical deterioration schedules for vehicles, maintenance facilities, stations, train control systems, electric power systems, and communication systems through special onsite engineering surveys. Transit vehicle conditions also reflect the most recent information on vehicle age, use, and level of maintenance from the NTD; age information for all other assets is collected through special surveys. The information used in this edition of the C&P Report is from 2018.

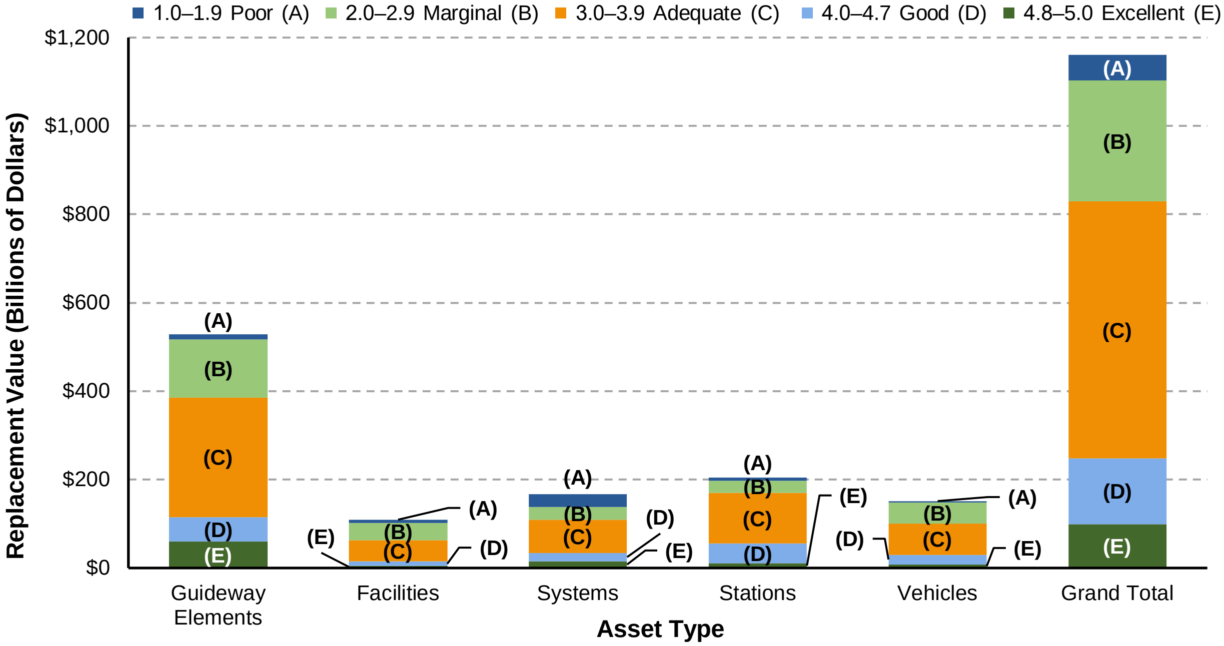
Average maintenance expenditures and major rehabilitation expenditures for vehicles are also available on a modal basis. When calculating conditions, FTA assumes that agency maintenance and rehabilitation expenditures for a particular mode are the same average value for all vehicles the agency operates 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 updated the deterioration schedules for guideway structures (including bridges and tunnels), facilities, buses, and some station types over the period from 2018 to 2019. The impact of these updates is reflected in 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 17 of the Nation's largest rail and fixed-route bus transit agencies to support analysis of nonvehicle needs. Because these data are not collected annually, it is not possible to provide accurate time-series analysis of nonvehicle assets. FTA is working to develop improved data in this area. Appendix C provides a more detailed discussion of TERM's data sources.

Exhibit 6-22 shows the distribution of asset conditions, by replacement value, across major asset categories for the entire U.S. transit industry. Condition estimates for assets are weighted by the replacement value of each asset. This weighting accounts for the fact that assets vary substantially in replacement value. For example, a $1 million railcar in poor condition is a much bigger problem than a $1,000 turnstile in similar condition. To illustrate the calculation involved, the cost-weighted average of a $100 asset in condition 2.0 and a $50 asset in condition 4.0 would be (100×2.0+50×4.0)/(100+50)=2.67. The unweighted average would be (2+4)/2=3.

Exhibit 6-22: Distribution of Asset Physical Conditions by Asset Type for All Modes, 2018



Note: In contrast to prior reports, this chart includes nonreplaceable assets; empirical decay curves for these asset types were added to TERM in 2018.

Sources: Transit Economic Requirements Model (TERM); National Transit Database.

The Replacement Value of U.S. Transit Assets

The total value of the transit infrastructure in the United States for 2018 was estimated at $1,161 billion in 2018 dollars, or nearly $1.2 trillion. The estimates for the individual components of this total, presented in *Exhibit 6-23*, are based on asset inventory information in TERM. They exclude the value of assets belonging to special service operators, which are agencies that provide services under the Seniors and Individuals with Disabilities Program (Sect. 5310), but which do not report to NTD. Rail assets totaled $979.9 billion, or 84 percent of all transit assets. Nonrail assets were estimated at $177.5 billion. Joint assets totaled $4 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).

Exhibit 6-23: Estimated Value of the Nation's Transit Assets, 2018

Transit Asset	Nonrail	Rail	Joint Assets	Total
Maintenance Facilities	$74.3	$33.7	$1.3	$109.3
Guideway Elements	$9.5	$518.7	$0.0	$528.3
Stations	$23.1	$181.7	$0.2	$204.9
Systems	$7.4	$157.6	$2.5	$167.6
Vehicles	$63.2	$88.2	$0.0	$151.3
Total: All Assets	**$177.5**	**$979.9**	**$4.0**	**$1,161.3**

Notes: Asset values are based on total estimated replacement value including planning, design, project management, acquisition and disposal.

Dollar values are in billions.

Source: Transit Economic Requirements Model (TERM).

Transit Road Vehicles (Urban and Rural Areas)

Bus vehicle age and condition are reported by vehicle type for 2008 to 2018 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 6 percent, from 7.0 to 7.4 years, from 2008 through 2018. Similarly, the average condition rating for all bus types (calculated as the weighted average of bus asset conditions, weighted by asset replacement value) remained relatively stable between 3.5 and 3.2, 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 11.8 percent in 2008 to 15.1 percent in 2018.

KEY TAKEAWAY

The average fleet age for buses was 7.4 years in 2018, up from 7.0 in 2008, but the percentage of vehicles below the replacement threshold increased from 11.8 percent in 2008 to 15.1 percent in 2018.

As shown in *Exhibit 6-24*, the Nation's overall transit road vehicle fleet grew from 2008 through 2018. The cutaway fleet more than doubled between 2008 and 2018, whereas articulated buses increased by 45 percent. Most other vehicle types decreased.

Exhibit 6-24: Transit Bus Fleet Count, Age, and Condition, 2008–2018

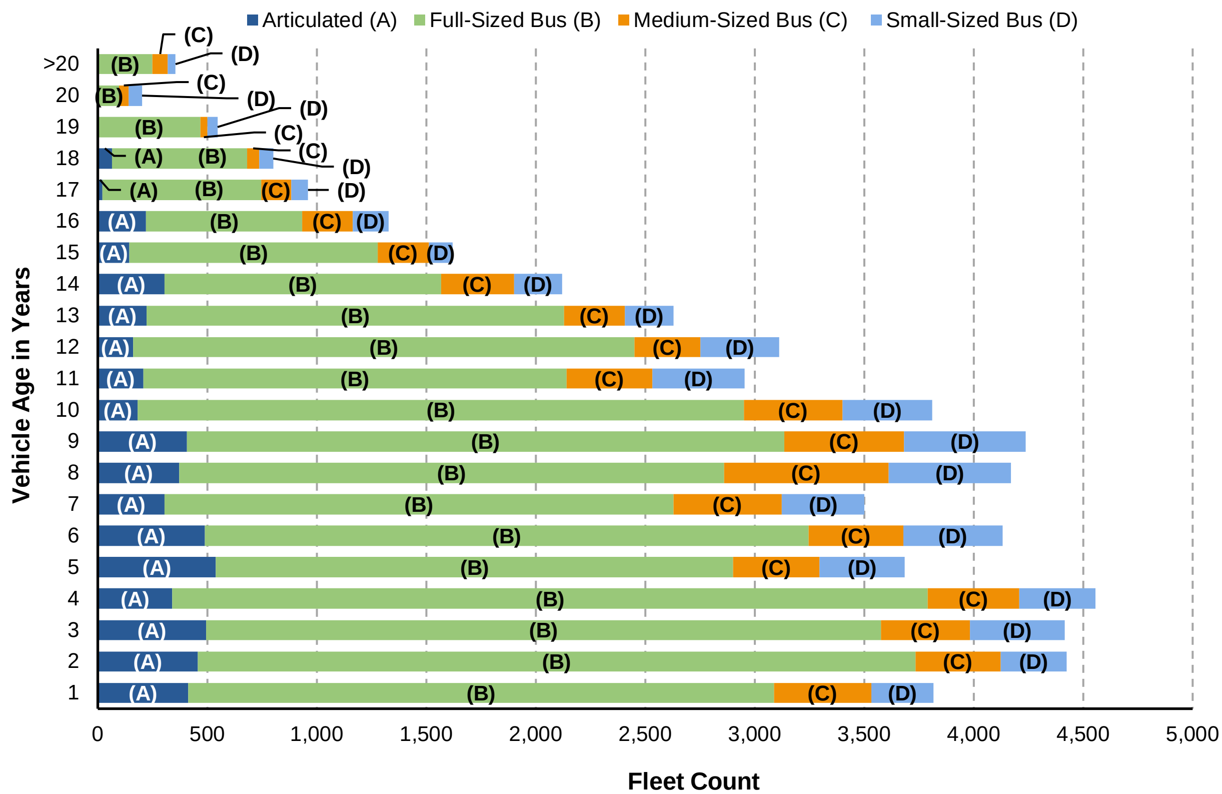
Kind of Bus	Fleet Count, Age, and Condition	2008	2010	2012	2014	2016	2018
Articulated Buses	Fleet Count	3,900	4,654	4,836	5,373	5,061	5,670
	Average Age (Years)	6.3	6.5	7.0	7.2	7.2	7.2
	Average Condition Rating	3.4	3.4	3.3	3.3	3.3	3.3
	Below Condition 2.5 (Percent)	3.6%	4.8%	17.0%	14.8%	18.3%	17.3%
Full-Size Buses	Fleet Count	45,999	45,783	45,314	45,717	42,447	40,754
	Average Age (Years)	7.9	7.8	8.0	8.2	8.4	8.5
	Average Condition Rating	3.4	3.4	3.4	3.4	3.3	3.3
	Below Condition 2.5 (Percent)	12.2%	4.8%	10.4%	15.8%	15.3%	11.1%
Medium-Size Buses	Fleet Count	7,577	8,169	7,615	7,753	7,495	7,168
	Average Age (Years)	8.3	7.9	7.4	7.6	8.0	8.5
	Average Condition Rating	3.7	3.8	3.9	3.9	3.8	3.7
	Below Condition 2.50 (Percent)	9.2%	8.8%	5.0%	5.5%	5.6%	7.9%
Small Buses	Fleet Count	8,689	8,743	8,434	8,267	6,949	6,127
	Average Age (Years)	6.5	6.8	6.7	7.2	8.0	8.5
	Average Condition Rating	3.3	3.3	3.3	3.2	3.1	3.0
	Below Condition 2.5 (Percent)	21.1%	25.4%	27.6%	28.8%	32.0%	35.7%
Cutaways	Fleet Count	19,477	23,268	26,983	26,753	38,861	40,198
	Average Age (Years)	4.6	4.1	4.5	5.7	5.9	6.0
	Average Condition Rating	3.6	3.8	3.5	3.3	3.2	3.1
	Below Condition 2.5 (Percent)	9.3%	8.9%	11.1%	9.5%	11.9%	17.0%
Subtotal: Buses	**Total Fleet Count**	**85,642**	**90,617**	**93,182**	**93,863**	**100,813**	**99,917**
	Weighted Average Age (Years)	**7.0**	**6.7**	**6.7**	**7.1**	**6.9**	**7.4**
	Weighted Average Condition Rating	**3.5**	**3.5**	**3.4**	**3.4**	**3.3**	**3.2**
	Below Condition 2.5 (Percent)	**11.8%**	**8.2%**	**12.1%**	**14.2%**	**14.6%**	**15.1%**
Vans	Fleet Count	28,846	30,650	28,759	29,207	26,581	29,008
	Average Age (Years)	4.9	3.6	4.0	5.4	5.7	5.4
	Average Condition Rating	3.4	3.8	3.7	3.4	3.3	3.4
	Below Condition 2.5 (Percent)	9.3%	6.5%	8.2%	5.8%	10.3%	11.9%
Total: Buses and Vans	**Total Fleet Count**	**114,488**	**121,267**	**121,941**	**123,070**	**127,394**	**128,925**
	Weighted Average Age (Years)	**6.1**	**5.9**	**6.0**	**6.3**	**6.3**	**7.0**
	Weighted Average Condition Rating	**3.4**	**3.6**	**3.5**	**3.4**	**3.3**	**3.3**
	Below Condition 2.5 (Percent)	**11.1%**	**7.8%**	**11.1%**	**12.2%**	**13.7%**	**14.4%**

Note: Table excludes NTD records with no date built values.

Sources: Transit Economic Requirements Model (TERM); National Transit Database.

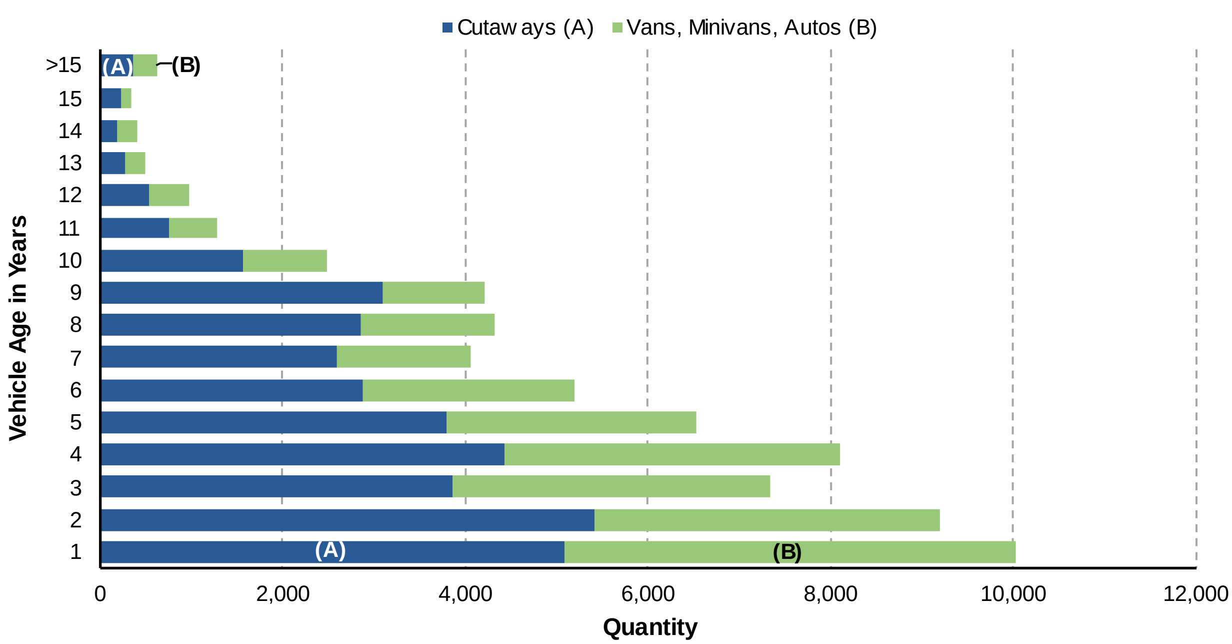
Exhibit 6-25 presents the age distribution of the Nation's transit buses, and *Exhibit 6-26* presents the age distribution of the Nation's transit vans, minivans, and autos. Note that full-size buses and vans account for the highest proportion (roughly 50 percent) of the Nation's rubber-tire transit 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. Note also that the share of the bus fleet with an age below their expected useful life was quite high in 2018. Most of the buses in the national fleet were 8 years old or less.

Exhibit 6-25: Age Distribution of Fixed-route Buses, 2018



Sources: Transit Economic Requirements Model (TERM); National Transit Database.

Exhibit 6-26: Age Distribution of Vans, Minivans, Autos, and Cutaways, 2018



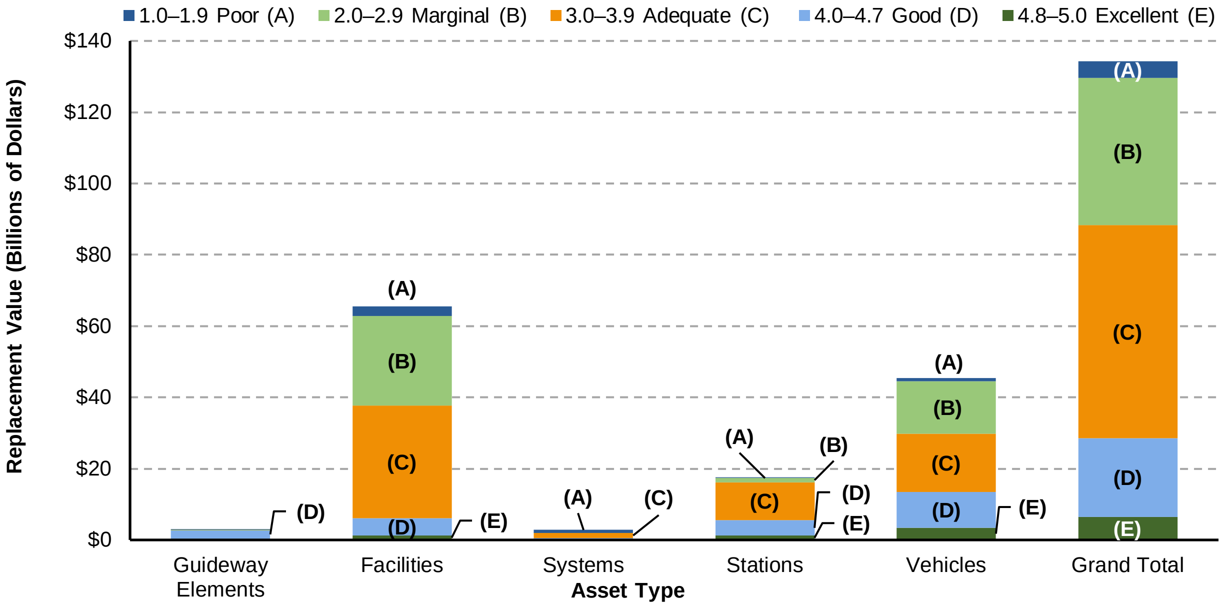
Sources: Transit Economic Requirements Model (TERM); National Transit Database.

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 6-27* shows TERM estimates of current conditions for the major categories of replaceable fixed-route bus assets. Vehicles comprise roughly one-third of all fixed-route bus assets, and maintenance facilities make up roughly half. Forty-two percent of bus maintenance facilities are rated below condition 3.0, compared with 33 percent for fixed route bus vehicles.

Exhibit 6-27: Distribution of Estimated Asset Conditions by Asset Type for Fixed-Route Bus, 2018



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

Rail Vehicles

NTD compiles annual data on all rail vehicles; these data are shown in *Exhibit 6-28*, broken down by major category. Measured across all rail vehicle types, the average age of the Nation's rail fleet is between 20 and 25 years old. The average condition of all rail vehicle types (calculated as the weighted average of vehicle conditions, weighted by vehicle replacement cost) is also relatively stable, declining slightly from 3.5 to 3.2 since 2008. The percentage of vehicles below the SGR replacement threshold (condition 2.5) increased from 4.2 to 9.2 percent from 2008 to 2018. Most vehicles in lesser condition occur in the heavy rail fleet. Notably, the percentage of heavy rail vehicles below the SGR threshold increased from 6.1 to 15.2 percent from 2008 to 2018.

From 2008 to 2018, the Nation's rail transit fleet grew at an average annual rate of roughly 2 percent. This rate of growth was due largely to the rate of increase in the commuter rail self-propelled passenger coach fleet (which represents about 14 percent of the total fleet and grew at an average annual rate of 2.9 percent over this period). In contrast, the heavy rail fleet grew the slowest at 0.6 percent, but it represents more than half of all rail vehicles. The annual rates of increase in light rail, commuter rail locomotives, and commuter rail passenger vehicles were between 1 and 2 percent, at 1.7, 1.8, and 1.2 percent, respectively. These three modes account for nearly one-third of all rail vehicles. 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 6-28: Rail Fleet Count, Age, and Condition, 2008–2018

Kind of Rail	Fleet Count, Age, and Condition	2008	2010	2012	2014	2016	2018
Commuter Rail Locomotives	Fleet Count	790	822	877	898	946	858
	Average Age (Years)	19.6	19.4	17.8	19.5	19.7	26.8
	Average Condition Rating	3.6	3.6	3.7	3.7	3.6	3.2
	Below Condition 2.5 (Percent)	0.0%	0.0%	1.8%	1.8%	2.7%	3.6%
Commuter Rail Passenger Coaches	Fleet Count	3,539	3,711	3,758	3,742	4,027	3,737
	Average Age (Years)	19.9	19.1	20.2	18.9	18.7	27.7
	Average Condition Rating	3.6	3.7	3.6	3.6	3.7	3.2
	Below Condition 2.5 (Percent)	0.0%	0.0%	0.4%	4.7%	4.5%	4.4%
Commuter Rail Self-propelled Passenger Coaches	Fleet Count	2,665	2,659	2,930	2,945	2,946	3,057
	Average Age (Years)	18.9	19.7	19.7	17.5	17.4	10.5
	Average Condition Rating	3.7	3.7	3.6	3.7	3.7	3.9
	Below Condition 2.5 (Percent)	0.0%	0.0%	0.0%	0.1%	0.0%	0.1%
Heavy Rail	Fleet Count	11,570	11,648	11,587	11,859	11,967	11,892
	Average Age (Years)	21.0	18.8	19.9	20.7	22.9	27.2
	Average Condition Rating	3.3	3.4	3.4	3.4	3.3	3.0
	Below Condition 2.5 (Percent)	6.1%	5.2%	3.7%	11.4%	16.3%	15.2%
Light Rail[1]	Fleet Count	2,151	2,222	2,241	2,416	2,428	2,328
	Average Age (Years)	17.1	18.1	14.6	17.8	18.3	21.5
	Average Condition Rating	3.6	3.5	3.6	3.5	3.5	3.3
	Below Condition 2.5 (Percent)	7.1%	6.9%	6.3%	2.8%	2.0%	0.6%
Total Rail	**Total Fleet Count**	**20,715**	**21,062**	**21,393**	**21,860**	**22,314**	**21,872**
	Weighted Average Age (Years)	**20.1**	**18.9**	**19.3**	**19.6**	**20.8**	**24.4**
	Weighted Average Condition Rating	**3.5**	**3.5**	**3.5**	**3.5**	**3.4**	**3.2**
	Below Condition 2.5 (Percent)	**4.2%**	**3.6%**	**2.8%**	**7.4%**	**9.9%**	**9.2%**

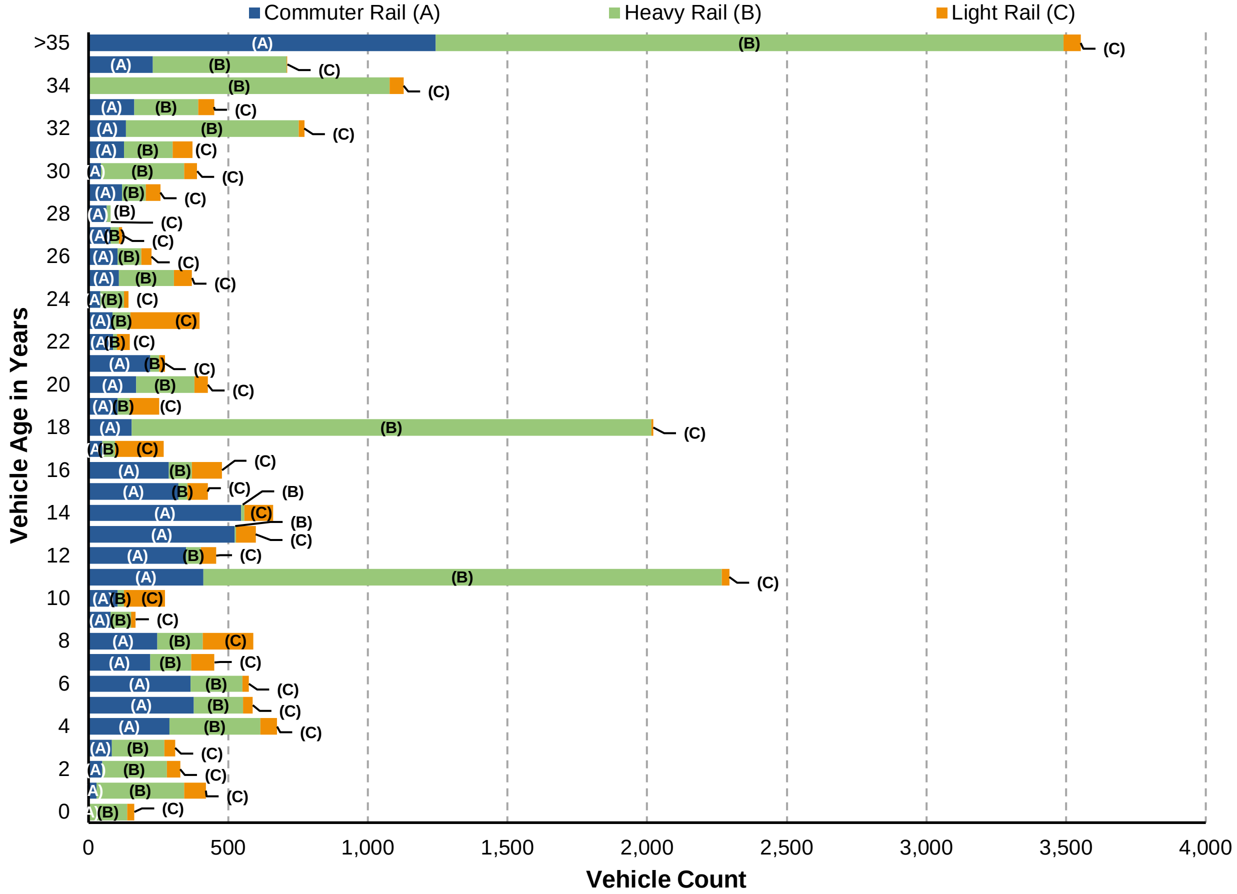
[1]Excludes vintage streetcars.

Sources: Transit Economic Requirements Model (TERM); National Transit Database.

Exhibit 6-29 presents the age distribution of the Nation's heavy rail, light rail, and commuter rail transit vehicles. Heavy rail vehicles account for more than half the Nation's rail fleet, whereas light rail, a mode more frequently found in smaller rail markets, accounts for only 11 percent of rail vehicles. Roughly one-third of commuter rail vehicles and one-half of heavy rail vehicles are more than 25 years old—with nearly 3,500 heavy and commuter rail vehicles exceeding 35 years in age. Just under half (48 percent) of all rail vehicles, including 47 percent of commuter rail vehicles and 59 percent of heavy rail vehicles, are located in the greater New York City area (which includes portions of New Jersey and Connecticut), the Nation's largest transit market.

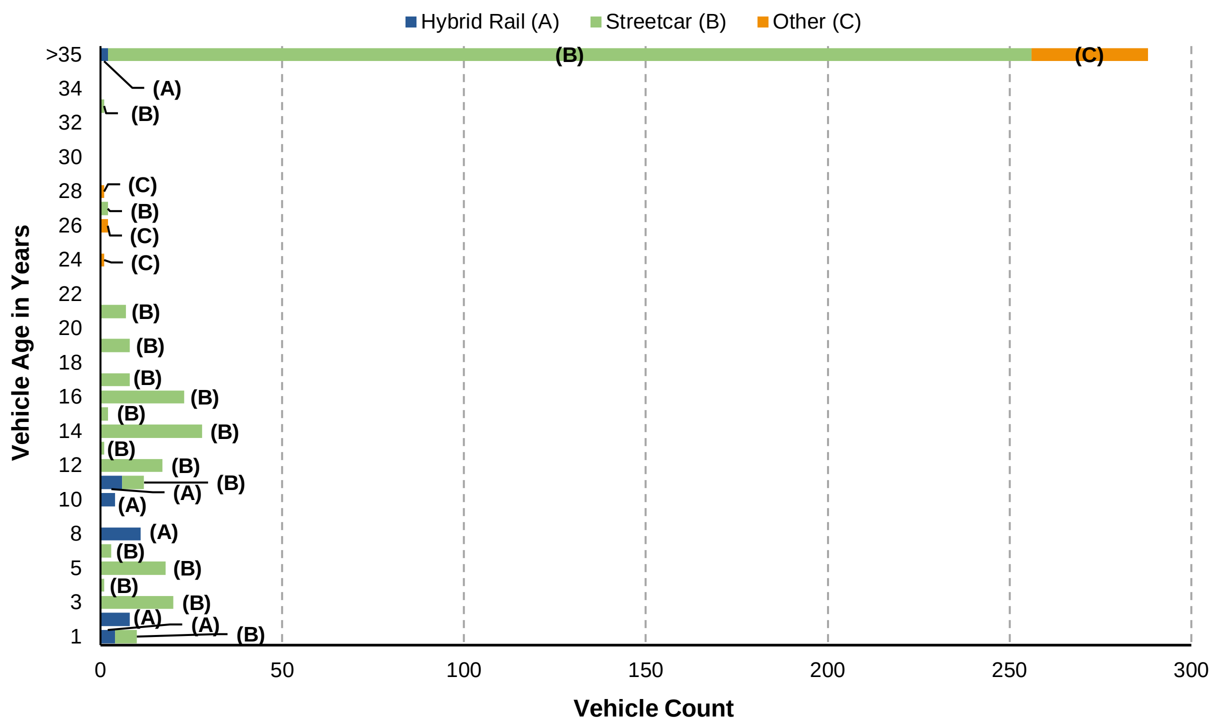
Comparing the results shown in *Exhibit 6-29* with the age distribution of transit buses and vans displayed in *Exhibit 6-25* and *Exhibit 6-26*, rail vehicles lack the relatively clear pattern of preferred retirement age that is found in buses and vans. *Exhibit 6-30* presents the age distribution of the Nation's hybrid rail, streetcar, and other rail transit vehicles. Streetcar rail vehicles account for 85 percent of the vehicles presented in *Exhibit 6-30*, whereas hybrid rail vehicles account for 7 percent. Sixty-three percent of streetcar rail vehicles are more than 25 years old.

Exhibit 6-29: Age Distribution of Heavy, Commuter, and Light Rail Transit Vehicles, 2018



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

Exhibit 6-30: Age Distribution of Hybrid Rail, Streetcar, and Other Rail Transit Vehicles, 2018



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

Other Rail Assets

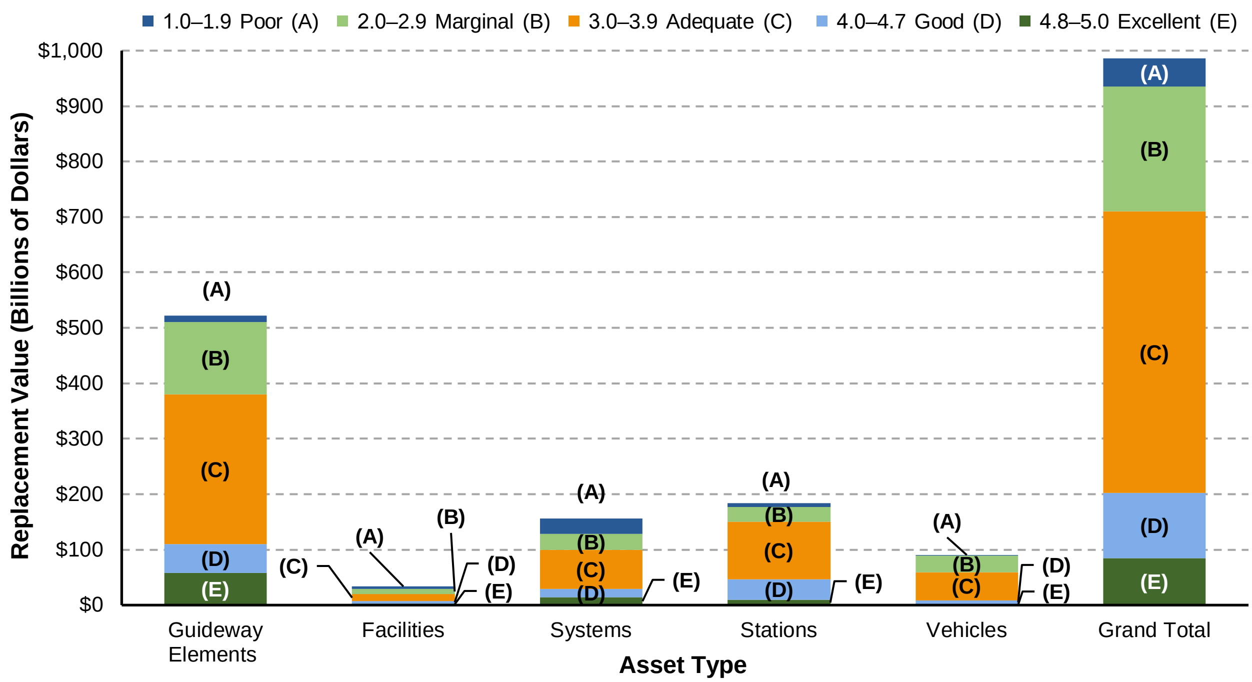
Assets associated with nonvehicle transit rail can be divided into five general categories: guideway elements, facilities, systems, stations, and vehicles. TERM estimates of the condition distribution of replaceable assets for each category are shown in *Exhibit 6-31*.

The largest category by replacement value is guideway elements, which consist of tracks, ties, switches, ballasts, tunnels, and elevated structures and have a replacement value of $522.1 billion, of which $11.4 billion is rated below condition 2.0 (2 percent) and $130.3 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.

The second largest category by replacement value is passenger stations. These elements include station buildings, platforms, passenger access (elevators, escalators, pedestrian walkways, parking), parking, and signage. The replacement value of this category is $183.3 billion, of which $6.8 billion is rated below condition 2.0 (4 percent) and $25.9 billion is rated between conditions 2.0 and 3.0.

Systems have a replacement value of $156.5 billion, of which $27.9 billion is rated below condition 2.0 and $28.6 billion is rated between conditions 2.0 and 3.0.

Exhibit 6-31: Distribution of Asset Physical Conditions by Asset Type for All Rail, 2018

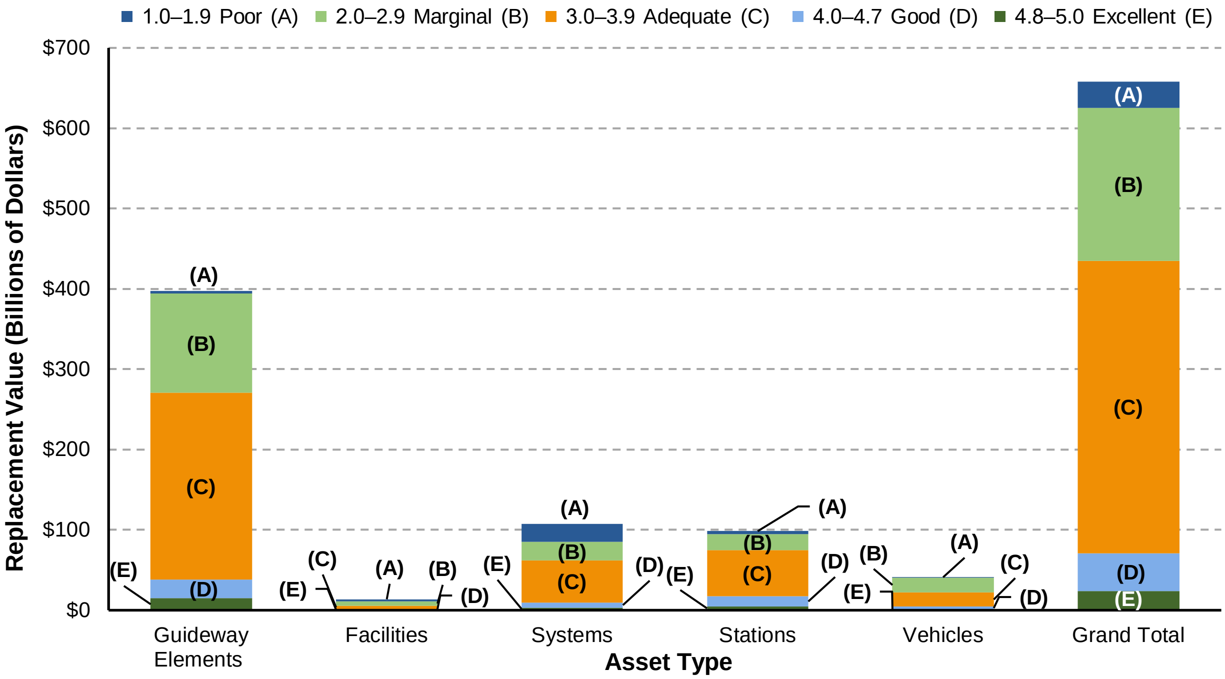


Source: Transit Economic Requirements Model (TERM); National Transit Database.

Facilities, consisting principally of maintenance and administration buildings, have a replacement value of $33.6 billion. The value of facilities rated below condition 2.0 is $4.1 billion, and the value of facilities between conditions 2.0 and 3.0 is $9.8 billion.

While *Exhibit 6-31* depicts the condition distribution for all rail modes. *Exhibit 6-32* presents the condition distribution of heavy rail assets only. Heavy rail represents $658.3 billion (67 percent) of the total transit rail replacement cost of $985.9 billion and also accounts for roughly half of all rail transit vehicles. Heavy rail systems also serve some of the Nation's oldest and largest transit systems, including Boston, New York, Washington, San Francisco, Philadelphia, and Chicago. *Exhibit 6-33* shows the average age and relative condition of nonvehicle transit assets for fixed-route bus and rail modes reported for 2018.

Exhibit 6-32: Distribution of Asset Physical Conditions by Asset Type for Heavy Rail, 2018



Sources: Transit Economic Requirements Model (TERM); National Transit Database.

Exhibit 6-33: Nonvehicle Transit Assets: Age and Condition, 2018

Category	Mode Type	Average Age	Avg. Condition	Percent Below Condition 2.5
Facilities	Rail	38.2	3.2	22%
	Fixed-route Bus	30.3	3.1	13%
	All	**33.64**	**3.18**	**17%**
Guideway Elements	Rail	69.5	3.5	3%
	Fixed-route Bus	28.3	3.9	6%
	All	**69.09**	**3.48**	**3%**
Stations	Rail	27.9	3.6	6%
	Fixed-route Bus	20.8	3.8	3%
	All	**27.47**	**3.59**	**6%**
Systems	Rail	37.0	3.2	26%
	Fixed-route Bus	22.3	3.6	20%
	All	**35.97**	**3.22**	**25%**

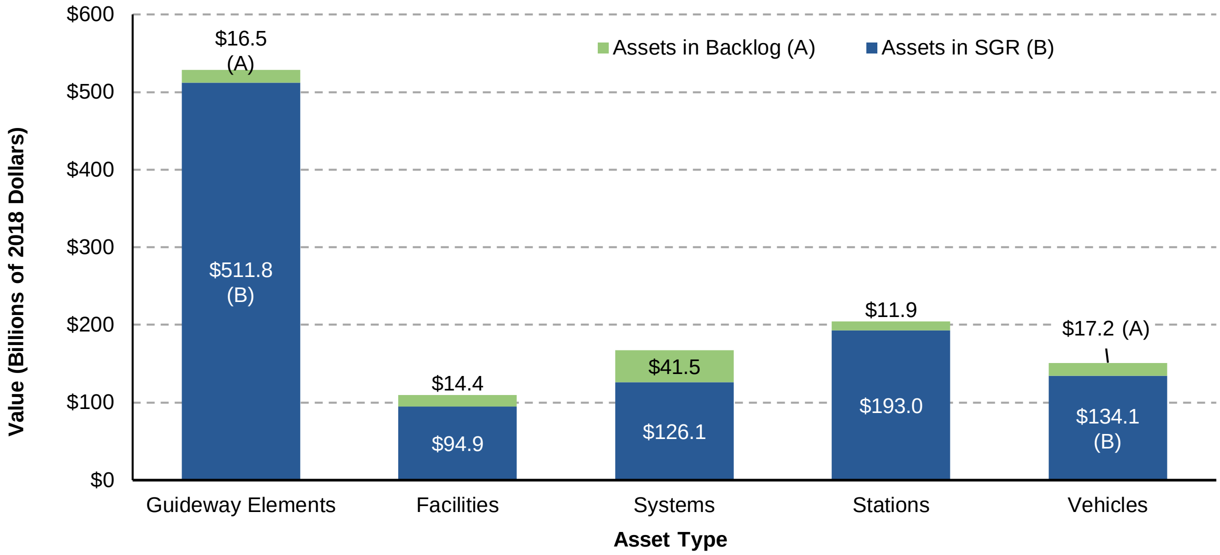
Source: Transit Economics Requirement Model (TERM).

Asset Conditions and SGR

The preceding discussion in this section focused on the replacement value of transit assets in excellent, good, adequate, marginal, or poor condition. The rest of this section considers the value of assets in SGR versus those assets with deferred reinvestment needs (i.e., a reinvestment "backlog"). This discussion is intended to 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 versus assets in the reinvestment backlog was estimated using TERM.

Exhibit 6-34 presents the value of both replaceable and nonreplaceable transit assets in SGR versus those assets in the reinvestment backlog, segmented by asset type. Based on this analysis, roughly $1,060 billion or 91 percent of all transit assets are in SGR, with the remaining $101 billion (9 percent) making up the reinvestment backlog. The backlog consists of $16.0 billion for guideway, $14.3 billion for facilities, $41.5 billion for systems, $11.7 billion for stations, and $17.2 billion for vehicles. These results are somewhat comparable to the results in *Exhibit* 6-22, to the extent that the backlog assets in *Exhibit 6-34* 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).

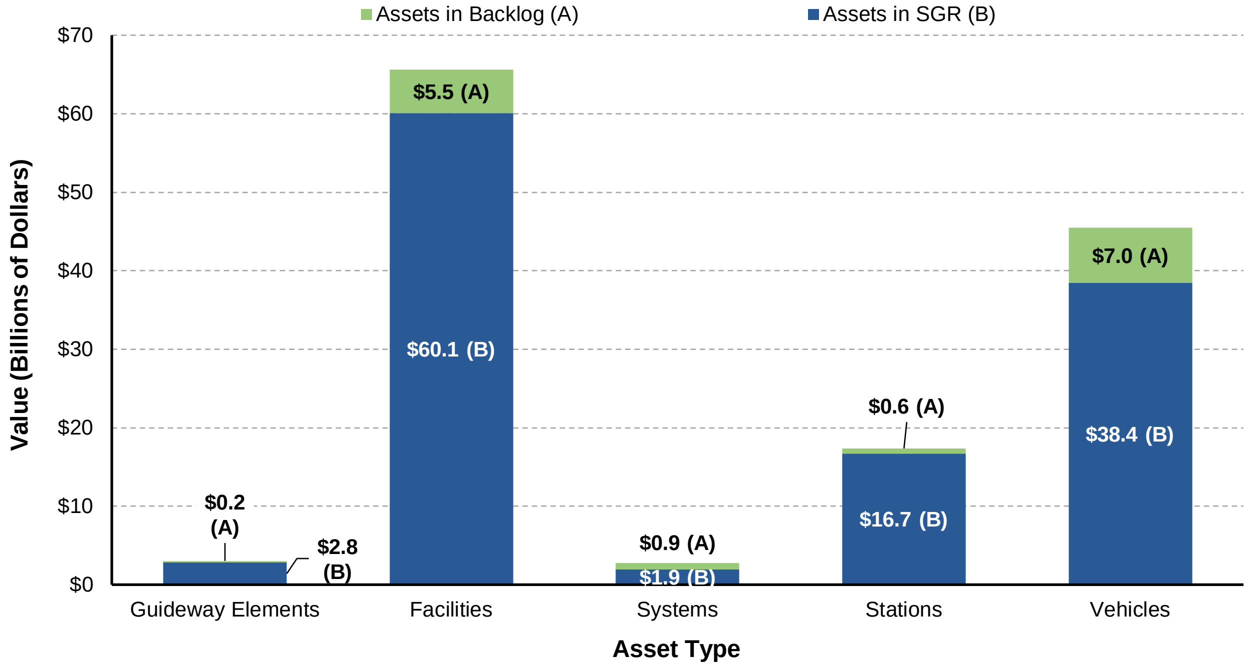
Exhibit 6-34: Value of U.S. Transit Assets in SGR vs. Backlog by Asset Type, 2018



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

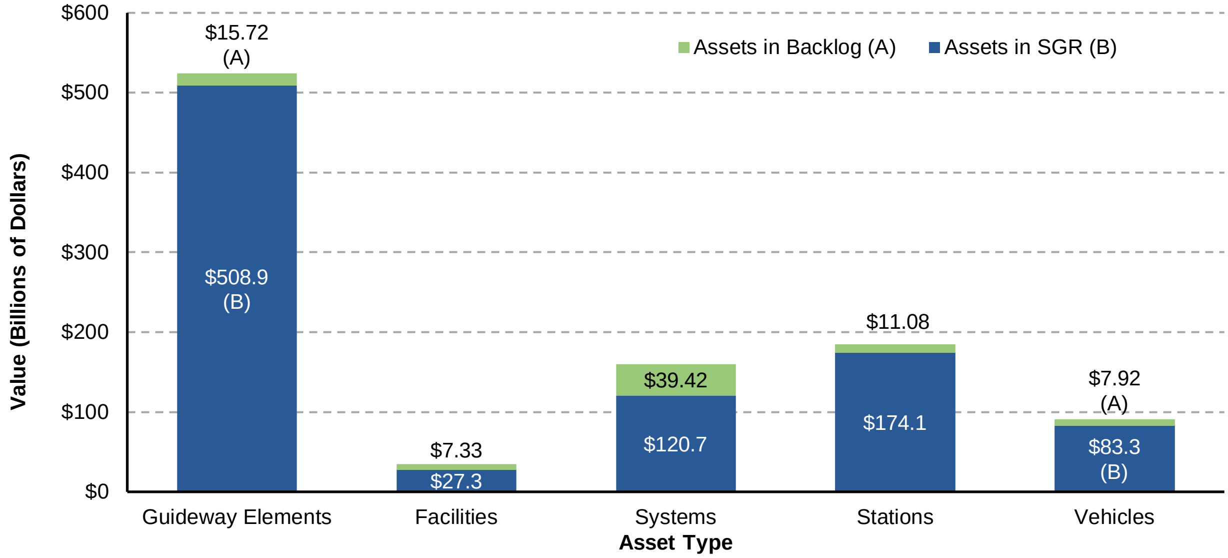
Exhibit 6-35 and *Exhibit 6-36* provide a similar presentation of transit assets in SGR versus those in the backlog, segmented by fixed-route bus and all rail assets, respectively. *Exhibit 6-35* highlights the fact that 83 percent of fixed-route bus asset value and 88 percent of the bus backlog are 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 6-36*, demonstrating rail's large share of total transit asset value. Based on these two charts, the reinvestment backlog constitutes 11 percent of fixed-route bus asset holdings and 9 percent of rail asset holdings (by value).

Exhibit 6-35: Value of U.S. Transit Assets in SGR vs. Backlog by Asset Type for Fixed-Route Bus

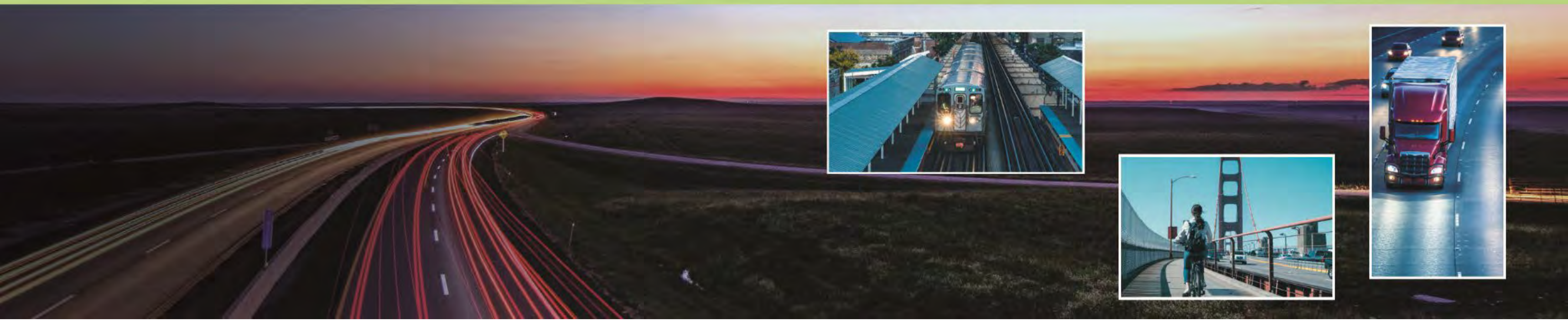


Source: Transit Economic Requirements Model (TERM); National Transit Database.

Exhibit 6-36: Value of U.S. Transit Assets in SGR vs. Backlog by Asset Type for Rail, 2018



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 2018 dollars, except where noted otherwise. The chapters consider scenarios for investment from 2019 through 2038 that are geared toward maintaining some indicator of physical condition or operational performance at its 2018 level, sustaining investment at recent levels (2014–2018), or achieving some objective linked to benefits versus costs. The average annual investment level for the 20 years from 2019 through 2038 is presented for each scenario.

Chapter 7, Capital Investment Scenarios, defines the 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.

Chapter 9, Sensitivity Analysis, explores the impacts on scenario projections of changes to several key assumptions, such as the discount rate and the future rate of growth in travel demand.

Last, Chapter 10, Impacts of Investment, explores the impacts of alternative levels of possible future investment on various indicators of conditions and performance. It also explains how the scenario projections were derived from results obtained with the models developed over the years for the C&P Report. The models have evolved 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). Their scope, however, even collectively, does not cover all potential 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

In this report, the term "investment" refers to capital spending, which does not include spending on maintenance. It does, however, include 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 provided in Chapter 2 of this report.

The projections for the 20-year capital investment scenarios shown in this report reflect complex technical analysis that attempts 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 projections of system conditions and performance in these 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 practice, the BCR omits some types of benefits and costs because of difficulties in quantifying them and valuing them monetarily, and these benefits and costs can and do affect project selection. In addition, project selection can be guided by other considerations besides benefit-cost analysis (BCA). (For example, New and Small Starts transit projects with Full Funding Grant Agreements are exempted from a BCA test.)

Highway and Bridge Investment Scenarios

Projections of 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 different models and techniques for highway preservation and capacity expansion than for bridge preservation. Investments in bridge repair, rehabilitation, and replacement are modeled by the National Bridge Investment Analysis System (NBIAS); investments 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. Because of 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 highway bridges on public roads, 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, non-model-based estimates must be generated for roads functionally classified as rural minor collectors, rural local, or urban local. In addition, HERS lacks information that would be needed to model types of capital spending identified as “system enhancement” in Chapter 2. This includes 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 2014–2018 Spending Scenario

Some C&P Report editions have included analyses of 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 also taken in the next three editions. Although the base year–level scenario provided a frame of reference to readers, spending levels in a base year could be disproportionately influenced by one-time events and thus might not be representative of typical spending.

The 24th C&P Report replaced this scenario with the Sustain Recent Spending scenario based on a 5-year average of annual spending (2012–2016) converted to base-year (2016) constant dollars. This edition follows the approach of the 24th C&P Report, using the Sustain 2014–2018 Spending scenario based on average annual spending for 2014–2018, converted to base-year (2018) constant dollars. This approach smooths out annual variations and makes scenarios more consistent between editions of the C&P Report. (In addition, as discussed in Chapter 2, the 2018 highway spending data presented in this report was estimated, because actual data was not available in time for inclusion. Basing the scenario on a range of years rather than on a single year also reduces the influence of estimated data.)

Choice of 5-year Period for the Sustain 2014–2018 Spending Scenario

The shift from a Sustain Current (1-year) Spending scenario to a Sustain 2014–2018 (5-year) Spending scenario was driven by the 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 is too long to be representative of typical recent spending. Although shorter periods, such as 3 years, were considered, a 5-year period was selected on the basis of an examination of historical annual spending patterns.

The 5-year (2014–2018) average annual highway capital spending level of $115.1 billion is representative of each of the past 5 years of spending. Although the average is slightly higher than spending in some years (e.g., 2014: $112.0 billion and 2016: $112.4 billion), it is slightly lower than in other years (e.g., 2017: $119.0 billion and 2018: $117.0 billion). Similarly, the 5-year (2014–2018) average annual transit capital spending level of $20.5 billion is representative of each of the last five years of spending, individually. Average annual transit capital spending is slightly higher in some years (e.g., 2014: $19.2 billion), it is slightly lower in other years (e.g., 2018: $21.1 billion). The use of a 5-year average makes one-time events or an aberrant year less likely to skew funding levels. With the 5-year average, no single year is greater or lower than roughly 3 percent of the average.

Exhibit II-1 presents the derivation of the annual investment level for the Sustain 2014–2018 Spending scenario. Using the National Highway Construction Cost Index to convert spending from current dollars to constant 2018 dollars yields average annual capital spending from 2014 to 2018 of $115.1 billion. The Sustain 2014–2018 Spending scenario projects the potential impacts of sustaining capital spending at this level in constant-dollar terms for the 20-year period of 2019 through 2038. *Exhibit II-1* also shows the portion of total capital spending that went to Interstate highways, the National Highway System, and Federal-aid highways. The distribution varied annually (for example, the share of capital spending for Federal-aid highways was 75.2 percent in 2014 but 80.0 percent in 2018), illustrating the utility of smoothing out the analysis using a multiyear perspective.

Exhibit II-1: Derivation of Annual Investment Level for the Sustain 2014–2018 Spending Scenario, Highways

Category	Functional System	2014	2015	2016	2017	2018	5-Year Average
National Highway Construction Cost Index (2003 Quarter 1 = 1.0000)	Four-quarter Average	1.6816	1.6984	1.6606	1.6745	1.7861	
Highway Capital Spending, All Levels of Government (Billions of Dollars)	Current Dollars	$105.4	$109.3	$104.5	$111.5	$117.0	$109.6
	Constant 2018 Dollars[1]	$112.0	$115.0	$112.4	$119.0	$117.0	$115.1
Highway Capital Spending, by System (Billions of Constant 2018 Dollars)[2]	Interstate Highway System	$26.9	$27.6	$26.4	$27.8	$27.4	$27.2
	National Highway System	$59.8	$61.4	$59.0	$59.9	$59.0	$59.8
	Federal-aid Highways	$84.2	$86.4	$83.8	$95.1	$93.6	$88.6
	All Roads	$112.0	$115.0	$112.4	$119.0	$117.0	$115.1

[1] Spending was converted from current to 2018 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 2018.

[2] The distribution by system in 2015 and 2016 was estimated based on 2014 data; the distribution by system in 2017 was estimated based on 2018 data.

Sources: 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-dollars remains flat between 2019 and 2038—not at the recent spending (2014–2018) level, however, but at the level that would result in selected performance indicators having the same values in 2038 as in 2018. For this edition of the C&P Report, the HERS component of the scenario is defined as the lowest level of investment required to maintain the share of vehicle miles traveled (VMT) on pavements with poor ride quality and the share of VMT on severely congested roads at their base-year level or better. For the NBIAS component, the benchmark performance indicator is the percentage of bridges in poor condition, weighted by deck area.

HERS Performance Indicators in the 24th and 25th Editions of the C&P Report

One important difference between the 24th and 25th editions is a change in the performance indicators of the Maintain Conditions and Performance scenario and the Improve Conditions and Performance scenario.

For the HERS component of these scenarios, the 24th edition assesses average pavement roughness (using the International Roughness Index [IRI] as a proxy for pavement condition) and average delay per VMT. Pavements with an IRI value of less than 95 inches per mile are considered to have "good" ride quality, whereas pavements with an IRI value of greater than 170 inches per mile are considered to have "poor" ride quality. Pavements with IRI values between these ranges are considered "fair."

For the 25th edition, average pavement roughness was replaced with the projected share of travel on pavements with poor ride quality (that is, with an IRI value of 170 or higher). In addition, average delay was replaced with the share of travel projected to occur under severely congested conditions, as measured by the volume-to-service flow (V/SF) ratio. (A V/SF ratio above 0.80 is associated with congested conditions, whereas a ratio above 0.95 is considered severely congested).

This change in metrics focuses the impacts on "poor" rather than "average" conditions and performance and brings the HERS definitions more in line with the NBIAS definitions, which already target "poor" conditions.

Improve Conditions and Performance Scenario

The investment levels for the Improve Conditions and Performance scenario are estimates of what would be needed to fund all cost-beneficial highway and bridge improvements. This scenario represents an "investment ceiling" above which further investment would not be cost-beneficial, even if the available funding were unlimited. 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 Noncapital Spending

Maintenance and other noncapital spending is substantial, constituting roughly half of all highway expenditures (see Chapter 2, Exhibit 2-10). One important question about the Improve Conditions and Performance scenario is how increasing the capital investment level could affect future noncapital costs.

Although the HERS model focuses on capital investments, in estimating the benefits of such investments it also considers the impact of investment on routine maintenance costs. The HERS model estimates maintenance spending per mile on the basis of pavement condition and strength, with maintenance costs rising as pavement condition declines. Increases in capital spending on rehabilitation projects therefore generally reduce the need for future maintenance spending by improving pavement condition. Conversely, greater spending on capacity expansion projects increases the number of lanes that need to be maintained and thus implies higher future maintenance costs, all other things being equal. With 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 38.1 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, because 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 unclear, however, whether increased planning costs would be directly proportional to increased capital investment levels. Other noncapital costs, such as administration and highway patrol, are not captured in the HERS model but do not necessarily vary much 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 that HERS and NBIAS evaluate can be related to the system of highway functional classification introduced in Chapter 1 and to the broad categories of capital improvements introduced in Chapter 2 (system rehabilitation, system expansion, and system enhancement). NBIAS relies on the National Bridge Inventory (NBI) database, which covers bridges in all highway functional classes, and evaluates improvements that generally fall in the system rehabilitation category.

HERS evaluates pavement improvements—resurfacing or reconstruction—and highway widening; the types of improvements included in these categories correspond roughly 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, because 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 2-14 (see Chapter 2) shows capital improvement types for which data is routinely collected from the States by category: 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 2-14*, HERS splits spending on "reconstruction with added capacity" among these categories.

For some of the capital improvement types shown in *Exhibit 2-14*, the correspondence is close but not exact. In particular, the extent to which HERS covers the construction of new roads and bridges is unclear. Although not directly modeled in HERS, such capital improvement is often motivated by a desire to alleviate congestion in a corridor and thus would be captured indirectly by the HERS analysis in 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 the desire to encourage economic development or accomplish other goals besides reducing congestion on the highway network, such investments would not be captured in the HERS analysis.

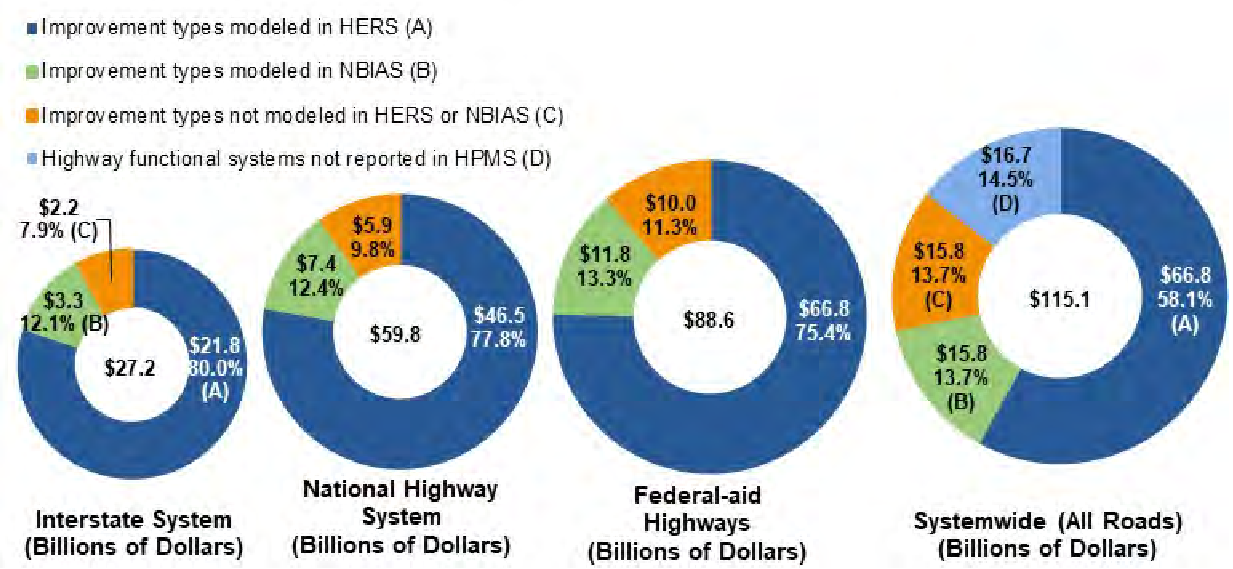
Other comparability issues include:

- Some of the relocation expenditures identified in *Exhibit 2-14* 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 2-14* 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 spending on the "safety" category in *Exhibit 2-13*. Some safety deficiencies, however, might be accounted for in 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 in 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 evaluates. Although HERS incorporates assumptions about future investments in operations, the capital components of which would be classified as system enhancements, it does not evaluate the need for the investments. In addition, HERS does not identify safety-oriented investment opportunities, but instead considers the ancillary safety impacts of capital investments that are primarily for system rehabilitation or capacity expansion. (Part IV of this report makes a recommendation to begin capturing Model Inventory of Roadway Elements [MIRE] data in the HPMS. The inclusion of such data would facilitate the analysis of safety-oriented investments in HERS in the future.)

Exhibit II-2 shows that the systemwide highway capital spending for the Sustain 2014–2018 Spending scenario was $115.1 billion. (The Sustain 2014–2018 Spending scenario is discussed in greater detail in Chapter 7.) Of that spending, $66.8 billion (58.1 percent) was for the types of improvement that HERS models, and $15.8 billion (13.7 percent) was for the types of improvement that NBIAS models. The other $32.5 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 (2014–2018) 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 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 for the system as a whole. Of the $88.6 billion in spending on capital improvements to Federal-aid highways by all levels of government in the Sustain 2014–2018 Spending scenario, 75.4 percent was within the scope of HERS, 13.3 percent was within the scope of NBIAS, and 11.3 percent was for spending not captured by either model. The distribution differs for the National Highway System and the Interstate System, with higher shares within the scope of HERS (77.8 percent in the National Highway System and 80.0 percent in the Interstate System). The distribution in NBIAS is lower—approximately 12 percent (12.4 percent for the National Highway System and 12.1 percent for the Interstate System)—whereas the share captured by neither is less than 10 percent (9.8 percent for the National Highway System and 7.9 percent for the Interstate System).

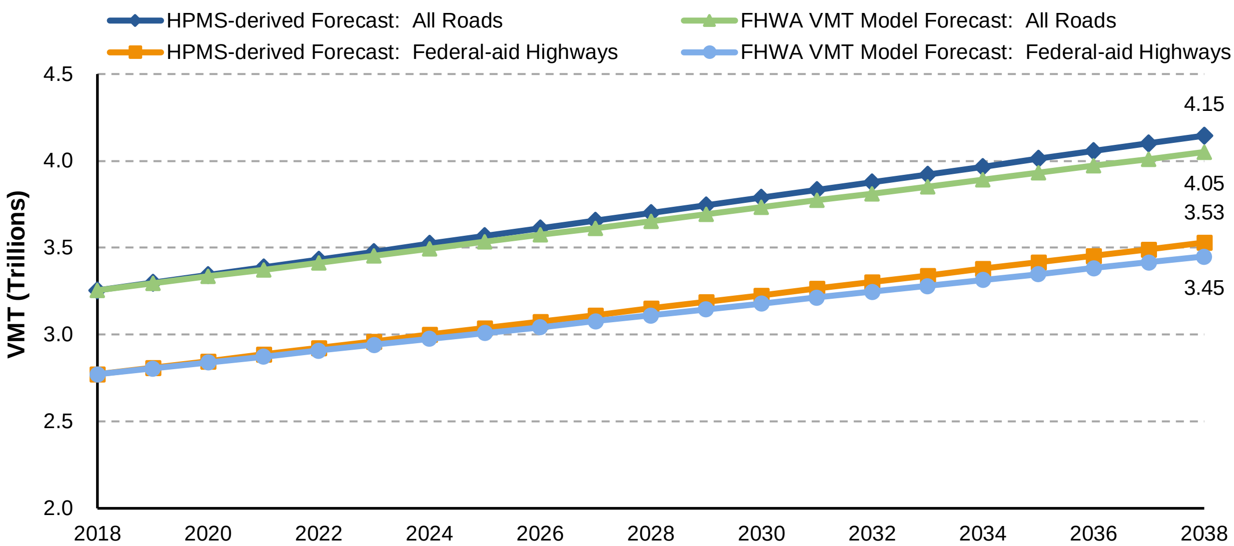
Future Travel Volumes Assumed in HERS and NBIAS

As discussed in Chapter 9, Traffic Growth Projections, the HERS and NBIAS modeling in this edition of the C&P Report supplements section-level travel forecasts from the HPMS and bridge-level traffic forecasts from the NBI with a 20-year national-level VMT forecast from an FHWA econometric model. Aggregating the forecasts for individual sample sections yields a composite weighted average annual travel growth rate of 1.22 percent. (Aggregating the traffic forecasts for individual bridges yields an average of 1.31 percent per year.) These location-specific forecasts were scaled down proportionally so that the national average would match the 1.1-percent value published online in FHWA Forecasts of Vehicle Miles Traveled (VMT): Spring 2019.

Exhibit II-3 translates the HPMS-derived VMT growth rate and the FHWA VMT model forecast into projected VMT for each year from 2018 to 2038. 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 1.10-percent annual FHWA VMT growth rate implies that national VMT will rise from 3.26 trillion in 2018 to 4.05 trillion in 2038, with VMT on Federal-aid highways rising from 2.77 trillion to 3.45 trillion during this period. Applying the 1.22-percent HPMS-derived forecast annual growth rate would yield national VMT of 4.15 trillion, of which 3.53 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 projects over 20 years.

Exhibit II-3: Annual Projected Highway VMT Based on HPMS-derived Forecasts or FHWA VMT Forecast Model, 2018–2038



Note: VMT is vehicle miles traveled; HPMS is Highway Performance Monitoring System. Year-by-year values are shown only for FHWA VMT Model Forecast: All Roads, because these would be most appropriate for citation in FHWA's official forecast.

Sources: Highway Performance Monitoring System; FHWA Forecasts of Vehicle Miles Traveled, May 2019.

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 data from HPMS to calculate incremental BCA to evaluate highway improvements. HPMS includes State-supplied information on current roadway characteristics, conditions, and 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 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 a statistically reliable estimation for each urbanized area, and at the statewide level for rural and small urban areas. For each geographic category, stratified random samples are drawn by traffic volume group. (The sampling methodology is detailed in the HPMS Field Manual [https://www.fhwa.dot.gov/policyinformation/hpms/fieldmanual/].)

A HERS simulation begins with an evaluation of the state of the highway system using data from the HPMS sample on pavement, roadway geometry, traffic volume and composition (percentage of trucks), and other characteristics. For sections with one or more deficiencies, the model 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 benefit, with benefits defined as reduction 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 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 is available. The 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 funding period.

Operations Strategies

HERS considers the impacts of certain types of highway operational improvements that feature intelligent transportation systems. HERS evaluates the following strategies:

- 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, in-vehicle navigation systems with real-time traveler information.

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. Because of the nature of this two-step process, HERS does not analyze tradeoffs between these types of operational improvements and potential widening options.

The analyses presented in this edition assume that operational improvements over the next 20 years will continue to be made at a rate consistent with existing patterns. HERS is also equipped to analyze the impact of a more aggressive operational improvement strategy over 20 years or over 5 years. The 2013 C&P Report and the 2015 C&P Report included sensitivity analyses exploring these alternative scenarios.

The HERS model relies on a variety of assumptions about travel behavior and 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.

Travel Demand Elasticity

A key feature of the HERS economic analysis is the influence of the cost of travel on the 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 relative to base-year levels, as measured by travel delay, pavement condition, and crash costs. 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
- 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 for 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 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 improvement 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 projected level of future VMT is affected directly by the assumed level of future highway capital spending. Simulations with higher investment levels that lead to reductions in average user cost will project higher future traffic volumes than will simulations with lower investment levels that lead to increases in average user cost. 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 for 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.. The analyses are based on synthesized element-level data. 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 modeling 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 information on the cost of maintenance, repair, and rehabilitation (MR&R) actions, is used to predict the life-cycle costs of maintaining bridges and to develop MR&R policies based on the condition of a bridge element. In this analysis, bridge replacement is recommended if an evaluation results in lower life-cycle costs than those 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. It then identifies potential improvements—such as widening lanes, raising a bridge to increase vertical clearance, and strengthening to increase load-carrying capacity—and evaluates their potential benefits and costs. NBIAS evaluates potential bridge replacement 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 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 portions of 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.

Sustain 2014–2018 Spending

The Sustain 2014–2018 Spending scenario projects the potential impacts of sustaining preservation and expansion spending at recent spending levels (2014–2018), based on average annual spending over 5 years (2014–2018) converted to base-year (2018) 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 2018 dollars yields an average annual capital spending level from 2014 to 2018 of $20.5 billion. The Sustain 2014–2018 Spending scenario projects the potential impacts of sustaining capital spending at this level in constant-dollar terms over the 20-year period of 2019 through 2038. The scenario applies BCA to prioritize investments within this target budget.

Exhibit II-4: Derivation of the Annual Investment Level for the Sustain 2014–2018 Spending Scenario, Transit

Transit Investment Scenario	Functional System	2014	2015	2016	2017	2018	5-Year Average
RS Means Constriction Index (2018=100)	Four-quarter Average	90.77	92.44	93.03	95.82	100.00	
Transit Capital Spending, All Modes (Billions of Dollars)	Current Dollars	$17.4	$19.3	$19.4	$19.6	$21.1	$19.4
	Constant 2018 Dollars	$19.2	$20.8	$20.9	$20.5	$21.1	$20.5
Annual Transit Capital Expenditures, by Purpose (Billions of Constant 2018 Dollars)	Preservation	$12.1	$13.4	$13.7	$14.0	$14.5	$13.5
	Expansion	$7.0	$7.5	$7.2	$6.5	$6.7	$7.0

Note: Excludes reduced reporter agencies.
Source: National Transit Database.

SGR Benchmark

The SGR 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 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.

Expansion and Expansion with Growth

The Expansion and Expansion with Growth scenarios add a system expansion component to the system preservation needs associated with the SGR Benchmark. Both scenarios incorporate a benefit-cost test for evaluating a portion of potential investments; thus, their system preservation components are somewhat smaller than the level identified in the SGR Benchmark.

This edition of the C&P Report introduces significant changes to the estimation of transit expansion investment. Instead of focusing on the investment required to support rider growth as was done in recent C&P Report editions, this edition introduces new “components” to the analysis of the investment required to meet performance and coverage objectives. These components enable the assessment of the investment needed to introduce service to transit deserts, to increase service on low-frequency routes, to reduce crowding for high-utilization operators, and to increase operating speeds in urbanized areas (UZAs) with speeds below the national average. This section summarizes each of the analysis components used in this year’s report to estimate the level of investment in these types of service enhancements. Chapter 7 includes a discussion of the investment scenarios and their associated investment level estimates.

Transit expansion investment levels for recent C&P Report editions were estimated using a single, ridership growth-based approach. This edition uses six separate analysis components to estimate transit expansion investment levels: one for investing in expansion assets to accommodate expected ridership growth, and five for investing to improve transit performance and/or accessibility (e.g., by expanding service coverage or increasing frequency). With one exception (New Starts Pipeline), each analysis component was designed to determine specific performance and/or accessibility improvement targets. Approaches to estimating these components could independently identify the same (or similar) investments in performance improvement in the same location (e.g., investment in light rail expansion in the same UZA), and any instances of such double-counting were removed from the final expansion investment tally.

Investments to Improve Performance and Accessibility

Investments to improve performance, accessibility, and the quality of transit service include those that expand transit asset holdings with the intention of improving transit performance measures such as system coverage, service frequency, operating speed, and capacity (e.g., fleet size or throughput). *Exhibit II-5* provides descriptions of the five components used to identify investments in transit performance improvement in this edition of the C&P Report, which are included in both the Expansion and the Expansion with Growth scenarios.

Exhibit II-5: Components to Improve Performance and Accessibility

Expansion Analysis Component	Component Objective
Service Coverage (Transit Deserts)	Expand transit service to cover areas without service but with sufficient residential density to support fixed-route service
Service Frequency	Increase service frequency where residential density indicates that service is inadequate
New Starts Pipeline	Invest in all New Starts Projects currently approved in the New Starts Pipeline
Average Speed Improvement	Improve the average transit operating speeds in urbanized areas that are well below the national average
Vehicle Occupancy Improvement	Reduce vehicle occupancy rates (crowding) for agencies that are well below the national average (calculated separately for each transit agency-mode combination)

Source: Transit Economic Requirements Model.

Investments to Accommodate Ridership Growth

The Expansion with Growth scenario includes estimated expansion investment levels required to support projected growth in passenger miles traveled (PMT), taking into account the decline and expected slow recovery of ridership following the COVID-19 pandemic. Specifically, these projections assume ridership will continue to increase at the trend rate experienced since the start of the pandemic (March 2020) through 2030 before reaching 100 percent of 2019 ridership levels, and will thereafter resume the trend rate of growth in PMT, calculated as the compound 15-year (2003–2018) average annual PMT growth by FTA region, urbanized area (UZA) stratum, and mode. Under these assumptions, investment in expansion assets does not occur until ridership re-attains pre-pandemic levels in these individual submarkets.

Appendix C provides additional technical information on Transit Economic Requirements Model (TERM) and the methodologies used to generate the estimates for the current edition of the C&P Report.

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 for 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 transit capital assets required to attain specific investment goals (e.g., to attain SGR), subject to limited capital funding.
- **Expansion:** The level of investment in the expansion of transit fleets, facilities, and rail networks required to improve performance, accessibility, and the quality of transit service, and to support the projected growth in transit demand (i.e., to maintain performance at 2018 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 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.

TERM estimates current and future preservation investment needs by first assessing the condition of the Nation's stock of transit assets. (The results of this analysis were presented in Chapter 6 of this report.) TERM 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 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 that the model identifies at the time those investment needs come due. Hence, with unconstrained analyses after any initial deferred investment is addressed, the 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 factored in 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, depending on the level of capital reinvestment. Finally, with some exceptions, TERM's BCA is used to determine the order in which reinvestment activities are completed when funding capacity is limited, with investments having the highest BCA addressed first. These exceptions include the SGR Benchmark scenario, which does not include any benefit-cost tests, and New and Small Starts projects that have approved Full Funding Grant Agreements (in the Sustain Spending and Growth Scenarios).

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 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, datasets used in generating the scenarios, and scenario definitions.

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 more sophisticated in other ways, over time. The HERS model was first used in the production of the 1995 C&P Report. TERM was introduced in the 1997 C&P report, and NBIAS was first used in the 2002 C&P report. Each of these tools has subsequently undergone several rounds of updates and refinements to improve their accuracy and expand their coverage. Appendix D describes the ongoing *Reimagining the C&P Report in a Performance Management-Based World* effort begun in late 2012, which includes an evaluation of alternative methodologies to replace or improve the BCA-driven tools used currently.

As in any modeling process, assumptions have been made to make analysis practical and to report within the limitations of the available data. Because asset owners at the State and local levels make the ultimate decisions about highways, bridges, and transit systems, they 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 other Federal activities, but such data is not sufficiently robust to make definitive recommendations about specific transportation investments in specific locations.

Each model used in this report—HERS, NBIAS, and TERM—omits various types of investment impacts from its BCAs. To some extent, 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 the budget for data collection. In the future, technological progress in data collection and growing demand for data for performance management systems for transportation infrastructure probably 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 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 investment 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 estimates of confidence intervals cannot be developed as the component variables used to estimate the future needs of the system are not independent.

Each input data and component variable that feeds into the investment analysis has a unique level of uncertainty or confidence based on sampling procedures, potential variations in the sample population, simplifications, and assumptions. For example, the HPMS data used for the HERS model are a representative sample of the national roadway systems. To ensure a high level of sample representation of the population, HPMS data are collected with defined sampling precision requirements. *Exhibit II-6* shows HPMS sampling precision requirements based on sampling by functional class and geographic location.

Exhibit II-6: HPMS Sample Selection Precision Level Based on Functional Class

Functional Class	Rural	Small Urban (5,000–49,000)	Urbanized (<200,000)	Urbanized (>200,000)
Interstate	90-5	90-5	80-10	90-10
Other Freeway and Expressway	90-5	90-5	80-10	90-10
Other Principal Arterial	90-5	90-5	80-10	90-10
Minor Arterial	90-10	90-10	80-10 (*70-15)	90-10
Major Collector	80-10	80-10	80-10 (*70-15)	80-10
Minor Collector		80-10	80-10 (*70-15)	80-10

Notes: If a sample is designed at the 90-10 confidence interval and precision rate, the resultant sample estimate will be within 10 percent of the true value, 90 percent of the time. These precision levels will be applied if a State has three or more urbanized areas with a population <200,000.

Source: Table 6.2 Precision Levels, Highway Performance Monitoring System (HPMS) Field Manual.

If a sample is designed at the 90-10 confidence interval and precision rate, the resultant sample estimate will be within 10 percent of the true value, 90 percent of the time. Lower precision rates are defined for lower-level functional roads and lower population densities because of the limited resources of the communities managing those systems.

Another critical input into the highway needs estimate is the projected compounded annual growth rate (CAGR) for VMT. As discussed above the VMT forecast used in the HERS model is constrained to the average of the national VMT growth rate estimated by the FHWA VMT model. To understand the level of uncertainty in the forecasted VMT growth rate, the upper and lower bounds for the CAGR for VMT was computed from 10,000 draws of the model coefficient estimates (Monte Carlo simulation), using the baseline economic forecast data. The results estimate that at the 95th percentile, the CAGR will be 1.9 percent, and at the 5th percentile it will be 0.4 percent with a mean value of 1.1 percent.

Supplemental analysis on alternative modeling strategies and sensitivity analysis on alternative parameter values is performed to assess the impacts and significance of these uncertainties on future investment levels and future highway performance estimates. The analysis in Chapter 8 of this edition summarizes the impacts of selected alternative analysis strategies on future investment and performance. The analysis in Chapter 9 of this edition of the C&P Report further addresses uncertainty by exploring the sensitivity of the scenario projections to changes in parameters such as discount rate, value of time saved, and statistical value of lives saved. To the extent 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 difficult because of the uncertainties related to travelers' behavior. Even when the underlying relationships may be modeled correctly, 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 long-term growth rates, particularly in light of recent declines in transit ridership, are uncertain. And neither the transit nor highway travel forecasts reflect the potential impacts of emerging transportation technology options such as car sharing, 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 from 2018 and ending in 2038. 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.**

SECTION SUMMARY

- The Improve Conditions and Performance scenario requires annual investment of $151.1 billion, compared to the $115.1 billion of the Sustain 2014–2018 Spending scenario.
- Annual investment under the Maintain Conditions and Performance scenario is $79.0 billion. Since this is less than the Sustain 2014–2018 Spending scenario level, this suggests that recent investment (2014–2018) levels are sufficient to keep overall conditions and performance from worsening over time.
- Approximately 36.1 percent of the investment required under the Improve Conditions and Performance scenario would go toward addressing existing backlog ($1.1 trillion in total backlog).
- The Highway Repair Backlog was $852 billion in 2018. This represents the portion of the total investment backlog associated with system rehabilitation and system enhancement, and excludes system expansion needs.

Each capital investment scenario produces 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 public 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 28.2 percent of the spending in each scenario, consistent with the estimated weighted average share of total capital spending directed toward these investments for 2014 through 2018.

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. Chapter 10 presents conditions and performance outcomes in 20 years in highways and bridges under the investment scenarios presented in this chapter, as well as additional alternative levels of future investment.

Scenarios Selected for Analysis

This section examines three spending scenarios based on capital investment by all levels of government combined. This report does not comment on what portion should be funded by the Federal government, State governments, local governments, or the private sector. Analyses were conducted for the entire public road network. 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.

As discussed in the Introduction to Part II, combined highway capital spending by all levels of government for 2014 through 2018 averaged $115.1 billion per year, in constant 2018 dollars. The objective of the Sustain 2014–2018 Spending scenario is to predict the impact on highway conditions and performance after 20 years if capital spending remains constant (adjusted for inflation) at this level over the whole analysis period. The shares of recent spending (2014–2018) that correspond to capital investment types modeled in HERS or NBIAS are assumed to remain constant; however, the models are free to direct this funding to different functional classes or types of spending.

Changes in Scenario Definitions Relative to the 24th C&P Report

The key difference between the scenarios presented in this report relative to those in the 24th edition is that the HERS-derived component of the Maintain Conditions and Performance scenario targets different performance indicators. In the 24th edition, the Maintain Conditions and Performance scenario sought to identify the level of spending necessary to maintain projected average pavement roughness and average delay.

For this edition, average pavement roughness was replaced with the projected share of travel on pavements with poor ride quality. Average delay was replaced with the share of travel projected to occur under severely congested conditions, as measured by the volume to service flow (V/SF) ratio. A V/SF ratio above 0.80 is associated with congested conditions, whereas a ratio above 0.95 is considered severely congested.

This change in metrics focuses the impacts on “poor” rather than “average” conditions and performance; it also brings the HERS definitions more closely in line with the NBIAS definitions, which already target “poor” conditions.

The remaining scenarios presented in this edition are defined consistently with those presented in the 24th edition. The Sustain Recent Spending scenario was renamed for this edition as the Sustain 2014–2018 scenario to clarify the specific years of spending it is based on, and that it does not reflect Federal funding authorized by the Infrastructure Investment and Jobs Act (IIJA), otherwise known as the Bipartisan Infrastructure Law (BIL).

The Maintain Conditions and Performance scenario seeks to identify the level of investment needed to keep selected measures of 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 (with a benefit-cost ratio at or above 1.0). *Exhibit 7-1* describes the derivation of each of these scenarios in greater detail.

The projections for conditions and performance in each scenario are estimates of what could be achieved with a given level of investment scenario, assuming an economically driven approach to project selection, in which projects with the highest estimated benefit-cost ratios are always implemented first. The projections do not necessarily represent what would be achieved given current decision-making practices, which often include noneconomic 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.

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

Scenario Component	Sustain 2014–2018 Spending Scenario	Maintain Conditions and Performance Scenario	Improve Conditions and Performance Scenario
HERS-Derived	Sustain spending on types of capital improvements modeled in HERS at the average level over the five-year period 2014 through 2018 in constant-dollar terms over the next 20 years.	Set spending at the lowest level at which (1) projected share of travel on pavements with poor ride quality in 2038 matches (or is better than) the value in 2018 and (2) projected share of travel on severely congested roads in 2038 matches (or is better than) the value in 2018.	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).
NBIAS-Derived	Sustain spending on types of capital improvements modeled in NBIAS at the average level over the five-year period 2014 through 2018 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 2038 matches that in 2018.	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).
Other (Nonmodeled)	Sustain spending on types of capital improvements not modeled in HERS or NBIAS at the average level over the five-year period 2014 through 2018 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.

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

Backlog Definition

The Investment Backlog is a subset of the Improve Conditions and Performance scenario that focuses on the investment needs for highway and bridge improvements that could be economically justified for immediate implementation, based on the base-year conditions and operational performance of the highway system. The Investment Backlog does not consider future increases in VMT or future physical deterioration of infrastructure assets. The Improve Conditions and Performance scenario has an analysis period of 20 years, whereas the Investment Backlog examines investment needs only in the base year (2018 in this report). 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 base-year highway and bridge investment backlog. 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 a definitive indicator of changes in overall system conditions and performance.

The term “Highway Repair Backlog” is used in this report to describe a subset of the Investment Backlog that excludes system expansion investments.

Exhibit 7-2: Relationships Among the Improve Conditions and Performance Scenario, the Investment Backlog, and the Highway Repair Backlog

Coverage	Improve Conditions and Performance Scenario	Investment Backlog	Highway Repair Backlog
Improvement Types Considered	Includes all types of highway capital improvements, including System Rehabilitation, System Enhancement, and System Expansion.	Same as Improve Conditions and Performance Scenario.	Includes System Rehabilitation and System Enhancement investments only.
Period Considered	Addresses existing conditions and performance deficiencies, as well as deficiencies expected to arise over 20 years.	Addresses existing conditions and performance deficiencies only.	Addresses existing conditions deficiencies only.

Scenario Spending Levels and Sources

Exhibit 7-3 summarizes capital investment levels associated with each 20-year scenario and the subsets of the Improve Conditions and Performance scenario, stated in constant 2018 dollars. The Sustain 2014–2018 Spending scenario fixes average annual investment at its recent 5-year (2014–2018) average level of $115.1 billion, resulting in total investment of greater than $2.3 trillion over 20 years.

Exhibit 7-3: Highway and Bridge Capital Investment Levels for 2019–2038, by Scenario

Scenario	20-year Total (Billions of 2018 Dollars)	Average Annual (Billions of 2018 Dollars)	Percent Difference Relative to Actual 2014–2018 Spending	Annual Investment Pattern
Sustain 2014–2018 Spending Scenario	$2,301.2	**$115.1**	0.0%	Flat
Maintain Conditions and Performance Scenario	$1,579.2	**$79.0**	-31.4%	Flat
Improve Conditions and Performance Scenario	$3,021.3	**$151.1**	31.3%	Variable
Investment Backlog	$1,089.4			
Highway Repair Backlog	$852.0			

Notes: The Investment Backlog and Rehab and Enhance are one-time estimates rather than sums across 20 years.
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 $79.0 billion, 31.4 percent less than the Sustain 2014–2018 Spending scenario level. This difference in annual investment suggests that recent levels of investment (average levels for 2014–2018) 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 state of the overall system as a whole, it may result in a combination of improvements and deterioration of subsets of the overall network. The investment level is constant over the whole analysis period.

KEY TAKEAWAY

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 $151.9 billion, 31.3 percent higher than the level of the Sustain 2014–2018 Spending scenario.

Achieving the objectives of the Improve Conditions and Performance scenario to fund all cost-beneficial potential projects would require an estimated average annual spending level of $151.1 billion, which exceeds the Sustain 2014–2018 Spending scenario level by 31.3 percent. Because of the 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. The total 20-year investment needed under this scenario is estimated to be approximately $3.0 trillion to address both the existing backlog and additional cost-beneficial investments over the next 20 years.

Investment needs for two subsets of the Improve Conditions and Performance scenario are also reported in *Exhibit 7-3*. The Investment Backlog reflects the funding required to cover all base-year highway and bridge improvements with a benefit-cost ratio greater than or equal to 1.0. It is estimated that the system needs about $1.089 trillion to eliminate the existing backlog recorded in 2018. The $852.0 billion Highway Repair Backlog includes system rehabilitation and enhancement needs, but excludes system expansion needs. Additional discussion of the backlog is presented in the Highway and Bridge Investment Backlog section later in this chapter.

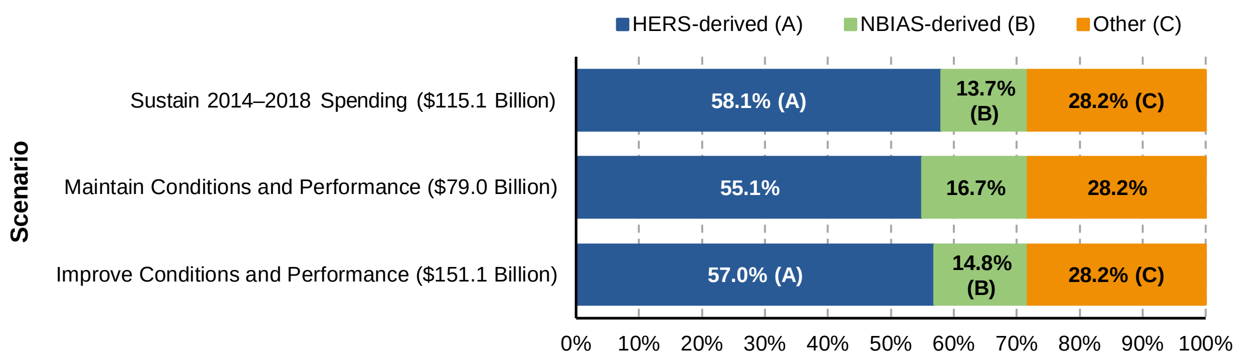
The compositions of the estimates of average annual investment levels are presented in *Exhibit 7-4*. By definition the shares of HERS- and NBIAS-derived components are identical under the Actual 2014–2018 Spending and Sustain 2014–2018 Spending scenarios. Other (nonmodeled) spending, is assumed to comprise the same share, fixed at 28.2 percent of total investment in all 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 public roads classified in Chapter 2 as system enhancements (safety enhancements, traffic operation improvements, and environmental enhancements).

KEY TAKEAWAY

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 2038 are maintained at 2018 levels. The average annual level of investment associated with this scenario is $79.0 billion, 31.4 percent lower than the level of the Sustain 2014–2018 Spending scenario.

The HERS-derived component represents spending on pavement rehabilitation and capacity expansion on Federal-aid highways, ranging between 55.1 percent and 58.1 percent of total investment needs. The NBIAS-derived component represents rehabilitation spending on all bridges, including those not on Federal-aid highways, and accounts for 13.7 percent to 16.7 percent of the total investment. 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.

Exhibit 7-4: Source of Highway and Bridge Capital Investment Scenarios, by Model



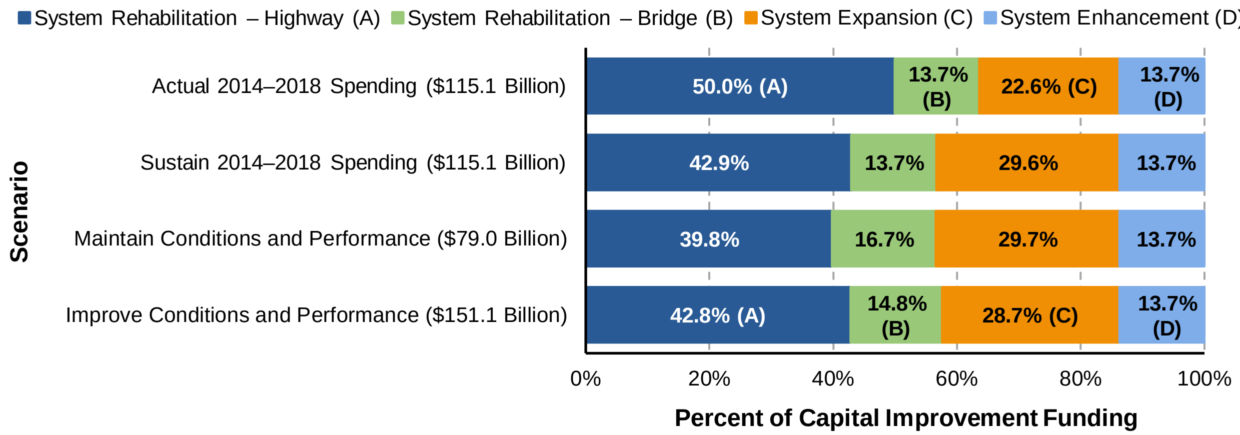
Sources: Highway Economic Requirements System (HERS) and National Bridge Investment Analysis System (NBIAS).

Scenario Investment Patterns and Conditions and Performance Projections

Exhibit 7-5 compares the distributions by improvement type from each investment scenario. The HERS model generates projected investment needs for highway system rehabilitation and highway expansion, whereas the NBIAS model generates projected investment needs for bridge rehabilitation. System enhancement is fixed at 13.7 percent of each scenario's total investment (based on actual recent spending distributions from 2014 to 2018).

As noted in Chapter 2, the share of capital outlay directed to system expansion by all levels of government combined on all roads declined from 36.9 percent in 2008 to 19.8 percent in 2018. The HERS and NBIAS modeling results suggest system expansion shares falling between these two points. Under the Sustain 2014–2018 Spending scenario, spending on system expansion constitutes 29.6 percent of the total. The Maintain Conditions and Performance and Improve Conditions and Performance scenarios suggest similar spending proportions on system expansion, at 29.7 percent and 28.7 percent, respectively.

Exhibit 7-5: Highway and Bridge Capital Investment Scenarios by Improvement Type, 2019–2038, Compared with Actual 2014–2018 Spending



Average Annual Distribution by Improvement Type	Actual 2014–2018 Spending	Sustain 2014–2018 Spending Scenario	Maintain Conditions & Performance Scenario	Improve Conditions & Performance Scenario
System Rehabilitation – Highway	$57.5	$49.4	$31.4	$64.6
System Rehabilitation – Bridge	$15.8	$15.8	$13.2	$22.3
System Rehabilitation – Total	**$73.3**	**$65.2**	**$44.7**	**$87.0**
System Expansion	$26.0	$34.1	$23.5	$43.3
System Enhancement	$15.8	$15.8	$10.8	$20.8
Total, All Improvement Types	**$115.1**	**$115.1**	**$79.0**	**$151.1**

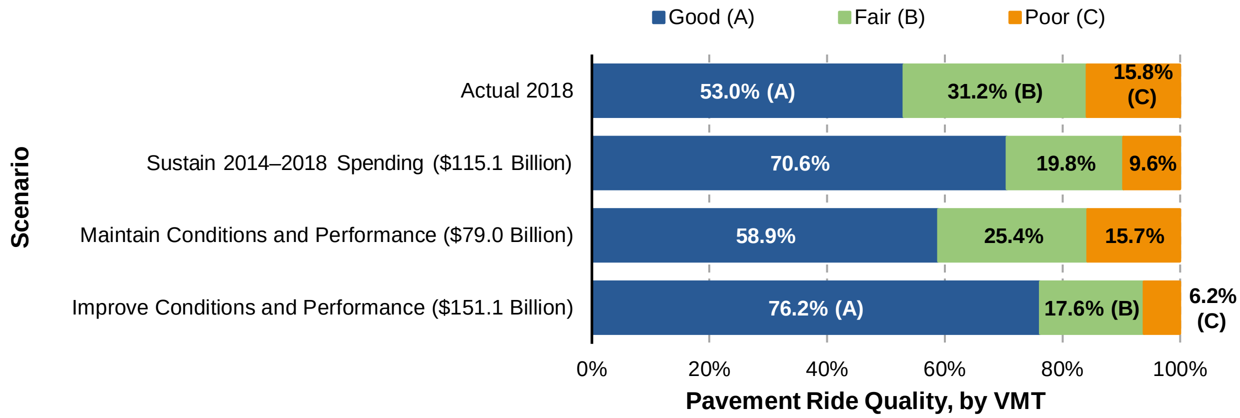
Note: Values are in billions of 2018 dollars.

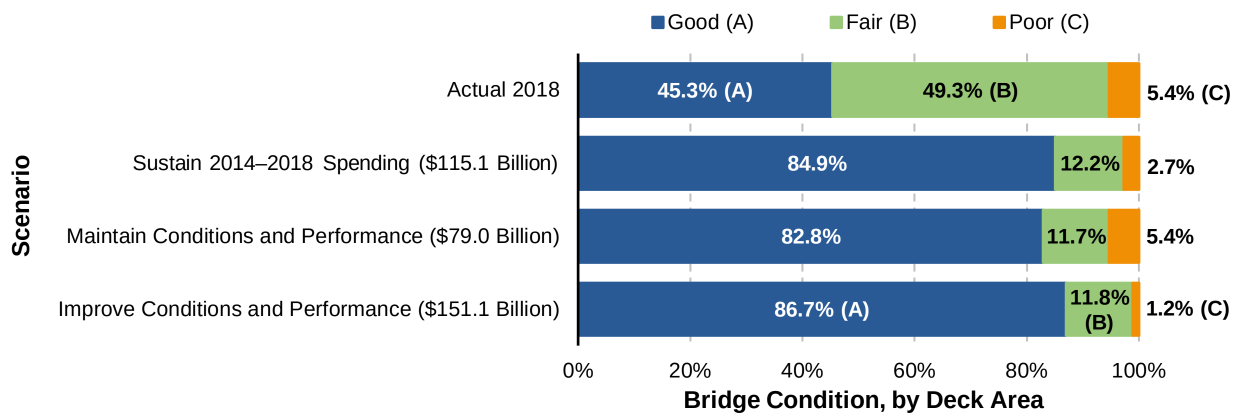
Sources: Highway Economic Requirements System and National Bridge Investment Analysis System.

Under the Improve Conditions and Performance scenario, annual spending on highway and bridge rehabilitation averages $87.0 billion, considerably more than the $73.3 billion of such annual spending from 2014 to 2018. This result suggests that achieving a state of good repair on the Nation's highways and bridges by implementing cost-beneficial system rehabilitation improvements would require either a significant increase in overall capital 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). The $115.0 billion of total capital outlay under the Sustain 2014–2018 Spending scenario exceeds the combined levels of system rehabilitation ($87.0 billion) and system enhancement ($20.8 billion) under the Improve Conditions and Performance scenario.

Exhibit 7-6 presents conditions and performance indicators for all 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 public roads in *Exhibit 7-6*. In contrast, NBIAS considers bridges on all public roads including those not on Federal-aid highways.

Exhibit 7-6: Highway and Bridge Capital Investment Scenarios, 2019–2038: Projected Impacts on Selected Highway Performance Measures





Projection Type	Highway Performance Measure	Actual 2018 Values	Sustain 2014–2018 Spending Scenario	Maintain Conditions & Performance Scenario	Improve Conditions & Performance Scenario
Projected 2038 Pavement Ride Quality and Bridge Conditions	Percent of VMT on pavements with good ride quality[1]	53.0%	70.6%	58.9%	76.2%
	Percent of VMT on pavements with fair ride quality[1]	31.2%	19.8%	25.4%	17.6%
	Percent of VMT on pavements with poor ride quality[1]	15.8%	9.6%	15.7%	6.2%
	Percent of bridges rated as good condition, by deck area	45.3%	84.9%	82.8%	86.7%
	Percent of bridges rated as fair condition, by deck area	49.3%	12.2%	11.7%	11.8%
	Percent of bridges rated as poor condition, by deck area	**5.4%**	2.7%	**5.4%**	1.2%
Projected 2038 Congestion	Percent of VMT on congested roads[1]	20.3%	20.9%	24.5%	19.1%
	Percent of VMT on severely congested roads[1]	**11.2%**	8.8%	**11.2%**	7.5%
Projected Changes by 2038 Relative to 2018	Percent change in average IRI (VMT-weighted)[1]	0.0%	-12.5%	-0.4%	-18.7%

[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.

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

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

Under the Sustain 2014–2018 Spending scenario, the share of vehicle miles traveled (VMT) on Federal-aid highways with poor ride quality would be reduced from 15.8 percent in 2018 to 9.6 percent in 2038, whereas the share on pavements with good ride quality would rise considerably from 53.0 percent to 70.6 percent. The share of VMT on congested roads (a V/SF ratio above 0.80) would increase slightly from 20.3 percent to 20.9 percent, whereas the share of VMT on severely congested roads (a V/SF ratio above 0.95) would decrease from 11.2 percent to 8.8 percent.

The cells shaded in *Exhibit 7-6* are the values relevant to the definition of the Maintain Conditions and Performance scenario. The share of bridges (as measured by deck area) rated in poor condition is estimated to be 5.4 percent in 2038 and the share of VMT on severely congested roads would be 11.2 percent in 2038. Both metrics match their actual values in 2018 as expected. However, the values of other indicators are different between their actual 2018 values and the Maintain Conditions and Performance scenario outputs.

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 2038, whereas the share on pavements with good ride quality would rise to 76.2 percent. The share of VMT on congested roads (a V/SF ratio of 0.80) would decrease to 19.1 percent.

The average International Roughness Index (IRI) value would decrease (improve) by 12.5 percent in 2038 relative to 2018. The share of bridges (weighted by deck area) that are rated as poor would halve from 5.4 percent in 2018 percent to 2.7 percent in 2038, whereas the share of good bridges would rise considerably from 45.3 percent to 84.9 percent.

The share of VMT on severely congested roads (a V/SF ratio of 0.95) would decrease to 7.5 percent. Average IRI would decrease (improve) by 18.7 percent over the 20-year period. The share of bridges (weighted by deck area) that are rated in poor condition is projected to drop to 1.2 percent in 2038, whereas the share rated as good would rise to 86.7 percent.

The Improve Conditions and Performance scenario would not eliminate all poor pavements and bridges because in some cases improving assets becomes cost-beneficial only after assets have declined into poor condition, and in others improving assets before they reach poor condition is cost-beneficial. Therefore, at the end of any given year, some portion of the pavement and bridge population would remain in poor condition.

KEY TAKEAWAY

The Sustain 2014–2018 Spending scenario assumes that capital spending by all levels of government is sustained through 2038 at the average annual level from 2014 to 2018 ($115.1 billion), and that all spending supports only cost-beneficial projects. Under these assumptions, the share of travel on pavements with poor ride quality is projected to improve (i.e., be reduced) by 6.2 percentage points, and the share of bridges classified as poor is also projected to improve, declining from 5.4 percent in 2018 to 2.7 percent by 2038.

KEY TAKEAWAY

Under the Maintain Conditions and Performance scenario, $44.7 billion per year would be directed to system rehabilitation, $23.5 billion to system expansion, and $10.8 billion to system enhancement. The share of travel on severely congested roads and the share of bridges classified as poor in 2038 would match their 2018 levels.

KEY TAKEAWAY

Under the Improve Conditions and Performance scenario, the share of travel on pavements with poor ride quality is projected to improve (i.e., to be reduced) from 15.8 percent to 6.2 percent; the share of travel on severely congested roads is projected to improve from 11.2 percent to 7.5 percent. The share of bridges classified as poor is also projected to improve, decreasing from 5.4 percent in 2018 to 1.2 percent in 2038.

VMT-Weighting and Deck Area-Weighting

The performance indicators presented in Exhibit 7-6 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.

Improve Conditions and Performance Scenario

The design of the Improve Conditions and Performance scenario makes it easier to further explore the results compared to 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 for all assets in the system, one would obtain the same result for each functional class whether analyzed separately or as part of a systemwide run.

Spending by Capital Improvement Type and System

Exhibit 7-7 compares the distribution of spending for the Improve Conditions and Performance scenario by system and by capital improvement type against the distribution of actual recent spending (average levels for 2014–2018). As noted in Chapter 1, the Interstate Highway System is a subset of the NHS, which is a subset of Federal-aid highways, which subsequently is a subset of the overall network of public roads. About 22.1 percent of the Improve Conditions and Performance scenario investment is dedicated to improvements to Interstate highways, 50.6 percent to improvements to the NHS, and 78.4 percent goes for improvements to Federal-aid highways.

The capital investment in the Improve Conditions and Performance scenario shown in *Exhibit 7-7* varies relative to the actual recent (2014 to 2018) spending amounts. To fund all projects that are cost-beneficial, total capital investment on all public roads would need to be increased by 31.3 percent to $151.1 billion. This increase would not be distributed equally across improvement types. As noted previously, system expansion would increase under the Improve Conditions and Performance scenario. Chapter 2 concludes that trends have shown a decline in system expansion spending over the last 10 years (with an annual rate of change of -1.7 percent, see *Exhibit 2-17*). The HERS model results suggest that to improve conditions, annual investment on system expansion and bridge rehabilitation would need to increase. Annual investment on system expansion would increase by 66.8 percent, and investment on bridge

KEY TAKEAWAY

The Improve Conditions and Performance scenario includes average annual spending of $87.0 billion (57.6 percent) for the $151.1 billion for system rehabilitation, $20.8 billion (13.7 percent) for system enhancement, and $43.3 billion (28.7 percent) for system expansion.

rehabilitation would increase by 41.7 percent. Capital investment for highway system rehabilitation would rise modestly by 12.4 percent. As presented in Chapter 2, highway rehabilitation spending has nearly doubled from 2008 to 2018 (see *Exhibit 2-17*), and under the Improve Conditions and Performance scenario the model indicates that Interstate and NHS rehabilitation spending are below average annual investment levels (-32.0 percent and -8.1 percent, respectively), indicating that investments have made headway on improving pavements. Investment in system enhancement is designed to increase at the same rate as total investment, by 31.3 percent.

Overall spending on all improvement types for Interstate highways under the Improve Conditions and Performance scenario is $33.3 billion per year, 22.4 percent higher than actual 2014–2018 spending. Total investment on the NHS is 27.9 percent higher under this scenario than actual 2014–2018 spending, and investment on Federal-aid highways is 33.6 percent higher.

Exhibit 7-7: Improve Conditions and Performance Scenario, 2019–2038: Distribution by System and Improvement Type Compared with Actual 2014–2018 Spending

Investment	System Component	System Rehabilitation			System Expansion	System Enhancement	Total	Percent of Total
		Highway	Bridge	Total				
Average Annual Investment	Interstate Highway System	$10.5	$7.8	$18.3	$12.2	$2.8	$33.3	22.1%
	National Highway System	$27.2	$13.7	$40.9	$27.9	$7.7	$76.5	50.6%
	Federal-aid Highways	$46.9	$19.1	$66.0	$39.2	$13.2	$118.4	78.4%
	All Roads	$64.6	$22.3	$87.0	$43.3	$20.8	$151.1	100.0%
Percentage Above (positive %) or Below (negative %) Average 2014–2018 Annual Investment	Interstate Highway System	-32.0%	138.6%	-2.1%	91.3%	31.3%	22.4%	
	National Highway System	-8.1%	85.2%	10.5%	64.3%	31.3%	27.9%	
	Federal-aid Highways	6.6%	62.5%	18.4%	71.7%	31.3%	33.6%	
	All Roads	12.4%	41.7%	18.7%	66.8%	31.3%	31.3%	

Note: Values are in billions of 2018 dollars.

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

For Interstate highways and the NHS, the largest gap between average annual investment under the Improve Conditions and Performance scenario and average actual 2014–2018 investment is for bridge rehabilitation. The $7.8 billion in average annual bridge rehabilitation needs identified under the Improve Conditions and Performance scenario for Interstate highways is 138.6 percent higher than actual spending in this category from 2014 to 2018. The required investment for bridge rehabilitation is also considerably higher than spending in this category for the NHS (85.2 percent).

Spending by Improvement Type and Highway Functional Class

Exhibit 7-8 presents the distribution by improvement type and highway functional class for the Improve Conditions and Performance scenario. Within the $118.4 billion of average annual investments identified for Federal-aid highways, $24.5 billion (20.7 percent) was for highways and bridges in rural areas. The data show that other principal arterial roads are the largest investment category in the rural locations ($7.1 billion) whereas Interstates are the largest category in urban locations ($27.8 billion). *Exhibit 7-9* compares the annual investment with actual 2014–2018 spending. Negative percentages indicate potentials for resource reallocation to achieve higher economic efficiency.

Exhibit 7-8: Improve Conditions and Performance Scenario, 2019–2038: Average Annual Investment Distribution by Functional Class and Improvement Type

Location	Functional Class	System Rehabilitation			System Expansion	System Enhancement	Total
		Highway	Bridge	Total			
Rural Federal-aid Highways	Interstate	$2.4	$1.5	$3.9	$0.8	*$0.9*	$5.5
	Other Principal Arterial	$3.7	$1.2	$4.9	$1.2	*$1.1*	$7.1
	Minor Arterial	$3.1	$1.0	$4.1	$0.8	*$0.9*	$5.7
	Major Collector	$3.2	$1.6	$4.8	$0.2	*$1.1*	$6.1
	Subtotal	**$12.3**	**$5.4**	**$17.7**	**$2.9**	**$3.9**	**$24.5**
Urban Federal-aid Highways	Interstate	$8.1	$6.3	$14.4	$11.4	*$2.0*	$27.8
	Other Freeway and Expressway	$3.9	$2.1	$6.0	$5.3	*$0.9*	$12.1
	Other Principal Arterial	$9.7	$2.5	$12.3	$9.5	*$2.6*	$24.3
	Minor Arterial	$8.2	$2.0	$10.2	$6.6	*$2.2*	$19.0
	Collector	$4.7	$0.8	$5.5	$3.4	*$1.7*	$10.7
	Subtotal	**$34.6**	**$13.8**	**$48.4**	**$36.3**	**$9.3**	**$93.9**
Rural and Urban Combined	**Total, Federal-aid highways[1]**	**$46.9**	**$19.1**	**$66.0**	**$39.2**	**$13.2**	**$118.4**
	Non-Federal-aid Highways	*$17.7*	$3.2	$21.0	*$4.1*	*$7.6*	$32.7
	Total, All Public Roads	**$64.6**	**$22.3**	**$87.0**	**$43.3**	**$20.8**	**$151.1**

Note: Values are average annual investment levels over 20 years in billions of 2018 dollars.

[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.

Exhibit 7-9: Improve Conditions and Performance Scenario Compared with Actual 2014–2018 Spending by Functional Class and Improvement Type, Percent Change

Location	Functional Class	System Rehabilitation			System Expansion	System Enhancement	Total
		Highway	Bridge	Total			
Rural Federal-aid Highways	Interstate	-53.9%	142.4%	-32.9%	-44.7%	31.3%	-29.6%
	Other Principal Arterial	-30.9%	63.9%	-19.0%	-66.6%	31.3%	-31.0%
	Minor Arterial	-9.5%	21.2%	-3.4%	-25.1%	31.3%	-3.6%
	Major Collector	-21.8%	12.9%	-12.8%	-69.9%	31.3%	-13.2%
	Subtotal	**-31.5%**	**47.7%**	**-18.2%**	**-55.6%**	**31.3%**	**-21.4%**
Urban Federal-aid Highways	Interstate	-20.8%	137.7%	11.9%	128.4%	31.3%	43.5%
	Other Freeway and Expressway	83.5%	138.3%	99.7%	190.4%	31.3%	121.4%
	Other Principal Arterial	71.1%	5.4%	51.5%	85.8%	31.3%	60.5%
	Minor Arterial	76.3%	55.9%	71.9%	138.2%	31.3%	83.2%
	Collector	39.0%	-9.8%	28.4%	125.1%	31.3%	49.7%
	Subtotal	**32.9%**	**69.1%**	**41.5%**	**123.3%**	**31.3%**	**63.3%**
Rural and Urban Combined	**Total, Federal-aid highways[1]**	**6.6%**	**62.5%**	**18.4%**	**71.7%**	**31.3%**	**33.6%**
	Non-Federal-aid Highways	31.3%	-19.5%	19.7%	31.3%	31.3%	23.6%
	Total, All Public Roads	**12.4%**	**41.7%**	**18.7%**	**66.8%**	**31.3%**	**31.3%**

Note: Positive percentage indicate the average annual Improve Conditions and Performance level for 2019-2038 is higher than average recent spending from 2014 to 2018. Negative percentages indicate the Improve Conditions and Performance level is lower.

[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.

Extracting increased granularity of data from 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 (2014 to 2018) spending are for system expansion for urban other freeways and expressways (190.4 percent), bridge rehabilitation on the rural portion of the Interstate System (142.4 percent), and bridge rehabilitation on the urban portion of the other freeways and expressways (138.3 percent). The Improve Conditions and Performance scenario also suggests total investment decreases in rural arterials and major collectors (down 21.4 percent) and increases in urban arterials and collectors (up 63.3 percent). Among functional classes, the gap between investment needs under the Improve Conditions and Performance scenario and 2014–2018 spending is the highest on urban other freeways and expressways (121.4 percent). Conversely, investment needs are the lowest relative to 2014–2018 spending on rural other principal arterials, 31.0 percent lower than the actual 2014–2018 spending.

The Improve Conditions and Performance scenario also suggests that increasing investment for system rehabilitation on urban bridges by 69.1 percent and increasing system expansion on urban highways and bridges by 123.3 percent could be economically justified. This resource allocation also includes a lower investment level in rural system expansion (decrease by 55.6 percent) and higher investment level in rural bridge rehabilitation (increase by 47.7 percent).

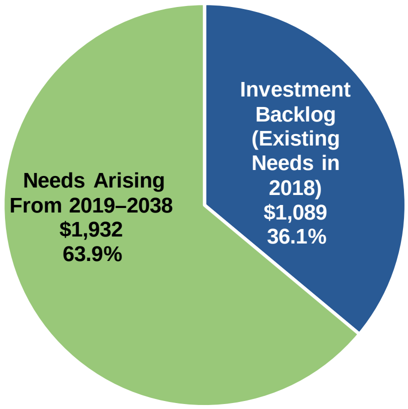
The largest funding gaps (in percentage terms) relative to actual recent (2014 to 2018) spending are for system expansion for urban other freeways and expressways (190.4 percent), bridge rehabilitation on the rural portion of the Interstate System (142.4 percent), and bridge rehabilitation on the urban portion of Interstate and the other freeways and expressways (137.7 percent and 138.3 percent, respectively).

Highway and Bridge Investment Backlog

As discussed earlier in this chapter, the Investment Backlog represents all highway and bridge improvements that could be economically justified for immediate implementation to address any base-year conditions and operational performance deficiencies of the 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 base-year highway and bridge investment backlog.

Conceptually, the Investment Backlog represents a subset of the investment levels reflected in the Improve Conditions and Performance scenario. *Exhibit 7-3* identified an average annual investment level of $151.1 billion for this scenario, for a 20-year total of over $3.0 trillion. Of this total, roughly $1.1 trillion (36.1 percent) is attributable to the existing backlog as of 2018; the remainder is attributable to additional projected pavement, bridge, and capacity needs that might arise over the next 20 years (see *Exhibit 7-10*).

Exhibit 7-10: Composition of 20-year Improve Conditions and Performance Scenario, Investment Backlog vs. Emerging Needs



Note: Values are in billions of 2018 dollars.

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

Exhibit 7-11 presents an estimated breakdown of the $1.1 trillion backlog estimated for 2018, by type of capital improvement. 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.

KEY TAKEAWAY

About 36.1 percent of the capital investment under the Improve Conditions and Performance scenario would go to addressing a backlog of cost-beneficial investments of $1.1 trillion. The rest would address new needs arising from 2019 through 2038.

Of the estimated $1.1 trillion total backlog, approximately $195.9 billion (18.0 percent) is for the Interstate System, $509.9 billion (46.8 percent) is for the NHS, and $848.5 billion (77.9 percent) is for Federal-aid highways.

The share of the total backlog attributable to system expansion is 27.0 percent ($52.9 billion) for the Interstate System, 29.2 percent ($148.7 billion) for the NHS, 24.5 percent ($207.5 billion) for Federal-aid Highways, and 21.8 percent ($237.4 billion) on all public roads. The estimated Highway Repair Backlog (which excludes system expansion needs) is $143.0 billion on the Interstate System, $361.2 billion on the NHS, $641.0 billion on Federal-aid highways, and $852.0 billion on all public roads.

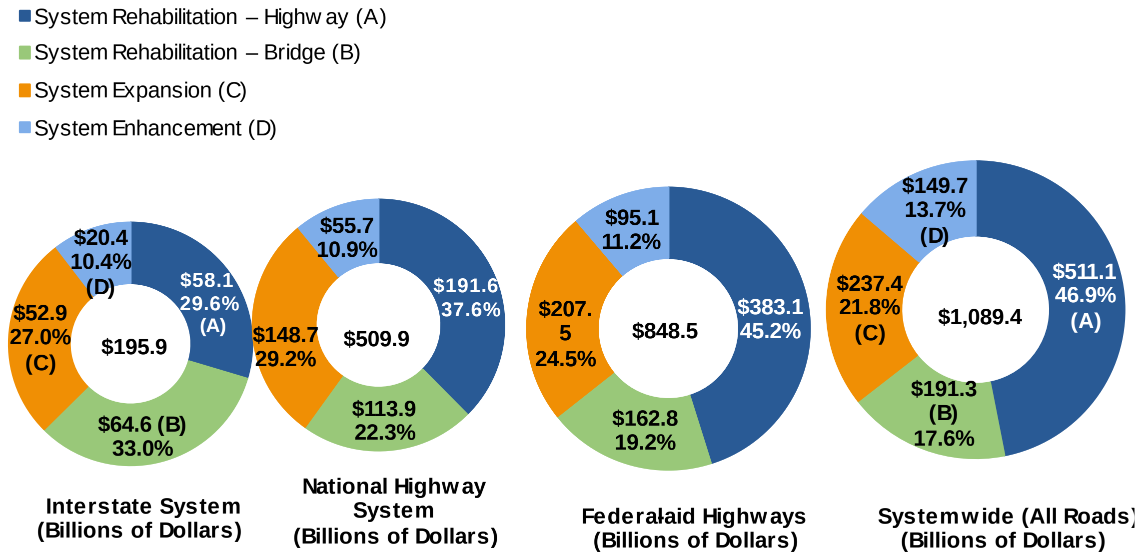
The share of the total backlog attributable to system rehabilitation for the Interstate System is 62.6 percent; for the NHS it is 59.9 percent and for Federal-aid highways it is 64.3 percent. For all roadways, approximately 64.5 percent ($702.4 billion) of the total backlog is attributable to system rehabilitation needs. However, the proportion of system rehabilitation dedicated to bridges, relative to total capital spending, differs substantially across systems: 33.0 percent on the Interstate System, 22.3 percent on the NHS, 19.2 percent on Federal-aid highways, and 17.6 percent on all public roads. The portion of highway system rehabilitation increases across highway systems in the opposite direction: 29.6 percent on the Interstate System, 37.6 percent on the NHS, 45.2 percent on Federal-aid highways, and 46.9 percent on all public roads.

KEY TAKEAWAY

The $1.1 trillion backlog includes $237 billion for system expansion and $852 billion for existing assets. This $852 billion Highway Repair Backlog includes $511 billion for the pavement component of system rehabilitation investments, $191 billion for the bridge component of system rehabilitation investments, $237 billion for system expansion, and $150 billion for system enhancement.

The more than $1.1 trillion estimated backlog is weighted toward urban areas: approximately 59.8 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 and urban areas also face relatively greater problems with congestion than do rural areas. Very little of the backlog spending (just $20.0 billion) is targeted toward system expansion on rural Federal-aid highways.

Exhibit 7-11: Estimated Highway and Bridge Investment Backlog in 2018, by System and Improvement Type



System Component	System Rehabilitation[1]			System Enhancement	Subtotal, Highway Repair Backlog	System Expansion	Total Investment Backlog	Percent of Total
	Highway	Bridge	Total					
Federal-aid Highways – Rural	$97.0	$52.5	$149.6	*$27.9*	$177.5	$20.0	$197.5	18.1%
Federal-aid Highways – Urban	$286.1	$110.2	$396.4	*$67.2*	$463.5	$187.4	$650.9	59.8%
Federal-aid Highways – Total	**$383.1**	**$162.8**	**$545.9**	**$95.1**	**$641.0**	**$207.5**	**$848.5**	**77.9%**
Non-Federal-aid Highways	*$127.9*	$28.5	$156.4	*$54.6*	$211.0	*$29.9*	$240.9	22.1%
All Public Roads	**$511.1**	**$191.3**	**$702.4**	**$149.7**	**$852.0**	**$237.4**	**$1,089.4**	**100.0%**
Interstate System	$58.1	$64.6	$122.6	*$20.4*	$143.0	$52.9	$195.9	18.0%
National Highway System	$191.6	$113.9	$305.5	*$55.7*	$361.2	$148.7	$509.9	46.8%

[1]Italicized values are estimates for the system components and improvement types not modeled in the Highway Economic Requirements System (HERS) or the National Bridge Investment Analysis System (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.

Note: Values are in billions of 2018 dollars.

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 2014–2018 Spending, Expansion, and Expansion with Growth, as well as a State of Good Repair (SGR) Benchmark. All scenarios, as well as the SGR Benchmark, are based on funding levels and estimated investment levels across all levels of government—Federal, State, and local—combined.

This edition of the C&P Report introduces significant changes to the estimation of transit expansion investment levels compared with prior reports. Recent C&P editions focused solely on levels of expansion investment required to support future rider growth; this edition introduces several new analysis components designed to estimate the level of investment required to attain service performance and service coverage objectives. These new components estimate investment levels required to (1) introduce service to "transit deserts," areas where there is no scheduled fixed-route transit service available within walking distance of one-half mile, (2) increase service on low-frequency routes, (3) reduce crowding for high-utilization operators, (4) increase operating speeds in urbanized areas with speeds below the national average, and (5) funding for planned New Starts Pipeline investments. Appendix C includes a detailed description of each of the individual analysis components used in this edition to estimate the level of investment associated with these types of service enhancements.

SECTION SUMMARY

At 2014–2018 spending levels, the SGR backlog is expected to increase marginally from an estimated $101.4 billion in 2018 to $106.2 billion in 2038, a 4.8-percent increase over 20 years. An estimated $19.5 billion from all sources in annual reinvestment would be required to fully eliminate the SGR backlog by 2038 (versus $13.5 billion in annual spending over 2014–2018).

In addition, the following investment levels in expansion would be required for the Expansion and Expansion with Growth scenarios.

- **Expansion scenario:** This scenario forecasts investments of $6.6 billion per year in new assets to support planned New Starts investments ($1.4 billion), add or expand service to underserved regions ($0.3 billion), reduce crowding on high utilization systems ($2.4 billion), and increase operating speeds in urban areas where the average speed is low ($2.4 billion).
- **Expansion with Growth scenario:** This scenario forecasts $8.5 billion per year to address all Expansion scenario expansion investments as well as projected ridership growth, taking recent ridership declines due to COVID-19 into account.

In contrast to recent C&P Reports, where expansion investment estimates focused solely on investments to address growing rider demand, the estimates for the current Expansion scenarios were developed using a range of new methodologies with increased focus on service supply and quality.

Expansion Investment Estimation Components

Transit expansion investment levels for recent C&P Report editions were estimated using a single, ridership growth-based approach. This edition uses six separate analysis components to estimate transit expansion investment levels: one for investing in expansion assets to accommodate expected ridership growth, and five for investing to improve transit performance and/or accessibility (e.g., by expanding service coverage or increasing frequency). With one exception (New Starts Pipeline), each analysis component was designed to determine specific performance and/or accessibility improvement targets. The following descriptions of each component discuss objective, methodology, impacted modes or service regions, and supporting data sources. Approaches to estimating these components could independently identify the same (or similar) investments in performance improvement in the same location (e.g., investment in light rail expansion in the same UZA), and any instances of such double-counting were removed from the final expansion investment tally.

Investments to Improve Performance and Accessibility

Investments to improve performance, accessibility, and the quality of transit service include those that expand transit asset holdings with the intention of improving transit performance measures such as system coverage, service frequency, operating speed, and capacity (e.g., fleet size or throughput). *Exhibit 7-12* provides descriptions of the five components used to identify investments in transit performance improvement in this edition of the C&P Report.

Exhibit 7-12: Components to Improve Performance and Accessibility

Expansion Analysis Component	Component Objective
Service Coverage (Transit Deserts)	Expand transit service to cover areas without service but with sufficient residential density to support fixed-route service
Service Frequency	Increase service frequency where residential density indicates that service is inadequate
New Starts Pipeline	Invest in all planned and approved projects in the New Starts Pipeline
Average Speed Improvement	Improve the average transit operating speeds in urbanized areas that are well below the national average
Vehicle Occupancy Improvement	Reduce vehicle occupancy rates (crowding) for agencies that are well below the national average (calculated separately for each transit agency-mode combination)

Source: Transit Economic Requirements Model.

Appendix C provides additional technical information on the Transit Economic Requirements Model (TERM) and the methodologies used to generate the estimates for the current edition of the C&P Report.

Service Coverage and Service Frequency

New methodologies were developed to identify and quantify 20-year capital expansion investment levels for communities that are either not served by fixed-route transit service or are underserved based on the frequency of service currently provided. Residents of transit deserts lack accessibility to fixed-route transit service, despite having sufficient residential density to supports this level of service. Other communities within urbanized areas may have some existing fixed-route transit service within walking distance, but not at a frequency level that is justified based on residential densities. In both instances, the supply of transit service may be insufficient relative to the potential demand that could be supported within these areas.

The Transit Capacity and Quality of Service Manual, published by the Transportation Research Board of the National Academies of Science, Engineering, and Medicine, identifies accessibility as a "measure of availability" and frequency as a "measure of comfort and convenience." Both are central to the quality of transit service experienced by passengers.[32]

The term "first-mile/last-mile" refers to the challenges and potential solutions to reducing the distance between a traveler's origin or destination and a transit station or bus stop. Expanding coverage addresses first-mile/last-mile accessibility by reducing the distance to the nearest bus stop and making transit a more convenient option for travelers. Even if transit service is provided within walking distance, the frequency of service is a key determinant of whether transit is chosen over other modes such as driving. Both coverage and frequency are critical

[32] Transportation Research Board, 2013. *Transit Capacity and Quality of Service Manual*, 3rd Edition, Section 4.3, "Quality of Service Framework." Available at https://www.trb.org/Main/Blurbs/169437.aspx

issues for transit agencies as they strive to retain and attract transit riders in an equitable manner. Land-use policies that encourage transit-oriented development (TOD) can lead to significant increases in transit use and improved access to the system. Overall transit performance can improve when bus routes do not need to deviate from existing high-frequency corridors to serve activity centers not located near transit. It should be noted that transit agencies typically do not have control over land use and must coordinate with local and state agencies to promote transit-supportive land use policies.

The analysis identifies regions in each of the Nation's urbanized areas that warrant either introducing fixed-route transit service or adding transit service based on housing density. These two geography-based components were estimated nationally for all UZAs with complete and validated Generalized Network Transit Specification (GTFS) transit networks, which included 297 UZAs representing 95 percent of the total transit VRM provided in UZAs. These results were factored into the expansion investment levels for the remaining 188 UZAs not originally included in the analysis. Investments to improve service in underserved communities consist of investments in buses and their support assets.

There is a strong, widely accepted relationship between density and fixed-route transit ridership. For this analysis, housing unit density is used to identify residential neighborhoods that have sufficient density to support fixed-route transit. Housing unit density can be calculated using Census data at the block group level, but other factors beyond the scope of this analysis are also important for determining where to offer fixed-route transit service such as the need for connections to jobs and activities, connections to other transit services, the pedestrian network around bus stops, traffic congestion, and parking prices in the service area.

The two types of density-based analysis are:

- **Expand Coverage by Serving Transit Deserts:** This component identifies regions in each urbanized area that are not served by fixed-route transit but that warrant fixed-route transit service according to their housing unit density.
- **Improve Frequency:** Similarly, this component identifies regions in UZAs that are served by fixed-route transit but that warrant an increase in service frequency—again, based on density.

Exhibit 7-13 lists the dwelling unit density thresholds used to identify the minimum average headway supported. For example, based on these guidelines, an area with less than four dwelling units per acre is considered to not have sufficient density to support regular fixed-route transit service. Dwelling unit density of at least seven dwelling units per net acre are needed to support bus headways of 30 minutes or better.

Exhibit 7-13: Minimum Headway Supported by Density Levels

Dwelling Unit Density	Minimum Average Headway Supported
< 4 dwelling units/net acre	Density insufficient to support regular fixed-route transit
4 dwelling units/net acre	60 minutes
7 dwelling units/net acre	30 minutes
15 dwelling units/net acre	15 minutes

Source: Pushkarev, B.S., and J.M. Zupan, 1977. *Public Transportation and Land Use Policy*, as cited in Transportation Research Board, 2013. *Transit Capacity and Quality of Service Manual*, 3rd Edition, Exhibit 5-2.

These headway thresholds are the current standards established by the Transit Capacity and Quality of Service Manual. Future research, including future editions of this report, will consider revisiting these standards based on current ridership trends including post-COVID changes. The suitability of these standards is explored in more detail in Appendix C, specifically in the "Service Coverage and Service Frequency" section.

A. Data Sources and Preprocessing

The service coverage analysis and the service frequency analysis are based on the same data sources used to calculate residential density and the availability and frequency of transit service. The density-based analysis uses multiple data sources to determine housing unit density and transit service levels in UZAs:

- Block group and UZA geography data were downloaded from the Tiger/LINE portal on the Census Bureau website in shapefile format.
- Demographic information, including data on population and housing units for all block groups, was downloaded separately from the Census Bureau's data portal.
- Generalized Network Transit Specification (GTFS) feeds were compiled for UZAs where data were available. A variety of sources were used to compile GTFS feeds, including aggregators such as Transitland, State-specific GTFS databases, and direct downloads from agency websites. Each feed was checked to ensure that the files required to assess frequency (stops.txt, stop_times.txt, routes.txt, and trips.txt) were present and formatted properly.

Appendix C contains exhibits listing the data used in the service coverage and service frequency components of the transit investment analysis, by UZA, including the transit revenue miles of service provided and the population served.

Dwelling unit density was calculated for all block groups that fall within UZA boundaries by dividing the total number of housing units in a block group by the area of each block group in square miles. For density, the primary source used in this analysis was the 2010 Census at the block group level.

To project transit service expansion levels to 2038, it is necessary to determine which block groups might move into a different stratum of dwelling unit density in the next 20 years. In the absence of a source for long-range population and dwelling unit forecasts at the block group level, trendline growth rates were used to project future density. Historical population and dwelling unit counts from the 2000 and 2010 censuses, as well as population and dwelling unit estimates from the 2017 American Community Survey, were compiled for each block group. Using the 2000 and 2017 population and dwelling unit totals, the compound annual growth rate (CAGR) was calculated for population and dwelling units separately for each block group.

Using the 2000 and 2017 population and dwelling unit totals, the compound annual growth rate (CAGR) was calculated for population and dwelling units separately for each block group. The formula for this calculation can be found in Appendix C under "Data Sources and Pre-Processing." This CAGR was applied to each year between 2018 and 2038 to project the future dwelling units for each block group. Because block groups with extremely high growth or large decline between 2000 and 2017 might skew the data, a 3-percent annual growth cap was applied to ensure reasonableness. The dwelling unit density for each block group in 2038 was used in the analysis of future service coverage and service frequency expansion levels.

B. Coverage Analysis

The coverage, or transit desert, analysis is designed to account for portions of UZAs that are not served by any regular fixed-route transit service but where housing unit density is high enough to support regular service. As shown in *Exhibit 7-13*, areas with a residential density of four housing units per acre and higher can support at least hourly fixed-route bus service. This analysis determines which block groups in a UZA were not served by regular transit service and applies a factor to calculate the vehicle revenue miles (VRM) needed to serve the transit desert block groups where coverage deficiencies were identified.

The analysis has the following steps (*Exhibit 7-14*):

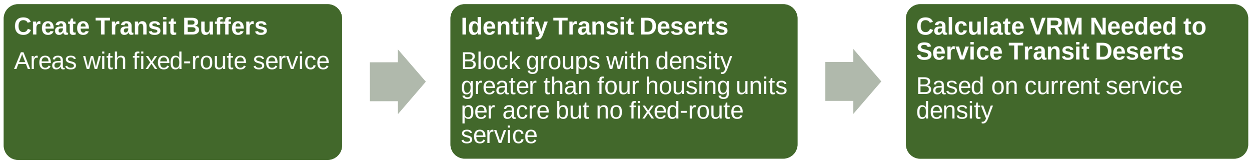
1. **Create transit buffers.** Block group geography and transit stop locations, using the GTFS feeds, were compiled for all UZAs in a geographic information system (GIS). For this analysis, areas within one-half mile[33] of each bus stop or station were classified as being within a walkable buffer of the bus stop. These transit buffers indicate the areas that have walk access to fixed-route transit service.

   This analysis was a straight-line analysis. In practice, the true service area for a transit stop is limited by the extent to which sidewalks are available and the extent to which there are barriers to pedestrian traffic. Attempting to address these walkability considerations was beyond the resources available for this edition of the C&P Report.

2. **Identify transit deserts.** Overlaying the transit stops with the block groups in the UZAs enables the identification of block groups that are expected to have a density greater than four dwelling units per net acre in 2038 but are not currently served by fixed-route transit, i.e., transit deserts.

3. **Calculate VRM needed to serve transit deserts.** The VRM needed to serve transit deserts is calculated by applying the service density ratio of the entire UZA to the area of the desert block groups. Annual fixed-route VRMs for each UZA were calculated by summing the annual VRM of the Motor Bus, Commuter Bus, and Rapid Bus modes in the service tables of the National Transit Database (NTD). The equations used to calculate VRM can be found in Appendix C in the "Coverage Analysis" section.

Exhibit 7-14: Coverage Analysis Methodology



Source: Analysis by Federal Transit Administration.

This approximation of service needs assumes that the amount of VRM required to serve the transit desert block groups will be proportional to the area of the desert block groups—but this is a rough approximation. Actual service levels would be expected to differ from the estimate if development is uneven within a block group, requiring service to just a portion of the block group; if the service levels in a service area are much higher than is needed to serve transit desert block groups; or if the block group is far removed from the service area, requiring additional VRM to connect transit desert block groups to transit routes.

Exhibit 7-15 summarizes the service coverage analysis results. The analysis found that 1,446 block groups, totaling 2.2 million people, would qualify as transit deserts based on current density levels. At 2038 population density levels, a total of 2,609 block groups with a population of 5.1 million people would qualify as transit deserts. Serving all desert block groups that would reach the threshold density by 2038 would require an increase in VRM of 1.5 percent over current service levels, for all UZAs nationwide.

[33] Guerra, Erick, Robert Cervero, and Daniel Tischler, 2012. "Half-Mile Circle: Does It Best Represent Transit Station Catchments?" *Transportation Research Record* 2276 (1): 101–9. https://doi.org/10.3141/2276-12

Exhibit 7-15: Coverage Analysis Results

Coverage	Fixed-Route Vehicle Revenue Miles	Population	Number of Block Groups	Area of Block Groups (square miles)
All UZAs Analyzed	1,981,622,912	176,217,778	159,269	267,354
Additional Coverage Needed to Serve Deserts (2038 Density Levels)	30,217,445 (+1.5%)	5,120,679 (+2.9%)	2,609	900

Source: Analysis by Federal Transit Administration.

C. Frequency Analysis

The transit coverage analysis identifies only service deficiencies for areas with no fixed-route transit service. Analysis of service frequency was also conducted, to account for portions of UZAs that have fixed-route service but where service is inadequate for the residential density. The transit frequency analysis was designed to account for new service needed in these areas; it divides block groups into residential density categories with specific recommended hourly peak fixed-route transit headways, as shown previously in *Exhibit 7-13*. For example, block groups with a density of seven dwelling units per net acre are assumed to be able to support fixed-route bus service at 30-minute headways or better.

Each block group was evaluated based on its existing peak period transit service, calculated from the highest-frequency transit stop within a half-mile buffer of the block group. If the peak period service was less frequent than the recommended service level for the density threshold of a given block group, the transit route serving the block group was flagged as having a frequency deficiency. A calculation was made of the VRM necessary to increase service on the deficient route to meet the recommended peak headway.

The analysis includes the following steps:

1. **Calculate stop frequency from GTFS.** The average headway was calculated at each bus stop along each route in the morning peak period from 5 to 9 a.m., using GTFS feeds.
2. **Calculate the minimum headway for block groups with transit service.** For each block group, the frequencies at bus stops within walking distance (less than one-half mile) of the block group were compiled. The bus stop with the most frequent service—service with the shortest headway—was associated with the block group in which it is located.
3. **Determine underserved block groups and underserved routes.** All block groups where the calculated bus stop headway was longer than the required minimum headway, based on dwelling unit density, are classified as underserved. The next step was to determine which specific routes need more service to bring every block group up to its recommended frequency thresholds.
4. **Calculate VRM required to meet frequency thresholds.** The number of additional peak-period trips on each route needed to meet the frequency threshold was multiplied by the length of the route to calculate the additional revenue miles needed to meet frequency thresholds in the peak periods. The total daily additional VRM was summed for the UZA and factored to obtain the annual VRM needed to make up frequency deficiencies. Service increases are assumed for the entire length of a route that is serving any block group with a deficient frequency level affecting the additional service required.

Exhibit 7-16 summarizes the service coverage analysis results.

Exhibit 7-16: Analysis Results: Additional Service Needed to Address Frequency Deficiencies

Fixed-Route Vehicle Revenue Miles	Population in Underserved Block Groups	Routes Receiving Frequency Upgrades Based on Density Thresholds			
		To 15-Minute Headways	To 30-Minute Headways	To 60-Minute Headways	Total
85,055,160 (+4.3%)	5,120,679	457	806	433	1,696

Source: Analysis by Federal Transit Administration.

New Starts Pipeline

As with the Service Coverage and Service Frequency components, the New Starts Pipeline is a new analysis. The objective of the New Starts Pipeline component is to assess the expected investment cost of all planned and FTA-approved new starts and small starts projects for the period 2018 through 2038. This component ensures that these planned expansion investments were accounted for in both project acquisition costs and expected asset rehabilitation and replacement costs for this 20-year period. To assess the long-term life-cycle reinvestment requirements of these expansion investments, this component used standard project parameters available for each new starts project—including project route miles by alignment type (at-grade, elevated, and below-grade), station counts, and fleet size—to generate as many as 45 asset records for each new starts project. This conversion mapping of project parameters to asset records is presented in *Exhibit 7-17*.

Exhibit 7-17: Conversion of New Starts Project Parameters into Replaceable Assets and One-time Project Costs

New Starts Project Parameter	Assets with Recurring Costs (Rehab/Replace)	One-Time Project Costs
Total Alignment Length	• Train control • Crossing protection • Traction power • Communications • Central control	• Right-of-way acquisition • Sitework (earthwork, clearing) • Utility relocation • Temporary structures • Environmental mitigation
Alignment Length by Grade	• At-grade alignment • Elevated structures • Subway tunnels • Retained cut / fill • Ballasted track • Embedded track • Direct fixation track • Special trackwork	
Station Count (w/ Alignment by Grade)	• At-grade stations • Elevated stations • Subway stations • Parking • Pedestrian access • Fare collection	
Facility Count (w/ Fleet Count)	• Maintenance facilities (light and heavy maintenance, storage) • Admin facilities • Rail yard	
Fleet Vehicle Count	• Revenue vehicles • Service vehicles	

Source: New Starts Project Pipeline.

This conversion was mode-specific (reflecting differences in asset types and costs between bus and rail modes) and includes records for all major replaceable asset types—including track, structures, facilities, system assets (train control, electrification, and communications), and fleet. These project records also document one-time project costs, including right-of-way acquisition, utility relocation, sitework, environmental mitigation, and project management. These asset-level project records were then used to assess the acquisition cost of the expansion projects and their expected future rehabilitation and replacement actions after project completion.

Data Source – New Starts Project Pipeline: FTA maintains a detailed listing of transit projects with existing Full Funding and Small Starts Grant Agreements. This project "pipeline" documents the sponsoring agency, project mode, and expected project design initiation and completion dates. In addition, this listing provides the project parameter values required to generate the listing of replaceable asset records as outlined in *Exhibit 7-17*. This includes project alignment length and grade mix, and the number of expansion stations, vehicles, and maintenance facilities. As shown in *Exhibit 7-18*, the New Starts listing used for this analysis included 55 projects covering a range of transit modes (including light, heavy, and commuter rail; streetcar; and bus rapid transit investments) and with a total of close to 400 new route miles, over 700 passenger stations, and more than 1,000 new rail cars and buses. The completion dates for these projects extend through 2030.

Exhibit 7-18: New Starts Project Parameter Totals, By Mode

Mode	Number of Projects	Total Route Miles	Station Count	Fleet Count
Commuter Rail	6	132.3	29	90
Heavy Rail	5	19.7	9	362
Light Rail	13	103.4	115	298
Streetcar	4	120.1	506	314
Bus Rapid Transit	27	10.7	44	27
Total	**55**	**386.2**	**703**	**1,091**

Source: New Starts Project Assets.

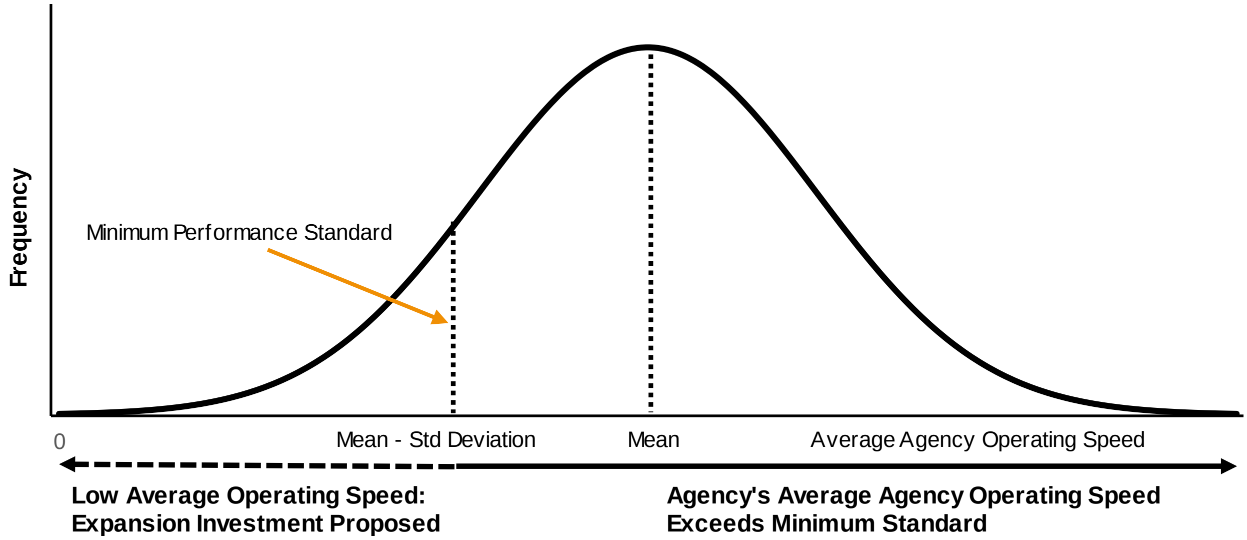
Data Source – New Starts Project Assets: FTA also maintains a Capital Cost Database that documents the as-built costs of a large sample of completed New Starts projects, including all rail and bus modes. This source was used to develop the conversion of New Starts project parameters into replaceable assets (as shown in *Exhibit 7-17*). The New Starts parameters include mode, miles of alignment by grade, number of stations and facilities, and number of vehicles. These parameters are used to determine the required miles of track, train control, electrification, and substations, as well as the cost of these required assets.

Average Speed Improvement

The Average Speed Improvement component is a legacy TERM analysis component that has not been used in recent editions of the C&P Report. It is reintroduced for this edition as an additional approach to identifying performance improvement investments. Specifically, the Average Speed Improvement component is designed to identify those UZAs with average operating speeds well below the national average and seeks to raise those speeds to a minimum operating speed standard through the introduction of transit expansion investment. This module operates on the premise that average operating speeds for rail and bus rapid transit (BRT) are higher than for standard bus service. Hence, the substitution of rail transit capacity in place of existing bus capacity in larger UZAs (population over 1 million) or the substitution of BRT for bus in smaller UZAs (population over 500,000) was made to increase the average operating speed for the entire urbanized area.

Minimum Service Standard: This component calculates the average UZA transit operating speed as the weighted average speed across existing rail and bus service (excluding commuter rail) within the UZAs, weighted by vehicle miles. The values were calculated using data obtained from the NTD. The minimum service standard for average UZA operating speed was then calculated as the national average transit operating speed, less one standard deviation, calculated across all UZAs over 500,000 population (see *Exhibit 7-19*).

Exhibit 7-19: National Distribution of Average Transit Operating Speeds



Source: Transit Economic Requirements Model User's Guide.

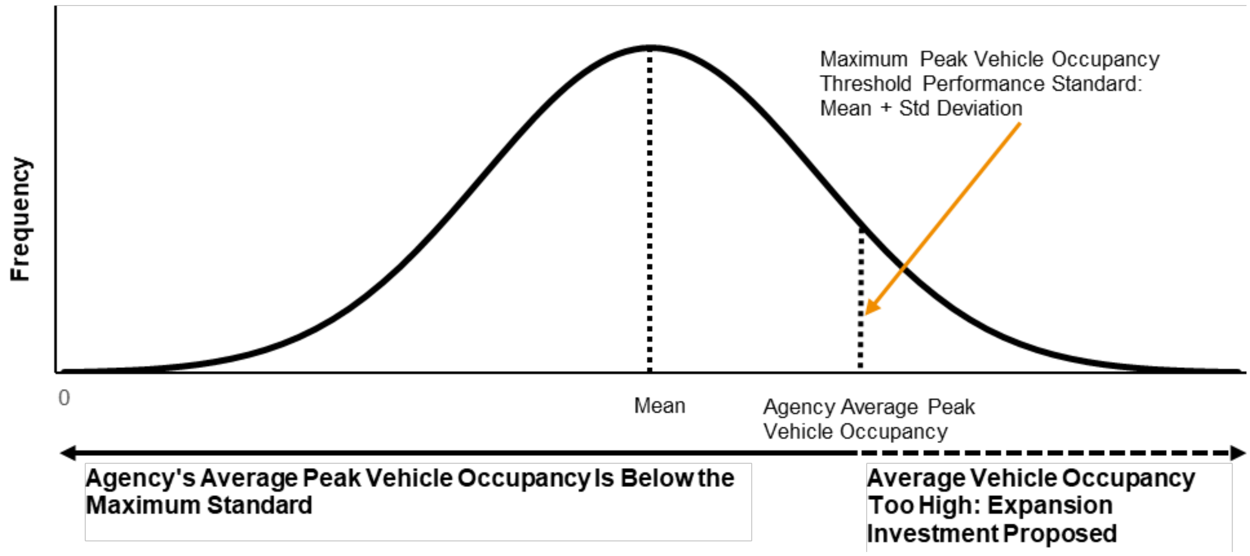
Mode Selection: The selection of which mode to invest in was determined first by the mode types already existing in each urbanized area and second by the population size of that urbanized area. Specifically, this component will first look to invest in the fastest existing rail mode within an urban area (excluding commuter rail) and hence will select heavy rail over light rail if both are already present. Note that commuter rail was not included as an option here as the intent was to focus speed improvements on operating speeds toward the urban core. Commuter rail systems were therefore excluded, as these systems typically extend well beyond the urban core. If the urban area does not currently have existing heavy rail, light rail, or BRT service, this component will select light rail for UZAs over 1 million in population and BRT for UZAs between 500,000 and 1 million population.

Expansion Asset Investments: Having identified UZAs with average operating speeds below the minimum service standard, this component then estimates the number of additional miles of rail or BRT service require to attain that standard for each individual UZA. Depending on mode, this includes investment in guideway track and structures, stations, vehicles, maintenance facilities, systems assets, right-of-way acquisition, design, project mobilization, and project management costs. Investment costs and quantities were based on as-built costs for New Starts projects as documented in FTA's Capital Cost Database. As shown later in this chapter, the Average Speed Improvement component accounts from roughly one-third of total expansion investment level generated across all component analyses.

Vehicle Occupancy Improvement

The Vehicle Occupancy Improvement component is also a legacy TERM analysis component, not used in recent C&P editions and reintroduced for this edition to identify performance-improving investments. The Vehicle Occupancy Improvement component was designed to identify U.S. transit agency modes with vehicle occupancy rates above the national average. The component then seeks to reduce crowding for these high-occupancy agency modes to a maximum occupancy threshold by investing in expansion vehicles and related support assets. These expansion investments were assessed on an agency-mode basis (i.e., individual transit modes were treated separately for each transit agency identified in NTD) (see *Exhibit 7-20*).

Exhibit 7-20: National Distribution of Peak Vehicle Occupancy



Source: Transit Economic Requirements Model User's Guide.

Service Standard: This component calculates vehicle occupancy at the agency-mode level as riders per vehicle operated in maximum service. The values were calculated using data obtained from the NTD. The maximum service standard was calculated separately for each transit mode as the national average vehicle occupancy, plus one standard deviation, across all UZAs over 500,000 in population.

Expansion Asset Investments: After the identification of agency modes with vehicle occupancy levels above the maximum service standard, this component then estimates the number of additional vehicles required to attain that standard. Depending on mode and the number of expansion vehicles identified, this component may also invest in additional supporting assets (e.g., maintenance facilities, passenger stations, and systems assets). This component also accounts for roughly one-third of total expansion investments generated for all component analyses.

Investment to Maintain Performance—Rider Growth

Unlike analysis of investments required to *improve* performance, in which multiple components were used, investments to maintain performance were assessed using a single component. Specifically, the Maintain Improvement component seeks to determine the degree of expansion of the size of the Nation's transit fleets and ridership growth such that the ratio of unlinked passenger trips per peak transit vehicle remains constant over time for each transit mode.

To forecast the number of new transit vehicles, this component projects future transit demand for the local agency modes identified in NTD using the 15-year ridership growth rate trend (from 2003 to 2018) for agency modes operating the same mode in the same FTA region (there are 10 FTA regions) and of similar population size (over 1 million; 1 million to 500,000; 500,000 to 250,000; and under 250,000). If a transit agency operates in an urban area with a positive growth trend, the component assumes the agency will need to acquire sufficient additional vehicles to maintain its current vehicle occupancy levels given the growth in rider demand. This analysis also forecasts expansion investments in other asset types needed to support projected new vehicle acquisitions. Depending on the total increase in fleet size, this can include investment in maintenance facilities, and in the case of rail systems, additional route miles made up of guideway, trackwork, stations, train control, and traction power systems. The component does not predict asset expansion investments for agency-mode combinations with current ridership levels that are well below the national average. Cost estimates for these types of investments are based on the most recent cost data for fleet vehicles and for mode-specific transit expansion projects.

For this edition of the C&P Report, the 15-year ridership growth trends have been adjusted to account for the significant decline in ridership beginning in March 2020 due to COVID-19. Specifically, the growth-based analysis assumes ridership will not recover to pre-pandemic levels until 2030, after which the pre-pandemic trend rate of growth in passenger miles traveled (PMT) growth will resume. Under these assumptions, investment in expansion assets does not occur until ridership reaches and begins to exceed the pre-pandemic levels. Understanding the many unknowns regarding future ridership growth given the significant impact of COVID-19, the rider growth-based investment levels presented in this report provide an estimate of what potential post-pandemic growth might look like under these specific assumptions.

Double-counting Adjustment

The use of multiple components to estimate transit expansion investment levels leads to the possibility that two or more components will occasionally (and independently) make the same or similar expansion investment for the same agency (e.g., two or more components determine that a specific agency would benefit from an expansion investment in the same rail mode). Where this occurs, there would be double-counting of expansion investments. TERM has been modified to look for and correct this form of double-counting. Additional detail on the double-counting checks is provided in Appendix C (See “Double Counting Adjustment” section).

Scenarios

For this report, the 20-year investment levels for transit capital assets have been estimated using an SGR Benchmark analysis and three investment scenarios that build on the expansion investment components described above:

- **SGR Benchmark –** Level of reinvestment in existing assets to attain and maintain a state of good repair over the next 20 years.
- **Sustain 2014–2018 Spending –** Assess the impact of maintaining capital investments in preservation and expansion at 2014–2018 expenditure levels for the next 20 years.
- **Expansion –** Estimate the level of capital investment required to improve transit performance (based on the components described above).
- **Expansion with Growth –** Estimate the level of capital investment required to improve and maintain transit performance given limited transit rider growth.

Following are more detailed descriptions of the SGR Benchmark and the three scenarios, with a high-level summary of scenario characteristics (including identification of the expansion components used for each scenario) provided in *Exhibit 7-21* and summary capital investment estimates for each scenario presented in *Exhibit 7-22*.

KEY TAKEAWAY

For this report, the 20-year investment levels for transit capital assets have been estimated using the SGR Benchmark analysis and three investment scenarios that build on expansion investment components. The SGR Benchmark analysis found that the level of expenditure required to immediately attain and maintain SGR for the next 20 years, $20.3 billion per year, is roughly 50 percent higher than current asset preservation expenditures of $13.5 billion per year. Unlike the three capital investment scenarios which, with minor exceptions, apply a cost-benefit test to all investment needs, SGR Benchmark investments are not subject to any cost-benefit tests.

Exhibit 7-21: Descriptions of the SGR Benchmark and the Three Transit Investment Scenarios

Scenario Aspect	SGR Benchmark	Sustain 2014–2018 Spending	Expansion	Expansion With Growth
Description	Level of investment to attain and maintain SGR over next 20 years (no assessment of expansion needs)	Sustain preservation and expansion spending at recent levels (average from 2014–2018) over next 20 years	Preserve existing assets and expand asset base to improve system performance, but with no ongoing growth in ridership	Preserve existing assets and expand asset base to improve system performance, with ongoing but limited ridership growth
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 service capacity	Assess unconstrained preservation and capacity expansion needs to improve system performance	Assess unconstrained preservation and capacity expansion needs to improve system performance with limited growth
Apply Benefit-Cost Test?	No	Yes[1]	Yes[2]	Yes[2]
Preservation?	Yes[3]	Yes[3]	Yes[3]	Yes[3]
Expansion?	No	Yes	Yes	Yes

[1] To prioritize investments under constrained funding.

[2] Note that New and Small Starts projects with approved Full Funding Grant Agreements are exempt from the benefit-cost test.

[3] Replace at condition 2.5.

Source: Transit Economic Requirements Model.

Exhibit 7-22: Annual Average Cost by Investment Scenario, 2018–2038

Population Size	Category	Mode, Purpose, and Asset Type	SGR Benchmark	Sustain 2014–2018 Spending	Expansion	Expansion with Growth
Urbanized Areas Over 1 Million in Population[1]	**Nonrail[2]**	Preservation	$4.9	$3.3	$4.5	$4.5
		Expansion	NA	$2.3	$2.5	$2.6
		Subtotal Nonrail[3]	$4.9	$5.6	$7.0	$7.1
	Rail	Preservation	$13.0	$8.7	$12.4	$12.4
		Expansion	NA	$3.7	$3.0	$4.8
		Subtotal Rail[3]	$13.0	$12.4	$15.4	$17.3
	Total, Over 1 Million in Population[3]		**$18.0**	**$18.0**	**$22.4**	**$24.3**
Urbanized Areas Under 1 Million in Population and Rural	**Nonrail[2]**	Preservation	$2.2	$1.5	$1.8	$1.9
		Expansion	NA	$0.9	$0.9	$1.0
		Subtotal Nonrail[3]	$2.2	$2.3	$2.8	$2.8
	Rail	Preservation	$0.2	$0.1	$0.1	$0.1
		Expansion	NA	$0.1	$0.1	$0.1
		Subtotal Rail[3]	$0.2	$0.2	$0.2	$0.2
	Total, Under 1 Million and Rural[3]		**$2.3**	**$2.5**	**$2.9**	**$3.0**
Total Preservation			$20.3	**$13.5**	**$18.8**	**$18.9**
Total Expansion			**NA**	**$7.0**	**$6.6**	**$8.5**
Total[3]			**$20.3**	**$20.5**	**$25.3**	**$27.4**

[1]Includes 37 different urbanized areas.

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

[3]Note that totals may not sum due to rounding.

Note: All investment values are in billions of 2018 dollars.

Source: Transit Economic Requirements Model.

SGR Benchmark

The 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 investments of existing transit assets (it does not consider expansion investments). Moreover, the SGR Benchmark does not require investments to pass the Transit Economic Requirements Model's (TERM's) benefit-cost test: it includes investments necessary to bring all assets to

SGR regardless of whether TERM indicates that reinvestment is warranted. Thus, the SGR Benchmark is illustrative and should not be considered one of the three investment scenarios.

Sustain 2014–2018 Spending

The Sustain 2014–2018 Spending scenario assesses the expected impact on asset conditions and system performance if annual reinvestment expenditures were sustained at their recent 5-year average (2014–2018) over the next 20 years.[34] For this report, these recent preservation and expansion expenditure levels are both roughly in line with the level of investment required to maintain asset conditions and performance at 2018 levels. Note that annual expenditure levels are expected to increase beyond the 2014–2018 levels under the Bipartisan Infrastructure Law (BIL).

Expansion and Expansion with Growth

The Expansion and Expansion with Growth scenarios estimate the total combined 20-year investment levels for both transit expansion and transit asset preservation. The expansion investments in both scenarios were driven by the level of investment required to (1) support planned New Starts/Small Starts investments, (2) attain specific service targets for areas currently unserved or underserved by transit, (3) attain specific service performance targets for urban areas with low average operating speeds, and (4) reduce crowding for transit agencies with high-capacity utilization.

KEY TAKEAWAY

The Expansion scenario estimates the total combined 20-year investment levels for both transit expansion and transit asset preservation. The expansion investments were driven by the level of investment required to (1) support planned New Starts/Small Starts investments, (2) attain specific service targets for areas currently unserved or underserved by transit, (3) attain specific service performance targets for urban areas with low average operating speeds, and (4) reduce crowding for transit agencies with high-capacity utilization, all relative to 2018 levels.

In addition, the Expansion with Growth scenario includes estimated expansion investment levels required to support projected growth in PMT, taking into account the decline and expected slow recovery of ridership following the COVID-19 pandemic. Specifically, these projections assume ridership will continue to increase at the trend rate experienced since the start of the pandemic (March 2020) through 2023 and will thereafter resume the trend rate of growth in PMT, calculated as the compound 15-year average annual PMT growth by FTA region, urbanized area (UZA) stratum, and mode. Under these assumptions, investment in expansion assets does not occur until ridership re-attains pre-pandemic levels in these individual submarkets.

Exhibit 7-22 summarizes the analysis results for each scenario and the SGR Benchmark. Note that all three scenarios and the SGR Benchmark use the same asset condition replacement threshold (i.e., assets are replaced at condition rating of 2.5 when budget is sufficient) for assessing transit reinvestment levels. The total preservation expenditure amounts differ across each scenario primarily because of either (1) an imposed budget constraint (as in the Sustain 2014–2018 Spending scenario) or (2) application of TERM's benefit-cost test. (The SGR Benchmark does not apply the benefit-cost test.)

[34] In prior reports, this scenario tied preservation and expansion spending to the most recent reporting year (in this case, 2018). For this report, the Sustain 2014–2018 Spending scenario has been modified to follow the inflation-adjusted annual average preservation and expansion spending for the most recent 5-year period reported to the NTD (2014–2018). This 5-year annual average helps smooth year-to-year variations in spending while limiting the analysis to more recent program funding levels.

A brief review of the 20-year national-level investment level analysis in *Exhibit 7-22* reveals the following:

- **SGR Benchmark:** The level of expenditures required to immediately attain and maintain SGR over the upcoming 20 years, $20.3 billion per year, is roughly 50 percent higher than current asset preservation expenditures of $13.5 billion per year.
- **Sustain 2014–2018 Spending scenario:** Total preservation spending under this scenario of $13.5 billion per year is well below that of the SGR Benchmark and the other scenarios. Sustaining 2014–2018 spending levels is marginally less than that required to maintain the current size of the SGR backlog. Total expansion spending of $7.0 billion per year is more than required to address the expansion investment levels as identified by the Expansion scenario, but less than the amount estimated for the Expansion with Growth scenario.
- **Expansion Scenario:** Total preservation investment levels are estimated at $18.8 billion per year. This amount is less than the need spending under the SGR Benchmark because TERM's cost-benefit test projects that the Nation would not need to reinvest in certain transit assets that fail to meet the test. Total expansion investments are estimated at $6.6 billion per year.
- **Expansion with Growth Scenario:** Total preservation investment levels are estimated at $18.9 billion per year. This amount is slightly more than in the Expansion scenario because of the 20-year reinvestment levels for the additional assets required to support ridership growth. Total expansion levels are estimated at $8.5 billion per year. This amount is about 22 percent higher than current spending levels.

KEY TAKEAWAY

The Expansion with Growth scenario builds on the needs identified in the Expansion scenario, including estimated expansion investment levels required to support projected growth in passenger miles traveled (PMT), taking into account the decline and expected slow recovery of ridership following the COVID-19 pandemic. Under these assumptions, investment in expansion assets does not occur until ridership reaches pre-pandemic levels in individual submarkets.

Sustain 2014–2018 Spending Scenario

From 2014 to 2018, as reported to the NTD, transit operators spent an average of $20.5 billion annually on capital projects. Of this amount, $13.5 billion was for preserving existing assets and $7.0 billion was for investments to expand service—both to improve service performance and to support ongoing ridership growth. The Sustain 2014–2018 Spending scenario considers the impact on asset conditions and service performance if these expenditure levels were sustained in constant-dollar terms through 2038.

TERM's funding allocation: The following analysis of the Sustain 2014–2018 Spending scenario relies on TERM's allocation of the recent preservation and expansion expenditure amounts to the Nation's existing transit operators, their modes, and their assets over the

KEY TAKEAWAY

Under the Sustain 2014–2018 Spending scenario, total preservation spending of $13.5 billion per year is well below that of the SGR Benchmark and other scenarios. Sustaining 2014–2018 spending levels is marginally less than that required to maintain the current size of the SGR backlog, but therefore significantly less than the $19.5 billion required to eliminate the backlog over 20 years. Total expansion spending of $7.0 billion per year is slightly more than that required to address the expansion investment levels identified in the Expansion scenario, but less than the amount estimated for the Expansion with Growth scenario. In this report, 2014–2018 spending levels are based on the inflation-adjusted annual average preservation and expansion spending for the most recent 5-year period reported to the NTD (2014–2018). This 5-year annual average helps smooth year-to-year variations in spending while limiting the analysis to more recent program funding levels.

upcoming 20 years, as depicted in *Exhibit 7-23*. TERM uses different approaches to allocate capital funding to preservation versus expansion investments. Specifically, TERM used an internal prioritization routine to allocate the $13.5 billion in preservation funding among competing preservation needs. Here, all identified investment options are first prioritized based on their estimated physical condition and their criticality to service reliability, safety, and operating costs (based on asset type). Based on this prioritization analysis, preservation investments are ranked from highest to lowest priority and funding is then allocated to the highest-ranked investments until the preservation funds are fully consumed.

In contrast, expansion investments identified by the expansion components (i.e., the New Starts Pipeline, Service Coverage and Frequency, and the Improve Speed and Occupancy components) are prioritized using TERM's benefit-cost analysis, an analysis that occurs at the conclusion of the model run (see Appendix C in the "Benefit-Cost Calculations" section for greater detail). With one exception, the $7.0 billion in expansion funding was allocated to the identified investments with the highest benefit-cost ratios, again until funding is fully consumed. The exception is projects identified by the New Starts Pipeline component. Given that these New Starts projects have already been approved, they are assumed to have first access to the limited capital expansion funds (i.e., ahead of all other component investments). In other words, funding is not allocated to investments identified by the other expansion components until all of the New Starts Pipeline investments have been funded.

Exhibit 7-23: Sustain 2014–2018 Spending Scenario: Average Annual Investment by Asset Type, 2018–2038

Category	Asset Type	Preservation	Expansion	Total
Rail	Guideway Elements	$2.3	$1.2	$3.5
	Facilities	$0.2	$0.2	$0.3
	Systems	$3.3	$0.3	$3.6
	Stations	$0.7	$0.8	$1.4
	Vehicles	$2.4	$0.7	$3.1
	Other Project Costs	$0.0	$0.6	$0.6
	Subtotal Rail*	**$8.8**	**$3.8**	**$12.6**
	Subtotal UZAs Over 1 Million[1]	**$8.7**	**$3.7**	**$12.4**
	Subtotal UZAs Under 1 Million and Rural[1]	**$0.1**	**$0.1**	**$0.2**
Nonrail	Guideway Elements	$0.0	$0.3	$0.3
	Facilities	$0.2	$0.6	$0.8
	Systems	$0.4	$0.1	$0.5
	Stations	$0.0	$0.1	$0.1
	Vehicles	$4.1	$1.9	$6.0
	Other Project Costs	$0.0	$0.0	$0.0
	Subtotal Nonrail*	**$4.7**	**$3.2**	**$7.9**
	Subtotal UZAs Over 1 Million[1]	**$3.3**	**$2.3**	**$5.6**
	Subtotal UZAs Under 1 Million and Rural[1]	**$1.5**	**$0.9**	**$2.3**
Total		**$13.5**	**$7.0**	**$20.5**
Total UZAs Over 1 Million		**$12.0**	**$6.0**	**$18.0**
Total UZAs Under 1 Million and Rural		**$1.5**	**$1.0**	**$2.5**

[1] Note that totals may not sum due to rounding.

Note: All investment values are in billions of 2018 dollars.

Source: Transit Economic Requirements Model and FTA staff estimates.

Preservation Investments

As noted earlier in this section, transit operators spent an estimated $13.5 billion annually from 2014–2018 on rehabilitating and replacing existing transit infrastructure. If this level of spending is sustained over the forecasted 20 years, the condition of existing transit assets would decline overall while roughly maintaining the size of the investment backlog. The decline in overall condition of assets would result largely from deteriorating conditions in assets that are currently relatively new but would not reach replacement age over this period.

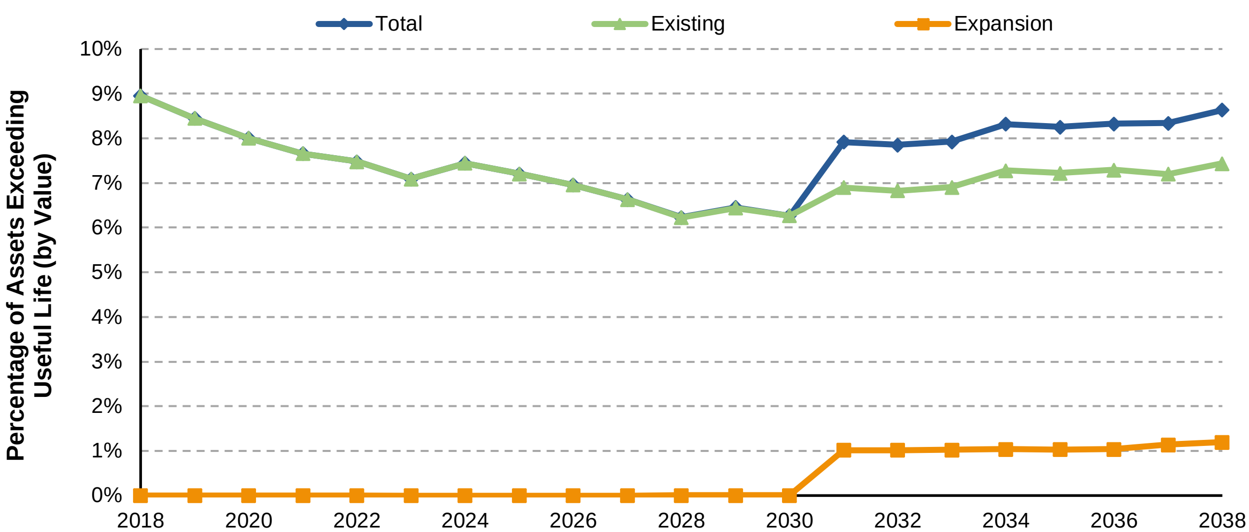
Similarly, *Exhibit 7-24* presents the proportion of transit assets (by value) that are estimated to exceed their useful life. Under the Sustain 2014–2018 Spending scenario, this amount declines from roughly 9 percent to 6 percent by 2030 before recovering to roughly 7 percent by 2038. However, when the impact of expansion assets is added, the percentage of assets that exceed their useful life is projected to return to just under 9 percent by 2038.

KEY TAKEAWAY

The Sustain 2014–2018 Spending scenario assesses the expected impact on asset conditions and system performance if annual reinvestment expenditures are sustained at their 2014–2018 5-year average over the next 20 years. For this report, the 2014–2018 preservation and expansion expenditure levels are roughly in line with the estimated level of investment required to maintain the deferred investment backlog and system performance at 2018 levels.

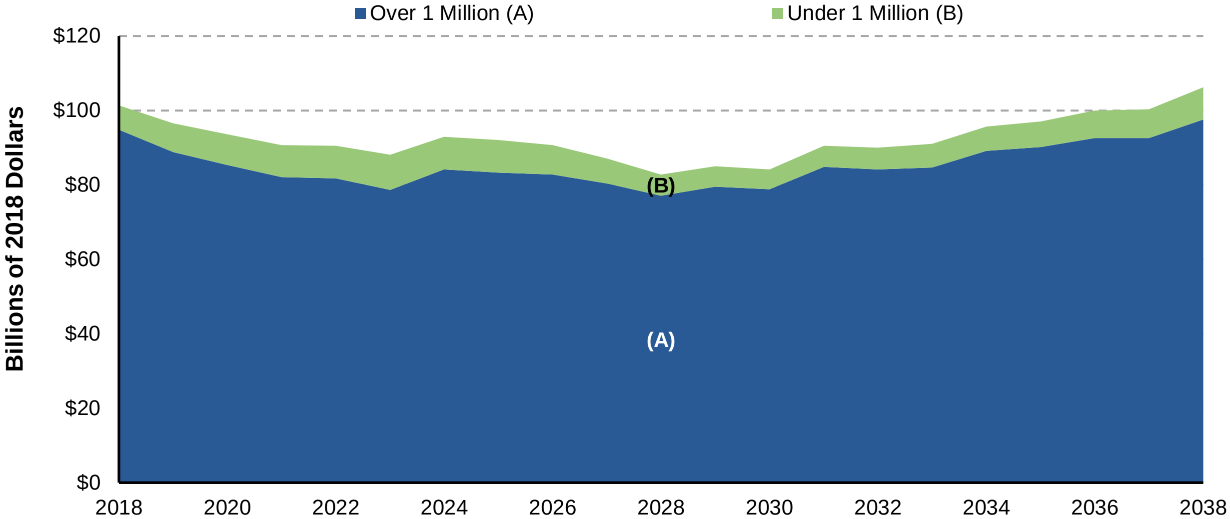
Finally, *Exhibit 7-25* presents the projected change in the size of the investment backlog if reinvestment levels are sustained at the recent level of $13.5 billion in constant-dollar terms. As described in Chapter 8, the investment backlog represents the level of investment required to replace all assets that exceed their useful life and to address all rehabilitation activities that are currently past due. Rural and smaller urban investment levels 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. The current rate of capital reinvestment is only slightly higher than that required to maintain the size of the current investment backlog, with the size of that backlog projected to increase marginally from the currently estimated level of $101.4 billion to roughly $106.2 billion by 2038.

Exhibit 7-24: Sustain 2014–2018 Spending Scenario: Percentage of Assets Exceeding Useful Life, 2018–2038



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 7-25: Projected Backlog under the Sustain 2014–2018 Spending Scenario, 2018–2038



Source: Transit Economic Requirements Model.

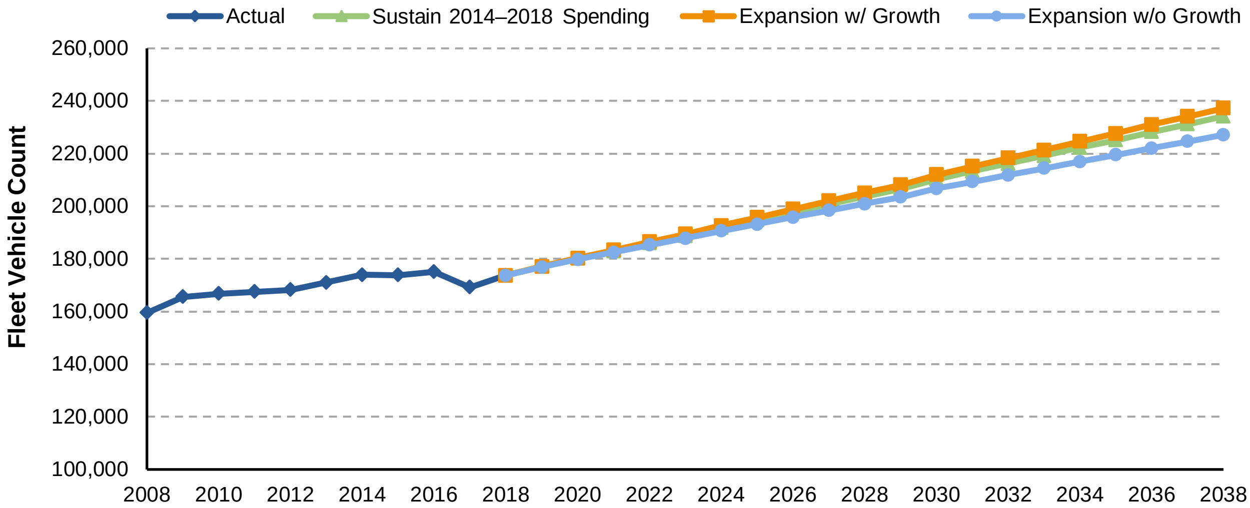
The chart in *Exhibit 7-25* also estimates the size of the backlog according to the size of geographic area. The lower portion shows the backlog for UZAs having populations greater than 1 million and the upper portion shows the backlog for all other UZAs and rural areas combined. This segmentation highlights the significantly higher existing backlog for those UZAs serving the largest number of transit riders.

Expansion Investments

In addition to the average $13.5 billion spent on preserving transit assets in recent years, transit agencies spent an average of $7.0 billion on expansion investments to service new areas, support ridership growth, and improve transit performance. This section compares the impact of this recent level of expansion investment with the expansion investments under the Expansion and Expansion with Growth scenarios, focused on the quantity of expansion investments in fleet vehicles, stations, and fixed guideway route miles.

TERM's projections of fleet expansion for the Sustain 2014–2018 Spending, Expansion, and Expansion with Growth scenarios are presented in *Exhibit 7-26*. Here, the fleet expansion projections for the Sustain 2014–2018 Spending scenario fall roughly between those of the Expansion and Expansion with Growth scenarios. This result is not unexpected given that average annual expenditures for the Sustain 2014–2018 Spending scenario ($7.0 billion) fall between those of the Expansion and Expansion with Growth scenarios ($6.6 billion and $8.5 billion respectively). The various scenarios project that the national transit fleet size will need to grow from 173,000 in 2018 to between 125,000 and 237,000 by 2038.

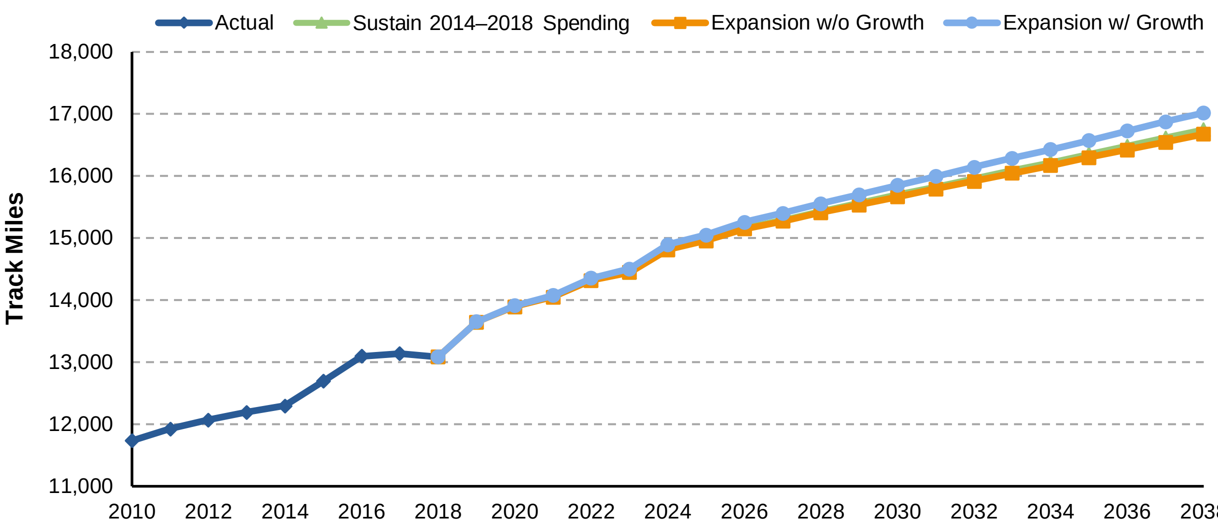
Exhibit 7-26: Projection of Fleet Size by Scenario



Note: Data through 2018 are actual; data after 2018 are estimated based on trends.
Source: Transit Economic Requirements Model.

Similarly, the projected increase in rail track miles for the Sustain 2014–2018 Spending scenario is higher than that for the Expansion scenario but less than that for the Expansion with Growth scenario, as shown in *Exhibit 7-27*. All scenarios project that total rail track miles will need to grow by about 3,500 to 4,000 additional miles on top of the 13,000 miles in place as of 2018. In 2018, commuter rail accounted for 65 percent of all rail track miles, with most of the remainder consisting of heavy rail (17 percent) and light rail (16 percent). The average commuter rail system is on the order of two to six times the length of typical heavy and light rail systems, respectively.

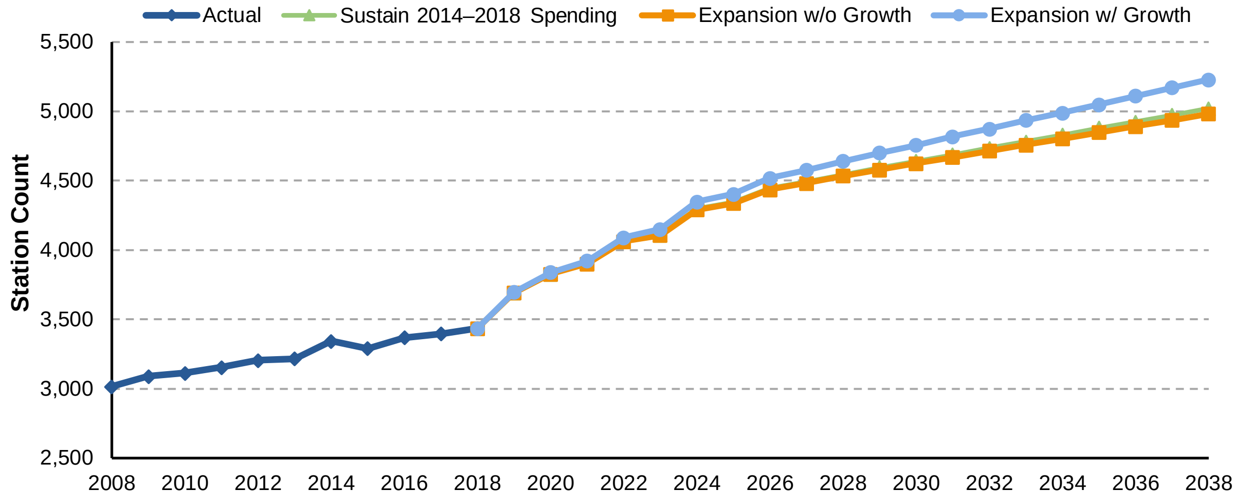
Exhibit 7-27: Projection of Track Miles by Scenario



Note: Data through 2018 are actual; data after 2018 are estimated based on trends.
Source: Transit Economic Requirements Model.

The projected increases in the number of rail passenger stations under the Sustain 2014–2018 Spending, Expansion, and Expansion with Growth scenarios are presented in *Exhibit 7-28*. Here again, expansion station counts for the Sustain 2014–2018 Spending scenario fall between those of the Expansion and Expansion with Growth scenarios. Note that much of the expansion investment is dominated by light rail stations, which make up close to two-thirds of expansion stations, followed by commuter rail with 17 percent and heavy rail with 12 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).

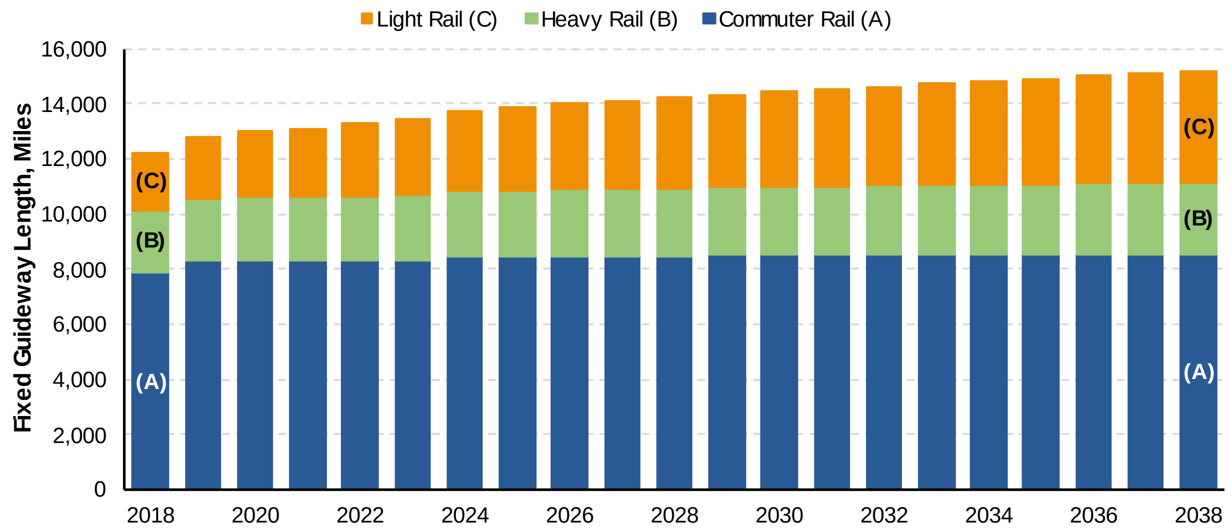
Exhibit 7-28: Projection of Rail Stations by Scenario



Note: Data through 2018 are actual; data after 2018 are estimated based on trends.
Source: Transit Economic Requirements Model.

Exhibit 7-29 presents TERM's projection for total fixed guideway miles for light, heavy, and commuter rail under the Expansion with Growth scenario. TERM projects different investment levels for each year, which are added to the existing total stock as of 2018. Heavy rail's total mileage increases under this scenario by more than 16 percent over the 20-year period of analysis, but its share of the projected annual fixed guideway route miles between the three rail modes remains relatively constant at around 18 percent. Similarly, the total commuter rail mileage increases by roughly 8 percent but with the share of total miles declining from 65 percent to 56 percent. In contrast, the share of total miles increases for light rail (17 percent to 27 percent).

Exhibit 7-29: Stock of Fixed Guideway Miles by Year Under Expansion with Growth Scenario, 2018–2038



Source: Transit Economic Requirements Model.

SGR Benchmark

The SGR Benchmark estimates the level of annual investment required to replace all assets that currently exceed their useful lives (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. This is the same methodology used in FTA's *National State of Good Repair Assessment*, released in June 2012.

In contrast to the scenarios described in this chapter, the SGR Benchmark neither (1) assesses expansion investment levels nor (2) applies TERM's benefit-cost test to investments. This is a purely engineering-based performance benchmark that assesses the total magnitude of unaddressed reinvestment levels regardless of whether keeping these assets in service would be cost-beneficial.

What Is the Definition of State of Good Repair?

State of good repair is defined by FTA in its Transit Asset Management Rule, 49 CFR Part 625.5 as: "The condition in which a capital asset is able to operate at a full level of performance."

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 7-30*. An estimated $20.3 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 $13.0 billion (64 percent) is required to bring rail assets to SGR. Note that a large proportion of rail reinvestment spending would be associated with guideway elements (including aging elevated and tunnel structures) and rail stations in need of reinvestment. Bus-related reinvestment spending under this benchmark is primarily associated with aging vehicle fleets.

Exhibit 7-30 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 largest 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 close to two-thirds of the total reinvestment required to bring all assets to an SGR. This high proportion of total investment levels reflects the high proportion of reinvestment in older rail assets located in these larger urban areas.

Exhibit 7-30: SGR Benchmark: Average Annual Investment by Asset Type, 2018–2038

Category	Asset Type	Urbanized Area Over 1 Million Population	Urbanized Area Under 1 Million Population	Total
Rail	Guideway Elements	$3.8	$0.0	$3.8
	Facilities	$0.8	$0.0	$0.8
	Systems	$2.1	$0.0	$2.1
	Stations	$3.8	$0.0	$3.8
	Vehicles	$2.4	$0.0	$2.4
	Subtotal Rail[1]	**$12.9**	**$0.1**	**$13.0**
Nonrail	Guideway Elements	$0.1	$0.0	$0.1
	Facilities	$1.1	$0.5	$1.6
	Systems	$0.2	$0.0	$0.2
	Stations	$0.4	$0.2	$0.6
	Vehicles	$3.2	$1.6	$4.8
	Subtotal Nonrail[1]	**$5.1**	**$2.3**	**$7.4**
Total*		**$18.0**	**$2.4**	**$20.3**

[1] Note that totals may not sum due to rounding.

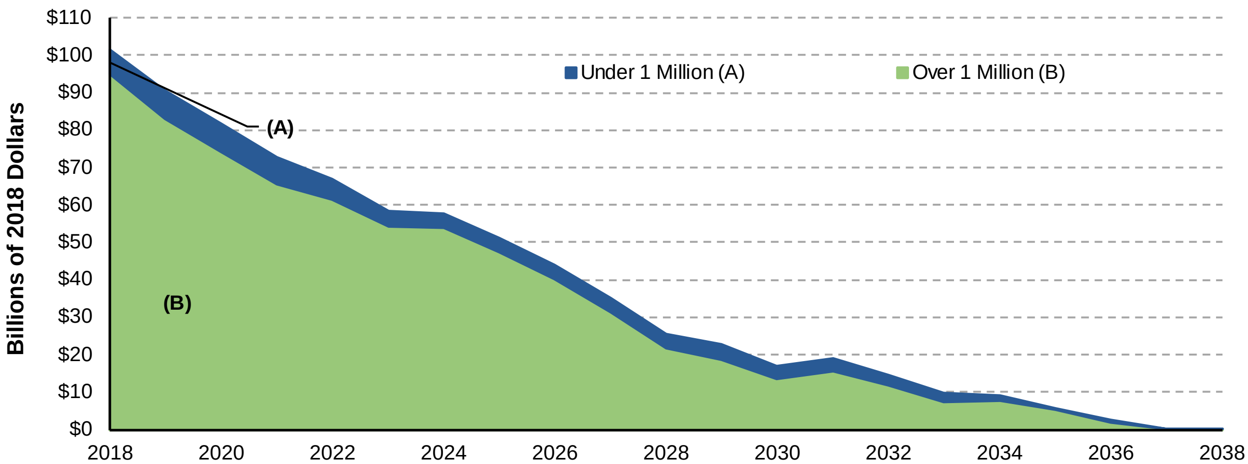
Note: All investment values are in billions of 2018 dollars.

Source: Transit Economic Requirements Model.

Impact on the Investment Backlog

Exhibit 7-31 shows the estimated impact of $19.5 billion in annual expenditures on the existing investment backlog over the 20-year forecast period. Given this level of expenditures, the backlog would be projected to be eliminated by 2038.

Exhibit 7-31: Investment Backlog: State of Good Repair Benchmark ($19.5 Billion Annually)

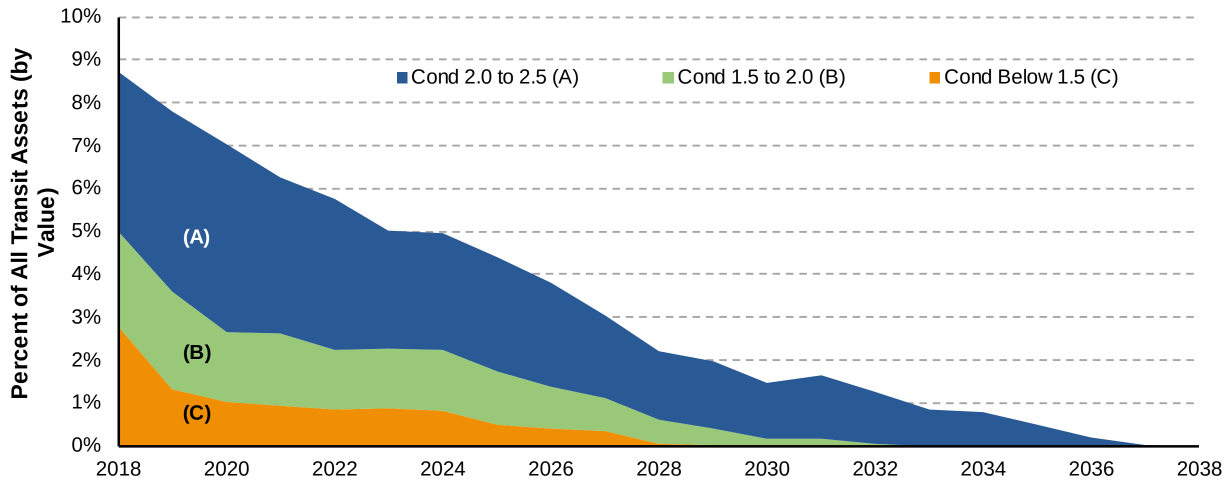


Source: Transit Economic Requirements Model.

Impact on Conditions

In drawing down the investment backlog, annual capital expenditures of $19.5 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 7-32* 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 tunnel structures and subway stations in tunnel structures; these are considered assets that require ongoing capital rehabilitation expenditures but are rarely actually replaced (given their very long service lives). 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 just under 9 percent of assets in 2018 to less than 1 percent by 2038. 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 7-32* capture only a subset of assets in the SGR backlog as depicted in *Exhibit 7-31*. Specifically, the total SGR backlog shown in *Exhibit 7-31* includes not only those assets in need of replacement (i.e., those at less than condition 2.5) but also those in need of rehabilitation or other form of capital reinvestment.

Exhibit 7-32: Proportion of Transit Assets Not in State of Good Repair (Excluding Nonreplaceable Assets)



Source: Transit Economic Requirements Model.

Expansion and Expansion with Growth Scenarios

The Expansion and Expansion with Growth scenarios use TERM's benefit-cost test to determine which assets warrant rehabilitation or replacement. 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 the total estimated level of investment. Higher ridership levels increase the benefits of transit assets, such that preservation investments tend to be slightly higher in the Expansion with Growth scenario than in the Expansion scenario.

Expansion and Expansion with Growth Assumptions

As described earlier in this chapter, expansion investment estimates for the Expansion and Expansion with Growth scenarios are driven by a common set of expansion investment components that assess the level of investment required to (1) support planned New

Starts/Small Starts investments and (2) deliver specific service-related performance improvements. These five expansion investment estimation components include the following:

- **Implement New/Small Starts Pipeline**: This component identifies approved New and Small Starts projects planned for construction during the 20-year period of analysis. These investments consist of a mix of rail and bus rapid transit investments.
- **Expand Coverage to Serve Transit Deserts:** This component identifies regions within each of the Nation's more than 400 urbanized areas that are not currently served by transit but warrant transit service based on household densities. Investments to address transit deserts typically consist of investments in bus vehicles and their support assets.
- **Improve Frequency:** This component identifies regions within urbanized areas that *are* currently served by transit but warrant an increase in service frequency, again based on household density. These investments consist primarily of bus fleet expansions.
- **Reduce Crowding:** This component identifies agency modes with high ridership per peak service vehicle and invests in fleet expansion and related support assets to reduce crowding to a minimum service standard.
- **Improve Average Operating Speeds:** This component identifies urbanized areas with average transit operating speeds that are well below the national average and identifies potential rail or bus rapid transit (BRT) investments to bring the region up to a minimum average speed standard.

The investment level outputs generated by these components have been adjusted to remove instances of potential double-counting of investments across components.

Ridership Growth Assumptions

In addition to the five components used to identify performance-improving investments, the Expansion with Growth scenario also includes the level of investment required to *maintain* existing service levels given potential ridership growth over the 20-year forecast period. Given the significant decline in transit ridership in March of 2020 in response to the COVID-19 pandemic, the growth assumptions used by this scenario are very conservative in comparison to prior Conditions and Performance Reports. Specifically, this scenario assumes that (1) ridership will grow steadily to reach pre-pandemic levels by roughly 2030. Thereafter, ridership is projected to return to the 15-year growth trends of the 2003–2018 timeframe (with growth rates determined across more than 250 submarkets, segmented by FTA region, UZA size, and transit mode). TERM will not initiate investment in expansion assets in a submarket until ridership in that market is estimated to reattain 100 percent of pre-pandemic levels.

The rate of transit recovery remains highly uncertain. Given the significant decline in ridership in 2020, recovery does not occur in this scenario until roughly 2030 (depending on the market). The Expansion with Growth scenario is intended to provide some understanding of what potential growth might look like and the implications for 20-year expansion investment levels.

Expansion and Expansion with Growth Scenario Investment Levels

Exhibit 7-33 presents TERM's projected capital investment levels on an annual average basis under the Expansion and Expansion with Growth scenarios, segmenting investment levels for asset preservation and asset expansion.

Exhibit 7-33: Expansion and Expansion with Growth Scenarios: Average Annual Investment by Asset Type, 2018–2038

Category	Asset Type	Expansion			Expansion With Growth		
		Preservation	Expansion	Total	Preservation	Expansion	Total
Rail	Guideway Elements	$3.6	$0.9	$4.5	$3.6	$1.3	$4.9
	Facilities	$0.8	$0.1	$0.9	$0.8	$0.2	$1.0
	Systems	$3.8	$0.2	$4.0	$3.8	$0.3	$4.1
	Stations	$2.0	$0.5	$2.5	$2.0	$0.8	$2.8
	Vehicles	$2.4	$0.4	$2.8	$2.4	$0.8	$3.1
	Other Project Costs	$0.0	$0.9	$0.9	$0.0	$1.5	$1.5
	Subtotal Rail[1]	$12.5	$3.1	$15.6	$12.5	$4.9	$17.5
	Subtotal UZAs Over 1 Million[1]	$12.4	$3.0	$15.4	$12.4	$4.8	$17.2
	Subtotal UZAs Under 1 Million and Rural[1]	$0.1	$0.1	$0.2	$0.1	$0.1	$0.2
Nonrail	Guideway Elements	$0.0	$0.3	$0.3	$0.0	$0.3	$0.3
	Facilities	$1.2	$0.6	$1.7	$1.2	$0.6	$1.7
	Systems	$0.4	$0.1	$0.4	$0.4	$0.1	$0.4
	Stations	$0.2	$0.1	$0.3	$0.2	$0.1	$0.3
	Vehicles	$4.6	$2.2	$6.7	$4.6	$2.3	$6.8
	Other Project Costs	$0.0	$0.3	$0.0	$0.0	$0.3	$0.3
	Subtotal Nonrail*	$6.3	$3.4	$9.7	$6.3	$3.6	$9.9
	Subtotal UZAs Over 1 Million[1]	$4.5	$2.0	$6.5	$4.5	$2.1	$6.6
	Subtotal UZAs Under 1 Million and Rural[1]	$1.8	$0.9	$2.7	$1.9	$0.9	$2.8
Total Investment[1]		**$18.8**	**$6.6**	**$25.3**	**$18.9**	**$8.5**	**$27.4**
Total UZAs Over 1 Million[1]		**$16.9**	**$5.0**	**$21.9**	**$16.9**	**$6.9**	**$23.8**
Total UZAs Under 1 Million and Rural[1]		**$1.9**	**$1.0**	**$2.9**	**$1.9**	**$1.0**	**$3.0**

[1] Note that totals may not sum due to rounding.

Note: All investment values are in billions of 2018 dollars.

Source: Transit Economic Requirements Model.

Expansion Investment Levels

Under the Expansion scenario, combined 20-year investment levels for system preservation and expansion are estimated to average $25.3 billion each year. Roughly 74 percent of this amount, or $18.8 billion, is for preserving existing assets, including approximately $12.5 billion for preserving existing rail infrastructure assets alone.

The approximately $1.5 billion difference between the $20.3 billion in annual preservation spending under the SGR Benchmark and the $18.8 billion in preservation spending under the Expansion scenario is due entirely to the application of TERM's benefit-cost test under the Expansion scenario causing some existing assets to not be replaced, as they do not pass TERM's cost-benefit test.

Expansion investment levels in this scenario total $6.6 billion annually. This amount includes $5.0 billion annually in expansion investments in UZAs with more than 1 million population and $1.0 billion for smaller urbanized areas.

KEY TAKEAWAY

Total preservation investment levels under the Expansion scenario are estimated to be $18.8 billion per year. This is less than the needed spending under the SGR benchmark because TERM's cost-benefit test projects that the Nation would not need to reinvest in certain transit assets that do not pass the test. Total expansion investments are estimated to be $6.6 billion per year.

Expansion with Growth Investment Levels

Total investment levels under the Expansion with Growth scenario are estimated at $27.4 billion annually, roughly eight percent higher than the total investment levels under the Expansion scenario. The Expansion with Growth scenario total includes $18.9 billion for system preservation and an additional $8.5 billion for system expansion. The $1.9 billion difference between the Expansion with Growth and the Expansion scenarios is entirely accounted for by investments to address potential ridership growth as needed to maintain 2018 service performance levels. Under the Expansion with Growth scenario, rail consumes 58 percent of total expansion investment funding; investments in bus account for the rest. Overall annual expansion spending under the Expansion with Growth scenario ($8.5 billion) exceeds 2014–2018 spending levels ($7.0 billion) by roughly $1.5 billion annually.

Expansion Investment Levels by Component

As described earlier, the transit expansion investment levels presented in *Exhibit 7-33* were estimated using multiple components, each based on a differing investment objective. *Exhibit 7-34* presents the average annual reinvestment levels generated by each of these assessment components, as well as the estimated levels of annual operating and maintenance costs required to support operation of these expansion assets when placed into service. Given the range of annual levels across these components, capital and operating costs are presented here in millions (versus billions) of dollars. As *Exhibit 7-34* makes clear, investment levels are highest for those related to New Starts, Average Speed Improvement, Vehicle Occupancy Improvement, and Rider Growth. Investment costs for the New Starts and Average Speed Improvement components are driven primarily by a high level of investment in rail expansions. Investment costs for the Vehicle Occupancy Improvement and Rider Growth components are driven primarily by vehicle expansion costs across all mode types. In contrast, the estimated investment levels to address Service Coverage and Frequency improvements are significantly lower given their bus-only focus and the limited geographic areas addressed by these components.

KEY TAKEAWAY

Total preservation investment levels under the Expansion with Growth scenario are estimated to be $18.9 billion per year. This is slightly more than in the Expansion scenario because of the 20-year reinvestment levels for the additional assets required to support ridership growth. Total expansion levels are estimated to be $8.5 billion per year. This is about 22 percent higher than 2014–2018 spending.

The combined average annual capital cost of these components is of similar magnitude to the $7.0 billion average annual level of expansion investment experienced nationally from 2014–2018 (a key input for the Sustain 2014–2018 Spending scenario). Specifically, under the Expansion scenario these components produce a combined annual investment total of $6.6 billion ($0.4 billion below recent expansion spending), whereas the Expansion with Growth scenario totals to $8.5 billion annually ($1.5 billion above 2014–2018 spending).

The capital and operating costs presented in *Exhibit 7-34* are *annual average* amounts calculated over the 20-year forecast period running through 2038. This leads to the potentially unexpected result that the reported operating costs exceed capital costs for this forecast period. Most capital costs occur only *once* during this 20-year period (when the expansion asset is acquired), whereas operating costs recur *every year* from the year of asset acquisition through the end of the forecast period. Therefore, although the capital cost of an acquisition greatly exceeds the annual cost of its operation and maintenance, the one-time capital acquisition cost is lower than the recurring annual cost of operations averaged over 20 years.

Finally, *Exhibit 7-35* presents TERM's projected year-by-year investment levels for each expansion component, highlighting the relative levels and timing of investments across each component. The New Starts Pipeline and Average Speed Improvement investments depicted in this exhibit are predominantly investments in rail and bus rapid transit system extensions. The investments in Service Coverage and Frequency, Vehicle Occupancy, and Growth tend to be dominated by fleet expansion investments.

Exhibit 7-34: Expansion and Expansion with Growth Scenarios: Average Annual Investment by Performance Improvement Type, 2018–2038

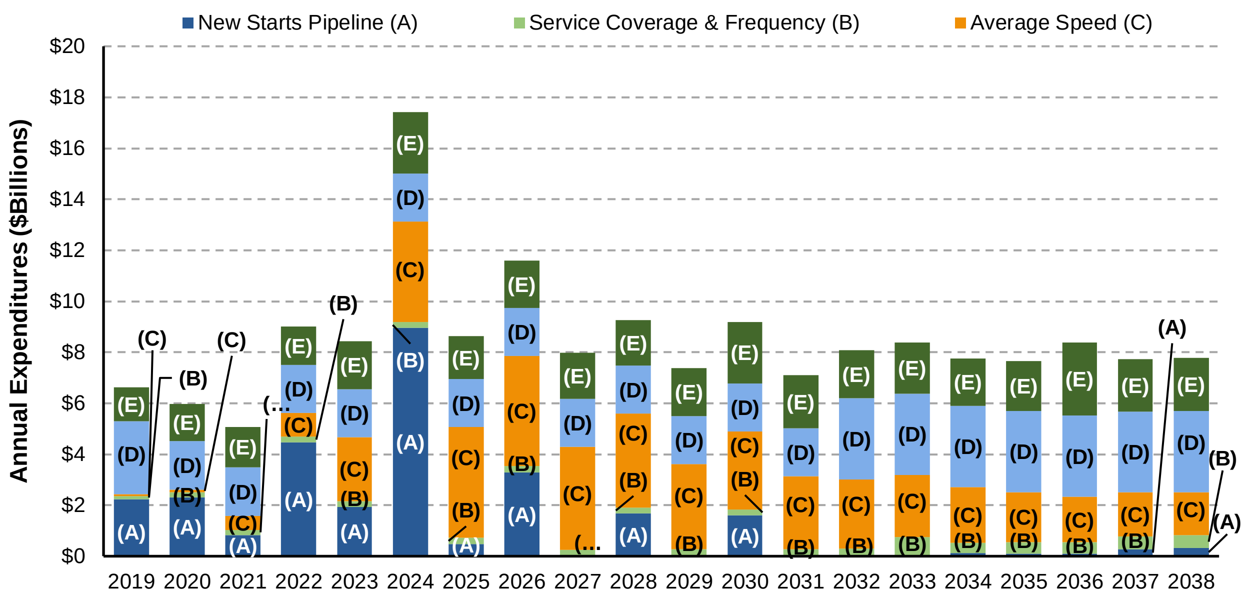
Performance Improvement Type	Asset Type	Expansion	Expansion with Growth
Capital	New Starts Pipeline	$1,448.8	$1,448.8
	Service Coverage	$98.4	$98.4
	Service Frequency	$233.7	$234.0
	Average Speed	$2,411.7	$2,411.7
	Vehicle Occupancy	$2,383.7	$2,388.9
	Growth	NA	$1,919.6
	Subtotal Capital	**$6,576.2**	**$8,501.3**
Operating	New Starts Pipeline	$1,159.8	$1,159.8
	Service Coverage	$210.4	$210.4
	Service Frequency	$406.6	$406.6
	Average Speed	$3,293.5	$3,293.5
	Vehicle Occupancy	$4,825.2	$4,836.1
	Growth	NA	$1,215.9
	Subtotal Operating	**$9,895.5**	**$11,122.4**
Total Avg. Annual Cost		**$16,471.8**	**$19,623.7**

[1] Note that totals may not sum due to rounding.

Note: All investment values are in millions of 2018 dollars.

Source: Transit Economic Requirements Model.

Exhibit 7-35: Annual Capital Investment Costs by Assessment Component: Expansion with Growth Scenario, 2019–2038



Source: Transit Economic Requirements Model.

The New Starts Pipeline investments tend to be highest during the earlier years of the projection period and drop off in later years. This pattern reflects that fact that this component captures FTA's listing of approved New Starts investments, a listing that currently only extends to 2030. Assuming New Starts investments were to continue throughout the remainder of the forecast period, the average annual investment levels for the two Expansion scenarios should be expected to be of similar magnitude to that presented in *Exhibits 7-34* and *7-35*. FTA is assessing options to account for these out-year New Starts investments. Finally, the annual investment levels presented in *Exhibit 7-35* correspond to the projected future expansion in the Nation's rail fleets, guideway route miles, and stations as shown in *Exhibits 7-26*, *7-27* and *7-28*.

Impact on Conditions and Performance

As noted earlier, both the Expansion and Expansion with Growth scenarios use the same rules followed in the SGR Benchmark to replace or rehabilitate assets (e.g., with assets being replaced at condition rating 2.5). Both scenarios result in transit achieving a state of good repair over the 20-year time horizon.

Differences exist between the SGR Benchmark and the Expansion and Expansion with Growth scenarios in total asset conditions by 2038. First, the SGR Benchmark does not apply TERM's benefit-cost test and hence includes all reinvestment investments—regardless of their cost-effectiveness. In contrast, the Expansion and Expansion with Growth scenarios report only reinvestments in those assets that pass TERM's benefit-cost test. Second, the Expansion and Expansion with Growth scenarios both introduce new, expansion assets into service. The introduction of these new assets, all in excellent condition, has the impact of increasing the average condition (and reducing the average age) of the Nation's transit assets.

Scenario Impacts Comparison

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 considers a few additional investment impact measures. These comparisons are presented in *Exhibit 7-36.* The first column of data in *Exhibit 7-36* presents the current values for each of these measures (as of 2018). The subsequent columns present the estimated future values in 2038, assuming the levels, allocations, and timing of expenditures associated with each of the three investment scenarios and the SGR Benchmark.

Exhibit 7-36: Scenario Investment Benefits Scorecard

Category	Measure	Baseline 2018: Actual 2014–2018 Spending, Conditions and Performance	Projected Spending, Conditions and Performance Values in 2038			
			SGR Benchmark	Sustain 2014–2018 Spending	Expansion	Expansion with Growth
Average Annual Capital Expenditures	Preservation	$13.5	$20.3	$13.5	$18.8	$18.9
	Expansion	$7.0	$0.0	$7.0	$6.6	$8.5
	Total	$20.5	$20.3	$20.5	$25.3	$27.4
Average Annual Operating Expenditures	Operating & Maintenance Costs	$95.2	$95.2	$105.9	$105.7	$106.9
Conditions (Existing Assets)	Average Physical Condition Rating	3.4	3.5	3.3	3.5	3.5
	Investment Backlog (Billions of Dollars)	$101.4	$0.0	$106.2	$0.0	$0.0
	Investment Backlog (% of Replacement Costs)	9%	0%	9%	0%	0%
	Backlog Ratio[1]	6.5	0.0	6.8	0.0	0.0
Performance (Asset Counts)	Total Passenger Fleet	173,718	173,718	234,173	227,158	237,220
	Total Passenger Stations	3,436	3,436	5,022	4,982	5,230
Total Route Miles		13,109	13,109	14,926	14,851	15,174

[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.

Note: Dollar amounts are in billions of 2018 dollars.

Source: Transit Economic Requirements Model.

Exhibit 7-36 includes the following measures:

- **Average annual capital expenditures (billions of dollars):** This amount is broken down into preservation and expansion expenditures.
- **Average annual operating expenditures (billions of dollars):** This amount captures the estimated differences in future total operating and maintenance costs given the varying levels of expenditures on service expansions under the Sustain 2014–2018 Spending, Expansion, and Expansion with Growth scenarios compared with operating and maintenance costs in 2018.
- **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 average annual level of investment required to maintain assets in a state of good repair once the backlog is eliminated.

Chapter 8: Supplemental Analysis

Supplemental Analysis – Highways

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. This section additionally explores DOT's backlog performance target and progress toward addressing this repair backlog.

Following the discussion of backlog, this section explores the sources of investment needs changes compared with previous C&P Reports, implied funding gaps, and the impact of externalities on investment levels.

This section then 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.

Finally, this section also examines the timing of investment over the 20-year analysis period and addresses the caveats of modeling varied investment patterns on ride quality and congestion. A subsequent section of this chapter provides supplementary analysis regarding the transit investment scenarios.

SECTION SUMMARY

- Compared in constant dollar terms, the highway repair backlog has decreased between the 24th and 25th editions.
- The gaps between the average annual investment levels between the Improve Conditions and Performance scenario and base-year spending, and between the Maintain Conditions and Performance scenario and base-year spending, have decreased between the 24th and 25th editions.
- As should be expected, favoring system rehabilitation over system expansion projects (Rehabilitation First investment strategy) would lead to better overall physical conditions (pavement ride quality) and worse operational performance (congestion).
- The timing of investment is not very significant in terms of conditions and performance results after 20 years; the advantage of front-loading investment comes mainly from allowing users to enjoy the benefits from improved conditions and performance earlier.

Comparison with the 24th 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 25th edition of the C&P Report and the 24th edition, the periods analyzed differ. This 25th edition covers a 20-year period of 2019 through 2038; the 24th C&P Report covered 2017 through 2036.

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) for the 25th C&P Report were set as spending at the lowest level at which (1) the projected share of vehicle mile traveled (VMT) on pavements with poor ride quality in 2038 matches (or is better than) the value in 2018, and (2) the projected share of VMT on severely congested roads in 2038 matches (or is better than) the value in 2018. This was a change from the 24th C&P Report, which instead targeted the average International Roughness Index (IRI) for pavements and average delay per VMT. The 25th C&P Report's 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, the same as in the 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 24th and this 25th edition assumes that cost-beneficial investments will be addressed immediately as they are identified.

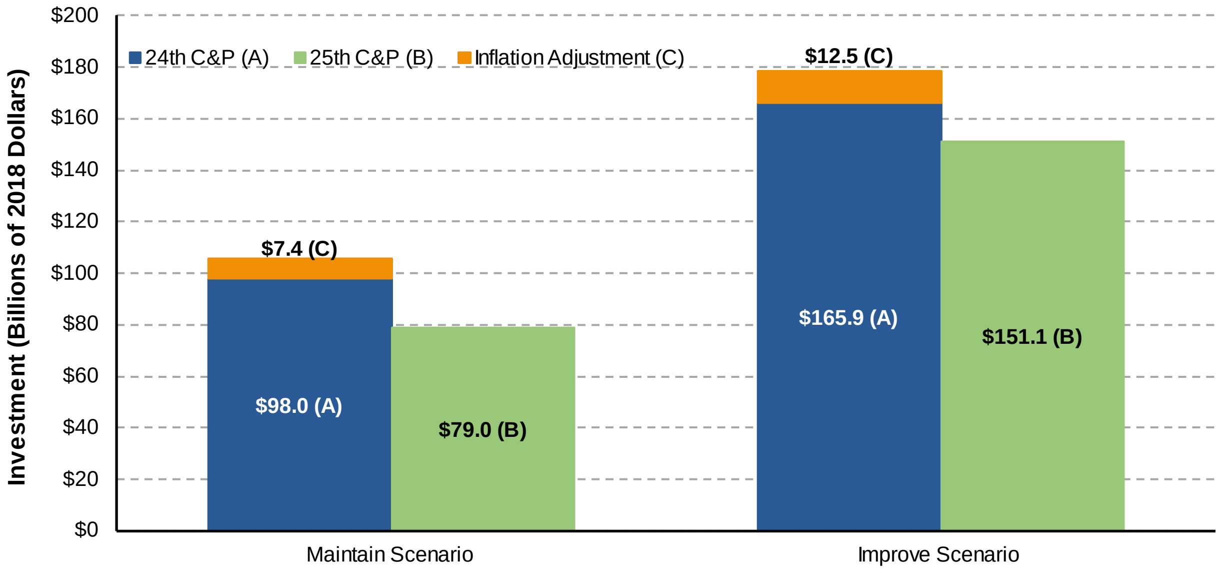
As discussed in Chapter 2, highway construction costs were converted to constant dollars using FHWA's National Highway Construction Cost Index (NHCCI) 2.0, which increased by 7.6 percent between 2016 and 2018. Consequently, the observed and projected highway construction costs would increase by 7.6 percent after adjusting the need figures in the 24th C&P Report's scenario from 2016 constant dollars to 2018 dollars. *Exhibit 8-1* shows that the 24th C&P Report estimated the average annual investment level in the current Maintain Conditions and Performance scenario at $98.0 billion in 2016 dollars; this figure shifts up to $105.4 billion in 2018 dollars after adjusting for inflation using NHCCI 2.0 (adding $7.4 billion). The comparable amount for the Maintain Conditions and Performance scenario presented in Chapter 7 of this edition is $79.0 billion in 2018 dollars, approximately 25.1 percent lower than the adjusted 24th C&P Report estimate.

Similarly, the average annual investment level in the 24th C&P Report for the Improve Conditions and Performance scenario was estimated to be $165.9 billion in 2016 dollars, the equivalent of $178.4 billion in 2018 dollars after adjusting for inflation. The comparable amount for the Improve Conditions and Performance scenario presented in Chapter 7 of this edition is $151.1 billion, 15.3 percent lower than the adjusted annual investment level based on the 24th C&P Report.

KEY TAKEAWAY

The average annual investment level in the 25th C&P Report for the Improve Conditions and Performance scenario ($151.1billion) is 15.3 percent lower than in the 24th C&P report ($178.4 billion) when adjusted to the same dollar-year.

Exhibit 8-1: Selected Highway Investment Scenario Projections from the 25th C&P Report Compared with Projections from the 24th 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; National Bridge Investment Analysis System.

Progress in Reducing the Highway Repair Backlog

DOT has established a performance target to reduce the backlog of $830 billion in highway repairs by 50 percent by 2040. This target represents the goal of the Department to address needed highway and bridge improvement projects that have lagged in implementation. Chapter 7 identifies the highway and bridge capital investment levels of the Improve Conditions and Performance scenario and defines the backlog subsets. The $830 billion target represents the combination of the System Rehabilitation and System Enhancement portions of the backlog presented in the 24th C&P, and excludes the System Expansion portion of the backlog.

KEY TAKEAWAY

The Department of Transportation has established a performance target to reduce the backlog of $830 billion [2016 dollars] in highway repairs by 50 percent by 2040. Although the 2018 Highway Repair backlog of $852 billion is 2.6 percent higher, in constant-dollar terms, it has decreased from the 24th C&P Report to the 25th C&P Report by 4.6 percent.

Exhibit 8-2 compares the backlogs reported in the 24th and 25th C&P. In nominal dollar terms the backlog rose 2.6 percent from $830 billion (expressed in 2016 dollars) to $852 billion (expressed in 2018 dollars). However, between 2016 and 2018, the National Highway Construction Cost Index rose by 7.6 percent, indicating that in 2016 constant-dollar terms, the backlog actually decreased by 4.6 percent.

Exhibit 8-2: Comparison of Backlog in 24th C&P Report and 25th C&P Report

Backlog Component	Reported 24th C&P Backlog, Billions of 2016 Dollars	Reported 25th C&P Backlog, Billions of 2018 Dollars	Adjusted 25th C&P Backlog, Billions of 2016 Dollars	Percent Change in Backlog 25th C&P vs. 24th C&P	
				In Nominal Dollars	In Constant 2016 Dollars
System Rehabilitation	$687.4	$702.4	$653.0	2.2%	-5.0%
System Enhancements	$142.9	$149.7	$139.2	4.7%	-2.6%
Highway Repair Backlog	**$830.3**	**$852.0**	**$792.1**	**2.6%**	**-4.6%**
System Expansion	$180.5	$237.4	$220.7	31.5%	22.3%
Total C&P Report Backlog	**$1,010.8**	**$1,089.4**	**$1,012.8**	**7.8%**	**0.2%**

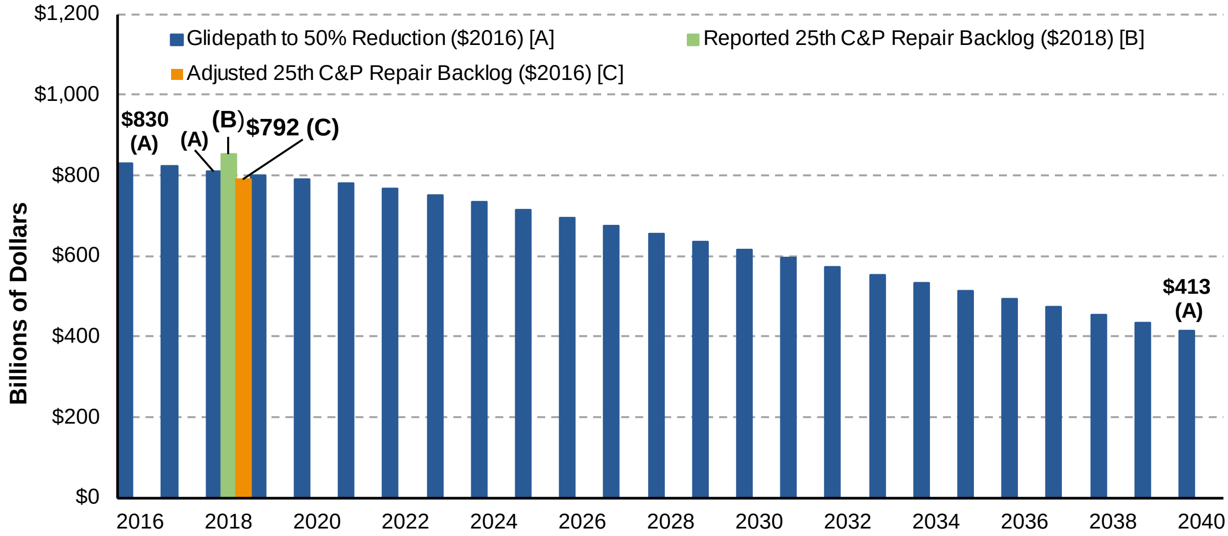
Note: The percentages shown in nominal dollar terms are direct comparisons of the reported backlog figures in each edition, though one is stated in 2016 dollars and the other in 2018 dollars.

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

Exhibit 8-3 illustrates the projected glidepath identified when the performance target was set. This forecast factored in increased Federal funding made available under the Bipartisan Infrastructure Law (BIL), enacted as the Infrastructure Investment and Jobs Act (IIJA), Pub. L. 117-58 (Nov. 15, 2021), and assumed that Federal funding would be sustained in constant-dollar terms in future years. Similarly, the combination of State, local, and private funding was assumed to be sustained in constant-dollar terms.

Similar to the comparison in *Exhibit 8-2*, *Exhibit 8-3* shows that although the nominal dollar comparison would suggest the repair backlog is growing, when compared in constant 2016 dollars the repair backlog is actually declining ahead of schedule as the reduction through 2018 is close to the level of reduction the glidepath had projected through 2020.

Exhibit 8-3: Progress Toward Reducing $830 Billion Highway Repair Backlog by 50 Percent by 2040



Note: The target of reducing the $830 billion highway repair backlog by 50 percent by 2040 had assumed reductions (in constant 2016 dollars) of 2 percent by 2018 and5 percent by 2020. While the 2018 highway repair backlog reported in this edition is higher in nominal dollar terms, expressed in constant 2016 dollars it decreased by 5 percent to $792 billion indicating that progress toward meeting the target is ahead of schedule.

Sources: Highway Economic Requirements System (HERS); National Bridge Investment Analysis System (NBIAS).

Sources of Investment Needs Changes

Exhibit 8-4 presents the sources of the differences between the 24th and 25th C&P Report values for the Backlog and the Improve Conditions and Performance Scenario. Under the Improve Conditions and Performance scenario, total estimated average annual investment needs decreased by $14.8 billion from the 24th to the 25th C&P Report. Of this change, the HERS-derived component shows a $5.6 billion decrease in average annual investment, whereas the NBIAS-derived component is smaller at a $2.7 billion decrease. The nonmodeled component is estimated at a $6.6 billion decrease between the 24th and 25th C&P Reports.

Exhibit 8-4: Sources of Differences Between the Backlog and Improve Conditions and Performance Scenario Values Presented in the 24th and 25th C&P Reports

Description	Factors Influencing Results	Improve C&P Scenario – Average Annual Investment ($ Billions)	Backlog ($ Billions)
Values from 24th C&P Report		**$165.9**	**$1,010.8**
Changes in HERS Results Due to:	Upgrades to Data Preprocessor	$4.4	$85.4
	Changes to VMT Forecast	-$0.6	$0.0
	Updates to Parameters	$2.5	-$3.5
	Upgrades to Analytical Procedures	-$13.2	-$82.6
	Updates to HPMS Data	$1.3	$11.9
Changes in NBIAS Results Due to:	Major Model Upgrades and Updates to NBI Data	-$2.7	$59.5
Changes in Nonmodeled Estimates Due to:	Change in HERS and NBIAS Results and Update to Nonmodeled Share of Recent Spending	-$6.6	$7.8
Values from 25th C&P Report		**$151.1**	**$1,089.4**

Source: Highway Economic Requirements System.

The HERS-derived component can be further decomposed to identify the sources of the investment change. *Exhibit 8-4* shows that the upgrades to analytical procedures are a major source of decrease ($13.2 billion), driven by upgrades to the average annual daily traffic calculations, updates to section length and diversion elasticities, and updates to speed calculations on sections with traffic signals and stop signs. Other HERS factors influencing results are less significant, such as changes to the VMT forecast ($0.6 billion) and updates to parameters ($2.5 billion). The change in the NBIAS-derived component (a $2.7 billion decrease) is driven by model upgrades and enhancements (see Appendix B for greater detail).

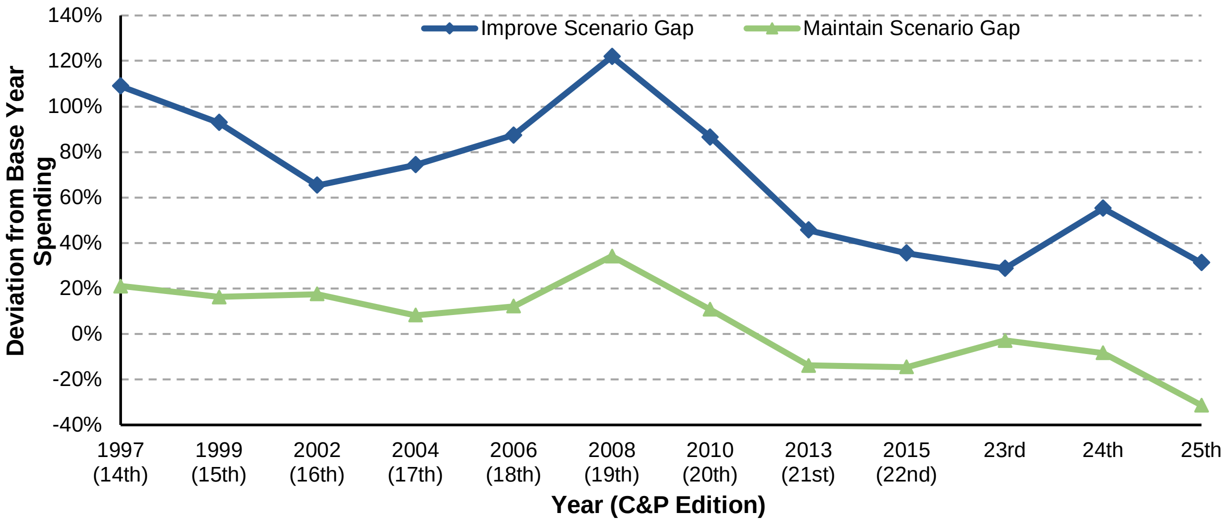
Exhibit 8-4 also presents the differences in Backlog estimates between the 24th and 25th C&P Reports, with the 25th C&P Report showing a Backlog increase of $79.4 billion. The $11.3 billion increase in the HERS-derived component is driven largely by upgrades to the data pre-processor (as a result of updates to the pre-processing of HPMS section data, which provides improved and more internally consistent treatment of data) at an $85.4 billion increase, upgrades to the analytical procedures at an $82.6 billion decrease, and updates to the HPMS data (between 2016 and 2018) at an $11.6 billion increase. The NBIAS-derived component shows a Backlog increase of $59.5 billion (driven by the inclusion of capacity expansion needs and updated element definitions), with the nonmodeled component increasing by $7.8 billion.

Comparisons of Implied Funding Gaps

Each edition of the C&P 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 8-5 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 8-5: Comparison of Average Annual Highway and Bridge Investment Scenario Estimates with Base-period Spending, 1997 Edition to 25th 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 across reports. Negative numbers signify that the investment scenario estimate was lower than base-period spending. The base period for the 25th edition is the average from 2014 to 2018, expressed in 2018 dollars. The base period for the 24th edition was 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; 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 dropped steadily from its peak in the 2008 C&P Report through the 23rd Report, before rising again in the 24th Report, and resuming its decline in the 25th 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 8-5* 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.

Externalities

Externalities represent the uncompensated impact of one person's actions on the wellbeing of a bystander. Two types of externalities are usually defined for highway systems: (1) impacts of drivers on each other, and (2) impacts of drivers on society. Typically, the focus of highway externalities is on negative externalities, or an imposed undesirable impact on others. Congestion is a common example of a negative externality that drivers have on other drivers. Similarly, emissions and noise pollution are externalities imposed by drivers on society. It is important to include externalities, where possible, in the modeling process to attain realistic pricing, cost, and benefit outputs.

HERS includes some types of externalities in its computation of net benefits, but not in its computation of the implicit price (in the form of travel time costs, vehicle operating costs, and crash costs) that highway users pay to use the system. Changes in this implicit price are assumed to influence travel demand, which is simulated in HERS through its calculations of travel demand elasticity (e.g., adding capacity to congested highway sections will initially lower the initial implicit price, leading to induced demand). The existence of externalities means that highway use is underpriced from the individual driver's perspective, which leads to overconsumption. This in turn may result in investments in system expansions that might not be needed were implicit prices more in line with overall societal impacts. If externalities were internalized in some manner, be it through altruism or through some sort of pricing scheme, it would reduce demand for highway travel and thus reduce the benefits associated with adding capacity.

Exhibit 8-6 illustrates the potential impact of internalizing externalities during peak period travel under severely congested conditions. Increasing the assumed implicit price to include externalities would significantly reduce the average annual investment level under the Improve

Conditions and Performance scenario to approximately the level that all levels of government combined have been spending in recent years.

The level of cost-beneficial capacity investments identified by HERS (HERS-derived System Expansion) would be 44.9 percent lower. The level of cost-beneficial pavement investments identified by HERS (HERS-derived System Rehabilitation) would be 10.6 percent lower, in part because the pavement portion of some projects that would have involved both pavement improvements and capacity expansion would be deferred outside the 20-year analysis period.

Exhibit 8-6: Impact of Externalities on the Improve Conditions and Performance Scenario Average Annual Investment Levels

Scenario/Alternative	HERS-derived System Rehabilitation	HERS-derived System Expansion	NBIAS-derived Component	Other (Nonmodeled) Component	Total
Recent Spending: Average Annual (2014–2018)	$44.0	$22.8	$15.8	$32.5	$115.1
Improve Conditions and Performance Scenario: Average Annual (2019–2038)	$46.9	$39.2	$22.3	$42.6	$151.1
Improve Conditions and Performance Alternative (Assuming Externalities Internalized during Severe Congestion): Average Annual (2019–2038)	$41.9	$21.6	$22.3	$33.8	$119.6
Percentage Change in Improve Conditions and Performance Due to Alternative Assumption	-10.6%	-44.9%	0.0%	-20.8%	-20.8%

Note: HERS projects pavement (System Rehabilitation) and capacity (System Expansion) investment needs for Federal-aid Highways. NBIAS projects bridge (System Rehabilitation) investment needs. Other nonmodeled items include System Enhancements on all roads, and pavement and capacity investments needs off of Federal-aid Highways. See Chapter 7 for definitions. Dollar values are in billions of 2018 dollars.

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

Although congestion externalities are highest during periods of severe congestion, environmental externalities occur during both peak and off-peak periods. Extending this illustrative analysis to other times of day would result in even larger reductions in the estimated level of cost-beneficial investments.

Allocation of Investment

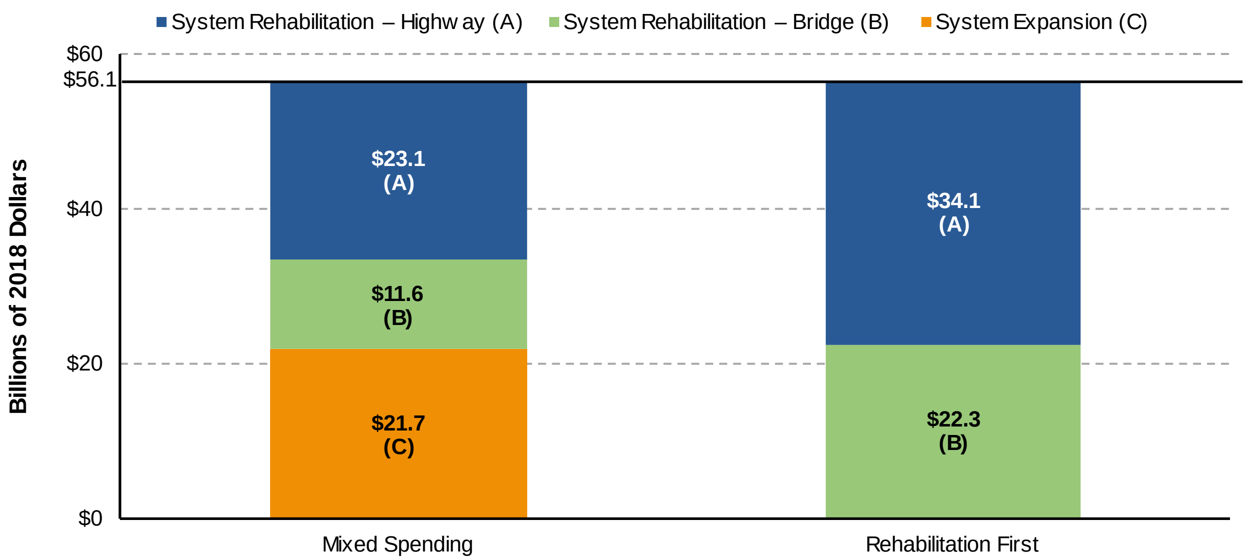
Currently, potential projects evaluated by HERS and NBIAS are treated equally in a pool of candidates for capital improvement. The models use the benefit-cost ratio (BCR) to rank and implement projects, regardless of which spending category or functional class they happen to fall into. For funding-constrained 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 system expansion projects and system rehabilitation projects based solely on BCR, rather than through a predetermined allocation.

Exhibit 8-7 describes alternative approaches 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 versus system rehabilitation. The Mixed Spending allocation includes a mix of both rehabilitation and expansion investment. 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 Rehabilitation First case, the $56.4 billion budget level represents the sum of (1) the $22.3 billion average annual level of cost-beneficial investment from the NBIAS-derived component of the Improve Conditions and Performance scenario, and (2) the $34.1 billion computed by HERS as the average annual level of cost-beneficial investment on Federal-aid highways assuming no new capacity can be added anywhere. This latter figure is considerably lower than the $46.9 billion for highway system rehabilitation on Federal-aid highways reflected in the Improve Conditions and Performance scenario. This apparent discrepancy results from projects that involve both System Rehabilitation and System Expansion components. When widening a facility, system owners typically resurface or reconstruct the existing lanes as well, resulting in improvements to both operational performance (at least in the short term) and pavement condition. In the absence of a widening component, some potential projects would likely be deferred until pavement conditions further deteriorate.

For the Mixed Spending case, the $56.4 billion annual budget level was split proportionally between HERS and NBIAS based on their relative shares of the Improve Conditions and Performance scenario. The $11.6 billion allotted to NBIAS all went for Bridge System Rehabilitation, whereas the $54.8 allotted to HERS was split between Highway System Rehabilitation and System Expansion based on the model's regular procedure of ranking potential projects based on their BCR.

Exhibit 8-7: Capital Investment under Alternative Allocations



Source: FHWA staff analysis.

Alternative Allocation of Investment in HERS

Exhibit 8-8 compares the hypothetical annual spending levels under the Mixed Spending and Rehabilitation First strategies. Among these spending strategies, the Mixed Spending strategy allocates more resources to the expansion of highways and bridges, while still allocating some funding for rehabilitation. Under the Rehabilitation First strategy, the entirety of capital spending goes to system rehabilitation, leaving nothing for capacity expansion.

For instance, under the Mixed Spending strategy for rural Interstates, HERS directed $0.4 billion for system expansion and $1.1 billion for system rehabilitation, totaling $1.5 billion. Under the Rehabilitation First strategy, HERS directed $1.5 billion annually to system rehabilitation on rural Interstates. (See Chapter 1 for additional discussion of functional classification.)

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

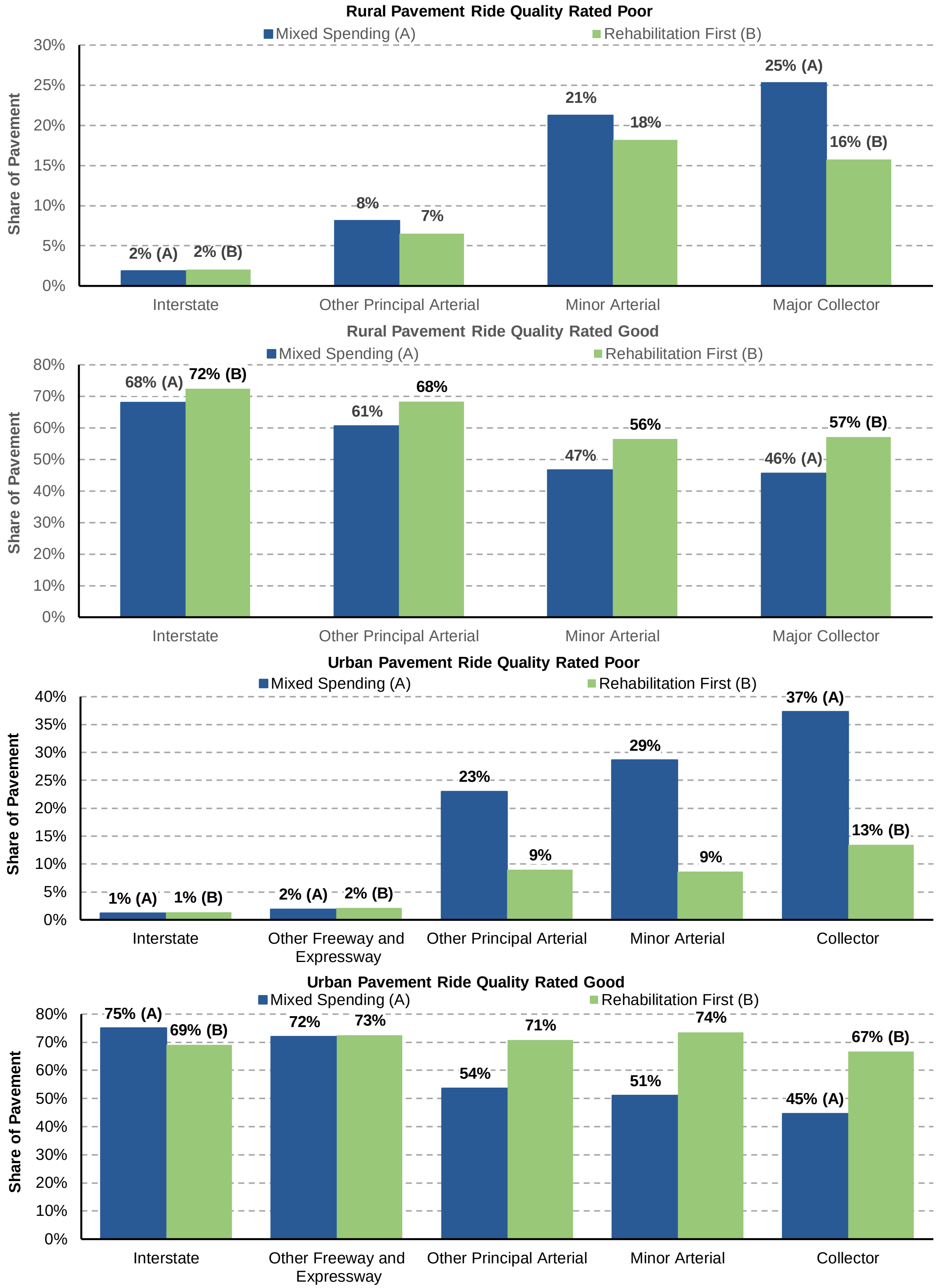
Type	Functional Class	System Expansion Spending		System Rehabilitation Spending	
		Mixed Spending Strategy	Rehabilitation First Strategy	Mixed Spending Strategy	Rehabilitation First Strategy
Rural Arterials and Major Collectors	Interstate	$0.4	$0.0	$1.1	$1.5
	Other Principal Arterial	$0.5	$0.0	$1.7	$2.7
	Minor Arterial	$0.4	$0.0	$1.5	$2.5
	Major Collector	$0.1	$0.0	$1.7	$2.7
	Rural Total	**$1.5**	**$0.0**	**$5.9**	**$9.4**
Urban Arterials and Collectors	Interstate	$6.5	$0.0	$4.3	$3.3
	Other Freeway and Expressway	$3.0	$0.0	$2.1	$2.0
	Other Principal Arterial	$5.3	$0.0	$4.6	$7.9
	Minor Arterial	$3.5	$0.0	$4.0	$7.0
	Collector	$2.0	$0.0	$2.1	$4.3
	Urban Total	**$20.3**	**$0.0**	**$17.2**	**$24.5**
Total		**$21.7**	**$0.0**	**$23.1**	**$34.1**

Source: Highway Economic Requirements System.

Exhibit 8-9 illustrates the impacts on pavement ride quality in 2038 from two 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. In almost all cases, the Rehabilitation First strategy results in better ride quality (higher share of travel on pavements with ride quality rated good, and lower share of travel on pavements with ride quality rated poor) compared with the Mixed Spending strategy. For rural Major Collectors under the Rehabilitation First strategy, for example, the projected shares of travel on pavements with ride quality rated good and poor were 57 percent and 16 percent, respectively, whereas the comparable shares for the Mixed Spending strategy were 46 percent and 25 percent, respectively. The exception to this trend was on urban Interstates, which show worse ride quality under the Rehabilitation First strategy as a result of some potential projects featuring both rehabilitation and expansion elements being deferred until a later date once the expansion elements were removed from consideration.

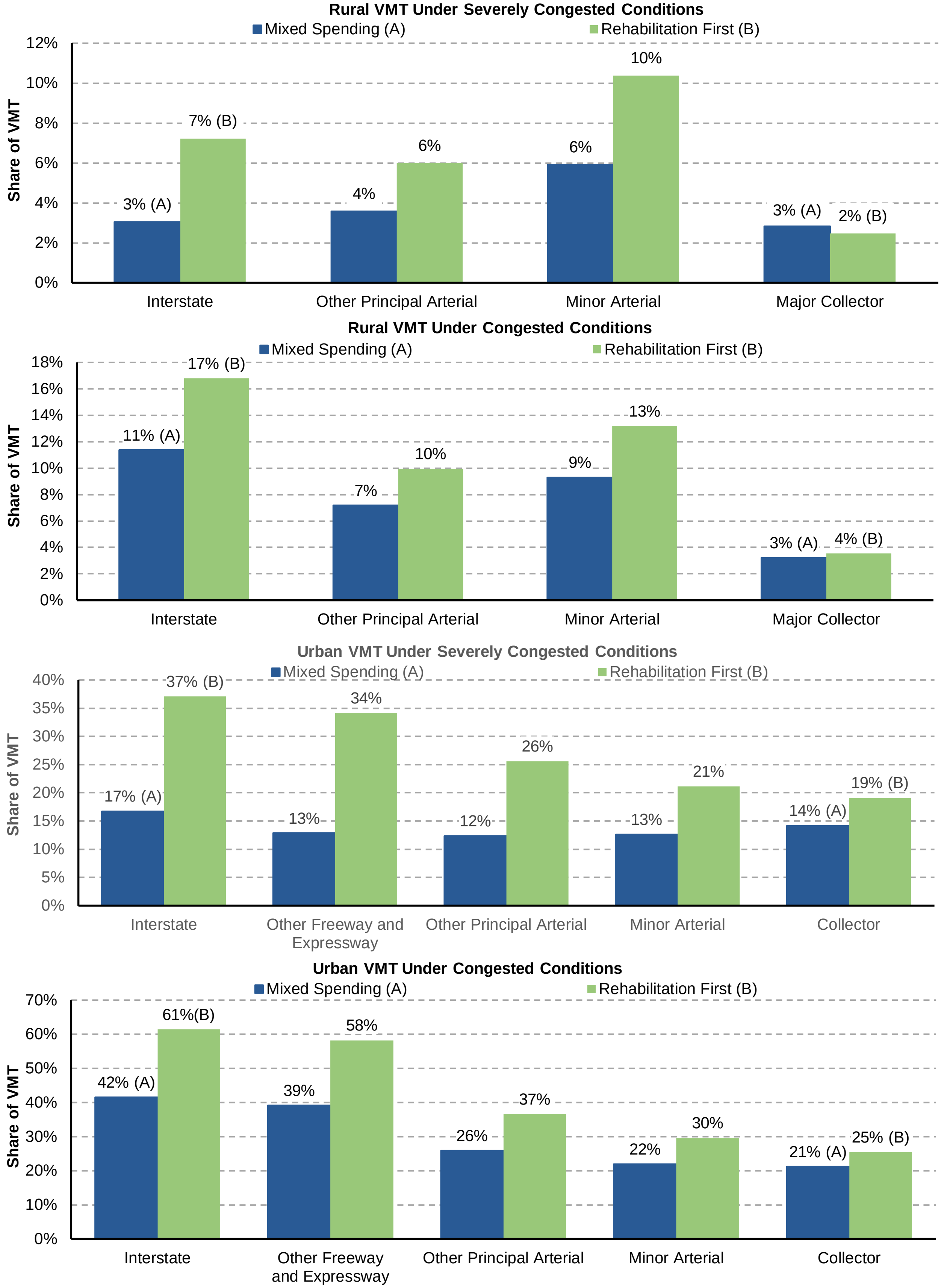
HERS also simulates congestion in 2038, which varies by alternative spending distributions (see *Exhibit 8-10*). The Mixed Spending strategy delivers better travel conditions in almost all cases. The Mixed Spending strategy results in 24 percent of VMT on congested roadways (a volume/service flow ratio above 0.80) and 11 percent on severely congested roads (a volume/service flow ratio above 0.95), respectively. Comparable metrics for the Rehabilitation First strategy are 34 percent and 21 percent, respectively.

Exhibit 8-9: Comparison of 2038 Highway Pavement Ride Quality by Functional Class under Alternative Strategies



Source: Highway Economic Requirements System.

Exhibit 8-10: Comparison of 2038 Travel under Congested and Severely Congested Conditions by Functional Class under Alternative Strategies



Source: Highway Economic Requirements System.

Alternative Allocation of Investment in NBIAS

Exhibit 8-11 presents the average annual spending on bridge rehabilitation under two defined spending strategies. Bridge capital expansion is modeled in HERS, whereas NBIAS captures only system preservation and rehabilitation. Hence, no system expansion spending for NBIAS is reported here. *Exhibit 8-11* presents a Mixed Spending strategy, where spending is divided between expansion and rehabilitation, as well as a Rehabilitation First strategy. Annual spending for system rehabilitation is $11.6 billion under the Mixed Spending strategy and $22.3 billion under the Rehabilitation First strategy.

Exhibit 8-11: Comparison of Annual NBIAS Spending by Functional Class under Alternative Strategies

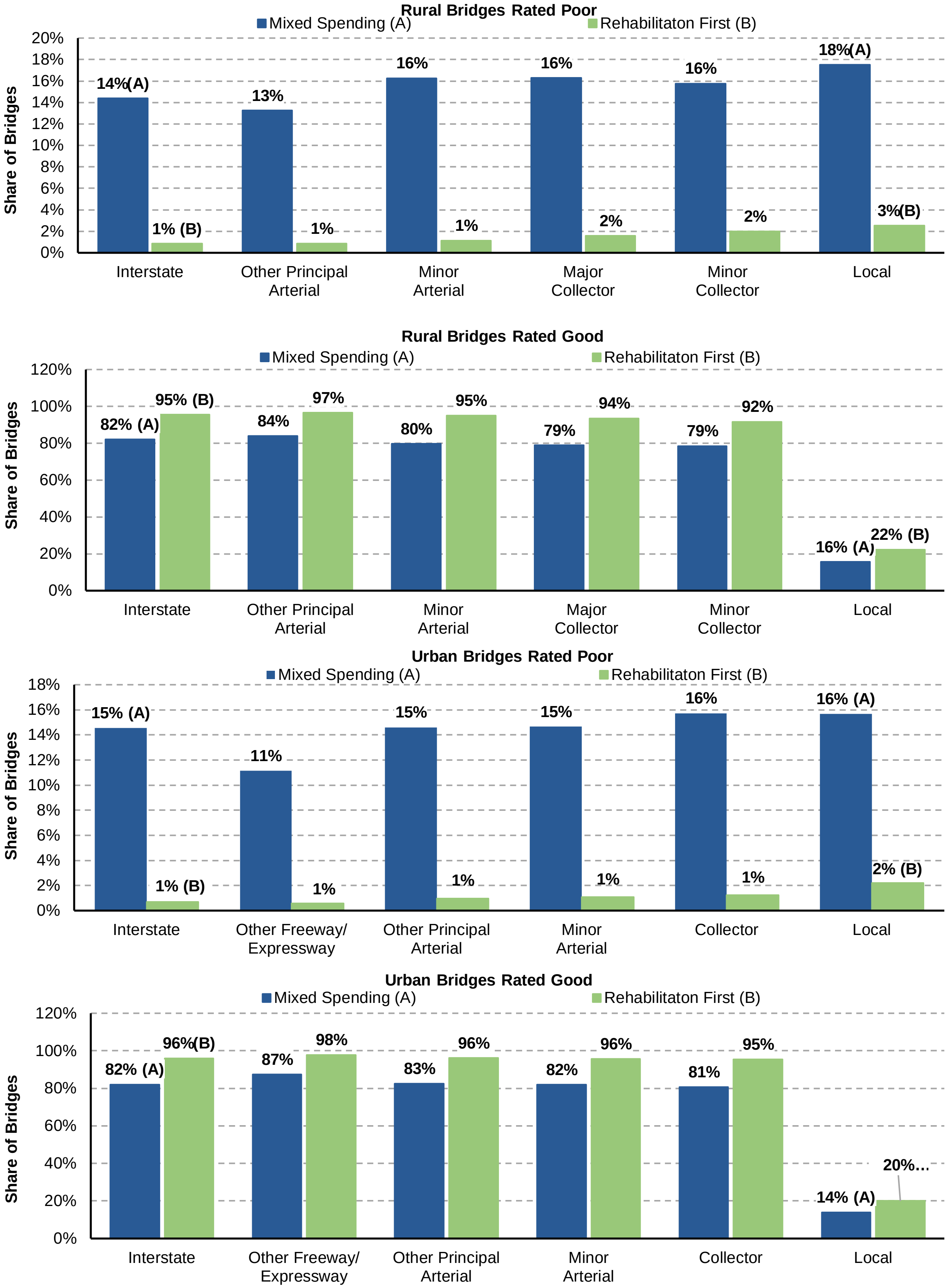
Rural/Urban	Functional Class	System Rehabilitation Spending	
		Mixed Spending Strategy	Rehabilitation First Strategy
Rural	Interstate	$0.8	$1.5
	Other Principal Arterial	$0.8	$1.2
	Minor Arterial	$0.5	$1.0
	Major Collector	$0.8	$1.6
	Minor Collector	$0.3	$0.7
	Local	$0.8	$1.7
	Rural Total	**$4.1**	**$7.8**
Urban	Interstate	$3.2	$6.3
	Other Freeway and Expressway	$1.2	$2.1
	Other Principal Arterial	$1.3	$2.5
	Minor Arterial	$1.0	$2.0
	Collector	$0.4	$0.8
	Local	$0.4	$0.8
	Urban Total	**$7.6**	**$14.6**
Total		**$11.6**	**$22.3**

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 Mixed Spending strategy, $0.8 billion went for improvements to rural Interstate bridges. The level of rural Interstate bridge spending for the Rehabilitation First strategy was at a higher level of $1.5 billion.

Exhibit 8-12 illustrates the projected impacts of the two alternative investment strategies. The charts compare the share of bridges (weighted by deck area) rated as poor and good in 2038 by functional class in rural and urban areas. For example, the share of rural Interstate bridges rated as poor in 2038 would be higher under the Mixed Spending strategy (14 percent) compared with the Rehabilitation First strategy (1 percent). A similar pattern can be observed for each of the other rural and urban functional classes, where the Rehabilitation First strategy consistently results in a higher share of bridges rated as good and a lower share of bridges rated as poor in 2038 than does the Mixed Spending strategy.

Exhibit 8-12: Comparison of 2038 Bridge Condition by Functional Class under Alternative Strategies



Note: Shares are weighted by bridge deck area.

Source: National Bridge Investment Analysis System.

Implications and Caveats

This illustrative example of the application of alternative investment strategies highlights the potential advantages of a fix-it-first type approach, particularly in terms of reducing the share of poor pavements and bridges. The tradeoff is that congestion would increase relative to a mixed investment approach that includes capacity expansion projects.

In reality, the distinction between system rehabilitation and system expansion investments is not always clear cut. As noted above, when widening a facility, system owners typically resurface or reconstruct the existing lanes as well. Some projects that do not add lanes might still involve the widening of existing lanes, which can have an impact on increasing vehicle speeds.

System rehabilitation projects can also influence congestion in cases where pavement conditions have deteriorated to the point that they are affecting vehicle speed. Capital improvements of any kind also involve work zones, which lead to temporary increases in congestion. Additionally, system conditions and performance indicators can 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 2014–2018 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: $1.598 trillion for HERS and $394 billion for NBIAS. Translated into annual average spending, this equates to $79.9 billion per year for HERS and $19.7 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 2014–2018 Spending scenario and the Maintain Conditions and Performance scenario both assume flat spending. Chapter 7 specifies the spending level under the Sustain 2014–2018 Spending scenario as the average level over the 5-year period 2014–2018 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 2038 would match, or be better than, their average values in 2018.

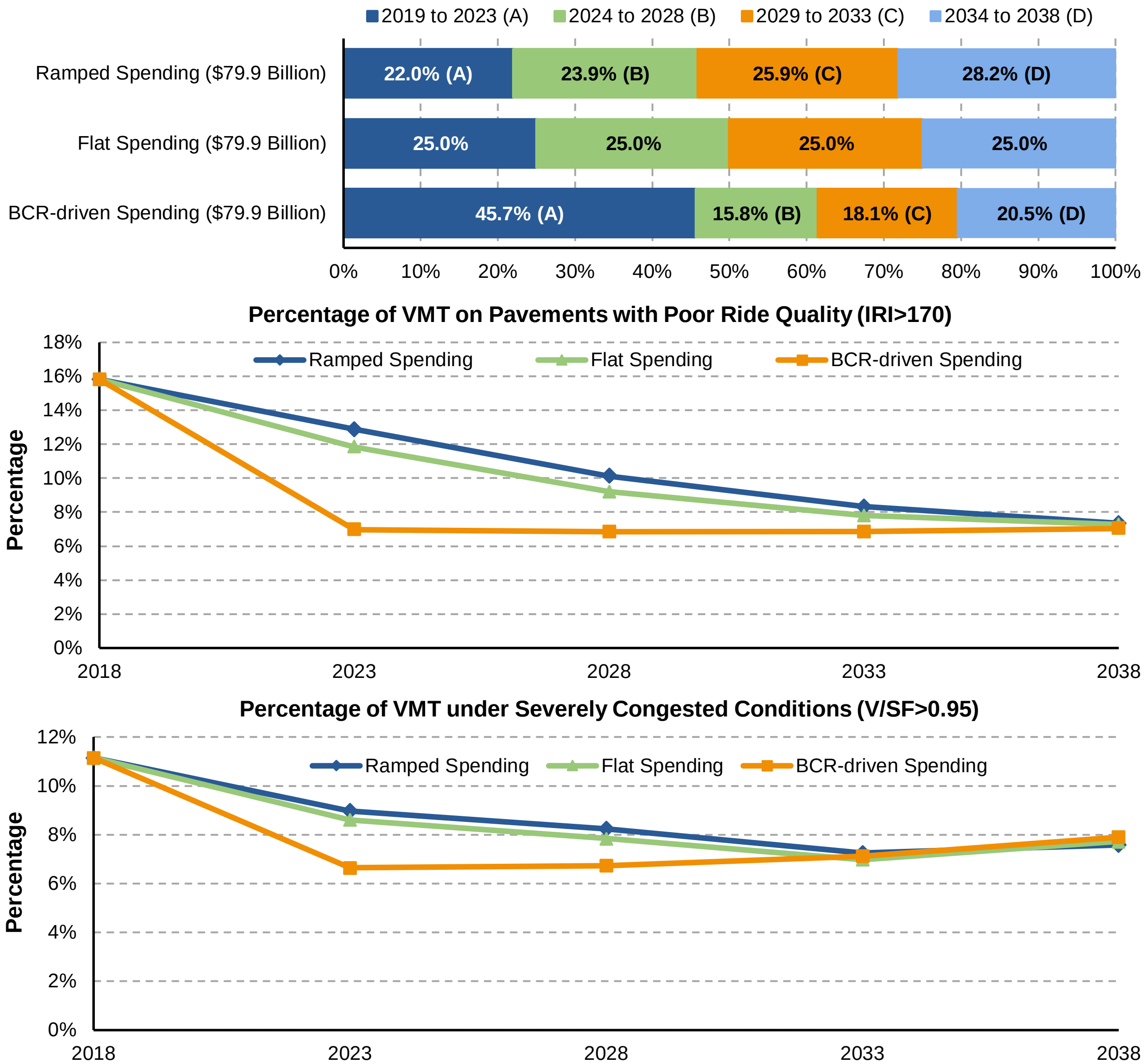
The ramped spending assumption is that any change from the combined investment level by all levels of government would occur gradually over time and at a constant growth rate. The constant growth rate of the ramped spending analysis measures future investment in real terms; thus, the distribution of 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 fewer projects are cost-beneficial.

Alternative Timing of Investment in HERS

Exhibit 8-13 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 $1.598 trillion over 20 years in constant 2018 dollars.

Exhibit 8-13: Impact of Investment Timing on HERS Results for a Selected Investment Level – Effects on Pavement Ride Quality and Severe Congestion



Note: VMT is vehicle miles traveled; IRI is International Roughness Index, measured in inches per mile; V/SF is Volume/Service Flow.
Source: Highway Economic Requirements System (HERS).

As shown in the top panel of *Exhibit 8-13*, 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 1.67 percent per year to reach the total budget constraint of $1.598 trillion over 20 years. Only 22.0 percent of the total 20-year investment occurs in the first 5-year period, 2019–2023, whereas 28.2 percent of total investment occurs in the last 5-year period, 2034–2038.

For the BCR-driven spending alternative, a minimum BCR cutoff of 1.109 was applied, which resulted in a total 20-year investment of $1.598 trillion. A high proportion of total spending, 45.7 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 sharply to 15.8 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 across 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 2023.

The middle panel of *Exhibit 8-13* presents the percentage change of percent of VMT on pavements with poor ride quality (IRI>170), compared with the 2018 level under the three investment cases. A reduction in VMT on pavements with poor ride quality implies 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 the percentage of VMT on pavements with poor ride quality—from 15.8 percent to 7.0 percent. The improvement under the BCR-driven spending alternative is largely unchanged by the last 5-year period, at 7.0 percent. Slower but steady pavement improvement over time is achieved under the ramped spending and flat spending assumptions. By 2023, the proportion of VMT on pavements with poor ride quality decreases to 12.9 percent and to 11.8 percent under the ramped spending and flat spending assumptions, respectively. By the end of 20-year period, the proportion of VMT on pavements with poor ride quality under the ramped spending and flat spending assumptions reaches 7.3 percent for each investment case.

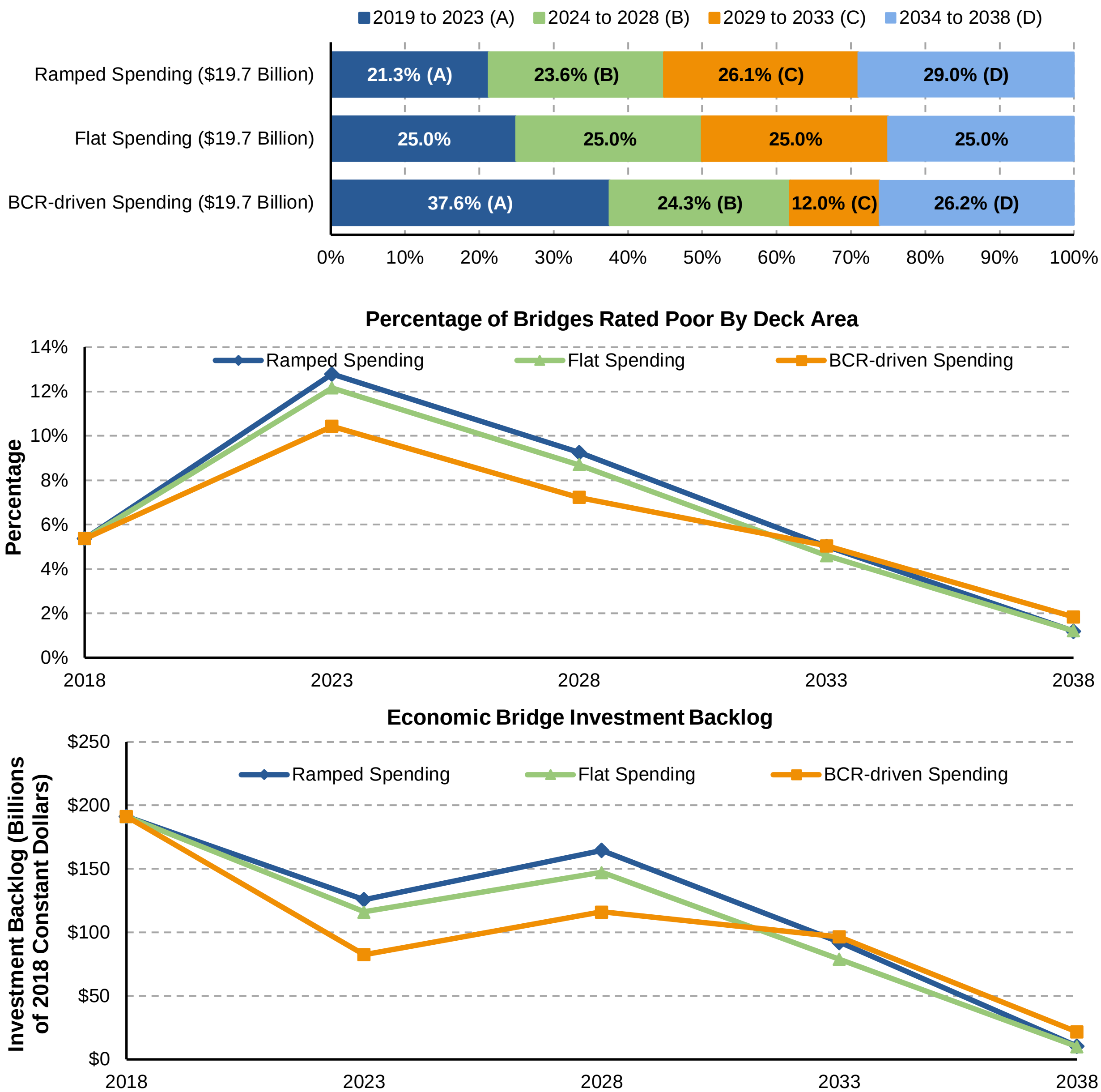
The bottom panel of *Exhibit 8-13* illustrates the percentage of VMT under severely congested conditions (volume/service flow>0.95), relative to its 2018 level. Under each investment case, the percentage of VMT declines until 2033 before increasing slightly by the end of the 20-year study period. In the first 5 years, the BCR-driven spending approach results in the largest reduction in percentage of VMT under severely congested conditions, from 11.2 percent to 6.6 percent, with the ramped spending approach resulting in the smallest reduction, decreasing to 9.0 percent. By 2038, the reductions in the percentage of travel under severely congested conditions converge to between 7.6 and 7.9 percent under all three alternative spending assumptions.

These results show that the BCR-driven approach achieves the largest reductions in poor pavement and congested conditions in the medium term (the first and second 5-year periods) because existing backlog is addressed all at once. The ramped spending approach results in the smallest improvements 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 8-14 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 $394 billion in constant 2018 dollars was assumed for each alternative analyzed.

Exhibit 8-14: 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.

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 $394 billion in constant 2018 dollars. The top panel of *Exhibit 8-14* indicates that more investment occurs in the later years under the ramped case of gradual and constant growth—from 21.3 percent in the initial 5-year period to 29.0 percent in the last 5-year period. The BCR-driven spending case applies a minimum BCR cutoff of 2.04. It is front-loaded, which requires a large portion of the total 20-year investment in the first 5-year period (37.6 percent) and declines to 26.2 percent in the last 5-year period. Spending levels remain constant at $19.7 billion per year in the flat spending case.

Although different investment patterns produce slightly different outcomes, the trends across investment patterns are similar. The middle panel of *Exhibit 8-14* shows that, under all investment patterns, the percentage of bridges rated poor by deck area increases in the first 5-year period. The percentage of bridges rated poor by deck area are slightly better than initial 2018 level (5.4 percent) by 2033 (around 5 percent), and bridges show improvement under the BCR-driven, flat, and ramped investment pattern by 2038 (1.8 percent, 1.2 percent, and 1.2 percent, respectively).

The economic bridge investment backlog also exhibits similar trends under the alternative investment timing strategies. The lower panel of *Exhibit 8-14* indicates that from 2018 to 2023, 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. Intermediate years of analysis show slightly increasing backlog in 2028, followed by decreasing backlog in 2033, for all investment patterns. By the end of the analysis period, all investment patterns show steep declines in backlog, with BCR-driven spending, flat spending, and ramped spending resulting in backlogs of $21.6 billion, $10.1 billion, and $10.4 billion, respectively

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 and expected future capital needs. Specifically, this section addresses the following topics:

- Forecasts of asset condition and useful life consumed under three scenarios: (1) Sustain 2014–2018 Spending, (2) Expansion, and (3) Expansion with Growth, as well as a discussion of the State of Good Repair (SGR) Benchmark;
- An analysis of changes in the estimated size of the SGR backlog over the past 10-year period and analysis of the key drivers of those changes; and
- A discussion of how the expected adoption of electric buses is expected to impact bus fleet and total investment needs.

SECTION SUMMARY

The national condition level of transit assets in 2018 stood at 3.41 (on a scale from 1 to 5), roughly in the middle of the adequate condition range (3.0–3.9).

Asset Conditions under Investment Scenarios

Expansion and Expansion with Growth Investment scenarios: After an initial jump, the average condition in 2038 is projected to be in the 3.6 range under these scenarios.

Sustain 2014–2018 Spending: Under this scenario, the average condition is predicted to decrease consistently from the 2018 level (3.4) to 3.3, in the bottom of the adequate condition range. This result is due mainly to two factors: (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.

Electric Bus Fleet Costs

Assuming broad adoption of electric buses in place of existing diesel and CNG models by 2038, total bus fleet acquisition costs can be expected to increase by roughly 25 to 30 percent through 2028.

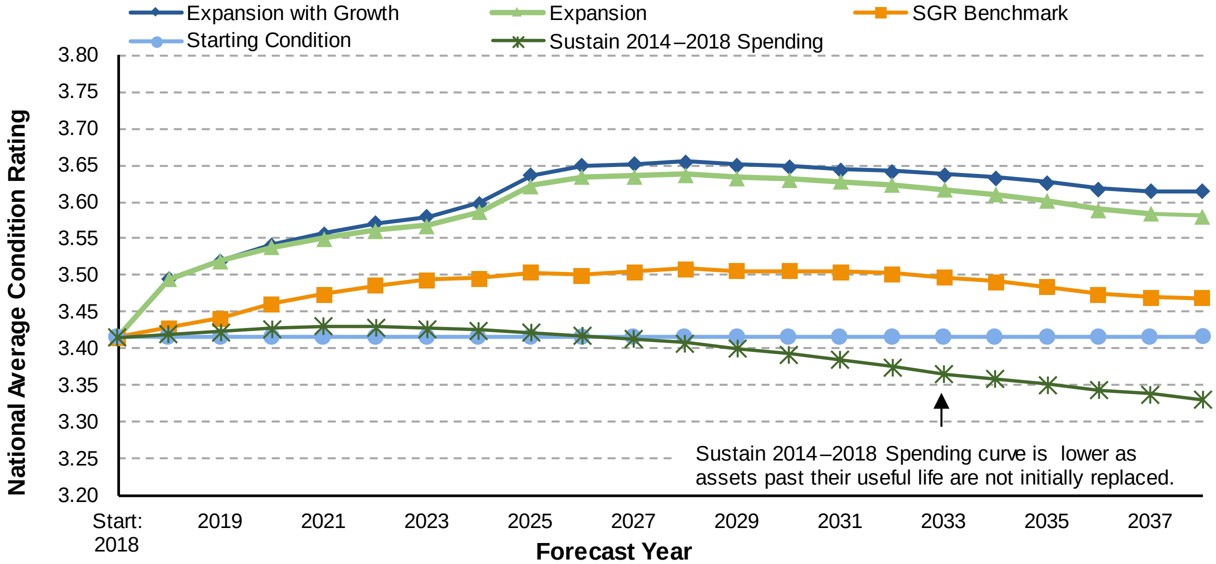
Asset Condition Forecasts and Expected Useful Service Life Consumed

Exhibit 8-15 presents year-by-year projections of the average condition of the Nation's transit assets under each of the three investment scenarios and the SGR Benchmark (described in Chapter 7). Note that these projections predict the condition of all transit assets in service during each year of the 20-year analysis period, including transit assets that exist today and any investments in additional assets under these scenarios. The Sustain 2014–2018 Spending, Expansion, and Expansion with Growth scenarios each make investments in expansion, which increases the pool of assets, whereas the SGR Benchmark reinvests only in existing assets.

Sustain 2014–2018 Spending Scenario

Exhibit 8-15 shows that the estimated current average condition of the Nation's transit assets is 3.42 on the condition scale of 1 to 5 as defined in Chapter 6. As discussed in Chapter 7, expenditures under the financially constrained Sustain 2014–2018 Spending scenario are only sufficient to keep the existing backlog from growing. In addition, the condition of very long-lived assets—such as tunnels, subway stations, and historic buildings—continues to decline slowly 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 8-15.*[35]

Exhibit 8-15: Asset Condition Forecast for All Existing and Expansion Transit Assets, Smoothed



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

SGR Benchmark and Expansion Scenarios

In contrast to the financially constrained Sustain 2014–2018 Spending scenario, the SGR Benchmark and the Expansion and Expansion with Growth scenarios are all financially unconstrained with respect to reinvestment needs. Hence, the SGR Benchmark and the two growth scenarios assume a level of investment sufficient 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). To provide a more realistic depiction of potential future changes in asset conditions, the “unconstrained” asset preservation (SGR) investments for these scenarios have been evenly distributed over the 20-year period of analysis. This adjustment to these otherwise unconstrained needs analyses avoids the appearance of a single, large increase in average asset conditions in the first year of the projection, followed by a slow steady decline in subsequent conditions. Rather, conditions as presented in *Exhibit 8-15* increase and decline in a manner reflective of a more realistic level of annual expenditures through 2038, while still assuming sufficient funding to address all SGR needs by the end of the analysis period in 2038.

As with the Sustain 2014–2018 Spending scenario, the average condition estimates for the SGR Benchmark and the Expansion and Expansion with Growth scenarios all start with an average condition of 3.42. From here, the average condition for each of these scenarios continues to rise throughout roughly the first 10 years of the forecast period. For the SGR Benchmark, this increase is driven entirely by the rapid replacement of assets that currently exceed their useful life. For the Expansion and Expansion with Growth scenarios, this initial improvement in conditions is more rapid and more significant, being driven by the same increase in preservation investments as the SGR Benchmark as well as by significant investments in new expansion assets. In subsequent years, the improvement is larger for the Expansion with Growth scenario, which adds investments to support ridership growth on top of the same five expansion component investments included in the Expansion scenario (including

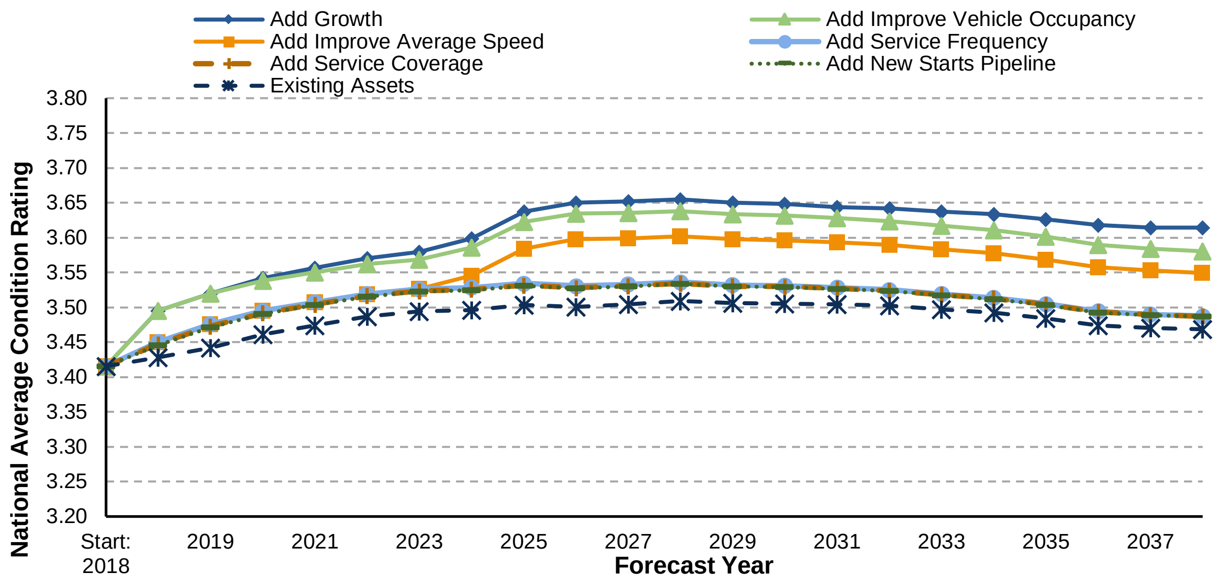
[35] Note that annual capital expenditures are expected to increase under the Bipartisan Infrastructure Law.

the New Starts, Service Coverage, Service Frequency, Average Speed Improvement, and Vehicle Occupancy Improvement expansion components).

Despite the ongoing investments in asset replacement and asset expansion, the increase in average conditions for these three scenarios begins to slow in the later years of the forecast period and then average conditions start to decline. Two related factors drive this decline. First, because the weighted average life span for transit assets is roughly 65 years, close to 90 percent of transit assets have life spans that exceed the 20-year length of the forecast period. Hence, most of the backlog assets replaced, and expansion assets added, during the early years of the forecast period will have significant remaining life by the end of the 20-year forecast period. The collective effect of their slow aging throughout the remainder of the forecast period serves to continually pull down the national average condition. This downward pull gets stronger later in the forecast period, as there are fewer over-age assets to replace and as the stock of added expansion assets continues to increase. Second, the transit industry has undergone significant expansion since 1980—particularly in rail systems, which tend to be dominated by assets with long useful lives. Again, given these long lives, a significant proportion of these expansion assets will also not have reached the end of their useful lives even by 2038, maintaining their own downward pull on the average. Together, these two 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.

In contrast to *Exhibit 8-15*, which compares the condition forecasts of the four investment scenarios, *Exhibit 8-16* focuses solely on the Expansion with Growth scenario to provide a segmented view of the condition impacts of the five expansion components that drive expansion needs within that scenario. Specifically, this exhibit shows each expansion component's contribution to the cumulative change in assets conditions for the Expansion with Growth scenario over the 20-year forecast period (beginning with the stock of existing assets at the bottom of the chart, then showing the impact of adding the New Starts Pipeline investments, followed by the Service Coverage assets, and so on). Note that whereas the New Starts, Improve Average Speed, Improve Vehicle Occupancy, and Growth components each yield notable improvements in asset conditions, the contributions from Service Coverage and Service Frequency are less visible on the chart. This difference reflects the relatively small levels of expansion investment for these latter two components.

Exhibit 8-16: Asset Condition Forecast for All Existing and Expansion Transit Assets, Smoothed (Expansion with Growth only)



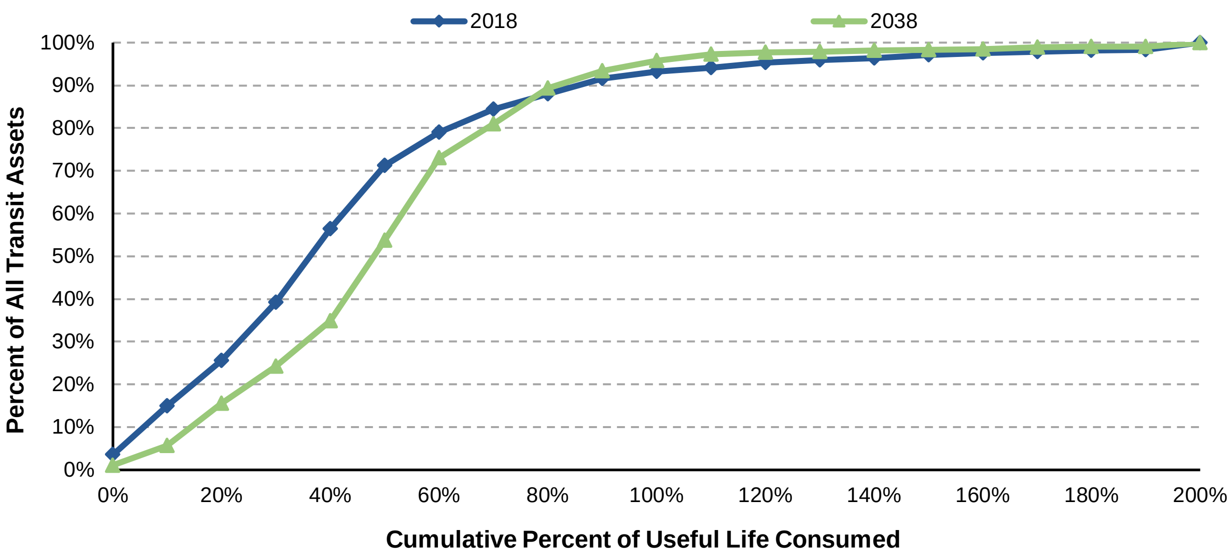
Source: Transit Economic Requirements Model.

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 percentage of asset life consumed between the start and end years of analysis for each scenario: Sustain 2014–2018 Spending, Expansion, Expansion with Growth, and the SGR Benchmark. This analysis demonstrates how the objectives of each investment scenario drive differences in the long-term distribution of asset ages relative to asset useful life. It also provides life-cycle comparisons across transit assets with a wide range of lifespans (ranging from roughly 5 to 100 years) by using the percentage of life consumed as a common indicator.

The distribution of the percentage of useful life consumed for the start and end years of the Sustain 2014–2018 Spending scenario forecast is shown in *Exhibit 8-17*. This is a cumulative distribution. For example, the chart shows that 76.8 percent of replaceable assets were at or below 80 percent of life consumed as of 2018. In contrast, the analysis projects that roughly 80 percent of all replaceable assets will be at or below 59.3 percent of life consumed by 2038. In general, *Exhibit 8-17* suggests that the Sustain 2014–2018 Spending scenario has tended to result in a decreased distribution in the percentage of life consumed by the year 2038 (i.e., the 2038 curve lies mostly to the right of the 2018 curve). Most notably, there has been an increase in the percentage of assets that exceed 100 percent of useful life consumed and need replacement.

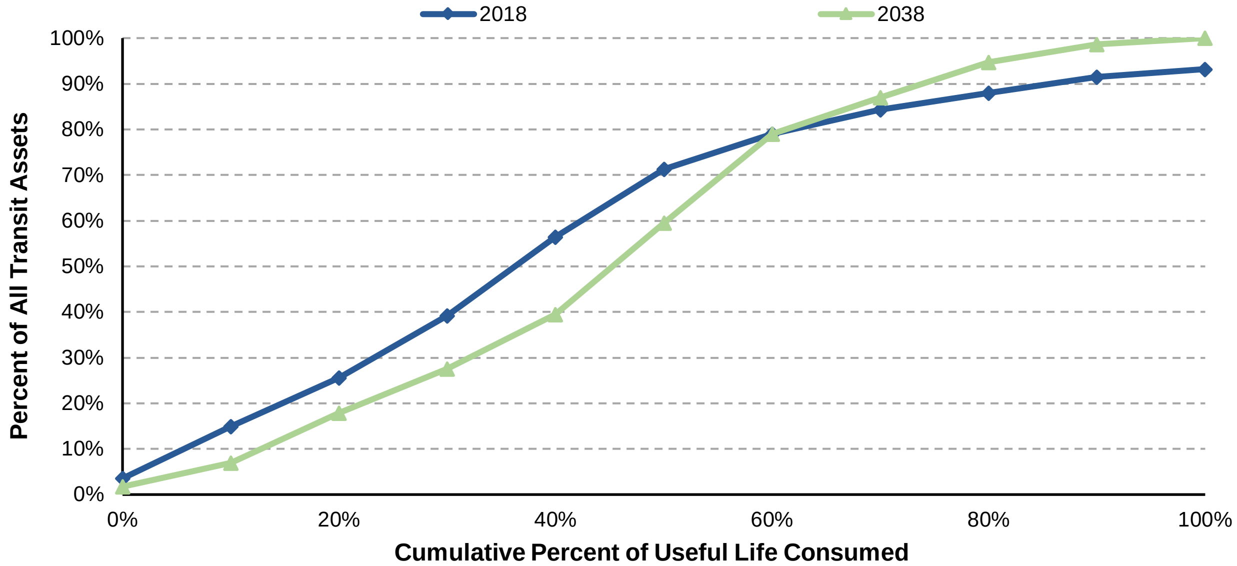
Exhibit 8-17: Sustain 2014–2018 Spending Scenario—Cumulative Asset Percent of Useful Life Consumed (Replaceable Assets)



Source: Transit Economic Requirements Model.

Similarly, *Exhibit 8-18* presents the cumulative percentage of useful life consumed under the SGR Benchmark (which is financially unconstrained with respect to reinvestment needs but does not include any expansion investments). Given the nature of the benchmark (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 2014–2018 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.

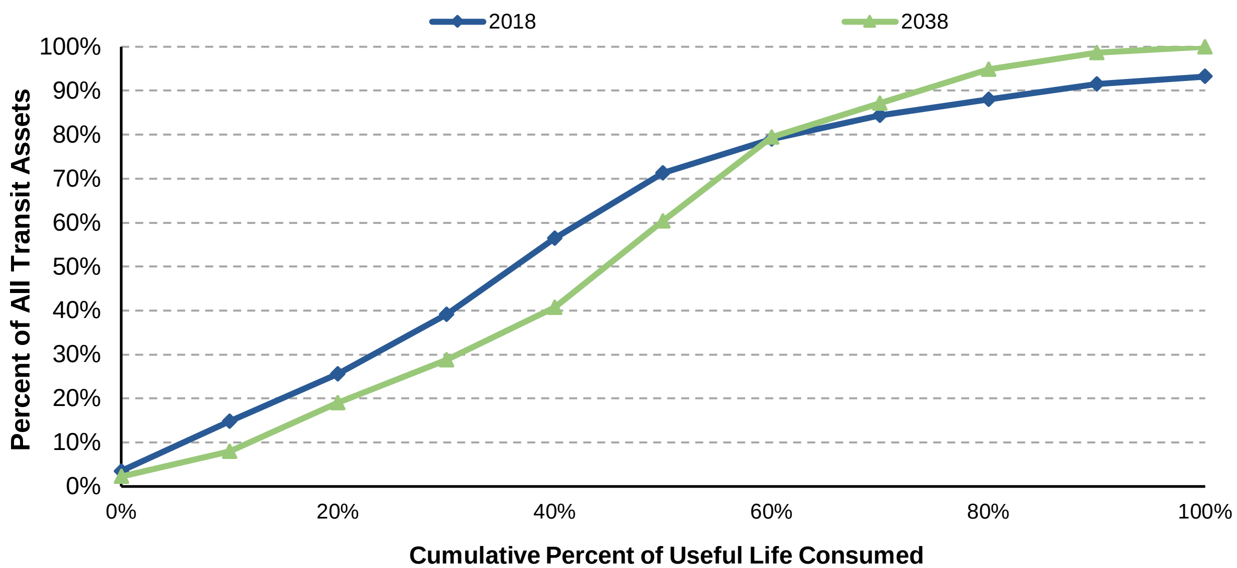
Exhibit 8-18 SGR Baseline—Cumulative Asset Percent of Useful Life Consumed (Replaceable Assets)



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

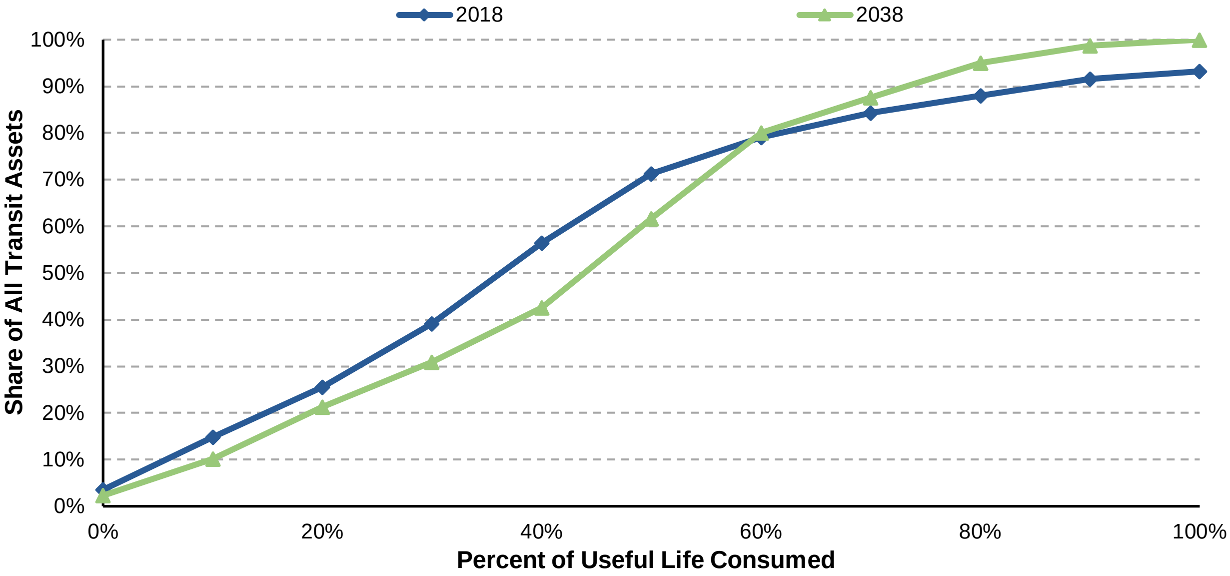
Finally, *Exhibits 8-19* and *8-20* present projections for the percentage of useful life consumed under the Expansion and Expansion with Growth scenarios respectively (which are financially unconstrained with respect to reinvestment needs and invest in expansion assets when cost-beneficial). As these 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). Note that the Expansion with Growth scenario assumes that ridership levels do not rebound from COVID-19 and reattain their 2018 levels until 2030.

Exhibit 8-19: Expansion—Cumulative Asset Percent of Useful Life Consumed (Replaceable Assets)



Source: Transit Economic Requirements Model.

Exhibit 8-20: Expansion with Growth Scenario—Cumulative Asset Percent of Useful Life Consumed (Replaceable Assets)



Source: Transit Economic Requirements Model

Backlog Estimates Across Recent C&P Reports

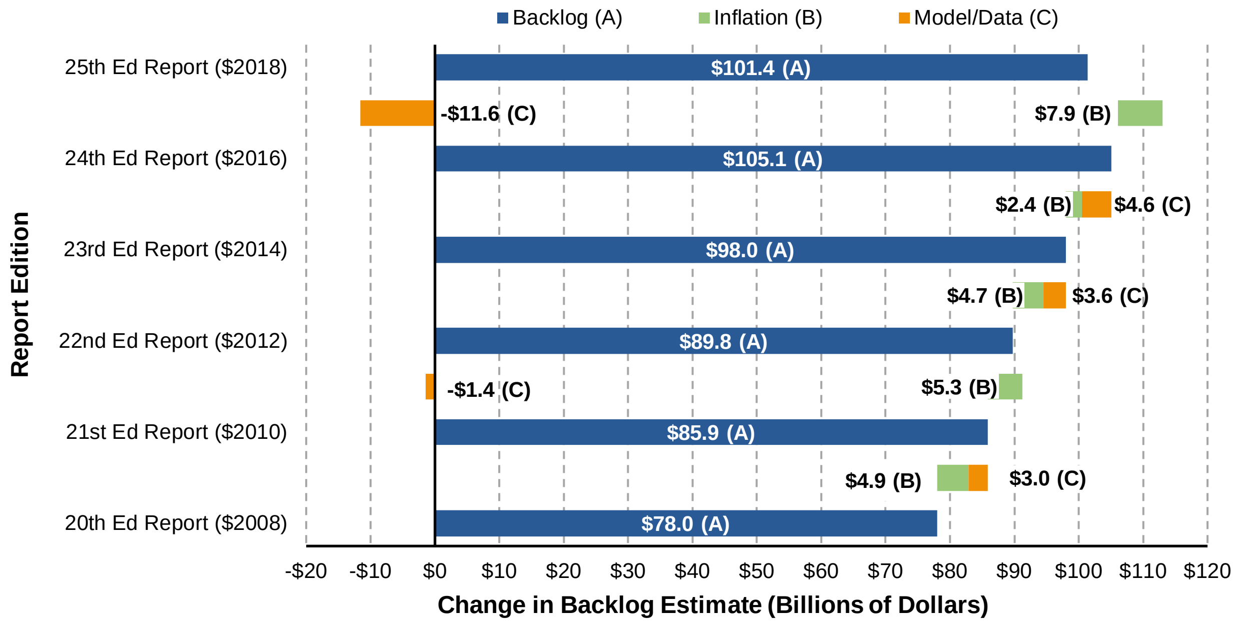
Prior to this 25th edition of the C&P Report, the backlog estimate had increased steadily since backlog estimates were first published in the 2010 C&P Report. Changes in the backlog over that period are a function of four causes:

- Inflation: C&P Report editions are typically published every two years. Therefore, backlog increases should be expected due to inflation alone. Much of the estimated backlog increase is caused by inflation, as shown in *Exhibit 8-21*.
- Additional assets exceeding their useful service life: 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.
- Changes to asset 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).
- Changes to TERM methodology/assumptions: Changes in asset decay curves are the primary source of model-based changes.

Given the third and fourth sources of change on this list, 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 in a long-term trend. Nevertheless, due to the very strong policy interest in understanding the change in the state of good repair backlog over time, *Exhibit 8-21* shows the trends in TERM's estimate of the backlog since 2008.

The current backlog estimate of $101.4 billion (in 2018 dollars) represents a $3.7 billion decline from the $105.1 billion (in 2016 dollars) estimate in the 24th C&P Report. As shown in *Exhibit 8-21*, this decline is due primarily to changes to TERM as well as to the data sources that feed it (specifically, revisions to TERM's asset decay curves and the introduction of inventory data from the National Transit Database's Asset Inventory Module, or AIM).

Exhibit 8-21: Change in Backlog Estimate Since the 2010 Report



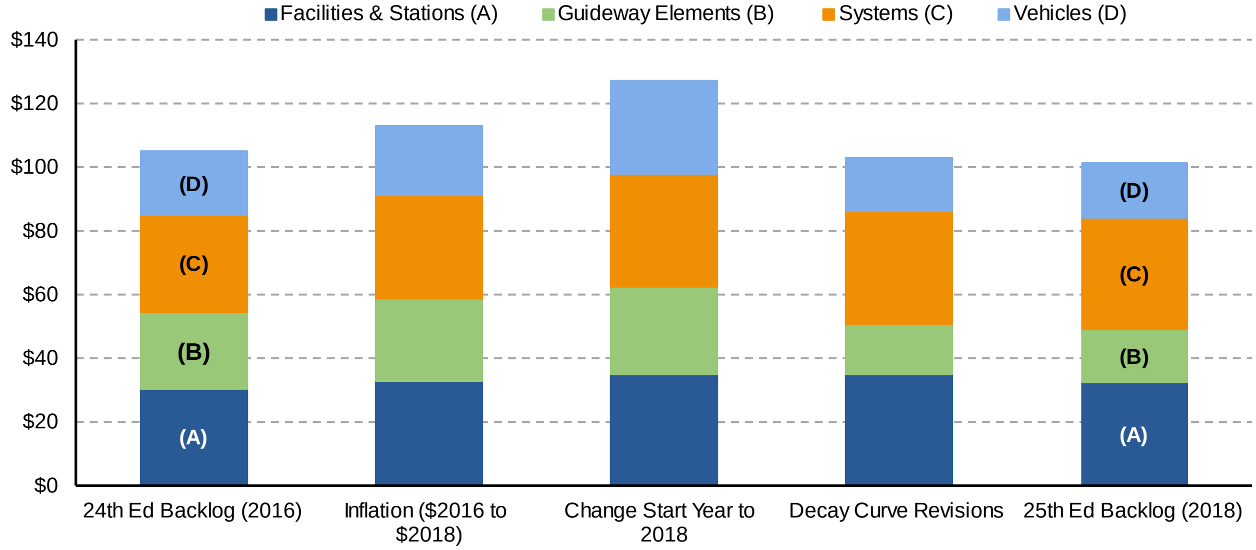
Source: Transit Economic Requirements Model.

Exhibit 8-22 provides a more detailed breakdown of the specific changes that resulted in the $3.7 billion decline in the backlog estimate. This is the first decline in the backlog estimate since 2008. Reading *Exhibit 8-22* from left to right provides a step-by-step overview of the key changes that led to this reduction:

- **C&P Report 24th Edition Backlog (2016):** Backlog was estimated to be $105.1 billion as of 2016 (in 2016 dollars).
- **25th Edition Backlog (2018):** The 25th Edition backlog estimate is attained by replacing the 2016 asset inventory used for the 24th Edition C&P Report with the updated 2018 asset inventory. This reduces the backlog estimate by a further $1.5 billion to the final total of $101.4 billion (2018 dollars) by removing a number of assets that were replaced via investments made between 2016 and 2018.
- **Inflation:** Inflating the 2016 estimate from 2016 dollars to 2018 dollars increases the estimate by $7.9 billion, bringing the total to $113.0 billion (now in 2018 dollars).
- **Additional Assets Exceeding their Useful Life:** Starting with the national inventory used for the C&P Report 24th Edition, that asset inventory has $14.3 billion in assets reaching the end of their useful lives between 2016 and 2018. This increases the backlog to $127.3 billion (in 2018 dollars).
- **Decay Curve Revisions:** Over the period 2018 through 2019, FTA undertook a nationwide assessment of the expected useful life and rates of asset decay for a broad range of asset types, including buses, bridges, light rail stations and bus transfer centers. This research had the impact of “flattening” the decay curves for several asset types, most notably buses and bridges. As a result TERM now estimates these assets to have a longer useful life than it did in 2024, which in turn reduces the size of the backlog by $24.4 billion. (See *Exhibit 8-22*).

Exhibit 8-22 shows that implementing the revised asset decay curves resulted in a significant decline in the estimated size of the investment backlog. Had this change been implemented in the 24th edition of the C&P Report, the estimated value of the backlog for 2016 would have been $89.8 billion (2016 dollars) instead of the $105.1 billion estimate published in that edition.

Exhibit 8-22: Step-by-Step Backlog Comparison Between the 2016 and 2018 Estimates



Note: Values are in billions of dollars (2018).
Source: Transit Economic Requirements Model.

Impact of Electric Buses on Transit Investment Scenarios

The investment scenarios presented in Chapter 7 implicitly assume that all replacement and expansion assets will use the same technologies as 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), transit operators often select new technology options to improve service quality or to support other objectives. New technologies may be more costly than preexisting assets of the same type.

Current industrywide plans to replace up to 100 percent of existing diesel, gasoline, and CNG powered motor bus fleets with electric buses (including vehicles powered by electric batteries, overhead catenaries, or fuel cells) are an important example of this kind of technological change. Although many operators have already initiated this transition on their own, investment in electric vehicles is now encouraged at the Federal level through FTA's Low or No Emission Vehicle Program and is required for California operators by that State's Innovative Clean Transit regulation (requiring the State's bus and paratransit fleets to transition to 100 percent zero-emission buses by 2040). Although the transition to electric buses offers significant environmental benefits in the form of reduced emissions of greenhouse gases and conventional air pollutants, it will also lead to increased acquisition and eventual replacement costs compared with the current bus fleet mix—both in the form of higher-cost buses and the additional infrastructure required to support their operation (e.g., electric bus charging stations and modifications to maintenance facilities).

Although some key factors in electric vehicle investment may be currently difficult or impossible to estimate with certainty—including the actual acquisition costs, fleet rehabilitation requirements, fleet life expectancy, and the ultimate rate of adoption—there is sufficient understanding of these variables to estimate the likely order-of-magnitude impact on long-term investment needs. To that end, *Exhibit 8-23* provides revised estimates of the long-term capital investment needs for the SGR Benchmark, along with the Expansion and Expansion with Growth scenarios, under the assumption of widespread adoption of electric vehicle fleets in place of existing diesel, CNG, and gasoline bus models (as assumed for the baseline scenarios). The exhibit then compares these revised needs estimates with the original scenario values presented in Chapter 7. Specifically, the revised estimates make the following assumptions regarding electric vehicles:

- **Adoption Rates:** The analysis in *Exhibit 8-23* assumes that all agencies in urbanized areas over 1 million in population will target 100 percent adoption of electric vehicles by 2040. In addition, and consistent with California's Innovative Clean Transit regulation, it is assumed that all California operators target 100 percent adoption of electric buses by 2040. Finally, the analysis in *Exhibit 8-23* also assumes that these U.S. bus operators shift to electric vehicle purchases based on California's fleet transition requirements (which require that 25 percent of vehicles purchased in 2023–2025 are electric, increasing to 50 percent between 2026 and 2028, and then 100 percent thereafter).
- **Vehicle Costs:** Cost assumptions are based on recent acquisition data for electric buses obtained from the Innovative Clean Transit portal of the California Air Resources Board. Based on these data, the average acquisition cost of a new 40-foot electric bus is assumed to start at roughly $1.2 million, including the cost of related infrastructure (e.g., charging stations, facility modifications). This source also provided projections of the expected future rate of decline in electric buses prices as the size of the market for this new technology continues to expand. Finally, this source provided data on the cost differential between 40-foot and larger and smaller electric buses, which were required to estimate acquisition costs for all bus vehicle lengths. Currently, industry vendors are not selling electric vehicle versions of transit cutaway vans, minivans, and other "non-bus" rubber-tire vehicles, and have no set plans to introduce them. Given this situation, the cost of these smaller vehicle types was assumed to remain the same as in the original scenarios.
- **Useful Life:** Electric buses are assumed to have the same expected useful lives as diesel and CNG buses, and similar mid-life rehabilitation requirements.

Based on these assumptions, the estimated impact of a 100-percent transition to electric buses in urban areas over 1 million (and all urban areas in California) by 2040 is to increase nonrail fleet costs by roughly 25 to 30 percent and to increase overall scenario costs by roughly 6 to 8 percent. This equates to a roughly $2.2 billion increase in annual funding through 2038 to cover the transition to 100-percent electric fleets.

Exhibit 8-23: Impact of Electric Vehicles on Average Annual Needs by Scenario

Impact Category Cost	Capital Cost Increases	SGR Benchmark		Expansion		Expansion with Growth	
		Billions of 2018 Dollars	Percent Change from Baseline	Billions of 2018 Dollars	Percent Change from Baseline	Billions of 2018 Dollars	Percent Change from Baseline
Nonrail Fleet Cost	Baseline (current bus fleet mix)	$4.74		$6.70		$6.80	
	100% Electric by 2040	$5.86	24%	$8.68	30%	$8.78	29%
Scenario Total Cost	Baseline (current bus fleet mix)	$20.30		$25.35		$27.36	
	100% Electric by 2040	$21.43	6%	$27.27	8%	$29.23	7%

Source: Transit Economic Requirements Model.

Chapter 9: Sensitivity Analysis

Sensitivity Analysis – Highways

When forecasting outcomes in investment modeling, sound practice 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, the Improve Conditions and Performance scenario and the Maintain Conditions and Performance scenario, presented in Chapter 7.

SECTION SUMMARY

Both the Improve Conditions and Performance scenario and the Maintain Conditions and Performance scenario are 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 average annual investment requirements by 25.1 percent and 22.5 percent, respectively.

Reducing projected average annual VMT growth (from 1.1 percent per year to 0.9 percent) reduces the average annual investment levels for both scenarios (-5.0 percent for the Maintain Conditions and Performance scenario, and -6.9 percent for the Improve Conditions and Performance scenario), whereas increasing the project average annual VMT growth (from 1.1 percent per year to 1.3 percent) increases the average annual investment levels for both scenarios (14.6 percent for the Maintain Conditions and Performance scenario, and 6.1 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 2038 at 2018 levels. The Highway Economic Requirements System (HERS) inputs to this scenario identify the lowest level of investment at which the 2038 projections for each of two measures—the projected share of travel on pavements with poor ride quality and the share of travel projected to occur under severely congested conditions—indicate conditions and performance that match (or are better than) those in the 2018 base year. In practice, the binding constraint was generally the projected share of travel under severely congested conditions. Changes to the assumptions that cause HERS to increase the share of investment directed to system expansion will tend to reduce the level of investment needed to achieve the goals of this scenario. Conversely, changes to the assumptions that cause HERS to place more value on system rehabilitation will tend to increase the level of investment needed to maintain the share of travel under severely congested conditions. This interpretation is complicated by the fact that, in some sensitivity runs, the binding constraint can flip from the projected share of travel under severely congested conditions to the projected share of travel on pavements with poor ride quality.

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 2038 matches that in 2018. 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 2018. In the analyses presented in Chapters 7 and 10, traveler time savings are valued per person hour at $15.20 for personal travel and between $28.53 and $38.08 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. The Improve Conditions and Performance scenario sensitivity results match the trend discussed previously: any change to the assumptions that increases the value of benefits (e.g., higher value of personal travel time) will result in a higher average annual investment level (3.4 percent). Conversely, assuming lower values of time reduces the average annual investment level by 5.6 percent.

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	Scenario Component	Maintain Conditions and Performance Scenario		Improve Conditions and Performance Scenario	
		Billions of 2018 Dollars	Percent Change from Baseline	Billions of 2018 Dollars	Percent Change from Baseline
Baseline[1] (50% of Hourly Earnings)	HERS-derived Component	$43.5		$86.1	
	NBIAS-derived Component	$13.2		$22.3	
	Other (Nonmodeled) Component	$22.3		$42.6	
	Total	**$79.0**		**$151.1**	
Lower (35% of Hourly Earnings)	HERS-derived Component	$53.8	23.8%	$80.5	-6.5%
	NBIAS-derived Component	$13.1	-0.5%	$21.8	-2.4%
	Other (Nonmodeled) Component	$26.3	18.1%	$40.2	-5.6%
	Total	**$93.3**	**18.1%**	**$142.5**	**-5.6%**
Higher (60% of Hourly Earnings)	HERS-derived Component	$44.8	3.1%	$89.5	4.0%
	NBIAS-derived Component	$13.3	0.5%	$22.6	1.2%
	Other (Nonmodeled) Component	$22.8	2.5%	$44.1	3.4%
	Total	**$80.9**	**2.5%**	**$156.2**	**3.4%**

[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 2019 through 2038. Business travel is valued at 100% of hourly earnings for all three alternatives.

Sources: Highway Economic Requirements System (HERS); National Bridge Investment Analysis System (NBIAS).

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 2018 Spending scenario presented in Chapter 7, the values for these HERS and NBIAS components total $82.6 billion. In 2018, nonmodeled spending accounted for 28.2 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 28.2 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.

Results of the Maintain Conditions and Performance scenario are more difficult to interpret because the binding metric changes between sensitivity runs. Assuming lower values of travel time increases the average annual investment level for the Maintain Conditions and Performance scenario by 18.1 percent; however, assuming higher values of travel time also increases the average annual investment level by 2.5 percent. At the higher value of time, the projected share of travel on pavements with poor ride quality becomes the driving indicator rather than the share of travel on severely congested roads.

For the NBIAS-derived component of the scenarios, the effects of changing the assumed value of time are small (at most, a 2.4-percent change in average annual investment levels). Assuming lower values of time decreases average annual investment, and conversely assuming higher values of time increases investment. 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.

For the HERS-derived component of the Improve Conditions and Performance scenario, reducing the value of traveler time results in a 6.5-percent reduction in average annual investment levels, whereas increasing the value of traveler time results in a 4.0-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 23.8-percent increase in average annual investment levels; increasing the value of travel time increases average annual investment levels by 3.1 percent.

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. For the Improve Conditions and Performance scenario, this allows the criteria for the scenario to be met 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.

Discount Rate

Benefit-cost analyses apply a discount rate to future streams of costs and benefits, which effectively reduces the value of benefits and costs expected to arise further in the future compared with 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.[36] 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

[36] https://obamawhitehouse.archives.gov/omb/circulars_a004_a-4/

4.0 percent reported to be used by the Minnesota DOT and the Florida DOT respectively.[37] 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 considered by HERS and NBIAS, 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.

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 follows DOT's guidance on the "value of a statistical life" saved in 2018, which recommends a base value of $10.5 million (per updated guidance issued in 2021), but also requires that regulatory and investment analyses include sensitivity tests using alternative values of $6.3 million as the lower bound and $14.7 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 Highway Performance Monitoring System (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 less than 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 and Performance 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 25.1 percent (to $188.9 billion), due to a 22.7-percent increase in the HERS component and a 34.2-percent increase in the NBIAS component. 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 $21.2 billion (to $129.9 billion).

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[37] *Use of Benefit-Cost Analysis by State Departments of Transportation Report to Congress*, Federal Highway Administration, 2016, available at: https://www.fhwa.dot.gov/policy/otps/pubs/bca_report/senate_bca_report_05172016_revised.pdf. 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.

Exhibit 9-2: Impact of Alternative Discount Rate Assumptions on Highway Investment Scenario Average Annual Investment Levels

Alternative Assumptions About Discount Rate	Scenario Component	Maintain Conditions and Performance Scenario		Improve Conditions and Performance Scenario	
		Billions of 2018 Dollars	Percent Change from Baseline	Billions of 2018 Dollars	Percent Change from Baseline
Baseline (7% Discount Rate)	HERS-derived Component	$43.5		$86.1	
	NBIAS-derived Component	$13.2		$22.3	
	Other (Nonmodeled) Component	$22.3		$42.6	
	Total	**$79.0**		**$151.1**	
Lower (3% Discount Rate)	HERS-derived Component	$44.6	2.6%	$105.6	22.7%
	NBIAS-derived Component	$24.8	88.2%	$30.0	34.2%
	Other (Nonmodeled) Component	$27.3	22.5%	$53.3	25.1%
	Total	**$96.8**	**22.5%**	**$188.9**	**25.1%**
Higher (10% Discount Rate)	HERS-derived Component	$44.6	2.6%	$74.4	-13.6%
	NBIAS-derived Component	$10.3	-22.3%	$18.8	-15.7%
	Other (Nonmodeled) Component	$21.6	-3.2%	$36.7	-14.0%
	Total	**$76.4**	**-3.2%**	**$129.9**	**-14.0%**

Note: The baseline levels shown correspond to the systemwide scenarios presented in Chapter 7. The investment levels shown are average annual values for the period 2019–2038.

Sources: Highway Economic Requirements System (HERS); National Bridge Investment Analysis System (NBIAS).

For the Maintain Conditions and Performance scenario, changing the discount rate has more complex effects within the models. The total investment trends for the Maintain Conditions and Performance scenario are similar to those of the Improve Conditions scenario: reducing the discount rate increases total investment (by 22.5 percent, up to $96.8 billion), whereas increasing the discount rate lowers total investment (by 3.2 percent, down to $76.4 billion).

For HERS-derived spending, the modeling of the Maintain Conditions and Performance scenario indicates investment at $44.6 billion (a 2.6-percent increase), regardless of an increase or decrease in discount rate. This result is coincidental; the expenditure patterns for the two alternatives differ significantly. Assuming a 10-percent discount rate, HERS directs a greater share of spending to urban Interstates and urban other principal arterials—in particular for capacity expansion—than if a 3-percent discount rate were assumed. Raising the discount rate reduces the relative impacts of benefits and dis-benefits that occur further in the future, so that factors such as induced demand gradually filling up new roadway capacity would have less of an effect on the overall BCR for a given project.

The NBIAS-derived component of spending in the Maintain Conditions and Performance scenario is more sensitive to the discount rate, with multiple simultaneous drivers. Reducing the discount rate from 7 percent to 3 percent causes this component to increase by 88.2 percent (to $24.8 billion). Increasing the discount rate to 10 percent causes the NBIAS-derived component to decrease by 22.3 percent (to $10.3 billion). In general, NBIAS-derived spending functions such that when the discount rate is lowered the future benefits are valued more, and projects that were once not cost-beneficial (BCRs less than 1.0) become cost-beneficial (BCRs greater than 1.0). The projects that flip are recognized as needs within the system, which draws more funding. A complicating factor is that changing the discount rate makes the NBIAS Maintenance, Repair, and Rehabilitation (MR&R) module more aggressive, whereby the model allocates investments to improve bridges currently in fair condition to good condition—thereby reducing the share of investment going toward improving bridges in poor condition.[38] This in turn requires a large increase in investment (an 88.2-percent increase from baseline) to keep the share of bridges in poor condition from rising under the lower discount rate assumption.

[38] A separate sensitivity test was conducted in which the same MR&R policies were applied as in the baseline run. In this case the NBIAS results were insensitive to changes in the discount rate (roughly 0.2-percent difference in investment levels whether increasing or decreasing the discount rate).

When increasing the discount rate, the NBIAS-derived component of spending under the Maintain Conditions and Performance scenario functions similarly to the Improve Conditions and Performance scenario: higher discount rates result in lower future benefits from projects, which decreases the number of cost-beneficial projects and leads to lower investment totals.

Traffic Growth Projections

For each of the approximately 130,000 sections of highway in its sample, 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 vehicle miles traveled (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 (VNTSC) 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.[39]

The national forecasts used in the present analysis were published online as *FHWA Forecasts of Vehicle Miles Traveled (VMT): Spring 2019.*[40] For all vehicle types combined, VMT growth is forecast to average 1.1 percent annually over 20 years starting in 2019. 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, whereas 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).[41]

[39] The most recent documentation for the supporting model is available at: http://www.fhwa.dot.gov/policyinformation/tables/vmt/vmt_model_dev.cfm

[40] https://www.fhwa.dot.gov/policyinformation/tables/vmt/2019_vmt_forecast_sum.pdf

[41] 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.

Exhibit 9-3: Projected Average Percent Growth per Year in VMT by Vehicle Class, 2018–2038

Vehicle Class	VMT Growth Rate		
	Baseline	From Low Economic Growth Forecast	From High Economic Growth Forecast
Passenger Vehicles	1.1%	0.9%	1.2%
Single-unit Trucks	1.6%	1.1%	2.0%
Combination Trucks	1.5%	1.1%	1.5%
All Vehicles	1.1%	0.9%	1.3%

Source: FHWA National Vehicle Miles Traveled Projection (May 2019).

Alternative Growth Rates

Generally, assumptions 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. This report's modeling of the impacts of alternate VMT growth rates are presented in *Exhibit 9-4*.

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]	Scenario Component	Maintain Conditions and Performance Scenario		Improve Conditions and Performance Scenario	
		Billions of 2018 Dollars	Percent Change from Baseline	Billions of 2018 Dollars	Percent Change from Baseline
Baseline[2] (1.1% per Year, Tied to May 2019 Baseline Forecast)	HERS-derived Component	$43.5		$86.1	
	NBIAS-derived Component	$13.2		$22.3	
	Other (Nonmodeled) Component	$22.3		$42.6	
	Total	**$79.0**		**$151.1**	
Lower (0.9% per Year, Tied to May 2019 Low Economic Growth Forecast)	HERS-derived Component	$40.7	-6.4%	$79.9	-7.2%
	NBIAS-derived Component	$13.1	-0.5%	$21.0	-5.9%
	Other (Nonmodeled) Component	$21.2	-5.0%	$39.7	-6.9%
	Total	**$75.0**	**-5.0%**	**$140.6**	**-6.9%**
Higher (1.3% per Year, Tied to May 2019 High Economic Growth Forecast)	HERS-derived Component	$51.7	18.9%	$92.0	6.9%
	NBIAS-derived Component	$13.3	0.4%	$23.1	3.2%
	Other (Nonmodeled) Component	$25.5	14.6%	$45.2	6.1%
	Total	**$90.5**	**14.6%**	**$160.3**	**6.1%**

[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 2019–2038.

Sources: Highway Economic Requirements System (HERS); National Bridge Investment Analysis System (NBIAS).

In the Improve Conditions and Performance scenario, replacing the baseline traffic growth assumptions with the low-growth assumptions reduces the estimated investment level needed to achieve the scenario's objective of funding for all cost-beneficial improvements by 6.9 percent. For the HERS component of investment funding, the change from baseline to low-growth assumptions reduces the investment level by 7.2 percent. A lower VMT growth reduces the NBIAS component by 5.9 percent.

For the Maintain Conditions and Performance scenario, this same sensitivity test has somewhat less effect on the required investment level, with total investment reduced by 5.0 percent, with reductions of 6.4 percent (HERS component) and 0.5 percent (NBIAS component).

Replacing the baseline traffic growth assumptions with the high-growth assumptions increases the estimated investment levels. In the Improve Conditions and Performance scenario, total investment levels increase by 6.1 percent, driven by the HERS component (which shows a 6.9-percent increase). The increase in the NBIAS component is smaller, at 3.2 percent. In the Maintain Conditions and Performance scenario, increasing the VMT growth forecast results in a 14.6-percent increase in estimated investment level, driven almost entirely by the HERS component (18.9 percent) compared to the NBIAS component (0.4 percent).

What if Traffic Doesn't Grow, or Grows More Slowly?

Although VMT at the national level has sometimes decreased from 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 2019 through 2038 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 nonmodeled capital spending types. Eliminating the baseline assumption of 1.1-percent annual growth in VMT would reduce the average annual investment level under the Improve Conditions and Performance scenario by 29.3 percent (to $106.9 billion), and similarly reduce the average investment level under the Maintain Conditions and Performance scenario by 22.3 percent (to $61.4 billion).

Slower VMT growth is also a possibility. The U.S. Energy Information Administration (EIA) and several other institutions publish their own VMT growth rates. Often these growth rates differ as a result of slightly different underlying data and assumptions. The differences between EIA's forecasts and those from the FHWA models developed by the VNTSC arise from three sources:

- Mathematical structure of the models and the explanatory variables on which they rely;
- Sensitivity of historical variation in VMT to variation in the common explanatory variables used by the models; and
- Projected future values of the explanatory variables.

EIA's reference case from its 2021 *Annual Energy Outlook* projects lower annual average growth in VMT by vehicle class for the 2018–2038 period than do any of the three alternatives presented in *FHWA Forecasts of Vehicle Miles Traveled (VMT): Spring 2019* (*Exhibit 9-3*), with all vehicles combined showing annual growth of 0.60 (0.57 for passenger vehicles, 0.78 for single-unit trucks, and 0.88 for combination trucks). Differences in VMT forecasts are likely attributable to EIA's higher forecast of global petroleum prices and fuel costs compared to the assumptions made by VNTSC, which rely on IHS Markit forecasts.

Replacing the baseline traffic growth assumptions with the EIA growth assumptions decreases estimated investment levels, as a reduction in VMT results in lower benefits for assessed projects. In the Maintain Conditions and Performance scenario, total investment levels decrease by 11.0 percent (to $70.2 billion). Similarly, in the Improve Conditions and Performance scenario average annual investment levels decrease by 15.7 percent (to $127.3 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 levels, 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 levels for the State of Good Repair (SGR) Benchmark and the Expansion and Expansion with Growth scenarios discussed in Chapter 7 vary in response to changes in the assumed values of these input variables. Given the introduction of new methodologies for estimating expansion investment levels, sensitivity analysis has also been conducted to examine how changes to the assumptions about service coverage and frequency thresholds would affect the Expansion scenario investments. Note that, by definition, funding under the Sustain 2014–2018 Spending scenario does not vary with changes in any input variable, and thus this scenario is not considered in this sensitivity analysis.

SECTION SUMMARY

- TERM is sensitive to changes in the replacement threshold greater than 0.25. Increasing the replacement thresholds from 2.50 to 3.00 results in up to an 85-percent increase in replacement costs.
- Modeled changes in capital costs under different scenarios are as follows:
  - SGR Benchmark (no benefit-cost analysis [BCA] test): a 25-percent increase in unit costs for preservation translates directly to a 25-percent increase in total replacement investment costs.
  - Expansion and Expansion with Growth scenarios (applies to BCA test): a 25-percent increase in capital cost results in a 14- to 15-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 per hour) increases investment by 1–3 percent.
- TERM is relatively insensitive to changes in the discount rate. Decreasing 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 applies only 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 investments for the SGR Benchmark and the Expansion and Expansion with 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 investment levels 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 levels do not strictly increase with the replacement threshold in the Expansion and Expansion with 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		Expansion		Expansion with Growth	
	Billions of 2018 Dollars	Percent Change from Baseline	Billions of 2018 Dollars	Percent Change from Baseline	Billions of 2018 Dollars	Percent Change from Baseline
Very Late Asset Replacement (2.00)	$12.8	-37%	$18.0	-29%	$19.9	-27%
Replace Assets Later (2.25)	$16.4	-19%	$21.2	-16%	$23.2	-15%
Baseline (2.50)	$20.3		$25.3		$27.4	
Replace Assets Earlier (2.75)	$23.8	17%	$27.9	10%	$29.8	9%
Very Early Asset Replacement (3.00)	$37.5	85%	$38.6	52%	$40.1	47%

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 2018) 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 varies by agency and asset) to 2018 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 Expansion or Expansion with 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 other two scenarios do employ this test. Hence, for the Expansion and Expansion with 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 a roughly 14- to 15-percent increase in investments 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		Expansion		Expansion with Growth	
	Billions of 2018 Dollars	Percent Change from Baseline	Billions of 2018 Dollars	Percent Change from Baseline	Billions of 2018 Dollars	Percent Change from Baseline
Baseline (No Change)	$20.3		$25.3		$27.4	
Increase Costs by 25%	$25.4	25%	$29.2	15%	$31.1	14%

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 Highways section of this chapter.

For this C&P Report, the Expansion and Expansion with Growth scenarios are the only scenarios with investment level estimates that are sensitive to changes in the benefit-cost ratio. (Note that the Sustain 2014–2018 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 investment level estimates of the Expansion with Growth scenario, with expansion investments segmented by expansion components. (Sensitivity results for the Expansion Scenario are very similar.) TERM applies the value of time to all in-vehicle travel, but then doubles it to $30.40 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." Based on this sensitivity analysis, doubling or halving this variable leads to changes in investment ranging from an increase of roughly 2 percent to a decrease of up to 3 percent.

Exhibit 9-7: Impact of Alternative Value of Time Rates on Transit Investment Estimates: Expansion with Growth Scenario (Billions of $2018)

Changes in Value of Time	Preservation	Scenario Expansion Components				Full Scenario			
		New Starts Pipeline	Service Coverage	Service Frequency	Average Speed	Vehicle Occupancy	Growth	Expansion with Growth	Percent Change from Baseline
Reduce by 50% ($7.6)	$18.4	$1.4	$0.1	$0.2	$2.4	$2.4	$1.6	$26.5	-3%
Baseline ($15.2)	$18.9	$1.4	$0.1	$0.2	$2.4	$2.4	$1.9	$27.4	
Increase by 100% ($30.4)	$19.2	$1.4	$0.1	$0.2	$2.4	$2.4	$2.1	$27.8	2%

Source: Transit Economic Requirements Model.

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 Highways section of this chapter. For this sensitivity analysis, and for consistency with the discussion earlier on HERS and NBIAS discount rate sensitivity, TERM's investment level estimates for the Expansion with Growth scenario were re-estimated using a 3-percent discount rate. The results of this analysis, with expansion investments segmented by expansion component, are presented in *Exhibit 9-8*. This analysis shows a 1-percent increase in total investments when using the lower discount rate.

Exhibit 9-8: Impact of Alternative Discount Rates on Transit Investment Estimates: Expansion with Growth Scenario (Billions of $2018)

Discount Rates	Preservation	Scenario Expansion Components						Full Scenario	
		New Starts Pipeline	Service Coverage	Service Frequency	Average Speed	Vehicle Occupancy	Growth	Expansion with Growth	Percent Change from Baseline
7% (Baseline)	$18.9	$1.4	$0.1	$0.2	$2.4	$2.4	$1.9	$27.4	
3%	$19.0	$1.4	$0.1	$0.2	$2.4	$2.4	$1.9	$27.6	1%

Source: Transit Economic Requirements Model.

Changes in the Service Coverage and Frequency Thresholds

As described in Chapter 7, the estimation of expansion investments identified urbanized areas (UZAs) that warrant introducing fixed-route transit service or adding transit service based on housing unit density levels. Sensitivity analysis was conducted to understand how changes in the density and service parameters would impact the estimated investment levels for the Expansion scenario. These sensitivity tests were conducted on a subset of 24 UZAs, including large and small UZAs, representing 15 percent of the national total for vehicle revenue miles. Two sensitivity tests were conducted:

1. Reduce Density Thresholds to Support Fixed-Route Service: This sensitivity test reduces the minimum density thresholds for both the Transit Coverage and Transit Frequency improvement components (see *Exhibit 9-9*). Specifically, for transit coverage investments, the minimum number of dwellings needed to support fixed-route transit service is reduced from four to three dwelling units/net acre. For transit frequency improvements, the minimum number of dwellings needed to support more frequent levels of peak-period service was reduced as follows:
   - From four to three dwelling units/net acre: 60-minute headway service
   - From seven to six dwelling units/net acre: 30-minute headway service
   - From 15 to 12 dwelling units/net acre: 15-minute headway service
2. Increase Transit Frequency: This test sets the maximum peak period headway at 30 minutes for peak-period service, regardless of density. Hence, under this test, any route with a headway greater than 30 minutes is reduced to 30 minutes.

Exhibit 9-9: Minimum Dwelling Units per Acre Parameters for Reduce Density Thresholds to Support Fixed Route Service Sensitivity Tests

Capital Cost Increases	Transit Coverage	Transit Frequency		
		60-Minute Headways	30-Minute Headways	15-Minute Headways
Baseline (Expansion Scenario)	4	4	7	15
Reduce Density Thresholds to Support Fixed-Route Service	3	3	6	12

Source: Transit Economic Requirements Model.

Exhibit 9-10 shows the results of this analysis for the sample of 24 urbanized areas. For transit coverage, the change to a density threshold of three dwelling units per acre would result in a 71-percent increase in expansion costs relative to the transit coverage component of the baseline Expansion scenario. For transit frequency, changing the density thresholds for peak-period service would result in a 42-percent increase in expansion costs relative to the transit frequency component of the baseline Expansion scenario. These significant percentage increases in coverage and frequency improvement costs reflect the large number of block groups that benefit from each of the threshold reductions. At the same time, given the relatively small share of the total expansion investments resulting from service coverage and frequency deficiencies, the impact on the overall Expansion scenario (including SGR and expansion needs) total would be smaller, roughly a 2-percent increase in the Expansion scenario total relative to the baseline.

Capping the maximum headway at 30 minutes in the peak period, regardless of density levels, would have a more significant impact on total expansion investment levels, resulting in a 412-percent increase in the transit frequency component of the baseline Expansion scenario. However, because the increasing transit frequency component is a relatively small part of the overall Expansion scenario (including SGR and expansion needs), this would translate into a 7-percent increase in the Expansion scenario total relative to the baseline. Here again, this very large increase in investment costs results from the significant number of block groups with densities in the range of four to six dwellings per acre.

Exhibit 9-10: Impact of Changes in Density and Frequency on Transit Coverage and Frequency Components: Sample of 24 UZAs (Expansion Scenario)

Capital Cost Increases	Transit Coverage		Transit Frequency		Coverage and Frequency Total (Sample of 24 UZAs)	
	Millions of 2018 Dollars	Percent Change from Baseline	Millions of 2018 Dollars	Percent Change from Baseline	Millions of 2018 Dollars	Percent Change from Baseline
Baseline	$32.7		$23.4		$56.1	
Reduce Density Thresholds to Support Fixed-Route Service	$55.8	71%	$33.2	42%	$89.0	59%
Increase Frequency to 30-Headway Maximum Regardless of Density	$32.7	N/A	$119.7	412%	$152.4	172%

Source: Transit Economic Requirements Model..

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.

SECTION SUMMARY

- HERS results indicate it is cost-beneficial to reduce the percentage of travel under congested conditions and the percentage of travel on pavements with poor ride quality, but not necessarily to reduce average pavement roughness.
- FHWA estimates that each additional dollar spent on a cost-beneficial highway capital project results in $1.80 of additional gross domestic product (GDP) over the course of 30 years.
- NBIAS results suggest that if spending is sustained at 2014–2018 levels for bridges on Federal-aid highways, NHS bridges, and Interstate bridges, it would be insufficient to keep the deck area-weighted share of bridges in poor condition from rising over time.

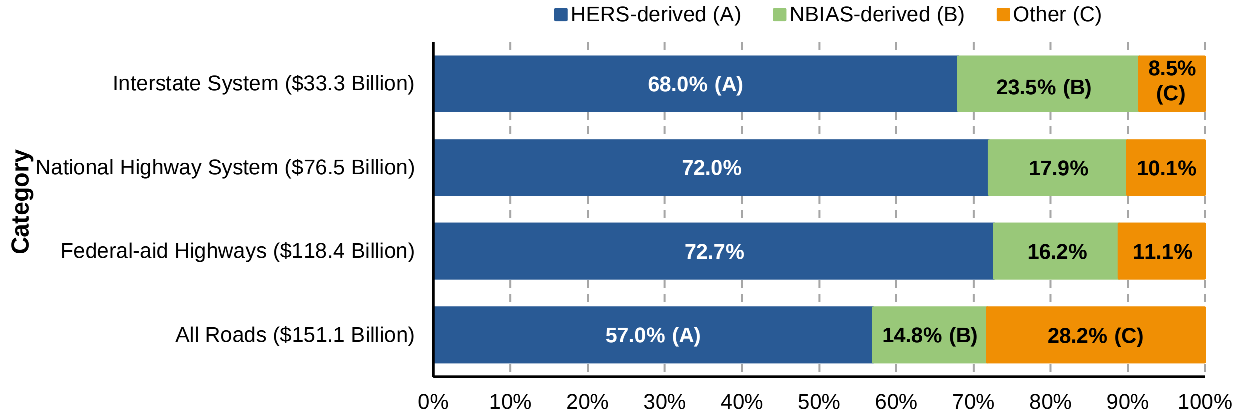
This section examines the types of investments used within the scopes of the Highway Economic Requirements System (HERS) and the National Bridge Investment Analysis System (NBIAS) and provides more context for the capital investment scenarios for highways presented in Chapter 7. This section also presents the impacts of increased highway funding on the economy using a macroeconomic model called USAGE Hwy. 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 $151.1 billion average annual investment level for all public roads under this scenario, 14.8 percent was derived from NBIAS (corresponding to the $22.3 billion identified as “System Rehabilitation – Bridge” in the “All Roads” row) and 57.0 percent was derived from HERS (corresponding to the $46.9 billion and $39.2 billion identified as “System Rehabilitation – Highways” and “System Expansion,” respectively, in the “Federal-aid Highways” row). The remaining 28.2 percent was nonmodeled; this corresponds to the $20.8 billion identified as “System Enhancement” in the “All Roads” row plus the difference between the amounts shown in the “All Roads” and the “Federal-aid Highway” rows for “System Rehabilitation – Highways” ($17.7 billion, computed as $64.6 billion minus $46.9 billion) and “System Expansion” ($4.1 billion, computed as $43.3 billion minus $39.2 billion). Each of the nonmodeled input values was computed using scaling procedures so that its share of the total scenario investment level would match its share of recent spending from 2014 through 2018.

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 ($33.3 billion), the National Highway System (NHS) ($76.5 billion, including the amount directed to Interstate highways), and Federal-aid Highways ($118.4 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.

Exhibit 10-1: Improve Conditions and Performance Scenario, 2019 Through 2038: 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				
Interstate Highway System	$10.5	$7.8	$18.3	$12.2	$2.8	$33.3	22.1%
National Highway System	$27.2	$13.7	$40.9	$27.9	$7.7	$76.5	50.6%
Federal-aid Highways	$46.9	$19.1	$66.0	$39.2	$13.2	$118.4	78.4%
All Roads	$64.6	$22.3	$87.0	$43.3	$20.8	$151.1	100.0%

[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."

Note: Average annual investment values are in billions of 2018 dollars.

Sources: Highway Economic Requirements System (HERS) and National Bridge Investment Analysis System (NBIAS).

The average annual investment level for Federal-aid highways is 72.7 percent HERS-derived, 16.2 percent NBIAS-derived, and 11.1 percent nonmodeled. The average annual investment level for the NHS is 72.0 percent HERS-derived, 17.9 percent NBIAS-derived, and 10.1 percent nonmodeled. The share of spending by source of estimate for the Interstate System is 68.0 percent HERS-derived, 23.5 percent NBIAS-derived, and 8.5 percent nonmodeled.

How were the investment levels presented in Exhibits *10-2* to *10-14* and *10-20* to *10-23* 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.

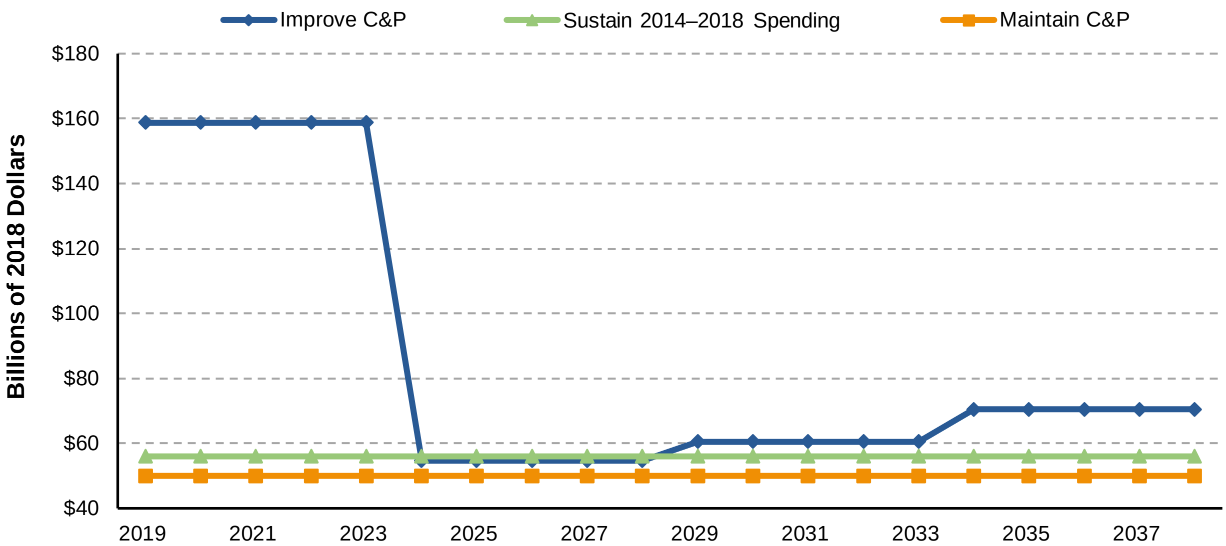
Most of the HERS and NBIAS analyses presented in this chapter assume a fixed amount of spending in constant dollars in each of the 20 years of the analysis period. However, the highest levels shown (the one or more shown above the bold horizontal line in the tables) are based on model runs constrained by a benefit-cost ratio.

Impacts of Federal-aid Highway Investments Modeled by HERS

Exhibit 10-2 introduces the eight investment levels presented in the next several exhibits to illuminate the relationship between the levels of investment modeled in HERS and the future conditions and performance of Federal-aid highways. The "Improve C&P" reference in the top row of *Exhibit 10-2* signifies that this level of investment feeds into the Improve Conditions and Performance scenario in Chapter 7, which is defined by attaining a minimum benefit-cost ratio (BCR) of 1.0 in each year over the 20-year analysis period. The remaining seven runs are funding-constrained, for which HERS ranks potential projects in order of BCR and implements them until the funding constraint is reached.

Exhibit 10-2: HERS Annual Investment Levels Analyzed for Federal-aid Highways, 2019–2038

Annual Investment Levels for Three Investment Scenarios



Spending Modeled in HERS for Federal-aid Highways, 2019–2038

Average Annual Over 20 Years			Cumulative					
Total HERS Spending	System Rehabilitation Spending[1]	System Expansion Spending[1]	5-year 2019 through 2023	5-year 2024 through 2028	5-year 2029 through 2033	5-year 2034 through 2038	20-year 2019 through 2038	Link to Chapter 7 Scenario
$86.1	$46.9	$39.2	$793.6	$273.3	$302.5	$352.1	$1,721.5	Improve C&P
$80.0	$43.6	$36.4	$400.0	$400.0	$400.0	$400.0	$1,600.0	
$74.0	$40.3	$33.7	$370.0	$370.0	$370.0	$370.0	$1,480.0	
$66.8	$35.9	$30.9	$334.1	$334.1	$334.1	$334.1	$1,336.2	2014–2018 Spending
$60.0	$31.9	$28.1	$300.0	$300.0	$300.0	$300.0	$1,200.0	
$52.0	$27.4	$24.6	$260.0	$260.0	$260.0	$260.0	$1,040.0	
$43.5	$22.2	$21.3	$217.4	$217.4	$217.4	$217.4	$869.4	Maintain C&P
$36.0	$17.8	$18.2	$180.0	$180.0	$180.0	$180.0	$720.0	

[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.

Note: Values are in billions of 2018 dollars. The FHWA National Highway Construction Cost Index version 2.0 provides constant-dollar conversions for highway capital outlay.

Source: Highway Economic Requirements System (HERS).

One funding level shown in *Exhibit 10-2* represents the spending level designed to match a specific level of performance in 2038; a spending level of $43.5 billion is projected to be adequate to keep the share of VMT on roads with severe congestion in 2038 (as measured by volume/service flow ratio) from rising above the share in 2018 (see discussion of V/SF ratio in the Introduction to Part II). 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. [Under this scenario, spending is set at the lowest level at which (1) projected share of travel on pavements with good ride quality in 2038 matches (or is better than) the value in 2018 and (2) projected share of travel on severely congested roads in 2038 matches (or is better than) the value in 2018.]

The 2014–2018 Spending reference in *Exhibit 10-2* indicates that this level of spending ($66.8 billion) supplies the Sustain 2014–2018 Spending scenario presented in Chapter 7. This represents the average annual level of constant-dollar investment from 2014 to 2018 that was directed toward the types of improvements modeled in HERS. The remaining five of the eight 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 $17.8 billion to $46.9 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 $18.2 billion to $39.2 billion across reported investment levels) has a more pronounced impact on operational performance measures such as delay.

Investment Levels and BCRs by Funding Period

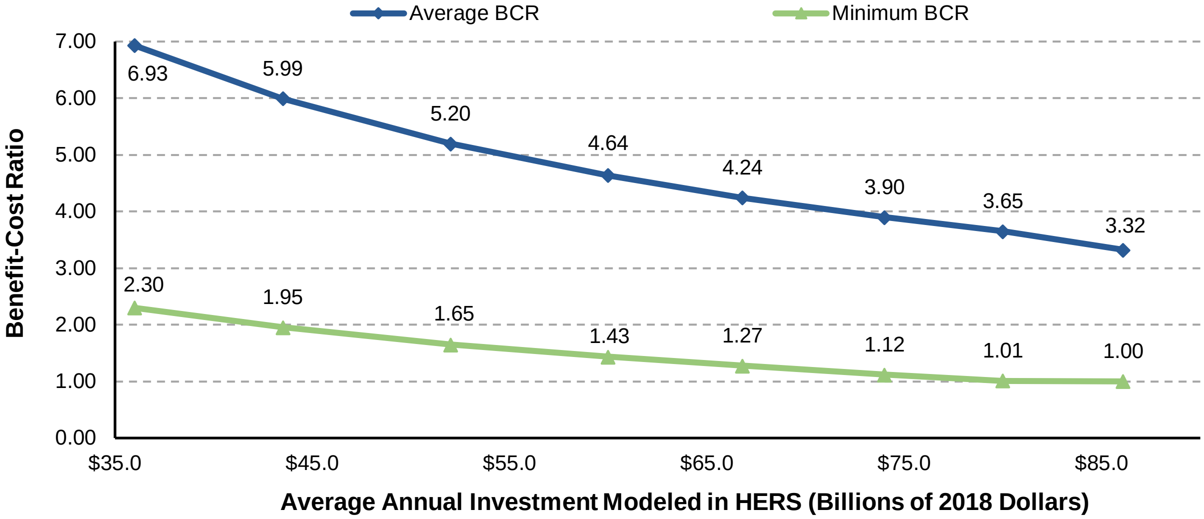
Exhibit 10-2 illustrates how the eight future funding levels for Federal-aid highways that were selected for further analysis in this section would translate into cumulative spending in 5-year intervals (corresponding to the 5-year analysis periods used in HERS). Achieving a minimum BCR of 1.0 in all four funding periods would require a 20-year investment of $1,721.5 trillion for the "Improve C&P" scenario. Within that period, HERS would invest $793.6 billion in the first 5 years, $273.3 billion in the second 5 years, $302.5 billion in the third 5 years, and $352.1 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 seven rows remain constant in each 5-year funding period based on how these analyses were defined.

Exhibit 10-3 illustrates the marginal BCRs (i.e., the lowest BCR among the improvements selected within a funding period) associated with the eight future funding levels. *Exhibit 10-3* also provides the minimum BCRs (which represent the lowest marginal BCR) and the average BCRs (i.e., the total level of benefits of all improvements divided by the total cost of all improvements) across all funding periods. 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. This results in the fourth funding period having the lowest marginal BCRs and the minimum BCR over the entire 20-year analysis period being equal to the marginal BCR in the fourth 5-year period.

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 $86.1 billion, the average BCR of 3.32 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 (Billions of 2018 Dollars)	Average BCR 20-year: 2019 through 2038	Marginal BCR[1,2]				Minimum BCR 20-Year: 2019 through 2038	Link to Chapter 7 Scenario
		5-year 2019 through 2023	5-year 2024 through 2028	5-year 2029 through 2033	5-year 2034 through 2038		
$86.1	3.32	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	Improve C&P
$80.0	3.65	1.93	1.34	1.11	**1.01**	**1.01**	
$74.0	3.90	2.05	1.45	1.21	**1.12**	**1.12**	
$66.8	4.24	2.25	1.59	1.38	**1.27**	**1.27**	2014–2018 Spending
$60.0	4.64	2.46	1.76	1.54	**1.43**	**1.43**	
$52.0	5.20	2.70	2.02	1.75	**1.65**	**1.65**	
$43.5	5.99	3.08	2.38	2.05	**1.95**	**1.95**	Maintain C&P
$36.0	6.93	3.53	2.78	2.44	**2.30**	**2.30**	

[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.

Note: BCR is benefit-cost ratio.

Source: Highway Economic Requirements System (HERS).

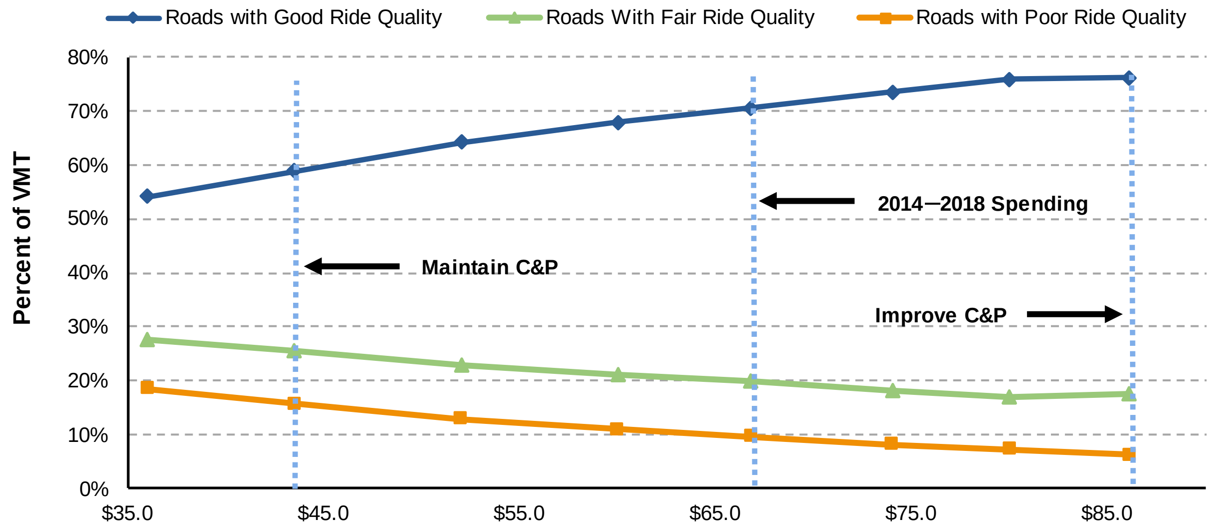
Impact of Future Investment on Ride Quality on Federal-aid Highways

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 2038 than they were in 2018. At the highest level of annual investment analyzed ($86.1 billion, including $46.9 billion for system rehabilitation), VMT-weighted average International Roughness Index (IRI) is projected to decrease by 18.7 percent. For the $43.5 billion average annual HERS investment level associated with the Maintain C&P scenario, pavements on Federal-aid highways are projected to be slightly smoother on average in 2038 compared to 2018, whereas for the lower investment levels Federal-aid highways are projected to have higher average IRI in 2038 than they did in 2018.

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 ($36.0 billion, including $17.8 billion for system rehabilitation), the 2038 projection for the percentage of travel occurring on pavements with "poor" ride quality is lower than the 15.8 percent that occurred in 2018, 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 2038 range from 76.2 percent at the highest level of average annual investment modeled to 54.1 percent at the lowest level of investment modeled.

Exhibit 10-4: Projected Impact of Alternative Investment Levels on 2038 Pavement Ride Quality Indicators for Federal-aid Highways

Average Annual Investment Modeled in HERS (Billions of 2018 Dollars)



Projected 2038 Condition Measures on Federal-aid Highways

HERS-modeled Capital Investment Average Annual Spending[1]		Percent of VMT on Roads with Ride Quality of:			Average IRI		Link to Chapter 7 Scenario
Total	System Rehabilitation[2]	Good (IRI<95)	Fair (IRI 95 to 170)	Poor (IRI>170)	VMT-weighted	Change Relative to Base Year	
$86.1	$46.9	76.2%	17.6%	6.2%	91.4	-18.7%	Improve C&P
$80.0	$43.6	75.9%	16.9%	7.3%	92.5	-17.7%	
$74.0	$40.3	73.5%	18.3%	8.2%	94.8	-15.7%	
$66.8	$35.9	70.6%	19.8%	9.6%	98.3	-12.5%	2014–2018 Spending
$60.0	$31.9	67.9%	21.1%	11.0%	101.6	-9.6%	
$52.0	$27.4	64.1%	23.0%	12.9%	105.9	-5.8%	
$43.5	$22.2	58.9%	25.4%	15.7%	112.0	**-0.4%**	Maintain C&P
$36.0	$17.8	54.1%	27.5%	18.5%	118.0	5.0%	
	Base Year Values:	**51.7%**	**32.5%**	**15.8%**	**112.4**		

[1] The HERS model relies on information from the HPMS sample section database, which is limited to those portions of the road network that are generally eligible for Federal funding (i.e., Federal-aid highways) and excludes roads classified as rural minor collectors, rural local, and urban local.

[2] The system rehabilitation component of HERS-modeled spending would likely have a greater impact on the performance indicators in this exhibit than would the system expansion component that is also reflected in the total.

Note: IRI is International Roughness Index; VMT is vehicle miles traveled. Values are in billions of 2018 dollars.

Source: Highway Economic Requirements System (HERS).

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.

Impact of Future Investment on Travel Delay, Speed, and Congestion on Federal-aid Highways

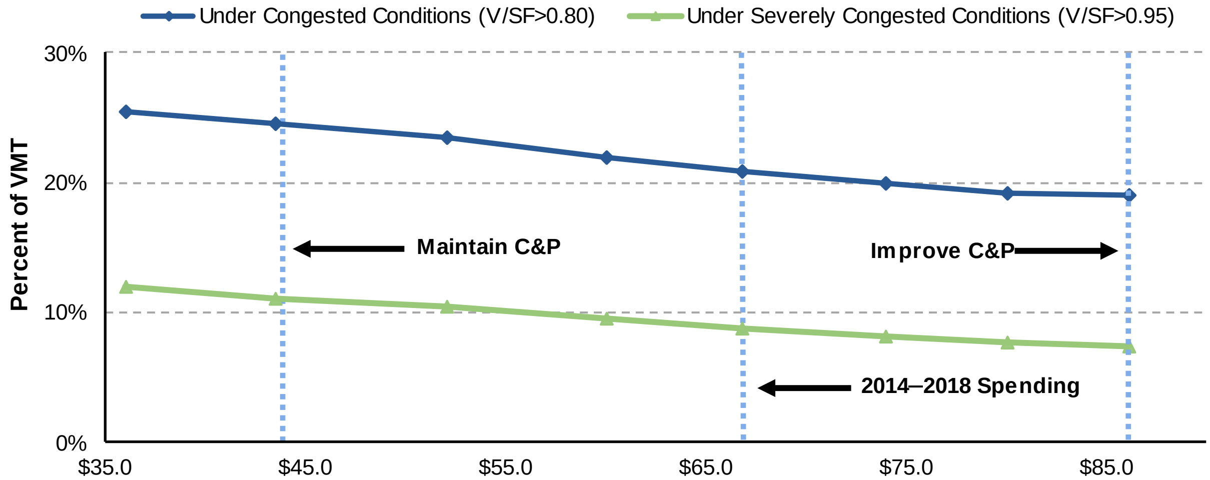
Exhibit 10-5 shows the HERS projections for the impact of investment levels on average speed, travel delay, and volume/service flow (V/SF) ratio. As explained in Chapter 7, in defining the Maintain Conditions and Performance scenario this edition of the report replaces average delay with V/SF ratio greater than 0.95 as the targeted measure of a highway's operational performance. A ratio of 0.80 is associated with congested conditions, and a ratio above 0.95 is considered severely congested. The exhibit splits out the portion of the investment that HERS allocates for system expansion, which tends to reduce travel delay more compared with 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 $18.2 billion, then $21.3 billion (which feeds into the Maintain Conditions and Performance scenario in Chapter 7) to an average annual investment of $39.2 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 2038 is lower than the 2018 level (64.3 hours), with reductions in delay ranging from 8.0 hours (64.3 hours minus 56.3 hours) in the lowest level of investment analyzed to 11.9 hours (64.3 hours minus 52.4 hours) in the highest. The projected increases in average vehicle speed are narrow, ranging from 43.3 miles per hour to 44.0 miles per hour, compared with the 2018 level of 41.9 miles per hour. Although the percentage of VMT on congested roads (with V/SF greater than 0.80) in 2038 is projected at 25.5 percent at the lowest level of investment—higher than the 20.3 percent in 2018—it is projected to decrease to 19.1 percent at the highest level of investment. The improvement of travel under severely congested conditions, measured by the percentage of VMT on roads with V/SF greater than 0.95, is more pronounced, ranging from 12.0 percent at the lowest investment level down to 7.5 percent at the highest investment level in 2038, compared with 11.2 percent in 2018.

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 hours of delay per vehicle and average speed than on the projections for the percentage of VMT on congested and severely congested roads as measured by V/SF. 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.

Exhibit 10-5: Projected Impact of Alternative Investment Levels on 2038 Highway Travel Delay, Speed, and Volume/Service Flow Ratios on Federal-aid Highways

Average Annual Investment Modeled in HERS (Billions of 2018 Dollars)



Projected 2038 Performance Measures on Federal-aid Highways

HERS-modeled Capital Investment Average Annual Spending		Average Speed (mph)	Annual Hours of Delay per Vehicle[2]	Percent of VMT on Roads with: V/SF > 0.80	Percent of VMT on Roads with V/SF > 0.95	Link to Chapter 7 Scenario
Total	System Expansion[1]					
$86.1	$39.2	44.0	52.4	19.1%	7.5%	Improve C&P
$80.0	$36.4	44.0	52.4	19.2%	7.7%	
$74.0	$33.7	43.9	52.8	20.0%	8.2%	
$66.8	$30.9	43.9	53.2	20.9%	8.8%	2014–2018 Spending
$60.0	$28.1	43.8	53.7	21.9%	9.5%	
$52.0	$24.6	43.6	54.5	23.5%	10.5%	
$43.5	$21.3	43.5	55.3	24.5%	11.2%	Maintain C&P
$36.0	$18.2	43.3	56.3	25.5%	12.0%	
Base Year Values:		**41.9**	**64.3**	**20.3%**	**11.2%**	

[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 11,843, the average VMT per registered vehicle in 2018. 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.

Note: VMT is vehicle miles traveled.

Sources: Highway Economic Requirements System (HERS); Highway Statistics 2015, Table VM-1.

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 highway user costs, the model includes the costs of travel time, vehicle operation, and crashes.

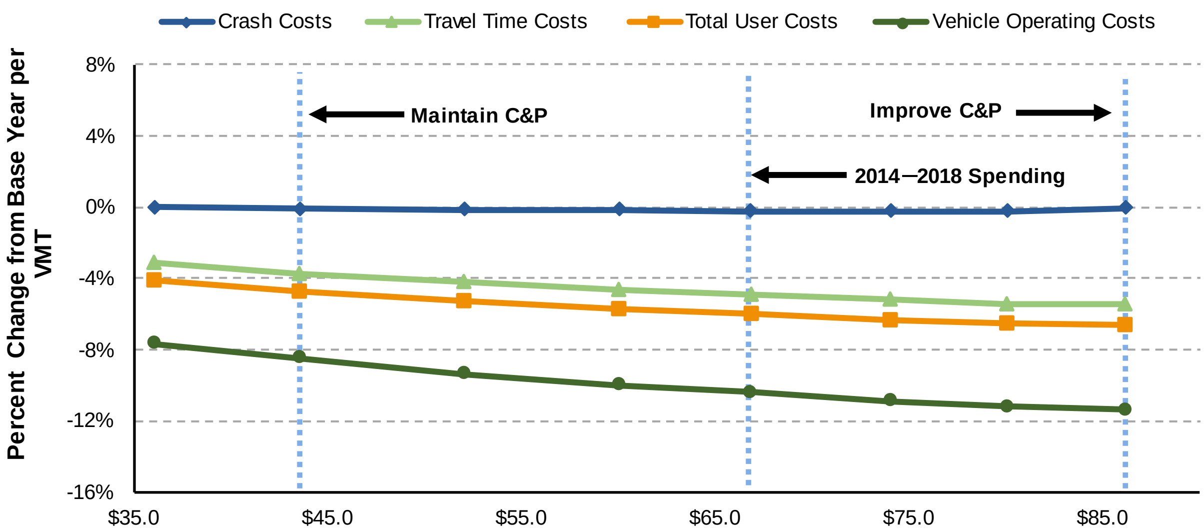
Exhibit 10-6 shows the projected changes from 2018 in average user cost of travel on Federal-aid highways by cost component. For Federal-aid highways, HERS estimates that user costs—the costs of travel time, vehicle operation, and crashes—averaged $1.470 per mile traveled in 2018.

Average user cost per VMT is projected to decrease from the 2018 values by 4.1 percent at the lowest level of spending ($36.0 billion) to 6.6 percent at the highest level of spending ($86.1 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 2038 are projected to be only 0.1 to 0.2 percent lower than they were in 2018.

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 the Highway Performance Monitoring System (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), such safety-focused investments are not evaluated. Thus, the findings presented in *Exhibit 10-6* do not show how such investments affect highway safety and the overall safety impact is underestimated.

Exhibit 10-6: Projected Impact of Future Investment Levels on 2038 User Costs on Federal-aid Highways

Average Annual Investment Modeled in HERS (Billions of 2018 Dollars)



Projected 2038 Performance Measures on Federal-aid Highways

HERS-modeled Investment on Federal-aid Highways Average Annual Investment	Average Total User Costs ($/VMT)	Percent Change Relative to Base Year Average per VMT				Link to Chapter 7 Scenario
		Total User Costs	Travel Time Costs	Vehicle Operating Costs	Crash Costs	
$86.1	$1.373	-6.6%	-5.5%	-11.4%	-0.1%	Improve C&P
$80.0	$1.374	-6.5%	-5.5%	-11.2%	-0.2%	
$74.0	$1.377	-6.3%	-5.2%	-10.9%	-0.2%	
$66.8	$1.381	-6.0%	-4.9%	-10.4%	-0.2%	2014–2018 Spending
$60.0	$1.386	-5.7%	-4.6%	-10.0%	-0.2%	
$52.0	$1.392	-5.3%	-4.2%	-9.4%	-0.2%	
$43.5	$1.400	-4.7%	-3.7%	-8.5%	-0.1%	Maintain C&P
$36.0	$1.409	-4.1%	-3.2%	-7.7%	0.0%	
Base Year Values:	**$1.470**					

Note: VMT is vehicle miles traveled. Values are in billions of 2018 dollars.

Source: Highway Economic Requirements System (HERS).

Crash costs form the smallest of the three components of highway user costs. For 2018 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, 12.2 percent; travel time cost, 58.0 percent; and vehicle operating cost, 29.8 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.

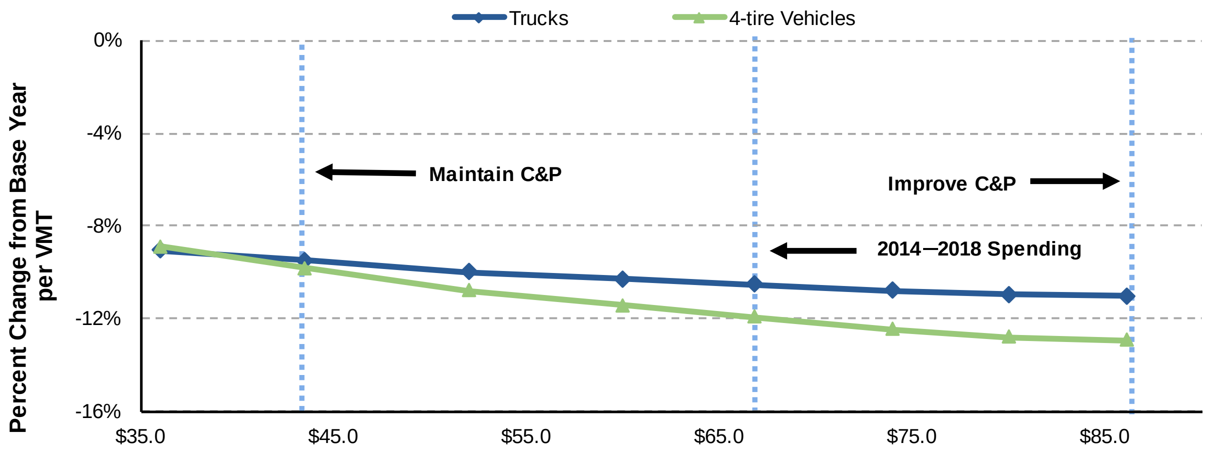
The projected decrease in vehicle operating costs between 2018 and 2038 is 11.4 and 7.7 percent at the highest and lowest investment level, respectively. The projected 2018–2038 change in travel time cost per VMT ranges from a decrease of 5.5 percent at the highest level of assumed investment to a decrease of 3.2 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 2038 by 2.3 percentage points, saving travelers hundreds of millions of hours per year in aggregate.

Impact on Vehicle Operating Costs on Federal-aid Highways

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 11.9 percent at the Sustain 2014–2018 Spending investment level and by 12.9 percent at the Improve C&P investment level for four-tire vehicles from 2018 to 2038. Vehicle operating costs per mile for trucks are projected to decline by 10.5 percent and 11.0 percent for the same period, respectively.

Exhibit 10-7: Projected Impact of Future Investment Levels on 2038 Vehicle Operating Costs on Federal-aid Highways

Average Annual Investment Modeled in HERS (Billions of 2018 Dollars)



Projected 2038 Performance Measures on Federal-aid Highways

HERS-modeled Investment on Federal-aid Highways Average Annual Investment	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	
$86.1	$0.388	$0.318	$0.947	-12.9%	-11.0%	Improve C&P
$80.0	$0.389	$0.319	$0.948	-12.8%	-11.0%	
$74.0	$0.390	$0.320	$0.950	-12.4%	-10.8%	
$66.8	$0.392	$0.322	$0.952	-11.9%	-10.5%	2014–2018 Spending
$60.0	$0.394	$0.324	$0.955	-11.4%	-10.3%	
$52.0	$0.397	$0.326	$0.958	-10.8%	-10.0%	
$43.5	$0.401	$0.330	$0.963	-9.8%	-9.5%	Maintain C&P
$36.0	$0.404	$0.333	$0.968	-8.9%	-9.1%	
Base Year Values:	**$0.438**	**$0.366**	**$1.064**			

Note: VMT is vehicle miles traveled. Values are in billions of 2018 dollars.

Source: Highway Economic Requirements System (HERS).

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 2019.[42] The average price of gasoline is assumed to increase between 2018 and 2038 by 29.5 percent, whereas the average price of diesel fuel is assumed to increase by 33.9 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 during the same period. These changes are represented in HERS as increases in average miles per gallon of 50.7 percent for light-duty vehicles, 22.0 percent for six-tire trucks, and 34.6 percent for other trucks. The net result is that the average vehicle operating costs for both trucks and four-tire vehicles are projected to decline across all funding levels.

Impact of Future Investment on VMT on Federal-aid Highways

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 2018 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 2018 user costs at $1.470 per mile. If the 2038 values assigned to those same user cost components were applied in 2018, however, HERS would compute 2018 user costs to be $1.449 per mile. This "adjusted baseline" is the relevant point of comparison when examining the impact of user cost changes on VMT.

User costs are projected to decline from 2018 to 2038, relative to the baseline, by between 4.1 percent (at the lowest level of investment analyzed) and 6.6 percent (at the highest level of investment analyzed). However, relative to the adjusted baseline user costs are projected to decline by between 2.8 percent and 5.2 percent, respectively. Because the percentage change in adjusted total user costs was negative and increasing for each investment level identified, the effective annual projected VMT growth associated with each investment level is higher than the 1.10-percent baseline projection in all cases, ranging from 1.32 percent to 1.46 percent.

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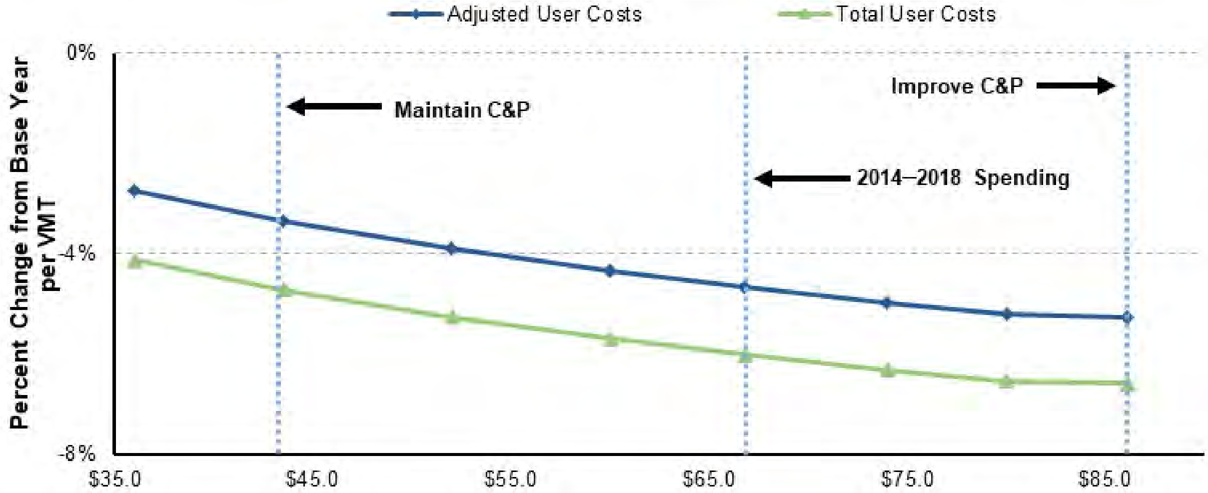
[42] https://www.eia.gov/outlooks/archive/aeo19/

Exhibit 10-8: Projected Impact of Future Investment Levels on 2038 User Costs and VMT on Federal-aid Highways

Average Annual Investment Modeled in HERS (Billions of 2018 Dollars)



Projected 2038 Indicators on Federal-aid Highways

HERS-modeled Investment on Federal-aid Highways (Average Annual Investment in Billions of 2018 Dollars)	Average Total User Costs[1] ($/VMT)	Percent Change in User Costs vs. Actual 2018	Percent Change in User Costs vs. Adjusted Baseline	Projected Trillions of VMT[2]	Annual Percent Change in VMT vs. 2018	Link to Chapter 7 Scenario
$86.1	$1.373	-6.59%	-5.25%	3.701	1.56%	Improve C&P
$80.0	$1.374	-6.53%	-5.20%	3.663	1.51%	
$74.0	$1.377	-6.31%	-4.97%	3.651	1.49%	
$66.8	$1.381	-6.01%	-4.67%	3.633	1.47%	2014–2018 Spending
$60.0	$1.386	-5.69%	-4.34%	3.615	1.44%	
$52.0	$1.392	-5.25%	-3.90%	3.592	1.41%	
$43.5	$1.400	-4.71%	-3.35%	3.563	1.37%	Maintain C&P
$36.0	$1.409	-4.12%	-2.75%	3.532	1.32%	
Base Year Values:	**$1.470**			**2.716**	**1.10%**	
Adjusted Baseline:	**$1.449**					

[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 2038 to the data for 2018 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 took 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 1.1-percent baseline projection in all cases.

Note: VMT is vehicle miles traveled.

Source: Highway Economic Requirements System (HERS).

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 Sustain 2014–2018 Spending funding level signifies the level of spending that maintains 2014 to 2018 average spending in constant-dollar terms on NHS roads. The Maintain Share with V/SF>0.80 funding level denotes the spending level sufficient to maintain the share of VMT on NHS roads with a volume-to-service-flow ratio greater than 0.80 associated with congested conditions in 2038 to match the level in 2018. The Maintain Average 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 2038 to match the level in 2018. The Maintain Share with IRI>170 represents the spending level projected to allow the share of VMT on NHS roads with IRI greater than 170 to remain constant for the same period. Although these investment levels are defined in a parallel manner to the respective 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 two of the seven investment levels presented in the next three exhibits were selected to fill gaps between the five data points linked to specific criteria.

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 2038. Across the investment levels presented, HERS allocates between $12.3 billion and $27.7 billion in average annual spending on NHS roads to system rehabilitation and between $14.3 billion and $28.0 billion in average annual spending on NHS roads to system expansion.

Exhibit 10-9: HERS Investment Levels Analyzed for the National Highway System and Projected Minimum Benefit-cost Ratios, User Costs, and VMT

HERS-modeled Investment on the NHS (Average Annual Over 20 Years in Billions of 2018 Dollars)			Projected NHS Indicators			
Total HERS Spending[1]	System Rehabilitation Spending	System Expansion Spending	Minimum BCR 20-year 2019 through 2038[2]	Average 2038 Total User Costs ($/VMT)[3]	Projected 2038 VMT (Trillions)[4]	Description
$55.7	$27.7	$28.0	**1.00**	$1.269	2.409	BCR ≥ 1.0
$52.0	$25.8	$26.2	1.01	$1.270	2.388	
$46.5	$23.0	$23.5	1.15	$1.275	2.375	Sustain 2014–2018 Spending
$43.4	$21.2	$22.1	1.26	$1.278	2.367	Maintain Share with V/SF>0.80
$38.0	$18.3	$19.7	1.49	$1.284	2.351	
$30.9	$14.6	$16.3	1.83	$1.293	2.326	Maintain Average IRI
$26.6	$12.3	$14.3	2.13	$1.300	2.306	Maintain Share with IRI>170
Base Year Values:				**$1.374**	**1.750**	
Adjusted Baseline:				**$1.355**		

[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 (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 2038 to the data for 2018, 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 took 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.

Note: VMT is vehicle miles traveled; BCR is benefit-cost ratio; IRI is International Roughness Index.

Source: Highway Economic Requirements System (HERS).

Average user costs are projected to be lower in 2038 than they were for the adjusted baseline ($1.355 per VMT) for all investment levels presented. When implementing all cost-beneficial projects (the highest level of investment, an annual average of $55.7 billion), average total user costs are projected to be 6.32 percent lower ($1.269 per VMT) than were adjusted baseline user costs in 2018 ($1.355 per VMT). At the Sustain 2014–2018 Spending level of investment (an annual average of $46.5 billion), average total user costs are projected to be 5.92 percent lower ($1.275 per VMT) than were adjusted baseline user costs in 2018. At the Maintain Share with V/SF>0.80 level of investment (an annual average of $43.4 billion), average total user costs are projected to be 5.71 percent lower ($1.278 per VMT) than were adjusted baseline user costs in 2018. At the Maintain Average IRI (an annual average of $30.9 billion) and Maintain Share with IRI>170 (an annual average of $26.6 billion), average total user costs are projected to be the highest at $1.293 and $1.300 per VMT with the lowest declines compared to the adjusted baseline user costs in 2018 at 4.49 and 4.04 percent, respectively.

VMT on the NHS is expected to rise from 1.750 trillion in 2018 to 2.409 trillion in 2038 at the highest level of investment analyzed, equating to an average annual growth rate of 1.61 percent. At the lowest level of investment analyzed, VMT is projected to rise by 1.39 percent annually to 2.306 trillion.

Impact of Future Investment on NHS Congestion, Speed, Delay, and Travel Time Costs

The tabular portion of *Exhibit 10-10* presents the projections of NHS averages for congestion and time-related indicators of performance, along with the spending amount that HERS allocates for NHS expansion projects (which have stronger effects on congestion and time-related indicators of performance than do preservation projects).

At the highest level of investment in system expansion ($28.0 billion), the percentage of VMT on congested roads, represented by V/SF greater than 0.80, is projected to be 21.6 percent of the total VMT in 2038, compared to the baseline of 24.0 percent in 2018. At the lowest level of investment in system expansion ($14.3 billion), the percentage of VMT on congested roads in 2038 is projected to be 29.1 percent of the total VMT. The percentage of VMT on severely congested roads, represented by V/SF greater than 0.95, is projected to be 7.2 and 12.0 percent of the total VMT in 2038, at the highest and the lowest levels of investment, respectively, compared to the baseline of 12.8 percent in 2018.

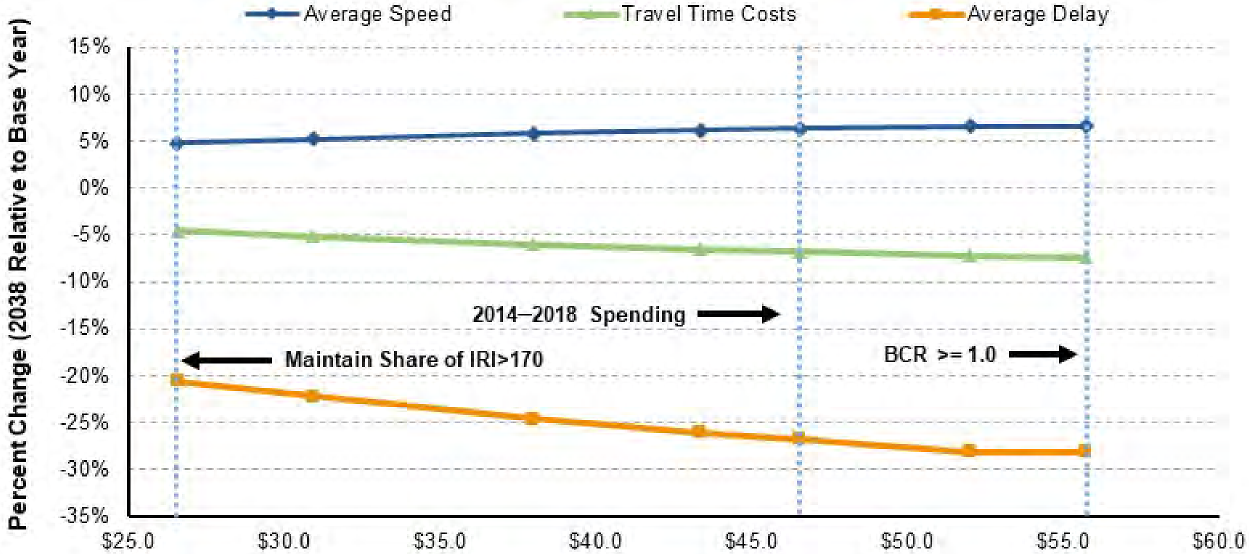
The graph is plotted based on the total average annual NHS investment modeled in HERS, including spending on both system rehabilitation and system expansion. For all investment levels presented in *Exhibit 10-10*, average travel speed is projected to be higher in 2038 than it was in 2018. The average travel speed is 4.8 percent higher at the lowest level of investment in system expansion (an annual average of $14.3 billion) and 6.6 percent higher at the highest level of investment in system expansion (an annual average of $28.0 billion).

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 2038 is projected to be 28.1 percent lower than it was in 2018. At the lowest level of investment in system expansion presented in the exhibit, average delay per VMT in 2038 is projected to be 20.6 percent lower than it was in 2018.

Travel time costs per VMT in 2038 are projected to decrease across the investment levels presented. Travel time costs per VMT in 2038 are projected to decrease by 7.3 percent relative to 2018 at the highest investment level and to decrease by 4.6 percent at the lowest level of investment.

Exhibit 10-10: Projected Impact of Future Investment Levels on 2038 Highway Speed, Travel Delay, Travel Time Costs, and Volume-Service Flow Ratios on the National Highway System

Average Annual NHS Capital Investment Modeled in HERS (Billions of 2018 Dollars)



Projected 2038 Performance Measures on the NHS

HERS-modeled Investment on the NHS Average Annual Spending		Percent of VMT on Roads with:		Percent Change Relative to Base Year			
Total	System Expansion[1]	V/SF > 0.80	V/SF > 0.95	Average Speed	Average Delay per VMT	Travel Time Costs per VMT[2]	Description
$55.7	$28.0	21.6%	7.2%	6.6%	-28.1%	-7.3%	BCR ≥ 1.0
$52.0	$26.2	22.0%	7.7%	6.6%	-28.1%	-7.3%	
$46.5	$23.5	23.4%	8.5%	6.3%	-26.7%	-6.8%	Sustain 2014–2018 Spending
$43.4	$22.1	**24.0%**	8.9%	6.1%	-26.1%	-6.5%	Maintain Share with V/SF>0.80
$38.0	$19.7	25.6%	9.8%	5.8%	-24.6%	-6.0%	
$30.9	$16.3	28.2%	11.2%	5.2%	-22.2%	-5.2%	Maintain Average IRI
$26.6	$14.3	29.1%	12.0%	4.8%	-20.6%	-4.6%	Maintain Share with IRI>170
Base Year Values:		**24.0%**	**12.8%**				

[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.

Note: VMT is vehicle miles traveled; IRI is International Roughness Index; BCR is benefit-cost ratio. Values are in billions of 2018 dollars.

Sources: Highway Economic Requirements System (HERS); Highway Statistics 2018, Table VM-1.

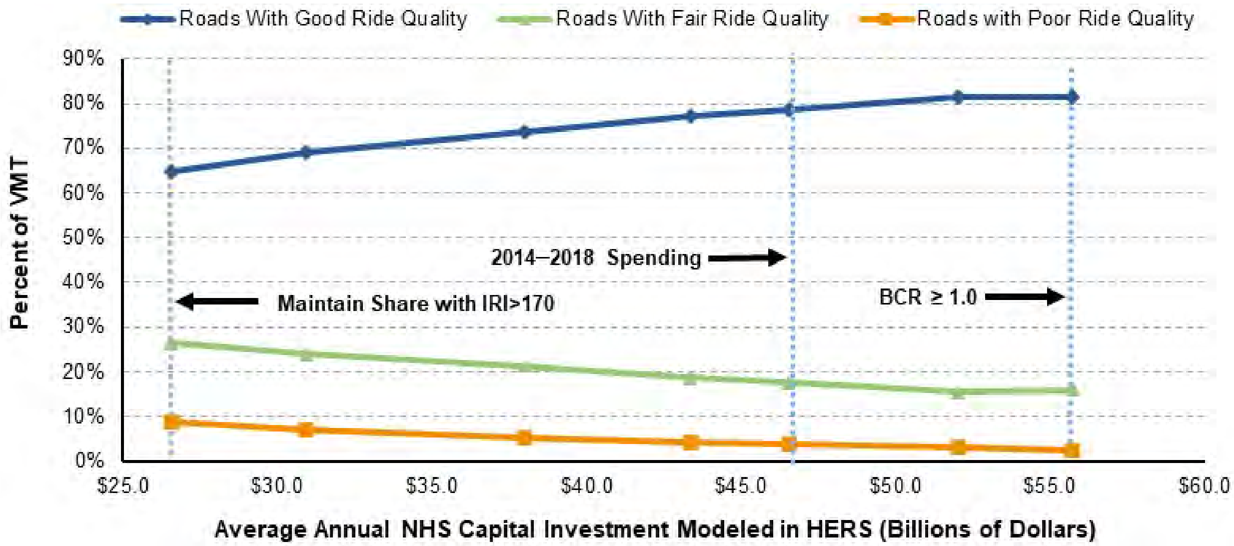
Impact of Future Investment on NHS Pavement Ride Quality

The tabular portion of *Exhibit 10-11* shows the portion of modeled NHS spending that HERS allocates to rehabilitation projects (which have a greater influence on average pavement quality compared with 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 $27.7 billion allocated to system rehabilitation), HERS projects that pavements with an IRI below 95 (the criterion presented in Chapter 6 for rating ride quality as “good”) would carry 81.4 percent of the

VMT on the NHS in 2038, up from the 64.1 percent estimated for 2018. The model projects a declining share of NHS travel on pavements with "fair" ride quality (IRI between 95 and 170), from 26.4 percent at the lowest investment level (an annual average of $12.3 billion allocated to system rehabilitation) to 16.1 percent at the highest investment level, lower than the NHS travel on pavements with "fair" ride quality at 27.1 percent in 2018. The average IRI of the NHS system is estimated at 83.6 in 2038 compared with 96.1 in 2019 at the highest investment level, achieving the classification of providing "good" ride quality at the aggregate level.

Exhibit 10-11: Projected Impact of Future Investment Levels on 2038 Pavement Ride Quality Indicators for the National Highway System



Projected 2038 Condition Measures on the NHS

HERS-modeled Investment on the NHS Average Annual Spending (Billions of 2018 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
$55.7	$27.7	81.4%	16.1%	2.5%	83.6	-13.0%	BCR ≥ 1.0
$52.0	$25.8	81.6%	15.4%	3.0%	84.0	-12.6%	
$46.5	$23.0	78.7%	17.5%	3.7%	86.4	-10.1%	Sustain 2014–2018 Spending
$43.4	$21.2	77.2%	18.6%	4.2%	88.1	-8.3%	Maintain Share with V/SF>0.80
$38.0	$18.3	73.6%	21.3%	5.2%	91.4	-4.9%	
$30.9	$14.6	68.9%	24.0%	7.1%	96.1	**0.0%**	Maintain Average IRI
$26.6	$12.3	64.8%	26.4%	**8.8%**	100.3	4.4%	Maintain Share with IRI>170
	Base Year Values:	**64.1%**	**27.1%**	**8.8%**	**96.1**		

[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.

Note: VMT is vehicle miles traveled; IRI is International Roughness Index; BCR is benefit-cost ratio.

Source: Highway Economic Requirements System (HERS).

At the highest level of investment, the model finds it to be cost-beneficial to reduce the VMT-weighted share of pavements with an IRI above 170 (the criterion presented in Chapter 6 for rating ride quality as "poor") from 8.8 percent in 2018 to 2.5 percent in 2038, 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.

At the Maintain Share with V/SF>0.80 investment level of $16.9 billion average annual spending allocated to system rehabilitation (maintains a constant share of VMT under congested conditions) pavements with “good” ride quality are projected to carry 77.2 percent of the VMT on the NHS, up from the 64.1 percent estimated for 2018. The model projects 18.6 percent share of NHS travel on pavements with “fair” ride quality, compared to 27.1 percent in 2018. During the same period the share of NHS travel on pavements with “poor” ride quality would drop from 8.8 to 4.2 percent. The average IRI of the NHS system estimated at 88.1 is sufficient to provide “good” ride quality at this investment level.

At the lowest investment level presented—Maintain Share with IRI>170 (an annual average of $12.3 billion allocated to system rehabilitation)—the share of NHS travel carried by pavements with an IRI above 170 would remain the same at 8.8 percent, whereas the share of NHS travel on pavements with an IRI below 95 would increase slightly to 64.8 percent in 2038 from 64.1 percent in 2018. The average IRI would increase to 100.3 from 96.1 for the same period.

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.

The highest two investment levels shown in the three exhibits presented in this section are based on model runs constrained by a BCR. The top row in each table represents a run within which all potential improvements with a BCR of 1.0 or higher are implemented; this corresponds to the definition of the Improve Conditions and Performance scenario presented in Chapter 7. The second row (Sustain 2014–2018 Spending) in each table represents a run at which the average annual investment level over 20 years matches the average annual level from 2014 to 2018 in constant-dollar terms by all levels of government combined. (HERS was unable to identify $21.8 billion of cost-beneficial investment annually assuming spending remained at this fixed amount in each year, so the analysis was redone as a BCR-constrained run under which spending varies by year.) The Maintain Share with V/SF>0.80 funding level represents the spending level sufficient to maintain the share of VMT on the Interstate highways with volume-to-service-flow ratio greater than 0.80 associated with congested conditions in 2038 to match the level in 2018. Similarly, the Maintain Share with V/SF>0.95 funding level denotes the spending level sufficient to maintain the share of VMT on the Interstate highways with volume-to-service-flow ratio greater than 0.95 associated with severely congested conditions over the same period. 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 System 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 2038, along with the amount that HERS allocates to Interstate projects. Across the Interstate highway investment levels presented, HERS allocates between $4.5 billion and $10.9 billion in average annual spending to system rehabilitation and between $5.7 billion and $12.2 billion in average annual spending to system expansion.

Average user costs are projected to be lower in 2038 than the adjusted baseline ($1.253 per VMT) for all investment levels presented. At the highest level of investment presented in *Exhibit 10-12* (an annual average of $23.0 billion), average total user costs are projected to be 8.19 percent lower ($1.158 per VMT) in 2038 than they were in 2018. At the 2014 to 2018 level of investment (an annual average of $21.8 billion), average total user costs are projected to be 7.96 percent lower ($1.161 per VMT) in 2038 than they were in 2018. At the Maintain Share with V/SF>0.80 (an annual average of $16.9 billion) and the Maintain Share with V/SF>0.95 (an annual average of $10.2 billion) levels of investment, average total user costs ($1.172 and $1.194 per VMT) are projected to be 6.94 and 4.96 percent lower over the same period, respectively.

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 Interstate Highways (Average Annual Over 20 Years, in Billions of 2018 Dollars)			Projected Interstate Indicators			
Total HERS Spending[1]	System Rehabilitation Spending	System Expansion Spending	Minimum BCR 20-year 2017 through 2038[2]	Average 2038 Total User Costs ($/VMT)[3]	Projected 2038 VMT (Trillions)[4]	Description
$23.0	$10.9	$12.2	**1.00**	$1.158	1.138	BCR ≥ 1.0
$21.8	$10.2	$11.7	1.09	$1.161	1.134	Sustain 2014–2018 Spending
$19.0	$8.8	$10.2	1.12	$1.166	1.125	
$16.9	$7.6	$9.2	1.37	$1.172	1.118	Maintain Share with V/SF>0.80
$14.0	$6.3	$7.7	1.72	$1.179	1.107	
$12.0	$5.3	$6.7	2.04	$1.186	1.097	
$10.2	$4.5	$5.7	2.45	$1.194	1.087	Maintain Share with V/SF>0.95
Base Year Values:				**$1.236**	**0.822**	
Adjusted Baseline:				**$1.253**		

[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 2038 to the data for 2018 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 took 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.

Note: VMT is vehicle miles traveled; BCR is benefit-cost ratio.

Source: Highway Economic Requirements System (HERS).

Interstate VMT is projected to rise from 0.822 trillion in 2018 to 1.138 trillion in 2038 at the highest level of investment analyzed, equating to an average annual growth rate of 1.64 percent. At the lowest level of investment analyzed (Maintain Share with V/SF>0.95), Interstate VMT is projected to rise by 1.41 percent annually to 1.087 trillion.

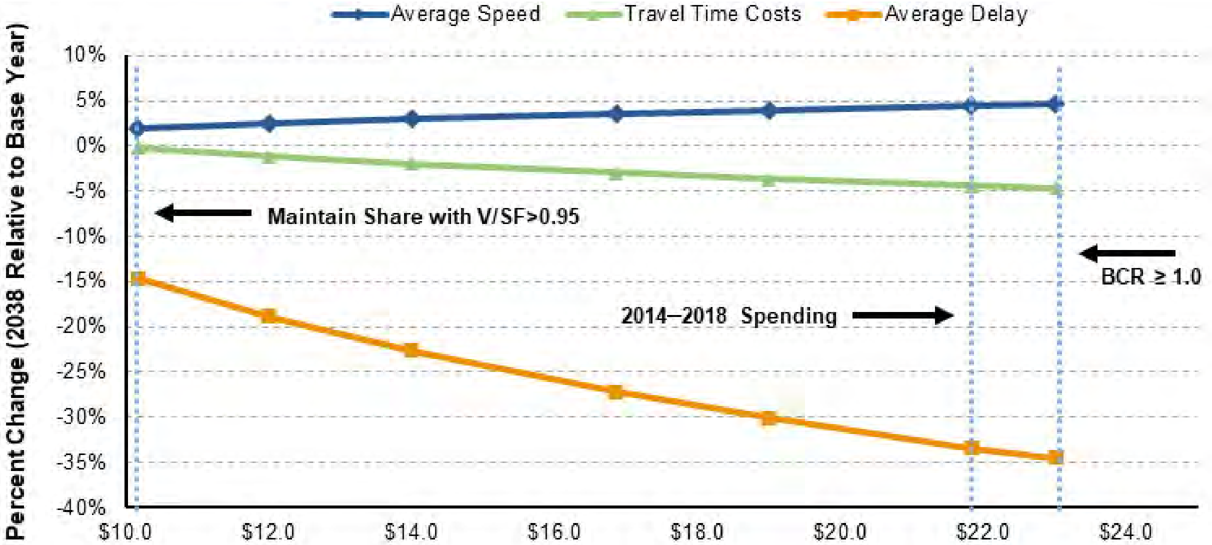
Impact of Future Investment on Interstate System Congestion, Speed, Delay, and Travel Time Costs

The tabular portion of *Exhibit 10-13* presents the projections of Interstate System averages for congestion and time-related indicators of performance, along with the amount that HERS allocates for Interstate System expansion projects (which have a relatively larger impact on congestion and time-related compared with system rehabilitation projects).

At the highest level of investment in system expansion ($12.2 billion), the percentage of VMT on Interstate highways, represented by V/SF greater than 0.80, is projected to be 23.8 percent of the total VMT in 2038, compared to the baseline of 27.7 percent in 2018. At the lowest level of investment in system expansion ($5.7 billion), the percentage of VMT on Interstate highways in 2038 is projected to be 34.7 percent of the total VMT. The percentage of VMT on severely congested Interstate highways, represented by V/SF greater than 0.95, is projected to be 7.6 and 13.9 percent of the total VMT in 2038, at the highest and the lowest levels of investment, respectively, compared to the baseline of 13.9 percent in 2018.

Exhibit 10-13: Projected Impact of Future Investment Levels on 2038 Highway Speed, Travel Delay, Travel Time Costs, and Volume-Service Flow Ratios on the Interstate System

Average Annual Interstate System Capital Investment Modeled in HERS (Billions of 2018 Dollars)



Projected 2038 Performance Measures on Interstate Highways

HERS-modeled Average Annual Investment on Interstate Highways		Percent of VMT on Roads with:		Percent Change Relative to Base Year			
Total	**System Expansion[1]**	**V/SF > 0.80**	**V/SF > 0.95**	**Average Speed**	**Average Delay per VMT**	**Travel Time Costs per VMT**	**Description**
$23.0	$12.2	23.8%	7.6%	4.6%	-34.5%	-4.6%	BCR ≥ 1.0
$21.8	$11.7	25.0%	8.2%	4.5%	-33.4%	-4.4%	Sustain 2014–2018 Spending
$19.0	$10.2	26.3%	9.8%	4.0%	-30.1%	-3.6%	
$16.9	$9.2	**27.7%**	10.4%	3.6%	-27.2%	-3.0%	Maintain Share with V/SF>0.80
$14.0	$7.7	30.5%	11.8%	3.0%	-22.6%	-2.0%	
$12.0	$6.7	33.6%	13.1%	2.4%	-18.9%	-1.1%	
$10.2	$5.7	34.7%	**13.9%**	1.9%	-14.7%	-0.2%	Maintain Share with V/SF>0.95
Base Year Values:		**27.7%**	**13.9%**				

[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.

Note: VMT is vehicle miles traveled; BCR is benefit-cost ratio. Values are in billions of 2018 dollars.

Sources: Highway Economic Requirements System (HERS); Highway Statistics 2018, Table VM-1.

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 2038 than it was in 2018. At the highest level of investment presented in *Exhibit 10-13* (average annual investment in system expansion of $12.2 billion), average Interstate highway travel speed is projected to be 4.6 percent higher in 2038 than it was in 2018. At the lowest level of investment level (average annual investment in system expansion of $5.7 billion), average Interstate highway travel speed is projected to be 1.9 percent higher in 2038 than it was in 2018.

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 2038 is projected to be 34.5 percent lower than it was in 2018. At the lowest level of investment, average delay per VMT in 2038 is projected to be 14.7 percent lower than it was in 2018. Travel time costs per VMT in 2038 are projected to decrease by 4.6 percent relative to 2018 at the highest investment level and to remain virtually the same at the lowest level of investment.

Impact of Future Investment on Interstate System Pavement Ride Quality

The tabular portion of *Exhibit 10-14* shows the amounts of Interstate System spending that HERS allocates to rehabilitation projects (which have a greater influence on average pavement quality compared with 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.

At the highest level of investment presented in *Exhibit 10-14* (an annual average of $10.9 billion allocated to system rehabilitation), HERS projects that pavements with an IRI below 95 (the criterion described in Chapter 6 for rating ride quality as "good") would carry 83.5 percent of the VMT on Interstate highways in 2038, up from the 77.1 percent estimated for 2018. The model projects a declining share of Interstate highway travel on pavements with "fair" ride quality (IRI between 95 and 170), from 29.1 percent at the lowest investment level (an annual average of $4.5 billion allocated to system rehabilitation) to 16.0 percent at the highest investment level, lower than the Interstate highway travel on pavements with "fair" ride quality at 19.4 percent in 2018. The average IRI of the Interstate highways is estimated at 79.2 in 2038 at the highest investment level, the same as in 2018, achieving the classification of providing "good" ride quality at the aggregate level.

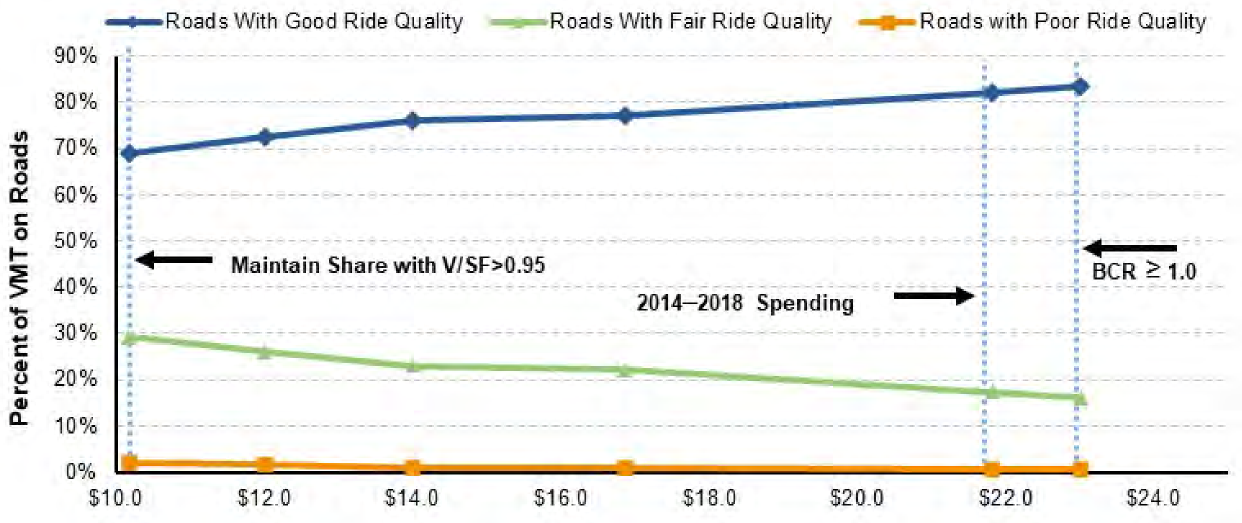
At the highest level of investment, the model finds it to be cost-beneficial to reduce the VMT-weighted share of pavements with an IRI above 170 (the criterion presented in Chapter 6 for rating ride quality as "poor") from 3.5 percent in 2018 to 0.5 percent in 2038, but predicts the costs of completely eliminating "poor" ride quality 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.

At the Maintain Share with V/SF>0.80 investment level of $7.6 billion average annual spending allocated to system rehabilitation (maintaining a constant share of VMT under congested conditions) pavements with "good" ride quality are projected to carry 77.1 percent of the VMT on Interstate highways, the same as the percentage estimated for 2018. The model projects a 22.0-percent share of Interstate highway travel on pavements with "fair" ride quality, up from 19.4 percent in 2018. During the same period the share of Interstate highways travel on pavements with "poor" ride quality would drop from 3.5 to 0.9 percent. The average IRI of the Interstate System estimated at 83.5 in 2028 is sufficient to provide "good" ride quality at this investment level.

At the lowest investment level—Maintain Share with V/SF>0.95 (an annual average of $4.5 billion allocated to system rehabilitation)—the share of Interstate travel carried by pavements with an IRI above 170 would decrease to 1.9 percent in 2038 from 3.5 percent in 2018. During the same period the share of Interstate travel on pavements with an IRI below 95 would decrease to 69.0 percent from 77.1. The average IRI would increase to 89.3 from 89.2 for the same period, still sufficient to provide "good" ride quality at this investment level.

Exhibit 10-14: Projected Impact of Future Investment Levels on 2038 Pavement Ride Quality Indicators for the Interstate System

Average Annual Interstate System Capital Investment Modeled in HERS (Billions of 2018 Dollars)



Projected 2038 Condition Measures on Interstate Highways

HERS-modeled Average Annual Investment on Interstate Highways		Percent of VMT on Roads with Ride Quality of:[1]			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
$23.0	$10.9	83.5%	16.0%	0.5%	79.2	0.0%	BCR ≥ 1.0
$21.8	$10.2	82.3%	17.3%	0.5%	80.0	1.0%	Sustain 2014–2018 Spending
$19.0	$8.8	80.4%	18.9%	0.7%	81.9	3.4%	
$16.9	$7.6	77.1%	22.0%	0.9%	83.5	5.4%	Maintain Share with V/SF>0.80
$14.0	$6.3	76.0%	23.0%	1.0%	84.9	7.2%	
$12.0	$5.3	72.5%	26.0%	1.5%	87.2	10.1%	
$10.2	$4.5	69.0%	29.1%	1.9%	89.3	12.8%	Maintain Share with V/SF>0.95
Base Year Values:		**77.1%**	**19.4%**	**3.5%**	**79.2**		

[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.

Note: VMT is vehicle miles traveled; IRI is International Roughness Index; BCR is benefit-cost ratio. Values are in billions of 2018 dollars.

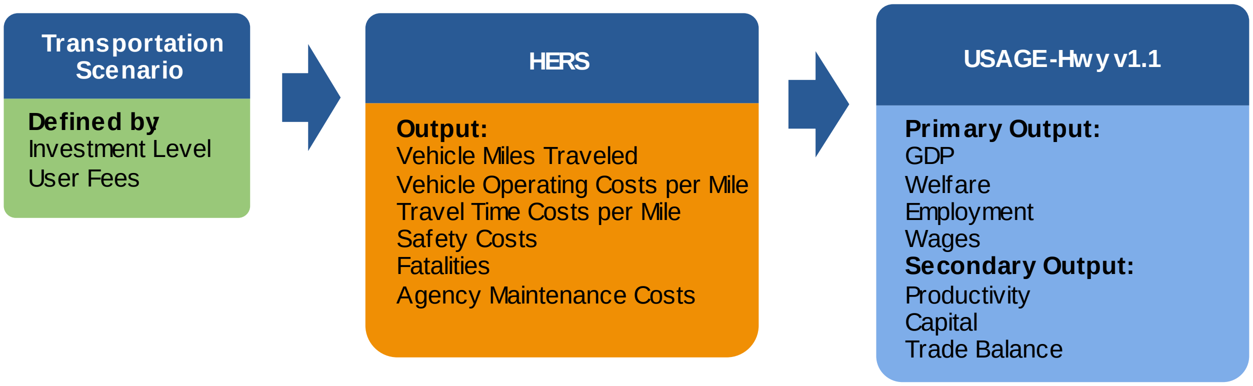
Source: Highway Economic Requirements System (HERS).

Impacts of Increased Highway Capital Investment on the Economy

To understand the impact of transportation investments on the economy, FHWA developed a dynamic computable general equilibrium model of the U.S. economy, called USAGE-Hwy, tailored to focus on transportation-related industries. It analyzes the interconnection among industries in the U.S. economy to understand the wider economic impacts from policy interventions. USAGE-Hwy models the impacts of spending on highway investments through two channels: stimulus impacts from government expenditures and the impacts of improved highway performance on the productivity of industries and households that use highways. This section provides estimates of macroeconomic impacts of increased highway capital investment, derived from a 30-year analysis using the USAGE-Hwy model.

Exhibit 10-15 depicts the macroeconomic impact analysis framework. Estimates of improved highway performance from increases in highway investment are generated from the Highway Economic Requirements System (HERS) model; see Chapter 7 of this report. The USAGE-Hwy model translates those performance effects and the financial impacts related to funding the highway investment into implications for the national economy as measured by GDP, welfare (measured primarily by consumption), employment, and wages. Additional measures of macroeconomic activity, including productivity, capital levels, and trade balances are available. The USAGE-Hwy also has the capacity to investigate the employment impacts of those spending scenarios for different demographic groups of the U.S. workforce. An overview of the analysis framework is provided in Appendix F.

Exhibit 10-15: Macroeconomic Impact Analysis Framework



Source: FHWA, Office of Transportation Studies, Economic Investment Strategies Team.

Highway Performance Impacts

The increased investment under the Improve Conditions and Performance scenario produces many improvements in highway system performance, such as improved travel times and improved pavement condition. Improvements in highway system performance reduce user costs, such as travel time and vehicle operating costs per mile. These performance improvements, which are summarized in *Exhibit 10-16*, are expected to increase demand for highway travel. The VMT under the Improve Conditions and Performance scenario would be higher than under the baseline scenario represented by Sustain 2014–2018 Spending. It is estimated VMT would be 33 billion higher in year 20 and 50 billion higher in year 30. Total fuel consumption increase is due to the increase in VMT.

Adaptation of 20-Year HERS Scenario Inputs to 30 Years for USAGE

The USAGE-Hwy model typically uses a 30-year analysis period to ensure that the full long-run impacts of alternative policies are captured. For purposes of this analysis, the 20-year HERS runs supporting both the Improve Conditions and Performance scenario and the Sustain 2014–2018 scenario were extended by an additional 10 years at the funding level of the Sustain 2014–2018 scenario. This approach was meant to capture the full impacts of the higher 20-year investment levels under the Improve scenario without assuming such higher investment levels would be sustained indefinitely. The differences in VMT and other impacts between the Improve and Sustain scenarios beyond the first 20 years are due to the benefits of improved system performance resulting from higher levels of investment to address pavement and congestion needs in prior funding periods.

Exhibit 10-16: Highway Performance Impacts from Improve Conditions and Performance Scenario Compared with Sustain 2014–2018 Spending Scenario

Highway Performance Indicators	Difference in Year 20	Difference in Year 30
Vehicle Miles Traveled	+ 33.0 billion VMT	+ 50.0 billion VMT
Vehicle Operating Costs per Mile	- $12.6 billion	- $9.3 billion
Travel Time Costs per Mile	- $9.0 billion	- $4.8 billion
Total Maintenance Costs	- $32 million	- $20 million
Fuel Consumption per Mile	+ 0.40 billion gallons	+ 0.42 billion gallons

Source: Highway Economic Requirement System (HERS).

Macroeconomic Impacts

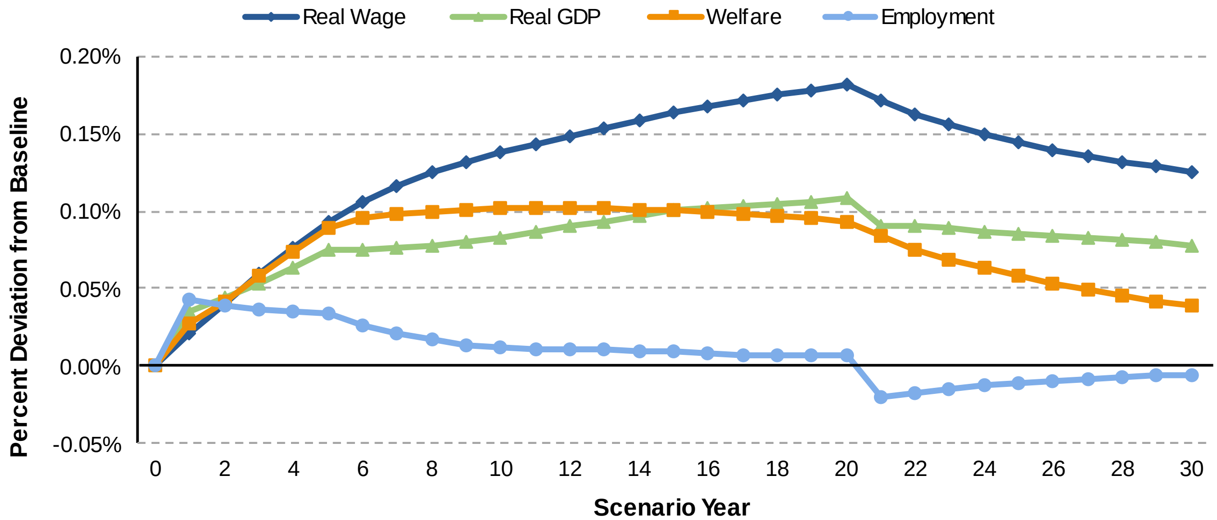
Exhibit 10-17 summarizes the dynamic macroeconomic effects of highway investment derived from the USAGE-Hwy model, which compares the Improve Conditions and Performance highway investment scenario to the baseline Sustain 2014–2018 Spending scenario. *Exhibit 10-18* presents the average annual macroeconomic impacts over 20 and 30 years. The primary macroeconomic effects are presented in terms of GDP, employment, wages, and welfare:

- GDP is a measure of the total value of all the goods and services produced by a country;
- Employment refers to total employment within the U.S. economy;
- Wages are average wages for all employed persons; and
- Welfare is measured as the summation of private consumption (excluding medical expenses),[43] leisure time valued at value of time from USDOT guidance, and any changes in fatalities valued using the value of statistical life (VSL) from USDOT guidance:[44]

[43] Welfare-relevant consumption excludes medical expenditures because medical expenditures may be considered welfare-reducing in that they decrease the ability to consume other welfare-improving goods.

[44] U.S. Department of Transportation, 2020. *Benefit-Cost Analysis Guidance for Discretionary Grant Programs*. https://www7.transportation.gov/office-policy/transportation-policy/benefit-cost-analysis-guidance-discretionary-grant-programs-0

Exhibit 10-17: Macroeconomic Impacts from Improve Conditions and Performance Scenario Compared with Sustain 2014–2018 Spending Scenario



Source: USAGE-Hwy Model.

Exhibit 10-18: Summary of Macroeconomic Impacts from Improve Conditions and Performance Scenario Compared with Sustain 2014–2018 Spending Scenario

Macroeconomic Impacts	Average Change over 20 Years	Average Change over 30 Years
GDP	+ $17.0 billion per year	+ $17.2 billion per year
	(+ $341 billion over 20 years)	(+ $516 billion over 30 years)
Employment	+ 28,300 jobs per year	+ 13,100 jobs per year
Wage	+ $92 per year per worker	+ $96 per year per worker
Welfare	+ $10.5 billion per year	+ $9.2 billion per year
	(+ $209 billion over 20 years)	(+ $277 billion over 30 years)
Capital	+ $0.7 billion per year	+ $1.0 billion per year
	(+ $15 billion over 20 years)	(+ $30 billion over 30 years)
Productivity	+ 0.07 percent per year	+ 0.07 percent per year

Source: USAGE-Hwy Model.

These effects are reported as the percentage deviation of the Improve Conditions and Performance scenario from the baseline scenario.

With an additional $14.2 billion of annual highway investment injected into the economy, GDP would respond by continuously expanding above baseline conditions for the first 20 years of the investment period, with peak GDP projected to be 0.11 percent higher than the baseline in year 20. Highway investment has a long-lasting effect, as demonstrated by GDP remaining above the baseline trajectory even after the investment level falls to the baseline level from year 21 to 30. By year 30, GDP is still 0.08 percent above the baseline level. The USAGE-Hwy models increases in economic output from highway investment mainly through three channels: (1) improved total labor and capital productivity, (2) higher aggregate capital levels, and (3) expanded employment. On average, over the 30-year analysis period, GDP is 0.08 percent higher than that of the baseline level. This expansion in economic output is equivalent to $17.2 billion per year in the 2018 economy or $516 billion in total over 30 years. Dividing this 30-year incremental increase in GDP of $516 billion by the 20-year additional investment amount of $283.8 billion results in a GDP multiplier for highway investment of 1.8. That is, based on this analysis, each additional dollar spent on cost-beneficial highway capital projects results in $1.80 of additional GDP over the course of 30 years.

The USAGE-Hwy model results indicate that most of the GDP increase comes from productivity gains derived from reductions in vehicle operating costs per mile and reductions in travel time costs per mile. Additionally, aggregate capital levels remain higher than baseline estimates due to the increased highway investments throughout the first 20 years. Aggregate capital levels stay higher than baseline even after highway investment returns to the baseline level in year 21, a result of continued economic growth compared with the baseline. Finally, expanded employment also contributes to higher GDP in the first 20 years of the analysis period as more people are engaged in economic activity. However, GDP drops by a small amount due to employment falling below the baseline level after the elevated investment period ends.

In aggregate, employment is estimated to spike by 0.04 percent in year 1 compared with the baseline, in response to the increase in highway investment. Employment remains above the baseline levels throughout the 20-year investment period, but the magnitude of this employment boost diminishes gradually through the latter part of the 20-year investment period, dropping to 0.01 percent in year 20. During the 20-year period of increased investment, average employment is estimated to be almost 0.02 percent above the baseline level, equivalent to approximately 28,300 jobs per year in the 2018 economy.

After year 20, when the additional investment stops, employment falls below baseline levels. Some portion of the drop in employment is the straightforward result of lower demand for labor once the additional highway investment ceases. Another contributor to the fall in employment is the lag between a drop in demand in labor and the adjustment in relative wages needed to equalize demand and supply of labor. Wages take time to adjust, and for a time are too high to achieve the employment of the baseline scenario. The USAGE-Hwy model depicts this lag in wage adjustments as “sticky” wages. After the initial negative shock in year 21, employment trends back toward the baseline as wages gradually adjust to their market clearing levels. Combining the positive employment impacts from years 1 through 20 and the negative impacts during years 21 through 30, the average employment is 0.01 percent above baseline over the entire 30-year analysis period, equivalent to 13,100 jobs per year in the 2018 economy.

Due to the increase in demand for labor during the investment period, wages rise to 0.13 percent above the baseline level on average over the 20-year period (equivalent to $92 per year per worker in the 2018 economy). Similar to the dynamics of total employment, wages begin to decline after year 20 when investment returns to baseline levels, but the positive impacts on wages persist: average wages remain 0.13 percent above baseline over the 30-year period (equivalent to $96 per year per worker in the 2018 economy).

Welfare impacts are positive throughout the 30-year period. These benefits last beyond the 20-year increased investment period because highways are long-lived assets, so benefits for households and consumers continue to accrue after their construction is complete. The difference in welfare between the Improve Conditions and Performance scenario and the Sustain 2014–2018 Spending scenario is the difference in the monetized values for household nonmedical consumption, and leisure time between the two scenarios. Highway investment increases productivity and allows higher outputs to be created using the same or lower level of resources (including time), thus freeing up resources for different uses; it also offers households higher levels of welfare, enhancing consumption and more leisure time. Average welfare is 0.09 percent higher than the baseline in the first 20 years of the investment period, equivalent to $10.5 billion per year in the 2018 economy. Over the 30-year period average welfare is 0.08 percent above the baseline level, equivalent to $9.2 billion per year in the 2018 economy.

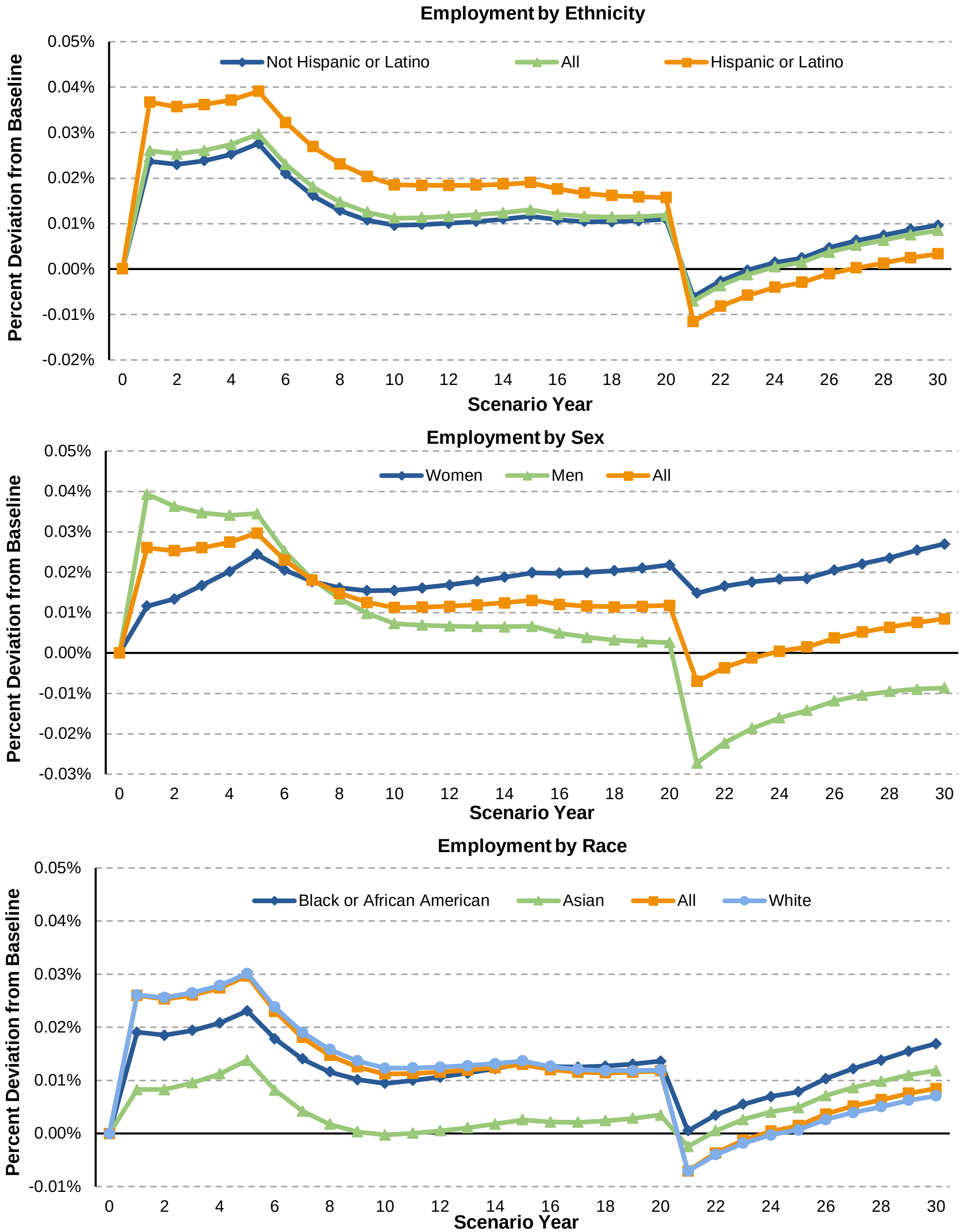
Distribution of Employment Impacts

The USAGE-Hwy model can be combined with Bureau of Labor Statistics (BLS) data to explore potential employment impacts from increased highway investment on different demographic groups of workers. The USAGE-Hwy model estimates changes in output separately for each industry in the U.S. economy. The BLS publishes data describing the number of people employed in each industry by occupation and the demographic characteristics of people working in each occupation (i.e., sex, race, and ethnicity). Combining the two data sets, an estimate of the employment impacts on different demographic groups from increased highway investments is made, under the assumption that the demographic makeup of each occupation remains constant through the period of analysis.

Exhibit 10-19 presents the employment impacts for different demographic groups of workers from the Improve Conditions and Performance scenario compared with the baseline Sustain 2014–2018 Spending scenario from the exploratory method described above.

Employment of Hispanic or Latino workers increases proportionally more than the employment of workers who are not Hispanic or Latino during the 20-year increased investment period (the top panel of *Exhibit 10-19*). This divergence in employment by ethnicity can be attributed to the overrepresentation of Hispanic or Latino workers in construction occupations. Employment in the Road and Bridge Construction industry is estimated to increase by 16.9 percent over the baseline throughout the 20-year investment period, whereas all other industries have output changes of 0.5 percent or less. In the Road and Bridge Construction industry (as in all construction industries), the majority of workers (74 percent) are in the Construction and Extraction Occupations. In 2018, 37.0 percent of the Construction and Extraction Occupations workforce was Hispanic or Latino compared with 17.3 percent of the total workforce. Similarly, when highway investment levels drop to baseline levels after year 20, overall employment drops with more dramatic and negative employment impacts for Hispanic or Latino workers, with a deeper and larger reduction in employment between year 21 and 30 compared with workers who are not Hispanic or Latino.

Exhibit 10-19: Employment by Demographics



Source: USAGE-Hwy Model.

The impacts on employment of women compared with men from increased highway investment are shown in the central panel of *Exhibit 10-19*. Initially, although employment levels for both women and men rise above the baseline due to the increased investment, the employment impacts on men are higher than those on women. This is because men (as with Hispanic or

Latino workers) are overrepresented in Construction and Extraction Occupations; men comprised 96.6 percent of workers in this occupation in 2018, compared with 53.1 percent of the total workforce. However, beginning in year 8, the employment increases for women exceed the increases for men because the benefits of highway investment start to spill over to other industries that are not dominated by men, driven by the productivity-enhancing impacts of highways. At the conclusion of the investment period in year 20, construction industry employment drops, resulting in a steep drop in employment for men due to their overrepresentation in Construction and Extraction Occupations. On the other hand, female employment remains above the baseline and relatively stable, because women workers enjoy the benefits from the productivity-enhancing aspect of highway investment that are not limited to a small group of industries or occupations. Overall, men see more volatility in employment throughout the analysis period compared with women.

The differential impacts from increased highway investment by racial group is shown in the lower panel of *Exhibit 10-19*. The detailed race-by-occupation data from BLS present information separately for White, Black or African American, and Asian workers. During the initial investment period, the largest employment increases are experienced by White workers and the smallest are experienced by Asian workers due to their relative proportions of the Construction and Extraction Occupations category. White workers comprise 87.5 percent of these occupations and Asian workers comprise 1.6 percent, compared with 78.0 percent and 6.3 percent of the total workforce, respectively.

After the investment period ends, Black or African American employment shows the strongest positive impact over the baseline when compared with the other racial groups. The increased level of employment for Black or African American workers occurs because this group is relatively overrepresented in Community and Social Service Occupations and Healthcare Support Occupations. These occupations are composed of 20.4 and 26.2 percent Black or African American workers respectively, compared with 12.3 percent of the total workforce. Both occupations are heavily used by the Medical Services industry which, as discussed in reference to female employment impacts, is an industry for which there is a relatively high income-elasticity of demand. As a consequence, the economic growth created from increased highway investment has a more pronounced impact on these occupations in which Black or African American workers are overrepresented compared with the total workforce.

These findings illustrate the complexity of the potential impacts on different subgroups of increased highway investment. Employment impacts by gender or race vary depending on: (1) the cycle of expenditures, such as direct construction expenditures initially and indirect expenditures for other services, and (2) the concentration of subgroups in different occupations.

Impacts of Investments Modeled by NBIAS

The expenditures modeled in NBIAS pertain primarily 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 10-20 through *10-23* 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.

Bridge Performance Measures in *Exhibits 10-20* to *10-23*

Exhibits 10-20 to *10-23* 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)
- Bridge 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 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.

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 2038 would match that in 2018 (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 "2014–2018 Spending").

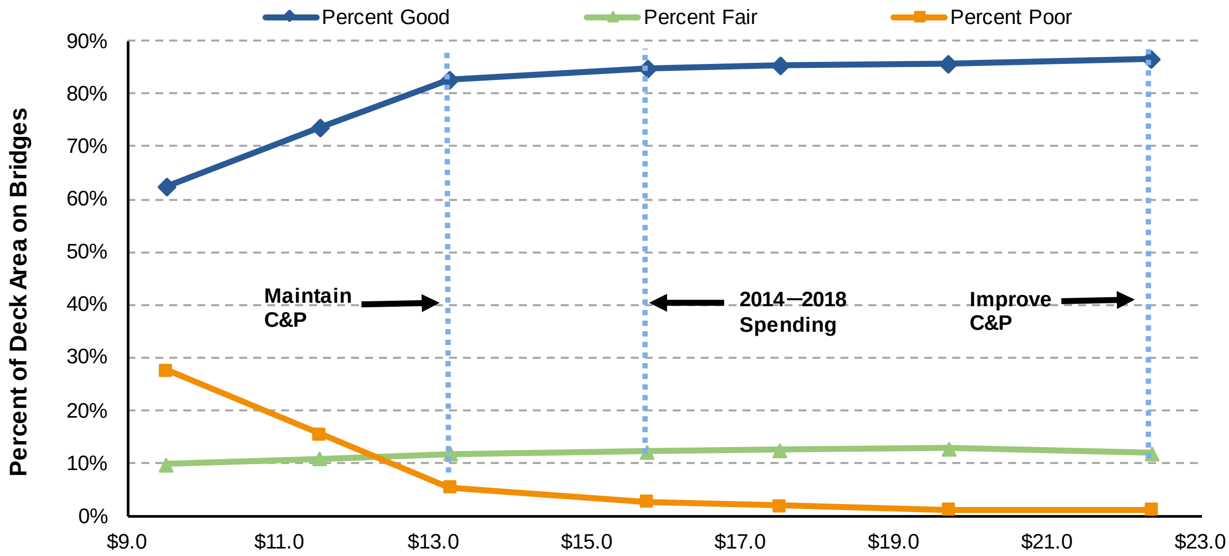
The remaining rows in these exhibits were selected to fill gaps between the three data points linked to specific scenarios and to extend the lower end of the range of investment levels analyzed.

Impacts of Systemwide Investments Modeled by NBIAS

For investments of the types modeled by NBIAS, *Exhibit 10-20* shows how the total amount invested over the 20-year analysis period influences the bridge performance levels projected for the final year, 2038. At $15.8 billion, the investment level feeding into the Sustain 2014–2018 Spending scenario presented in Chapter 7, projected performance for 2038 would improve relative to 2018 for each performance measure considered. The share of bridges classified as in "poor" condition would decrease from 5.4 percent to 2.7 percent, whereas the share of bridges classified as in "good" condition would increase from 45.3 percent in 2018 to 84.9 percent in 2038. The average Health Index would rise from 87.9 to 91.5. The Economic Investment Backlog would decrease to $56.4 billion (70.5 percent below its 2018 level of $191.3 billion).

Exhibit 10-20: Projected Impact of Future Investment Levels on 2038 Bridge Condition Indicators for All Bridges

Average Annual Investment Modeled in NBIAS (Billions of 2018 Dollars)



Projected 2038 Condition Indicators on All Bridges

NBIAS-modeled Average Annual Investment on All Bridges	Weighted by Deck Area			Health Index	Economic Investment Backlog (Billions of 2018 Dollars)[1]	Link to Chapter 7 Scenario
	Percent Good[1]	Percent Fair	Percent Poor			
$22.3	86.7%	11.8%	1.2%	92.3	$0.0	Improve C&P
$19.7	85.8%	12.7%	1.2%	92.2	$10.1	
$17.5	85.4%	12.5%	1.9%	91.9	$34.3	
$15.8	84.9%	12.2%	2.7%	91.5	$56.4	2014–2018 Spending
$13.2	82.8%	11.7%	**5.4%**	90.7	$115.0	Maintain C&P
$11.5	73.5%	10.8%	15.5%	88.4	$199.2	
$9.5	62.5%	9.8%	27.6%	85.7	$297.7	
Base Year Values:	**45.3%**	**49.3%**	**5.4%**	**87.9**	**$191.3**	

[1]Analysis assumes an aggressive maintenance strategy in addition to the capital investment modeled in NBIAS. To the extent that maintenance is less aggressive, that would tend to reduce the projected share of bridges rated as good.

Note: Values are in billions of 2018 dollars.

Source: National Bridge Investment Analysis System (NBIAS).

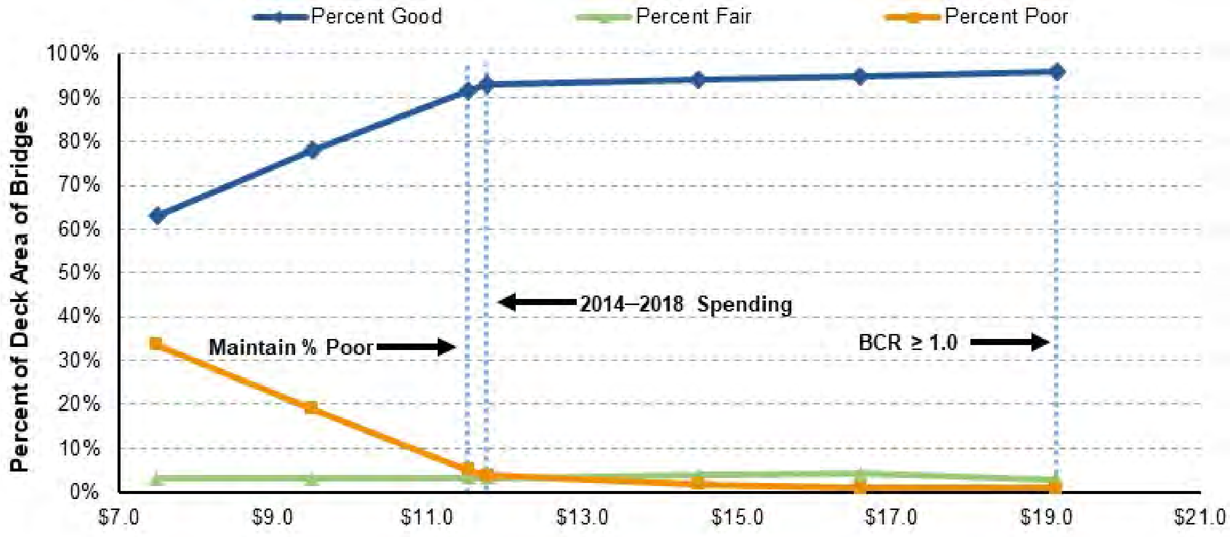
The highest level of spending shown in *Exhibit 10-20* averages $22.3 billion per year (this feeds into the Improve Conditions and Performance scenario in Chapter 7). This level of investment is projected to reduce the deck-area-weighted share of bridges in poor condition to 1.2 percent and to eliminate the Economic Investment Backlog for bridges by 2038. 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 10-21* compares performance projections for 2038 at various levels of investment with measured performance in 2018. If spending on the types of improvements modeled in NBIAS were sustained at the 2014 to 2018 level of $11.8 billion (in constant dollars), performance results would improve for each performance measure considered. The average Health Index would rise (improve) from 87.9 to 91.0. The percentage of bridges in "poor" condition weighted by deck area would decline from 5.1 percent to 3.8 percent, and the share of bridges classified as in "good" condition would increase from 44.4 percent in 2018 to 92.9 percent in 2038.

Exhibit 10-21: Projected Impact of Future Investment Levels on 2038 Bridge Condition Indicators for Federal-aid Highway Bridges

Average Annual Investment Modeled in NBIAS (Billions of 2018 Dollars)



Projected 2038 Condition Indicators on Federal-aid Bridges

NBIAS-Modeled Investment on Federal-aid Bridges Average Annual Investment	Weighted by Deck Area			Health Index	Economic Investment Backlog[1]	Description
	Percent Good[1]	Percent Fair	Percent Poor			
$19.1	95.9%	2.9%	0.9%	92.4	**$0.0**	BCR ≥ 1.0
$16.6	94.7%	4.2%	0.9%	92.3	**$9.9**	
$14.5	94.2%	3.8%	1.8%	91.8	**$32.2**	
$11.8	92.9%	3.2%	3.8%	91.0	**$82.7**	2014–2018 Spending
$11.5	91.6%	3.2%	**5.1%**	90.8	**$91.7**	Maintain % Poor
$9.5	77.9%	3.1%	18.9%	87.7	**$187.6**	
$7.5	63.2%	3.1%	33.6%	84.4	**$286.1**	
Base Year Values:	**44.4%**	**50.5%**	**5.1%**	**87.9**	**$162.8**	

[1]Analysis assumes an aggressive maintenance strategy in addition to the capital investment modeled in NBIAS. To the extent that maintenance is less aggressive, that would tend to reduce the projected share of bridges rated as good.

Note: BCR is benefit-cost ratio. Values are in billions of 2018 dollars.

Source: National Bridge Investment Analysis System (NBIAS).

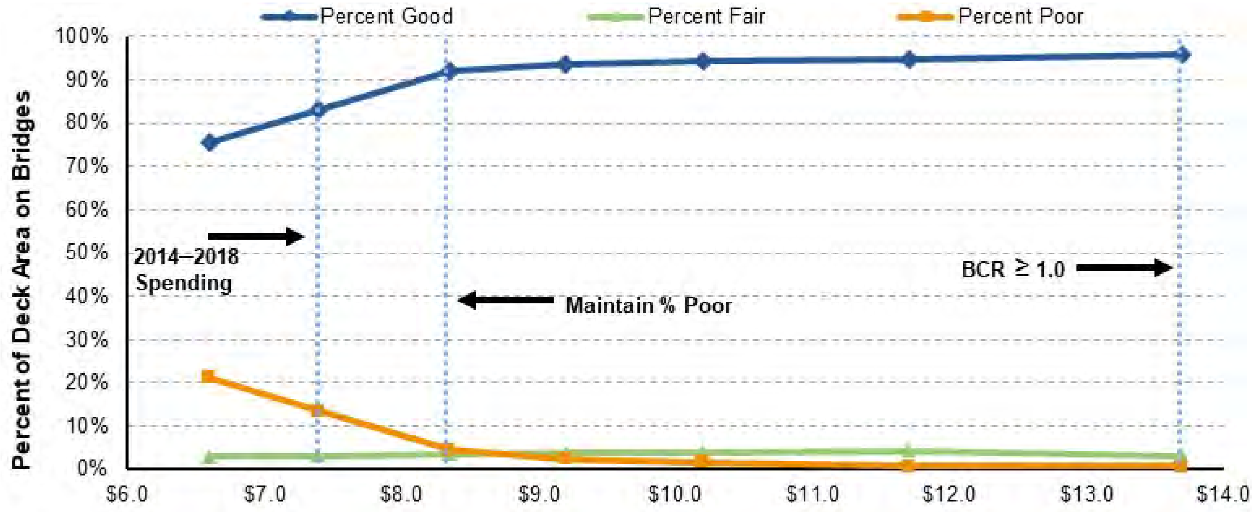
At the $19.1 billion average annual investment level consistent with the Improve Conditions and Performance scenario, NBIAS projects that the percentage of bridges in "poor" condition weighted by deck area would decrease to 0.9 percent on Federal-aid highways. The Economic Investment Backlog would be reduced to zero by 2038, and the average Health Index would increase from 87.9 to 92.4.

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 10-22*. If spending on the types of improvements modeled in NBIAS on NHS bridges was sustained at the 2014 to 2018 level of $7.4 billion in constant-dollar terms, the deck-area-weighted share of bridges in "poor" condition would increase from 4.5 percent in 2018 to 13.5 percent in 2038. The average annual investment needed to maintain this indicator at its 2018 level is higher at $8.3 billion. This finding deviates from the one identified above for all bridges and Federal-aid bridges, for which spending in 2018 was estimated to be above the level needed to maintain this metric at base-year levels.

Exhibit 10-22: Projected Impact of Future Investment Levels on 2038 Bridge Condition Indicators for Bridges on the National Highway System

Average Annual Investment Modeled in NBIAS (Billions of 2018 Dollars)



Projected 2038 Condition Indicators on NHS Bridges

NBIAS-Modeled Investment on NHS Bridges Average Annual Investment	Weighted by Deck Area			Health Index	Economic Investment Backlog	Description
	Percent Good[1]	Percent Fair	Percent Poor			
$13.7	95.8%	3.2%	0.8%	92.1	**$0.0**	BCR ≥ 1.0
$11.7	94.7%	4.4%	0.8%	92.0	**$9.0**	
$10.2	94.2%	3.9%	1.7%	91.5	**$26.2**	
$9.2	93.7%	3.7%	2.5%	91.1	**$42.2**	
$8.3	91.9%	3.5%	**4.5%**	90.6	**$64.7**	Maintain % Poor
$7.4	83.1%	3.3%	13.5%	88.6	**$106.9**	2014–2018 Spending
$6.6	75.6%	3.1%	21.2%	86.9	**$142.3**	
Base Year Values:	**43.4%**	**52.1%**	**4.5%**	**87.9**	**$113.9**	

[1] Analysis assumes an aggressive maintenance strategy in addition to the capital investment modeled in NBIAS. To the extent that maintenance is less aggressive, that would tend to reduce the projected share of bridges rated as good.

Note: BCR is benefit-cost ratio. Values are in billions of 2018 dollars.

Source: National Bridge Investment Analysis System (NBIAS).

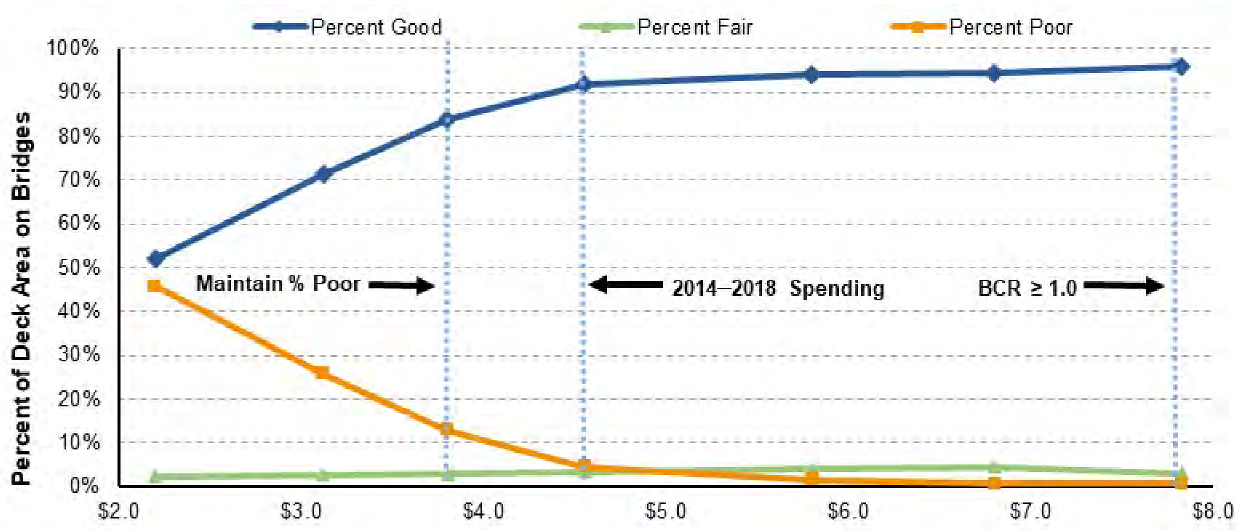
The highest level of investment analyzed, $13.7 billion, is projected to reduce the Economic Investment Backlog to zero by 2038. The percentage of bridges in "poor" condition would decrease from 4.5 percent in 2018 to 0.8 percent in 2038. The average Health Index would improve from 87.9 to 92.1 during the same period.

Impacts of Interstate System Investments Modeled by NBIAS

Exhibit 10-23 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 2014 to 2018 level of $3.1 billion in constant-dollar terms, the share of bridges rated as "poor" would increase from 4.5 percent in 2018 to 25.8 percent in 2038, weighted by deck area. By 2038, the average Health Index would fall from 87.4 to 84.9, and the Economic Investment Backlog would increase from $64.6 billion in 2018 to $98.8 billion in 2038. An average annual investment of $4.6 billion would be needed to keep the deck area-weighted share of bridges in "poor" condition from rising above its 2018 level in 2038. For the highest level of investment analyzed (implementing all cost-beneficial projects identified), the average annual investment level of $7.8 billion is estimated to be sufficient to reduce the Economic Investment Backlog to zero by 2038, decrease the deck area-weighted share of bridges rated as "poor" to 0.7 percent, and increase the average Health Index to 91.5.

Exhibit 10-23: Projected Impact of Alternative Investment Levels on 2038 Bridge Condition Indicators for Interstate Bridges

Average Annual Investment Modeled in NBIAS (Billions of 2018 Dollars)



Projected 2038 Condition Indicators on All Bridges

NBIAS-modeled Average Annual Investment on All Bridges	Weighted by Deck Area			Health Index	Economic Investment Backlog (Billions of 2018 Dollars)[1]	Link to Chapter 7 Scenario
	Percent Good[1]	Percent Fair	Percent Poor			
$7.8	95.9%	3.0%	0.7%	91.5	$0.0	Improve C&P
$6.8	94.3%	4.6%	0.8%	91.3	$4.6	
$5.8	94.0%	4.1%	1.6%	90.8	$15.4	
$4.6	91.8%	3.5%	4.5%	89.7	$40.4	2014–2018 Spending
$3.8	83.9%	2.9%	**13.0%**	87.7	$68.0	Maintain C&P
$3.1	71.4%	2.6%	25.8%	84.9	$98.8	
$2.2	51.8%	2.4%	45.7%	80.5	$145.2	
Base Year Values:	**38.3%**	**57.2%**	**4.5%**	**87.4**	**$64.6**	

[1] Analysis assumes an aggressive maintenance strategy in addition to the capital investment modeled in NBIAS. To the extent that maintenance is less aggressive, that would tend to reduce the projected share of bridges rated as good.

Note: BCR is benefit-cost ratio. Values are in billions of 2018 dollars.

Source: National Bridge Investment Analysis System (NBIAS).

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 2038. 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.

Starting with the 24th edition of the C&P Report, a cost-effectiveness optimization feature was introduced in TERM that affects the way TERM forecasts reinvestment needs. This 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.

SECTION SUMMARY

- The recent level of current investment in transit asset preservation ($13.5 billion) is roughly the amount required to maintain the SGR backlog at current levels.
- An annual average expenditure of $19.5 billion is required to eliminate the SGR backlog by 2038.
- The recent level of investment in service expansion ($7.0 billion in 2018 dollars) could support an increase in U.S. transit seating capacity by roughly 1.9 million additional seats by 2038 (approximately a 1.6-percent annual growth in seating capacity). This might result in less-crowded conditions in stations, trains, and buses, along with increased operating speeds.
- Under the Expansion with Growth scenario, an additional $1.5 billion in annual expansion investment (an annual total of $8.5 billion) is required to deliver the seating capacity required to support that scenario's capacity increase of 2.1 million seats by 2038 without increasing vehicle crowding.

A detailed discussion of the new cost-effectiveness optimization feature is presented later in in this section, under Prioritization and the Cost-Effectiveness Investment Criterion.

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.

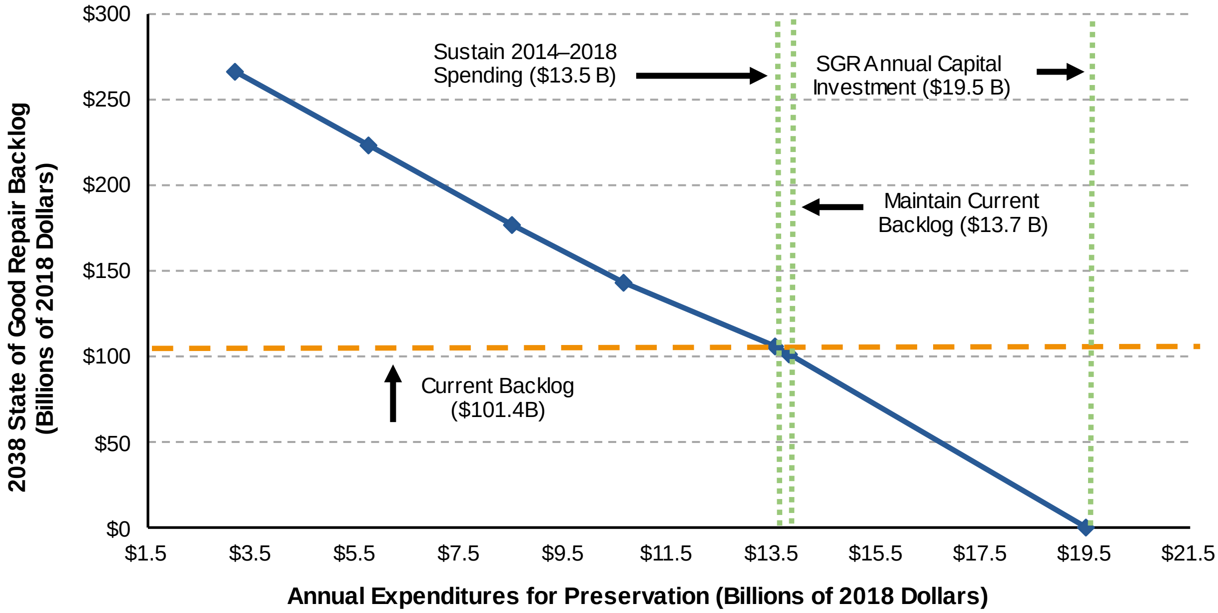
Impact of Preservation Investments on Transit Backlog and Conditions

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 2038) 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 10-24* and had been the primary measure in previous editions. This additional perspective is needed because average condition has become less meaningful 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 $101.4 billion (see Chapter 7).

Exhibit 10-24: Impact of Preservation Investment on 2038 Transit State of Good Repair Backlog in All Urbanized and Rural Areas



Average Transit Conditions in 2038

Average Annual Investment (Billions of 2018 Dollars)	Average Annual Percent Change vs. 2018	Average Condition Rating in 2038	Backlog in 2038 (Billions of 2018 Dollars)	Percent Change from Current Backlog	Funding Level Description
$19.5	3.5%	3.47	$0.0	-100%	SGR in 20 Years
$13.8	0.2%	3.41	$101.4	0%	Maintain Current Backlog
$13.5	0.0%	3.40	$106.5	5%	Sustain 2014–2018 Spending
$10.6	-2.5%	3.25	$143.8	42%	Reduce Funding Annually by 2.5%
$8.5	-5.0%	3.19	$177.5	75%	Reduce Funding Annually by 5%
$5.7	-10.0%	3.10	$223.8	121%	Reduce Funding Annually by 10%
$3.2	-20.0%	3.00	$266.8	163%	Reduce Funding Annually by 20%

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.

Exhibit 10-24 presents the estimated impact of differing levels of annual capital reinvestment on the expected size of the reinvestment backlog in 2038. 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 ($101 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.

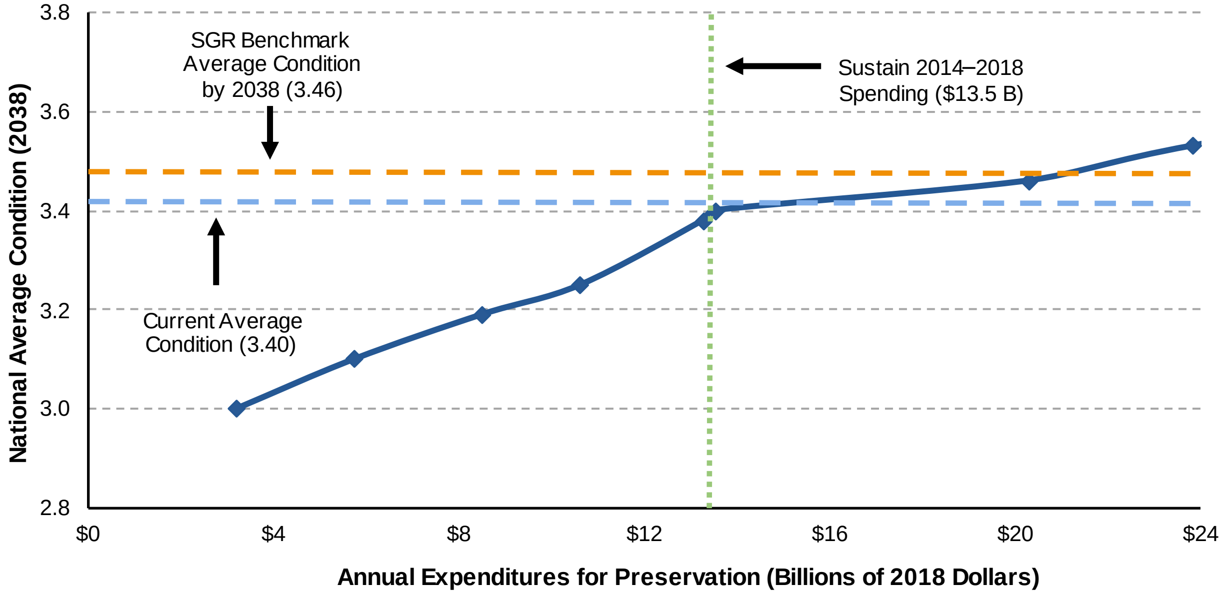
As shown in *Exhibit 10-24*, TERM analysis suggests that the 2014–2018 average annual rate of capital reinvestment of $13.5 billion is marginally higher than that required to maintain the SGR backlog and, if sustained over the next 20 years, would result in a reinvestment backlog of roughly $100.4 billion by 2038. In contrast, increasing the annual rate of reinvestment to an average of $18.1 billion would fully eliminate the backlog by 2038. Finally, an annual level of reinvestment of roughly $13.3 billion is required to maintain the backlog at its current level.

Transit Conditions

Exhibit 10-25 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 2038. 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) whereas 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 10-25* 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 (guideway and track, facilities, systems, stations, and vehicles) and the average annual percentage change in constant-dollar funding from 2014–2018 levels to achieve each projected condition level.

Further review of *Exhibit 10-25* allows several observations: First, sustained spending at the 2014–2018 average annual level of $13.5 billion is sufficient to maintain average condition of *existing* assets at roughly their estimated 2018 level (3.4). Second, significantly higher levels of reinvestment are required to increase average annual conditions beyond this level. For example, an additional $6.8 billion in annual spending (to $20.3 billion) is required to increase aggregate average conditions from 3.40 to 3.46 (as required to attain and maintain SGR). These significant increases are largely due to the high cost of reducing replacement life cycles across all assets as required to attain higher average condition levels. Note here that annual transit capital expenditures are expected to increase under the Bipartisan Infrastructure Law.

Exhibit 10-25: Impact of Preservation Investment on 2038 Transit Conditions in All Urbanized and Rural Areas



Average Transit Conditions in 2038

Average Annual Investment (Billions of 2018 Dollars) Total Capital Outlay	Average Annual Percent Change vs. 2014–2018	Asset Categories					All Transit Assets	Notes
		Guideway	Facilities	Systems	Stations	Vehicles		
$37.5	0.0%	3.90	3.24	3.92	3.55	3.69	3.75	Unconstrained, Replace at 3.00
$23.8	0.0%	3.49	3.21	3.84	3.49	3.59	3.53	Unconstrained, Replace at 2.75
$20.3	3.9%	3.47	3.19	3.76	3.31	3.47	3.46	SGR (Unconstrained, Replace at 2.50)
$13.5	0.0%	3.40	2.83	3.69	3.18	3.48	3.40	Sustain 2014–2018 Spending
$13.3	-0.2%	3.37	2.82	3.61	3.13	3.46	3.38	Maintain Current Backlog
$10.6	-2.5%	3.36	2.72	3.49	3.07	3.27	3.25	
$8.5	-5.0%	3.32	2.68	3.35	3.03	3.13	3.19	
$5.7	-10.0%	3.24	2.67	3.19	3.02	2.92	3.10	
$3.2	-20.0%	3.19	2.67	3.04	3.00	2.55	3.00	

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.

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).

C&P Reports prior to the 24th edition relied on four investment criteria (condition, reliability, safety, and operations and maintenance cost impacts). The constrained needs analyses in the 24th edition and this 25th edition of the C&P Report also include the impact of a 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.

The prioritization routine determines the order in which reinvestment needs are addressed. Hence, any changes to that routine—such as 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 in *Exhibit 10-26*. Specifically, *Exhibit 10-26* 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 24th C&P Report (with a start year of 2016) and the one used for this current 25th edition (with a start year of 2018). 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 these models, inclusion of the cost-effectiveness criterion is found to reduce the size of the year-20 backlog by roughly $10.7 billion for the 24th edition and $1.9 billion for the current 25th edition. 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 10-26: Impact of the Cost-Effectiveness Criterion on the Year-20 Backlog

Cost-Effectiveness Criterion	Edition	Analysis Start Year	Cost Year	Annual Budget ($Billions)	SGR Backlog		
					Year 0	Year 20	Change
Off	24th C&P	2016	$2016	$11.610	$105.1	$113.0	
	25th C&P	2018	$2018	$13.540	$101.4	$108.1	
On	24th C&P	2016	$2016	$11.610	$105.1	$102.3	($10.7)
	25th C&P	2018	$2018	$13.540	$101.4	$106.2	($1.9)

Source: Transit Economic Requirements Model.

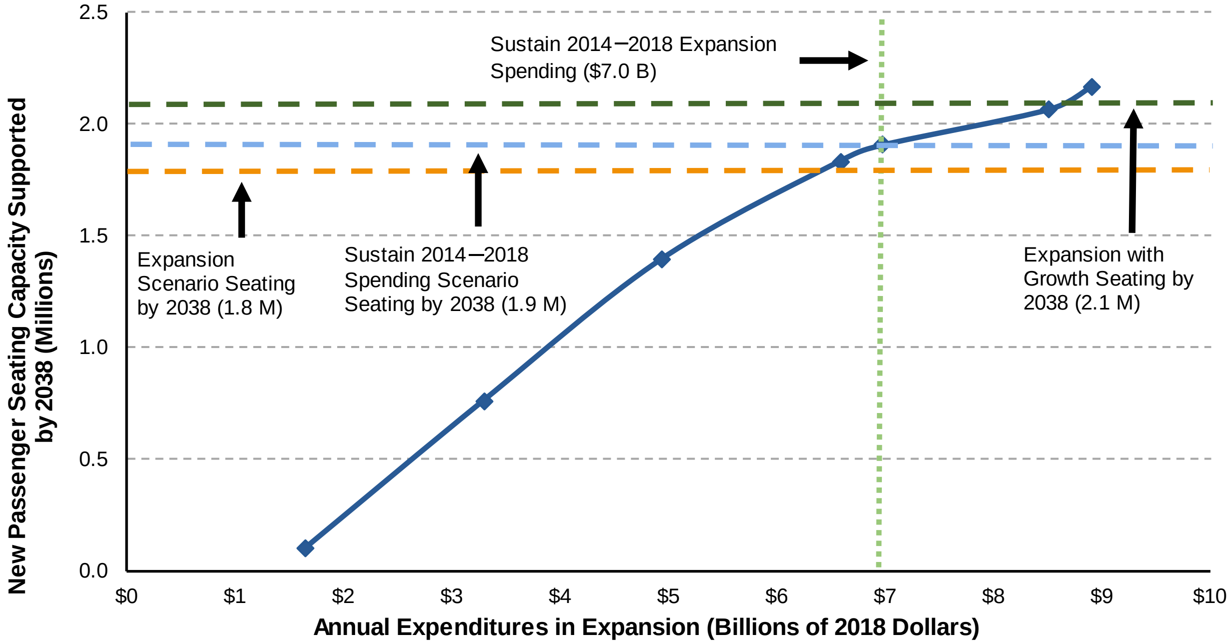
Impact of Expansion Investments on Transit Capacity

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 expand transit capacity and potentially to improve service performance for existing transit system users.

Exhibit 10-27 shows the relationship between aggregated annual capital spending by all levels of government on expansion investments and the additional passenger seating capacity that transit systems would be able to supply by 2038. As the upward sloping curve of the chart indicates, higher levels of investment are required to provide increased rider seating capacity. Note that if investment levels are insufficient to support the estimated growth in ridership, vehicle occupancy rates will tend to increase, potentially leading to increased crowding on high-utilization systems and potentially leading to increased dwell times at stops and reduced average operating speeds.

The findings presented in *Exhibit 10-27* suggest the following trends. First, the 2014–2018 rate of investment in asset expansion ($7.0 billion in 2018 dollars) could support an increase in U.S. transit seating capacity by roughly 1.9 million additional seats by 2038 (approximately a 1.6-percent annual growth in seating capacity). Under the Expansion with Growth scenario, an additional $1.5 billion in annual expansion investment (an annual total of $8.5 billion) is required to deliver the seating capacity required support that scenario's estimate ridership increase (without increasing vehicle crowding).

Exhibit 10-27: New Passenger Seating Capacity in 2038 Supported by Expansion Investments in All Urbanized and Rural Areas



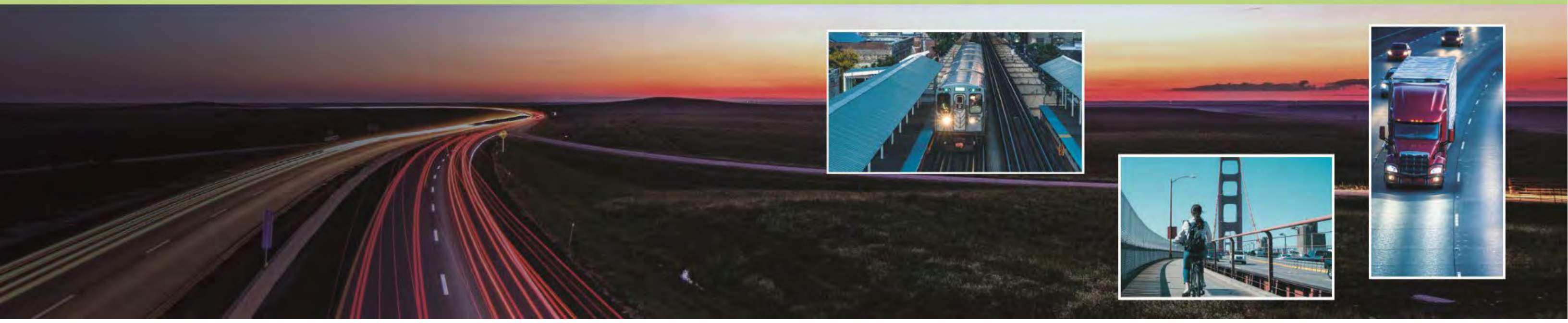
Total New Passenger Seating by 2038

Average Annual Investment (Billions of 2018 Dollars)	Average Annual Percent Change vs. Sustain 2014–2018 Spending	New Transit Passenger Seating Capacity (Millions of Seats)	Average Annual Growth in Seating[1]	Funding Level Description
$8.9	2.4%	2.2	1.8%	Higher Growth (+5%)
$8.5	1.9%	2.1	1.7%	Expansion with Growth Scenario
$7.0	0.0%	1.9	1.6%	Sustain 2014–2018 Spending
$6.6	-0.6%	1.8	1.5%	Expansion Scenario
$4.9	-3.6%	1.4	1.2%	Reduced Expansion Scenario (-25%)
$3.3	-8.5%	0.8	0.7%	Reduced Expansion Scenario (-50%)
$1.6	-20.1%	0.1	0.1%	Reduced Expansion Scenario (-75%)

[1]As compared with estimated total urban seating in 2018; only includes increases covered by investments passing TERM's benefit-cost test.

Notes: 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: Additional Information

Introduction

Two topics are explored in two separate chapters: COVID-19 and greenhouse gases (GHG). Both topics have vastly changed and continue to change the way we live by threatening our overall welfare, wellbeing, and way of life. Topics are discussed in reference to their impact on the transportation system. Each chapter also discusses potential strategies for positive change.

Chapter 11 – Impacts of the COVID-19 Pandemic on Transportation: Everyone has been exposed to the dangerous health impacts of COVID-19, either directly or indirectly. This chapter explores the impacts of the COVID-19 pandemic on the highway and transit systems using metrics traditionally discussed throughout this report, including traffic volume and ridership declines, as well as funding deficits. It also discusses changes in travel behavior in response to pandemic requirements for social distancing.

Chapter 12 – Greenhouse Gas Mitigation: The transportation sector is the largest source of GHG emissions in the United States. Studies show that GHG emissions contribute to warming of the atmosphere, which in turn causes or exacerbates extreme weather events such as heatwaves and hurricanes. This chapter explores the current state of GHG emissions, and more specifically, carbon dioxide (CO_2) emissions contributed by the highway and transit components of the transportation sector. Recent trends in CO_2 and other GHG emissions are compared with current policy goals on emissions reduction. The chapter also highlights Federal resources and programs to promote awareness and fund mitigation programs.

The need for social distancing during the COVID-19 pandemic has highlighted the importance of accessibility to goods and services and thus the need for mobility for overall wellbeing. However, the production and delivery of goods and services generates GHG emissions, which affect our wellbeing through the impacts of climate change. Understanding these two issues can help us find an important balance as we strategize for an improved way of life.

Chapter 11: Impacts of the COVID-19 Pandemic on Transportation

Impacts of the COVID-19 Pandemic on Transportation – Introduction

On January 21, 2020, the first case of Coronavirus Disease 2019 (COVID-19) was identified in the United States. By March 13 the World Health Organization had declared COVID-19 a pandemic. On March 15 the President declared a nationwide public health emergency, providing additional authorities to the Federal, State, and local governments to take actions to combat the disease and its consequences. To contain the disease, many States ordered their citizens to stay at home except to access essential services, to wear masks, and to socially distance from each other when in public. These orders resulted in many people working from home and students shifting to online instruction; some businesses closed as people avoided nonessential services.

As more people stayed home and limited their travel, vehicle miles traveled (VMT) declined by 18.9 percent in March 2020 and by 40.1 percent in April 2020, compared with the same months in 2019. Continuing caution and extended social distancing measures have changed the way people conduct business, shop for goods and services, and socialize.

This chapter discusses the impacts of COVID-19 on travel trends, transportation funding revenues, and other consequences. Some of these changes were temporary; others may be longer lasting. This chapter highlights these changes and discusses the role of transportation investments on the economy.

Travel Trends During the COVID-19 Pandemic

This section explores data and analyses of vehicular traffic trends during the COVID-19 pandemic to quantify the reduction in use of the system during business closures and the rate of readoption once businesses reopened. Even if traffic has rebounded to pre-pandemic levels, certain trends may have developed that could affect travel behavior in the future.

Exhibit 11-1 displays the number of people in the United States staying at home and not staying at home each day from January 1, 2019, through June 30, 2021. Staying at home is defined as making no movement or trip more than one mile away from home based on a national panel of anonymized mobile device data collected and analyzed for the Bureau of Transportation Statistics.[45] A multilevel weighting method, using both device and trip-level weights, expands the sample to the underlying population at the county and state levels. In 2019, an average of 63.4 million people opted to stay home on any given day, and 262.8 million people opted to leave home for work, school, healthcare, goods and services, or other reasons. By March 15, 2020, States began shutdown orders to maintain social distancing; the number of people opting to stay at home sharply increased by 37 percent compared with the 2019 average. The number of people staying at home peaked on April 12, 2020, at more than 110 million, nearly 73.5 percent higher than the 2019 annual average.

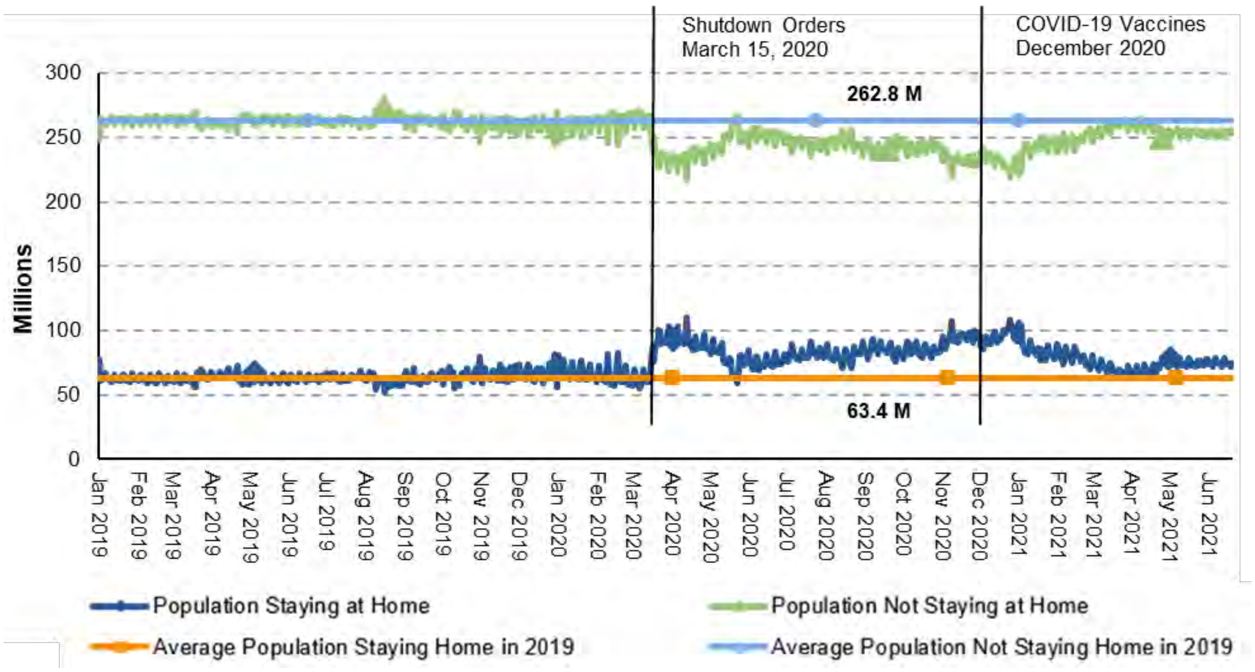
During April 2020, States reported widespread cases of COVID-19, and the United States was the global leader for reported deaths (23,036). Service-oriented industries suffered loss of business due to the shutdown and social distancing orders, as well as a shortage of workers due to increased safety risks and/or infection rates. The population choosing to stay at home decreased to pre-pandemic levels in mid-May of 2020 during the partial reopening of some States and talks of expected guidance from the White House on implementing the Opening up

[45] BTS Daily Travel Metrics, Trips By Distance: Methodology and Validation; University of Maryland. Department of Transportation. Bureau of Transportation Statistics; 2022-01-30; DOI : https://doi.org/10.21949/1529096

America Again Framework.[46] However, this trend was quickly halted in late May and early June when more people opted to stay at home, likely due to increasing COVID-19 cases and the associated U.S. death toll from COVID-19 surpassing 100,000 people. By the summer and fall of 2020, the number of people opting to stay home increased daily, likely due to the increase in COVID-19 cases and deaths. Between March and December 2020, the average population staying at home was 33 percent higher than the 2019 average.

In December 2020, the Advisory Committee on Immunization Practices recommended the use of COVID-19 vaccines, first for health care professionals and residents of long-term care facilities, and later for persons 16 years or older. Subsequently, the number of people opting to stay home declined through the early half of 2021. By March 2021, more than 100 million Americans were vaccinated against COVID-19, doubling to over 200 million by the end of April 2021. However, COVID-19 cases continued to climb, largely due to a new variant. By midyear 2021, the number of people staying at home was consistently about 18 percent higher than the pre-pandemic average, suggesting a shift in the proportion of the population that opted to stay home.

Exhibit 11-1: Population Staying/Not Staying at Home



Source: U.S. Department of Transportation, Bureau of Transportation Statistics. Trips by Distance. https://data.bts.gov/Research-and-Statistics/Trips-by-Distance/w96p-f2qv

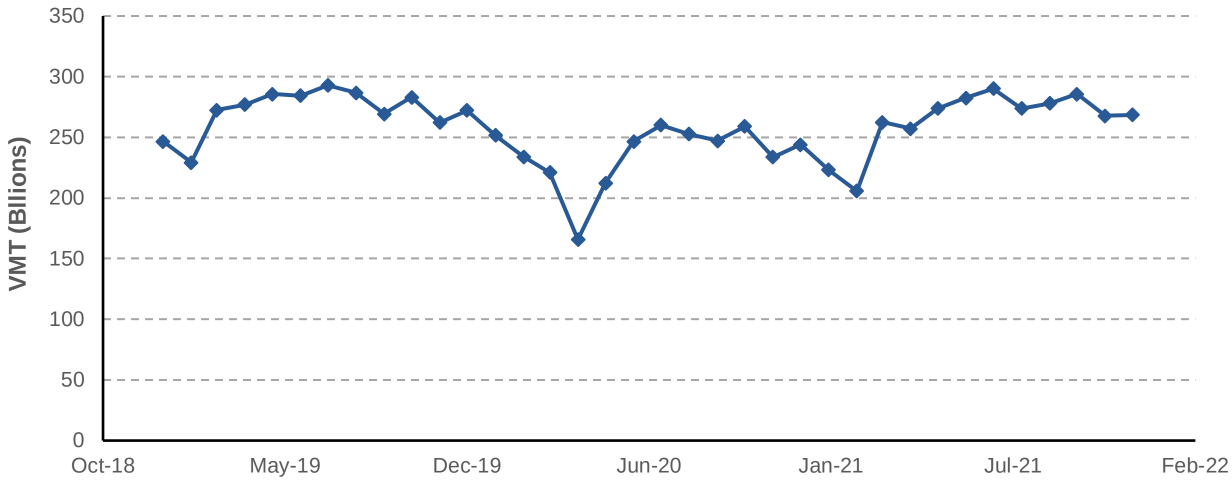
The upward shift in the proportion of people staying at home affected demand for transportation. More people staying home means less travel on roadways and decreased use of public transit and other modes of travel. However, persons at home still required goods and services, which they opted to acquire by ordering online or by phone, leading to increased truck traffic and demand for delivery services. This chapter discusses the impacts that COVID-19 had on the transportation system, such as changes in VMT, transit ridership trends, safety trends, and revenue.

[46] Center for Infectious Disease Research and Policy (CIDRAP), 2020. CDC COVID-19 reopening guidelines shelved. May 7, 2020. https://www.cidrap.umn.edu/news-perspective/2020/05/report-cdc-covid-19-reopening-guidelines-shelved

Impacts of the COVID-19 Pandemic on Transportation – Highways

Total VMT has remained relatively steady since 2010, with highest increase of 2.6 percent in 2016 and an annual average increase of 1.1 percent from 2010 to 2019. However, in 2020, total VMT decreased by about 11 percent, to 2.82 trillion, compared with 3.28 trillion in 2019.[47] *Exhibit* 11-2 displays total monthly VMT data between January 2019 and December 2021. Despite seasonal variations (summer peaks and winter troughs), April 2020 shows a steep drop in VMT to 0.166 trillion, about 40 percent lower than 2019 levels. VMT quickly rebounded in July 2020 to 0.260 trillion but was still 11 percent lower than the July 2019 VMT of 0.293 trillion. July 2021 VMT was closer to pre-pandemic levels at 0.290 trillion and rebounded to levels above the pre-pandemic era in September 2021.

Exhibit 11-2: Monthly Traffic Volume Trends, January 2019–December 2021



Month	VMT (Trillions of Miles)			Percent Change 2019–2020	Percent Change 2019–2021
	2019	2020	2021		
January	0.247	0.252	0.223	2.1%	-9.5%
February	0.229	0.234	0.206	2.0%	-10.3%
March	0.273	0.221	0.263	-18.9%	-3.7%
April	0.277	0.166	0.257	-40.2%	-7.1%
May	0.286	0.212	0.274	-25.6%	-4.2%
June	0.284	0.247	0.282	-13.3%	-0.7%
July	0.293	0.260	0.290	-11.2%	-0.9%
August	0.287	0.253	0.274	-11.9%	-4.5%
September	0.269	0.247	0.278	-8.2%	3.2%
October	0.283	0.259	0.286	-8.5%	0.9%
November	0.262	0.234	0.268	-10.9%	2.2%
December	0.272	0.244	0.268	-10.3%	-1.4%
Total	**3.262**	**2.828**	**3.169**	**-13.3%**	**-9.5%**

Note: Data were assembled by the Federal Reserve Bank of St. Louis by adding recent FHWA traffic volume trends data to historical monthly VMT data.

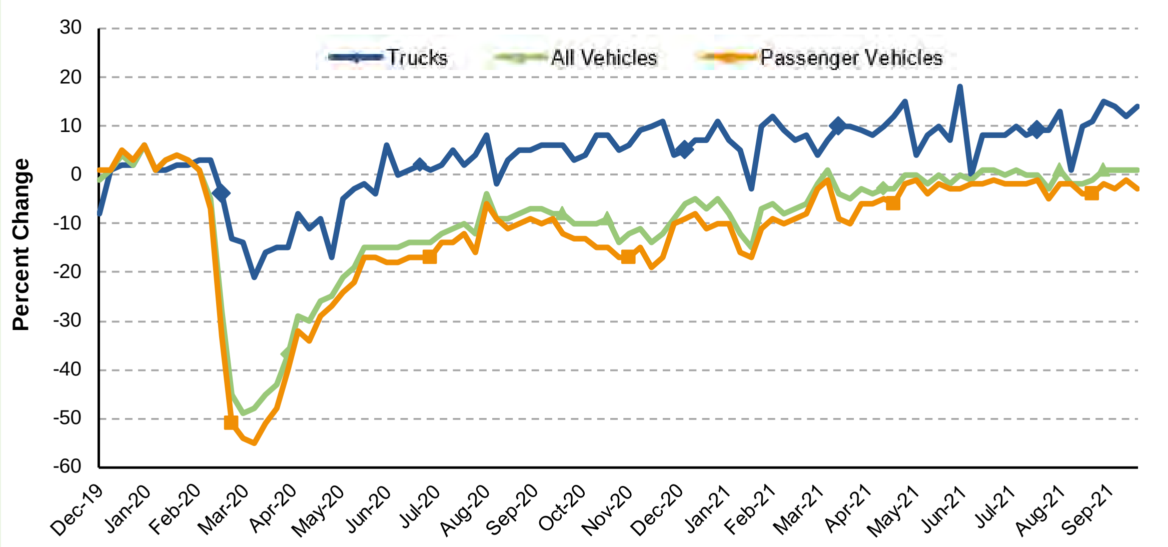
Source: Federal Highway Administration, Traffic Volume Trends Data, January 2019 through December 2021. Accessed at https://fred.stlouisfed.org/series/TRFVOLUSM227NFWA

[47] FHWA Highway Statistics, Annual Vehicle Miles, various years, Table VM-2.

Change in Weekly Interstate System VMT: 2019–2021

The Interstate system experienced the highest drop in VMT compared with the other functional classes. Examining the percentage change in VMT on the Interstate System by week in 2020 and 2021 compared with the same weeks in 2019 for passenger vehicles, trucks, and all VMT helps to explain some of the shifts in travel behavior. FHWA has produced these data weekly since the first week of 2020. *Exhibit 11-3* shows data from the first week of 2020 through the 42nd week of 2021 (October 17). Weekly Interstate VMT was much lower at the onset of the pandemic compared with 2019. Weekly VMT totals for the 15th week of 2020 (April 5) were 48, 55, and 21 percent lower than the previous year for all vehicles, passenger vehicles, and trucks, respectively, whereas the drop in total VMT for all vehicles was 40 percent. VMT later rebounded: by the end of September 2021, VMT for all vehicles was roughly the same as in 2019. However, this overall increase masks the differences in Interstate VMT patterns between passenger vehicles and trucks. Passenger vehicle VMT was still 13 percent below 2019 levels in October 2020, whereas truck VMT was 14 percent higher. Truck VMT has been higher than 2019 values since the 27th week of 2020 (June 28), likely due to fewer people personally traveling as well as an increase in shipping due to online shopping.

Exhibit 11-3: Percentage Change in Weekly Interstate VMT Compared with 2019



Source: https://www.fhwa.dot.gov/policyinformation/weeklyreports/

Traffic in urban areas declined significantly in 2020, with total VMT falling by 12.2 percent in 2020 compared with 2019. This reduction was likely related to stop-work orders eliminating the daily need for workers to commute to city centers and the decline in tourists seeking entertainment and retail. During this time, total rural VMT declined by 8.2 percent, as shown in *Exhibit 11-*. Urban Interstates had the biggest decline in VMT during 2020 compared with 2019 at 14 percent, followed by other urban arterials (including freeways and expressways) with a 12.2 percent reduction in VMT. Preliminary 2021 VMT totals indicate rural VMT has increased by 2.6 percent over pre-pandemic levels (2019), or 25.2 million more VMT, whereas urban VMT is 2.6 percent below 2019 totals.

The components of total VMT in urban and rural areas or on Interstates, arterial, or collector roadways are discussed in greater detail in Chapter 1 of this report. Generally, 2018 data from *Exhibit 1-9* indicate that 70.7 percent of highway route miles were in rural areas but 70.2 percent of total VMT was in urban areas. In other words, almost three-quarters of the Nation's traffic volume in 2018 was located on a little under a third (31.2 percent) of the Nation's highways, i.e., in urban areas.

In 2019, the composition of urban and rural VMT was the same as 2018, but the share of rural VMT showed a small increase in 2020 from 30.2 percent to 31.1 percent. Breaking down VMT by functional class as a composite of total VMT in rural and urban areas, separately, shows how the composition of vehicular travel changed during the pandemic. For example, *Exhibit 11-5* shows that the percentage of VMT on urban roadways declined for all functional class except local roadways. Conversely, the percentage of total VMT in rural areas increased on other arterial, collector, and local roadways.

Exhibit 11-4: Total VMT by Functional Class, 2019–2021

VMT Functional Class	Functional System	VMT (Trillions)			Percent Change 2019 to 2020
		2019	2020	2021P	
Rural Areas (under 5,000 in population)	Interstate	0.262	0.232	0.269	-11.4%
	Other Arterial	0.384	0.353	0.391	-8.1%
	Collector	0.207	0.194	not available	-6.1%
	Local	0.132	0.125	not available	-5.2%
	Total Rural	**0.984**	**0.904**	**1.009**	**-8.2%**
Urban Areas (5,000 or more in population)	Interstate	0.576	0.495	0.558	-14.0%
	Other Arterial	1.157	1.016	1.122	-12.2%
	Collector	0.240	0.212	not available	-11.7%
	Local	0.306	0.277	not available	-9.3%
	Total Urban	**2.278**	**2.000**	**2.219**	**-12.2%**
Total VMT		**3.262**	**2.904**	**3.228**	**-11.0%**

Notes: (P) indicates 2021 preliminary VMT totals. Other Arterial includes other freeways and expressways, other principal arterials, and minor arterials. Collector is the sum of major and minor collectors.

Sources: Federal Highway Administration, Highway Statistics, Table VM-202; preliminary 2021 VMT totals from https://www.fhwa.dot.gov/policyinformation/travel_monitoring/tvt.cfm as of May 16, 2022.

Exhibit 11-5: Percentage of Total VMT by Functional Class, 2019 and 2020

Functional Class Data	Functional System	Percentage of Total VMT	
		2019	2020
Rural Areas (under 5,000 in population)	Interstate	8.0%	8.0%
	Other Arterial	11.8%	12.1%
	Collector	6.3%	6.7%
	Local	4.0%	4.3%
	Subtotal Rural	**30.2%**	**31.1%**
Urban Areas (5,000 or more in population)	Interstate	17.7%	17.1%
	Other Arterial	35.5%	35.0%
	Collector	7.4%	7.3%
	Local	9.4%	9.5%
	Subtotal Urban	**69.8%**	**68.9%**
Total		**100.0%**	**100.0%**

Note: Other Arterial includes other freeways and expressways, other principal arterials, and minor arterials. Collector is the sum of major and minor collectors.

Source: Federal Highway Administration, Highway Statistics, Table VM-202.

These data indicate that although traffic volumes were reduced in 2020, the reduction in VMT was smaller in rural areas and on local roadways than in urban areas. These data suggest that travelers who would typically travel to and within city centers were instead doing their travel outside of the city or on local roads only and foregoing their commutes to city centers, as many workers were able to work from home. Workers in rural areas may not have had the same options to work from home as workers in urban areas, so their trips did not decline as much compared with workers in urban areas.

Monthly Fatalities from Vehicle Crashes

A June 2021 (revised) NHTSA report[48] showed that there were 36,096 people killed in motor vehicle traffic crashes on U.S. roadways during 2019 (this total was later revised to 36,355). This represents a decrease from the 36,835 fatalities in 2018. Although traffic volumes declined in 2020, roadway fatalities increased. By the end of 2020, a total of 38,680 fatalities had occurred due to roadway crashes, a 7.2-percent increase from 2019, or 2,584 more fatalities (2020 fatality totals were later revised to 38,824). The total number of annual fatalities increased to an estimated 42,915 at the end of 2021, representing 6,819 more deaths than in 2019, an 18.9-percent increase. Preliminary data for the first two quarters of 2022 (January to June) show that 20,175 people died in motor vehicle traffic crashes, an increase of about 0.5 percent compared with the 20,070 fatalities NHTSA projected for the first half of 2021. However, NHTSA projected that the second quarter of 2022, from April to June, had the first decline in fatalities after seven consecutive quarters of year-to-year increases in fatalities that began in the third quarter of 2020.[49]

KEY TAKEAWAY

Recent data show a final count of 36,835 fatalities in 2018, 36,335 fatalities in 2019, 38,824 fatalities in 2020, and an estimated 42,915 in 2021.

On average, 35.4 percent of crash fatalities took place on urban arterials in 2019, comparable to the 35.5 percent of total VMT on urban arterials in 2019. However, rural areas have experienced more than their collective share of roadway fatalities based on the proportion of VMT in rural areas. For example, 21.1 percent of total fatalities in 2019 were on rural arterials, which carried only 11.8 percent of VMT; similarly, 18.7 percent of roadway fatalities took place on rural collector and local roadways, which carried only 4.0 percent of total VMT. As shown in *Exhibit 11-6*, the disparity between the proportion of VMT and roadway fatalities increased on rural collector and local roadways in 2020, with 19.5 percent of roadway fatalities taking place there. A smaller percentage of fatalities (17.3 percent) occurred on rural collector and local roadways in 2020. However, total roadway fatalities increased on both urban Interstates and urban collector and local roadways from 2019 through 2021.

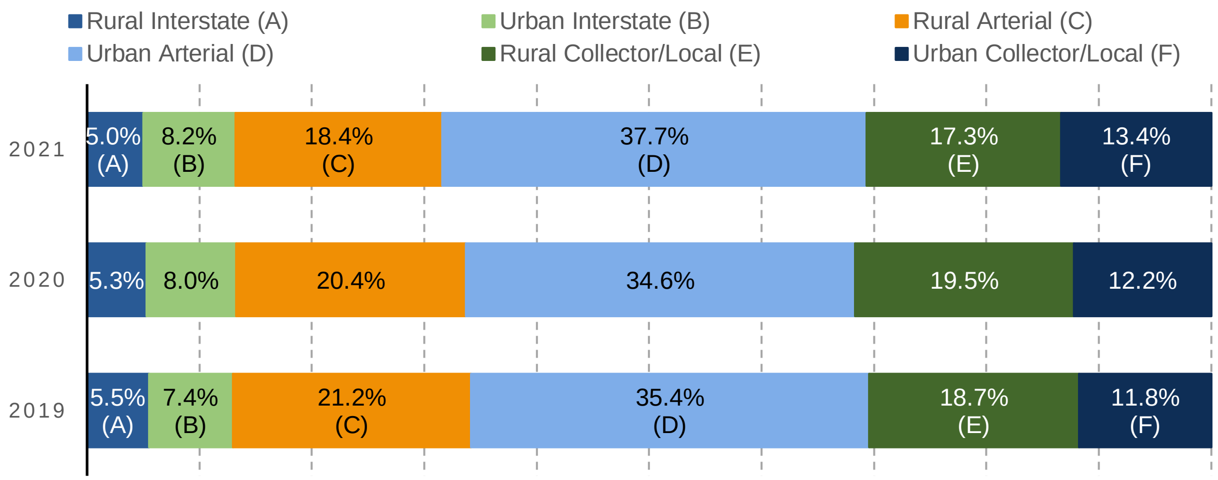
Bikeshare and E-Scooter Trends

Based on data produced by the Bureau of Transportation Statistics (BTS), monthly ridership of docked bikeshare and e-scooter systems fell during the initial months of the pandemic; however, ridership rebounded and expanded in 2021. Refer to the Transit section of this chapter for greater detail on the use of bikeshare and e-scooter systems during the COVID-19 pandemic.

[48] https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/813118

[49] https://www.nhtsa.gov/press-releases/early-estimates-traffic-fatalities-first-half-2022

Exhibit 11-6: Percentage of Total Fatalities by Functional Class, 2019–2021



Source: National Center for Statistics and Analysis, June 2021 (revised) and May 2022. Early estimates of motor vehicle traffic fatalities and fatality rate by sub-categories in 2020, 2021 (Crash Stats Brief Statistical Summary. Report Nos. DOT HS 813 118 and DOT HS 813 298). National Highway Traffic Safety Administration.

The onset of the COVID-19 pandemic saw an increase in several types of vehicle-related crash fatalities such as single-vehicle, ejected vehicle occupant, and speed-related crash fatalities. Single-vehicle crashes increased by 9 percent in 2020 compared with 2019. The largest increase in single-vehicle-related crash fatalities occurred in April 2020, when single-vehicle crashes made up 60 percent of all fatalities.

Total fatalities involving vehicle occupants (excluding motorcycles) who were ejected (6,052) in 2020 increased by 20 percent compared with 2019 totals. Fatalities due to speed-related crashes increased by 11 percent in 2020 compared with 2019.

Interesting shifts are revealed when looking at crash-related fatalities by person-related characteristics such as age, gender, and race. Traffic fatalities among people between the ages of 16 and 44 years increased by 14 to 18 percent, whereas fatalities among people 65 years and older decreased by 9 percent. People above age 65 had the highest share of crash fatalities prior to the pandemic, accounting for roughly 20 percent of crash fatalities in 2019. In 2020, people aged 25–34 had the highest share of fatalities at 20 percent. The percentage of roadway fatalities by gender shows an increase in male fatalities in 2020, as shown in *Exhibit 11-7*. Males accounted for about 72 percent of roadway fatalities in 2020.

African American (Black) roadway fatalities increased by 23 percent in 2020 compared with 2019, the highest rate for any racial group. Over the same period, more than 75 percent of crash fatalities were Caucasian (White), about 19 percent were Black, and roughly 2 percent were American Indian and 2 percent Asian/Pacific Islander. According to the Census Bureau estimates from July 2019, White people made up 76.3 percent of the total population, Black people 13.4 percent, American Indian 1.3 percent, Asian/Pacific Islander 6.1 percent, and other 2.8 percent.[50] Black and American Indian people thus make up a disproportionately larger share of traffic deaths, whereas White and Asian/Pacific Island people make up a smaller portion, compared with their shares of the population.

[50] https://www.census.gov/quickfacts/fact/table/US/PST045219,

Exhibit 11-7: Crash Fatalities by Demographics in 2019 and 2020

Crash Fatality Demographics	Gender, Age, Race	Percentage of Total in 2019	2019	2020	Percent Change 2019 to 2020
Gender	Male	71%	25,664	27,967	9.0%
	Female	29%	10,432	10,712	2.7%
Age	<16	3%	1,226	1,266	3.3%
	16-24	16%	5,633	6,454	14.6%
	25-34	18%	6,560	7,714	17.6%
	35-44	14%	5,126	5,862	14.4%
	45-54	14%	4,967	5,190	4.5%
	55-64	15%	5,357	5,623	5.0%
	65+	20%	7,227	6,571	-9.1%
Race	White	78%	28,058	29,092	3.7%
	Black	17%	6,090	7,494	23.1%
	American Indian	2%	583	645	10.6%
	Asian/Pacific Islander	2%	792	565	-28.7%
	All Other Races	2%	573	884	54.3%
Total Fatalities		**100%**	**36,096**	**38,680**	**100.0%**

Source: National Center for Statistics and Analysis, June 2021 (revised). Early estimates of motor vehicle traffic fatalities and fatality rate by sub-categories in 2020 (Crash Stats Brief Statistical Summary. Report No. DOT HS 813 118). National Highway Traffic Safety Administration.

Pandemic Transportation Impacts and Recovery

The drastic decline in VMT during 2020 and the relatively quick rebound to 2019 traffic volumes by early 2021 can provide some insight into potential travel trends spurred by the pandemic. Examining the types of travel and travel purpose can also provide insight into new or changing travel behavior.

BTS has published data collected by the Maryland Transportation Institute and Center for Advanced Transportation Technology Laboratory at the University of Maryland on daily trip data and people staying at home. The data are obtained from mobile devices and are collected from multiple sources that meet a set of quality standards. The effort creates (personal) trip data aggregated at the county, State, and national levels, as well as the population staying at home.

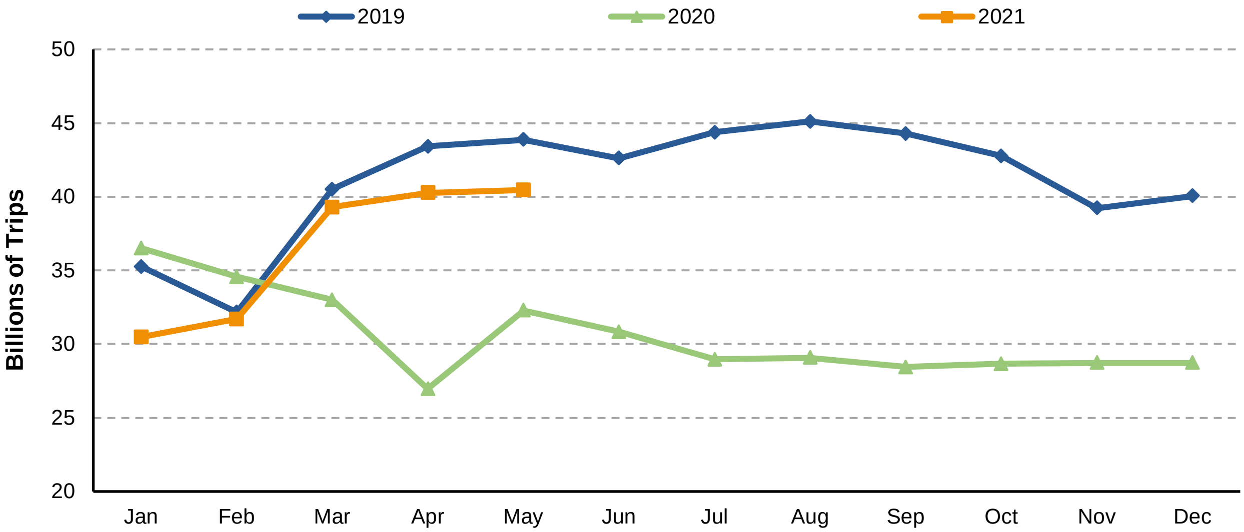
Daily Travel Trends

Exhibit 11-8 shows national trip totals in 2019 through May of 2021. Daily trip totals have been aggregated to monthly for quick comparisons. Trips are defined as movements that include a stay of longer than 10 minutes at a location away from home. A movement with multiple stays of longer than 10 minutes before returning home is counted as multiple trips. Similar to volume decreases, trip totals drastically declined—by as much as 38 percent in 2020 compared with 2019 totals—but were near (about 90 percent of) pre-pandemic levels by early 2021.

The national trip totals are based on data from mobile devices, which are carried by the traveler during the trip. These personal trips account for travel on all modes of transportation, not just vehicular travel. Based on BTS data, the daily average number of trips per person was 4.1 in 2019 and decreased to 3.1 per person per day in 2020, below the 3.4 daily trips per person reported in the 2017 National Household Travel Survey (NHTS).

People travel for many reasons. The latest available NHTS data from 2017 indicate that more than a quarter of all trips (28 percent) were for social and recreational purposes, followed by other family/personal business (20 percent), work trips (19 percent), shopping trips (18 percent), school and places of worship (11 percent), and all other (4 percent).

Exhibit 11-8: National Monthly Trip Totals



Note: Monthly summation of national daily trip totals.
Source: U.S. Department of Transportation, Bureau of Transportation Statistics, Trips by Distance. https://data.bts.gov/Research-and-Statistics/Trips-by-Distance/w96p-f2qv

Trip lengths can vary by trip purpose; looking at changes in trip length in aggregate may help to explain the change in travel behavior during COVID public health emergency. In 2017, the average trip length for all trips was 11.6 miles. People living in lower-density rural areas traveled 77 percent farther (average of 15.6 miles) on average per trip than did urban travelers (average of 8.8 miles). Most personal trips are 25 miles or less. *Exhibit 11-9* shows the average person trip length by trip purpose from the 2017 NHTS.

Exhibit 11-9: 2017 Average Person Trip Length by Trip Purpose

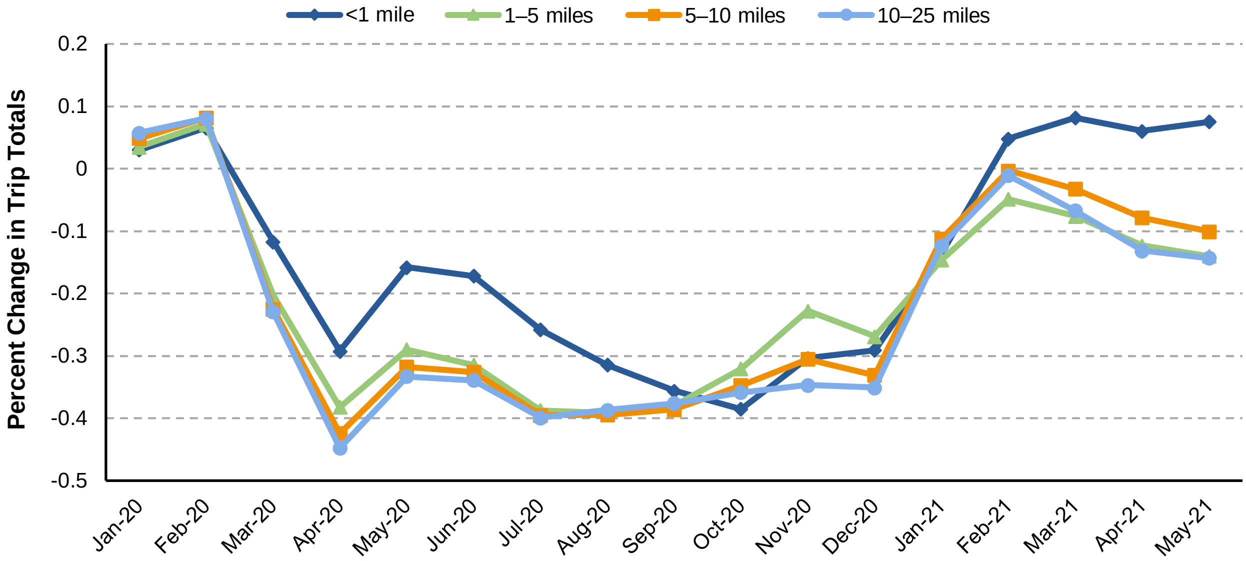
Trip Purpose	Average Trip Distance (Miles)
Work-related Business	25.9
To/from Work	11.5
All Purposes	10.7
Social and Recreational	8.7
Shopping	7.1
Other Family/Personal Errands	6.8
School/Church	6.4
Other	37.5

Source: 2017 National Household Travel Survey.

Daily personal trips by distance in 2020 and 2021 compared with the same month in 2019 are shown for trip distances of 25 miles or less in *Exhibit 11-10*.

COVID-19 affected both the quantity of travel and the types of travel. Based on aggregated monthly trip totals, trips less than one mile made up 24.3 percent of all trips in March 2019, increasing to 26.3 percent in March 2020 and 27.1 percent in March 2021, resulting in monthly totals that were up to 8 percent higher in 2021 than in 2019. Note that these trips for 1 mile or less were performed by all modes of travel, including walking and biking, suggesting that people may have increased their nonvehicular travel for short distances in 2020 and 2021.

Exhibit 11-10: Percentage Change in Aggregated Daily Trip Totals Less Than 25 Miles (Compared with 2019)



Note: Monthly summation of daily trip totals.
Source: U.S. Department of Transportation, Bureau of Transportation Statistics. Trips by Distance. https://data.bts.gov/Research-and-Statistics/Trips-by-Distance/w96p-f2qv

Exhibit 11-11 shows the percentage change in trip totals greater than 25 miles in distance. Trips greater than 50 miles increased significantly after April 2020 and were 30 percent higher than pre-pandemic levels by November 2020. This increase coincided with shelter-in-place orders coupled with increased online shopping for groceries and supplies, triggering an increase in local and regional truck deliveries. According to the American Transportation Research Institute (ATRI), local (less than 100 miles) truck trips more than doubled, increasing from 7.8 percent to 18.2 percent of all truck trips during the pandemic, and regional (100 to 455 miles) truck trips increased from 31 percent to 33.8 percent of all truck trips over this same period.[51]

Telework Trends

The COVID-19 pandemic and the resulting social distancing and stay-at-home orders significantly increased the percentage of workers who worked from home. The percentage of workers working from home increased from 4.9 percent in January 2020 to a high of 40.7 percent in July 2020. By December 2020, 34.2 percent of all workers worked from home.

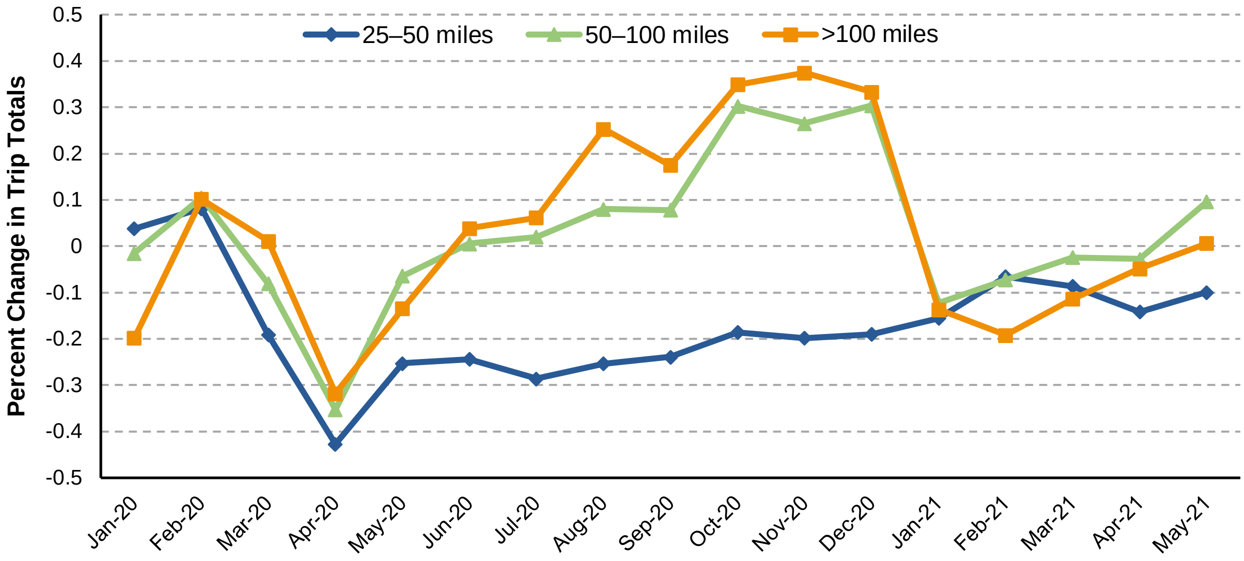
Refer to the Transit section of this chapter for more information on telework during the pandemic.

A growing number of activities that have traditionally required travel can now be accomplished virtually. Broadband and other telecommunication technologies allow people and businesses to conduct everyday activities—such as shopping, attending meetings, teleworking, learning, and receiving medical care—without the need to travel. The practice of substituting in-person activities with virtual activities is likely here to stay.

Understanding the opportunities and impacts of potential shifts from travel to activities such as ecommerce, telework, and remote learning can inform planning and policy in areas such as access to goods and services, mobility, sustainability, and equity.

[51] American Transportation Research Institute and Owner-Operator Independent Driver Association Foundation, 2020. *COVID-19 Impacts on the Trucking Industry*. https://www.commerce.senate.gov/services/files/1BB292D4-6FAE-4078-A1B5-48BF40FF660B

Exhibit 11-11: Percentage Change in Aggregated Daily Trip Totals Greater than 25 Miles (Compared with 2019)



Note: Monthly summation of daily trip totals.

Source: U.S. Department of Transportation, Bureau of Transportation Statistics. Trips by Distance. https://data.bts.gov/Research-and-Statistics/Trips-by-Distance/w96p-f2qv

Tele-Education

Access to high-speed Internet is growing every year, with "access" defined as whether someone in the household uses or connects to the Internet regardless of whether they pay for the service. In 2015, only 77.3 percent of U.S. households had access to high-speed Internet; by 2018, that number was over 85 percent. More recent data from 2020 estimate that more than 93 percent of all households have access to high-speed Internet. Access to broadband Internet made distance learning possible for many people during the pandemic.

During the Fall of 2020 through to the Winter of 2021 school year, over 80 percent of grade school and post-secondary education was performed outside of educational facilities, referred to as distance learning, and approximately 64 to 70 percent was conducted using online resources.

Source: U.S. Census Bureau Household Pulse Survey, Education Table 2: COVID-19 Pandemic Impact on How Children Received Education, by Select Characteristics: United States. https://www.census.gov/programs-surveys/household-pulse-survey.html

Economic Impacts of the COVID-19 Pandemic

The initial transportation-related response to COVID-19 was to reduce travel, as many activities could be performed online from home. Some activities, however, particularly personal services and recreational activities, could not be performed online. These businesses lost clients and suffered loss of revenues and employees. The reduction in economic activity resulted in governments losing tax revenues from sales taxes and personal incomes. Federal and State governments lost fuel excise tax revenues due to reduced economic activity and travel. The Federal government responded by passing COVID-19 emergency and supplemental funding laws to help sustain the economy through supporting local and State governments, businesses, and individuals. This section explores the effect of COVID-19 on the Highway Trust Fund.

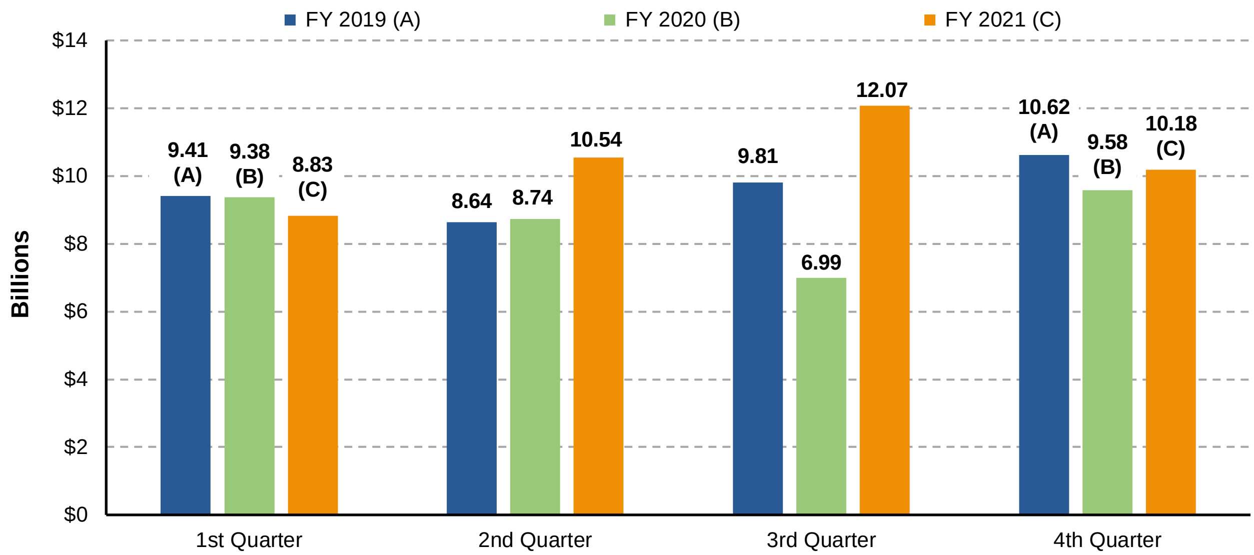
Impacts of COVID-19 on the Highway Trust Fund

The Highway Trust Fund is supported with the proceeds of certain highway-related Federal excise taxes, including the taxes on highway gasoline and diesel, heavy vehicle use, truck and trailer sales, and the sales of truck tires. These taxes are typically paid to the Internal Revenue Service (IRS) by the producer or importer of the taxable product; exceptions include the tax on trucks and trailers, which is paid by the retailer, and the heavy vehicle use tax, which is paid by the heavy vehicle owner.

On a quarterly basis, after processing the tax returns, the IRS issues a certification of the taxes collected by type for the Highway Account (and the Mass Transit Account). If the certified amount for a tax is greater than or less than the original deposits, an adjustment is made. In addition to tax receipts, the certification includes the receipts from certain civil penalties imposed under the Internal Revenue Code and deposited in the Highway Account. Generally, the IRS certifies receipts approximately five months after the liability quarter.

The emergence of COVID-19 and the resulting nationwide reduction in travel led to a significant decline in excise taxes collected by the IRS and deposited into the Highway Account (and Mass Transit Account) of the Highway Trust Fund. These impacts began in April 2020 and continued into Fiscal Year (FY)[52] 2021. *Exhibit 11-12* shows the quarterly receipts by FYs 2019–2021.

Exhibit 11-12: Highway Account Certified Paid Liabilities (Receipts)



Note: Based on quarterly IRS tax certifications for the Highway Account for highway-related Federal excise taxes, including taxes on highway gasoline and diesel, heavy vehicle use, truck and trailer sales, and the sales of truck tires. In addition to tax receipts, the certification includes the receipts from certain civil penalties imposed under the Internal Revenue Code.

Source: IRS quarterly trust fund certifications.

Based on IRS quarterly trust fund certifications, the Highway Account saw a $2.82 billion reduction in tax revenues deposited in the third quarter of FY 2020 (April–June 2020) compared with FY 2019, representing a 29-percent decline. This trend continued with a reduction of $1.04 billion (a 10-percent decline) in the fourth quarter of FY 2020 compared with FY 2019. Continuing into FY 2021, the Highway Account experienced a $0.57 billion reduction in the first quarter (a 6-percent decline) compared with the average of deposits for the first quarter of FY 2019 and FY 2020. As VMT started to recover, the second quarter of FY 2021 saw an increase of $1.85 billion (21 percent) over the average of the FY 2019 and FY 2020 second quarters. The

[52] The Federal government's fiscal year runs from October 1 of one calendar year through September 30 of the next.

third quarter of FY 2021 saw an increase of $3.67 billion (44 percent) over the average of the FY 2019 and FY 2020 third quarters.

The most significant impacts to the Highway Account occurred in the third quarter of FY 2020, when tax receipts declined by $2.82 billion compared to the third quarter of 2019. All Federal excise tax receipts saw a decline in this period, including from taxes on gasoline and related fuels, diesel and other fuels such as compressed natural gas, retail tax on trucks and trailers, taxes on highway-type truck tires, and the heavy vehicle use tax.

Compared with the third-quarter average of FY 2019 and FY 2021 combined, the Highway Account experienced the following loss in Federal excise tax receipts by source in the third quarter of FY 2020:

- Gasoline and related fuels: 37 percent reduction,
- Diesel and other fuels: 30 percent reduction,
- Retail tax on trucks and trailers: 44 percent reduction,
- Highway-type truck tires: 50 percent reduction, and
- Heavy vehicles use tax: 38 percent reduction.

Economic Recovery Funding

The stay-at-home orders and the closing of nonessential services resulted in loss of income and jobs for many businesses, organizations, and individuals. The real GDP (a total value of goods and services produced within a country) declined by 31.4 percent in the second quarter of 2020 from the previous quarter. To assist State and local governments, businesses, and individuals through this period, Congress enacted three laws to provide emergency relief funding:[53]

- The Coronavirus Aid, Relief and Economic Security (CARES) Act, signed on March 27, 2020, provided a total of $2 trillion in relief aid, of which $114.8 billion went to transportation modes;
- The Coronavirus Response and Relief Supplemental Appropriations (CRRSA) Act, signed December 7, 2020, provided a total of $2.3 trillion in aid, of which $900 billion was distributed for COVID-19 relief, to include $45 billion for transportation; and
- The American Rescue Plan Act of 2021, signed March 11, 2021, included a total of $1.9 trillion in relief aid, of which $58.4 billion was devoted to transportation.

The three laws have provided a total of $4.8 trillion in relief funding, of which $218.2 billion went toward supporting transportation expenditures. Air carriers and transit agencies received the bulk of the funding at $87 billion and $69.5 billion, respectively. Highways received $10 billion from the CRRSA Act, which has been administered by FHWA as additional grant funding for highway infrastructure programs for FY 2021. This funding, combined with Federal-aid highway funds for the fiscal year, has been used to supplement State highway infrastructure projects to respond to the changing needs and increased costs associated with COVID-19.

The COVID-19 relief funding also provided supplemental funding to local and State governments to make up for the loss of revenue and increased expenditures due to the COVID-19 public health emergency. The emergency relief funding sustained economic activity and provided welfare support to businesses and individuals who lost incomes. Real GDP increased by 33.1 percent in the third quarter of 2020 compared with the previous quarter, following passage of the CARES Act.

[53] Bureau of Transportation Statistics, Undated. "COVID-19 Stimulus Funding for Transportation in the CARES Act and Other Supplemental Bills." Website visited on 7/12/22. https://data.bts.gov/stories/s/2cyr-4k8j

Impacts of the COVID-19 Pandemic on Transportation – Transit

Section 1 – COVID-19 Pandemic

Public Transit Ridership

Public transit ridership decreased by 81 percent between April 2019 and April 2020. Although all modes of transit decreased, some transit modes were hit harder by the pandemic. The two most strongly affected modes were commuter rail and commuter bus. As seen in *Exhibit 11-13*, both modes experienced 93-percent reductions in ridership between April 2019 and April 2020. The least-affected mode was local bus service, whose ridership decreased by only 71 percent during the same period.

Although many office workers were no longer commuting to work during the pandemic, local bus service still provided commuter services to essential workers at hospitals, grocery stores, pharmacies, and other businesses that remained open. In late 2020 and early 2021, ridership and service levels gradually increased. By April 2021, ridership had increased by 114 percent from April 2020 but was still down 59 percent from April 2019.

Overall, rail modes were more affected than nonrail modes. Between April 2019 and April 2021, ridership on rail modes decreased by 66 percent, whereas nonrail modes decreased by 52 percent. These steep declines indicate that the pandemic was not over, and ridership has not returned to pre-pandemic levels.

Ridership among the top 10 agencies has varied during the pandemic. For example, Bay Area Rapid Transit (BART) in the San Francisco area is a regional rail service that is focused on commuter services and providing connections to regional hubs such as airports. BART experienced an 81-percent decrease in weekly ridership between January 2020 and May 2021, the largest drop among the top 10 transit agencies (see *Exhibit 11-14*). The three agencies whose ridership rebounded most quickly were LA Metro, New Jersey Transit, and the Metropolitan Transportation Authority in New York City. In the same period, weekly ridership declines for these agencies were 42 percent, 52 percent, and 54 percent, respectively.

Section Summary

- Between April 2019 and April 2021, ridership on rail modes decreased by 66 percent, whereas nonrail modes decreased by 52 percent.
- Due to service cuts, between April 2019 and April 2021, vehicle revenue miles on rail modes vehicle revenue miles decreased by 16 percent due to service cuts; vehicle revenue miles on nonrail modes decreased by 20 percent.
- If the current trends hold, we can expect to see permanent decreases in transit ridership, especially among rail modes and commuter bus. These services may take considerable time to regain their previous ridership.
- Essential workers, many of whom are low-income workers, were the most affected by transit service cuts and restructurings.
- In the lowest income bracket, less than $25,000 a year, workers in these households were very likely to be commuting, with only 13 percent of households having had a worker who was able to telework at least part of the time.
- To right-size service with demand and have a balanced budget, many agencies may be forced to both increase fares and offer less frequent service.
- For the top 10 transit agencies, fare revenue decreased between 19 percent and 70 percent.

Exhibit 11-13: Monthly Ridership: April 2019, April 2020, April 2021

Type	Mode	Description	April 2019	April 2020	April 2021	Two-Year Change
Rail	Heavy Rail	Ridership	326,431,818	30,014,960	113,866,889	
		Annual Percent Change		-91%	279%	-65%
	Light Rail	Ridership	40,162,974	9,267,082	14,313,293	
		Annual Percent Change		-77%	54%	-64%
	Streetcar	Ridership	4,845,885	629,869	1,577,115	
		Annual Percent Change		-87%	150%	-67%
	Commuter Rail	Ridership	43,296,839	2,834,168	9,855,571	
		Annual Percent Change		-93%	248%	-77%
	Other Rail	Ridership	2,898,545	360,052	791,477	
		Annual Percent Change		-88%	120%	-73%
	Subtotal	Ridership	**417,636,061**	**43,106,131**	**140,404,345**	
		Annual Percent Change		**-90%**	**226%**	**-66%**
Nonrail	Bus	Ridership	378,285,510	107,822,955	181,377,193	
		Annual Percent Change		-71%	68%	-52%
	Demand Response	Ridership	8,732,635	2,301,834	5,022,806	
		Annual Percent Change		-74%	118%	-42%
	Commuter Bus	Ridership	7,298,540	536,015	1,480,397	
		Annual Percent Change		-93%	176%	-80%
	Other Nonrail	Ridership	23,231,476	4,685,050	10,685,246	
		Annual Percent Change		-80%	128%	-54%
	Subtotal	Ridership	**417,548,161**	**115,345,854**	**198,565,642**	
		Annual Percent Change		**-72%**	**72%**	**-52%**
Total		Ridership	**835,184,222**	**158,451,985**	**338,969,987**	
		Annual Percent Change		**-81%**	**114%**	**-59%**

Notes: Other Rail includes hybrid rail, monorail/automated guideway, inclined plane, cable car, Alaska railroad, and aerial tramway. Other Nonrail includes vanpool, público, ferryboat, bus rapid transit, and trolleybus.

Source: National Transit Database.

Exhibit 11-14: Weekly Ridership, Top 10 Agencies, Jan 2020–May 2021

Agency	Jan 2020	Mar 2020	May 2020	Jul 2020	Sep 2020	Nov 2020	Jan 2021	Mar 2021	May 2021	Percent Change
MTA New York City Transit	72,334	39,188	11,729	24,373	28,529	26,660	24,902	29,828	33,490	-54%
Chicago Transit Authority	8,279	5,224	2,045	2,905	3,068	2,639	2,435	3,070	3,370	-59%
Los Angeles County Metropolitan Transportation Authority	6,949	4,677	2,751	3,608	3,760	3,757	3,083	3,736	4,060	-42%
Massachusetts Bay Transportation Authority	6,875	3,747	1,144	1,993	2,361	2,206	1,880	2,253	2,622	-62%
Washington Metropolitan Area Transit Authority	6,805	3,800	723	1,187	1,684	1,643	1,419	1,797	2,072	-70%
Southeastern Pennsylvania Transportation Authority	5,942	4,080	1,070	1,945	2,068	1,845	1,791	2,082	2,175	-63%
New Jersey Transit Corporation	4,925	3,132	1,032	1,958	2,274	1,974	1,835	2,174	2,352	-52%
City and County of San Francisco	4,104	4,101	694	957	996	1,094	1,012	1,283	1,460	-64%
King County Department of Metro Transit	2,454	1,349	719	909	950	795	767	885	938	-62%
San Francisco Bay Area Rapid Transit District	2,295	1,001	182	299	309	332	268	355	429	-81%

Notes: Ridership is in thousands. Weekly ridership was calculated by dividing monthly ridership by the number of weeks in each month. Top 10 agencies were determined using unlinked passenger trips (UPT) for January 2020.

Source: National Transit Database.

Transit Service

As ridership plummeted in March and April of 2020, transit agencies reduced service to match ridership levels and save money. Of the 518 agencies that reported service in April 2019, 505 agencies (97 percent of all agencies) reduced service between April 2019 and April 2020. In many cases, agencies eliminated entire bus routes or significantly reduced frequencies. The two primary indicators of service levels are Vehicle Revenue Miles (VRM) and Vehicle Revenue Hours (VRH. As shown in *Exhibits 11-15* and *11-16*, all modes experienced declines in VRM and VRH between April 2019 and April 2020, but the decreases were less severe than the ridership decreases seen in *Exhibits 11-13* and *11-14*. As shown in *Exhibits 11-15* and *11-16*, both VRM and VRH increased across all modes between April 2020 and April 2021. The two-year change in VRM and VRH between April 2019 and April 2021 shows differences across modes, with all modes still having less service than in pre-pandemic times. Although rail modes experienced more declines in ridership, nonrail modes experienced more service cuts.

Between April 2019 and April 2021, the VRM and VRH of rail modes decreased by 16 percent and 13 percent, respectively, whereas VRM and VRH of nonrail modes decreased by 20 percent and 19 percent. As shown in *Exhibits 11-15* and *11-16*, nonrail commuter bus service levels were hit the hardest by the pandemic: between April 2019 and April 2021, VRM decreased by 49 percent and VRH decreased by 46 percent. The two least-affected modes were heavy rail and bus. Heavy rail VRM decreased by 10 percent and VRH decreased by 7 percent. Bus VRM decreased by 10 percent and VRH decreased by 11 percent. In many cases, service was cut on routes that catered primarily to white-collar commuters who were no longer making daily trips to offices. In other cases, service was cut because of increased sickness in the workforce, or because workers needed to stay home with children who were now in remote learning, or because it became increasingly difficult to fill open positions. In some cases, service cuts were driven by supply chain disruptions reducing the availability of spare parts for vehicles.

Exhibit 11-15: VRM: April 2019, April 2020, and April 2021

Type	Modes	Description	April 2019	April 2020	April 2021	Two-Year Change
Rail	Heavy Rail	VRM	58,732	36,518	52,798	
		Annual Percent Change		-38%	45%	-10%
	Light Rail	VRM	10,138	7,271	8,216	
		Annual Percent Change		-28%	13%	-19%
	Streetcar	VRM	613	253	426	
		Annual Percent Change		-59%	68%	-31%
	Commuter Rail	VRM	29,563	17,272	22,312	
		Annual Percent Change		-42%	29%	-25%
	Other Rail	VRM	703	356	462	
		Annual Percent Change		-49%	30%	-34%
	Subtotal	**VRM**	**99,749**	**61,670**	**84,214**	
		Annual Percent Change		**-38%**	**37%**	**-16%**
Nonrail	Bus	VRM	155,627	112,285	139,634	
		Annual Percent Change		-28%	24%	-10%
	Demand Response	VRM	68,349	22,968	48,041	
		Annual Percent Change		-66%	109%	-30%
	Commuter Bus	VRM	10,107	3,460	5,164	
		Annual Percent Change		-66%	49%	-49%
	Other Nonrail	VRM	23,089	9,986	13,903	
		Annual Percent Change		-57%	39%	-40%
	Subtotal	**VRM**	**257,171**	**148,699**	**206,742**	
		Annual Percent Change		**-42%**	**39%**	**-20%**
Total		**VRM**	**356,920**	**210,369**	**290,956**	
		Annual Percent Change		**-41%**	**38%**	**-18%**

Notes: VRM is in thousands. Other Rail includes hybrid rail, monorail/automated guideway, inclined plane, cable car, Alaska railroad, and aerial tramway. Other Nonrail includes vanpool, público, ferryboat, bus rapid transit, and trolleybus.

Source: National Transit Database.

Exhibit 11-16: VRH: April 2019, April 2020, April 2021

Type	Modes	Description	April 2019	April 2020	April 2021	Two-Year Change
Rail	Heavy Rail	VRH	2,945	1,836	2,729	
		Annual Percent Change		-38%	49%	-7%
	Light Rail	VRH	649	446	524	
		Annual Percent Change		-31%	17%	-19%
	Streetcar	VRH	88	37	58	
		Annual Percent Change		-58%	57%	-33%
	Commuter Rail	VRH	966	589	741	
		Annual Percent Change		-39%	26%	-23%
	Other Rail	VRH	59	19	25	
		Annual Percent Change		-68%	31%	-57%
	Subtotal	VRH	**4,706**	**2,927**	**4,078**	
		Annual Percent Change		**-38%**	**39%**	**-13%**
Nonrail	Bus	VRH	13,275	9,511	11,795	
		Annual Percent Change		-28%	24%	-11%
	Demand Response	VRH	4,675	1,827	3,117	
		Annual Percent Change		-61%	71%	-33%
	Commuter Bus	VRH	413	147	221	
		Annual Percent Change		-64%	50%	-46%
	Other Nonrail	VRH	913	376	538	
		Annual Percent Change		-59%	43%	-41%
	Subtotal	VRH	**19,275**	**11,862**	**15,671**	
		Annual Percent Change		**-38%**	**32%**	**-19%**
Total		**VRH**	**23,982**	**14,789**	**19,749**	
		Annual Percent Change		**-38%**	**34%**	**-18%**

Notes: VRH is in thousands. Other Rail includes hybrid rail, monorail/automated guideway, inclined plane, cable car, Alaska railroad, and aerial tramway. Other Nonrail includes vanpool, público, ferryboat, bus rapid transit, and trolleybus.
Source: National Transit Database.

Transit Worker Safety

Operator safety was a constant worry throughout the pandemic. Operators—especially bus operators—are in constant contact with customers throughout their shifts. This exposure led many transit agencies to enact a plethora of new policies and procedures to minimize risk to operators. Some of these policies included suspending or discontinuing fare collection, implementing rear-door boarding, requiring masks for customers and operators, enhancing cleaning procedures for the buses, installing shields between operators and customers, and placing caps on the number of riders allowed on each bus and train.

Despite these measures, many operators were infected with COVID-19. The Amalgamated Transit Union (ATU) tracked ATU member deaths and reported 173 members had died from COVID-19 in the same period.[54] Many transit operators and customer service representatives are not union members, so this number does not fully capture the loss of life among transit workers from COVID-19. To estimate the full impact of COVID-19 on transit operators, FTA collected monthly data related to impacts from COVID-19. As of October 2021, FTA estimated 631 transit worker deaths from COVID-19.[55]

Financial Impacts to Transit

As ridership and service levels declined during the pandemic, farebox revenue and other important revenue sources such as income tax and sales tax also decreased. *Exhibit 11-17* highlights the fare revenue changes from 2019 to 2020 for the top 10 agencies. Transit revenue

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[54] Amalgamated Transit Union, 2022. *Remember Our Fallen*. Available at: https://www.atu.org/remember-our-fallen

[55] Federal Transit Administration, 2022. *Agency Information Collection Activity Under OMB Review.* Available at: federalregister.gov/documents/2021/09/23/2021-20559/agency-information-collection-activity-under-omb-review

was further reduced in the spring of 2020 when some systems halted fare collection to help minimize contact between riders and transit operations personnel. Most agencies resumed fare collection by the second or third quarter of 2020.

Exhibit 11-17: Top 10 Transit Agencies: Changes in Fare Revenues

Rank	Agency	2019 Fare Revenue	2020 Fare Revenue	Change in Fare Revenue
1	New York MTA	$6,359,236,788	$2,630,103,489	-59%
2	Chicago Transit Authority	$588,741,390	$236,301,686	-60%
3	Los Angeles County Metropolitan Transportation Authority	$280,870,183	$199,728,314	-29%
4	Massachusetts Bay Transportation Authority	$671,521,399	$545,414,783	-19%
5	Washington Metropolitan Area Transit Authority	$666,310,293	$492,953,775	-26%
6	Southeastern Pennsylvania Transportation Authority	$462,296,681	$353,276,517	-24%
7	New Jersey Transit Corporation	$979,873,625	$743,742,067	-24%
8	City and County of San Francisco	$196,820,505	$153,699,058	-22%
9	King County Department of Metro Transit	$239,071,077	$72,180,466	-70%
10	San Francisco Bay Area Rapid Transit District	$482,643,999	$341,586,797	-29%

Note: All 10 agencies suspended fare collection for a period of time during the pandemic. Some agencies suspended fares only on specific services and the length of suspensions varied among the agencies.

Source: National Transit Database.

To maximize flexibility for the agencies, existing Federal formula funds were made available at 100% federal share for expenses related to addressing the public health emergency. This flexibility was important because some of the fund sources that the Federal funds supplanted have no or few restrictions, so it was important to ensure agencies were able to maintain service. In addition, the Federal government provided several new funding packages to ensure transit agencies could continue to provide essential services to transit riders. Although it is not possible at this time to fully capture the financial impacts to transit agencies from COVID-19, the Federal emergency funding packages released in 2020 and 2021 for transit totaled more than $69 billion, as shown in *Exhibit 11-18*.

Exhibit 11-18: Additional Federal Transit Funding in Response to the Pandemic

Details	Coronavirus Aid, Relief, and Economic Security Act (CARES)	Coronavirus Response and Relief Supplemental Appropriations Act (CRRSAA)	American Rescue Plan (ARP)	Total Additional Federal Transit Funding
Date of New Funding	April 2020	January 2021	March 2021	
Transit Funding Amount	$24,925,000,000	$13,990,520,492	$30,459,887,764	$69,375,408,256

Source: Federal Transit Administration.

In July 2021, the American Public Transit Association (APTA) reported that 79 percent of agencies avoid layoffs and 62 percent of agencies avoid cutting service through the infusion of Federal funds.[56]

The financial impacts to transit agencies from COVID-19 have two components: (1) loss of revenue and (2) uncertainties about future revenues, ridership, and transit demand. These uncertainties make transit agencies apprehensive to backfill open positions and initiate new capital projects and fleet procurements. These delays could add costs to planned projects through inflation. Fully understanding the scale of the financial impact of the pandemic on transit agencies may take years.

A third financial impact was the additional cost of cleaning and disinfecting transit equipment to protect riders and transit workers. These additional costs were typically in the range of 5

[56] American Public Transit Association, 2021. *Policy Brief: COVID-19 Emergency Funding Critical to Public Transit's Survival*. July 29, 2021. Available at: https://www.apta.com/wp-content/uploads/APTA-SURVEY-BRIEF-COVID-19-Transit-Agency-Funding-07.29.2021.pdf

percent of pre-pandemic operating costs, and in most cases were offset by reduced operating costs from reductions in service.

Although the three Federal funding packages have been helpful, transit agencies still face extensive financial issues. According to a report for APTA prepared by EBP US, Inc., revenue sources will continue to remain below pre-pandemic numbers and new policies and procedures that are in place to respond to the pandemic will create additional shortfalls for transit. The report expects the 2021 shortfall to be $25.1 billion, followed by $15.1 billion in 2022 and $13 billion in 2023.[57] These transit funding shortfalls represent the cumulative impact of COVID-related declines in transit fare collections, local and state tax revenues dedicated to transit uses, and motor fuel taxes. The APTA report also suggests that agencies may address these declines by reducing expenditures on capital projects and diverting some capital funds to operating uses.

Transit and Public Health

In the spring of 2021 when COVID-19 vaccines became available, transit agencies across the Nation partnered with public health organizations to make the vaccine available to anyone who wanted it. This partnership included coordinating the logistics of getting people to and from vaccine appointments, waiving fees for transit trips to vaccine appointments, and allowing transit facilities to serve as mass vaccination sites for the public and for transit workers.

San Diego provides an example of transit agencies working with public health organizations to promote awareness and access options to vaccine appointments. The San Diego Metropolitan Transit Systems and the North County Transit District worked together to create consistent messaging, branding, and graphics, and shared a tool that allowed residents to book a vaccine trip using their transit systems.[58]

Many transit agencies allowed public health organizations to use their facilities as mass vaccination sites, which worked well because many transit agencies were still below pre-pandemic service levels and thus were able to maintain their services while providing a site for mass vaccinations. These transit facilities are often well served by transit, allowing drivers as well as transit riders to easily access the vaccination sites. In Los Angeles, LA Metro used Union Station, Harbor Gateway Transit Center, and other stations around Los Angeles County as vaccination sites.[59] In Covina, California, Foothill Transit repurposed the ground floor of its new bus depot and park-and-ride garage into a vaccination site. More than 2,000 people received a vaccination at the bus depot.[60]

More than 450 transit agencies across the country provided free transit trips to vaccine appointments and some provided additional demand-response services to accommodate door-to-door service for those in need of transportation.[61]

Travel Changes on Other Modes

Many data sources are available to help provide a picture of the totality of changes in trip-making across the United States during the pandemic. The previous section discussed

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[57] EBP US, Inc., 2021. *The Impact of the COVID-19 Pandemic on Public Transit Funding Needs in the U.S.* January 27, 2021. Available at: https://www.apta.com/wp-content/uploads/EBP-APTA-COVID-19-Impact-01.27.2021.pdf

[58] Mass Transit Magazine, 2021. "VaxTransit: 450+ Agencies in 41 States Provide Free Rides for Vaccines." March 29, 2021. Available at: https://www.masstransitmag.com/safety-security/article/21216186/vaxtransit-450-agencies-in-41-states-provide-free-rides-for-vaccines

[59] The Source, 2021. "COVID-19 vaccination sites at Metro transit stations." May 28, 2021. Available at: https://thesource.metro.net/2021/05/28/covid-19-vaccination-sites-at-metro-transit-stations/

[60] Pew, 2021. "Need a COVID-19 Vaccine? Visit Your Local Transit Center." April 12, 2021. Available at: https://www.pewtrusts.org/en/research-and-analysis/blogs/stateline/2021/04/12/need-a-covid-19-vaccine-visit-your-local-transit-center

[61] Mass Transit Magazine, 2021. "VaxTransit: 450+ Agencies in 41 States Provide Free Rides for Vaccines." March 29, 2021. Available at: https://www.masstransitmag.com/safety-security/article/21216186/vaxtransit-450-agencies-in-41-states-provide-free-rides-for-vaccines

changes in transit ridership due to the pandemic. Other important measures of travel on surface transportation modes include vehicle miles traveled (VMT), which is the total number of miles traveled by all motorized vehicles on roadways, bikeshare and e-scooters trips, and trips using transportation network companies (TNC) and taxis.

As seen in *Exhibit 11-2*, VMT decreased by 40.2 percent between April 2019 and April 2020. Transit ridership decreased by 81 percent during the same period. Although transit trips decreased more significantly, overall travel patterns decreased as people complied with the stay-at-home orders. Other factors influencing VMT include more freight traffic to support an increased demand in online shopping and more people driving instead of flying. In 2020, the number of passengers traveling by air decreased by 63 percent.[62] In addition to the decreases seen in transit ridership, air traffic, and VMT in the first year of the pandemic, other modes that move fewer people but serve a critical role in urban mobility were affected. As shown in *Exhibit 11-19*, 33 bikeshare and three e-scooter systems closed permanently between March 2020 and December 2020, representing 10 percent of all systems. Many of the systems that closed were docked bikeshare systems, which represent 78 percent of the closed systems. In the same period, five dockless bikeshare systems closed.

Exhibit 11-19: Bikeshare and E-Scooter Operations (March–December 2020)

Status	Docked Bikeshare	Dockless Bikeshare	E-Scooter	Total
Closed Permanently	28	5	3	36
Suspended Operations	20	5	126	151
Remained Open	55	47	86	188
Total	103	57	215	375

Source: Bureau of Transportation Statistics.

For the 75 docked bikeshare systems that did not close during the pandemic, 20 suspended operations and 55 remained open. These systems experienced decreased use throughout 2020 and into the first half of 2021. However, starting in June 2021, docked bikeshare systems trips began exceeding pre-pandemic trips, signaling a near recovery for the systems that remained open. As seen in *Exhibit 11-20*, trips in June, July, and August of 2021 exceed those during the same months in 2019.

Other modes that compete with transit for riders are taxis and TNCs; the two most popular TNCs are Lyft and Uber. During the pandemic, both Uber and Lyft experienced significant decreases in trips requested through their respective apps. In Seattle, Uber reported a 60–70-percent decrease in trips in March 2020.[63] Lyft reported similar numbers nationwide for the second quarter, about a 60-percent decrease in the number of rides requested.[64] In New York City, taxis experienced an 84-percent decrease in trips from pre-pandemic levels. In June 2020, New York City taxis provided 18,000 trips compared with 200,000 in pre-pandemic times.[65]

[62] Airports Council International, 2021. "The impact of COVID-19 on the airport business and the path to recovery." March 25, 2021. Available at: https://aci.aero/2021/03/25/the-impact-of-covid-19-on-the-airport-business-and-the-path-to-recovery/

[63] The Verge, 2021. "Uber is doing 70 percent fewer trips in cities hit hard by coronavirus." March 19, 2021. Available at: https://www.theverge.com/2020/3/19/21186865/uber-rides-decline-coronavirus-seattle-sf-la-nyc

[64] Los Angeles Times, 2020. "Lyft revenue plummets 61% as pandemic slams ride-hailing." August 12, 2020. Available at: https://www.latimes.com/business/technology/story/2020-08-12/lyft-revenues-plummet-61-as-pandemic-slams-ride-hailing

[65] NBC New York, 2020. "NYC Taxis, For-Hire Cars Took Sharp Hit With Pandemic, And Are Only Slowly Coming Back." July 29, 2020. Available at: https://www.nbcnewyork.com/news/local/nyc-taxis-for-hire-cars-took-sharp-hit-with-pandemic-and-are-only-slowly-coming-back/2541796/

Exhibit 11-20: Docked Bikeshare Ridership: 2019–2021

Month	2019	2020	2021	Two-Year Change
January	1,619,691	2,183,963	1,585,700	-2%
February	1,560,909	2,071,058	971,094	-38%
March	4,190,909	3,375,153	1,990,120	-53%
April	6,712,252	2,464,830	3,438,524	-49%
May	5,848,661	3,874,905	3,702,826	-37%
June	3,472,983	2,765,532	4,389,266	26%
July	4,493,643	3,949,012	5,326,755	19%
August	3,704,483	3,418,118	4,256,527	15%
Subtotal	**31,603,531**	**24,102,571**	**25,660,812**	**-19%**
Percent Change		**-24%**	**6%**	**-19%**
September	4,774,352	4,563,252	-	
October	3,149,370	3,030,392	-	
November	2,188,212	2,447,151	-	
December	1,611,745	1,586,761	-	
Annual Total	**43,327,210**	**35,730,127**	**25,660,812**	

Source: Bureau of Transportation Statistics.

Section 2 – Post-Pandemic Transportation Recovery

For many office workers, the pandemic initiated a long period of work from home. Although some workers went back to the office in 2020 and 2021, many are still working from home. As seen in *Exhibit 11-21*, American Community Survey data shows teleworking was increasing throughout the 2010s across many metropolitan areas.

Exhibit 11-21: Percentage of Teleworkers: Pre-pandemic

Geography	Region	2010	2015	2019
Metropolitan Areas	Atlanta	5.8%	6.7%	9.1%
	Lincoln	3.7%	2.6%	2.9%
	Detroit	3.0%	3.4%	4.4%
	Sacramento	5.5%	5.8%	7.7%
	New York City	3.9%	4.1%	4.8%
	Washington D.C.	4.9%	5.1%	6.3%
	Philadelphia	3.8%	4.3%	5.9%
	Boston	4.4%	4.9%	5.6%
	Los Angeles	5.0%	5.4%	6.3%
	San Francisco	6.2%	6.1%	7.2%
	Seattle	5.5%	5.8%	6.5%
	Dallas	4.6%	5.1%	6.6%
	Chicago	4.5%	4.6%	5.7%
	Phoenix	6.0%	5.9%	7.9%
Nation	**Percentage of Workers**	**4.3%**	**4.6%**	**5.7%**

Note: Telework figures are from 1-year American Community Surveys (ACS).

Source: American Community Survey.

Exhibit 11-22 shows that the pandemic supercharged this steadily increasing trend. During the pandemic, the Bureau of Transportation Statistics (BTS) added a question to its Household Pulse Survey about substituting telework for in-person work due to the pandemic. This source of information is the only national source of data available on teleworking during the pandemic. The data are not a one-for-one comparison to the American Community Survey (ACS) data that report the percentage of workers that work from home, but the BTS does provide data by metropolitan region of households with teleworkers. Since the BTS data report on the percentage of households and ACS reports on the percentage of workers, it is reasonable to assume the 2020 ACS data, when available, will show higher percentages of workers working from home than the BTS data show because some households contain more than one worker teleworking due to the pandemic. Another issue with comparing BTS and ACS is that BTS survey data do not capture the percentage of workers who worked from home before COVID. In the Atlanta region, for example, 9 percent of workers worked from home before the pandemic.

Exhibit 11-22: Households Teleworking Due to the Pandemic

Geography	Region	August 2020	March 2021
Metropolitan Areas	Atlanta	42.10%	50.4%
	Lincoln		
	Detroit	37.70%	41.3%
	Sacramento		
	New York City	45.2%	47.2%
	Washington D.C.	56.3%	59.6%
	Philadelphia	45.4%	49.2%
	Boston	53.9%	53.5%
	Los Angeles	43.3%	41.9%
	San Francisco	52.5%	50.1%
	Seattle	48.7%	47.8%
	Dallas	43.2%	48.1%
	Chicago	44.5%	44.5%
	Phoenix	42.0%	42.0%
Nation	Percent of Workers	36.3%	39.1%

Notes: Telework figures come from the Bureau of Transportation Statistics. The numbers represent people who answered yes to the following question: "Some adult in household substituted some or all of their typical in-person work for telework because of the coronavirus pandemic?" The Bureau of Transportation Statistics does not provide telework figures for Lincoln, NE and Sacramento, CA.

It is not clear when or whether in-person work will return to pre-pandemic levels. The reduced availability of childcare and children not being eligible for the initial vaccine created barriers to returning to the office. Parents can acquire COVID-19 at the office and take it home to their unvaccinated children. It has also taken many months to roll out vaccines across the Nation. Furthermore, throughout the pandemic some office workers have realized that they prefer to work from home, either fully remote or in a hybrid system where they work from home and in the office. Employers have likewise realized some benefits from remote work, including potential savings from reducing office space, increasing productivity, and having happier employees.

These changes have had serious impacts on the transportation system. For decades, transportation planning and engineering have focused on making the system efficient in peak periods when the transportation system is the busiest. For transit agencies, the number of buses and trains they own is predicated on how many they need to meet demand in peak periods.

On a more personal level, many people make decisions about where to live based on the location of their job and choose jobs close to where they live. If telework levels or hybrid work schedules continue, we could see nationwide shifts in housing demand, land use changes, and population shifts. Many people will still be restricted by proximity to daycare and schools, however: these twice-daily trips are expected to occur in the future regardless of telework policies.

In addition to reducing their work trips during the pandemic, people have increasingly opted for telehealth appointments, online learning, and more food delivery. In 2019, the Centers for Disease Control and Prevention (CDC) reported that only 43 percent of health centers were capable of providing telemedicine appointments. Just one year later, in 2020, the CDC reported that 95 percent of health centers had scheduled telehealth appointments.[66] The pandemic forced health providers to embrace technology to provide important health services safely throughout the pandemic. Both patients and providers may find that telehealth better meets

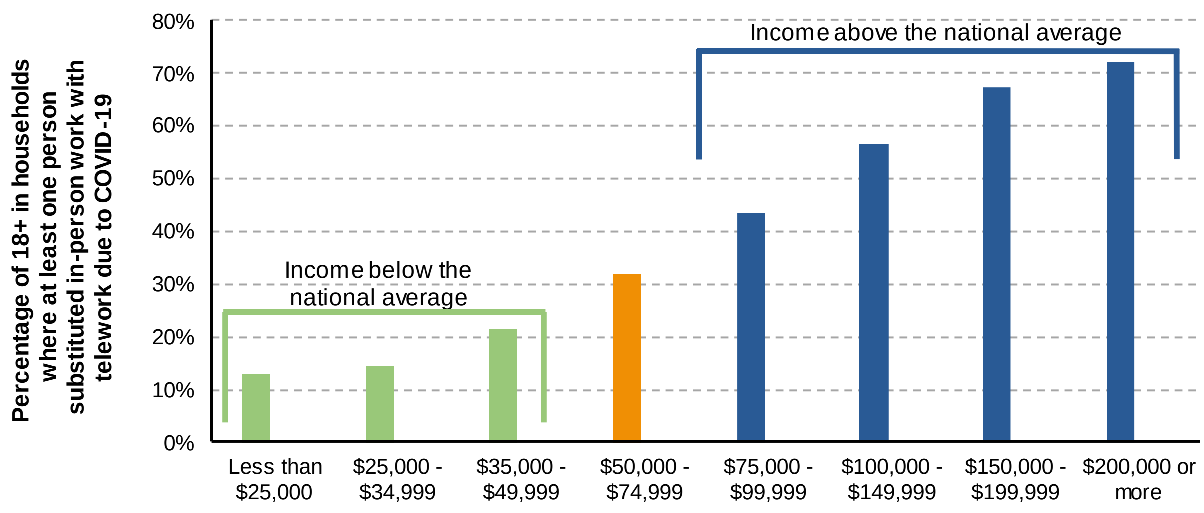
[66] Centers for Disease Control and Prevention, 2021. "Trends in Use of Telehealth Among Health Centers During the COVID-19 Pandemic—United States, June 26–November 6, 2020." February 19, 2021. Available at: https://www.cdc.gov/mmwr/volumes/70/wr/mm7007a3.htm

their needs and organization goals while saving time and money (e.g., for transit fare, gas, and parking). Moving forward, telehealth is expected to account for a larger percentage of appointments compared with pre-pandemic times.

Indoor dining was prohibited at many restaurants during the pandemic, leading restaurants to shift toward carryout and delivery. Although some restaurants provided their own delivery services, some relied on third-party services via smartphone apps. Doordash, one of the third-party apps, reported a 200-percent increase in business between 2019 and 2020.[67] Although food delivery does not ultimately result in fewer trips, it can reduce VMT if the apps match similar food-delivery orders and assign them to one driver.

Although many workers were able to work from home during the pandemic, many essential workers still went to work in person. *Exhibit 11-23* breaks down teleworkers by income bracket during the latter half of August 2020. It shows that higher-income workers were able to take fewer commuting trips during the pandemic and therefore were less affected or not affected at all by transit service cuts and restructuring. Essential workers, many of whom are low-income workers, were the most affected by transit service cuts and restructuring. These workers are the most likely to rely on transit because of their low wages. In the lowest household income bracket, less than $25,000 per year, workers were very likely to be commuting during the pandemic, with only 13 percent of households having a worker who was able to telework at least part of the time. With each higher income bracket, more workers were able to telework. In the highest income bracket, more than $200,000 per year, more than 72 percent of households had at least one worker who substituted telework for in-person work at least part of the time. Overall, workers in 14 percent of households with incomes below the national average were able to substitute some work for telework, compared with 60 percent of households with incomes above the national average.

Exhibit 11-23: Teleworkers by Income



Source: Bureau of Transportation Statistics.

In addition to relying on transit for commuting, low-income workers were more likely to rely on transit for other trips such as getting to the store or obtaining medical services. The BTS also tracked changes in online shopping during the pandemic. It found that household income was a determining factor in online shopping, with lower-income adults making fewer online purchases. Similar to teleworking, adults in higher income bracket were more likely to be shopping online.

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[67] MarketWatch, 2020. "The pandemic has more than doubled food-delivery apps' business. Now what?" November 27, 2020. Available at: https://www.marketwatch.com/story/the-pandemic-has-more-than-doubled-americans-use-of-food-delivery-apps-but-that-doesnt-mean-the-companies-are-making-money-11606340169

Interestingly, these trends are identical for adults who made fewer trips to the store. Low-income households made fewer online purchases and fewer trips to the store. Low-income workers were thus the most affected by COVID-19 in both their commute trips and shopping habits. They purchased less online and traveled to the store less frequently compared with higher-income households.[68]

Transit Equity during the Economic Recovery

Although telework may emerge in the post-pandemic world as a fixture of office work, many employees still need to commute, including most importantly essential employees. This category includes, but is not limited to, employees working in janitorial services, retail, logistics, healthcare, education, personal services, food services, libraries, emergency response, and transportation. Other demographics, including the elderly, youth, and the disabled, are also expected to still need to take physical trips, and may be more reliant on public transit for those trips. As the country emerges from the pandemic, transit agencies may realign service offerings with demand that includes fewer peak trips and more midday, early morning, and late night services that meet the needs of low-income workers, youth, disabled, and the elderly.

As shown in *Exhibit 11-24*, the length of trips people took before the pandemic in April 2019, during the pandemic in April 2020, and during the pandemic recovery in April 2021, changed drastically.

Exhibit 11-24: Travel Changes due to COVID-19

Trip Length in Miles	Description	April 2019	April 2020	April 2021	Two-Year Change
<1	Number of Trips	10,362,419	7,330,376	10,987,633	
	Annual Percent Change		-29%	50%	6%
1–3	Number of Trips	11,142,275	6,994,355	9,575,410	
	Annual Percent Change		-37%	37%	-14%
3–5	Number of Trips	5,355,969	3,194,571	4,891,026	
	Annual Percent Change		-40%	53%	-9%
5–10	Number of Trips	6,732,467	3,875,476	6,203,443	
	Annual Percent Change		-42%	60%	-8%
10–25	Number of Trips	6,680,762	3,690,326	5,804,524	
	Annual Percent Change		-45%	57%	-13%
25–50	Number of Trips	2,135,334	1,223,216	1,833,490	
	Annual Percent Change		-43%	50%	-14%
50–100	Number of Trips	641,406	415,049	623,570	
	Annual Percent Change		-35%	50%	-3%
100–250	Number of Trips	251,940	181,691	263,316	
	Annual Percent Change		-28%	45%	5%
250–500	Number of Trips	57,326	41,391	48,869	
	Annual Percent Change		-28%	18%	-15%
>=500	Number of Trips	47,779	20,539	27,618	
	Annual Percent Change		-57%	34%	-42%
Total		**43,407,678**	**26,966,990**	**40,258,900**	**-7%**

Note: Trips are in thousands.

Source: Bureau of Transportation Statistics.

Between April 2019 and April 2020, trips of all lengths decreased. The steepest decrease was for trips of more than 500 miles in length. In April 2021, trips of all lengths increased over trips taken in April 2020. Overall, between April 2019 and April 2021, some trip lengths surpassed pre-pandemic levels and some were still significantly below pre-pandemic levels. Short trips of less than one mile and longer trips of 100–250 miles increased past their pre-pandemic

[68] Bureau of Transportation Statistics, 2021. "Effects of COVID-19 on In-Person vs. Online Shopping by Race and Income." Available at: https://www.bts.gov/browse-statistical-products-and-data/covid-related/effects-covid-19-person-vs-online-shopping-race

numbers. Trips longer than 500 miles were the slowest to regain their pre-pandemic numbers, with an overall decrease of 42 percent between April 2019 and April 2021. The increase in trips that are 100–250 miles may indicate that people are willing to drive on trips they may have flown for in the past; it also indicates that people may now be taking vacation trips that are closer to home, especially in light of the decrease in trips over 500 miles.

Future Scenarios

Nearly two years into the pandemic, the immediate impacts to the transportation system are clear. What remains unclear is which impacts are temporary and which ones will continue.

Pre-pandemic and During the Pandemic

As outlined in *Exhibit 11-25*, before the pandemic a small percentage of the population was teleworking, transit fares represented about one-third of all transit revenue, and bikeshare and e-scooters were moving large numbers of people across urban areas. During the pandemic, transit ridership plummeted, the number of people teleworking increased dramatically, transit fares ceased to be collected or brought in very little revenue, and bikeshare trips and VMT decreased.

Exhibit 11-25: Future Scenarios

Factors	Pre-pandemic	New Normal
Transit Ridership	4.2 billion	Decline
Percentage of People Teleworking	5.7%	Increase
Transit Revenue	$77.4	Decline
Federal	$14.9	No change
System-Generated	$28.4	Decline
Local	$18.5	No change
State	$15.6	No change
VMT	2,830 billion	No change
Trips on Scooter / Bikeshare	43 million	Increase

Sources: Bureau of Transportation Statistics; National Transit Database; Federal Highway Administration; ACS.

New Normal

If current trends hold, we can expect to see permanent decreases in transit ridership—especially among rail modes and commuter bus. These services may never regain their previous ridership. With decreases in ridership, fare revenue will also have a new baseline much lower than in previous years. This loss of local revenue may force transit agencies to scale back or restructure services. Agencies may also need to develop new strategies to leverage Federal funds and to seek additional State and local funds. All other transit revenue sources are expected to remain relatively stable, including sales taxes and State and Federal funding. If both bikeshare and e-scooters continue their trip trends from the summer of 2021, we can expect these modes to continue to supplant both transit and TNC trips. As more people become accustomed to telework and employers respond to employee desires, a large percentage of workers may continue to work from home or commute only a few days per week. The new commute patterns that emerge in this scenario may be longer commutes from more rural or exurban areas to urban centers that could be served with commuter bus or rail. In a 2021 survey by FlexJobs, 65 percent of respondents said they wanted to work remotely on a permanent basis; about one-third of respondents wanted a hybrid work scheduled with some days at home and some in the office, and less than 5 percent wanted to work in the office full-time.[69]

[69] US DOT, 2020. Presentation on Transportation Challenges Post COVID-19, Nov. 18, 2020.

Section 3 – Financial Impacts of the COVID-19 Pandemic

As the United States continues to emerge from the pandemic, the complete financial implications for the transportation system are not known. However, some trends indicate where we are headed in terms of transportation demand and the infrastructure needed to support that demand. Traditionally, transit agencies have been focused on commute trips in the peaks. In addition to these trips being crucial to supporting urban centers, they also typically serve as the most cost-efficient trips for an agency. Full buses and trains in peak period trips help support less-efficient service in the early morning, midday, and late night. As agencies add more service over the next few years, the service will include peak period trips, but they may ultimately account for a smaller percentage of overall trips.

Many agencies may be forced to both increase fares and offer less frequent service. For agencies continuing to pursue capital investments such as bus rapid transit, these investments may be scaled to fit into future budgets. Also, some agencies may consider adding more infrastructure at bus stops if they maintain reduced headways, which force passengers to wait longer for a bus.

BART and COVID-19 Impacts

- Pre-pandemic farebox recovery ratio was 60 percent.
- Ridership decreased 85 percent due to the pandemic.
- Ridership decreases caused a $37 million loss in revenue per month, combined with other expected revenue source declines, the totally monthly loss is $55 million.
- “Management’s base case projections show ridership gradually recovering to 75 percent of pre-pandemic levels by 2025, which Fitch believes is reasonable. The district’s ridership projections are based on an analysis of the composition of its customer base as well as surveys of employers and riders. The district’s downside case is 59 percent of pre-pandemic ridership, and its upside case is 87 percent of prior ridership.”
- “BART officials expect late summer (2021) to be an inflection point, when widespread vaccination against the coronavirus will begin pushing ridership higher until March 2022, when it is projected to stabilize around 50 percent of pre-pandemic levels.”
- “BART is not on track to return to even 80 percent of its pre-pandemic ridership until the end of the decade.”

As discussed earlier in this chapter, transit agencies are funded through a variety of sources including Federal funds, State funds, sales taxes, vehicle taxes and fees, property taxes, fares, and advertising. The primary Federal funding sources are the Highway Trust Fund and General Fund, which are distributed through many Federal programs. As shown in *Exhibit 11-26*, the Highway Trust Fund – Mass Transit Account receipts fluctuated greatly between 2019 and up to November 2021. Between September 2019 and September 2021, receipts increased by 88 percent—the largest monthly increase over the two-year period. In contrast, receipts declined by 83 percent between April 2019 and April 2021. Overall, the monthly variations in receipts make it too difficult to predict any future trends.

Exhibit 11-26: Highway Trust Fund – Mass Transit Account Receipts

Month	2019	2020	2021	Two-Year Change
January	$446	$491	$437	-2%
February	$479	$463	$413	-14%
March	$477	$412	$355	-25%
April	$471	$385	$81	-83%
May	$402	$86	$441	10%
June	$484	$271	$445	-8%
July	$480	$476	$303	-37%
August	$364	$541	$461	27%
September	$762	$976	$1,434	88%
October	$113	$3,314	$104	-8%
November	$572	$509	$544	-5%
December	$473	$436		

Note: Receipts are in millions.
Source: United States Treasury.

Sales tax serves as one of the largest sources of local funds for transit agencies. Local and state revenue from the top 10 transit agencies decreased by 9 percent from 2019 to 2020, as shown in *Exhibit 11-27*. Some agencies experienced significant revenue loss from local tax revenue during the pandemic: for example, King County Metro in Seattle saw a nearly 64-percent decrease in sales tax and property tax revenue from 2019 to 2020.

Fares are another important local source of transit funding. Some transit agencies suspended fares during the pandemic to reduce interactions with operators. Transit agencies that maintained fares still suffered crippling drops in ridership that made their fare revenue plummet. Overall, fare revenue decreased by 44 percent, from $16 billion to $9 billion, for all transit agencies between 2019 and 2020.

Although Federal funds are important to transit agencies, most come with restrictions, rules, and regulations for spending. One particular regulation is matching Federal funds with local funds. As local funds plummeted, many transit agencies were worried about being able to use their Federal funds. One benefit of the three Federal supplemental funding packages was a loosening of local match requirements. Funding from all three packages can now be used without any local match requirement. This flexibility helped many agencies maintain basic service levels during the pandemic.

Exhibit 11-27: Local and State Revenue Sources for Top 10 Transit Agencies

Local

Agency	Sales and Property			Local General Fund			Other		
	2019	2020	Change	2019	2020	Change	2019	2020	Change
MTA New York	$708	$401	$0	$1,614	$1,573	-3%	$1,035	$636	-39%
Chicago Transit Authority	$508	$449	$0	$5	$5	0%	$78	$209	167%
Los Angeles County Metropolitan Transportation Authority	$1,915	$2,084	$0	$122	$79	-35%	$1	$0	-100%
Massachusetts Bay Transportation Authority	$0	$0		$170	$174	2%	$0	$0	
Washington Metropolitan Area Transit Authority	$0	$0		$1,060	$784	-26%	$0	$0	
Southeastern Pennsylvania Transportation Authority	$0	$0		$244	$123	-50%	$0	$0	
New Jersey Transit Corporation	$0	$0		$0	$0		$16	$2	-89%
City and County of San Francisco	$90	$37	-$1	$603	$564	-6%	$59	$41	-30%
King County Department of Metro Transit	$657	$233	-$1	$0	$0		$62	$56	-11%
San Francisco Bay Area Rapid Transit District	$23	$84	$3	$3	$5	57%	$18	$35	93%
Total	**$3,900**	**$3,288**	**$0**	**$3,821**	**$3,308**	**-13%**	**$1,269**	**$978**	**-23%**

State

Agency	Transportation Fund			State General Fund		
	2019	2020	Change	2019	2020	Change
MTA New York	$3,951	$3,281	-17%	$1,316	$1,377	5%
Chicago Transit Authority	$310	$291	-6%	$20	$20	1%
Los Angeles County Metropolitan Transportation Authority	$529	$845	60%	$73	$43	-41%
Massachusetts Bay Transportation Authority	$1,053	$1,077	2%	$367	$497	35%
Washington Metropolitan Area Transit Authority	$26	$0	-100%	$627	$501	-20%
Southeastern Pennsylvania Transportation Authority	$1,022	$1,051	3%	$0	$0	
New Jersey Transit Corporation	$21	$20	-3%	$1,332	$1,288	-3%
City and County of San Francisco	$228	$192	-16%	$0	$0	
King County Department of Metro Transit	$2	$3	59%	$24	$21	-11%
San Francisco Bay Area Rapid Transit District	$129	$96	-26%	$0	$0	
Total	**$7,270**	**$6,856**	**-6%**	**$3,760**	**$3,749**	**0%**

Local and State Revenue Totals

Agency	2019	2020	Change
MTA New York	$8,624	$7,268	-16%
Chicago Transit Authority	$921	$974	6%
Los Angeles County Metropolitan Transportation Authority	$2,640	$3,051	16%
Massachusetts Bay Transportation Authority	$1,591	$1,749	10%
Washington Metropolitan Area Transit Authority	$1,712	$1,285	-25%
Southeastern Pennsylvania Transportation Authority	$1,266	$1,174	-7%
New Jersey Transit Corporation	$1,369	$1,310	-4%
City and County of San Francisco	$979	$835	-15%
King County Department of Metro Transit	$745	$313	-58%
San Francisco Bay Area Rapid Transit District	$174	$220	27%
Total	**$20,021**	**$18,179**	**-9%**

Note: Revenue is in millions. Other includes tolls.

Source: National Transit Database.

Chapter 12: Greenhouse Gas Mitigation

Greenhouse Gas Mitigation – Highways

Section Summary

- The transportation sector is the largest source of GHG emissions in the United States, accounting for 29 percent of total U.S. GHG emissions as of 2019. On-road vehicles are the primary contributor to U.S. transportation GHG emissions.
- The transportation sector is expected to remain the largest source of U.S. CO_2 emissions through 2050, increasing at an average annual rate of 0.3 percent per year despite improvements in the energy efficiency of light-duty vehicles, trucks, and aircraft.
- Reducing the sector's CO_2 emissions by 50–52 percent below 2005 levels [the nationally determined contribution (NDC) that the United States targeted starting in April 2021] would require year-over-year reductions of almost 6 percent starting in 2022.
- There are three primary routes to reducing GHGs from transportation:
  - Increasing vehicle efficiency;
  - Transitioning to lower-carbon energy, including the sales of electric and alternative fuel vehicles; and
  - Shifting travel and goods movement to more efficient and low- or no-emission modes.

Actions to address climate change are increasingly urgent.[70] The Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report indicates that climate change is already affecting every inhabited region of the globe.[71] The report unequivocally states that human activities have increased atmospheric greenhouse gas (GHG) emission concentrations and resulted in the warming of the atmosphere, oceans, and land, with the average surface temperature having increased by approximately 2 degrees Fahrenheit since the 1800s. The report also points to growing evidence linking human production of GHG emissions to extreme events such as heatwaves, heavy precipitation, droughts, and hurricanes. It notes that every ton of carbon dioxide (CO_2) emissions—the primary human-produced GHG—contributes to climate change and that human-produced GHG emissions already in the atmosphere have assured that global surface temperatures will continue to increase until at least the mid-century even with significant reductions in CO_2 emissions. This warming will result in other changes that are irreversible for centuries to millennia, including the continued melting of mountain and polar glaciers, the loss of ice from the Greenland Ice Sheet, and the continued rise in global mean sea level.

GHG emissions have accumulated rapidly as the world has industrialized, with concentrations of atmospheric CO_2 increasing from roughly 278 parts per million in 1750[72] to 414 parts per million in 2020.[73] Human-produced GHG emissions have increased over this period, with larger absolute increases since 2000 despite a growing number of climate change mitigation policies having

[70] Wuebbles, D.J., D.R. Easterling, K. Hayhoe, T. Knutson, R.E. Kopp, J.P. Kossin, K.E. Kunkel, A.N. LeGrande, C. Mears, W.V. Sweet, P.C. Taylor, R.S. Vose, and M.F. Wehner, 2017. *Climate Science Special Report: Fourth National Climate Assessment, Volume I* [Wuebbles, D.J., D.W. Fahey, K.A. Hibbard, D.J. Dokken, B.C. Stewart, and T.K. Maycock (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, pp. 35-72, doi: 10.7930/J08S4N35. Available at: https://science2017.globalchange.gov/

[71] IPCC, 2021: *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press. In Press.

[72] *Ibid.* at p. 1–56.

[73] National Oceanic and Atmospheric Administration (NOAA), 2021. Trends in Atmospheric Carbon Dioxide. Available at: https://www.esrl.noaa.gov/gmd/ccgg/trends/

been implemented globally.[74] Once released, CO_2 and other GHGs, including methane (CH_4) and nitrous oxide (N_2O), take many years to leave the atmosphere. Atmospheric lifetimes are estimated to be 50–200 years for CO_2, 9–15 years for CH_4, and 120 years for N_2O.[75]

Climate Change Impacts on Transportation

The transportation sector will continue to be at risk from the impacts of climate change and stands to suffer from increases in heavy precipitation, flooding, excessive heat, rising sea levels, more frequent and widespread wildfires, and other extreme events. Impacts from these events threaten to increase the cost of maintaining, repairing, and replacing infrastructure, particularly those assets that are approaching or are beyond their design lives.

Climate impacts also threaten the performance of the entire transportation network as defined by national goals and performance management measures in statute, potentially undermining safety, environmental sustainability, economic vitality and mobility, congestion mitigation, and system reliability goals. Continuing impacts of climate change will not be distributed equally among communities. Disadvantaged communities that have been historically marginalized and overburdened may have a lower capacity to prepare for and recover from climate-related events, and thus will likely be affected more severely and will likely become even more vulnerable to future events.

The combination of long atmospheric lifetimes, increasing GHG emissions, and deforestation has resulted in increased atmospheric concentrations of these gases. The concentration of CO_2 in the atmosphere has increased every year since 1958, the year that measurements began.[76] It is notable that annual increases in emissions concentrations have occurred even when GHG emissions decreased on a year-over-year basis.[77] This phenomenon was demonstrated in 2020 when the global mean CO_2 concentration increased by 2.7 ppm relative to 2019[78] despite a 5.8 percent decrease in global energy-related CO_2 emissions, which represented the largest percentage decline since World War II.[79]

Scientists have made clear that the speed and scale of action needed to address climate change is greater than previously believed. The IPCC has warned that significant and potentially dangerous shifts in climate and weather are possible even at 1.5 degrees Celsius (2.7 degrees Fahrenheit) of global warming beyond preindustrial levels.[80] The IPCC estimates that to limit warming to 1.5 degrees Celsius, global net anthropogenic emissions of GHG emissions, such as CO_2, would need to decrease 45 percent below 2010 levels by 2030, reaching net zero by 2050.[81]

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[74] IPCC, 2014. *Climate Change 2014 Synthesis Report, Summary for Policymakers*. Available at: https://www.ipcc.ch/site/assets/uploads/2018/02/AR5_SYR_FINAL_SPM.pdf

[75] Wuebbles et al., 2017 at pp. 81–83.

[76] Globally averaged CH_4 emissions have been collected and updated monthly since 1983. The atmospheric CH_4 concentration has increased steadily since then. Data for global monthly mean N_2O are reliable starting in 2001. The atmospheric N_2O concentration has increased every year since then. See the NOAA Global Monitoring Laboratory web page at: https://gml.noaa.gov/ccgg/trends_ch4/

[77] NOAA, 2021. Trends in Atmospheric Carbon Dioxide. Available at: https://gml.noaa.gov/ccgg/trends/

[78] *Ibid*.

[79] International Energy Agency, 2021. *Global Energy Review: CO_2 Emissions in 2020*. Available at: https://www.iea.org/articles/global-energy-review-co2-emissions-in-2020

[80] IPCC, 2018. *Summary for Policymakers*, in *Global Warming of 1.5°C. An IPCC Special Report*. Available at: https://www.ipcc.ch/sr15/chapter/spm

[81] IPCC, 2021. *Special Report: Global Warming of 1.5°C*. Available at: https://www.ipcc.ch/sr15/chapter/chapter-1/

Executive Order 14008, "Tackling the Climate Crisis at Home and Abroad,"[82] acknowledges the urgency of pursuing action to avoid the most catastrophic impacts of the climate crisis and recommits the United States to the Paris Agreement, which has a goal of limiting global warming to preferably 1.5 degrees Celsius (2.7 degrees Fahrenheit) compared to preindustrial levels.[83] In addition, the United States has set a target to reduce economy-wide net CO_2 emissions by 50–52 percent by 2030 compared to 2005 levels, and aims to reach net zero emissions economy-wide by 2050.

Transportation's Contribution to GHG Emissions

Transportation is currently the largest source of GHG emissions in the United States, having surpassed emissions from electricity generation in 2016. The transportation sector accounted for 28.5 percent of total U.S. GHG emissions (1,871.7 out of 6,558.3 Tg CO_2e) and 34.6 percent of total U.S. CO_2 emissions as of 2019. U.S. transportation sources are also responsible for GHG emissions through other life-cycle processes, including the production and distribution of fuels; the manufacture, delivery and disposal of vehicles; and the construction and maintenance of transportation infrastructure. These indirect emissions sources are generally represented in other sector totals if they occur in the United States, or in other national inventories if they occur outside U.S. boundaries.

On-road vehicles (including cars, light-duty trucks, and freight trucks) are the primary contributors to U.S. transportation GHG emissions, accounting for over 83.1 percent of the sector's total in 2019. Light-duty vehicles represent 69.7 percent of total transportation GHG emissions (1,085.4 out of 1,871.7 Tg CO_2e), and medium- and heavy-duty vehicles account for 23.7 percent (444.4 out of 1,871.7 Tg CO_2e) (see *Exhibit 12-1*).

Exhibit 12-1: U.S. On-Road Vehicle GHG Emissions (Tg CO_2 Equivalent), 1990–2019

Type	Source	1990	2005	2015	2016	2017	2018	2019
On-Road	Light-Duty Vehicles	966.3	1,229.4	1,073.4	1,093.7	1,084.9	1,096.0	1,085.4
	Medium- and Heavy-Duty Trucks	230.3	404.1	413.9	417.9	431.4	442.1	444.4
	Motorcycles	1.7	1.6	3.7	3.9	3.8	3.8	3.6
	Buses	8.5	12.3	19.6	19.1	20.6	22.0	22.2
	Total On-Road	1,206.8	1,647.4	1,510.6	1,534.6	1,540.7	1,563.9	1,555.6
Non-Road	Aircraft	189.2	193.7	160.5	169.0	174.8	175.5	181.1
	Ships and Boats	47	45.4	33.8	40.8	43.9	41.2	40.4
	Rail	39	51.5	44.1	40.3	41.5	43.3	40.8
	Pipelines	36	32.4	38.5	39.2	41.3	49.9	53.7
Total Transportation		**1,517.9**	**1,970.2**	**1,787.5**	**1,823.9**	**1,842.2**	**1,873.8**	**1,871.7**
Total, All Sectors		**6,442.7**	**7,423.0**	**6,671.1**	**6,520.3**	**6,483.3**	**6,671.4**	**6,558.3**

Source: Adapted from U.S. EPA's Fast Facts, U.S. Transportation Sector Greenhouse Gas Emissions 1990–2019.

On-road vehicles have been among the fastest growing sources of GHG emissions in the United States since 1990, the first year of official estimates. A number of factors and policies have influenced on-road transportation GHG emissions.

Between 1990 and 2005, on-road GHG emissions increased by 36.5 percent, driven by rapid increases in both light- and heavy-duty travel. Over this timeframe, light-duty vehicle miles traveled (VMT) increased at an average rate of 2.1 percent per year, and medium- and heavy-duty truck VMT increased by an average of 2.6 percent per year. The growth in travel demand significantly outweighed modest improvements in the overall fuel efficiency of the overall fleet.

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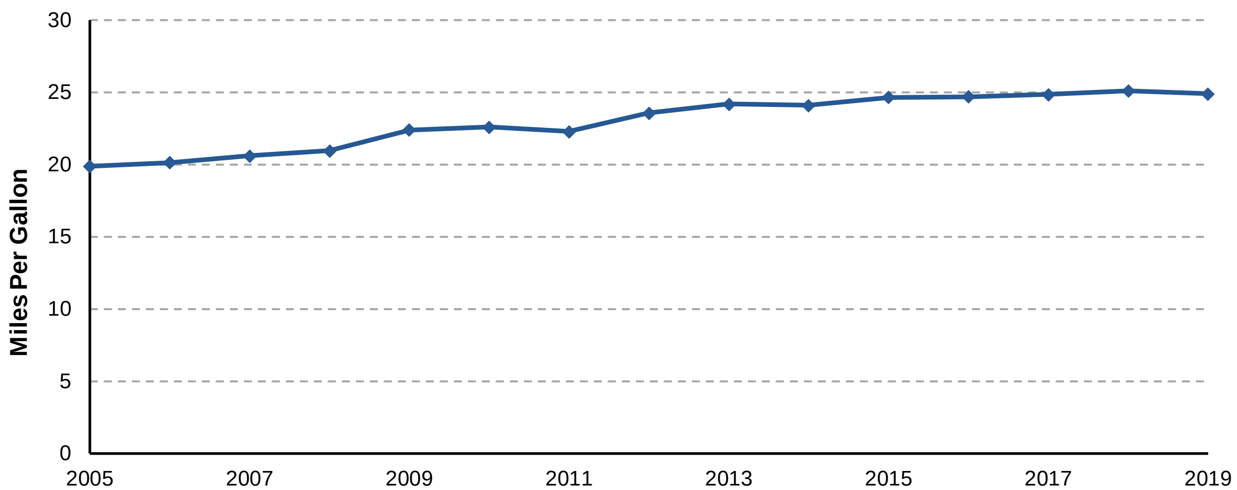
[82] Executive Order 14008, 2021. *Tackling the Climate Crisis at Home and Abroad*. January 27, 2021. 86 FR 7619, pp 7619-7633. Available at: https://www.federalregister.gov/documents/2021/02/01/2021-02177/tackling-the-climate-crisis-at-home-and-abroad

[83] U.S. Department of State, 2021. *U.S.-China Joint Statement Addressing the Climate Crisis*. Available at: https://www.state.gov/u-s-china-joint-statement-addressing-the-climate-crisis/

Notably, the fuel efficiency of *new* vehicles declined over this period, as sales of passenger cars were overtaken by those of light-duty trucks, including pickup trucks, minivans, and sport utility vehicles.

On-road GHG emissions subsequently declined by 8.3 percent from 2005 to 2015. During this timeframe, light-duty VMT increased at a significantly diminished rate of only 0.1 percent per year. Travel demand was influenced by high fuel prices for much of the period, decreasing growth in vehicle ownership (particularly among younger drivers), and other factors. Meanwhile, the tightening of light-duty vehicle fuel economy standards, along with higher fuel prices, increased the average fuel economy of new light-duty vehicles from 19.9 miles per gallon (mpg) to 24.6 mpg in 2015 (see *Exhibit 12-2*). Higher fuel prices also helped to push the fuel efficiency of heavy-duty vehicles higher—from 6.0 mpg to 6.6 mpg—although VMT of medium- and heavy-duty continued to grow at an average annual rate of more than 2.3 percent. Lastly, the implementation of a Federal renewable fuel standard, a program authorized under the Energy Policy Act of 2005 and expanded under the Energy Independence and Security Act of 2007, significantly increased the amount of ethanol in gasoline blends. In accordance with international GHG accounting principles, tailpipe CO_2 emissions from the combustion of biofuels are not included in transportation sector totals.[84]

Exhibit 12-2: Fuel Economy of New Light-Duty Vehicles, 2005–2019



Source: The 2021 EPA Automotive Trends Report: Greenhouse Gas Emissions, Fuel Economy, and Technology since 1975, Table 3.1.

Between 2015 and 2019, on-road GHG emissions once again reversed direction, increasing by 3.0 percent. By 2015, almost all gasoline consumed in the United States contained 10 percent ethanol, representing the current “blend wall” for light-duty vehicle consumption of ethanol, meaning that additional amounts of biofuel cannot be blended into most motor fuels because of potential harm to the engines of older vehicles. Additionally, lower fuel prices caused new light-duty vehicle buyers to favor less-efficient vehicles, significantly slowing improvements in the efficiency of the overall light-duty fleet. Lastly, light-duty VMT increased at an annual rate of 1.3 percent and medium and heavy-duty VMT increased at an annual rate of 1.8 percent, which more than offset marginal fuel efficiency improvements in the light- and heavy-duty fleets.

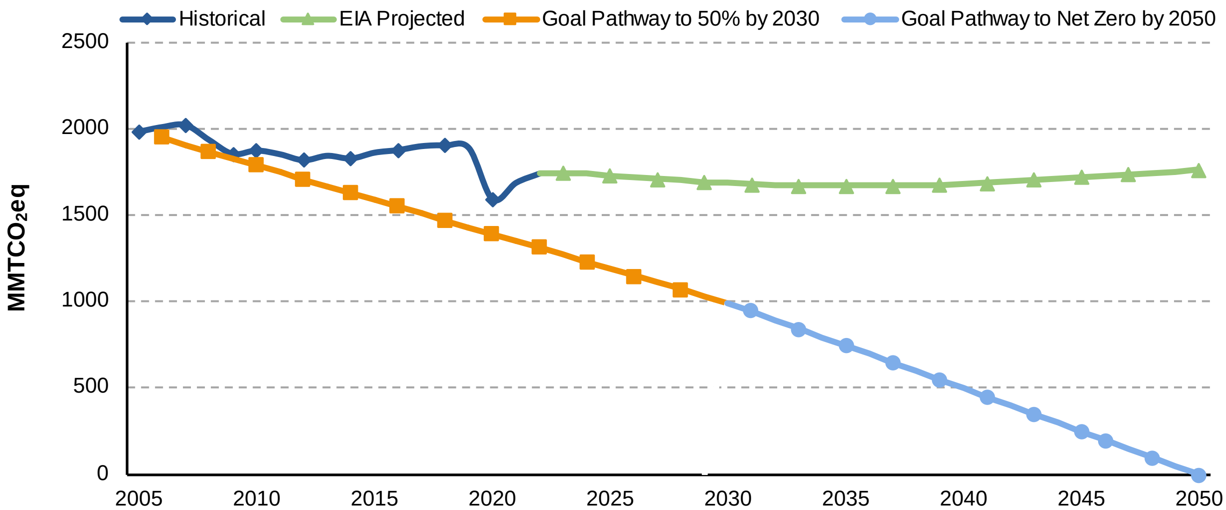
Accounting for GHG reduction policies in place at the end of 2020, the transportation sector is expected to remain the largest source of U.S. CO_2 emissions through 2050, increasing at an

[84] CO_2 emissions from the combustion of biofuels and biofuel additives are excluded from the calculation of source totals since it is assumed that CO_2 released during the combustion of biomass is recycled as forests and crops regenerate. The impact of land-use and forestry activity is reflected in the Land-Use Change and Forestry category and is assumed to be zero unless agricultural practices are unsustainable or lead to a land-use change.

average annual rate of 0.3 percent per year despite improvements in the energy efficiency of light-duty vehicles, trucks, and aircraft.[85]

By contrast, reducing the sector's CO_2 emissions by 50–52 percent below 2005 levels, which is the nationally determined contribution (NDC) that United States targeted starting in April 2021, would require year-over-year reductions of almost 6 percent starting in 2022 (see *Exhibit 12-3*). This rate of improvement would be approximately seven times greater than what was achieved in reducing on-road vehicle GHG emissions between 2005 and 2015. Achieving reductions of this magnitude would require a reversal of several trends, including consumers' increasing preference for larger and less-efficient vehicles, the increasing lifetime of vehicles on the road, the growth in light-duty VMT, and the long-term growth in demand for freight trucking. Vehicles on the road in 2030 would ultimately need to be far more efficient than the current vehicle fleet and operate on energy that is far less carbon-intensive.[86] This outcome would require that low-carbon vehicles enter the fleet significantly faster than new vehicles are currently entering the market. It would also require a reduction or elimination of "leakage," whereby sales of zero-emission vehicles (ZEVs) and high-efficiency vehicles in one area are correspondingly offset by sales of less-efficient vehicles under the Corporate Average Fuel Economy Program. Even with rapid deployment of low-carbon vehicles and significant improvements in vehicle fleet efficiency, reducing transportation CO_2 emissions by 50–52 percent could additionally depend on significant reductions in the VMT of light-, medium-, and heavy-duty vehicles. These outcomes are more likely to be realized with the aggressive implementation of a wide range of complementary policies across all levels of government.

Exhibit 12-3: Projected Transportation Sector Energy-related CO_2 Emissions Compared to Net Zero Goal



Source: U.S. Energy Information Administration, Annual Energy Outlook 2006 through 2021, Reference Case Table 18. Carbon Dioxide Emissions by Sector and Source. Projections: EIA, AEO2021 National Energy Modeling System run ref 2021.d113020a.

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[85] U.S. Energy Information Administration, 2021. *Annual Energy Outlook 2021*. Available at: https://www.eia.gov/outlooks/aeo/tables_ref.php

[86] The National Academies Press, 2013. *Transitions to Alternative Vehicles and Fuels*. Available at: https://www.nap.edu/catalog/18264/transitions-to-alternative-vehicles-and-fuels

Responding to the Climate Challenge

There are four primary routes to reducing GHGs from transportation:

1. Increasing vehicle fuel efficiency;
2. Transitioning to lower-carbon transportation energy sources, including electric and alternative fuel vehicles;
3. Shifting travel and goods movement to more efficient and low- or no-emission modes; and
4. Reducing travel distances through more efficient land-use patterns, such as increased density and mixed-use development.

Transportation agencies may also help reduce transport sector GHGs by changing how transport systems operate, how construction and maintenance practices for transportation infrastructure are carried out, and how their own agency operations are conducted.

Federal programs and policies to mitigate GHG emissions from the transportation sector have evolved over recent years.

Fuel Economy Standards

The U.S. Department of Transportation (DOT) establishes Corporate Average Fuel Economy (CAFE) standards that regulate fuel economy standards for LDVs (i.e., passenger cars and light trucks) and for medium- and heavy-duty trucks.

In December 2021, the National Highway Traffic Safety Administration (NHTSA) finalized CAFE standards for passenger cars and light trucks manufactured in model years 2024–2026 that would reverse a rollback of standards under the 2020 Safe Affordable Fuel Efficient Vehicles rule and could restore standards originally established for model year 2025 vehicles as part of a 2012 rule. Similarly, in 2021, the U.S. Environmental Protection Agency (EPA) began efforts to increase Federal GHG emissions and fuel economy standards for medium- and heavy-duty trucks starting in model year 2027.

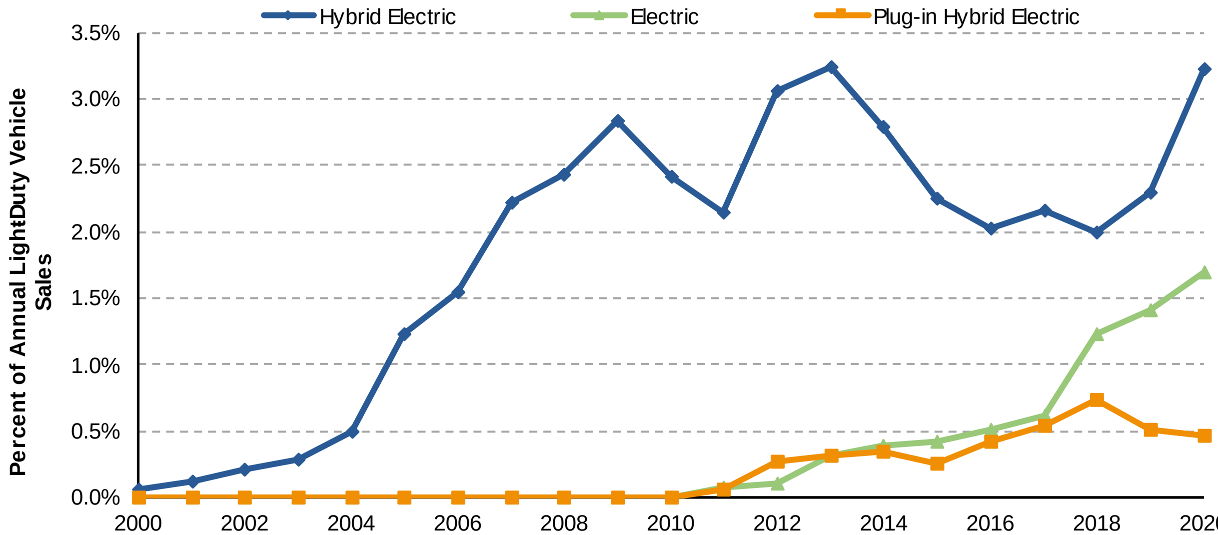
Supporting ZEVs and Other Alternative Fuel Vehicles

Depending upon how they are produced, alternative fuels can reduce CO_2 emissions compared with gasoline. Thus, increasing the use of alternative fuels, including electricity, biodiesel, and compressed natural gas, among others, provides an opportunity to lower GHG emission from the transportation sector. Electric vehicles (EVs) are inherently more efficient than internal combustion engine vehicles, especially when the electricity from which they are charged is generated from a low-carbon fuel source. The degree to which the electricity grid has been decarbonized varies from region to region in the United States.

California established a ZEV regulation requiring auto manufacturers to offer for sale specific numbers of ZEVs, including full battery-electric, hydrogen fuel cell, and plug-in hybrid EVs. Following California's lead, 10 States have since adopted the ZEV regulations (Colorado, Connecticut, Maine, Maryland, Massachusetts, New Jersey, New York, Oregon, Rhode Island, and Vermont). By requiring automakers to invest in clean technology, the ZEV program is considered a key driving force behind the expanding EV market. Additional Federal and State policies, such as rebates and tax credits, access to high-occupancy vehicle lanes, and other incentives, have also influenced EV adoption. These programs have been critical in increasing the market share of battery-electric and plug-in hybrid vehicles, which combined accounted for two percent of light-duty vehicle sales in 2020. Hybrid EVs represented over three percent of light-duty vehicle sales (see *Exhibit 12-4*).

One of the primary obstacles to more widespread adoption of EVs is the limited network of EV charging stations, including along highway corridors throughout the National Highway System and in communities, especially rural and disadvantaged communities. As such, supporting alternative fuel vehicles will require substantial increases in the availability of public alternative fueling and charging infrastructure. The Bipartisan Infrastructure Law (BIL), enacted as the Infrastructure Investment and Jobs Act (IIJA), Pub. L. 117-58 (Nov. 15, 2021), provides $7.5 billion in funding to build out a national network of EV charges along highway corridors to facilitate long-distance travel and within communities. This investment builds upon the ongoing work of FHWA's Alternative Fuels Corridors initiative,[87] which is helping to establish a national network of alternative fueling and charging infrastructure along National Highway System corridors. The purpose of the program is to add visibility to sections of the National Highway System that can sustain long-distance travel for alternative fuel vehicles. Once FHWA designates these corridors, States may install Alternative Fuel Corridor signs along the designated highway corridor. Since its inception in 2016, the Alternative Fuels Corridor Program has designated more than 165,000 miles of the National Highway System, including portions of 134 Interstates and 125 U.S. highways and State roads, in 49 States and Washington, DC. FHWA also coordinated with several State Departments of Transportation to develop the Alternative Fuel Toolkit,[88] which provides resources to help stakeholders deploy alternative fuels and vehicle infrastructure.

Exhibit 12-4. U.S. EVs Sales, 2000–2020



Source: U.S. Department of Energy, Energy Vehicle Technologies Office, Oak Ridge National Laboratory, Transportation Energy Data Book, Edition 39, Table 4.6, Table 4.7, and Table 6.2, available at https://tedb.ornl.gov/data/ as of May 19, 2021.

Transportation Planning

State and local transportation planning, as well as land use policy, can reduce overall emissions from the transportation system. Planning and policy can be used to improve the convenience and efficiency of the transportation system by better connecting origins and destinations, reducing travel distances, and increasing access to less emission-intensive modes (such as biking and transit). The benefits of these efforts include reduced congestion, VMT, and GHG emissions.

A growing number of transportation and regional planning agencies are considering climate change as part of their project evaluation and selection processes. For example, the Atlanta Regional Commission uses a series of performance criteria to evaluate and prioritize transportation projects in its regional transportation plan. One of its key performance criteria is air quality and climate change, which considers changes in GHG emissions. Similarly, the Broward metropolitan planning organization (MPO) evaluates and scores candidate projects

[87] https://www.fhwa.dot.gov/environment/alternative_fuel_corridors/

[88] http://altfueltoolkit.org/home/about/

against prioritization criteria. The prioritization criteria, which are based on the metropolitan transportation plan goals and objectives, include a metric for GHG and precursor emissions. U.S. DOT is also considering climate change in its investment decisions: in Fiscal Year 2021, the Department made climate change a key metric in its Rebuilding American Infrastructure with Sustainability and Equity (RAISE) grants, a $1 billion discretionary funding program.

Transportation, Climate, and Equity

Many disadvantaged communities have been historically marginalized and overburdened by pollution and underinvestment in housing and transportation. Justice40 is intended to help address these disparities by implementing a whole-of-government effort to ensure that Federal agencies work with States and local communities to deliver at least 40 percent of the overall benefits from Federal investment in climate and clean energy to disadvantaged communities. Policies and programs to reduce GHG emissions can help alleviate inequities by improving air quality and enhancing access to transportation options, including public transportation services and bicycle and pedestrian infrastructure.

Several States are pursuing programs that reduce GHG emissions and provide funding for transportation projects and programs that support climate and equity goals. Examples include:

- **California's Climate Action Plan for Transportation Infrastructure**: In July 2021, California adopted the Climate Action Plan for Transportation Infrastructure (CAPTI), which serves as a framework for State agencies responsible for transportation to align their planning, project development, and programming decisions, processes, and policies with the State's commitment to addressing the climate crisis as well as health and social equity goals.[89] The framework outlines a set of guiding principles for investment that are intended to reduce Californians' dependence on driving, increase multimodal options for all communities, and equitably meet the State's climate goals. In 2008, California passed **Senate Bill 375** which requires each of the State's MPOs to develop a Sustainable Community Strategy to illustrate how integrated land use, transportation, and housing planning will achieve regional GHG emission reduction targets.[90]
- **Transportation & Climate Initiative:** The Transportation & Climate Initiative is a regional collaboration of Northeast and mid-Atlantic States and the District of Columbia to reduce carbon emissions from the transportation sector. One of the initiative's key efforts is the development of a multijurisdictional cap-and-invest program, consisting of individual programs adopted and implemented under the independent legal authority of "Signatory Jurisdictions," designed to ensure reductions in CO_2 emissions from the transportation sector. Each Signatory Jurisdiction, in its discretion, will seek to invest strategically in lower-carbon transportation options and other investments. The jurisdictions have committed to invest at least 35 percent of proceeds to ensure that communities overburdened by pollution and underserved by the transportation system benefit equitably from clean transportation projects and programs.
- **Colorado's Proposed Greenhouse Gas Pollution Reduction Planning Standard:** In December 2021, the Colorado Department of Transportation (CDOT) established a new standard focused on using the transportation planning process to reduce GHG emissions from the transportation sector. The GHG Transportation Planning Standard requires CDOT and the State's five MPOs to determine the expected change in total pollution and GHG emissions from future transportation projects and to take steps to ensure that GHG emission

[89] California State Transportation Agency, 2021. *Climate Action Plan for Transportation Infrastructure*. Available at: https://calsta.ca.gov/-/media/calsta-media/documents/capti-july-2021-a11y.pdf

[90] California Air Resources Board. *Research on Land Use and Transportation Planning*, Available at https://ww2.arb.ca.gov/research/research-land-use-and-transportation-planning.

levels do not exceed set reduction amounts. To comply with the planning standard, CDOT and the MPOs must establish plans that meet GHG transportation reduction targets through a mix of transportation projects that limit and mitigate air pollution and improve quality of life and multimodal options. In the event that a plan fails to comply, CDOT and MPOs have the option to commit to GHG mitigation measures that provide travelers with cleaner and more equitable transportation options such as safer pedestrian crossings and sidewalks, better transit and better access to transit, or infrastructure that supports access to housing, jobs, and retail. If compliance still cannot be demonstrated even after committing to GHG mitigation measures, the Transportation Commission of Colorado will restrict the use of certain funds, requiring that dollars be focused on projects and approved GHG mitigation measures that help reduce transportation emissions and are recognized as approved mitigations.

- **Massachusetts Bay Transportation Authority (MBTA) Multi-Family Zoning Requirement:** In August 2022, Massachusetts began requiring that an MBTA community (excluding Boston) have at least one zoning district in which multi-family housing is permitted.[91] This community shall have a minimum gross density of 15 units per acre and must be located not more than half a mile from a commuter rail station, subway station, ferry terminal or bus station. This policy aims to promote transit-oriented development while also increasing multi-family housing accessibility. The intent is to provide better accessibility, increased mobility and utilization of transit, and reduced reliance on single-occupancy vehicles.

Transportation Investment Programs

Federal investments play an important role in shaping the Nation's transportation infrastructure. The Infrastructure Investment and Jobs Act (IIJA), also known as the "Bipartisan Infrastructure Law (BIL)," which was signed into law on November 15, 2021, provides record investments supporting a more equitable and climate-friendly transportation system for Fiscal Years 2022–2026. Key elements of the legislation that will help to reduce GHG emissions from the transportation sector include:

- Establishing a $7.5 billion grant program to strategically deploy publicly accessible EV charging and alternative fueling infrastructure along highway corridors.
- Establishing a $6.4 billion Carbon Reduction Program, which supports projects to reduce on-road CO_2 emissions, as well as the development of a carbon reduction strategy by each State in coordination with MPOs.
- Providing funding to school districts to purchase zero- and low-emission school buses.
- Providing $89.9 billion in guaranteed funding for public transit over five years. This includes funding to expand public transit options and purchase clean ZEVs.
- Investing $66 billion in passenger rail service, providing a climate-friendly alternative for moving people and freight.
- Providing funding for electric grid modernization that will facilitate the expansion of renewable energy and support the growing EV market.

FHWA Climate Resources

FHWA provides technical assistance, resources, and tools to support State, regional, and local agencies in incorporating climate change considerations into transportation planning and investment decisions. Example resources include:

- FHWA's Handbook for Estimating Greenhouse Gas Emissions[92] is designed to provide information on how to analyze on-road GHG emissions at the State and regional level, and how State DOTs and MPOs can incorporate those analyses into transportation plans.

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[91] Commonwealth of Massachusetts. https://www/mass.gov/info-details/multi-family-zoning-requirements-for-mbta-communities

[92] https://www.fhwa.dot.gov/environment/sustainability/energy/publications/ghg_handbook/index.cfm

- FHWA's Energy and Emissions Reduction Policy Analysis Tool,[93] or "EERPAT," is an integrated, State-level modeling system designed to evaluate strategies for reducing surface transportation GHG emissions and energy consumption. Policy options include local planning and operations strategies, EVs, low-carbon fuels and various pricing measures.
- The Congestion Mitigation and Air Quality (CMAQ) Emissions Calculator Toolkit[94] is a suite of spreadsheet-based tools to facilitate the calculation of air quality benefits—including GHG emission reduction benefits—from a variety of project types. The toolkit covers a wide range of project types, from alternative fuel vehicles to managed lane facilities.
- The Infrastructure Carbon Estimator Version 2.1 (ICE)[95] is a spreadsheet tool that estimates the life cycle energy and GHG emissions from the construction and maintenance of transportation facilities. It is intended to inform planning and pre-engineering analysis and can be used to identify alternative plans or projects that would result in lower GHG emissions. The tool also provides simple estimates of the emissions reduction benefits of a variety of mitigation strategies.

The Joint Office of Energy and Transportation was created through the Bipartisan Infrastructure Law, also known as the Infrastructure Investment and Jobs Act, to facilitate collaboration between the U.S. Department of Energy and the U.S. Department of Transportation. The Joint Office will provide technical assistance to State DOTs to support implementation of the National Electric Vehicle Infrastructure (NEVI) program, along with support for other programs that seek to deploy a network of electric vehicle chargers, zero-emissions fueling infrastructure and zero-emission transit and school buses.

[93] https://cleanenergysolutions.org/es/resources/energy-emissions-reduction-policy-analysis-tool#:~:text=The%20Energy%20and%20Emissions%20Reduction,measure%20the%20reduction%20potential%20of

[94] https://www.fhwa.dot.gov/environment/air_quality/cmaq/toolkit/

[95] https://www.fhwa.dot.gov/environment/sustainability/energy/tools/carbon_estimator/

Greenhouse Gas Mitigation – Transit

SECTION SUMMARY

In 2018, the use of public transportation avoided 75 million metric tons of GHG emissions while producing only 12 million metric tons.

APTA reports 6,256 hybrid electric buses (18 percent of the fleet), 269 battery electric buses (<1 percent), and approximately 40 fuel cell electric buses in active service (<0) in 2019.

Strategies to support the deployment of alternative fuel vehicles include:

- The acquisition, installation, or operation of publicly accessible electric vehicle charging infrastructure or hydrogen, natural gas, or propane vehicle fueling infrastructure; and
- The purchase or lease of zero-emission construction equipment and vehicles, including the acquisition, construction, or leasing of required supporting facilities.

The transportation sector is currently the largest source of greenhouse gas (GHG) emissions in the United States, contributing 29 percent of the country's total emissions, 83 percent of which comes from cars and trucks. Public transit plays an invaluable role in reducing emissions by decreasing personal vehicle use. In 2018, the use of public transportation avoided 75 million metric tons of GHG emissions while producing only 12 million metric tons.[96]

Transit can do more, though, in reducing overall GHG emissions nationwide. President Biden's Executive Order 14008, "Tackling the Climate Crisis at Home and Abroad," commits to deploying a government-wide approach to reach net zero emissions economy-wide by 2050. The Federal Transit Administration (FTA) is committed to achieving this goal by providing the support and resources needed to create a modern transit fleet that can reduce the environmental impacts of transportation.

The passing of the Bipartisan Infrastructure Law (BIL), enacted as the Infrastructure Investment and Jobs Act (IIJA), Pub. L. 117-58 (Nov. 15, 2021), provides critical resources and a framework to support public transit systems' transition to net zero emissions by 2050. One of the most pressing issues for FTA is to provide the necessary resources and initiatives to reduce the level of GHG emissions within the Nation's transit fleets.

Existing State of the National Public Transportation Fleet

Buses are the predominant vehicles used by the nation's transit agencies. According to the American Public Transportation Association (APTA) Vehicle Database, less than half (approximately 42 percent) of all buses in 2019 were diesel-powered; approximately 28 percent were either compressed natural gas, liquefied natural gas, or some blend; 18 percent were hybrid-electric buses; and the remaining 12 percent ran on gasoline, biodiesel, or other fuel types. Transit agencies are deploying battery electric buses in small numbers but at a rapidly increasing rate, a trend expected to continue. Transit buses that operate on hydrogen fuel cells are also being integrated into transit fleets. In terms of national fleet numbers, APTA reports 6,256 hybrid electric buses (18 percent of the fleet), 269 battery electric buses (<1 percent), and approximately 40 fuel cell electric buses in active service (<1 percent).[97]

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[96] Transportation Research Board, 2021. *TCRP Research Report 226: An Update on Public Transportation's Impacts on Greenhouse Gas Emissions*. Available at: https://www.trb.org/Main/Blurbs/181941.aspx

[97] American Public Transportation Association (APTA), 2019. *Policy Brief: Public Transit Leading in Transition to Clean Technology.* Available at: https://www.apta.com/research-technical-resources/research-reports/public-transit-leading-in-transition-to-clean-technology/

The National Transit Database provides annual updates of vehicle types and their propulsion technologies. *Exhibit 12-5* and *Exhibit 12-6* provide an overview of the fuel types, and numbers of vehicles by transit mode in the United States.

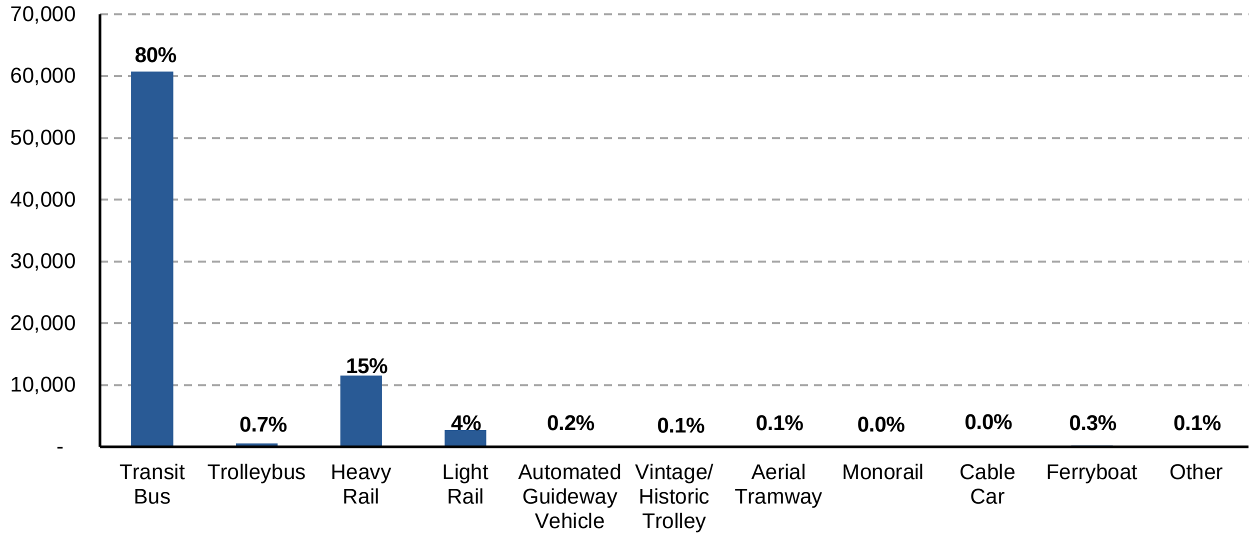
Exhibit 12-5: Fuel Type Use by Transit Mode

Vehicle Type	Diesel	Gasoline	Liquefied Petroleum	Compressed Natural Gas	Biodiesel	Other Fuel	Electric Propulsion (kWh)	Electric Battery (kWh)
Bus	305,423.3	8,800.1	1,456.0	165,842.6	30,625.0	1,458.3	62,014.5	28,471.1
Demand Response	5,179.4	65,145.8	6,569.0	6,132.6	714.5	445.6		59.0
Vanpool	0.3	9,930.3			2.4	0.0		69.1
Ferry	37,116.0				3,566.1			
Rail	106,886.2				1,231.4		6,079,985.6	
Other							27,543.4	
Total	**454,605.2**	**83,876.1**	**8,025.0**	**171,975.2**	**36,139.4**	**1,903.8**	**6,169,543.5**	**28,599.1**

Notes: Values for diesel, gasoline, liquefied petroleum, compressed natural gas, biodiesel, and other fuels are shown in thousands of gallons. Values for electric propulsion (kWh) and electric battery (kWh) are shown in thousands of kWh. The "Other" vehicle type includes cable car, inclined plane, monorail, and aerial tramway.

Source: National Transit Database.

Exhibit 12-6: Number of Vehicles by Mode



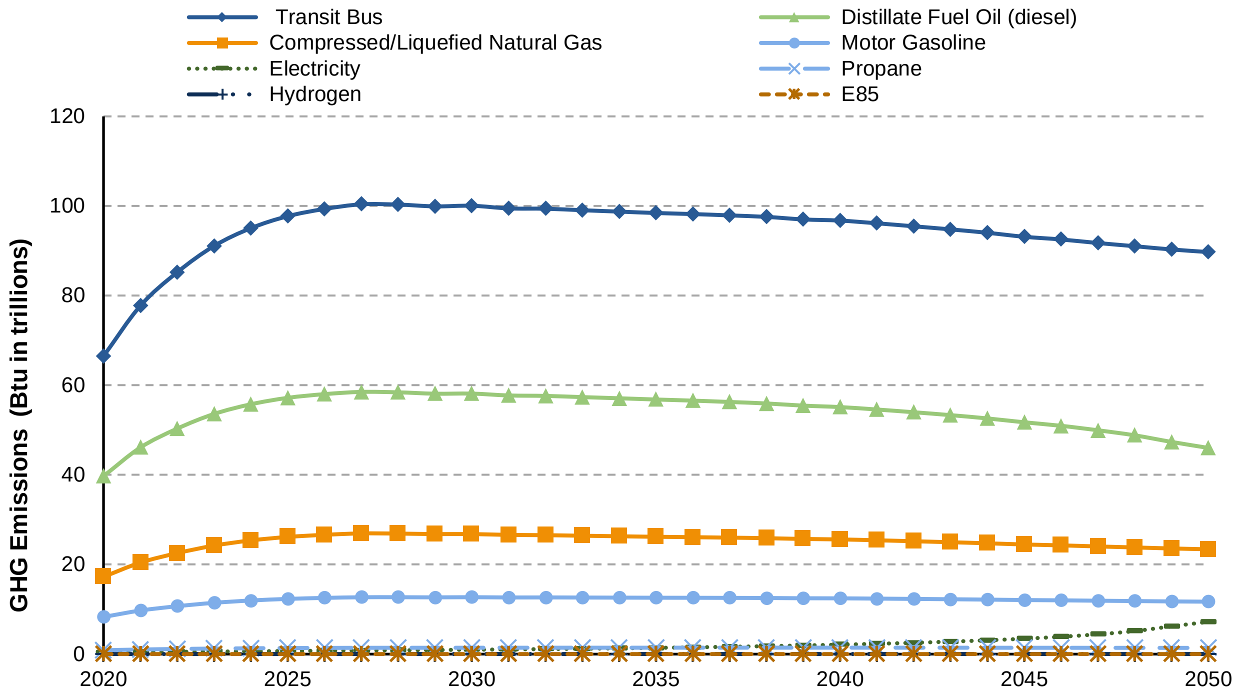
Source: National Transit Database.

Exhibit 12-7 represents existing and forecasted GHG emissions from the country's transit fleets.

Exhibit 12-8 shows existing and forecasted GHG emissions from transit rail.

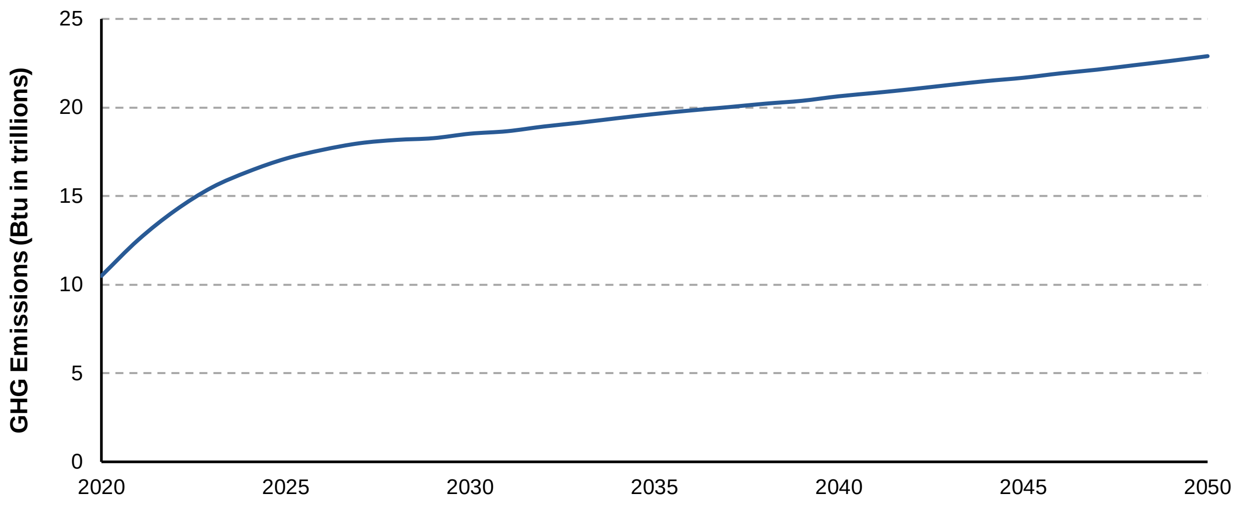
In light of new legislation such as the Infrastructure Investment and Jobs Act in 2021 along with programs continuing under the Surface Transportation Reauthorization Act, it will be incumbent upon FTA to further the adoption of low- and zero-emission vehicles and assets.

Exhibit 12-7: GHG Emissions for Transit Bus by Fuel Type (2020–2050)



Sources: FHWA; EIA Annual Energy Outlook 2021.

Exhibit 12-8: GHG Emissions for Transit Rail (2020–2050)



Note: The only fuel type for transit rail is electricity.
Sources: FHWA; EIA Annual Energy Outlook 2021.

FTA GHG Mitigation and Climate Change Resources

FTA has provided opportunities for local stakeholders to research, understand, and plan for GHG mitigation and adaptation initiatives to reduce the environmental impacts of transit. Multiple tools and initiatives are available to drive public transit commitments on climate change, as well as a new workforce technical assistance program to support sustainability. FTA continues to assess programmatic ways to drive effective responses to climate change.

One valuable resource available to transit agencies, State partners, and the public is FTA's Transit Greenhouse Gas Emissions Estimator, a Microsoft Excel-based tool that allows users to estimate the partial lifecycle GHG emissions generated from the construction, operation, and maintenance phases of a project across select transit modes. Users input general information about a project and the tool calculates annual GHG emissions by project phase. The tool, which was developed in connection with the FTA Greenhouse Gas Emissions from Transit Projects Programmatic Assessment, generates coarse but informative estimates of GHG emissions using limited project information and can be used for a broad range of transit projects. Transit agencies should work with the appropriate FTA regional office to determine whether to conduct project-specific analyses of GHG emissions and the best approaches for developing emissions estimates.[98]

Transit Oriented Development (TOD) reduces GHG emissions through comprehensive land-use planning strategies that prioritize compact development and allow for a low-carbon lifestyle. FTA's Pilot Program for TOD Planning provides funding to communities to integrate land use and transportation planning in new fixed-guideway and core-capacity transit project corridors. As required by statute, any comprehensive planning funded through the pilot program must examine ways to improve economic development and ridership, foster multimodal connectivity and accessibility, improve transit access for pedestrian and bicycle traffic, engage the private sector, identify infrastructure needs, and enable mixed-use development near transit stations.

On June 15, 2021, FTA launched the Sustainable Transit for a Healthy Planet Challenge to encourage transit agencies to build on progress already made and to further reduce GHG emissions from public transportation to support President Biden's GHG reduction goal. The challenge calls on transit agencies to develop climate action strategies with measurable goals to achieve GHG emission targets. All transit agencies nationwide, regardless of size or service area, are encouraged to develop climate action or sustainability plans that detail GHG reduction strategies, such as converting fleets to electric buses and making facilities more energy efficient. Throughout 2021 and early 2022, FTA provided technical assistance to support agencies in their development of climate action plans or other strategies. Challenge participants were offered opportunities for personalized technical assistance beginning in Fall 2021. To date, 166 agencies have signed up for the challenge.

On August 2, 2021, FTA announced the award of a $5 million cooperative agreement to the International Transportation Learning Center to support the Transit Workforce Center (TWC). The TWC is the first FTA-funded technical assistance center to directly support public transit workforce development. Its mission is to help transit agencies recruit, hire, train, and retain a diverse workforce needed now and in the future. The TWC will also help address the national transit worker shortage by providing technical assistance geared toward developing frontline transit workers' skills and recruiting workers to transit careers through programs such as apprenticeships and partnerships. The TWC's future efforts to assist the transit industry with electrification support the Biden-Harris Administration's goal of reducing GHG emissions by 50 percent by 2030 while creating good-paying union jobs.

FTA is leveraging all of these initiatives to accelerate the many actions needed by transit agencies to achieve a zero-emissions fleet and implement other carbon-neutral or GHG emissions reduction activities. As transit agencies adopt the fleet of the future, FTA will continue to monitor the resources and technical assistance needed to support these transitions.

FTA has also supported efforts to help the Nation's transit systems adapt to climate change. The FTA Transit and Climate Change Adaptation Program, which ran from 2011–2014, supported pilot studies in seven geographically diverse locations, involving nine transit agencies. Each study sought to identify current and future climate hazards, assess transit

[98] https://www.transit.dot.gov/regulations-and-guidance/environmental-programs/ftas-transit-greenhouse-gas-emissions-estimator

system vulnerabilities, and develop adaptation strategies to specific climate hazards in their regions.[99] The nine transit agencies that participated were:

- Metropolitan Atlanta Rapid Transit Authority
- Chicago Transit Authority
- Gulf Coast Transit Agencies (City of Galveston Island Transit, Metropolitan Transit Authority of Harris County, & Hillsborough Area Regional Transit)
- Los Angeles County Metropolitan Transportation Authority
- San Francisco Bay Area Rapid Transit
- Sound Transit (Seattle, Washington)
- Southeastern Pennsylvania Transportation Authority

FTA's Role Moving Forward

The passage of the BIL will provide billions of dollars of funding toward improving America's infrastructure. Specifically, the act provides $39 billion of new investment to modernize transit and improve accessibility, in addition to continuing existing transit programs for five years as part of surface transportation act reauthorization. This is the largest Federal investment in public transit in history and devotes a larger share of funds from surface transportation reauthorization to transit than ever before. It will repair and upgrade aging infrastructure, modernize bus and rail fleets, make stations accessible to all users, and bring transit service to new communities. It will also replace thousands of transit vehicles, including buses, with clean zero-emission vehicles.[100]

FTA will be an essential partner with State and local agencies in helping to disburse Infrastructure Act funds and providing technical and program expertise to reduce GHG emissions from transit fleets through the following activities:

- Establishing projects for the construction, planning, and design of on-road and off-road facilities for pedestrians, bicyclists, and other non-motorized forms of transportation.
- Establishing projects to support the deployment of alternative fuel vehicles, including:
  - The acquisition, installation, or operation of publicly accessible electric vehicle charging infrastructure or hydrogen, natural gas, or propane vehicle fueling infrastructure; and
  - The purchase or lease of zero-emission construction equipment and vehicles, including the acquisition, construction, or leasing of required supporting facilities.
- Establishing projects for diesel engine retrofits.
- Low or No Emission/Buses and Bus Facilities Grants – BIL continues this program which makes funding available to states, designated recipients, and local governmental entities that operate fixed route bus service to replace, rehabilitate, and purchase buses and related equipment and to construct bus-related facilities including technological changes or innovations to modify low- or no- emission vehicles or facilities. Changes to this program in BIL include:
- Grants for Buses and Bus Facilities formula national distribution is increased to $4 million for each state and $1 million for each territory.
- Requirement that applicants submit a zero-emission fleet transition plan with their applications to both Grants for Buses and Bus Facilities and Low or No Emissions Grants competitive programs for projects related to zero-emission buses.
- At least 25% of Low or No Emissions Grants funding must be used for low-emission vehicles and related facilities.

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[99] Federal Transit Administration, 2021. "Climate Considerations." Available at: https://www.transit.dot.gov/regulations-and-programs/environmental-programs/climate-considerations

[100] The White House, 2021. Fact Sheet: Historic Bipartisan Infrastructure Deal. Available at: https://www.whitehouse.gov/briefing-room/statements-releases/2021/07/28/fact-sheet-historic-bipartisan-infrastructure-deal/

- Establishing a pilot program that will provide grants for the purchase of electric or low-emitting ferries and the electrification of or other reduction of emissions from existing ferries.

FTA, along with its sister organizations within the U.S. Department of Transportation, will play a critical role in "reducing a community's environmental impacts from transportation and enhancing the quality of life for its residents. Public transportation can facilitate compact development, conserving land and decreasing travel demand, as well as reducing fuel use and greenhouse gas (GHG) emissions that contribute to climate change."[101]

The resources and tools discussed in this chapter can be viewed through the following links:

- FTA's Sustainable Transit for a Healthy Planet Challenge. Available at: https://www.transit.dot.gov/climate-challenge
- FTA's Transit Greenhouse Gas Emissions Estimator v2.0. Available at: https://www.transit.dot.gov/regulations-and-guidance/environmental-programs/ftas-transit-greenhouse-gas-emissions-estimator
- FTA Greenhouse Gas Emissions from Transit Projects: Programmatic Assessment. Available at: https://www.transit.dot.gov/research-innovation/greenhouse-gas-emissions-transit-projects-programmatic-assessment-report-0097
- Transit and Climate Change Adaptation: Synthesis of FTA- Funded Pilot Projects. Available at: https://www.transit.dot.gov/research-innovation/transit-and-climate-change-adaptation-synthesis-fta-funded-pilot-projects-report

FTA's Transit Workforce Center. Available at: https://www.transit.dot.gov/research-innovation/workforce-development-initiative

[101] Federal Transit Administration, 2021. "Climate Considerations." Available at: https://www.transit.dot.gov/regulations-and-programs/environmental-programs/climate-considerations

Part IV: Highway Freight Conditions and Performance Report

Introduction

This chapter meets the requirements of Section 1116(a) of the Fixing America's Surface Transportation (FAST) Act (Pub. L. 114-94, 23 U.S.C. §167(h)), which established a National Highway Freight Network (NHFN) and directed the Federal Highway Administration (FHWA) to prepare a biennial report on the conditions and performance of the NHFN in the United States.

This chapter serves as the third edition of the biennial Highway Freight Conditions and Performance Report to Congress and is submitted as part of FHWA's Status of the Nation's Highways, Bridges, and Transit Conditions and Performance Report to Congress: 25th edition. The data and analysis presented here are expected to help inform Congress on the conditions of NHFN infrastructure important to freight movement, specifically pavement and bridges, as well as overall performance for trucks moving along the NHFN. Decision makers need information on freight infrastructure condition and performance to optimize investments and strategies that can lead to improved transportation safety, mobility, economic growth, and community development.

Although the national freight transportation system is inherently multimodal, the primary focus of this report is the highway freight system per the statutory requirement for a biennial report on NHFN conditions and performance (23 U.S.C. §167(h)).

Summary of National Highway Freight Network Statutory Requirements

As established in the FAST Act and codified in 23 U.S.C. §167(h), Congress:

- Established the NHFN to strategically direct Federal resources and policies toward improved performance of this network and established the components of this network.
- Designated a National Highway Freight Program (NHFP) to improve efficient movement of freight on the NHFN and support additional goals, including investing in infrastructure that strengthens economic competitiveness and improves freight transportation safety and resilience.
- Established a national policy of maintaining and improving NHFN conditions and performance.
- Required the U.S. Department of Transportation to prepare and submit a biennial report that describes the conditions and performance of the NHFN.

In each edition of the *Highway Freight Conditions and Performance Report to Congress*, FHWA updates NHFN conditions and performance data to the latest year available when conducting the analysis. FHWA intends for each edition of the *Highway Freight Conditions and Performance Report to Congress* to build on previous editions to enhance the understanding of NHFN conditions and performance.

This edition updates the analysis of Critical Rural Freight Corridors (CRFCs), Critical Urban Freight Corridors (CUFCs), and State Freight Plans included in the second edition. This edition also draws on data from the Freight Mobility Trends (FMT) tool, an FHWA freight performance analysis tool published in 2020, for the performance exhibits. Finally, this edition includes enhanced special topic discussions aligned with U.S. Department of Transportation (DOT) policy priorities. See the What's New section of this chapter for details on updates and enhancements.

For the purposes of this report, the terms “conditions” and “performance” are defined as follows:

- **Conditions** refers to the physical state of infrastructure important to freight transportation (pavement and bridges).
- **Performance** reflects how freight is performing relative to specific goals (safety, mobility, and reliability).

The NHFN consists of four component roadways (see the Background section of this chapter for details on each component):

- Primary Highway Freight System (PHFS);
- Other Interstate portions not on the PHFS (non-PHFS);
- Critical Rural Freight Corridors (CRFCs); and
- Critical Urban Freight Corridors (CUFCs).

23 U.S.C. §167(h) did not specify how to report NHFN conditions and performance in the *Highway Freight Conditions and Performance Report to Congress*. As in the previous two editions of the *Highway Freight Conditions and Performance Report to Congress*, this edition reports on multiple conditions and performance indicators.

Several considerations guided the selection of indicators for this edition, including:

- Relevance of indicator to the National Highway Freight Program (NHFP) goals as defined in 23 U.S.C. §167(b);
- Alignment of indicator to established FHWA freight analysis approaches as well as analysis approaches used elsewhere in the FHWA *Conditions & Performance Report to Congress*;[102]
- Ability of indicator to provide a robust perspective on highway freight conditions and performance; and
- Ability of indicator to convey clear, concise, and digestible information.

Due to changes in analytical approaches, methodologies, and other factors, comparison of data presented in different editions of the *Highway Freight Conditions and Performance Report to Congress* is not always possible. Appendix E: Highway Freight Methodology provides additional detail.

The reported NHFN conditions indicators have not changed substantially over the three editions of the *Highway Freight Conditions and Performance Report to Congress*.[103] This edition includes several updated NHFN performance indicators (replacing previously reported performance indicators). These updates reflect FHWA investments in freight data and analysis tools that have created more robust opportunities for freight performance analysis.

Exhibit IV-1 shows the conditions and performance indicators reported in this edition and their corresponding NHFP goals.

This chapter includes the following sections:

- **Introduction** outlines the purpose of this chapter and summarizes key updates.
- **Background** describes Federal statutes that guide public investment in the freight transportation system, focusing on the NHFP.
- **Data and Analysis Approaches** provides an overview of data sources used to report on conditions and performance indicators as well as data constraints and opportunities.

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[102] FHWA’s Final Rule for Pavement and Bridge Performance Measures (23 CFR 490 Subparts C and D) established NHS pavement and bridge conditions performance measures as well as other conditions reporting requirements. Although 23 CFR 490 Subparts C and D required that targets be set only for NHS pavement and bridges, the Highway Freight Conditions and Performance Report to Congress applies the same criteria to NHFN pavement and bridges. See the Conditions Analysis section of this chapter for greater detail.

[103] The second and third editions excluded bridge age as an indicator. After publication of the first edition, FHWA determined that bridge age was not always an appropriate indicator of bridge condition.

- **Freight Demand Overview and Trends** describes elements of freight demand and its relationship to economic growth.
- **Conditions Analysis** reports on indicators of NHFN infrastructure conditions, including pavement and bridge indicators.
- **Performance Analysis** reports on indicators of NHFN performance, including safety, mobility, reliability, and freight demand indicators.
- **Critical Rural Freight Corridors and Critical Urban Freight Corridors** (CRFCs/CUFCs) provides an analysis on CRFCs/CUFCs, including States' justifications for designation.
- **Program Highlights** provide examples of Federal, State, and industry efforts that address NHFN conditions- and performance-related needs or issues.
- **Special Topics** discusses several topics of high-priority interest to DOT as they relate to freight transportation conditions and performance.

Exhibit IV-1: Conditions and Performance Indicators by National Highway Freight Program Goals

NHFP Goal	Indicator	Exhibit
Improved State of Good Repair	Pavement Ride Quality (based on the International Roughness Index (IRI))	IV-9
	Overall Pavement Condition	IV-10
	Individual Pavement Distresses	IV-10
	Overall Pavement Condition (by roadway functional class)	IV-11
	Bridge Condition (bridge structural elements, culverts, and overall condition)	IV-13
	Overall Bridge Condition (by roadway functional class)	IV-14
Reduced Congestion, Increased Efficiency, Increased Productivity, Increased Contribution of NHFN to Economic Competitiveness	Most Congested Corridors	IV-16, IV-17
	Multimodal Freight Facilities with Surrounding Roadway Congestion	IV-18
	Peak Period Planning Time Index Most Congested Corridors	IV-19
	Truck Reliability Index for Most Congested Corridors	IV-20
	National Truck Travel Time Reliability Index on the Interstate System	IV-21
	Truck Volumes for Most Congested Corridors	IV-22
Improved Safety	Fatal Crashes and Fatalities on the NHFN	IV-15

Source: U.S. Department of Transportation, Federal Highway Administration, Office of Freight Management and Operations.

What's New

This edition of the *Highway Freight Conditions and Performance Report to Congress* builds on and enhances the analysis of the previous two editions.

The first edition provided a baseline understanding of NHFN conditions and performance. The second edition improved this baseline by adding indicators and an analysis of CRFCs/CUFCs.[104] The second edition also highlighted Federal freight programs and activities that addressed freight infrastructure conditions and performance.

This third edition updates all conditions and performance indicators, the CRFC/CUFC analysis, and the State Freight Plan analysis. It also provides an enhanced NHFN performance analysis based on FHWA's FMT tool, as described in the Data and Analysis Approaches section of this chapter.

The NHFN is a relatively new network, established in 2015 by the FAST Act. FHWA expects to identify and report on trends in NHFN conditions and performance in future editions as the foundation of NHFN data grows. FHWA investments in freight data and analysis tools, described in in the Data and Analysis Approaches section, are also expected to increase the capacity for NHFN conditions and performance analysis.

[104] States had not submitted CRFC/CUFC designations to FHWA when the first edition was drafted.

Summary of Updates

This edition of the Highway Freight Conditions and Performance Report to Congress:

- Updates all condition and performance indicators using the latest data available at the time of writing;
- Provides an enhanced NHFN performance analysis based on the FHWA FMT tool, a freight performance analysis tool released in 2020;
- Updates and expands analysis of CRFCs/CUFCs and State Freight Plans;
- Updates and expands discussion of Federal programs and efforts that benefit freight conditions and performance assessments; and
- Discusses several special topics: supply chains, freight transportation equity, and climate impacts from freight movement.

Background

Several Federal programs govern public sector investment in the Nation's freight transportation system. This section provides an overview of Federal programs pertaining to the NHFN.

National Highway Freight Program

23 U.S.C. §167(b) 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 established the NHFP, a freight formula program designed to improve the efficient movement of freight on the NHFN, among other goals.

The NHFP represented the first dedicated Federal funding source for freight transportation projects. As defined in 23 U.S.C. §167(b), NHFP goals[105] include:

- Investing in infrastructure and operational improvements that strengthen economic competitiveness, reduce congestion, reduce the cost of freight transportation, improve reliability, and increase productivity;
- Improving the safety, security, efficiency, and resilience of freight transportation in rural and urban areas;
- Improving the state of good repair of the NHFN;
- Using innovation and advanced technology to improve NHFN safety, efficiency, and reliability;
- Improving the efficiency and productivity of the NHFN;
- Improving State flexibility to support multi-State corridor planning and address highway freight connectivity; and
- Reducing the environmental impacts of freight movement on the NHFN.

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, 23 U.S.C. §135, and 49 U.S.C §70202). To use NHFP funds for projects, States must identify relevant projects in their Statewide Transportation Improvement Program, and Metropolitan Planning Organizations (MPOs) must do so in their Transportation Improvement Program. The projects must also be consistent with States' long-range Statewide transportation plans and MPOs' metropolitan transportation plans.

[105] 23 U.S.C. §167 (a), (b). See https://www.fhwa.dot.gov/fastact/factsheets/nhfpsnhfpfs.cfm for additional information on the NHFP.

Pursuant to 23 U.S.C 167(h)(4), a State may not obligate NHFP funds apportioned to the State unless the State developed a State Freight Plan, as required by 49 U.S.C. §70202. To use NHFP funds for projects, States must include those projects in the State's Freight Investment Plan, a component of a State Freight Plan. The Bipartisan Infrastructure Law (BIL), enacted as the Infrastructure Investment and Jobs Act (IIJA) (Pub. L. 117-58), added significant new requirements for State Freight Plans; those requirements are described in greater detail below in Program Highlights.

States have four years to obligate NHFP funds, starting with the year in which NHFP funds are apportioned (i.e., States' authority to obligate Fiscal Year [FY] 2018 funds lapsed on September 30, 2021). As of July 31, 2021, when this analysis was compiled, States had obligated approximately 79 percent of all NHFP funds apportioned on a national basis through that date. Total obligations in 2019 exceed 100 percent because they include the FY2019 annual apportionment plus any remaining carryover balances from previous fiscal years. *Exhibit IV-2* shows the breakdown of States' progress in obligating NHFP funds by year of fund apportionment.

Exhibit IV-2: Percentage of National Highway Freight Program Funds Obligated or Unobligated, FY2018–FY2021

Category	FY2018	FY2019	FY2020	FY2021
Obligated	87.0%	105.0%	75.2%	47.9%
Unobligated	13.0%		24.8%	52.1%

Notes: Obligation data are as of July 31, 2021, so FY2021 data are a partial year. FY2019 obligations exceed 100 percent because States obligated $1.37 billion, which was more than their annual apportionment ($1.31 billion). NHFP funding is apportionment funding subject to the period of availability. The period of availability for the NHFP is four years (the year of apportionment plus three years). Total available NHFP funding for obligation in FY2019 was the annual apportionment ($1,311,785,913) plus any remaining carryover balances from previous fiscal years. Obligations can exceed annual apportionments due to funds availability.

Source: U.S. Department of Transportation, Federal Highway Administration, Office of Freight Management and Operations.

National Highway Transportation Networks

National highway transportation networks include the Interstate System, National Highway System (NHS), the National Network (NN), and the NHFN. Some components of the Interstate System, NHS, NN, and NHFN overlap.

The National Highway Transportation Networks are the following:

- **Interstate System:** The Dwight D. Eisenhower National System of Interstate and Defense Highways within the United States consists of highways designed, located, and selected in accordance with 23 U.S.C. §103 (c). The purpose of the Interstate System is to connect the Nation's principal metropolitan areas, cities, and industrial centers; serve national defense; and connect suitable border points with routes of continental importance in Canada and Mexico.
- **National Highway System:** 23 U.S.C. §103(a) designated the NHS, which consists of routes of importance to the Nation's economy, defense, and mobility. The NHS consists of routes that "serve major population centers, international border crossings, ports, airports, public transportation facilities, and other intermodal transportation facilities and other major travel destinations; meet national defense requirements; and serve interstate and interregional travel and commerce" (23 U.S.C. §103(a)). It is composed of the Interstate system, other principal arterials, the Strategic Highway Network, major Strategic Highway Network Connectors, and intermodal connectors. The purpose of the NHS is to direct Federal investments to routes of critical national importance.
- **National Network:** The NN is the system of roadways officially designated to accommodate commercial freight-hauling vehicles as authorized by the Surface Transportation Assistance Act of 1982 (Pub. L. 97-424) and specified in the U.S. Code of

Federal Regulations (23 CFR Part 658). The purpose of the NN is to support interstate commerce through regulating the size of trucks.

- **National Highway Freight Network:** 23 U.S.C. §167(h) designated the NHFN and established a national policy of maintaining and improving the conditions and performance of this 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 is composed of the Primary Highway Freight System (PHFS), other Interstate portions not on the PHFS (non-PHFS), Critical Rural Freight Corridors (CRFCs), and Critical Urban Freight Corridors (CUFCs). The purpose of the NHFN is to provide a "foundation for the United States to compete in the global economy and achieve the goals" of investing in infrastructure, improving safety and state of good repair, using innovation, improving efficiency, supporting multi-state corridor planning, and reducing the environmental impacts of freight movement (23 U.S.C. §167(a)).

National Highway Freight Network

23 U.S.C. §167 designated the NHFN and established national policies and resources to improve mobility on America's highways, create jobs and support economic growth, and accelerate project delivery for maintaining and improving the conditions and performance of the NHFN. The NHFN and the PHFS replaced the National Freight Network and Primary Freight Network established under the Moving Ahead for Progress in the 21st Century Act (MAP-21). 23 U.S.C. §167(d)(2) required the redesignation of the PHFS every five years and the mileage may not increase by more than three percent during each redesignation. The mileage of the other three NHFN components changes by formula based on the PHFS redesignation mileage. These regular redesignations ensure that the NHFN is a living network that changes over time.

The NHFN is composed of the following:

- **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. The FHWA Administrator must redesignate the PHFS every five years, subject to a cap of up to three-percent growth in total mileage with each redesignation.
- **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.
- **Critical Rural Freight Corridors (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.
- **Critical Urban Freight Corridors (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. CRFCs/CUFCs are discussed in greater detail in the Special Topics section of this report.

Exhibit IV-3 provides mileage counts for each of the NHFN's four components. As of January 2021, the NHFN consisted of an estimated 56,297 total miles. Of this total estimated mileage, the majority (approximately 98 percent) was also included as part of the NHS.

Exhibit IV-4 depicts a map of the NHFN as of January 2021.

Exhibit IV-5 provides estimated mileage counts for highway functional classifications represented on two categories of NHFN component roadways (PHFS/non-PHFS and CRFCs/CUFCs). Functional classifications define the role that each element of the roadway network plays in serving various travel needs. These classifications also convey expectations about roadway design, including speed, capacity, and relationship to existing and future land use development.[106] Several functional classification categories exist for roadways in urban and rural areas.

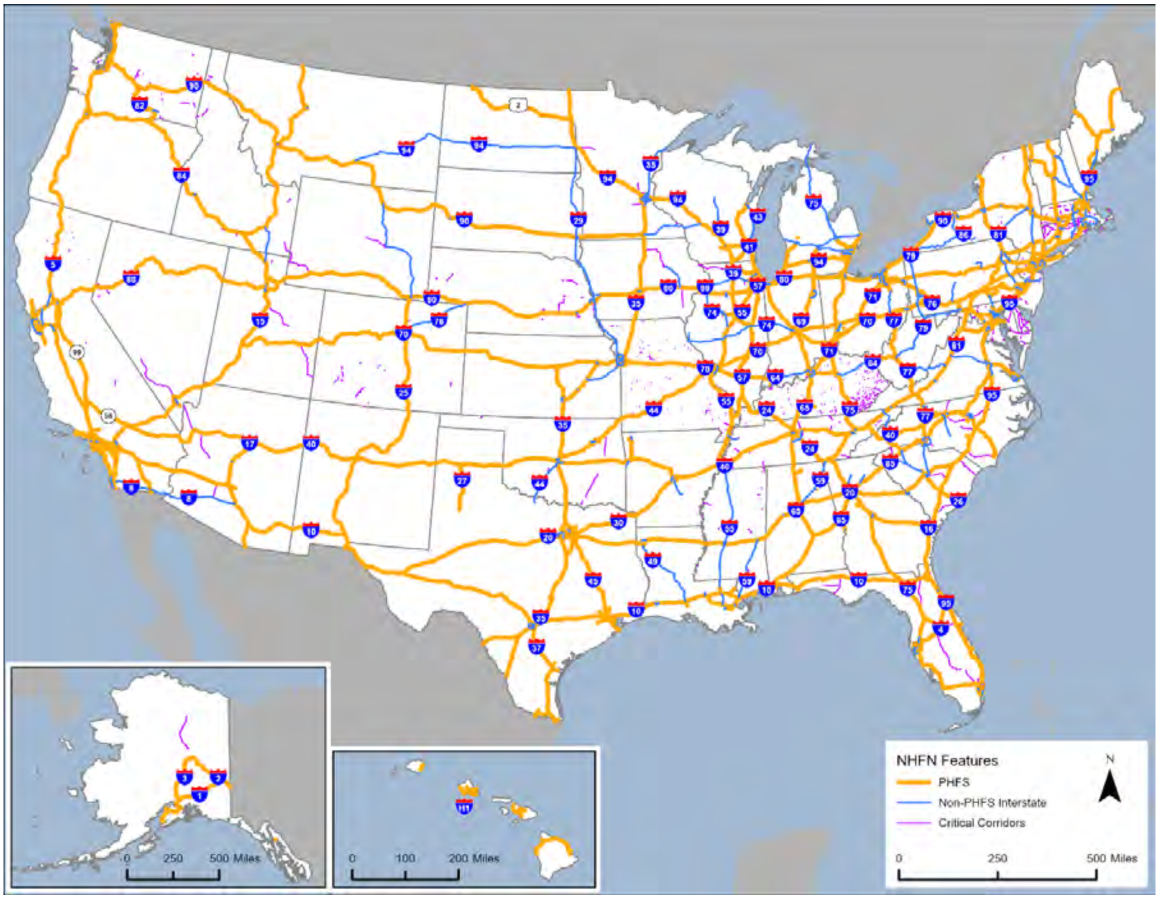
Of NHFN Interstate mileage, nearly 90 percent is on the PHFS and non-PHFS, whereas 10 percent consists of CRFCs/CUFCs. Of CRFC/CUFC mileage, 68 percent is classified as "Other Principal Arterials" (functional classification 3). Relatively little NHFN mileage is on lower functional classes (functional classification 4 through 7).

Exhibit IV-3: National Highway Freight Network Mileage by Component Roadway, 2021

NHFN Roadway Component	Mileage	Percentage of Total NHFN Mileage
PHFS	41,092	73%
Non-PHFS	9,524	17%
CRFCs	3,696	7%
CUFCs	1,985	4%

Notes: PHFS is Primary Highway Freight System; Non-PHFS is "Other Interstate portions not on the PHFS;" CRFCs are Critical Rural Freight Corridors; CUFCs are Critical Urban Freight Corridors. Percentages may not add up to 100 due to rounding.
Source: U.S. Department of Transportation, Federal Highway Administration, Office of Freight Management and Operations. Represents data as of January 2021.

Exhibit IV-4: National Highway Freight Network, 2021



Notes: This map shows a composite of all elements of the NHFN, which include the PHFS, non-PHFS, CRFCs, and CUFCs.
Source: U.S. Department of Transportation, Federal Highway Administration, Office of Freight Management and Operations. Represents data as of January 1, 2021.

[106] FHWA Highway Functional Classification Concepts, Criteria, and Procedures (2013). (https://www.fhwa.dot.gov/planning/processes/statewide/related/highway_functional_classifications/)

Exhibit IV-5: Estimated National Highway Freight Network Mileage by Functional Classification, 2021

Functional Classification (Code and Name)	Percent of Total NHFN Mileage (estimated)	PHFS and Non-PHFS Mileage (estimated)	CRFC/CUFC Mileage (estimated)
1. Interstate	83%	46,616	34
2. Other Freeway or Expressway	4%	1,373	732
3. Other Principal Arterial	10%	1,697	3,874
4. Minor Arterial	2%	352	661
5. Major Collector	0.69%	178	210
6. Minor Collector	0.05%	9	17
7. Local	0.49%	49	150

Notes: PHFS is Primary Highway Freight System; Non-PHFS is Other Interstates not on the PHFS; CRFCs are Critical Rural Freight Corridors; CUFCs are Critical Urban Freight Corridors. Mileage is estimated by linking NHFN 2021 to Highway Performance Monitoring System (HPMS) 2018. Percentages may not add up to 100 due to rounding.

Source: U.S. Department of Transportation, Federal Highway Administration, Office of Freight Management and Operations. Represents data as of January 2021.

Critical Rural Freight Corridors and Critical Urban Freight Corridors

Pursuant to Section 1116(a) of the FAST Act, States (including the District of Columbia), and in certain cases MPOs, can identify and designate CRFCs/CUFCs. CRFCs/CUFCs provide critical connectivity to the NHFN from freight transfer points and facilities such as intermodal and manufacturing facilities, distribution points, and other freight processing facilities. The intent of CRFCs/CUFCs is to allow States and MPOs a flexible opportunity to apply regional and local knowledge to identify freight-significant segments and address freight connectivity. States are responsible for designating CRFCs. In urbanized areas with populations over 500,000, MPOs are responsible for designating CUFCs in consultation with States and for determining how to distribute CUFC mileage among urbanized areas.

There is no deadline for CRFC/CUFC designations, but they are subject to mileage limitations based on centerline roadway mileage.[107] Total NHFN centerline mileage will change when States or MPOs elect to designate CRFCs/CUFCs. Mileage may also fluctuate due to mileage additions and deletions to the Interstate Highway System.

FHWA Freight Mobility Trends (FMT) Tool

The FMT tool uses truck travel data from the National Performance Management Research Dataset (NPMRDS) to convey and visualize freight performance information for the NHS, including national freight corridors, bottlenecks, and portions of the NHFN on the NHS. NPMRDS is a national set of vehicle probe data generated by location-based devices such as mobile devices that includes data on vehicle speed and travel time.

FMT tool users can select from among multiple performance indicators such as truck delay per mile, planning time index, and truck reliability index to visualize freight performance across years or in different geographic locations.

For more information, see https://ops.fhwa.dot.gov/freight/freight_analysis/mobility_trends/index.htm

See the Performance Analysis section for additional analysis of CRFCs/CUFCs.

[107] Information on the estimated maximum limit of CRFC/CUFC mileage for each State is available on the FHWA NHFN website in the table of NHFN mileages by State. See https://ops.fhwa.dot.gov/freight/infrastructure/nfn/maps/nhfn_mileage_states.htm

Data and Analysis Approaches

FHWA invests in research to improve freight data and analysis tools. Over time, these investments have strengthened the capacity for freight transportation analysis and have helped support more informed freight decision making. This section highlights key investments made since the first edition.

In 2020, FHWA released the FMT tool, a freight performance analysis tool that uses truck travel data to provide national freight mobility statistics and a dashboard to visualize performance of the freight highway transportation system.

The FMT tool offers a new opportunity not available in previous editions to provide a more in-depth look at NHFN performance. This edition used the FMT tool as the source for the mobility, reliability, and freight demand indicators reported in the Performance Analysis section. FHWA expects to continue to use the FMT tool as a key source for performance indicators included in future editions.

Since publication of the second edition, FHWA also:

- **Released Freight Analysis Framework (FAF) version 5 base year data**, in collaboration with DOT partners. The initial FAF version 5 release (incorporated in this edition) updated base year data to 2017. Forecasted data and highway flows from FAF version 5 had not yet been released at the time of this writing and are excluded from this edition.
- **Produced a NHFN data visualization webtool**.[108] This webtool provides users the ability to geospatially visualize NHFN roadway components and other NHFN information.
- **Conducted other research** to benefit freight performance analysis and decision-making. For example, FHWA is:
  - Exploring freight fluidity through development of a beta analysis tool to assess freight fluidity for five representative supply chains. Freight fluidity is one approach to examining the performance of multimodal freight transportation and supply chains. The fluidity analysis tool is expected to support users in assessing supply chain performance indicators such as travel time, reliability, and cost.
  - Piloting a scenario-based approach to freight supply chain performance analysis through the Freight and Fuel Transportation Optimization Tool (FTOT). FTOT is a geospatial information system (GIS)-based tool that analyzes user-defined scenarios. Inputs for scenarios can include raw material origins, destinations, transportation cost estimates, weightings, and other parameters for converting or refining materials. As part of this pilot, FHWA is working with State DOTs and MPOs in different States to test the utility of FTOT for freight planning and analysis. FHWA is synthesizing pilot findings to assess potential next steps.

The freight performance research efforts were ongoing as of this writing and documentation was in pre-publication status. FHWA expects that research findings and resulting innovations will support agencies in making more effective investments benefiting freight transportation system mobility and performance.

Analysis Constraints and Opportunities

FHWA uses multiple data sources to report on NHFN conditions and performance because no single source contains all information needed for the analysis. FHWA offices collaborate internally and with other DOT partners to access, synthesize, analyze, and review data for NHFN conditions and performance reporting.

[108] FHWA NHFN Visualization Tool. (https://fpcb.ops.fhwa.dot.gov/dataAnalysisTools.aspx)

Although conditions and performance data are available for most of the NHFN component roadways, actions would be needed to report such data comprehensively for all four subsystems of the roadways that make up the NHFN. For example, States are required to report information annually into the Highway Performance Monitoring System (HPMS), but providing data on lower functional classification roadways is generally optional. As a result, HPMS data on lower functional classification roadways are often missing or incomplete, which limits FHWA's ability to comprehensively analyze the condition of these roadway classifications.

Opportunities for data improvements exist that would benefit the preparation and consistency of future NHFN conditions and performance reports and allow for a better understanding of the NHFN and its needs. For example, FHWA is exploring strategies to improve the database relationship between NHFN geography and HPMS and National Bridge Inventory (NBI) data, which would facilitate the bridge conditions analysis reported in this chapter.

Exhibit IV-6 outlines the key data sources and data years used for this edition. Data sources are updated on different cycles and at different times. Therefore, the indicators present information from multiple data years. FHWA aimed to incorporate the most recent data available at the time of writing while aligning with data years used elsewhere in the FHWA *Conditions and Performance Report to Congress*.

Exhibit IV-6: Key Data Sources and Data Years Used in this Edition

Data Source	Overview	Data Year	Relevant Exhibit(s)
FHWA Freight Mobility Trends (FMT) Tool	Dashboard providing national freight performance statistics and information on freight highway bottlenecks, as based on an analysis of the National Performance Management Research Data Set (NPMRDS).	2019 FMT, which includes: ▪ 2019 NPMRDS data[1] ▪ 2016 NHFN data (excludes CRFCs and CUFCs)	IV-16, IV-17, IV-18, IV-19, IV-20, IV-22
National Performance Management Research Data Set (NPMRDS)	National set of vehicle probe data generated by location-based devices such as mobile devices, connected automobiles, portable navigation devices, and commercial fleet sensors that includes data on speed and travel time.[2]	2019	IV-16, IV-17, IV-18, IV-19, IV-20, IV-22
Freight Analysis Framework (FAF)	Data product that integrates information from a variety of sources to produce a comprehensive picture of freight movement among States and major metropolitan areas by all modes of transportation.	2015 (for highway flow data–FAF version 4)[3]	Not Applicable
Highway Performance Monitoring System (HPMS)	National-level highway information system that includes data on the extent, conditions, performance, use, and operating characteristics of the Nation's highways.	2018	IV-9, IV-10, IV-11
National Bridge Inventory (NBI)	Database containing comprehensive bridge condition and inventory data from Federal agencies and State and Tribal governments, and describing all bridges located on public roads.	2020[4]	IV-13, IV-14
Fatality Analysis Reporting System (FARS)	Nationwide census generated from State records for all crashes that occur on U.S. public roadways.	2019	IV-15

[1] The FMT tool version used for this edition included the PHFS as of 2016. It excluded data on CRFCs/CUFCs, because these segments may not be part of the NHS, change frequently with ongoing designations from States, and may not have associated NPMRDS data.

[2] The NPMRDS is the data source for the FMT tool.

[3] At the time of writing, FAF version 5 included only 2017 FAF base year data. FAF data for 2018–2019, forecasted years (2020–2050), and previous base years 1997–2012 in 5-year increments, will be released in later version updates. FAF version 5 will update highway flow data to 2017 but this information was unavailable at the time of writing. This edition used FAF version 4 for highway flow data (dated to 2015).

[4] The NBI version used for this edition included data as of December 2020. Data were filtered to include only bridges built in 2019 or earlier to align with the reporting approach used by other chapters of the FHWA Conditions and Performance Report to Congress.

Source: U.S. Department of Transportation, Federal Highway Administration.

Summary of Analysis: Constraints and Opportunities

NHFN is a network, not a database. To produce the conditions and performance analysis, FHWA uses geospatial processes to link information from multiple datasets to the NHFN. Appendix E: Highway Freight Methodology provides details on these processes.

FHWA is limited to the use of certain datasets for NHFN conditions and performance reporting:

- Published, national datasets;
- Highway-focused datasets; and
- Established datasets that align to reporting in other chapters of the FHWA Conditions and Performance Report to Congress.

The capacity for robust NHFN analysis is subject to the availability, quality, and extent of data sources. In some cases, FHWA's ability to analyze certain aspects of NHFN conditions and performance is limited because of limitations in the available data sources.

Freight Demand Overview and Trends

The Nation's freight transportation system is extensive, complex, and multimodal. It is composed of millions of miles of public roads, railways, navigable waterways, pipelines, and airways, as well as intermodal connectors and other freight transfer points.[109]

Nearly all the goods and materials Americans consume or produce require movement along the freight transportation system at some point. Trucks carry the majority of goods by both value and weight (about 72 percent and 65 percent, respectively).[110] A graphical representation of the overall freight flows by mode can be found online in the Freight Facts and Figures publication by the Bureau of Transportation Statistics.[111]

Transportation Services Index (TSI)

DOT created the Transportation Services Index (TSI) to capture the volume of freight and passenger activity in the for-hire transportation sector. The index combines available data on freight traffic, as well as passenger travel, and weights the data to provide a monthly measure of transportation services output. TSI can provide an index of just the for-hire freight sector or by individual modes.

For more information, see: https://www.transtats.bts.gov/OSEA/TSI/

In 2018, the Nation's freight transportation system moved a daily average of about 51 million tons of freight worth more than $51.8 billion.[112] Freight transportation volumes have grown with

[109] For example, in 2018, there were about 4.1 million miles of public road route miles (including the National Highway System), 92,000 miles of Class I railroad miles, over 27,000 miles of navigable inland waterway channels (including the Great Lakes-St. Lawrence Seaway), and over 2.7 million miles of oil and gas pipelines. Source: Bureau of Transportation Statistics, Freight Transportation System Extent & Use, 2018. (https://data.bts.gov/stories/s/Freight-Transportation-System-Extent-Use/r3vy-npqd)

[110] Bureau of Transportation Statistics, Freight Facts and Figures 2018. Railroads carry less than 3 percent of goods by value, but about 8 percent by weight. Goods carried by rail are typically bulk commodities such as agricultural products, coal, and chemicals. Inland and coastal waterways carry about 1.5 percent of goods by value and 4.5 percent by weight. Goods carried by water are typically bulk commodities such as grain or coal, as well as farm inputs such as fertilizer. Pipelines carry about 5 percent of liquid and gaseous energy resources by value and nearly 18 percent by weight. These resources include raw materials moved from areas of production to refineries as well as finished products moved to gasoline terminals, natural gas power plants, and other facilities. Intermodal facilities, another important component of the surface transportation freight system, serve to transfer freight from one mode to another. (Ibid.)

[111] https://data.bts.gov/stories/s/Freight-Transportation-System-Extent-Use/r3vy-npqd

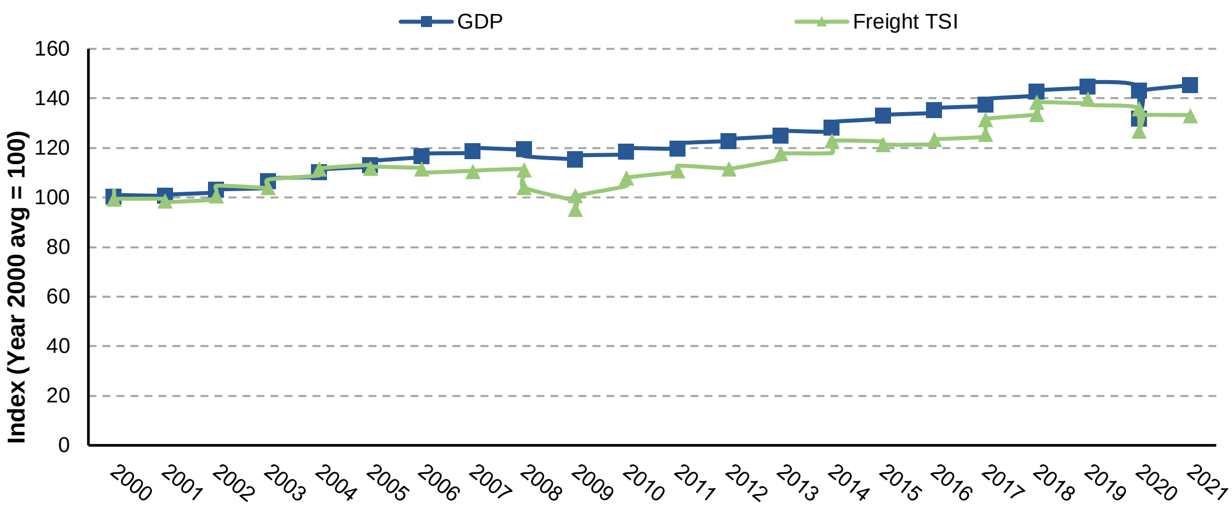
[112] Bureau of Transportation Statistics, Freight Facts and Figures 2018: Moving Goods in the United States. (https://data.bts.gov/stories/s/Moving-Goods-in-the-United-States/bcyt-rqmu). Data presented in the 2018 Freight Facts and Figures are based on FAF version 4.5.1, which includes data updated to 2018 and forecasts from 2020 through 2045.

the expansion of U.S. population and economic activity as well as the increasing interdependency of domestic and global economies. Between 2000 and 2019, the U.S. population grew by 16.6 percent (to 328.2 million), gross domestic product (GDP) increased by 45.2 percent, and median household income grew by 2.9 percent.[113] Over approximately the same period (2000 to 2018), total freight ton-miles grew by 3.7 percent, from 5,065,648 to 5,250,670.[114]

DOT forecasts expect an increase in freight volume from 2018 to 2045, but freight flow patterns and changes over this period may not be uniform across all economic sectors, modes, and locations.[115] Freight volumes reflect how different economic sectors are expanding or contracting and may have regional or local variance.

DOT created the Freight Transportation Services Index (TSI) to provide an aggregated measure of freight services as a subset of the economy. Changes in Freight TSI generally reflect changes in the demand for goods and services in the economy. Although GDP provides an overview of the full economy and of the value of goods and services, Freight TSI is specific to the for-hire portion of the transportation sector: it represents the value of goods movement services. *Exhibit IV-7* shows that Freight TSI increased from a low of 95.4 in April 2009 (reflecting the end of the December 2007–June 2009 economic downturn) to 133.93 in October 2020.[116] Although there were periods of declining Freight TSI between 2009 and 2020, the overall increase in Freight TSI over this timeframe indicates economic growth and growth in freight demand (note the initial dip in both GDP and Freight TSI in 2020 corresponding to the start of the COVID-19 pandemic).

Exhibit IV-7: Real Quarterly Gross Domestic Product and Freight Transportation Services Index, 2000–2021 (Seasonally Adjusted)



Notes: The Freight Transportation Services Index (TSI), created by the U.S. Department of Transportation (DOT), Bureau of Transportation Statistics (BTS), measures the movement of freight and is seasonally adjusted. The TSI numbers are BTS estimates.

Source: U.S. Department of Transportation, Bureau of Transportation Statistics. GDP is calculated based on data from U.S. Department of Commerce, Bureau of Economic Analysis, National Income and Product Account Table 1.1.6, available at https://apps.bea.gov/iTable/index_nipa.cfm. Freight TSI data are BTS estimates, available at https://www.transtats.bts.gov/OSEA/TSI/.

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[113] GDP figure reported is inflation-adjusted and median household income figure is reported in 2019 dollars. Over the 2000–2019 period, United States international trade grew faster than the overall economy, reflecting increased global interconnectivity. Source: Bureau of Transportation Statistics, Nation Served by Freight. (https://data.bts.gov/stories/s/The-Nation-Served-by-Freight/d3er-58uw)

[114] U.S. Ton-Miles of Freight. BTS Special Tabulation. (https://cms7.bts.dot.gov/us-ton-miles-freight)

[115] Bureau of Transportation Statistics, Moving Goods in the United States. (https://data.bts.gov/stories/s/Moving-Goods-in-the-United-States/bcyt-rqmu)

[116] Bureau of Transportation Statistics. Transportation Services Index: 2000 to 2020. (https://www.transtats.bts.gov/OSEA/TSI/)

Transportation decision makers need data on freight infrastructure conditions and performance to effectively address challenges and opportunities created by growing freight demand. For example, to ensure that the U.S. highway network can support continued national economic growth and competitiveness, decision makers need to understand and address the potential impacts of increased freight movement in areas such as safety, reliability, efficiency, and the environment. Decision makers also rely on freight system and performance information to optimize investments and operational strategies to address congestion and reliability.

Conditions Analysis

Deteriorating highway infrastructure can result in higher repair costs, increase travel time of goods (and passengers), and raise safety concerns.[117] Data on highway infrastructure conditions help inform asset management, maintenance, rehabilitation, and construction activities, as well as overall transportation decision making.

> **Conditions Analysis Highlights**
>
> As of 2018, most NHFN pavement mileage (about 76 percent) had "good" ride quality. More than half (57 percent) of NHFN mileage was of "good" overall condition.
>
> Interstates had the highest share of "good" overall pavement condition (59 percent) compared with other roadway functional classes.
>
> As of 2019, the NHFN included an estimated 84,165 bridges totaling approximately 4,934 miles. Of this bridge mileage, a small percentage (5 percent) was in "poor" overall condition. About one-third (37 percent) of bridge mileage was in "good" condition.
>
> NHFN bridges on urban "other freeways or expressways" had the most share of mileage in "good" condition (51 percent), compared with bridges on other functional roadway classes.

In previous editions of this chapter and the FHWA *Conditions and Performance Report to Congress,* FHWA established pavement and bridges as primary infrastructure condition analysis areas.

FHWA's criteria for assessing NHFN pavement and bridge conditions are the same as those used elsewhere in the FHWA *Conditions and Performance Report to Congress* as well as in the previous edition of this chapter. (*Exhibit IV-8* and *Exhibit IV-12* provide these criteria.)

As part of the implementation of the Transportation Performance Management (TPM) framework in 23 U.S.C. §150, FHWA published a Final Rule for Pavement and Bridge Performance Measures on January 18, 2017 (23 CFR 490 Subparts C and D). These regulations provide NHS pavement and bridge conditions performance measures, along with minimum condition standards, target establishment, progress assessment, and reporting requirements. The regulations also provide criteria for overall pavement ratings, based on combinations of ratings for individual distresses. State DOTs began reporting pavement and bridge performance in 2018. As in the previous edition, this edition continues to report pavement and bridge indicators consistent with those specified in 23 CFR 490. Although 23 CFR 490 requires that targets be set only for NHS pavement and bridges, the *Highway Freight Conditions and Performance Report to Congress* applies the same criteria to NHFN pavement and bridges.

[117] FHWA Conditions and Performance Report to Congress, 23rd edition, Chapter 6: Infrastructure Conditions.

Pavement Conditions

In previous editions of the FHWA *Conditions and Performance Report to Congress*, FHWA established that two useful indicators of pavement condition are the International Roughness Index (IRI) and the extent of pavement distresses.[118] IRI refers to pavement ride quality as experienced by a driver. Pavement distresses refer to the extent of cracking, rutting, or faulting on different pavement types.[119] These distresses are combined with IRI to derive an assessment of overall pavement condition. Pavement distresses convey how different types of pavement deteriorate, with potential implications for asset management, maintenance, and rehabilitation, as well as vehicle operating costs.[120]

Exhibit IV-8 provides the pavement condition indicator classifications used in this edition (and aligned to classifications used elsewhere in the FHWA *Conditions and Performance Report to Congress)*. For a section of pavement to be classified in "good" overall condition, ratings for IRI and all three relevant pavement distresses (cracking and rutting for asphalt pavements; cracking and faulting for concrete pavements) must be rated as "good." For a section of pavement to be classified as "poor," at least two of the ratings must be classified as "poor." Any pavement section not classified as "good" or "poor" is classified as "fair."

Exhibit IV-8: Pavement Conditions Classifications Used in this Edition

Conditions Indicator	Rating Criteria	Good	Fair	Poor
Pavement Ride Quality	The International Roughness Index (IRI) measures the cumulative deviation from a smooth surface in inches per mile.	IRI < 95	IRI 95 to 170	IRI > 170
Pavement 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).

Exhibit IV-9 summarizes NHFN pavement ride quality in 2018. About three-quarters (76 percent) of NHFN pavement mileage was rated "good," 19 percent of mileage was rated "fair," and 5 percent of mileage was rated "poor." Between 2014 and 2018, pavement ride quality (by IRI) remained largely the same.[121]

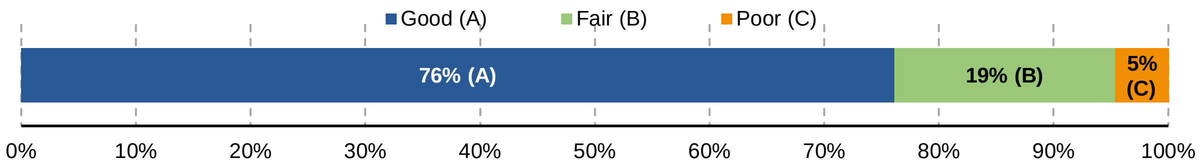
[118] HPMS data include both IRI and pavement distresses. HPMS is the data source for all pavement exhibits presented here.

[119] Distresses include the extent of faulting at the joints of concrete pavements, the extent of rutting on asphalt pavements, and the extent of cracking on both concrete and asphalt pavements.

[120] FHWA Long-Term Pavement Performance Automated Faulting Measurement, February 2015. (https://www.fhwa.dot.gov/publications/research/infrastructure/pavements/ltpp/14092/14092.pdf)

[121] Pavement condition by IRI values reported in previous chapter editions are included here for the reader's convenience. FHWA does not encourage a one-to-one comparison of indicators across chapter editions due to change in methodology approaches and other factors. The pavement condition by IRI values reported in the first chapter edition (which used 2014 HPMS data) and the second chapter edition (which used 2016 HPMS data) were the same across both editions. In those editions, 77 percent of pavement mileage was rated "good," 19 percent was rated "fair," and 4 percent was rated "poor."

Exhibit IV-9: National Highway Freight Network Pavement Ride Quality Based on IRI, 2018

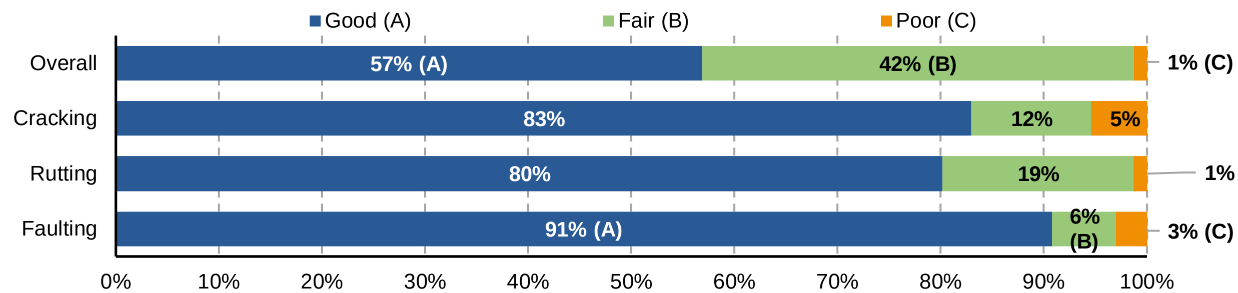


Notes: NHFN is National Highway Freight Network; IRI is International Roughness Index. With inclusion of Critical Rural Freight Corridors (CRFCs) and Critical Urban Freight Corridors (CUFCs) submitted as of January 1, 2021, the total mileage of the NHFN is 56,296. On roadways where the posted speed limit is less than (<) 40 mph, and data were available, the Present Serviceability Rating (PSR) was substituted for the IRI. This exhibit 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.

Source: U.S. Department of Transportation, Federal Highway Administration, Office of Highway Policy Information, Highway Performance Monitoring System (HPMS), 2018.

Exhibit IV-10 shows overall pavement condition and individual pavement distresses in 2018. Overall pavement condition is a combination indicator that assesses IRI and individual pavement distresses. Over half (57 percent) of NHFN mileage was rated "good" for overall pavement condition, whereas almost no mileage (1 percent) was "poor." A large portion of NHFN mileage with cracking, rutting, or faulting was rated "good" (83 percent, 80 percent, and 91 percent, respectively). NHFN mileage with cracking had the highest percent of "poor" pavement condition (5 percent of mileage), compared with NHFN mileage with rutting or faulting (1 percent and 3 percent, respectively).[122]

Exhibit IV-10: National Highway Freight Network Overall Pavement Condition and Individual Pavement Distresses, 2018



Note: Exhibit based on an analysis of NHFN mileage weighted by lane miles. Weighting by lane miles 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) and is consistent with the TPM framework. Overall pavement condition is derived from the combination of pavement ride quality (IRI) and individual pavement distress conditions.

Source: U.S. Department of Transportation, Federal Highway Administration, Office of Highway Policy Information, Highway Performance Monitoring System (HPMS), 2018. National Highway Freight Network (NHFN) as of January 1, 2021.

Exhibit IV-11 shows overall pavement condition by roadway functional class in 2018. In general, NHFN overall pavement condition declined with lower roadway functional class. However, more Minor Collector mileage (24 percent) was rated "good" than Minor Arterial and Major Collector mileage (22 percent and 14 percent, respectively).

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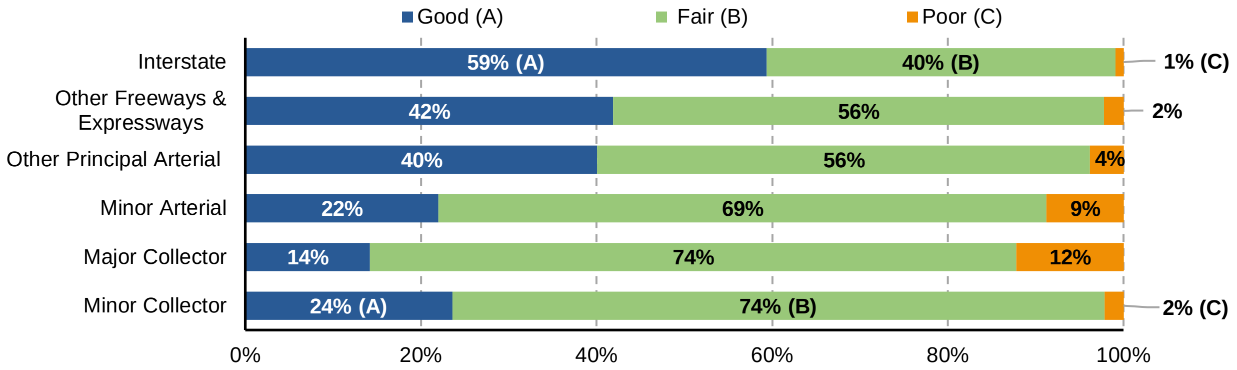
[122] Distresses are pertinent only to specific pavement types. Cracking was calculated for all pavement types on the NHFN, rutting was calculated only for asphalt pavement types, and faulting was calculated only for concrete pavement types. About 98 percent of total NHFN lane miles are represented in the cracking value, 74 percent of total NHFN lane miles are represented in the rutting value, and 20 percent of total NHFN lane miles are represented in the faulting value.

Exhibit IV-11: National Highway Freight Network Overall Pavement Condition by Roadway Functional Class, 2018



Notes: Exhibit 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. 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) and is consistent with the TPM framework. Overall ride quality is derived from the combination of a roadway's pavement ride quality (IRI) and individual pavement distress conditions.

Source: U.S. Department of Transportation, Federal Highway Administration, Office of Highway Policy Information, Highway Performance Monitoring System (HPMS), 2018. National Highway Freight Network (NHFN) as of January 1, 2021.

Bridge Conditions

In previous editions of the FHWA *Conditions and Performance Report to Congress*, FHWA established the utility of assessing conditions of bridge structural components (decks, superstructures, and substructures), culvert condition, and overall bridge conditions.[123]

Exhibit IV-12 provides the bridge conditions indicator classifications used in this edition (and aligned to classifications used elsewhere in the FHWA *Conditions and Performance Report to Congress)*.

Exhibit IV-12: Bridge Conditions Classifications Used in this Edition

Conditions Indicator	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).

The classification of a bridge in "poor" condition does not imply that the bridge is unsafe but 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.

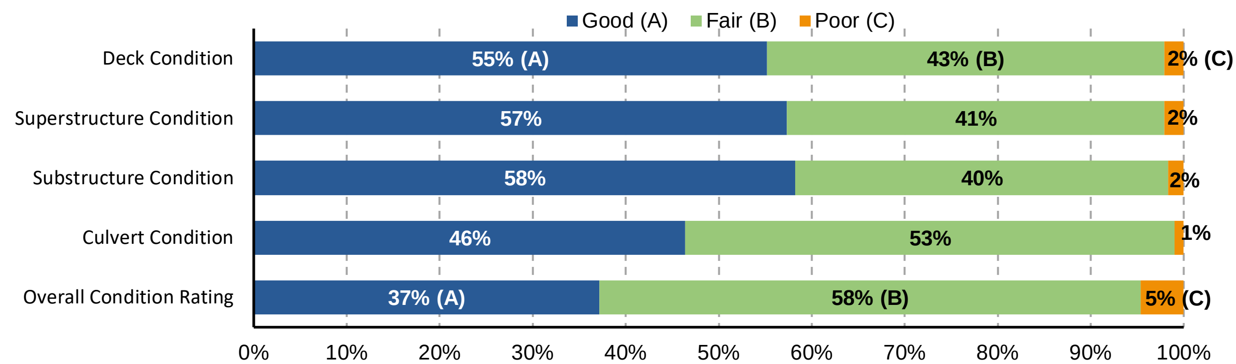
23 CFR 490 Subpart D provided the criteria for determining structurally deficient bridges and made them equal to the criteria that classify bridges as being in "poor" condition. 23 CFR 490 Subpart D considered only condition ratings for four structural items (deck condition, superstructure condition, substructure condition, and culvert condition). If any one of these is rated "poor," the bridge is classified as "poor." A bridge is classified as "good" only if all metrics are rated as "good."

[123] 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.

As of 2019, there were an estimated 84,165 bridges on the NHFN. FHWA used bridge length (by mileage) as the basis for the bridge exhibits instead of number of bridges to ensure a neutral analysis that avoided bias toward smaller bridges.[124] [125] The bridge condition analysis is based on an estimated total of 4,934 bridge miles (approximately 26,054,406 feet).

Exhibit IV-13 reports on conditions of NHFN bridge deck, superstructure, and substructure, as well as culvert mileage, and provides an overall bridge condition rating as of 2019. Bridge deck, superstructure, and substructure mileage had relatively similar "good," "fair," and "poor" conditions. Compared with these structural elements, culverts had approximately 10 percent less mileage rated "good" and 12 percent more mileage rated "fair." Approximately one-third (37 percent) of total NHFN bridge mileage was in "good" condition, 58 percent was in "fair" condition, and 5 percent was in "poor" condition (about the same as in 2016).[126] Between 2014 and 2019, bridge structural element conditions remained largely the same, with a slight decline in culvert mileage condition rated as "good" in 2019.

Exhibit IV-13: National Highway Freight Network Bridge Conditions, 2019



Note: Exhibit presents bridge mileage (bridge length) for each of the individual structural bridge components and an overall conditions rating. The overall conditions rating is derived from the combination of ratings on all four bridge structural components.
Source: U.S. Department of Transportation, Federal Highway Administration, Office of Bridges and Structures, National Bridge Inventory (NBI), 2020. National Highway Freight Network (NHFN) as of January 1, 2021.

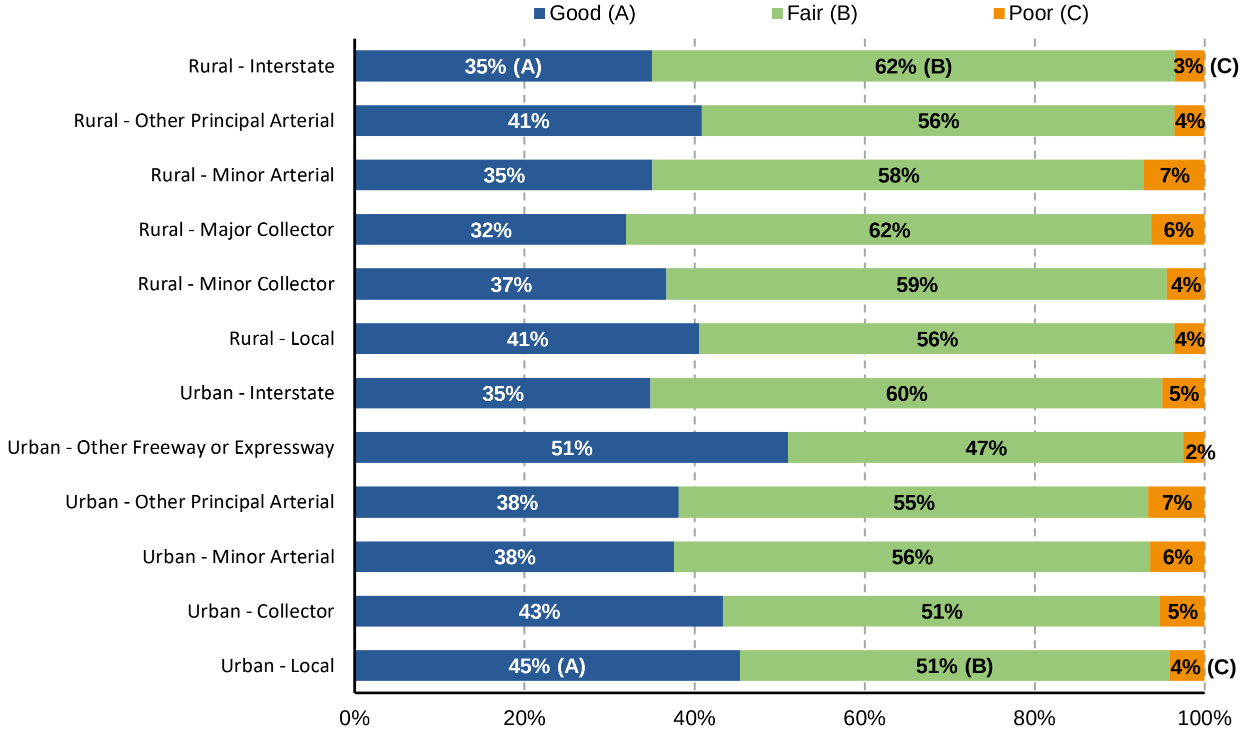
Exhibit IV-14 shows NHFN bridge conditions by roadway functional class. "Other Freeways or Expressways" in urban areas had the most share of "good" mileage (51 percent), whereas "Major Collectors" in rural areas had the lowest share of "good" mileage (32 percent). Overall, bridge mileage in urban areas is in better condition than bridge mileage in rural areas.

[124] A bridge deck refers to the roadway or traveling surface of the bridge. Bridge length refers to the length of the deck.

[125] This approach differs from the bridge condition performance measures required under 23 CFR 490 Subpart D, which required that bridge conditions be reported on the basis of bridge deck area.

[126] The first edition did not report an overall bridge condition indicator (other bridge indicators in the edition used 2014 NBI data). Overall bridge condition was reported in the second edition and used 2016 NBI data. As reported in the second edition, 53 percent of overall bridge mileage was rated as "good," 43 percent was rated as "fair," and 4 percent was rated as "poor." These values are included here for the reader's convenience. FHWA does not encourage a one-to-one comparison of indicators across chapter editions due to change in methodology approaches and other factors.

Exhibit IV-14: National Highway Freight Network Bridge Conditions by Roadway Functional Class, 2019



Notes: The NBI, and by extension, this exhibit, classifies roadways using the old functional classification system set by FHWA, which categorizes roadways into one of 12 functional classes. Under new guidance from FHWA as a result of the 2010 HPMS Reassessment Project, HPMS data reported starting in 2010 should use the revised functional classifications, which categorizes roadways into one of seven functional classes. See https://www.fhwa.dot.gov/policy/ohpi/hpms/fchguidance.cfm.

Source: U.S. Department of Transportation, Federal Highway Administration, Office of Bridges and Structures, National Bridge Inventory (NBI), 2020. National Highway Freight Network (NHFN) as of January 1, 2021.

Performance Analysis

Efficient and reliable freight movement contributes directly to economic development, provides safety and environmental benefits,[127] and supports improved quality of life and more equitable access to goods. Understanding how freight moves and where inefficiencies exist assists decision makers to develop more informed and effective policies, plans, and investments that support economic development and other areas.

In previous editions of this chapter and the FHWA Conditions and Performance Report to Congress, FHWA established safety, mobility, and reliability as key transportation performance analysis areas. As in previous editions, this edition includes indicators in each of these analysis areas but includes several updates (aligned to the FMT tool) that replace previously reported indicators.

Performance Analysis Highlights

Between 2014 and 2019, the number of fatal crashes and fatalities on the NHFN increased, with a peak in 2016. More fatalities and fatal crashes occurred on urban than rural NHFN roadways.

Between 2017 and 2019, congestion increased for 30 of the 50 most congested NHFN corridors.

Between 2017 and 2019, delay during peak travel times increased for just over half of the most congested NHFN corridors.

Between 2017 and 2019, average truck delay increased for just over half of the most congested NHFN corridors.

[127] FHWA. Freight Performance Measure Primer, 2017. (https://ops.fhwa.dot.gov/publications/fhwahop16089/chp1.htm)

Safety

Safety is the top DOT priority, a major NHFP goal, and a key element of freight performance. There is strong public interest in ensuring the safe movement of freight not only along the NHFN but along the full extent of the Nation's freight transportation system.

Exhibit IV-15 shows the number of fatal motor vehicle crashes and fatalities on the NHFN between 2014 and 2019. These data convey overall safety trends but do not necessarily indicate crashes or fatalities that involved or were caused by trucks or freight vehicle operators. Overall, between 2014 and 2019 the number of fatal crashes and fatalities on the NHFN increased, peaking in 2016.[128] More fatalities and fatal crashes occurred on NHFN roadways located in urban areas than on NHFN roadways located in rural areas.

Exhibit IV-15: Fatal Crashes and Fatalities on the National Highway Freight Network, 2014–2019

Year	Rural Areas: Fatal Crashes	Rural Areas: Fatalities	Urban Areas: Fatal Crashes	Urban Areas: Fatalities	Unknown: Fatal Crashes	Unknown: Fatalities	Total: Fatal Crashes	Total: Fatalities
2014	1,557	1,796	2,480	2,735			4,037	4,531
2015	1,776	2,092	2,727	3,003	2	2	4,505	5,097
2016	1,977	2,293	2,946	3,230	1	2	4,924	5,525
2017	1,834	2,077	3,006	3,289	1	2	4,841	5,368
2018	1,711	1,969	3,154	3,448	4	4	4,869	5,421
2019	1,783	2,067	2,939	3,169	1	1	4,723	5,237

Notes: The classification of urban and rural areas is based on the FHWA-approved adjusted Census boundaries of small urban and urbanized areas. According to 23 U.S.C. §101(a)(33), urban areas are those of population of at least 5,000, in contrast to the U.S. Census Bureau's threshold of 2,500. As of 2016, NHTSA reports the Fatality Analysis Reporting System (FARS) data using the FHWA adjusted urbanized areas of geography.

Source: National Highway Traffic Safety Administration, Fatality Analysis Reporting System (FARS) 2014–2019. National Highway Freight Network (NHFN), 2016.

Mobility

FHWA defines freight mobility in the FMT tool as "how well or efficiently freight moves."[129] Congestion is a key element of freight mobility and transportation professionals can examine congestion from several perspectives, including delay analysis.[130] Delay analysis compares normal (or "free-flow") speed to average traffic speed.[131]

Congestion and delay occur when traffic demand approaches or exceeds the available capacity of the system. Congestion is either "recurring," meaning it takes place at roughly the same place and time every day, or "nonrecurring" and caused by temporary disruptions (e.g., traffic incidents, bad weather, construction work) that render part of the roadway unusable.

Decision makers can use freight mobility indicators to effectively monitor and manage freight congestion as well as overall transportation system performance. Understanding where, when, and how delays and congested freight conditions occur supports more effective investment to address these conditions. Analysis of freight mobility also supports investment to benefit overall

[128] Although there was an overall increased trend in fatalities and fatal crashes on the NHFN between 2014 and 2019, year-over-year trends were uneven. For example, between 2016 and 2017, fatal crashes and fatalities declined on rural NHFN roadways.

[129] FHWA Freight Mobility Trends Report, 2020. Pre-publication draft as of July 2021.

[130] FHWA Conditions and Performance Report to Congress, 23rd edition.

[131] Free-flow speed is defined as the 85th percentile of off-peak speeds, where off-peak is defined as Monday through Friday, 9 a.m. to 4 p.m. and 7 p.m. to 10 p.m., as well as Saturday and Sunday 6 a.m. to 10 p.m. FHWA uses NPMRDS data to assess free-flow and average traffic speed and delay. NPMRDS (described earlier in this chapter) provides a compilation of vehicle probe-based travel time data of observed travel times, date/time, direction, and location for freight, passenger, and other traffic. The data are collected from a variety of sources, including mobile devices and sensors. FHWA makes NPMRDS data freely available to States and MPOs for use in performance management activities. See https://ops.fhwa.dot.gov/perf_measurement/ and https://ops.fhwa.dot.gov/perf_measurement/ucr/documentation.htm for details.

transportation mobility, safety, infrastructure, the environment, economic development, and quality of life.

To the freight industry, congestion and delay can mean longer freight travel times, less reliable pick-up and delivery times for truck operators, and higher operating costs passed along to consumers (with broader economic implications).[132] Congestion also negatively impacts the environment and surrounding communities.[133]

To report the mobility indicators presented here, FHWA used the FMT tool to identify 50 of the most congested corridors on the NHFN[134] based on 2019 truck hours of delay per mile.[135] Truck hours of delay per mile includes the full extent of truck congestion for all days throughout the year and is normalized by roadway length to compare varying-length roads.[136] Essentially, truck hours of delay per mile captures the degree of congestion weighted by the magnitude of truck volume.[137]

Exhibit IV-16 provides a map of the most congested NHFN corridors based on truck hours of delay per mile in 2019. Most of these locations occurred within or near major metropolitan areas, with the majority of corridors (82 percent) located in coastal metropolitan areas.[138] The most congested corridor was in the New York, New York area along Interstate (I)-95 on the George Washington Bridge and Cross Bronx Expressway. This corridor experienced 46 percent greater congestion than the next most congested corridor (I-90 between I-94 North and I-55 in Chicago, Illinois). Of the most congested NHFN corridors, six were located along I-10 extending from southern California to eastern Louisiana.

Exhibit IV-17 provides 2017, 2018, and 2019 truck hours of delay per mile values for the most congested NHFN corridors presented in *Exhibit IV-16*.[139] The exhibit lists corridors in descending order based on 2019 truck hours of delay per mile.

On 20 of the most congested NHFN corridors, truck hours of delay per mile decreased in 2019 compared with 2017. The largest decrease occurred in Atlanta, Georgia, along the I-75/I-85 corridor at the I-20 split, decreasing by 62 percent from 2017. The remaining 30 most congested NHFN corridors experienced an increase in delay between 2017 and 2019. The largest increase between 2017 and 2019 (141 percent) occurred in Houston, Texas, along the I-69/US-59 corridor at the Buffalo Speedway to I-45.

Indicators of highway mobility around major intermodal connections provide a multimodal perspective on freight. *Exhibit IV-18* conveys this perspective.

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[132] FHWA. Freight Performance Measure Primer, 2017. (https://ops.fhwa.dot.gov/publications/fhwahop16089/chp1.htm)

[133] FHWA. Freight Performance Measure Primer, 2017. (https://ops.fhwa.dot.gov/publications/fhwahop16089/chp1.htm)

[134] For purposes of conditions and performance reporting, FHWA observed that 50 corridors was an adequate sample size to provide a robust perspective on freight mobility with appropriate geographic diversity among corridor locations.

[135] Delay per mile is derived from analysis of NPMRDS data. NPMRDS data were used because this is FHWA's official data source for measuring and reporting congestion. NPMRDS (described earlier in this chapter) provides a compilation of vehicle probe-based travel time data of observed travel times, date/time, direction, and location for freight, passenger, and other traffic. The data are collected from a variety of sources, including mobile devices and sensors. FHWA makes NPMRDS data freely available to States and MPOs for use in performance management activities.

[136] FHWA Freight Mobility Trends Report, 2020. Pre-publication as of July 2021.

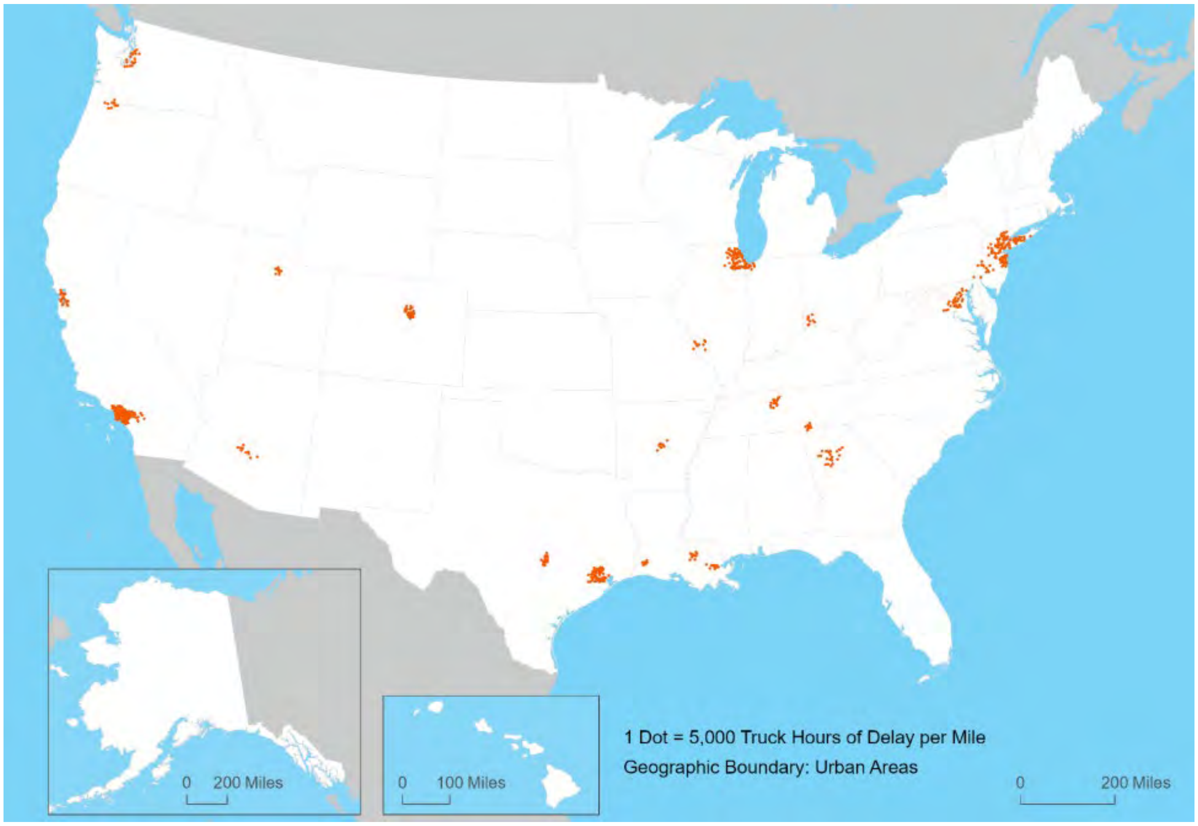
[137] FHWA Freight Mobility Trends Report, 2020. Pre-publication as of July 2021.

[138] No rural locations are represented in the top 50 congested corridors reported here.

[139] Previous chapter editions provided peak-period congestion indicators. The FMT tool does not include peak-period congestion as a performance indicator. This edition aligns to the indicators reported in the FMT tool, and thus departs from the approach taken in previous editions.

Exhibit IV-18 lists freight-significant airports,[140] maritime ports, border crossings, and rail intermodal facilities with surrounding highly congested roadways (based on truck hours of delay per mile).[141] For each facility type, the exhibit lists 10 facilities with the most hours of truck delay per mile on surrounding NHS roadways. The focus of this exhibit is not the mobility of freight moving through the facilities, but rather the mobility of the NHS roadways surrounding the facilities. The data indicate that roadways surrounding freight-significant airports and maritime ports experience the greatest mobility challenges.

Exhibit IV-16: Most Congested National Highway Freight Network Corridors, 2019



Notes: Mapped locations represent the 50 most congested NHFN corridors in 2019 based on truck hours of delay per mile for all days and times. Truck hours of delay per mile takes the difference between congested travel time and uncongested travel time (over a roadway segment), multiplied by the number of vehicle impacts, and divided by the length of the roadway segment in miles. Larger congestion values are symbolized with larger circles. CRFCs/CUFCs were not included in this analysis because the FMT tool version used as the data source did not include these segments.

Source: Freight Mobility Trends (FMT) tool, as provided by U.S. Department of Transportation, Federal Highway Administration, Office of Freight Management and Operations. National Highway Freight Network (NHFN), 2016.

[140] Freight-significant airports are airports with significant cargo operations by landed weight, as based on 2018 Bureau of Transportation Statistics data. FHWA Freight Mobility Trends Report, 2020. Pre-publication as of July 2021.

[141] These roadways are NHS roadways, not NHFN roadways. Congestion by annual truck hours of delay per mile was assessed for all directional segments of NHS roadways located within a five-mile radius surrounding each multimodal facility.

Exhibit IV-17: Truck Hours of Delay Per Mile for Most Congested National Highway Freight Network Corridors, 2017–2019

Corridor	Urban Area	Generalized Location	Length (Miles)	Delay per Mile: 2017	Delay per Mile: 2018	Delay per Mile: 2019
I-95/I-295	New York, NY	I-278/I-678 to NJ side of GW Bridge/SR-4	8.2	312,852	252,672	263,116
I-90/I-94	Chicago, IL	I-94N to I-55	10.5	159,705	155,066	140,942
I-605	Los Angeles, CA	I-5 to SR-60	6.5	133,629	125,865	139,777
I-35	Austin, TX	Airport Blvd to Stassney Ln	7.9	167,892	208,917	111,359
I-610	Houston, TX	I-69 to I-10	3.8	51,913	101,629	104,009
I-678	New York, NY	I-495 to Belt Parkway and I-295/I-95 to South end Bronx-Whitestone Bridge	5.8 2.9	105,555	103,500	100,237
I-405	Los Angeles, CA	I-105 to SR-42 Manchester Blvd	7.5	98,078	92,463	95,686
I-290	Chicago, IL	I-90/I-94 to I-290	13.5	84,761	100,833	94,778
I-69/US-59	Houston, TX	Buffalo Speedway to I-45	4.4	36,983	95,532	89,185
I-278	New York, NY	I-95/I-678 to Grand Central Pkwy and SR-27 Prospect Expy. to SR-29 Queens Blvd.	7.7, 9.2	87,110	86,481	88,339
I-24	Nashville, TN	US-41 to SR-155	5.8	83,765	93,316	86,920
I-10	Los Angeles, CA	20th Street to I-5 and at I-605	15.3 6.0	77,095	93,264	86,745
I-710	Los Angeles, CA	Cesar Chavez Ave. to Atlantic Blvd.	3.0	66,669	72,209	85,730
I-45	Houston, TX	US-90 to I-69	3.5	64,746	61,596	84,471
I-680	San Francisco, CA	SR-262 to SR-238	4.3	63,465	70,472	81,240
I-495	New York, NY	Little Neck Parkway to Queens Midtown Tunnel	14.3	78,841	61,096	70,916
I-5	Seattle, WA	I-90 to 85th St and SR-18 to Port of Tacoma Rd	7.1, 5.8	60,385	65,528	69,732
I-5	Los Angeles, CA	SR-134 Ventura Fwy. to I-605	19.8	68,776	80,290	68,560
I-76	Philadelphia, PA	University Ave to US-1	6.2	80,440	65,533	67,019
I-87	New York, NY	I-278 to 230th Street	5.9	77,558	66,426	64,891
I-105	Los Angeles, CA	I-405 to Long Beach Blvd	9.5	61,085	60,161	64,807
I-75/I-85	Atlanta, GA	I-20 to I-75/I-85 split	4.2	167,594	63,444	63,432
I-10	New Orleans, LA	At I-610	1.0	46,380	54,478	61,293
I-10	Lake Charles, LA	At I-210	9.3	13,045	31,628	61,114
I-210	Los Angeles, CA	SR-39/164 Azusa Ave to SR-19 Rosemead Blvd	10.0	36,627	60,395	60,414
I-10	Baton Rouge, LA	I-110 to SR-1	2.2	75,365	68,808	57,724
I-25	Denver, CO	I-70 to University Blvd	8.7	60,686	57,144	55,696
I-5	Portland, OR	Columbia River to Terwilliger Blvd	10.5	60,315	59,204	55,154
I-55	Chicago, IL	I-94 to SR-171	10.0	104,276	57,568	53,860
I-285	Atlanta, GA	East/SR-400 to US-78 and West/I-20 to Northside Dr	11.7, 11.2	60,380	50,469	53,821
I-495	Washington, DC	I-66 (VA) to I-95 (MD	19.5	48,931	45,461	53,507
I-70	Denver, CO	I-25 to I-270	4.8	50,426	55,902	53,461
I-30	Little Rock, AR	At I-630	1.9	47,435	40,687	51,924
I-80/I-580	San Francisco, CA	US-101 to University Avenue	8.0	53,852	52,091	51,110
I-10	Houston, TX	I-69 to I-45	2.1	46,699	49,558	50,107
I-270	Denver, CO	I-25 to I-70	5.8	45,247	49,507	50,104
I-95	Washington, DC	SR-123 to SR-286	6.3	39,447	44,650	49,241
I-110/CA-110	Los Angeles, CA	I-10 to SR-42 Stauson Ave.	3.4	55,502	61,570	48,762
I-10	Phoenix, AZ	At I-17 from 51st Ave to SR-143	13.9	60,973	51,349	48,254
I-15	Riverside, CA	At SR-91	2.2	43,572	45,982	48,175
I-15	Salt Lake City, UT	At I-215 (SR-173 to SR-48)	2.4	41,463	45,052	47,435
I-15	Los Angeles, CA	At I-10	3.2	42,171	47,039	47,170
I-80/I-94	Chicago, IL	I-294 to I-94	4.8	45,077	37,894	46,615
I-695	Baltimore, MD	I-95 to I-795	10.1	40,528	42,470	46,428
I-71/I-75	Cincinnati, OH	I-275 to Western Hills	9.2	42,393	39,841	44,603
I-90	Chicago, IL	I-90/94 to I-294	6.7	39,505	28,397	43,345
I-64	St. Louis, MO	Market St to I-70 (over Mississippi River)	5.0	58,640	41,678	42,771
I-294	Chicago, IL	At I-290 and at I-90	6.1, 3.9	52,964	59,784	42,295
I-405	Seattle, WA	I-90 to SR-520	3.7	34,131	36,903	40,760
I-75	Chattanooga, TN	At I-24	1.6	16,112	18,886	40,747

Note: Table displays the 50 most congested NHFN corridors in 2019 based on truck hours of delay per mile only for all days and times. The truck hours of delay per mile values are provided for each corridor for 2017, 2018, and 2019, and are ordered in descending order based on truck hours of delay per mile in 2019. Truck hours of delay per mile captures the degree of congestion weighted by the magnitude of truck volume and are reported as an annual sum. "Generalized locations" describe the locations of congested corridor segments. Multiple length values are corridors with major bottlenecks at two separate locations that are not contiguous.

Source: Freight Mobility Trends (FMT) tool and special analysis by U.S. Department of Transportation, Federal Highway Administration, Office of Freight Management and Operations. National Highway Freight Network (NHFN), 2016.

Exhibit IV-18: Multimodal Freight Facilities with Surrounding Highly Congested National Highway System Roadways, 2019

Facility Type	Facility Name	Location	Truck Hours of Delay per Mile on Surrounding NHS Roads
Freight-Significant Airport	Ontario International Airport	Ontario, CA	21,677
	Sky Harbor International Airport	Phoenix, AZ	20,075
	Los Angeles International Airport	Los Angeles, CA	14,019
	John F. Kennedy International Airport	New York, NY	12,955
	Miami International Airport	Miami, FL	12,070
	O'Hare International Airport	Chicago, IL	11,895
	Oakland International Airport	Oakland, CA	8,736
	Hartsfield-Jackson Atlanta International Airport	Atlanta, CA	8,735
	Seattle-Tacoma International Airport	Seattle, WA	6,085
	Memphis International Airport	Memphis, TN	5,767
Maritime Port	Port of New York & New Jersey	Bayonne, NJ	20,292
	Port of Oakland	Oakland, CA	16,728
	Port of Houston	Houston, TX	15,488
	Port of Tacoma	Tacoma, WA	10,090
	Port of Seattle	Seattle, WA	9,843
	Port of Long Beach	Long Beach, CA	9,634
	Port of New Orleans	New Orleans, LA	9,542
	Port of Los Angeles	Los Angeles, CA	8,448
	Port of Greater Baton Rouge	Baton Rouge, LA	7,759
	Port of Miami	Miami, FL	7,423
Border Crossing or Port of Entry (U.S.-side only)	Laredo Border Crossings	Laredo, TX	4,669
	Detroit Border Crossings	Detroit, MI	3,628
	El Paso Border Crossings	El Paso, TX	3,114
	Hidalgo Texas Port of Entry	Hidalgo, TX	2,586
	Blue Water Bridge	Port Huron, MI	2,550
	Otay Mesa Port of Entry	San Diego, CA	2,490
	Calexico East Port of Entry	Calexico, CA	2,324
	Blaine Pacific Highway Border Crossing	Blaine, WA	2,269
	Lewiston – Queenston Bridge	Lewiston, NY	1,900
	Sumas – Huntingdon Border Crossing	Sumas, WA	1,162
Intermodal Facility Area	Union Pacific Proviso Yard	Northlake, IL	13,807
	Union Pacific Englewood & Settegast Yards	Houston, TX	12,763
	Norfolk Southern Inman Yard	Atlanta, GA	12,379
	BNSF Denver Intermodal Facility	Denver, CO	10,732
	BNSF Memphis Intermodal Facility	Memphis, TN	6,559
	Norfolk Southern Oliver Yard	New Orleans, LA	6,131
	CSX Queensgate Yard	Cincinnati, OH	5,594
	BNSF Alliance Intermodal Facility	Haslet, TX	4,987
	KCS Knoche/Joint Agency Yard	Kansas City, MO	4,490
	Union Pacific North Little Rock Terminal	North Little Rock, AR	3,969

Note: Congestion represents the total truck delay per mile for all directional NHS segments within a five-mile radius of the freight-significant airports, maritime port, border-crossings (U.S-side only), or intermodal yard. Not all segments connect directly into the facilities listed. Within each facility type, the exhibit lists 10 facilities/locations with the most delay per mile (in hours) on surrounding roadways.

Source: Freight Mobility Trends (FMT) tool and special analysis by the U.S. Department of Transportation, Federal Highway Administration, Office of Freight Management and Operations.

Reliability

Reliability refers to consistency or dependability in travel times, as measured from day to day and/or across different times of the day.[142] Unreliable travel times can be caused by congestion, inclement weather conditions, work zones, or other factors.

To the freight industry, reliability is of critical importance. 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. An increased reliability of on-time delivery reduces both production and distribution costs. Unreliable freight travel times can increase fuel and driver costs and delay shipments, slowing down efficiency, negatively impacting productivity, and leading to adverse community and environmental impacts.[143] Shippers and carriers often use reliability measures to better plan for “just in time” delivery and anticipate freight trip times that consider variability in

[142] FHWA, Travel Time Reliability, 2006. (https://ops.fhwa.dot.gov/publications/tt_reliability/ttr_report.htm)

[143] FHWA Freight Mobility Trends Report, 2020. Pre-publication as of July 2021.

travel conditions. In the public sector, freight reliability indicators can be used to help analyze overall freight efficiency and productivity. Decision makers can use these analyses to inform what investments should be made to improve freight performance and where these investments should be targeted. Reliable freight movement promotes economic competitiveness and economic growth.[144]

This chapter edition reports on two reliability indicators: peak period Planning Time Index (PTI) and Truck Reliability Index (TRI). *Exhibit IV-19* reports on peak period PTI. *Exhibit IV-19* reports on TRI. Peak period PTI provides insight into the reliability of traffic during peak periods compared with free-flow periods, whereas TRI measures the reliability or consistency of truck travel times.

PTI compares the 95th percentile of peak period travel time[145] to free-flow travel time[146] to measure how much longer a total trip time will be compared with free-flow traffic periods.[147] For example, a PTI of 3.00 means that for a trip that takes 15 minutes in light traffic, a traveler should budget (or plan) a total of 45 minutes to ensure on-time arrival 95 percent of the time (15 X 3.00 = 45 minutes). In this example, the traveler should expect to spend three times as much time traveling compared with free-flow travel times to ensure on-time arrival 95 percent of the time. The PTI includes both typical delays as well as unexpected delays. In terms of reliability, PTI can indicate variation in total travel times during peak travel periods, with lower PTI values representing less variability to free-flow conditions and higher reliability, whereas higher PTI values suggest greater variation and lower reliability. *Exhibit IV-19* shows peak period PTI for the most congested NHFN corridors for 2017, 2018, and 2019.[148] The corridors are listed in descending order based on 2019 PTI values.

In the most congested NHFN corridors, only one corridor (I-95/I-295 in New York, New York, over the George Washington Bridge and Cross Bronx Expressway) had a PTI over 10.00. This indicates that in 2019 more than 10 times more travel time over the George Washington Bridge was necessary to ensure on-time arrival during peak periods, 95 percent of the time (i.e., 19 out of 20 trips).

FHWA developed the TRI to provide insight into day-to-day truck reliability. The TRI measures the reliability of roadway truck travel times over the course of a year by comparing the 95th percentile travel time to the 50th percentile travel time for five different times during the day.[149] TRI measures the reliability or consistency of truck travel times. It is calculated in the same way as the MAP-21 performance measure for Truck Travel Time Reliability (TTTR), but TRI results differ from TTTR due to differences in route segmentation.[150] The TRI route segmentation method allows for aggregation and the ability to report freight congestion indicators at various geographies. The FMT tool is the data source for the TRI values reported in this edition.

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[144] FHWA Freight Mobility Trends Report, 2020. Pre-publication as of July 2021.

[145] The a.m. peak period is 6 a.m. to 9 a.m. on weekdays; p.m. peak period is 4 p.m. to 7 p.m. on weekdays.

[146] Free-flow speed is the 85th percentile speed during off-peak times. Weekday off-peak periods are 9 a.m. to 4 p.m. and 7 p.m. to 10 p.m. Weekend off-peak period is 6 a.m. to 10 p.m.

[147] The FMT tool is the data source for the PTI values reported here. In the FMT tool, only truck data are used for the PTI reference speed calculation.

[148] The corridors in *Exhibit IV-19* are the same as those included in *Exhibit IV-20* but are sorted based on 2019 PTI.

[149] The five periods are: morning peak (6 a.m. to 10 a.m.), midday (10 a.m. to 4 p.m.), and afternoon peak (4 p.m. to 8 p.m.) on weekdays, 6 a.m. to 8 p.m. on weekends, and overnight every day from 8 p.m. to 6 a.m.

[150] The route segmentation approach involves combining roadway segments (these are Traffic Message Channel, or TMC, segments that provide the basis of the NPMRDS network) into longer corridors to support more robust national-scale analysis. This approach allows for aggregation and the ability to report freight statistics at a national geography. Additional information on TTTR is presented in *Exhibit IV-21*.

Exhibit IV-19: Peak Period Planning Time Index for the Most Congested NHFN Corridors, 2017–2019

Corridor	Urban Area	Generalized Location	Length (Miles)	Peak Period PTI: 2017	Peak Period PTI: 2018	Peak Period PTI: 2019
I-95/I-295	New York, NY	I-278/I-678 to NJ side of GW Bridge/SR-4	8.2	8.63	10.27	10.56
I-35	Austin, TX	Airport Blvd to Stassney Ln	7.9	7.22	8.56	9.93
I-610	Houston, TX	I-69 to I-10	3.8	4.50	8.18	9.21
I-80/I-580	San Francisco, CA	US-101 to University Avenue	8.0	9.21	9.23	9.15
I-680	San Francisco, CA	SR-262 to SR-238	4.3	6.60	7.33	8.73
I-76	Philadelphia, PA	University Ave to US-1	6.2	8.52	8.32	7.94
I-110/CA-110	Los Angeles, CA	I-10 to SR-42 Stauson Ave.	3.4	7.40	7.28	7.65
I-87	New York, NY	I-278 to 230th Street	5.9	7.25	6.92	7.54
I-710	Los Angeles, CA	Cesar Chavez Ave. to Atlantic Blvd.	3.0	8.53	8.10	7.38
I-10	Los Angeles, CA	20th Street to I-5 and at I-605	15.3; 6.0	5.75	5.39	7.26
I-90/I-94	Chicago, IL	I-94N to I-55	10.5	8.56	7.92	7.22
I-69/US-59	Houston, TX	Buffalo Speedway to I-45	4.4	5.34	8.34	7.19
I-5	Los Angeles, CA	SR-134 Ventura Fwy. to I-605	19.8	5.40	6.92	6.80
I-5	Seattle, WA	I-90 to 85th St and SR-18 to Port of Tacoma Rd	7.1; 5.8	6.70	7.44	6.43
I-90	Chicago, IL	I-90/94 to I-294	6.7	5.52	5.32	6.39
I-678	New York, NY	I-495 to Belt Parkway and I-295/I-95 to South end Bronx-Whitestone Bridge	5.8; 2.9	6.14	6.08	6.33
I-405	Los Angeles, CA	I-105 to SR-42 Manchester Blvd	7.5	6.53	5.91	6.27
I-405	Seattle, WA	I-90 to SR-520	3.7	5.94	6.47	6.25
I-15	Riverside, CA	At SR-91	2.2	5.76	5.92	6.08
I-278	New York, NY	I-95/I-678 to Grand Central Pkwy and SR-27 Prospect Expy. to SR-29 Queens Blvd.	7.7; 9.2	9.44	6.34	6.03
I-45	Houston, TX	US-90 to I-69	3.5	5.36	4.78	5.78
I-75/I-85	Atlanta, GA	I-20 to I-75/I-85 split	4.2	5.81	5.36	5.53
I-290	Chicago, IL	I-90/I-94 to I-290	13.5	5.78	5.91	5.49
I-270	Denver, CO	I-25 to I-70	5.8	5.32	5.38	5.33
I-5	Portland, OR	Columbia River to Terwilliger Blvd	10.5	3.71	4.54	5.17
I-10	Baton Rouge, LA	I-110 to SR-1	2.2	6.05	5.85	5.10
I-24	Nashville, TN	US-41 to SR-155	5.8	4.92	5.01	5.05
I-25	Denver, CO	I-70 to University Blvd	8.7	4.63	4.32	5.00
I-10	Houston, TX	I-69 to I-45	2.1	3.53	4.10	4.92
I-605	Los Angeles, CA	I-5 to SR-60	6.5	5.34	5.19	4.73
I-55	Chicago, IL	I-94 to SR-171	10.0	9.13	4.76	4.67
I-70	Denver, CO	I-25 to I-270	4.8	5.34	5.67	4.61
I-105	Los Angeles, CA	I-405 to Long Beach Blvd	9.5	4.55	8.33	4.54
I-95	Washington, DC	SR-123 to SR-286	6.3	4.04	4.27	4.40
I-495	New York, NY	Little Neck Parkway to Queens Midtown Tunnel	14.3	5.38	5.46	4.33
I-10	Lake Charles, LA	At I-210	9.3	1.57	2.01	4.12
I-64	St. Louis, MO	Market St to I-70 (over Mississippi River)	5.0	7.26	3.79	4.08
I-495	Washington, DC	I-66 (VA) to I-95 (MD	19.5	4.86	3.31	3.81
I-294	Chicago, IL	At I-290 and at I-90	6.1; 3.9	3.61	3.64	3.80
I-210	Los Angeles, CA	SR-39/164 Azusa Ave to SR-19 Rosemead Blvd	10.0	4.07	3.67	3.72
I-10	New Orleans, LA	At I-610	1.0	3.43	3.47	3.71
I-15	Los Angeles, CA	At I-10	3.2	3.43	3.71	3.71
I-695	Baltimore, MD	I-95 to I-795	10.1	3.42	3.54	3.48
I-285	Atlanta, GA	East/SR-400 to US-78; and West/I-20 to Northside Dr	11.7; 11.2	4.53	3.29	3.43
I-10	Phoenix, AZ	At I-17 from 51st Ave to SR-143	13.9	4.67	3.53	3.41
I-75	Chattanooga, TN	At I-24	1.6	1.98	1.95	3.38
I-80/I-94	Chicago, IL	I-294 to I-94	4.8	2.35	2.07	3.00
I-30	Little Rock, AR	At I-630	1.9	2.45	2.22	2.32
I-71/I-75	Cincinnati, OH	I-275 to Western Hills	9.2	5.23	2.11	2.28
I-15	Salt Lake City, UT	At I-215 (SR-173 to SR-48)	2.4	2.03	2.19	1.74

Note: Table displays the PTI for the top 50 most congested NHFN corridors in 2019 only for weekday peak periods. The corridors are ordered in descending order based on 2019 peak period PTI values. The PTI is the ratio of the 95th percentile travel time and travel time during free-flow conditions. The index is a multiplier that indicates the total time needed to ensure on-time arrival for 95 percent of trips (19 out of 20). “Generalized locations” describe the locations of congested corridor segments. Multiple length values are reported for segments that are in the same vicinity but are not contiguous.

Source: Freight Mobility Trends (FMT) tool, as provided by U.S. Department of Transportation, Federal Highway Administration, Office of Freight Management and Operations. National Highway Freight Network (NHFN), 2016.

Exhibit IV-20 provides the TRI for the most congested NHFN corridors. The TRI for each corridor is provided over three years (2017 to 2019).[151] The corridors are listed in descending order based on 2019 TRI value.

Exhibit IV-20 indicates that on 28 of the top 50 most congested corridors on the NHFN, TRI improved in 2019 compared to 2017, including the corridor with the worst TRI, located on I-10 in Baton Rouge, LA between I-110 and SR-1. The largest improvement in TRI occurred in St. Louis, MO on the I-64 corridor between Market Street and I-70 crossing the Mississippi River, improving 37 percent from 2017. The remaining 23 of the most congested corridors on the NHFN experienced worsening TRI between 2017 and 2019. The worst TRI increase occurred in Lake Charles, LA on I-10 at I-210, increasing 148 percent from 2017.

Truck Travel Time Reliability Index

In MAP-21, Congress established a set of national Transportation Performance Measures. Through Federal rulemaking (23 CFR 490 Subpart F), FHWA established the TTTR as a national performance measure to assess freight movement on the Interstate system. This metric considers factors that are unique to the freight industry, such as the use of the system during all hours of the day and the need to consider more extreme impacts to the system in planning for on-time arrivals.

In addition to PTI and TRI, FHWA also measures Truck Travel Time Reliability (TTTR) on the Interstate System reported by the States as part of the TPM framework established by MAP-21 in 23 U.S.C. §150. The TTTR index is a systems-based metric that uses the NPMRDS to calculate the average TTTR over the full Interstate System.

The TTTR index represents the additional average time that truck drivers on the Interstate System would need to add onto their typical travel times to ensure on-time arrival 95 percent of the time. Like TRI, TTTR is the ratio between the 95th percentile truck travel time to the 50th percentile truck travel time for five different times during the day for all Interstates.[152] The TTTR metric is weighted against all Interstate miles to determine a systemwide average. Higher TTTR values indicate a less reliable roadway, whereas lower TTTR values closer to 1.0 indicate a more reliable roadway.

Exhibit IV-21 provides the national TTTR index measured for the entire Interstate System over three years (2017 to 2019). Between 2017 and 2019, the national TTTR index on the Interstate System worsened from 1.36 to 1.39.

[151] The corridors in *Exhibit IV-20* are the same as those included in *Exhibit IV-19* but are sorted based on 2019 TRI.

[152] The five periods are: morning peak (6 a.m. to 10 a.m.), midday (10 a.m. to 4 p.m.), and afternoon peak (4 p.m. to 8 p.m.) on weekdays, 6 a.m. to 8 p.m. on weekends, and overnight every day from 8 p.m. to 6 a.m.

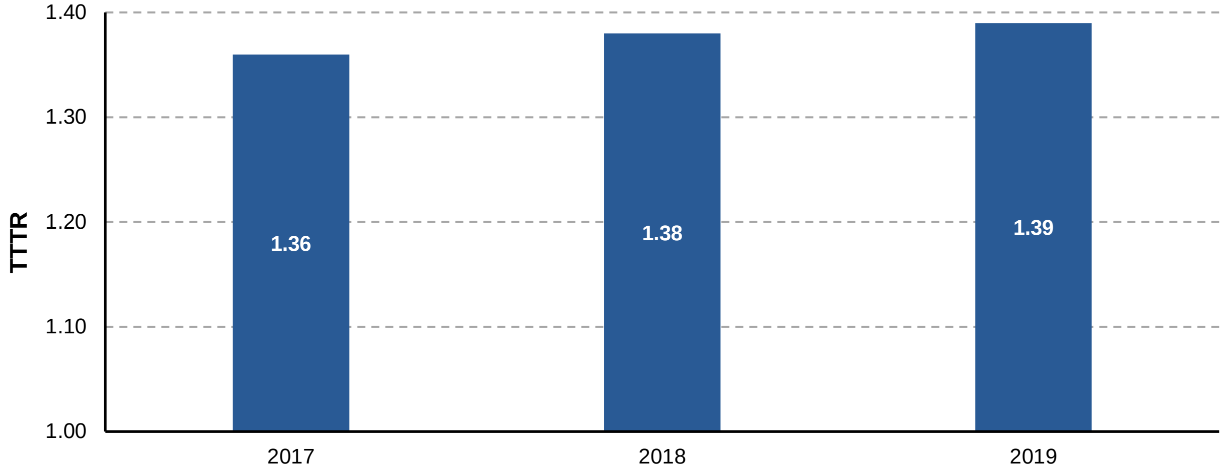
Exhibit IV-20: Truck Reliability Index for the Most Congested NHFN Corridors, 2017–2019

Road	Urban Area	Generalized Location	Length (Miles)	TRI: 2017	TRI: 2018	TRI: 2019
I-10	Baton Rouge, LA	I-110 to SR-1	2.2	4.05	4.24	3.97
I-10	Lake Charles, LA	At I-210	9.3	1.45	1.76	3.60
I-80/I-94	Chicago, IL	I-294 to I-94	4.8	2.18	1.93	2.64
I-405	Seattle, WA	I-90 to SR-520	3.7	2.25	2.38	2.63
I-35	Austin, TX	Airport Blvd to Stassney Ln	7.9	2.14	2.09	2.51
I-695	Baltimore, MD	I-95 to I-795	10.1	2.20	2.56	2.36
I-405	Los Angeles, CA	I-105 to SR-42 Manchester Blvd	7.5	2.35	2.30	2.24
I-15	Los Angeles, CA	At I-10	3.2	2.18	2.36	2.24
I-15	Riverside, CA	At SR-91	2.2	2.18	2.06	2.17
I-64	St. Louis, MO	Market St to I-70 (over Mississippi River)	5.0	3.44	2.27	2.16
I-294	Chicago, IL	At I-290 and at I-90	6.1 3.9	2.34	2.29	2.14
I-680	San Francisco, CA	SR-262 to SR-238	4.3	1.93	1.91	2.09
I-710	Los Angeles, CA	Cesar Chavez Ave. to Atlantic Blvd.	3.0	2.90	2.71	2.02
I-5	Los Angeles, CA	SR-134 Ventura Fwy. to I-605	19.8	1.33	2.05	2.01
I-10	Houston, TX	I-69 to I-45	2.1	1.72	1.87	2.00
I-87	New York, NY	I-278 to 230th Street	5.9	1.82	1.79	1.99
I-110/CA-110	Los Angeles, CA	I-10 to SR-42 Stauson Ave.	3.4	1.78	1.80	1.96
I-5	Portland, OR	Columbia River to Terwilliger Blvd	10.5	1.21	1.89	1.95
I-10	Phoenix, AZ	At I-17 from 51st Ave to SR-143	13.9	3.18	1.91	1.92
I-30	Little Rock, AR	At I-630	1.9	2.00	1.81	1.86
I-69/US-59	Houston, TX	Buffalo Speedway to I-45	4.4	1.76	2.27	1.84
I-270	Denver, CO	I-25 to I-70	5.8	1.87	1.75	1.82
I-495	New York, NY	Little Neck Parkway to Queens Midtown Tunnel	14.3	1.69	1.69	1.81
I-76	Philadelphia, PA	University Ave to US-1	6.2	1.67	1.71	1.79
I-495	Washington, DC	I-66 (VA) to I-95 (MD	19.5	2.48	1.66	1.78
I-24	Nashville, TN	US-41 to SR-155	5.8	2.31	2.02	1.72
I-25	Denver, CO	I-70 to University Blvd	8.7	1.66	1.65	1.72
I-95	Washington, DC	SR-123 to SR-286	6.3	1.60	1.69	1.69
I-55	Chicago, IL	I-94 to SR-171	10.0	1.46	1.71	1.68
I-75	Chattanooga, TN	At I-24	1.6	1.70	1.71	1.68
I-5	Seattle, WA	I-90 to 85th St and SR-18 to Port of Tacoma Rd	7.1 5.8	1.89	1.77	1.66
I-610	Houston, TX	I-69 to I-10	3.8	1.57	1.39	1.62
I-285	Atlanta, GA	East/SR-400 to US-78; and West/I-20 to Northside Dr	11.7 11.2	2.63	1.67	1.58
I-278	New York, NY	I-95/I-678 to Grand Central Pkwy. and SR-27 Prospect Expy. to SR-29 Queens Blvd.	7.7 9.2	1.73	1.56	1.55
I-45	Houston, TX	US-90 to I-69	3.5	1.55	1.35	1.54
I-75/I-85	Atlanta, GA	I-20 to I-75/I-85 split	4.2	1.71	1.56	1.52
I-10	New Orleans, LA	At I-610	1.0	1.59	1.57	1.52
I-10	Los Angeles, CA	20th Street to I-5; and at I-605	15.3 6.0	1.65	1.52	1.50
I-70	Denver, CO	I-25 to I-270	4.8	1.73	1.66	1.50
I-90/I-94	Chicago, IL	I-94N to I-55	10.5	1.72	1.63	1.45
I-95/I-295	New York, NY	I-278/I-678 to NJ side of GW Bridge/SR-4	8.2	1.41	1.45	1.44
I-290	Chicago, IL	I-90/I-94 to I-290	13.5	1.61	1.58	1.41
I-80/I-580	San Francisco, CA	US-101 to University Avenue	8.0	1.39	1.46	1.37
I-210	Los Angeles, CA	SR-39/164 Azusa Ave to SR-19 Rosemead Blvd	10.0	1.87	1.37	1.35
I-90	Chicago, IL	I-90/94 to I-294	6.7	1.33	1.78	1.35
I-105	Los Angeles, CA	I-405 to Long Beach Blvd’	9.5	1.44	3.97	1.34
I-678	New York, NY	I-495 to Belt Parkway and I-295/I-95 to South end Bronx-Whitestone Bridge	5.8 2.9	1.34	1.28	1.31
I-605	Los Angeles, CA	I-5 to SR-60	6.5	1.26	1.27	1.30
I-15	Salt Lake City, UT	At I-215 (SR-173 to SR-48)	2.4	1.73	1.60	1.27
I-71/I-75	Cincinnati, OH	I-275 to Western Hills	9.2	2.29	1.21	1.19

Note: Table displays the Truck Reliability Index (TRI) for the top 50 most congested NHFN corridors in 2019 based on truck hours of delay per mile. TRI is the ratio of the 95th percentile travel time to the 50th percentile travel time (median) computed for five different time periods a day: weekday morning peak, midday, and evening peak; weekend days; and overnight (all days). TRI is calculated the same as the MAP-21 performance measure for Truck Travel Time Reliability (TTTR), but results will differ from the NPMRDS TTTR due to differences in route segmentation. Where a tie exists, segments are then ranked by delay per mile. Higher TRI values indicate a less reliable corridor, whereas lower TRI values closer to 1.00 indicate a more reliable corridor. “Generalized locations” describe the locations of congested corridor segments. Multiple length values are reported for segments that are in the same vicinity but are not contiguous.

Source: Freight Mobility Trends (FMT) tool, as provided by U.S. Department of Transportation, Federal Highway Administration, Office of Freight Management and Operations. National Highway Freight Network (NHFN), 2016.

Exhibit IV-21: National Truck Travel Time Reliability Index on the Interstate System, 2017–2019



Note: TTTR is Truck Travel Time Reliability. Graph displays the TTTR averaged over the entire Interstate System. The TTTR index is the ratio of the 95th percentile truck travel time to the 50th percentile truck travel time calculated during specific times of the day: morning peak (6-10 a.m.), midday (10 a.m.–4 p.m.) and afternoon peak (4–8 p.m.) Mondays through Fridays; weekends (6 a.m.–8 p.m.); and overnights for all days (8 p.m.–6 a.m.).

Source: National Performance Management Research Data Set, Highway Performance Monitoring System, Federal Highway Administration, Office of Highway Policy, 2020.

Freight Demand

Truck volumes are indicators of freight demand. Coupled with the safety, mobility, and reliability indicators reported earlier in this chapter, truck volumes provide additional context for understanding freight performance. Expected growth in freight over the next 25 to 30 years will translate to higher volumes of freight vehicles on the Nation's freight transportation network, particularly on its highways (since trucks move most freight by both weight and value).

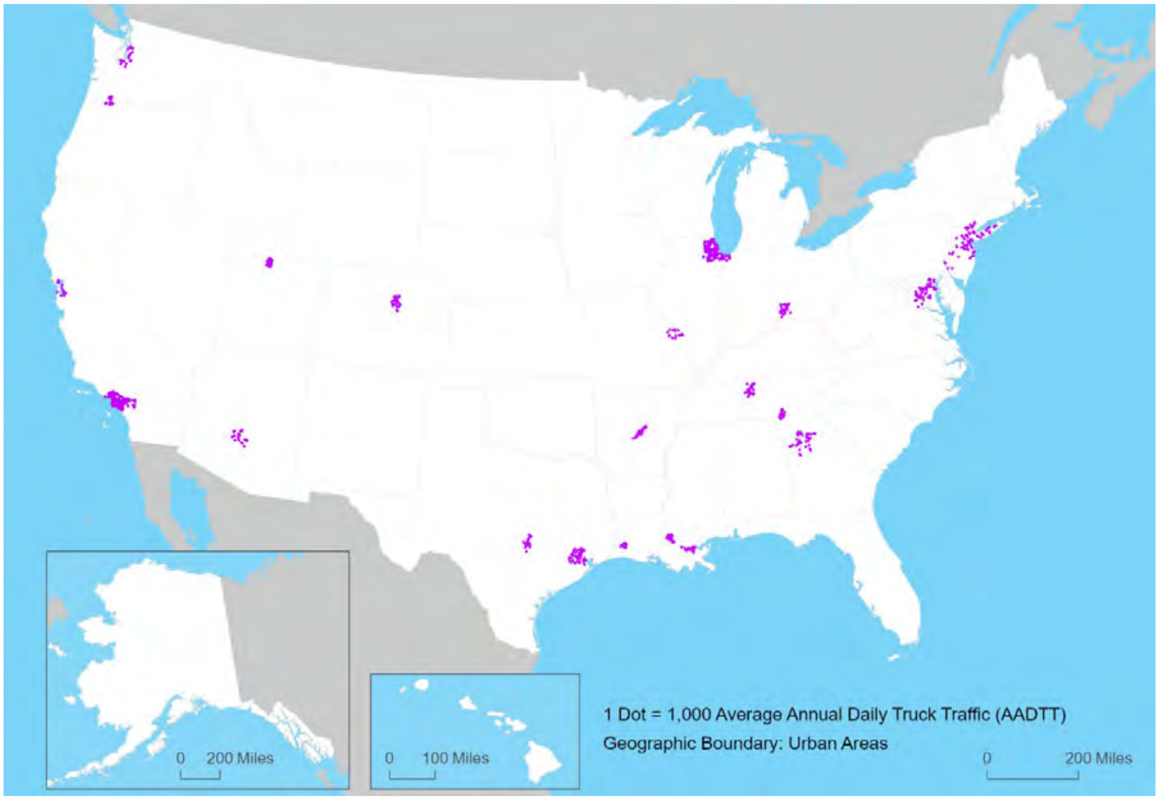
This edition uses 2019 AADTT as reported in the FMT tool to produce *Exhibit IV-22*.[153] The first edition reported average/forecasted daily long-haul truck traffic on the NHFN as a volume indicator (the second edition did not include this indicator). In a departure from the first edition's approach, this edition uses average annual daily truck traffic (AADTT), an established indicator of freight volume, due to new opportunities provided by the FMT tool for freight performance analysis.

Exhibit IV-22 provides AADTT for the most congested corridors on the NHFN. The exhibit shows where heavy freight volumes occur on congested corridors, although corridors with high AADTT may not necessarily be the most congested. For example, the corridor with the largest AADTT in 2019 was I-80/I-94 in the Chicago, IL area, but the bottleneck between I-294 to I-94 is lower on the list of the most congested NHFN corridors. This corridor experienced 119 percent more total truck traffic volume than the most congested NHFN corridor (I-95 through New York, NY) based on truck hours of delay per mile in 2019.[154] Unlike *Exhibit IV-16*, three of the four corridors with the largest AADTT were not located in coastal metropolitan areas.

[153] State DOTs report AADTT into HPMS. In the FMT tool, FHWA used specific analytic approaches to conflate NPMRDS TMC travel times to HPMS roadway segments (and associated volumes) to report AADTT. See the Freight Mobility Trends 2020 report (pre-publication draft as of July 2021) for additional details.

[154] The 2019 AADTT value along I-80/I-94 in Chicago, IL was 41,800. The 2019 AADTT value along I-95 in New York, NY was 19,110.

Exhibit IV-22: Truck Volumes for the Most Congested NHFN Corridors, 2019



Notes: AADTT is Average Annual Daily Truck Traffic. Mapped locations represent the AADTT for the 50 most congested corridors on the NHFN in 2019 based on truck hours of delay per mile for all days and times. Delay per mile is the difference in the congested travel time and the uncongested travel time (over a roadway segment), multiplied by the number of vehicles impacted, and divided by the length of the roadway segment in miles. AADTT is the total volume of truck traffic on a roadway segment for one year, divided by the number of days in the year. Larger AADTT values are symbolized with larger circles. CRFCs/CUFCs were not included in this analysis because the FMT tool version used as the data source did not include these segments.

Source: Freight Mobility Trends (FMT) tool, as provided by U.S. Department of Transportation, Federal Highway Administration, Office of Freight Management and Operations. National Highway Freight Network (NHFN), 2016.

Critical Rural Freight Corridors and Critical Urban Freight Corridors

CRFCs/CUFCs provide States (and MPOs in some cases) an opportunity to designate high-priority connectors from freight generators to the NHFN. FHWA encourages States and MPOs making CRFC designations to consider connectivity from the NHFN to freight facilities such as agricultural processing centers, grain elevators, intermodal facilities, and forestry facilities, as well as international ports of entry and energy production areas (among other considerations). FHWA encourages States making CUFC designations to consider routes from the NHFN to logistics centers, manufacturing and warehouse industrial areas, or intermodal facilities (among other considerations).

Submitting CRFC/CUFC designations is optional, but it enables States to apply NHFP funds to CRFC/CUFC routes.

As of January 1, 2021, designated and submitted CRFCs/CUFCs represented a total of 5,681 total miles, about 10 percent of total 2021 NHFN roadway mileage. As of this date, 29 States and the District of Columbia had submitted CRFC/CUFC designations to FHWA. Additionally, one State (New Mexico) submitted only CRFC designations and one State (Michigan) submitted only CUFC designations. For additional information on CRFCs/CUFCs, including a list of the most recently submitted CRFC/CUFC routes, see the NHFN Visualization Tool.[155]

When submitting CRFC/CUFC designations to FHWA, States are required to classify them using one or more specific route identifiers shown in *Exhibit IV-23* and *Exhibit IV-24*. These route identifiers provide flexibility for States to designate any functional class of roadway, including local roads, as well as planned routes. They outline general criteria for how States should classify CRFCs/CUFCs. Of the 11 route identifier categories, there are seven identifiers for CRFCs and four identifiers for CUFCs.

Exhibit IV-23: 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 average annual daily traffic (AADT) 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

Notes: PHFS is Primary Highway Freight System. AADT is average annual daily traffic.

Source: U.S. Department of Transportation, Federal Highway Administration, Office of Freight Management and Operations.

Exhibit IV-24: 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: U.S. Department of Transportation, Federal Highway Administration, Office of Freight Management and Operations.

States frequently used multiple CRFC/CUFC identifiers when submitting designations, indicating that States used the flexibility inherent in these categories to identify high-priority corridors. As of January 1, 2021, critical corridors identified as vital to regional freight movement (CUFC ID=K) and improving freight movement/contributing to economic development (CRFC ID=G) were the two most frequently used identifiers. They were also the only route identifiers used on their own (not in combination with at least one other route identifier). All other route identifiers were used in combination with at least one other route identifier. However, corridors identified as providing access to agricultural, mining, or intermodal facilities and international ports of entry (CRFC IDs=D and E) were more commonly used independently.

Exhibit IV-25 shows the percentage of CRFC/CUFC mileage that States or MPOs designated to each of the route identifiers. Overall, States designated about half of CRFC mileage (47 percent) and half of CUFC mileage (54 percent) using route identifiers indicating important connections to freight facilities (CRFC IDs=B, C, D, E, and F; and CUFC IDs=H and J). States designated the largest percentage of CRFC mileage (29 percent) using an identifier that indicated the routes had high truck volumes (CRFC ID=A). States or MPOs designated the

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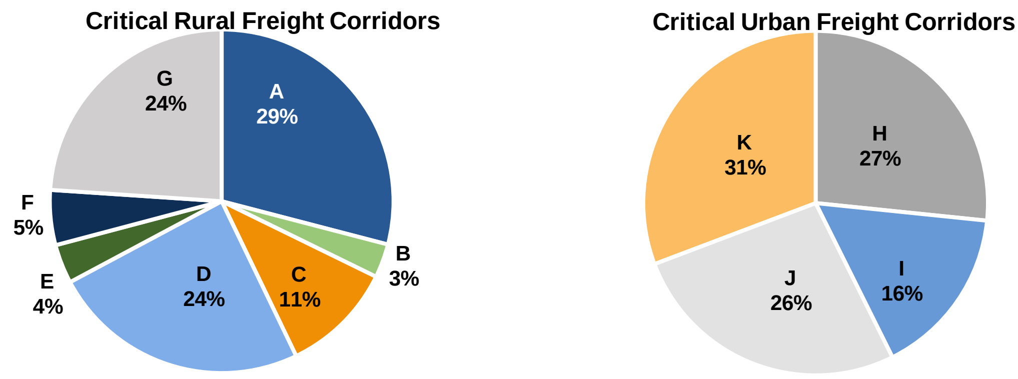
[155] https://fpcb.ops.fhwa.dot.gov/dataAnalysisTools.aspx

largest percentage of CUFC mileage (31 percent) using an identifier that indicated the routes were important to the movement of freight within a region (CUFC ID=K).[156]

Exhibit IV-25: Critical Rural Freight Corridor/Critical Urban Freight Corridor Route Identifier Frequency, 2021



Notes: Percentages are based on the corridor length (in miles) for CRFCs/CUFCs designated with each route identifier. The size of the pie chart slices represents the percentage of total miles designated with each route identifier. When a State or MPO designated a corridor using more than one route identifier, the mileage is counted toward each route identifier's total mileage. Because States or MPOs are permitted to use more than one route identifier to designate a corridor, the total mileage in this analysis represents more than the actual total mileage of CRFCs/CUFCs submitted to FHWA.

Source: U.S. Department of Transportation, Federal Highway Administration, Office of Freight Management and Operations. Represents data as of January 1, 2021.

Program Highlights

This section provides an overview of Federal, State, and industry efforts that address NHFN conditions- and performance-related needs or issues. These efforts include State Freight Plans and national initiatives to improve truck parking. These examples highlight the ways that decision makers and stakeholders in various sectors are using freight infrastructure conditions and performance information to inform investments and improve freight operations.

State Freight Plans

Section 8001(a) of the FAST Act (codified in 49 U.S.C. §70202) required each State receiving NHFP funding to develop a State Freight Plan. State Freight Plans are comprehensive plans for immediate and long-range freight planning activities and investment. 49 U.S.C. §70202 required that State Freight Plans address several conditions- and performance-related elements (among other required elements).[157] For example, State Freight Plans must:

- Address how heavy vehicle travel is projected to affect roadway condition and provide a description of improvements to address any expected deterioration;
- Provide an inventory of facilities with freight mobility issues, such as bottlenecks; and
- Consider any significant congestion or delay caused by freight movement and discuss any strategies to mitigate that congestion or delay.

The Bipartisan Infrastructure Law added several additional requirements for State Freight Plans and reduced the update period. A State Freight Plan must now be updated every four years and must address an eight-year forecast period, although DOT strongly encourages an outlook of

[156] Percentages do not include mileage that was submitted without a route identifier or were designated with an incorrect route identifier as based on the corridor's geographic location (e.g., a State used a CUFC route identifier to designate a CRFC).

[157] 49 U.S.C. §70202 outlined 10 requirements for State Freight Plans, but the plans may be organized in any structure that works best for individual States. 81 FR 71185: *Guidance on State Freight Plans and State Freight Advisory Committees* (2016) provides the list of 10 required elements. See https://www.federalregister.gov/documents/2016/10/14/2016-24862/guidance-on-state-freight-plans-and-state-freight-advisory-committees

two decades or more. All States previously completed a FAST-Act compliant State Freight Plan, and, at the time of writing, most had recently updated their State Freight Plans to meet the new BIL requirements.

FHWA analyzed submitted State Freight Plans to identify trends, including trends in how States considered conditions and performance topics.[158] In its analysis, FHWA found that the State Freight Plans address a wide array of conditions and performance-related needs, issues, and challenges that include infrastructure conditions, truck parking, and funding.[159] The State Freight Plans also include discussions of federally required freight-related performance measures, such as TTTR.[160] However, performance measure discussions were not limited to TTTR; FHWA's review identified more than 200 unique freight-related performance measures across the 51 State Freight Plans.[161]

Across the State Freight Plans, recurring conditions- and performance-related goals included connectivity, coordination, competitiveness, environment, mobility, safety and security, state of good repair, stewardship, and technology.[162] The use of innovative technologies and operational strategies to enhance freight service were discussed in most (88 percent) of the plans.[163] Examples of such strategies included the use of intelligent transportation system infrastructure to enhance safety, the use of transportation systems management and operations plans and signal optimization for freight, and employing technology to support truck size and weight and truck parking programs.

States are also required in their State Freight Plans to produce a freight investment plan that includes a list of priority projects and how NHFP funds would be invested and matched, if made available. In these freight investment plans, States noted many different types of projects, many of which directly addressed the facets of freight conditions and performance discussed in this report, including pavement and bridge condition, safety, congestion, and reliability.[164]

Truck Parking

MAP-21 Section 1401, also known as "Jason's Law" (MAP-21; P.L. 112-141), was established to address NHS commercial motor vehicle parking shortages to improve safety for motorized and nonmotorized users and commercial motor vehicle (CMV) operators.

Jason's Law required DOT to conduct a survey assessing States' capabilities to provide adequate CMV parking and rest facilities. The resulting survey report, published in 2015, identified a number of national truck parking challenges, including deficiencies in safe truck parking capacity and the existence of unofficial parking in areas not designated for this purpose.[165]

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[158] FHWA Review and Analysis of State Freight Plans, pre-publication draft, 25

[159] FHWA Review and Analysis of State Freight Plans, pre-publication draft, 25

[160] For more information, see https://www.tpmtools.org/resource/fhwa-transportation-performance-management/

[161] FHWA Review and Analysis of State Freight Plans, pre-publication draft, 50.

[162] For example, 92 percent of plans addressed mobility and safety and security, whereas more than 80 percent addressed economic competitiveness and more than 75 percent addressed state of good repair.

[163] FHWA Review and Analysis of State Freight Plans, pre-publication draft, 11.

[164] For example, Kentucky planned to focus investment on "corridors that exhibit a strong correlation between truck vehicle miles traveled and substandard pavement and bridge ratings on Tier 1, 2, and 3 highway freight network," whereas Tennessee recommended a broad array of freight programs to address "truck parking needs, first mile/last mile connections, freight bottlenecks, and freight spot safety improvements." Some States suggested improvements to a network, such as Texas's Multimodal Freight Network, whereas others targeted specific roads, such as Vermont's emphasis on Route 9. See FHWA *Review and Analysis of State Freight Plans*, pages 27-28.

[165] FHWA, "Jason's Law Truck Parking Survey Results and Comparative Analysis." August 2015. See: https://ops.fhwa.dot.gov/freight/infrastructure/truck_parking/jasons_law/truckparkingsurvey/index.htm

The first edition of the *Highway Freight Conditions and Performance Report to Congress* discussed the 2015 Jason's Law survey report findings in depth. The second edition discussed progress made to address truck parking challenges through DOT's formation of a National Coalition on Truck Parking (NCTP). The NCTP convenes stakeholders from the public sector, transportation organizations, freight industry, and other groups to advance safe truck parking through sharing noteworthy practices and other information.[166]

Jason's Law

Jason's Law directed DOT to conduct a survey and a comparative assessment, in consultation with relevant State motor carrier representatives, to:

- Evaluate the capability of each State to provide adequate parking and rest facilities for commercial motor vehicles engaged in interstate transportation.
- Assess the volume of commercial motor vehicle traffic in each State.
- Develop a system of metrics to measure the adequacy of commercial motor vehicle parking facilities in each State.

For more information, see: https://ops.fhwa.dot.gov/freight/infrastructure/truck_parking/index.htm

Jason's Law required DOT to periodically update the survey. To meet this requirement, DOT administered a follow-up survey in 2019 to several stakeholder groups, including States, State commercial vehicle safety (CVS) agencies, travel plaza and truck stop owners and operators, trucking firm managers, logistics personnel, port authorities, and truck drivers. DOT received responses representing all 50 States, 45 State CVS agencies, 524 truck stops, and 17 port authorities, as well as more than 11,000 individual truck drivers and over 700 trucking operations managers.[167]

The follow-up survey documented the location of almost 313,000 truck parking spaces, including almost 40,000 at public rest areas and toll service plazas and about 273,000 at private truck stops.[168] In comparison to the 2015 Jason's Law survey results, States reported an increase of 239 truck parking facilities and 1,978 truck parking spaces (respectively representing a 13-percent and 6-percent increase over the 2015 data).[169] The survey also found that more than 98 percent of truck driver respondents said they regularly experienced problems finding safe parking locations when rest was needed. Over 90 percent reported struggling to find safe parking at night (7 p.m. to midnight), similar to responses in the 2015 Jason's Law truck parking survey.

The 2015 Jason's Law survey report identified locations where States reported truck parking challenges; however, this analysis was limited as only 11 States provided detailed data on this topic. The 2019 survey asked State CVS agencies to report information on problematic truck parking locations and received responses from 45 State CVS agencies, allowing for a more detailed analysis. Overall, 80 percent of States identified unofficial/unauthorized truck parking in their State, with most problems occurring at or on:

- Freeway entrance and exit ramps;
- Freeway shoulders;
- Informal, as well as formally designated parking lots; and
- Local roadways accessing freeway ramps.

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[166] Additional information on the NCTP is available at: https://ops.fhwa.dot.gov/freight/infrastructure/truck_parking/workinggroups/index.htm.

[167] FHWA, "Jason's Law Truck Parking Survey and Comparative Assessment 2019 Update Report." Pre-publication draft, 2020.

[168] FHWA, "Jason's Law Truck Parking Survey and Comparative Assessment 2019 Update Report." Pre-publication draft, 2020.

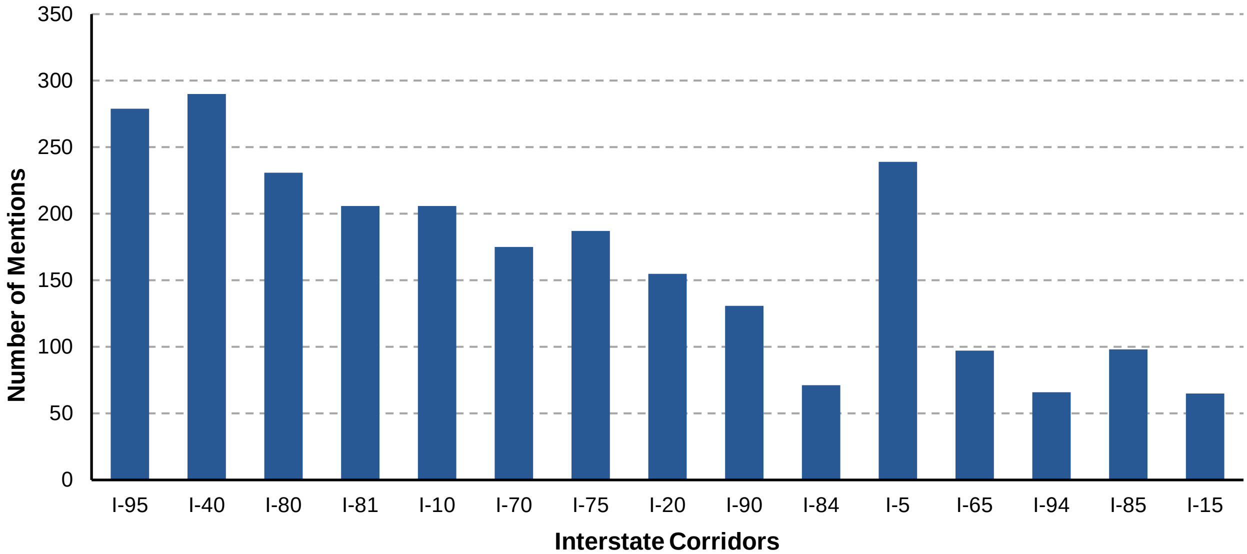
[169] FHWA, "Jason's Law Truck Parking Survey and Comparative Assessment 2019 Update Report." Pre-publication draft, 2020. This report notes that the increase in truck parking capacity reflects construction in some States, readjustment of current public facilities to offer more truck parking options, and improved State-level data. In comparing the initial and follow-up surveys, FHWA noted some variances in how States defined and reported public truck parking as well as some inaccuracies in the initial survey data. FHWA performed data validation to allow for a more accurate comparison.

The initial survey found that about half (47 percent) of problematic locations were on freeway interchange ramps, almost half (45 percent) were on road shoulders, and about one-quarter (24 percent) were on local streets. The 2019 survey showed some variation from these data. In comparison to the 2015 survey results, the percentage of shoulders and local roads reported as problematic locations decreased (to 34 percent and 10 percent, respectively), whereas the percentage of ramps reported as a problematic location increased to 58 percent.[170]

The follow-up survey also collected data on the Interstate corridors where truck parking shortages were noted. *Exhibit IV-26* shows the top 15 Interstate corridors identified with parking shortages, according to the survey. Truck drivers were given the opportunity to comment on the locations where they experience the most shortages in truck parking.

One of the new requirements for State Freight Plans that was included in the Bipartisan Infrastructure Law is that the Plans must include an assessment of the adequacy of commercial motor vehicle parking. As State Freight Plans are updated to comply with this new requirement, they will provide additional data on truck parking conditions.

Exhibit IV-26: Top 15 Interstates with Truck Parking Shortages by Number of Comments



Notes: Truck drivers were given an opportunity in the survey to comment on the locations where they most experience truck parking shortages. Word count functions were used to determine the number of mentions by drivers for the top 15 Interstate corridors. The number of mentions represents the number of comments and may not correspond to the actual number of drivers using the corridor.
Source: FHWA, "Jason's Law Truck Parking Survey and Comparative Assessment 2019 Update Report." Pre-publication draft, 2020.

Special Topics

This section provides information on high-priority DOT policy focus areas of improving safety, ensuring equitable access to opportunities, addressing resilience and climate change impacts, and creating jobs and fostering economic growth.[171] Consideration of these policy focus areas is relevant to understanding and improving freight conditions and performance. The sections below discuss specific freight conditions and performance topics pertaining to the equity, resilience/climate change, and economic focus areas. These discussions provide foundations

[170] Results are based on 1,988 locations reported by 40 States. Florida, Indiana, and California reported high numbers of truck parking problematic locations, whereas the remaining States reported 90 or fewer problematic locations.

[171] US DOT, Secretary of Transportation Pete Buttigieg. *Fiscal Year 2022 Budget Highlights.* https://www.transportation.gov/sites/dot.gov/files/2021-05/Budget-Highlights2022_052721_FINAL.PDF.

for future analysis, as established national data sources for DOT reporting are not yet available for these topics.

Supply Chains

DOT invests in research and innovation delivery to improve a national understanding of supply chains, protect national security, limit disruptions to goods movement, and ensure freight's continued contribution to economic development and quality of life. The Introduction to this chapter described several FHWA research efforts designed to improve supply chain analytical approaches, tools, and resources. For example, FHWA's freight fluidity research assesses freight transportation performance across multimodal supply chains and is building tools to support State DOT, MPO, and other transportation professionals in improved freight analysis and decision-making.

DOT and other Federal agencies are also researching supply chain challenges and needs to inform policy decisions. In early 2021, the White House issued Executive Order 14017 on America's Supply Chains, which directed DOT and several other Federal agencies to assess supply chain resilience in certain key industries. DOT issued its one-year report on Supply Chain resilience in the freight and logistics sector on February 24, 2022.[172]

Changes in consumer behavior, availability of raw materials, and technology innovations are examples of factors that may affect supply chains and efficiencies. For example, advances in 3-D printing may shorten supply chains for high-value, urgent products, potentially reducing air freight demand in particular.[173]

Unexpected disruptions caused by large-scale natural or human-induced incident events or global health emergencies can also significantly impact supply chains and freight movement in the short term, with potentially lasting economic implications. For example, due to changing consumer behaviors as a result of the COVID-19 pandemic, the share of e-commerce in total retail in the United States substantially increased. Between the first quarter of 2018 and the first quarter of 2020, the share of e-commerce rose from 9.6 percent to 11.8 percent, respectively, but then spiked to 16.1 percent between the first and second quarter of 2020.[174] The pandemic also affected supply chain efficiency (including availability of shipping containers) with resulting delays and rising costs.[175] Long-term economic and transportation implications of the pandemic are unknown, but could include changes in consumer demand for goods based on shifts in home and work locations and hours; shifts in freight volumes, mobility, and reliability; changes in manufacturing locations; and new needs for freight investment.

White House Directive on America's Supply Chains

Executive Order 14017 on America's Supply Chains directs the U.S. government to review supply chain risks to ensure the resilience of supply chains and maintain America's competitive advantage. The Executive Order also directs DOT and several other Federal agencies to conduct sectoral supply chain assessments, including an analysis of supply chains for the transportation industrial base.

Source: https://www.federalregister.gov/documents/2021/03/01/2021-04280/americas-supply-chains

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[172] Supply Chain Assessment of the Transportation Industrial Base: Freight and Logistics (2022), https://www.transportation.gov/supplychains

[173] Beyond Traffic (2017), p. 74. https://www.transportation.gov/policy-initiatives/beyond-traffic-2045-final-report

[174] Organization for Economic Co-Operation and Development (OECD), E-Commerce in the Times of COVID-19. October 2020. https://read.oecd-ilibrary.org/view/?ref=137_137212-t0fjgnerdb&title=E-commerce-in-the-time-of-COVID-19&_ga=2.202900497.1822048741.1627658750-1203935028.1627658750

[175] https://www.wsj.com/articles/container-ship-prices-skyrocket-as-rush-to-move-goods-picks-up-11625482800

Widespread impacts of unexpected supply chain disruptions underscore the need for public investment to improve freight movement safety, resilience, mobility, and reliability. DOT's ongoing research on these topics, as well as its response to White House policy directives, is expected to help identify and address the effects of unexpected disruptions. These efforts will also help address additional, related needs such as supply chain security concerns and weaknesses in physical infrastructure. Together these efforts are intended to build a more resilient freight transportation system and ensure freight's continued critical contribution to economic growth and quality of life.

Freight Transportation Equity

Transportation equity incorporates considerations of access, safety, environment, public health, and quality of life for all users. Freight transportation equity specifically focuses on how the movement of goods may contribute to or affect these considerations.

Although freight movement is crucial to economic development and quality of life, it may have negative impacts. For example, freight transportation corridors often pass through rural communities, but rural areas may lack convenient or affordable access to freight products or delivery options. There is also a disproportionate safety burden of the highway system on rural areas. Although only one-fifth of the Nation's population lives in rural areas, 46 percent of the Nation's highway fatalities occur on rural roads, 39 percent of all highway-rail crossing fatalities occur in rural areas, and the highway fatality rate is more than twice that in urban areas.[176,177]

CRFCs provide an opportunity to assist States, MPOs, and others in addressing rural freight access challenges through targeted investment.

In urban areas, innovative strategies are emerging to address congestion issues related to freight. However, equity issues may exist if these strategies are piloted or implemented in higher-income communities that may also have higher-quality infrastructure and broader access to freight delivery options.

The NHFP established a Federal role in reducing adverse environmental impacts of freight. As codified in U.S.C. Title 23, projects receiving NHFP funds should reduce the environmental impacts of freight movement on the NHFN and contribute to environmental and community mitigation for freight movement.

Outside of addressing freight's environmental impacts, other potential opportunities exist where DOT, in collaboration with other Federal partners, may have roles in improving freight equity in access, safety, environment, public health, and quality of life. Examples of opportunities include:

- Ensuring equitable access to goods and commodities;
- Addressing potential conflicts between freight vehicles, nonmotorized vehicles, and pedestrians in locations (particularly urban locations) such as curbs, sidewalks, and crosswalks;
- Addressing safe transportation of hazardous materials and mitigating negative environmental impacts of freight movement such as greenhouse gas emissions, noise, and light pollution;
- Facilitating freight mobility to mitigate congestion's negative economic impacts (e.g., lost productive hours); and
- Providing resources to assist both public- and private-sector stakeholders in decision making that supports more equitable land uses and siting of freight facilities.

[176] https://www.transportation.gov/rural

[177] Note: this statistic is not specific to the National Highway Freight system, but rather the National Highway System in general.

Recent White House directives aim to increase Federal agencies' capacity and ability to address equity, especially environmental justice.[178]

Spotlight on State Freight Plans: Freight Equity Themes

The FAST Act did not require States to address environmental justice or equity in their State Freight Plans, but some States elected to address this topic in State Freight Plans submitted to FHWA as of 2019.

For example, States considered the connection between freight infrastructure and community impacts as part of freight project planning, programming, and implementation. Some States included specific discussion of environmental justice analysis and tied freight planning and investment efforts to consideration of negative impacts on low-income and minority populations. Two examples are:

- Wisconsin's State Freight Plan, which includes specific environmental justice goals and a discussion of how the public outreach completed for its plan included environmental justice populations.
- Massachusetts' State Freight Plan, which outlined project criteria related to "social equity and fairness" to promote investment in the workforce, rural areas, and low-income urban neighborhoods.

While many States did not address environmental justice specifically in their plans, some included a general discussion of equity such as addressing disparities in access between rural and urban populations. Two examples are:

- South Carolina's State Freight Plan, which includes goals to accommodate the mobility needs of all of South Carolina's citizens, including rural populations.
- New Mexico's State Freight Plan, which noted the benefits that including diverse populations can bring to the freight planning and project development process.

The Bipartisan Infrastructure Law added new requirements for State Freight Plans that touch on aspects of environmental justice. For example, State Freight Plans must now include strategies and goals to reduce impacts of freight transportation on local air quality, wildlife habitat, and flooding.

Sources:

Wisconsin Department of Transportation, Wisconsin State Freight Plan, April 2018, 34.

Massachusetts Department of Transportation, Massachusetts State Freight Plan, 83.

South Carolina DOT, Charting a Course for 2040: South Carolina Multimodal Transportation Plan, South Carolina State Freight Plan, Amendment 1, December 1, 2017, 120.

There is a foundation of DOT work on equity (specifically environmental justice) that includes strategic collaboration with internal partners, research, and documenting noteworthy practices among States, regions, and localities. DOT grant programs now also incorporate racial equity and environmental justice as focus areas. For example, DOT's Infrastructure for Rebuilding America (INFRA) grant program funds transportation infrastructure projects supporting objectives that include racial equity, climate change and environmental impacts, and reducing barriers to opportunity.[179] The RAISE grant program, for which a new Notice of Funding

[178] For example, Executive Order 12898 established a framework for Federal agencies to develop a strategy to identify and address the disproportionately high and adverse human health or environmental effects of their actions on minority and low-income populations. For more information, refer to FHWA's environmental justice website: https://www.fhwa.dot.gov/environment/environmental_justice/

[179] https://www.federalregister.gov/documents/2021/02/25/2021-03885/notice-of-funding-opportunity-for-the-department-of-transportations-infrastructure-for-rebuilding

Opportunity was issued on April 23, 2021, encourages racial equity by "investing in projects that either proactively address racial equity and barriers to opportunity, including automobile dependence as a form of barrier, or redress prior inequities and barriers to opportunity."[180] The Advanced Transportation and Congestion Management Technologies Deployment Program, which funds new technologies that improve transportation systems, now promotes projects that support racial equity, environmental justice, and access to opportunity as well as environmental health.[181]

FHWA is developing research and resources to build on this foundation of transportation equity considerations and assist stakeholders in incorporating equity into freight transportation decision making.

Climate Impacts from and on Freight Movement

Freight transportation contributes to negative climate impacts and is also vulnerable to the impacts of climate change. In 2019, the transportation sector contributed about 29 percent of total U.S. greenhouse gas emissions. Of the transportation share, medium- and heavy-duty trucks contributed about 24 percent.[182] These impacts are likely to continue, as long-haul freight is expected to grow approximately 40 percent by 2040.[183]

Climate change may also contribute to the frequency and severity of disruptive weather events such as storms, extreme heat, wildfires, and flooding. These events can adversely impact freight infrastructure and mobility and create "ripple effects" by disrupting supply chains and regional or national movement of goods. Freight facilities may be particularly vulnerable to the impacts of severe weather events because many, such as coastal port facilities, are located in low-lying areas that may be susceptible to storm surges and flooding.

For example, changing weather patterns and snowmelt led to spring flooding in 2019 in Nebraska.[184] The floods catastrophically damaged infrastructure, with 3,300 highway miles flooded and 27 bridges damaged or destroyed. The floods had immediate and substantial impacts on Nebraska's economy. Agriculture is the State's leading industry, with every dollar in agricultural exports generating $1.28 in economic activity. The industry was significantly impacted due to impassible roads and bridges.

Climate-resilient freight transportation systems require robust crisis response and recovery as well as long-term planning and project prioritization to ensure a high level of freight performance and transportation infrastructure conditions. Examples of opportunities to mitigate catastrophic impacts include raising critical infrastructure at threatened facilities, improving resilience through protective infrastructure, use of nature-based design strategies, and planning for systems-level resilience by redirecting goods to other facilities or modes in the event of a weather incident.

At a national level, the highway freight portion of the transportation sector can play a role in decreasing greenhouse gas emissions to slow climate change, such as through adopting more fuel-efficient commercial trucks, developing lower- or zero-emission vehicles, or increasing the use of renewable fuel sources,[185] and through shifting to less-carbon-intensive transportation

[180] https://www.federalregister.gov/documents/2021/02/25/2021-03885/notice-of-funding-opportunity-for-the-department-of-transportations-infrastructure-for-rebuilding

[181] https://highways.dot.gov/newsroom/fhwa-announces-60-million-transportation-technology-grants-focus-equity-environment-and

[182] Environmental Protection Agency, U.S. Transportation Sector Greenhouse Gas Emissions, 1990-2019. June 2021. https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P10127TU.pdf

[183] Statistic is based on FAF version 4 data. FAF version 5 forecasted data were not available at the time of writing. U.S. Department of Transportation, Bureau of Transportation Statistics, 2017: Freight Facts and Figures, https://rosap.ntl.bts.gov/view/dot/34923

[184] This example and all data related to this example are cited in the U.S. Department of Transportation National Freight Strategic Plan, page 69. See: https://www.transportation.gov/freight/NFSP

[185] Carbon Pollution from Transportation. See: https://www.epa.gov/transportation-air-pollution-and-climate-change/carbon-pollution-transportation

modes. At a local and regional level, highway freight-focused strategies for reducing emissions may include efforts to electrify truck stops, decrease truck idling through efficient truck routing and congestion management and increased use of active transportation or lower- or zero-emissions vehicles to support last-mile delivery.

Spotlight on State Freight Plans: Freight and Climate Change Themes

The FAST Act did not require States to address climate change in their State Freight Plans, but some States elected to address this topic in State Freight Plans submitted to FHWA as of 2019.

FHWA's review of State Freight Plans found that 20 States specifically addressed climate change in their plans. Several additional plans discussed resilience in the context of climate disruption but did not mention the term climate change. The specific climate vulnerabilities discussed in State Freight Plans varied, but several plans described ways to create redundancies in freight infrastructure to withstand disruption caused by extreme weather events. For example:

- New Hampshire's State freight plan referenced the Statewide climate action plan as well as regional reports on climate impacts in northern and southern New Hampshire and highlighted the threat that climate change could pose to the economy in coastal communities.
- Louisiana's State freight plan highlights the impacts of climate volatility on the State's transportation systems, including impacts of sea-level rise, heat waves, and extreme events such as Hurricane Katrina. The plan also highlights the impacts of climate events on the State's port infrastructure.

FHWA also found that some States included greenhouse gas reduction goals in their plans. For example, California's freight plan discusses Statewide greenhouse gas reduction targets and describes how conversion of freight equipment to renewable sources could help meet these goals.

The Bipartisan Infrastructure Law amended the requirements for State Freight Plans to mandate inclusion of strategies and goals to decrease the severity of impacts of extreme weather and natural disasters on freight mobility.

Sources:
FHWA State of the Practice Scan. Freight Resilience Planning in the Face of Climate-Related Disruption: https://www.planning.dot.gov/documents/Freight_Resiliency_State_of_Practice_Scan_FINAL.pdf

New Hampshire Statewide Freight Plan: https://www.nh.gov/dot/org/projectdevelopment/planning/freight-plan/index.htm

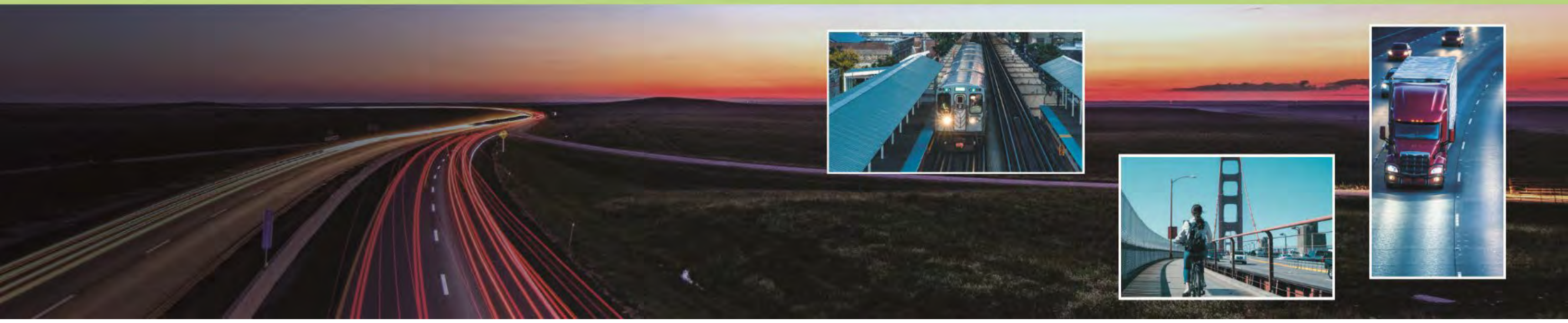
Louisiana Freight Mobility Plan: http://www.dotd.la.gov/Inside_LaDOTD/Divisions/Multimodal/Transportation_Plan/Misc%20Documents/FINAL_DOTD_Freight_Mobility_Plan_12-29-15_CLEAN_V2_final_version_with_adoption.pdf

California Freight Mobility Plan: https://dot.ca.gov/programs/transportation-planning/freight-planning/cfmp-2020

The White House issued three Executive Orders in early 2021 to emphasize the Administration's commitment to addressing the causes of climate impacts on the Nation's infrastructure, national security, and public health. Executive Order 14008 on Tackling the Climate Crisis at Home and Abroad affirms the actions that the Federal government has taken and will take to address the urgent challenges posed by climate change. This order emphasizes that the Federal government will "deploy the full capacity of its agencies to combat the climate crisis" through a government-wide approach. This order specifically mentions the transportation sector as one of the causes of climate change and lays out several actions for USDOT to address with respect to the transportation impacts of climate change, including the development of a climate action plan for the Department and participation in a national climate task force aimed at planning and implementing key climate initiatives.[186]

Climate impacts are a growing topic in freight planning and research. FHWA is researching strategies and tools to assist public-sector transportation professionals in considering climate change as part of freight planning and analysis, as well as addressing climate change through freight planning programs, activities, and project development. For example, FHWA intends to include an indicator in the FMT tool that reports on truck-based greenhouse gas emissions. FHWA expects that this indicator, once added, will support State DOTs, MPOs, and others in a more robust understanding of the environmental impacts of truck movement.

[186] https://www.federalregister.gov/documents/2021/02/01/2021-02177/tackling-the-climate-crisis-at-home-and-abroad



Part V: Changes to the Highway Performance Monitoring System

Changes to the Highway Performance Monitoring System

Since 1978, data from the Highway Performance Monitoring System (HPMS) have provided the basis for many reports critical to the FHWA mission, including apportionment formulas, Conditions and Performance Reports to Congress, and Agency performance measures. Legislative requirements and technical advances have necessitated the overhaul of the existing HPMS software application into HPMS Version 9.0.

Data for the 2021 data year will be reported from State DOTs in HPMS Version 9.0 during the Spring of 2022. The expected release of data from the HPMS for FHWA mission requirements and public dissemination is September 1, 2022.

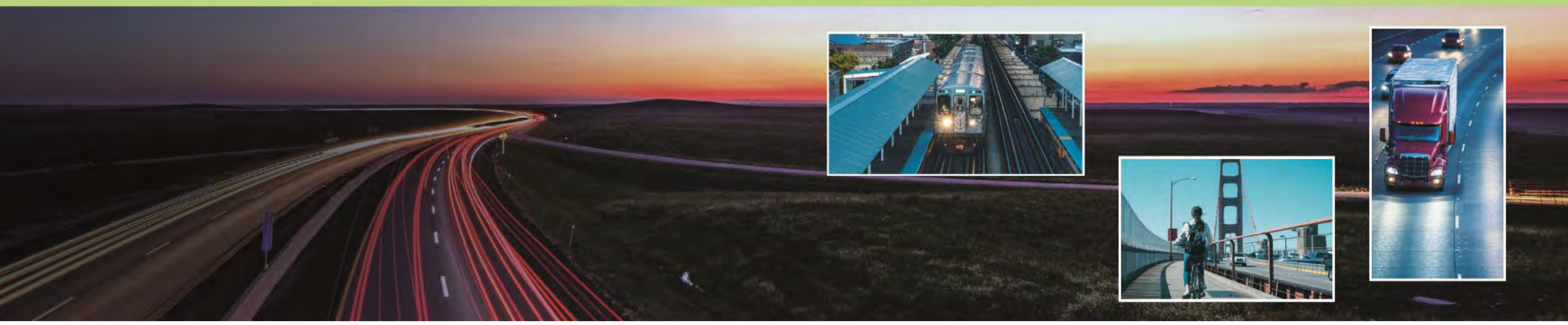
The HPMS is a national-level highway information system that includes data on the extent, condition, performance, use, and operating characteristics of the Nation's highways. The major purpose of the HPMS is to support a data-driven decision process within FHWA, DOT, and Congress. HPMS data are used extensively in the analysis of highway system condition, performance, and investment needs that are reported in the biennial Conditions and Performance Report. Congress has directed FHWA to build a National Road Network Pilot using the spatial data from HPMS, commonly known as the All Road Network of Linear Data (ARNOLD).

Programs throughout FHWA and DOT depend on data from the HPMS. For example:

- The FHWA Chief Financial Officer uses inventory data to support the Fiscal Information Management System for project locations.
- The Office of Policy and Governmental Affairs–Highway Economic Requirements System uses HPMS data to support the needs assessment chapters of the Conditions and Performance Report (i.e., the chapters in Part II of this report).
- The FHWA Office of Freight Operations uses HPMS data to support the Freight Analysis Framework.
- The FHWA Office of Infrastructure uses data from the HPMS to support the Transportation Performance Measures described in the Introduction to Part I of this report:
  - PM1 uses VMT to establish highway fatality and serious injury rates.
  - PM2 uses data from the HPMS to establish condition performance measures on the Interstate and National Highway System-designated highways.
  - PM3 uses data from the HPMS to help compute reliability and excessive delay measures.
- The FHWA Office of Safety will use data from the HPMS to support the Model Inventory of Roadway Elements program for safety analysis, including intersections and interchanges.
- The FHWA Federal Lands Management Division will use data in the HPMS to support its inventory, including ownership.
- NHTSA will use data from the HPMS in the Fatal Accident Reporting System as a link to police crash report

Version 9.0 of the HPMS will feature:

- An incremental update process that will result in closer to real-time information, particularly in the designation of the National Highway System, the National Network, the Strategic Highway Network and other designations.
- A topologic model to complement linear referencing and support spatial connectivity for routing.
- The improved representation of dual carriageways will support intersection modeling for safety analysis, highway project locations, and bridge locations from the National Bridge Inventory.



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, *Reinventing the C&P Report*. Appendix E provides methodology and information supporting the discussion of the conditions and performance of the National Highway Freight Network (NHFN) presented in Part IV. Appendix F provides background information relating to the discussion of macroeconomic impacts of highway investment presented in Chapter 11.

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 and rural areas. This includes an extended discussion of new procedures introduced in this edition to estimate needs for asset expansion investments. This appendix also describes the data and methods used to estimate the size of the state of good repair (SGR) backlog—the level of capital reinvestment needed to bring the Nation's transit assets to a full SGR—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. This appendix also describes expansions to scope of the C&P Report required by the Bipartisan Infrastructure Law (BIL), also known as the Infrastructure Investment and Jobs Act (IIJA).

Appendix E provides methodology and information supporting the discussion of the conditions and performance of the NHFN as well as Critical Rural and Urban Freight Corridors established under the Fixing America's Surface Transportation (FAST) Act.

Appendix F describes the **USAGE-Hwy Model**, which uses HERS model estimates of highway performance from increases in highway investment and the financial impacts related to funding the highway investment to evaluate their macroeconomic impact on gross domestic product, consumption, employment, and wages. Additional measures of macroeconomic activity may include productivity, capital levels, and trade balances.

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 24th C&P Report. The most complete reference on the HERS model is the *Highway Economic Requirements System Technical Report*.[187]

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 of different improvements;
- 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 for a total 20-year study period. 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 of highway improvements 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, HERS selects between 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 of added lanes determined by the model through benefit-cost analysis of the alternatives),[188] although capacity can also be added through widening of lanes or shoulders. For road geometry, HERS evaluates lane width, right shoulder width, shoulder type, curves, and grades. HERS identifies excess operating costs (e.g., fuel consumption, tire wear, and maintenance and repair costs) and suggests curve or grade reductions as improvements to reduce user costs. 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

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[187] The latest version of the *HERS Technical Report* is from 2019 (unpublished; available upon request).

[188] See section 4.4.1 of the *HERS Technical Report* for more information.

improvements of these types, evaluation would require road data beyond those currently provided by HPMS.

Exhibit A-1: HERS Model Overview

HERS Analysis Categories	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 for each of the four periods; *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 currently designed to capture impacts of targeted safety improvements. The benefits from crash rate reductions contribute modestly to the benefits that HERS estimates for most highway improvements. 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). For most of the project types that HERS evaluates, the positive or negative change in emissions is typically a small share of the overall project benefits.

Potential projects on different highway sections are ranked using a benefit-cost ratio (BCR), which is calculated by dividing these improvement benefits by the capital costs associated with implementing the improvement. A higher BCR indicates a project with comparatively higher benefits compared to costs. 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	Type	Benefits and Costs
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 Sulfur dioxides Fine particulate matter Carbon dioxide
	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*.

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 2018 dollars, and then compares the average values per vehicle hour from the 24th C&P Report to those used in the 25th 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 very small 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).

The values estimated for the 25th C&P Report differ from those in the 24th C&P Report, stemming from updates to the data used to estimate the various cost elements. The values used for the 25th C&P Report are generally higher. The value of time per person hour was updated using U.S. DOT's guidance on valuing travel time.[189] Average vehicle occupancy was updated using values from the 2017 National Household Travel Survey (NHTS); the 2009 NHTS was used in the 24th C&P Report.[190] The largest differences between the values in the 25th C&P Report and those in the 24th C&P Report stem from changes in the values for vehicle capital cost per vehicle, which were updated for the 25th edition using vehicle purchase price

[189] U.S. Department of Transportation, The Value of Travel Time Savings: Departmental Guidance for Conducting Economic Evaluations. Available at: https://www.transportation.gov/sites/dot.gov/files/docs/2016%20Revised%20Value%20of%20Travel%20Time%20Guidance.pdf

[190] U.S. Department of Transportation, Federal Highway Administration, 2017 National Household Travel Survey. Available at: https://nhts.ornl.gov/

estimates from an FHWA study, “Enhanced Prediction of Vehicle Fuel Economy and Other Vehicle Operating Costs,” as well as updated data on vehicle lifespans.[191]

Exhibit A-3: Estimated 2018 Values of Travel Time by Vehicle Type

Category	Travel Time Cost Element	Small Auto	Medium Auto	4-Tire Truck	6-Tire Truck	3–4 Axle Truck	Bus	4-Axle Combi-nation	5+-Axle Combi-nation
Business Travel	Value of Time per Person Hour	$38.08	$37.32	$36.06	$31.83	$33.95	$28.53	$32.10	$32.10
	Average Vehicle Occupancy	1.42	1.43	1.43	1.38	1.14	1.5	1.02	1.02
	Total Hourly Value of Occupants' Time	$54.07	$53.30	$51.58	$43.89	$38.84	$42.79	$32.62	$32.62
	Vehicle Capital Cost per Vehicle Hour	N/A	N/A	N/A	$23.85	$71.83	$17.07	$106.42	$49.63
	Inventory Value of Cargo	N/A	N/A	N/A	N/A	N/A	N/A	$0.11	$0.17
	Value of Time per Vehicle Hour	$54.07	$53.30	$51.58	$67.74	$110.67	$59.86	$139.15	$82.43
	Share of Vehicle Use for Business Travel	10.20%	8.60%	17.90%	100.00%	100.00%	10.10%	100.00%	100.00%
Personal Travel	Value of Time per Person Hour	$15.20	$15.20	$15.20	N/A	N/A	$15.20	N/A	N/A
	Average Vehicle Occupancy	1.62	1.7	1.66	N/A	N/A	12.64	N/A	N/A
	Value of Time per Vehicle Hour	$24.63	$25.79	$25.29	N/A	N/A	$192.14	N/A	N/A
	Share of Vehicle Use for Personal Travel	89.80%	91.40%	82.10%	N/A	N/A	89.90%	N/A	N/A
Average Values per Vehicle Hour	2018	$27.64	$28.17	$29.99	$67.74	$110.67	$252.00	$139.15	$82.43
	2016 (from 24th C&P Report)	$25.03	$26.92	$28.13	$53.07	$55.67	$228.89	$47.45	$44.73

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, with the operational strategies deployed listed in *Exhibit A-4* . HERS also considers the empirical impact relationships, which are estimated primarily from a meta-analysis of the DOT ITS Benefits Database (https://www.itskrs.its.dot.gov/benefits) that aggregated rates from studies for each of the operation strategies.

[191] Vehicle capitals costs were updated using (1) vehicle purchase price estimates and (2) reductions in the estimates of the hourly value of use-related depreciation.

Exhibit A-4: Impacts of Operations Strategies in HERS

Operations Category	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%
Connected/ Automated Vehicles Systems	Vehicle-to-Vehicle Communications	Capacity increase	30%
		Travel Times	-30%
	Autonomous Emergency Braking	Total Crashes	-35%
	Dynamic Signal Controllers	Delay	-10%
		Total Crashes	-40%

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 25th 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 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 challenge made splicing these two indices together to estimate cost changes between 2002 and 2005 ambiguous and 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.

For these reasons, FHWA conducted 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 10 States included in the database collectively covered more than 700 of the approximately 3,000 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 the 24th C&P Report. In this 25th C&P Report, the values of improvement costs are generated from the FHWA construction cost study and were inflated from 2016 values (in the 24th C&P Report) to 2018 dollars (for the 25th C&P Report).

In addition to updating the cost estimates in HERS, the study 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. *Exhibit A-7* and *Exhibit A-8* present seven types of widening obstacles. In addition to dense development, these obstacles 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 cost estimates for added lanes are differentiated by highway functional class and locational characteristics. HERS also continues its practice of distinguishing cost estimates for constructing highways on new alignments.

Exhibit A-5: Typical Rural Pavement Costs per Lane Mile Assumed in HERS by Type of Improvement

		Resurfacing		Shoulder	Typical Reconstruction		Total Reconstruction	
Category	Subcategory	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	$358	$1,057	$150	$1,253	$1,965	$1,732	$2,628
	Rolling	$424	$1,249	$175	$1,482	$2,321	$2,041	$3,096
	Mountainous	$540	$1,584	$217	$1,879	$2,940	$2,583	$3,913
Other Freeway and Expressway	Flat	$337	$948	$130	$1,182	$1,804	$1,660	$2,455
	Rolling	$398	$1,116	$150	$1,396	$2,128	$1,955	$2,889
	Mountainous	$506	$1,416	$188	$1,772	$2,697	$2,473	$3,652
Other Principal Arterial	Flat	$316	$862	$111	$1,113	$1,668	$1,589	$2,310
	Rolling	$374	$1,017	$128	$1,314	$1,968	$1,871	$2,717
	Mountainous	$475	$1,290	$160	$1,668	$2,494	$2,365	$3,435
Minor Arterial	Flat	$287	$763	$92	$1,014	$1,497	$1,450	$2,087
	Rolling	$339	$899	$106	$1,197	$1,765	$1,708	$2,457
	Mountainous	$431	$1,138	$131	$1,517	$2,235	$2,157	$3,101
Major Collector	Flat	$256	$667	$74	$907	$1,324	$1,309	$1,868
	Rolling	$302	$787	$86	$1,071	$1,562	$1,540	$2,196
	Mountainous	$384	$996	$107	$1,357	$1,976	$1,944	$2,771
Minor Collector	Flat	$226	$592	$55	$812	$1,182	$1,191	$1,700
	Rolling	$268	$697	$64	$958	$1,392	$1,400	$1,998
	Mountainous	$339	$882	$79	$1,214	$1,761	$1,767	$2,521
Local	Flat	$205	$540	$41	$743	$1,081	$1,112	$1,595
	Rolling	$241	$635	$46	$875	$1,273	$1,308	$1,874
	Mountainous	$304	$802	$56	$1,105	$1,606	$1,648	$2,360

Note: Values are in thousands of 2018 dollars per lane mile.

Source: Highway Economic Requirements System.

Exhibit A-6: Typical Urban Pavement Costs per Lane Mile Assumed in HERS by Type of Improvement

Category	Subcategory	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	$628	$2,121	$437	$1,992	$3,504	$2,536	$4,290
	Small Urbanized	$710	$2,418	$508	$2,276	$4,011	$2,943	$4,960
	Large Urbanized	$850	$2,979	$674	$2,782	$4,954	$3,618	$6,121
	Major Urbanized	$900	$3,270	$798	$3,013	$5,433	$3,892	$6,647
Other Freeway and Expressway	Small Urban	$594	$1,899	$384	$1,879	$3,200	$2,438	$3,996
	Small Urbanized	$672	$2,166	$449	$2,147	$3,666	$2,828	$4,623
	Large Urbanized	$803	$2,662	$593	$2,620	$4,519	$3,473	$5,700
	Major Urbanized	$852	$2,923	$705	$2,837	$4,955	$3,735	$6,187
Other Principal Arterial	Small Urban	$562	$1,713	$334	$1,772	$2,938	$2,344	$3,744
	Small Urbanized	$635	$1,953	$391	$2,022	$3,362	$2,716	$4,328
	Large Urbanized	$759	$2,396	$515	$2,466	$4,138	$3,332	$5,331
	Major Urbanized	$805	$2,627	$613	$2,665	$4,529	$3,583	$5,782
Minor Arterial	Small Urban	$507	$1,460	$267	$1,587	$2,551	$2,132	$3,310
	Small Urbanized	$575	$1,660	$309	$1,807	$2,909	$2,457	$3,809
	Large Urbanized	$688	$2,033	$407	$2,198	$3,570	$3,002	$4,672
	Major Urbanized	$729	$2,216	$478	$2,368	$3,885	$3,220	$5,049
Major Collector	Small Urban	$442	$1,227	$225	$1,386	$2,179	$1,876	$2,854
	Small Urbanized	$500	$1,393	$260	$1,577	$2,483	$2,154	$3,273
	Large Urbanized	$587	$1,683	$341	$1,887	$3,002	$2,582	$3,945
	Major Urbanized	$624	$1,838	$402	$2,032	$3,267	$2,765	$4,261
Minor Collector	Small Urban	$397	$1,071	$166	$1,230	$1,911	$1,706	$2,575
	Small Urbanized	$447	$1,211	$191	$1,393	$2,166	$1,944	$2,935
	Large Urbanized	$527	$1,459	$249	$1,662	$2,607	$2,315	$3,514
	Major Urbanized	$559	$1,581	$291	$1,782	$2,820	$2,473	$3,775
Local	Small Urban	$364	$939	$128	$1,125	$1,705	$1,596	$2,359
	Small Urbanized	$410	$1,064	$147	$1,273	$1,931	$1,811	$2,677
	Large Urbanized	$483	$1,275	$192	$1,512	$2,310	$2,143	$3,183
	Major Urbanized	$513	$1,380	$225	$1,620	$2,496	$2,283	$3,411

Note: Values are in thousands of 2018 dollars per lane mile.

Source: Highway Economic Requirements System.

Exhibit A-7: Typical Rural Capacity Costs per Lane Mile Assumed in HERS by Type of Improvement

Functional Class	Terrain Type	Add Lane If No Obstacles (Normal Cost)	Add Equivalent of One Lane of Capacity at High Cost Due to Obstacle to Widening of Type:[1]							New Construction	
			A	B	C	D	E	F	G	New Alignment (Normal Cost)	New Alignment (High Cost)
Interstate	Flat	$1,732	$4,809	$6,140	$6,280	$10,391	$6,906	$4,631	$4,487	$5,622	$19,903
	Rolling	$2,041	$6,239	$7,688	$7,183	$17,824	$8,417	$6,053	$5,854	$7,765	$27,487
	Mountainous	$2,583	$10,245	$12,387	$10,769	$28,048	$13,966	$9,835	$9,403	$12,003	$42,492
Other Freeway and Expressway	Flat	$1,660	$4,535	$5,812	$5,953	$9,959	$6,564	$4,347	$4,227	$5,311	$18,799
	Rolling	$1,955	$5,934	$7,307	$6,868	$17,078	$7,988	$5,747	$5,576	$7,372	$26,097
	Mountainous	$2,473	$9,648	$11,591	$10,211	$26,877	$13,001	$9,273	$8,895	$11,350	$40,179
Other Principal Arterial	Flat	$1,589	$4,342	$5,570	$5,704	$9,529	$6,313	$4,157	$4,051	$5,089	$18,015
	Rolling	$1,871	$5,686	$6,992	$6,611	$16,338	$7,628	$5,508	$5,356	$7,061	$24,998
	Mountainous	$2,365	$9,102	$10,856	$9,702	$25,709	$12,109	$8,763	$8,433	$10,796	$38,221
Minor Arterial	Flat	$1,450	$3,928	$5,106	$5,236	$8,960	$5,840	$3,732	$3,649	$4,651	$16,462
	Rolling	$1,708	$5,197	$6,439	$6,114	$15,500	$7,036	$5,013	$4,888	$6,527	$23,108
	Mountainous	$2,157	$8,268	$9,857	$8,906	$24,500	$10,969	$7,952	$7,671	$9,978	$35,321
Major Collector	Flat	$1,309	$3,605	$4,745	$4,859	$8,390	$5,476	$3,414	$3,340	$4,325	$15,310
	Rolling	$1,540	$4,761	$5,949	$5,667	$14,659	$6,514	$4,585	$4,473	$6,090	$21,560
	Mountainous	$1,944	$7,468	$8,902	$8,144	$23,289	$9,882	$7,183	$6,943	$9,276	$32,838
Minor Collector	Flat	$1,191	$3,247	$4,339	$4,446	$7,864	$5,060	$3,049	$2,994	$3,936	$13,933
	Rolling	$1,400	$4,324	$5,454	$5,220	$13,851	$5,986	$4,144	$4,054	$5,604	$19,838
	Mountainous	$1,767	$6,714	$7,999	$7,427	$22,093	$8,854	$6,447	$6,252	$8,522	$30,165
Local	Flat	$1,112	$2,993	$4,037	$4,138	$7,418	$4,749	$2,794	$2,756	$3,641	$12,892
	Rolling	$1,308	$4,012	$5,086	$4,899	$13,099	$5,584	$3,831	$3,762	$5,220	$18,479
	Mountainous	$1,648	$6,128	$7,275	$6,879	$20,919	$8,013	$5,881	$5,728	$7,894	$27,944

[1]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

Note: Values are in thousands of 2018 dollars.

Source: Highway Economic Requirements System.

Exhibit A-8: Typical Cost of Widening, per Urban Lane Mile, by Category and Type of Obstacle

Functional Class	Subcategory	Add Lane If No Obstacles (Normal Cost)	Add Equivalent of One Lane of Capacity at High Cost Due to Obstacle to Widening of Type:[1]							New Construction	
			A	B	C	D	E	F	G	New Alignment (Normal Cost)	New Alignment (High Cost)
Interstate	Small Urban	$2,536	$6,234	$8,055	$8,118	$15,286	$8,797	$6,014	$5,807	$7,540	$26,691
	Small Urbanized	$2,943	$8,103	$9,924	$9,590	$19,711	$10,874	$7,839	$7,584	$9,410	$33,310
	Large Urbanized	$3,618	$10,097	$12,550	$11,147	$22,998	$14,041	$9,659	$9,192	$11,278	$39,927
	Major Urbanized	$3,892	$11,909	$15,052	$13,663	$30,674	$17,804	$11,142	$10,472	$14,271	$50,519
Other Freeway and Expressway	Small Urban	$2,438	$5,733	$7,479	$7,511	$14,682	$8,223	$5,496	$5,317	$7,083	$25,071
	Small Urbanized	$2,828	$7,559	$9,309	$8,998	$18,927	$10,229	$7,287	$7,059	$8,886	$31,459
	Large Urbanized	$3,473	$9,621	$11,914	$10,682	$22,078	$13,279	$9,199	$8,781	$10,730	$37,987
	Major Urbanized	$3,735	$11,312	$14,228	$13,163	$29,446	$16,855	$10,572	$9,975	$13,550	$47,968
Other Principal Arterial	Small Urban	$2,344	$5,350	$7,022	$7,023	$14,086	$7,768	$5,119	$4,955	$6,734	$23,839
	Small Urbanized	$2,716	$7,113	$8,791	$8,503	$18,148	$9,684	$6,848	$6,637	$8,468	$29,978
	Large Urbanized	$3,332	$9,212	$11,349	$10,287	$21,162	$12,591	$8,818	$8,441	$10,281	$36,394
	Major Urbanized	$3,583	$10,824	$13,512	$12,772	$28,220	$16,016	$10,122	$9,589	$12,984	$45,963
Minor Arterial	Small Urban	$2,132	$4,695	$6,288	$6,262	$13,253	$7,031	$4,445	$4,312	$6,107	$21,617
	Small Urbanized	$2,457	$6,319	$7,926	$7,661	$17,133	$8,789	$6,042	$5,861	$7,721	$27,332
	Large Urbanized	$3,002	$8,382	$10,370	$9,468	$20,056	$11,494	$7,997	$7,669	$9,456	$33,476
	Major Urbanized	$3,220	$9,873	$12,360	$11,917	$26,911	$14,763	$9,183	$8,721	$11,988	$42,441
Major Collector	Small Urban	$1,876	$4,110	$5,632	$5,572	$12,333	$6,376	$3,872	$3,750	$5,553	$19,657
	Small Urbanized	$2,154	$5,560	$7,095	$6,854	$16,048	$7,932	$5,294	$5,129	$7,041	$24,926
	Large Urbanized	$2,582	$7,432	$9,260	$8,530	$18,860	$10,258	$7,076	$6,789	$8,616	$30,504
	Major Urbanized	$2,765	$8,887	$11,172	$11,028	$25,564	$13,471	$8,230	$7,828	$11,079	$39,218
Minor Collector	Small Urban	$1,706	$3,586	$5,026	$4,942	$11,582	$5,764	$3,341	$3,245	$5,023	$17,783
	Small Urbanized	$1,944	$4,909	$6,368	$6,154	$15,113	$7,173	$4,636	$4,497	$6,400	$22,656
	Large Urbanized	$2,315	$6,678	$8,365	$7,788	$17,819	$9,251	$6,332	$6,091	$7,875	$27,875
	Major Urbanized	$2,473	$8,004	$10,115	$10,240	$24,282	$12,336	$7,352	$7,014	$10,166	$35,990
Local	Small Urban	$1,596	$3,201	$4,559	$4,453	$10,955	$5,291	$2,959	$2,882	$4,621	$16,358
	Small Urbanized	$1,811	$4,436	$5,822	$5,633	$14,299	$6,597	$4,163	$4,047	$5,909	$20,918
	Large Urbanized	$2,143	$6,122	$7,677	$7,242	$16,872	$8,461	$5,787	$5,587	$7,296	$25,825
	Major Urbanized	$2,283	$7,216	$8,853	$9,496	$23,042	$10,867	$6,656	$6,461	$9,346	$33,083

[1]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

Note: Values are in thousands of 2018 dollars.

Source: Highway Economic Requirements System.

Safety Costs

For each highway functional class, HERS estimates the average cost to society per vehicle crash from injuries (including fatal injuries) and property damage. For injuries of varying severities, the estimated occurrence rate per crash is multiplied by the estimated cost per occurrence. The HERS safety cost parameters have been updated for the 25th C&P Report. Updated HERS safety cost parameters are presented in *Exhibit A-9* and *Exhibit A-10*. Nonreported crashes are not included in the analysis.

The occurrence rates in the 25th C&P Report were recalculated based on aggregated data from the Highway Safety Information System (HSIS)[192] and the *Highway Statistics Series.*[193] Data for Washington State, Ohio, and North Carolina were combined with vehicle miles traveled data from *Highway Statistics*. These States represent a range of geography from the States actively participating in the HSIS. These data indicate that crashes ranged from 0.66 crashes per million vehicle miles traveled (MVMT) on rural Interstates to 3.75 per MVMT on urban collectors. These occurrence rates are translated into fatality and injury crash ratios for use in HERS. The last update of the HERS safety parameters did not update the crash ratios due to a lack of data. For the 25th C&P Report, injury-per-crash ratio and fatality-per-crash ratio were updated using data from NHTSA's 2018 Crash Report Sampling System.[194] The national crash ratios are estimated at 0.40200 for injuries and 0.00539 for fatalities. These ratios were used to update the HERS injury/crash and fatality/crash values presented in *Exhibit A-9.*

Exhibit A-9: Crash Ratios by Functional Class

Functional Class	Crash Rate per MVMT	Injury/Crash Ratios	Fatality/Crash Ratios
Rural Interstate	0.6600	0.3751	0.0116
Rural Expressway	0.8100	0.5212	0.0097
Rural Principal Arterial	1.4100	0.5212	0.0097
Rural Minor Arterial	1.9700	0.4629	0.0082
Rural Collector	2.0000	0.5166	0.0107
Urban Interstate	1.0500	0.4049	0.0029
Urban Expressway	1.3300	0.3003	0.0033
Urban Principal Arterial	3.1000	0.3393	0.0017
Urban Minor Arterial	3.4100	0.2806	0.0015
Urban Collector	3.7500	0.2885	0.0016

Source: Highway Economic Requirements System.

To monetize injuries and fatalities, HERS uses the FHWA Highway Safety Benefit-Cost Analysis Guide and Tool[195] as the basis for developing crash unit cost values. HERS considers three injury categories: fatal, nonfatal injury, and no injury. The assumed cost per fatality equals the DOT estimate of the value of a statistical life in 2018 ($10.5 million), the base year for the modeling in this report.[196] 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

[192] The Highway Safety Information System is a multi-State database that contains crash, road inventory, and traffic volume data for a selected group of States. Available online at: https://www.hsisinfo.org/

[193] The Highway Statistics Series consists of annual reports containing data on motor fuel, vehicle registration, driver licenses, highway user taxation, highway mileage travel, and highway finance. Data for crash rates were obtained from Table VM-2. Available online at: https://www.fhwa.dot.gov/policyinformation/statistics.cfm

[194] The National Highway Traffic Safety Administration's Crash Report Sampling System is a sample of police-reported crashes involving vehicles, pedestrians, and cyclists, ranging from property-damage-only crashes to those that result in fatalities. Available online at: https://www.nhtsa.gov/crash-data-systems/crash-report-sampling-system

[195] Highway Safety Benefit-Cost Analysis Guide. Available online at: https://safety.fhwa.dot.gov/hsip/docs/fhwasa18001.pdf

[196] The 25th C&P Report uses the 2018 value of a statistical life ($10.5 million) as outlined in the Guidance on the Treatment of the Economic Value of a Statistical Life (VSL) in U.S. Department of Transportation Analyses – 2021 Update. Available online at: https://www.transportation.gov/sites/dot.gov/files/2021-03/VSL%20Update%202021%20-%20Transmittal%20Memo.pdf

fatal, and indeed such valuations are implicit in everyday choices.[197] Nonfatal injuries are valued using combined estimates of the severity scale used in Blincoe et al. from the Maximum Abbreviated Injury Scale (MAIS) to KABCO.[198] The assumed cost per nonfatal injury is $132,050. Applying this updated value to the functional classes yields the injury cost per reported injury column of *Exhibit A-10*.

Property damage costs were updated from 2016 to 2018 values by applying the Bureau of Labor Statistics Consumer Price Index.[199] *Exhibit A-10* also presents updated property damage per crash values.

Exhibit A-10: Safety Cost Estimates by Functional Class

Functional Class	Injury Cost per Reported Injury	Property Damage per Crash
Rural Interstate	$137,833	$11,401
Rural Principal Arterial	$178,261	$14,164
Rural Minor Arterial	$145,889	$14,164
Rural Collector	$202,576	$14,164
Urban Interstate	$145,889	$14,164
Urban Expressway	$121,431	$17,043
Urban Principal Arterial	$129,775	$17,043
Urban Minor Arterial	$105,316	$14,164
Urban Collector	$81,146	$14,164

Source: Highway Economic Requirements System.

Examples of HERS Impact Estimates

HERS calculates the impacts of investments on speeds, operating costs, crash costs, and emissions. These calculations use a set of lookup tables and equations that vary by vehicle type and other variables and are generally drawn from other published sources such as the Highway Capacity Manual and Highway Safety Manual. Greater detail is available in the *HERS Technical Report*.

Vehicle Operating Costs

Exhibit A-11 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.

[197] 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.

[198] Blincoe, L., T. Miller, E. Zaloshnja, and B. Lawrence. The Economic and Societal Impact of Motor Vehicle Crashes, 2010 (Revised). NHTSA, DOT-HS-812-013, May 2015, Washington, DC.

[199] Bureau of Labor Statistics Consumer Price Index. Available online at: https://www.bls.gov/cpi/

Exhibit A-11: Example of Vehicle Operating Costs per VMT

Type of Vehicle	International Roughness Index (IRI)	Vehicle Speed (miles per hour)					
		20	30	40	50	60	70
Small Automobiles	50	$0.324	$0.278	$0.263	$0.270	$0.292	$0.326
	95	$0.340	$0.295	$0.281	$0.290	$0.314	$0.352
	170	$0.374	$0.331	$0.319	$0.331	$0.361	$0.405
Combination Trucks	50	$1.085	$0.907	$0.833	$0.849	$0.944	$1.107
	95	$1.129	$0.953	$0.884	$0.906	$1.010	$1.183
	170	$1.222	$1.052	$0.995	$1.032	$1.156	$1.354

Note: Values are in 2018 dollars per vehicle mile traveled.

As *Exhibit A-11* 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 18.4 percent lower at an IRI of 50 compared with an IRI of 170 (per-VMT cost of $0.270 vs. $0.331). For a combination truck under the same conditions, the estimated reduction in operating costs would be 17.7 percent (per-VMT cost of $0.849 vs. $1.032). (Note that these results would differ for roads with curves or grades.)

Emissions

To estimate the costs of vehicle emissions, HERS combines data on emission rates, vehicle classes (four-tire vehicles, single-unit trucks, and combination trucks), highway type according to location (rural vs. urban), and access arrangement (unrestricted vs. restricted). HERS uses the EPA MOVES model to identify the emissions generated (CO, VOC, NO_x, SO_2, and $PM_{2.5}$)[200] based on the highway characteristics, speed, and vehicle class. The emission costs are then monetized using 2018 data from EPA's Benefits Mapping and Analysis Program,[201] specifically focusing on data related to on-road mobile sources (tailpipes) and refineries using a 7 percent discount rate. Consolidated unit cost data used in HERS are presented in *Exhibit A-12*. Values for CO were set to $0 based on updated information that the cost to human health is very low. Values for VOCs are set to $0 because the large variance in localized values makes setting a national value very difficult. Highway improvement projects are modeled as affecting emissions through their influence on travel volumes and speeds.

Example emission damage costs by highway characteristic, speed, and vehicle class are presented in *Exhibit A-13.*

Exhibit A-12: Estimated Unit Damage Costs of Criteria Pollutants for Use in HERS

Year	NOx	SO2	PM2.5
2018	$13,500	$35,000	$635,000
2023	$14,600	$38,000	$686,000
2028	$15,600	$42,000	$740,000
2033	$16,000	$43,000	$760,000
2038	$16,000	$43,000	$760,000

Note: Values in 2018 dollars per ton. Values for CO and VOCs were set to $0 (and not reported in the table).

Source: Highway Economic Requirements System.

[200] HERS captures some impacts of emissions but was not designed as an emissions estimation tool and should not be treated as such. This analysis captures the impacts of some pollutants on a nationwide basis for which impacts and monetary benefits are more easily quantified, but excludes others that are more dependent on the characteristics of individual airsheds. Evaluations for a specific project would be expected to use more sophisticated, location-specific modeling.

[201] Environmental Protection Agency, Technical Support Document, Estimating the Benefits per Ton of Reducing Directly emitted $PM_{2.5}$, $PM_{2.5}$ Precursors and Ozone Precursors for 21 Sectors. Available online at: https://www.epa.gov/sites/default/files/2018-02/documents/sourceapportionmentbpttsd_2018.pdf

Exhibit A-13 Example of Emission Damage Costs

Speed (mph)	Four-Tire Vehicles	Single-Unit Trucks	Combination Trucks
2.5	$0.0203	$0.8451	$1.6914
5	$0.0130	$0.4185	$0.8987
10	$0.0089	$0.2339	$0.5322
15	$0.0068	$0.1767	$0.4503
20	$0.0058	$0.1460	$0.3949
25	$0.0058	$0.1255	$0.3606
30	$0.0061	$0.1177	$0.3421
35	$0.0072	$0.1056	$0.2805
40	$0.0081	$0.1014	$0.2653
45	$0.0086	$0.0980	$0.2534
50	$0.0086	$0.0937	$0.2330
55	$0.0082	$0.0891	$0.2101
60	$0.0080	$0.0823	$0.1989
65	$0.0080	$0.0791	$0.2052
70	$0.0085	$0.0767	$0.2101
75	$0.0092	$0.0757	$0.2189

Note: Values are in dollars per vehicle mile.
Source: Highway Economic Requirements System.

To estimate the costs of CO_2 emissions, HERS follows DOT guidance[202] in using values from the Interagency Working Group on Social Cost of Greenhouse Gases.[203] The social cost of carbon represents the future economic damages that can be avoided by reducing emissions in each future year by one metric ton. The social cost of carbon is intended to include (but is not limited to) changes in net agricultural productivity human health, property damages from increased flood risk, and the value of ecosystem services due to climate change. The HERS model uses the value of CO_2 based on the 3-percent discount rate case and discounts resulting benefits at 3 percent. Social cost of CO_2 values are presented in *Exhibit A-14*.

Exhibit A-14: Social Cost of CO_2, 2020–2050

Year	3% Average
2020	$51
2025	$56
2030	$61
2035	$67
2040	$73
2045	$78
2050	$84

Note: Values are in 2018 dollars per metric ton of CO_2.
Source: Highway Economic Requirements System.

Other Impacts

Economic Effects

Investments in transportation that result in highway improvements can produce a variety of economic adaptations that result in increased highway use (termed “induced travel” or “induced demand”). These changes in highway use can result in both economic benefits and costs. One common example of benefits includes changes to freight logistics, such that more frequent

[202] U.S. Department of Transportation Benefit-Cost Analysis Guidance for Discretionary Grant Programs. 2021. Available online at: https://www.transportation.gov/sites/dot.gov/files/2021-02/Benefit%20Cost%20Analysis%20Guidance%202021.pdf

[203] HERS uses the value for CO_2 from the Interagency Working Group on Social Cost of Greenhouse Gases within the 2016 Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866. Available online at: https://www.epa.gov/sites/default/files/2016-12/documents/sc_co2_tsd_august_2016.pdf

shipments can economize on inventory and thus lower freight costs. 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. Other potential additional benefits can result from market and labor catchment areas expanding after highways improve; this can increase both productivity (by facilitating competition) and the variety of goods and services that are available. 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.

Induced travel, however, can also have negative economic effects. Additional vehicle travel can increase downstream congestion, increase accident risk, and cause additional polluting emissions. These costs may result from additional traffic volume or changes in transit systems that concentrate travel on a few links in the network. Longer and induced vehicle trips can lead to more automobile-dependent transportation and land use over the long term. FHWA continues to monitor and evaluate the growing body of research on these hard-to-measure costs and benefits for possible future treatment within HERS.

Land Use

Transportation decisions directly affect land use patterns and result in economic, social, and environmental impacts. Some transportation planning decisions can result in induced travel and increase sprawl, subsequently resulting in more dispersed and automobile-dependent systems. These investment decisions may result in increased roadway capacity, roadway speeds, and low vehicle operating costs but have inferior public transit service or poor walking and cycling conditions. Other planning decisions support more compact or multimodal development. These investment decisions may yield transit service improvements and encourage pedestrian and cycling improvements. These planning decisions often involve tradeoffs between mobility (physical movement of people and goods) and access (the ability to reach desired goods and activities). Although the HERS model does not currently consider land use, FHWA recognizes that the continued discussion of transit investments and their impact on land use is important and continues to explore the possibility of including land use in the HERS model in the future.

Equity

The HERS, NBIAS, and TERM models do not disaggregate impacts by demographic or socioeconomic categories, making it difficult to identify specific investment scenario impacts on equity. Equity refers to the fairness with which costs and benefits are distributed. In transportation planning decisions, equity considerations can arise from the tradeoffs among many factors, including public fund distributions, overall mobility and access for groups and individuals of different demographic or socioeconomic categories, fees associated with road use and parking, and vehicle ownership and operating costs. Although this analysis does not explicitly examine equity and cannot disaggregate results by demographic or socioeconomic categories, FHWA recognizes that the consideration of equity is important to future modeling and analysis efforts and continues to explore how equity can be included in future analyses.

Other Effects

The HERS model 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 optionality value of additional alternative routes or travel routes becoming less circuitous. The HERS model also does not consider the effects of modeled highway improvements on nonmotorized transportation. For motor vehicles, a possibly significant effect not captured in HERS is the increase in traveler comfort resulting from pavement improvements. Although research into the value placed by travelers on this benefit is scant, this value could conceivably be significant compared with savings in vehicle operating costs from pavement improvements, which HERS does measure.

Key Limitations of the HERS Model

Although all models have limitations, the HERS model simulates how highway investments can be made to address future needs. 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. HERS has several core limitations:

- HERS models independent HPMS roadway segments, whereas real projects tend to encompass multiple segments or consider impacts at a system or network level.
- Because HERS analyzes each highway section independently rather than the entire transportation system, it cannot fully evaluate the network effects of individual highway improvements. Although efforts have been made to account indirectly for some network effects, HERS is fundamentally reliant on its primary data source—the national sample of independent highway sections contained in HPMS. Fully recognizing all network effects would require developing significant new data sources and analytical techniques.
- HERS considers pavement surface condition only, with a focus on roughness and ride quality (IRI) and ignores problems with aging of the rest of the pavement structure.
- HERS also limits the improvement types considered, focusing on resurfacing and lane widening, and does not consider other safety improvements or demand management improvements. Research is conducted on an ongoing basis to assess the assumptions and data used within the model, and, when possible, the HERS model is adjusted to more accurately reflect real-world dynamics.

Enhancements in Progress

To address a number of its key limitations, and to keep HERS up to date with current modeling practices, HERS is undergoing a number of modeling enhancements, including:

- Updating vehicle operating costs,
- Re-parameterization of the pavement deterioration model, and

Inclusion of interchanges within the modeling framework.

Appendix B: Bridge Investment Analysis Methodology

National 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 616,000 highway bridges and culverts 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 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 and/or adding 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

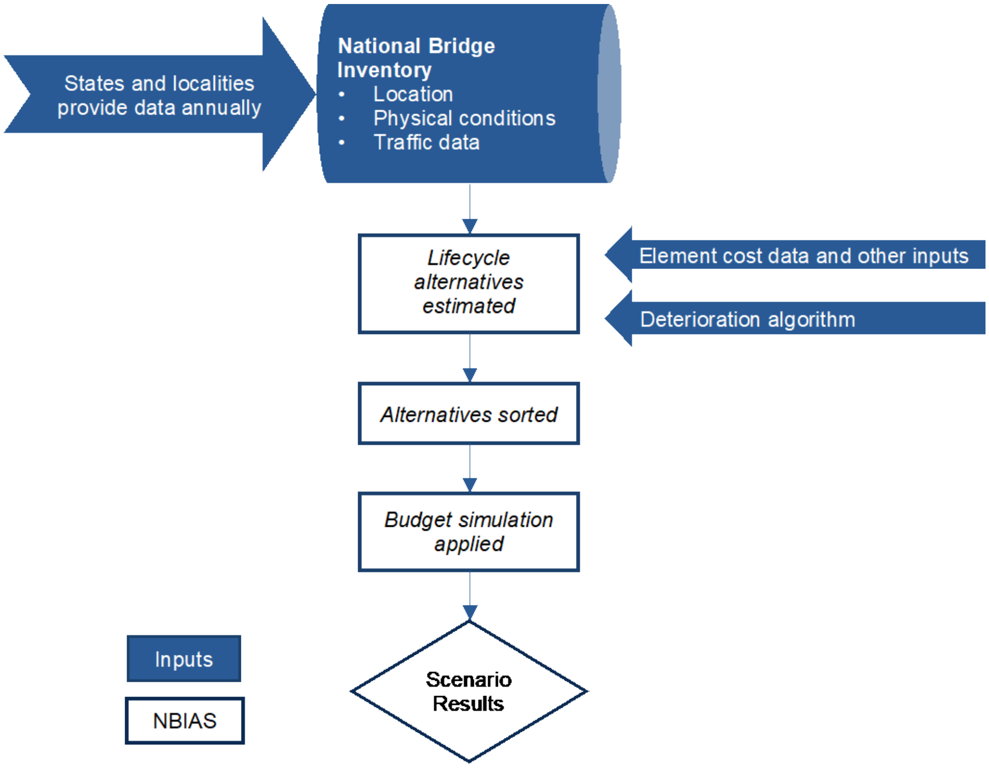
NBIAS analyzes each bridge and culvert in the NBI in a multiyear analysis period through a program simulation model. The model simulates deterioration, traffic, preservation needs, functional needs, and costs. Outcomes can be grouped by type of work performed (i.e., maintenance, repair, widening existing lanes, and adding lanes), 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 616,000 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.

Exhibit B-1. Overview of NBIAS Approach



Note: NBIAS is National Bridge Investment Analysis System.

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).

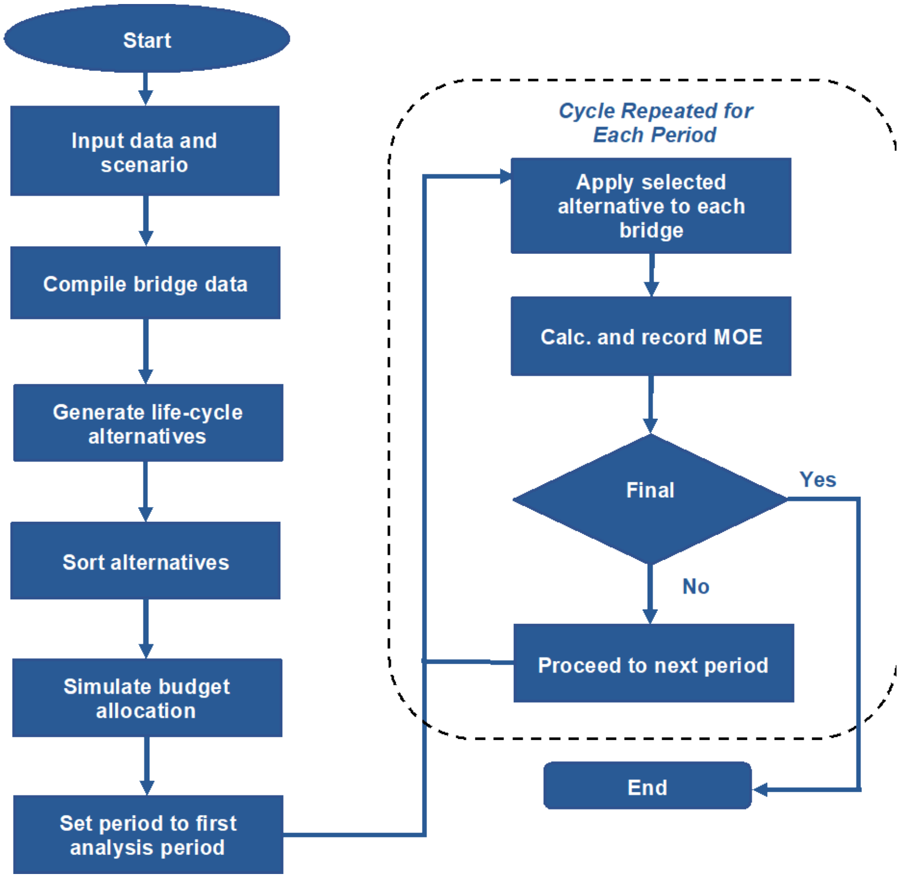
NBIAS then assesses whether repairs or replacement of individual elements are needed, or if functional improvements—such as widening existing lanes and shoulders, adding lanes, increasing vertical or horizontal clearances, and strengthening (to carry heavier loads)—would be required.

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-2 is a more detailed flow chart of the series of steps in the NBIAS modeling and decision- making approach. As illustrated in the figure, the process begins with specifying scenarios and model data and compiling the bridge data. The system then generates a set of different feasible life-cycle alternatives for each bridge in the inventory, where a life-cycle alternative specifies what treatments will be performed on the bridge each five-year period over a planning horizon of up to 50 years. The system then selects life-cycle alternatives from a list sorted in decreasing order of incremental benefit-cost ratio (IBCR) of each alternative relative to the next cheaper alternative.[204] Projects are selected from that sorted list until the budget constraints are reached. Once a life-cycle alternative has been selected for each bridge, the system then performs a simulation to determine the results of the budget allocation. For each simulation period the system calculates a range of different measures of effectiveness (MOE) summarizing the conditions and performance resulting from the selected alternatives.

Exhibit B-2: NBIAS Program Simulation Steps



Note: NBIAS is National Bridge Investment Analysis System.

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.

[204] 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.

Data on Bridge Inventory, Characteristics, and Cost

The NBI database is the primary data source for the NBIAS analyses presented in the 25th C&P report. The NBI covers nearly 616,000 bridges and culverts 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 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 is currently being enhanced as described below under “Future NBIAS Enhancements Currently Underway,” and was not used in the development of this report. States are now required to collect and report structural element 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).

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.

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 MR&R investments, and functional improvements.

Determining Maintenance, Repair, and Rehabilitation Needs

Once NBIAS has consolidated and organized data on bridge type, quantity, conditions, use, 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 for each bridge in the NBI by statistical means and applies 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 (also called MOEs), 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).

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,
- Adding new lanes to reduce congestion,
- 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. However, lanes and shoulder width of the new bridge are assumed to meet current design standards, and the system may add lanes to the new bridge if additional capacity is required to reduce congestion.

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

Two major enhancements are being introduced for future versions of NBIAS.

NBIAS was developed using the American Association of State Highway and Transportation Officials (AASHTO) Commonly Recognized Elements specification, and previous versions of the system supported import of element data following this 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. The element models in NBIAS were recently updated to use the newer element specification. Now the system 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.

Additionally, the reporting functionality of the system is being enhanced to improve the visualization of system results. This will simplify the installation and use of the reporting module of the system for viewing analysis results, while improving the overall accessibility and usability of the system.

Appendix C: Transit Investment Analysis Methodology

Transit Economic Requirements Model

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 methodologies used to generate the estimates for the current (25th) edition of the C&P Report.

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.

National Transit Database – Asset Inventory Module (NTD AIM)

This edition of the C&P Report is the first to use asset inventory data obtained from the National Transit Database's new Asset Inventory Module (NTD AIM). Prior to this improvement, TERM's asset inventory was populated using data obtained primarily through asset data requests to a sample of the Nation's larger rail and bus operators (and vehicle data as previously reported to NTD). As no standard exists for maintaining such data, asset inventory data obtained through agency requests were provided in a broad range of asset reporting hierarchies and data formats, and to varying levels of asset detail (all driven by each agency's own data management practices).

With the introduction of NTD AIM, FTA now obtains consistently reported asset inventory data for a large proportion of transit asset types, including revenue and service vehicles, stations and maintenance facilities, and guideway structures. Although it offers a significant improvement over data obtained through a sample of agency requests, NTD AIM does have some limitations. First, it does not cover all asset types (e.g., communications, subway ventilation, or maintenance equipment) or provide year-built data for some asset types (e.g., track, switches, crossings). Given this limitation, data supplied through direct agency requests are still needed for these and some other asset types to support TERM's minimum asset inventory requirements. (TERM's minimum asset inventory requirements include owning agency and asset type, mode, year built (or acquired), unit quantity, unit cost, and cost year.) Second, NTD AIM only provides unit cost data for service vehicles, which represent only a small proportion of the value of the Nation's transit assets. Hence, FTA has needed to develop standard unit replacement cost values for assets such as stations and facilities (per square foot) and elevated structures (per linear foot). A key challenge here is that transit asset replacement costs can vary significantly across the Nation. Finally, the "date-built" values AIM provides for subway and elevated track structures, train control, and traction power equipment are reported as the decade built instead of the year built. This results in "lumpy" data that can lead to swings in estimated needs depending on TERM's 20-year period of analysis.

Given these limitations and the need for comprehensive coverage of all major transit asset types, the asset inventory used for the 25th C&P Report has been developed using a mix of NTD AIM data, 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.

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 (25th) edition of the C&P Report, all of TERM's replacement condition thresholds have been set to trigger asset replacement at condition 2.5. (Under the Sustain 2014–2018 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 constant 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 two different types of capital investments: (1) rehabilitation and replacement expenditures, and (2) expansion investments needed to improve performance and accessibility or to support ongoing growth in transit ridership. These two 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 expendituresto 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

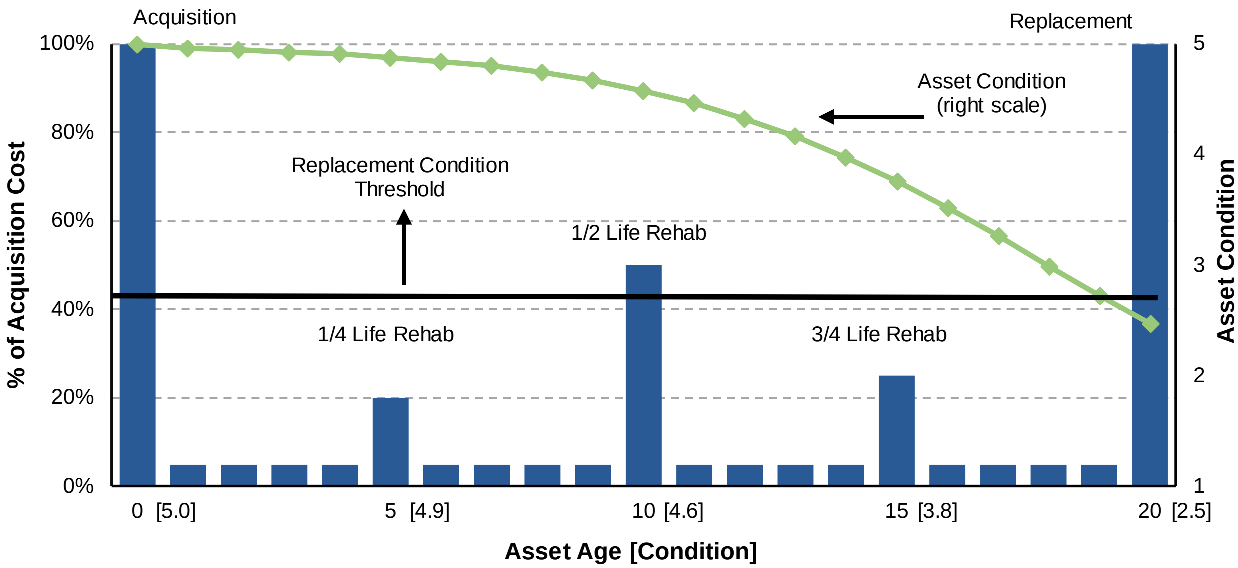
Rating	Condition	Description
Excellent	4.8–5.0	No visible defects, near-new condition
Good	4.0–4.7	Some slightly defective or deteriorated components
Adequate	3.0–3.9	Moderately defective or deteriorated components
Marginal	2.0–2.9	Defective or deteriorated components in need of replacement
Poor	1.0–1.9	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 that cost to the tally of total 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 improve performance and to support ongoing growth in transit ridership.

The Expansion and Expansion with Growth scenarios estimate the total combined 20-year investment levels for both transit expansion and transit asset preservation. The expansion investments in both scenarios were driven by the level of investment required to (1) support planned New Starts/Small Starts investments, (2) attain specific service targets for areas currently unserved or underserved by transit, (3) attain specific service performance targets for urban areas with low average operating speeds, and (4) reduce crowding for transit agencies with high-capacity utilization.

In addition, the Expansion with Growth scenario includes estimated expansion investment levels required to support projected growth in passenger miles traveled (PMT), taking into account the decline and expected slow recovery of ridership following the COVID-19 pandemic. Specifically, these projections assume ridership will continue to increase at the trend rate experienced since the start of the pandemic (March 2020) through 2023 and will thereafter resume the trend rate of growth in PMT, calculated as the compound 15-year average annual PMT growth by FTA region, urbanized area (UZA) stratum, and mode. Under these assumptions, investment in expansion assets does not occur until ridership re-attains pre-pandemic levels in these individual submarkets.

In addition to forecasting fleet expansion requirements to support the projected ridership increases or performance objectives, the model forecasts expansion investments in other assets needed to support that fleet expansion. These include 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. As with 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 ensures that the cost of rehabilitating and replacing the new assets is accounted for during the 20-year period of analysis.

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.

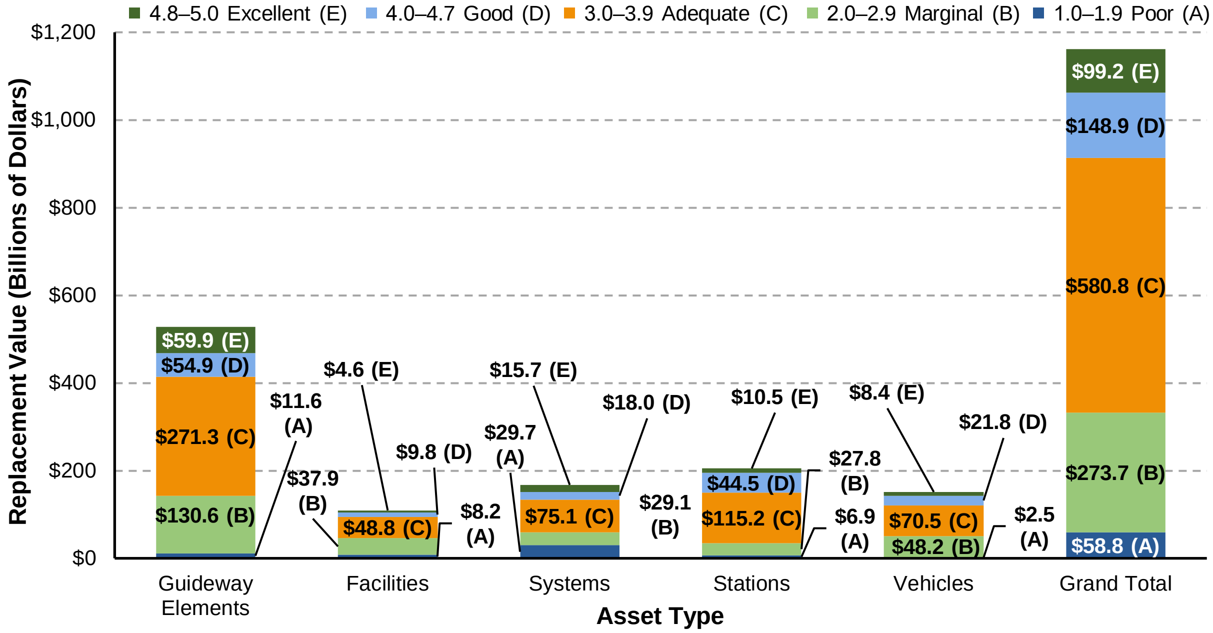
TERM decay curves serve two primary functions: (1) to estimate the physical conditions of groups of transit assets and (2) to determine the timing of rehabilitation and replacement reinvestment.

Estimation of 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 2018.

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.

Exhibit C-3: Distribution of Asset Physical Conditions by Asset Type for All Modes, 2018

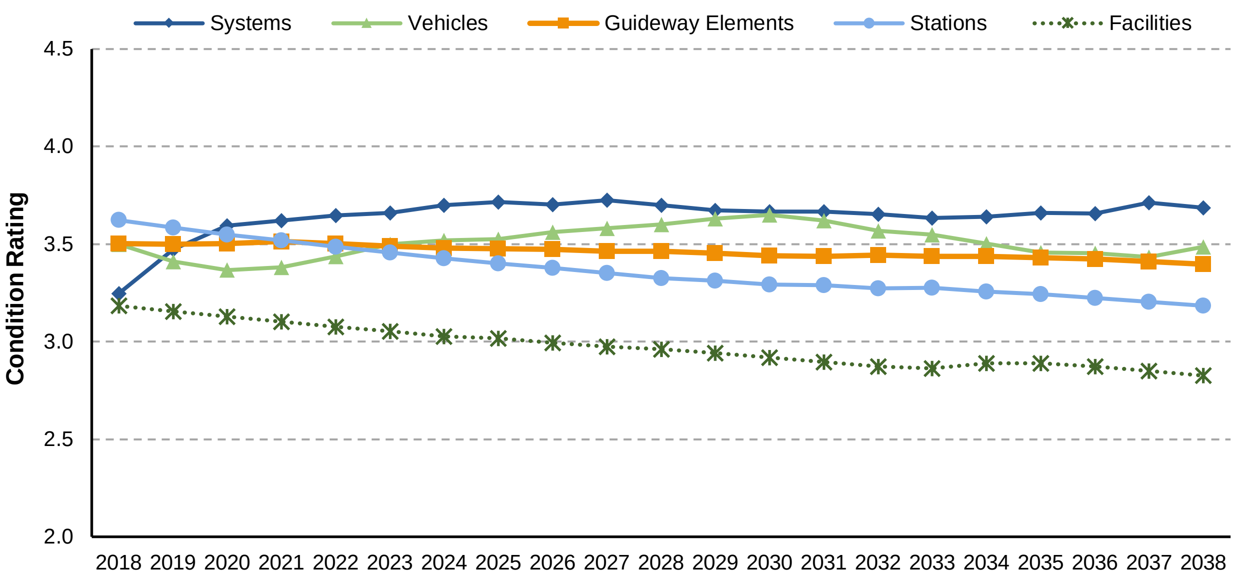


Note: In contrast to prior reports, this chart includes non-replaceable assets; empirical decay curves for these asset types were added to TERM in 2018.

Source: Transit Economics Requirements Model (TERM).

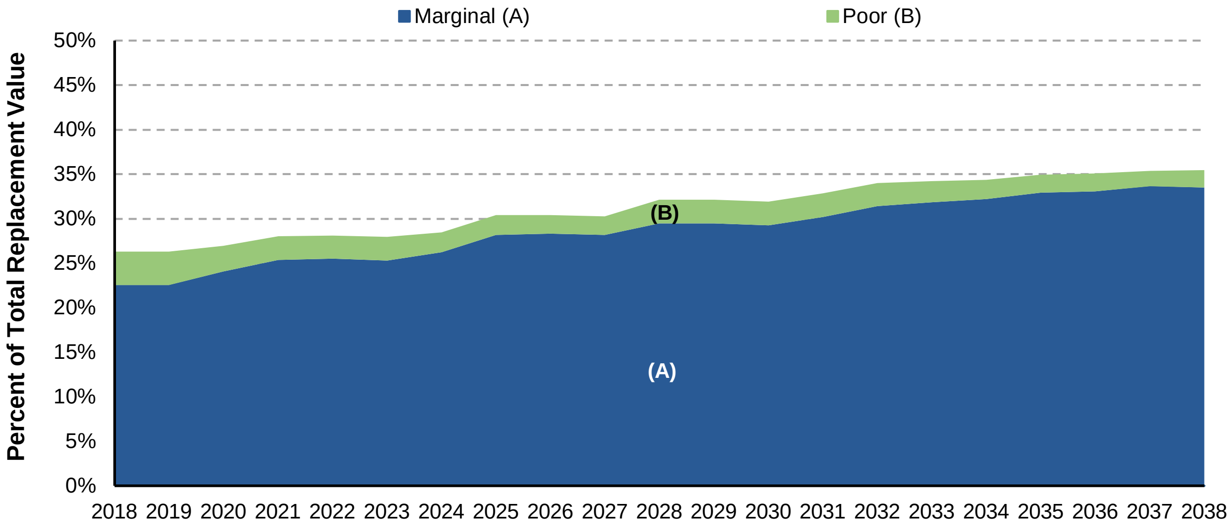
TERM also uses the decay curves to predict expected future asset conditions under differing capital reinvestment funding scenarios. An example of this type of analysis is presented in *Exhibits C-4* and *C-5*, which present TERM forecasts of the future condition of the national transit assets assuming 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, 2018–2038



Source: TERM, Sustain 2014–2018 Spending.

Exhibit C-5: Assets in Marginal or Poor Condition, 2018–2038



Source: TERM, Sustain 2014–2018 Spending (Excludes Unreplaceable Assets).

Determination of the Timing of Reinvestment

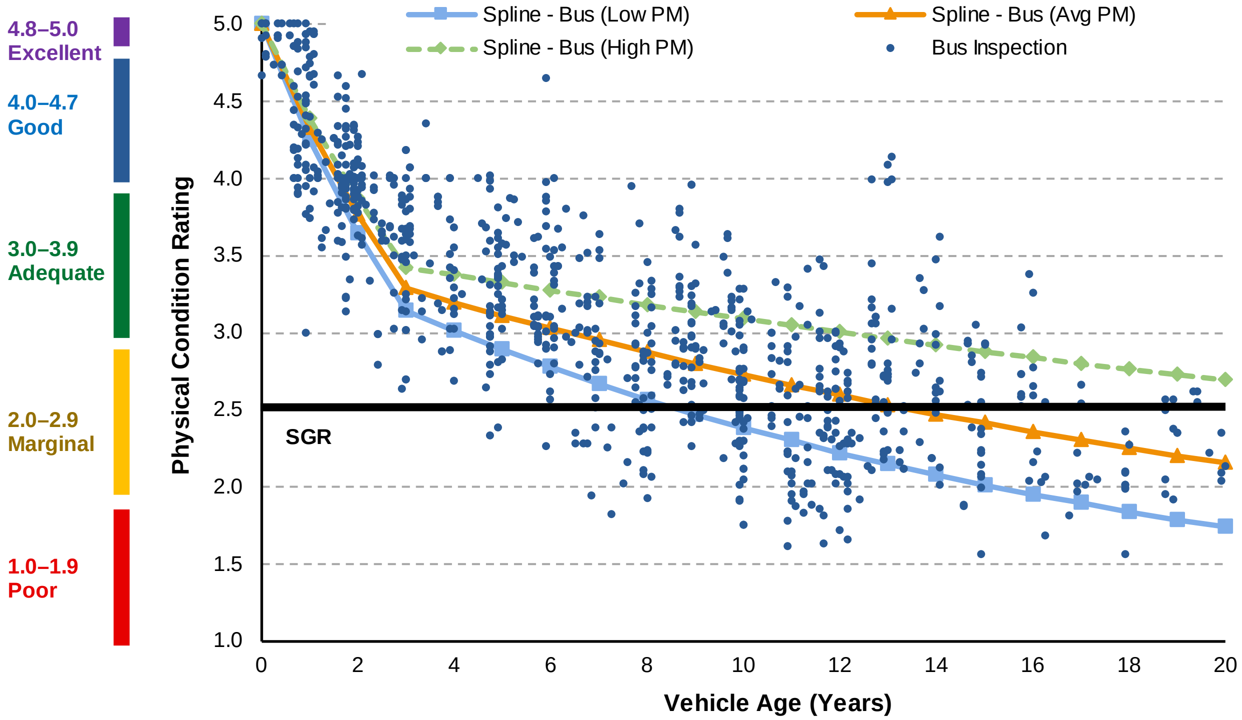
Another key use of the TERM asset decay curves is to determine when the individual assets identified in the asset inventory will require either rehabilitation or replacement, with the ultimate objective of estimating replacement needs and the size of the state of good repair (SGR) backlog. Over the 20-year 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.

Development of Asset Decay Curves

Asset decay curves are statistically estimated mathematical formulas that rate the physical condition of transit assets on a numeric scale of 5 (excellent) to 1 (poor).

Most 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*. The curves in this specific example were developed using a "spline" regression model. Unlike standard linear regression models, where the slope of the regression line remains constant for all input values, spline regression models feature changes in slope at distinct points along the line. In this example, the change in slope at age 3 captures the reduced rate of asset decay as bus vehicles approach their midlife. The reduction in the rate of bus decay at this age reflects a mix of decreased annual mileage (transit operators tend to focus their newest buses on their highest-demand routes) and increased rehab actions as vehicles begin to show increasing signs of wear.

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.

Asset Expansion Investments

In addition to devoting capital to maintain and replace aging assets, transit agencies frequently need to expand their service offerings to improve system performance or to cope with rising consumer demand. This edition of the C&P Report introduces several new approaches, and reintroduces two legacy approaches, and reintroduces two legacy approaches (Average Speed and Vehicle Occupancy Improvement Modules), to the estimation of those expansion investment needs. Both the new and legacy approaches were introduced with the aim of better capturing beneficial investments that improve transit performance (versus investments to maintain performance by accommodating trend ridership growth, as in recent C&P Report editions). Descriptions of these approaches follow, segmented into investments intended to improve service performance (e.g., serve transit deserts, increase service frequency or speeds) and those intended to maintain performance (given likely ridership growth).

Investments to Improve Performance: New Modules

Investments to improve performance, accessibility, and the quality of transit service include those that expand transit asset holdings with the intention of improving transit performance measures such as system coverage, service frequency, operating speed, or capacity (e.g., fleet size or throughput). *Exhibit C-7* provides descriptions of the five components used to identify transit performance improvement investments in this edition of the C&P Report.

Exhibit C-7: Components to Improve Performance and Accessibility

Expansion Analysis Component	Component Objective
Service Coverage (“Transit Deserts”)	Expand transit service to cover areas currently without service but with sufficient residential density to support fixed-route service.
Service Frequency	Increase service frequency where service is inadequate based on residential density.
New Starts Pipeline	Invest in all New Starts projects currently approved in the New Starts pipeline.
Average Speed Improvement	Improve average transit operating speeds of urbanized areas that are well below the national average.
Vehicle Occupancy Improvement	Reduce vehicle occupancy rates (crowding) for agencies that are well above the national average (calculated separately for each transit agency mode combination).

Source: Transit Economic Requirements Model.

Service Coverage and Service Frequency

New methodologies were developed to identify and quantify 20-year capital expansion investment levels for communities that are either not served by fixed-route transit service or are underserved based on the frequency of service currently provided. Residents of “transit deserts” lack accessibility to fixed-route transit service, despite having sufficient residential density that supports this level of service. Other communities within urbanized areas may have some existing fixed-route transit service within walking distance, but not at a frequency level that is justified based on residential densities. In both instances, the supply of transit service may be insufficient relative to the potential demand that could be supported within these areas.

The Transit Capacity and Quality of Service Manual (https://www.trb.org/Main/Blurbs/169437.aspx) identifies accessibility as a “Measure of Availability” and frequency as a “Measure of Comfort and Convenience.” Both are central to the quality of transit service experienced by passengers.[205] The term “first mile/last mile” refers to the challenges and potential solutions to reducing the distance between a traveler’s origin/destination and a transit station/stop. Expanding coverage directly addresses first mile/last mile accessibility by reducing the distance to the nearest bus stop and making transit an option for travelers. Even if transit service is provided within walking distance, the frequency of the service provided is a key determinant in whether transit is chosen over other modes such as driving. Both coverage and frequency are critical issues for transit agencies as they strive to retain and attract transit riders in an equitable manner.

The analysis identifies regions within each of the Nation’s urbanized areas that warrant introducing fixed-route transit service or adding transit service based on housing unit density levels. These two geography-based components were estimated nationally for all UZAs with complete and validated Generalized Network Transit Specification (GTFS) transit networks, which included 297 UZAs representing 95 percent of the total transit vehicle revenue miles provided in urbanized areas and factored to represent the expansion investment levels for the entire nation. Investments to address underserved communities typically consist of investments in bus vehicles and their support assets.

Decades of research have established the strong relationship between density and transit ridership. For this analysis, housing unit density was selected to identify residential neighborhoods that have sufficient density to support fixed-route transit. Housing unit density is a useful measure that can be calculated using Census data at the block group level for all urbanized areas. However, other factors beyond the scope of this analysis will affect whether transit service expansion leads to increased transit ridership, including but not limited to connections to jobs and activities, connections to other transit services, the pedestrian network around bus stops, traffic congestion, and parking prices within the service area.

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[205] Transportation Review Board, 2013. *Transit Capacity and Quality of Service Manual*, 3rd Edition, Section 4.3, “Quality of Service Framework.”

The two types of density-based analysis include:

- **Expand Coverage by Serving Transit Deserts:** This component identifies regions within each of the Nation's more than 400 UZAs that are not currently served by transit, but which warrant transit service based on housing unit density levels that support fixed-route bus service.
- **Improve Frequency:** Similarly, this component identifies regions within UZAs that *are* currently served by transit but warrant an increase in service frequency, again based on density thresholds.

Exhibit C-8 lists the dwelling unit density thresholds used to identify the minimum average headway supported. For example, based on these guidelines, an area with fewer than four dwelling units per acre is considered to have insufficient density to support regular fixed-route transit service. A dwelling unit density of at least seven dwelling units per net acre would be needed to support bus headways of 30 minutes or better.

Exhibit C-8: Minimum Headway Supported by Density Levels

Dwelling Unit Density	Minimum Average Headway Supported
< 4 dwelling units/net acre	Density insufficient to support regular fixed-route transit
4 dwelling units/net acre	60 minutes
7 dwelling units/net acre	30 minutes
15 dwelling units/net acre	15 minutes

Source: Pushkarev, B.S., and J.M. Zupan, 1977. Public Transportation and Land Use Policy, as cited in Transportation Research Board, 2013. *Transit Capacity and Quality of Service Manual*, 3rd Edition, Exhibit 5-2.

These headway thresholds are the current standards established by the Transit Capacity and Quality of Service Manual published by the Transportation Research Board of the National Academies of Science, Engineering, and Medicine. These standards may be subject to criticism because they are based on research from 1977. Moreover, this research explicitly used the number of riders that would produce enough fare revenue to cover operating costs to determine minimum average headway.[206] In recent years, public subsidies for fixed-route transit service have become more widely accepted. This is in part because fixed-route transit service is a public benefit for disadvantaged members of the community and because riders of public transportation provide positive externalities to the rest of the community by reducing roadway congestion and reducing demand for scarce parking spaces. Future research, including future editions of this report, will consider revisiting these standards with an eye toward the need to provide high-quality transit service to a diverse array of communities with the need to maintain efficient and sustainable transit operating practices.

Nevertheless, transit service with headways of 30 minutes and 60 minutes is of limited benefit. Few people with access to automobile transportation will choose to use transit with such long headways. Furthermore, transit service at these headways is of limited value to disadvantaged populations. For example, a transit-dependent person using a bus service with 60-minute headways usually cannot set their own work hours, and they cannot set the schedule of classes at a community college. A bus route with 60-minute headways may offer a rider the choice between arriving 50 minutes early for work or class or arriving 10 minutes late. If the rider needs to make a connection to another bus route, also with infrequent headway, the usefulness of the system becomes even more limited.

[206] Pushkarev, B.S., and J.M. Zupan, 1977. Public Transportation and Land Use Policy, as cited in Transportation Research Board, 2013. *Transit Capacity and Quality of Service Manual*, 3rd Edition

Data Sources and Pre-Processing

The service coverage and service frequency analyses are based on the same data sources used to calculate residential densities and the availability and frequency of transit service. The density-based analysis uses multiple data sources to identify housing unit densities and existing transit service levels within UZAs:

- Block group and UZA geography were downloaded from the Tiger/LINE portal on the Census Bureau website in shapefile format.
- Demographic information, including population, housing units, and any other variables of interest, for all block groups was downloaded separately from the Census Bureau's data portal.
- GTFS feeds were compiled for all UZAs, where available.
- Online-only exhibits described at the end of this Appendix include a list of UZAs, along with basic service characteristics including the transit revenue miles of service provided and the population served.
- Dwelling unit density was calculated for all block groups that fall within UZA boundaries by dividing the housing units by the land area of each block group in square miles. For the existing density conditions, the primary source used in this analysis was the 2010 Census at the block group level.

To project the transit service expansion levels out to 2038, it is necessary to determine which block groups might move into a different dwelling unit density stratum in the next 20 years. In the absence of a source for long-range population and dwelling unit forecasts at the block group level, trendline growth rates were used to project future densities. Historical population and dwelling unit counts from the 2000 and 2010 Census, as well as population and dwelling unit estimates from the 2017 American Community Survey, were compiled for each block group. Using the 2000 and 2017 population and dwelling unit totals, a compound annual growth rate (CAGR) was calculated for population and dwelling units separately for each block group.

> *Population CAGR (year 2000 to year 2017) = [(Population in 2017/Population in 2000) ^ (1/17)-1]*

This CAGR was applied to each year between 2018 and 2038 to project the future dwelling units for each block group. Due to the potential for outlier block groups with extremely high growth or decline between 2000 and 2017 to skew the data, a 3-percent annual growth cap was applied to ensure reasonableness. The dwelling unit densities for each block group in 2038 were used in the analysis of future service coverage and service frequency expansion levels.

Coverage Analysis

The coverage analysis is designed to account for portions of UZAs that are not served by any regular fixed-route transit service (referred to as transit deserts) but where housing unit densities are high enough to support regular service. As shown in *Exhibit C-8*, areas with a residential density of four housing units per acre and above can support at least hourly fixed-route bus service. This analysis determines which block groups in a UZA were not served by regular transit service and applies a factor to calculate the vehicle revenue miles (VRM) needed to serve the transit desert block groups where coverage deficiencies were identified.

The analysis includes the following steps, as shown in *Exhibit C-9*:

1. **Create transit buffers.** Block group geography and transit stop locations, using the GTFS feeds, were compiled for all UZAs in a geographic information system (GIS). For this analysis, areas within one-half mile of each bus stop or station were classified as being within a walkable buffer zone of the bus stop. These transit buffers indicate the areas that currently have walking access to fixed-route transit service.

2. **Identify transit deserts.** Overlaying the transit stops with the block groups in the UZAs allows for the identification of block groups that are expected to have a density greater than four dwelling units per net acre in 2038 but are not currently served by fixed-route transit, i.e., transit deserts.

3. **Calculate VRM needed to serve transit deserts.** The VRM needed to serve transit deserts is calculated by applying the service density ratio of the entire UZA to the area of the desert block groups. Annual fixed-route VRMs for each UZA were calculated by summing the existing annual VRM of the Motor Bus, Commuter Bus, and Rapid Bus modes in the NTD's service tables. The factor used is the overall service density for the UZA, which can be calculated as:

   UZA Service Density = Annual Fixed-Route VRM / Total Transit Service Area (Sq Mi)

   Hence the new annual VRM needed to serve all the desert block groups in a UZA can be expressed as:

   *New VRM to Provide Service to Transit Deserts = UZA Service Density * Area of Desert Block Groups (Sq Mi)*

Exhibit C-9 Coverage Analysis Methodology

Create Transit Buffers
Areas with fixed-route service

→

Identify Transit Deserts
Block groups with density greater than 4 housing units per acre but no fixed-route service

→

Calculate VRM Needed to Service Transit Deserts
Based on current service density

Source: Analysis by Federal Transit Administration.

This approximation of service needs is based on the assumption that the amount of VRM required to serve the transit desert block groups will be proportional to the area of the desert block groups. This is a rough approximation: actual service levels would be expected to differ from the estimate if development is uneven within the block group, requiring service to just a portion of the block group, if the service levels in the existing service area are much higher than is needed to serve desert block groups, or if the block group is far removed from the existing service area, requiring additional VRM to connect transit desert block groups to existing transit routes.

Estimates of new VRM resulting from transit deserts were calculated for both 2017 and 2038 density conditions. Service expansions required for the interim years from 2018 to 2037 were interpolated and used in TERM to calculate the annual capital investment levels.

Exhibit C-10 summarizes the service coverage analysis results. The analysis found that 1,446 block groups, totaling 2.2 million people, would qualify as transit deserts based on current density levels. At 2038 density levels, a total of 2,609 block groups with a population of 5.1 million people would qualify as transit deserts. Serving all desert block groups that would reach the threshold density by 2038 would require an increase in VRM of 1.5 percent over current service levels for all UZAs nationwide.

Exhibit C-10: Coverage Analysis Results

Coverage	Fixed-Route Vehicle Revenue Miles	Population	Number of Block Groups	Area of Block Groups (square miles)
All UZAs Analyzed	1,981,622,912	176,217,778	159,269	267,354
Additional Coverage Needed to Serve Deserts (2038 Density Levels)	30,217,445 (+1.5%)	5,120,679 (+2.9%)	2,609	900

Source: Analysis by Federal Transit Administration.

Frequency Analysis

The transit coverage analysis identifies service deficiencies only for areas with no existing fixed-route transit service. An additional analysis of service frequency was conducted to account for portions of urbanized areas that do have fixed-route service, but where service is inadequate based on its residential density. The transit frequency analysis was designed to account for new service needed in these areas by dividing block groups into residential density categories that each have a recommended hourly peak fixed-route transit headway, as shown in *Exhibit C-8*. For example, block groups with a density of seven dwelling units per net acre are assumed to be able to support fixed-route bus service at 30-minute headways or better.

Each block group was evaluated based on its existing peak period transit service, calculated from the highest-frequency transit stop within a half-mile buffer of the block group. If the existing peak period service was less frequent than the recommended service level based on the density threshold of a given block group, the transit route serving the block group was flagged as having a frequency deficiency. A calculation was made of the VRMs necessary to increase service on the deficient route to meet the recommended peak headway.

The analysis includes the following steps, as shown in *Exhibit C-11*:

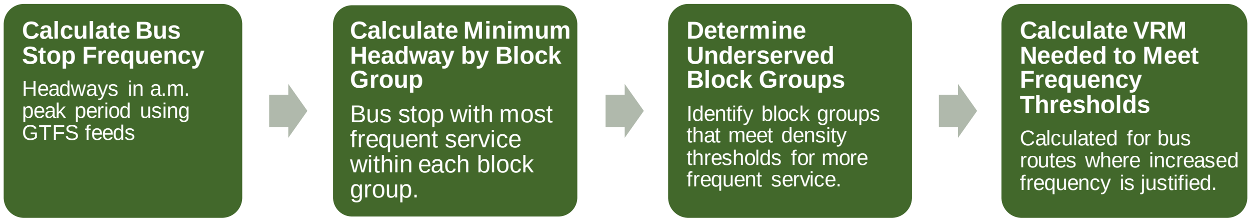
1. **Calculate stop frequency from GTFS.** The average headway was calculated at each bus stop along each route in the a.m. peak period from 5 a.m. to 9 a.m., using GTFS feeds.

2. **Calculate the minimum headway for block groups with transit service.** For each block group, the frequencies of service at bus stops within walking distance (less than one-half mile) of the block group were compiled. The bus stop with the most frequent (lowest headway) service was associated with the block group in which it is located.

3. **Determine underserved block groups and underserved routes.** All block groups where the calculated bus stop headway was greater (less frequent) than the required minimum headway, based on dwelling unit density, were classified as "underserved." The next step was to determine which specific routes need more service to bring every block group up to its recommended frequency thresholds.

4. **Calculate VRM required to meet frequency thresholds.** The number of additional peak-period trips on each route needed to meet the frequency threshold was multiplied by the length of the route to calculate the additional revenue miles needed to meet frequency thresholds in the peak periods. The total daily additional VRM was summed for the UZA and factored to obtain the annual VRM needed to address frequency deficiencies. Note that service increases are assumed over the entire length of a route that is serving any block groups with deficient frequency levels, affecting the additional service required.

Exhibit C-11: Frequency Analysis Methodology



Source: Analysis by Federal Transit Administration.

Estimates of new VRM resulting from service frequency deficiencies were calculated for both 2017 and 2038 density conditions. Service expansion required for the interim years from 2018 to 2037 were interpolated and used in TERM to calculate the annual capital investment levels. Increasing frequencies to address all block groups with deficiencies, based on 2038 density levels, would require an increase in VRM of 4.3 percent over current service levels for all UZAs nationwide. These service improvements would be needed on 1,696 routes. (See *Exhibit C-12*.)

Exhibit C-12: Analysis Results

Fixed-Route Vehicle Revenue Miles	Population in Underserved Block Groups	Routes Receiving Frequency Upgrades Based on Density Thresholds			
		To 15-Minute Headways	To 30-Minute Headways	To 60-Minute Headways	Total
85,055,160 (+4.3%)	5,120,679	457	806	433	1,696

Source: Analysis by Federal Transit Administration.

Improve Coverage and Frequency Components Asset Record Development

The Improve Coverage and Frequency components are both designed to estimate the level of fleet expansion required to support the projected VRM requirement estimates. Specifically, TERM determines the number of vehicles required to deliver the required VRM levels based on current VRM per active fleet vehicle for the UZA in which the expansion investment is being made (as determined by data reported by local operators for the UZA to NTD). These fleet vehicle assets are then added to TERM's asset inventory, after which they undergo the same asset decay, rehab, and replacement analyses applied to existing assets. Should there be insufficient funding to cover the future replacement or rehabilitation costs of any of these assets, the value of those deferred investment needs will be added to TERM's national backlog estimate.

New Starts Pipeline

As with the Service Coverage and Service Frequency components, the New Starts Pipeline is a new analysis not included in previous C&P Reports. The objective of the New Starts Pipeline component is to assess the expected investment cost of all FTA-approved New Starts and Small Starts projects for the period 2018 through 2038. This component assures that these planned expansion investments were accounted for both in terms of project acquisition costs and expected asset rehab and replacement costs within this 20-year period of analysis.

New Starts Asset Records: To help better assess the long-term life-cycle reinvestment requirements of these expansion investments, this component used standard project parameters available for each project—including project route miles, station counts, and fleet size—to convert the New Starts records into up to 45 different asset records (depending on the investment mode and the project parameter values). This included records for all major replaceable asset types—including track, structures, facilities, systems assets (train control, electrification, and communications), and fleet. These project records also document one-time project costs, including right-of-way acquisition, planning, design, sitework, environmental mitigation, and project management.

The mapping of project parameters to TERM asset records is presented in *Exhibit C-13*. The generated assets are then added to TERM's asset inventory as "expansion" assets, which are then acquired, decayed, rehabbed, and replaced in the same manner as existing assets. If capital funding is insufficient (under the Sustain 2014–2018 Spending scenario) to rehab or replace these assets after they are acquired, these deferred needs are added to TERM's estimate of the SGR backlog.

Data Source: FTA maintains a detailed listing of transit projects seeking Federal New Starts and Small Starts funding assistance. The project listing documents the sponsoring agency, project mode, expected project design initiation and completion dates, cost estimate, alignment length and grade mix, and finally the number of expansion stations, vehicles, and maintenance facilities. The New Starts listing used for this analysis included 55 projects with estimated completion dates through 2030 and covering a range of transit modes (including light, heavy, and commuter rail; streetcar; and bus rapid transit investments).

Exhibit C-13: Mapping of New Starts Project Parameters into TERM Asset Records

New Starts Project Parameter	Assets with Recurring Costs (Rehab/Replace)	One-Time Project Costs
Total Alignment Length	• Train control • Crossing protection • Traction power • Communications • Central control	• Right-of-way acquisition • Sitework (earthwork, clearing) • Utility relocation • Temporary structures • Environmental mitigation
Alignment Length by Grade	• At-grade alignment • Elevated structures • Subway tunnels • Retained cut / fill • Ballasted track • Embedded track • Direct fixation track • Special trackwork	
Station Count (with Alignment by Grade)	• At-grade stations • Elevated stations • Subway stations • Parking • Pedestrian access • Fare collection	
Facility Count (with Fleet Count)	• Maintenance facilities (light and heavy maintenance, storage) • Admin facilities • Rail yard	
Fleet Vehicle Count	• Revenue vehicles • Service vehicles	

Source: New Starts Project Pipeline.

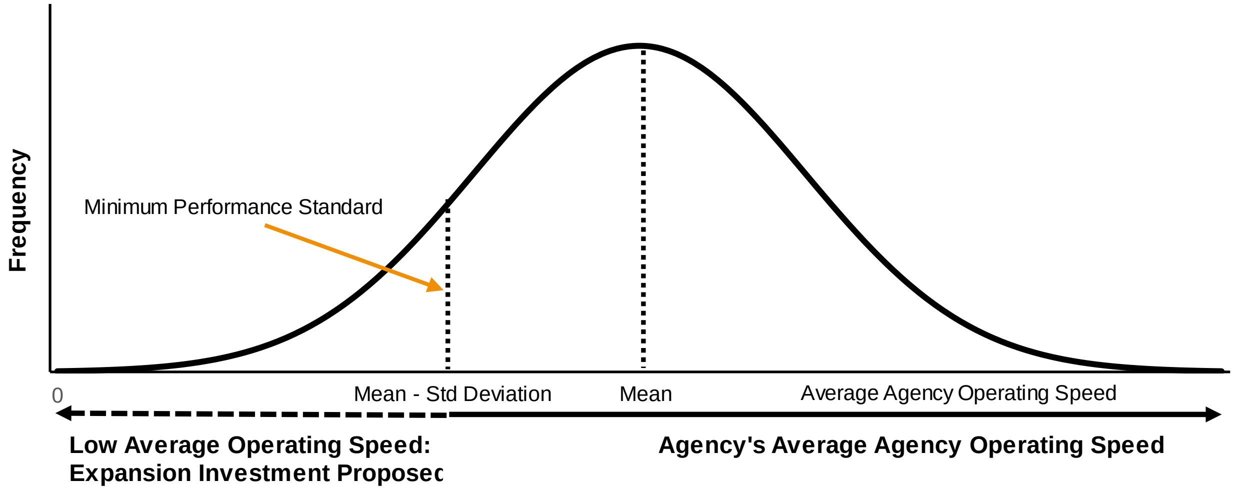
Average Speed Improvement

The Average Speed Improvement component is designed to identify those UZAs with average operating speeds well below the national average and seeks to raise those speeds to a minimum operating speed standard through the introduction of transit expansion investment. This module operates on the premise that average operating speeds for rail and bus rapid transit (BRT) are higher than for standard bus service. Hence, the substitution of rail transit capacity in place of existing bus capacity in larger UZAs (population over 1 million) or the substitution of BRT for bus in smaller UZAs (population over 500,000) is made to increase the average operating speed for the entire urbanized area.

Minimum Service Standard: This component calculates the average UZA transit operating speed as the weighted average speed across existing rail and bus service (excluding commuter rail) within the UZAs, weighted by vehicle miles. The values were calculated using data obtained from the NTD. The minimum service standard for average UZA operating speed is then calculated as the national average transit operating speed, less one standard deviation, calculated across all UZAs with greater than 500,000 population (see *Exhibit C-14*).

Mode Selection: The selection of which mode to invest in is determined first by the mode types already existing in each urbanized area and second by the population size of that urbanized area. Specifically, this component will first look to invest in the fastest existing rail mode within an urban area (excluding commuter rail) and hence will select heavy rail over light rail if both are already present. Note that commuter rail is not included as an option here as the intent is to focus speed improvements on operating speeds toward the urban core, and these systems typically extend well beyond the urban core. If the urban area does not currently have existing heavy rail, light rail, or BRT service, this component will select light rail for UZAs over 1 million in population and BRT for UZAs between 500,000 and 1 million in population.

Exhibit C-14: National Distribution of Average Transit Operating Speeds



Source: Transit Economic Requirements Model User's Guide

Expansion Asset Investments: Having identified UZAs with average operating speeds below the minimum service standard, this component then estimates the number of additional miles of rail or BRT service require to attain that standard for each individual UZA. Depending on mode, this includes investment in guideway track and structures, stations, vehicles, maintenance facilities, systems assets, right-of-way acquisition, design, project mobilization, and project management costs. Investment costs and quantities are based on as-built costs for New Starts projects as documented in FTA's Capital Cost Database.

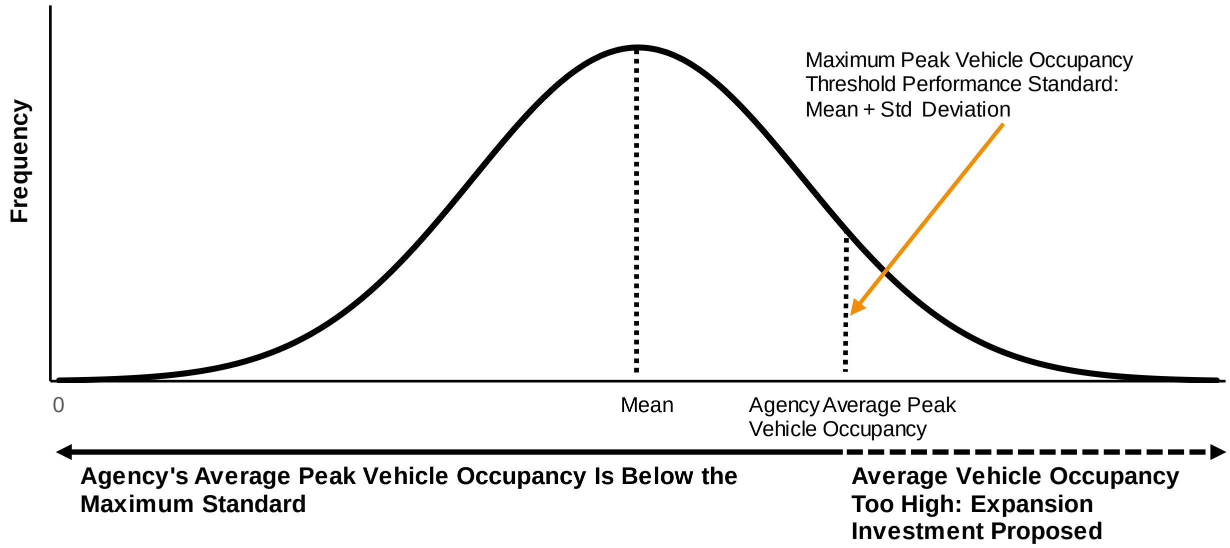
Asset Record Development: The Improve Average Speed component is designed to generate asset TERM records at the subcategory level of detail. This includes records both for replaceable assets and for one-time (nonrecurring) acquisition costs (e.g., project design, construction management, and purchases). This component first determines the total miles of guideway required to improve average UZA operating speeds to the minimum-performance standard, which is set to the national average less one standard deviation (based on data from the NTD). The component then determines the levels of investment in other asset types (e.g., train control, traction power, track, vehicles) as required to support the service expansion. TERM then uses these asset records to estimate the costs of asset acquisition, rehabilitation, and replacement, as well as asset condition, for the 20-year forecast horizon.

Vehicle Occupancy Improvement

The Vehicle Occupancy Improvement component is designed to identify those U.S. transit agency-modes with vehicle occupancy rates that are well above the national average. The component then seeks to reduce crowding for these high-occupancy agency-modes to a maximum occupancy threshold by investing in expansion vehicles and related support assets. These needs are assessed on an agency-mode basis (i.e., individual transit modes are treated separately for each transit agency identified in NTD) (see *Exhibit C-15*).

Service Standard: This component calculates vehicle occupancy at the agency-mode level as riders per vehicle operated in maximum service (VOMS). The values are calculated using data obtained from the NTD. The maximum service standard is calculated separately for each transit mode as the national average vehicle occupancy, plus one standard deviation, across all UZAs over 500,000 in population. Note here that the minimum service standard target is calculated at the start of the run and then remains fixed. The component continues to invest in expansion assets—from one year to the next—to attain those standards, subject to a maximum allowable annual investment level. This tends to spread investments across the period of analysis (versus making the entire investment in one period).

Exhibit C-15: National Distribution of Peak Vehicle Occupancy



Source: Transit Economic Requirements Model User's Guide

Expansion Asset Investments: Having identified agency-modes with vehicle occupancy levels above the maximum service standard, this component then estimates the number of additional vehicles required to attain that standard. Depending on the mode and the number of expansion vehicles identified, this component may also invest in additional supporting assets (e.g., maintenance facilities, passenger stations, systems assets, etc.), with the level of investment in other modes based on the size of the fleet investment (subject to minimum investment levels for these nonfleet asset types).

Asset Record Development: Similar to the Improve Average Speed component, the Improve Occupancy component is designed to generate asset TERM records at the subcategory level of detail. This includes records both for replaceable assets and for one-time (nonrecurring) acquisition costs (e.g., project design, construction management, and purchases). The Improve Occupancy component determines the level of fleet expansion required to reduce crowding to the maximum-performance standard, which is set to the national average plus one standard deviation (based on data from the NTD). TERM then uses these asset records to estimate the costs of asset acquisition, rehabilitation, and replacement, as well as asset condition, for the 20-year forecast horizon.

Double-counting Adjustment

The use of multiple components to estimate transit expansion investment levels leads to the possibility that two or more components will occasionally (and independently) look to make the same or similar expansion investment for the same agency (e.g., two or more components determine a specific agency would benefit from an expansion investment in the same rail mode). Where this occurs, there would be double counting of expansion investments. TERM has been modified to look for and correct this form of double-counting.

In practice, TERM identifies and corrects double-counting as follows (see *Exhibit C-16*). In practice, each of the performance improvement expansion component analyses is performed in a predetermined order, starting with the New Starts Pipeline component and followed consecutively by the Service Coverage, Service Frequency, Average Speed Improvement, and finally the Vehicle Occupancy Improvement analyses (in that order). As each successive component is run, TERM continually checks to determine if a preceding component analysis has already addressed any expansion investments identified by the component analysis currently underway. If prior components have indeed addressed some (or all) of the expansion investments identified by the subsequent component, the total investment levels for that subsequent component (e.g., miles of new guideway or number of expansion vehicles) are reduced or eliminated accordingly.

As shown in *Exhibit C-16*, TERM currently performs the following tests for double-counting:

First, the Average Speed Improvement component checks to determine whether any of the rail route expansion investments it has identified have already been addressed by the New Starts component. As described above, the Average Speed Improvement component is forced to select a specific mode when making investments to improve speed within a given UZA (e.g., the component must choose heavy rail if already present in a UZA). At the same time, mode selection is already clearly defined for all New Starts projects. Therefore, to check for double-counting between these two components, the Speed Improvement component determines (1) which specific mode to select in UZA X (e.g., heavy rail) and how many miles are required in that UZA (e.g., 10). The check then looks to see whether the New Starts component has already made any heavy rail investments in UZA X. If "yes," the check then determines whether the New Starts has added < 10 miles or >10 miles. If less than 10 miles, the Speed Improvement Module invests in the remaining require mileage. If >10 miles, the Speed Improvement Module does not invest in heavy rail expansion in UZA X

Exhibit C-16: Double-counting Checks and Adjustments

Components	Expansion Components				
	New Starts Pipeline	Transit Coverage	Frequency Improvements	Average Speed Improvements	Vehicle Occupancy Improvements
Order of Expansion Component Analyses					
Order in which Component Analyses Are Run					
Double-counting Checks and Adjustments					
Backward Checks and Adjustments for Double-counting					

Source: Analysis by Federal Transit Administration.

Second, the Vehicle Occupancy component determines whether that component's estimated levels of rail route or fleet expansion have already been addressed by either the New Starts component or the Average Speed Improvement components, and similarly reduces or eliminates its own expansion investments accordingly. As noted above, the Speed Improvement Module is forced to invest in a specific mode in each UZA based on the existing modes and UZA size and pre-existing modes (heavy rail, light rail, or BRT; see above) and the New Starts agencies and modes are already well defined for each project. Therefore, for the purpose of checking for double counting between the Speed and Occupancy Improvements, it is assumed there will be no more than one heavy rail, light rail, or BRT operator in any given UZA. In other words, if the Occupancy module is checking for double counting with the Speed module for a potential light rail investment (for example) in UZA X for Agency Y, it is assumed that no other agency is operating light rail in UZA X.

No Double-counting Correction for Ridership-Based Growth Investments: No double-counting check is currently implemented between the New Starts Pipeline component investments and the ridership growth component. This is based on the assumption that New Starts investments tend to address growth-related needs for the specific corridors served by those New Starts investments, whereas expansion to address ongoing rider growth supports entire UZAs. Even with that assumption in place, potential double-counting between these components is small, amounting to 2.5 percent of the combined investment levels of these two modules and only 1.0 percent of total expansion investment levels (see *Exhibit C-17*).

Exhibit C-17: Potential Double-counting Between New Starts and Rider Growth Components

Component	Rider Growth	New Starts Pipeline	Potential Double-counting	Total Expansion Needs
Total	$2,009.30	$1,398.80	$86.80	$8,503.90

Note: Dollar values are in millions.

Source: Analysis by Federal Transit Administration.

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 conducts a systemwide business-case analysis to determine if the value generated by an existing agency-mode combination is sufficient to warrant the projected cost to operate, maintain, and potentially expand that agency-mode. Rather than assessing the benefits and costs for each individual investment need for each agency-mode (e.g., replacing a worn segment of track for a city's rail system), 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 negative (i.e., the benefit-cost ratio is less than 1), 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:

$$Benefit/Cost\ \ Ratio_{agency-mode\ j} =$$

$$\left\{\frac{\sum_{t=1}^{20}\left\{\left(\left(\text{User, Agency \& Social Benefits}_{j,\ t=0}\right) * \left(1+\text{TPM Growth}_j\right)^t\right)/(1+i)^t\right\}}{\sum_{t=1}^{20}\left\{\left(\text{ReplaceCost}_{j,\ t} + \text{ExpansionCost}_{j,\ t} + \left(\text{O\&M Costs}_{j,\ t} * \left(1+\text{TPM Growth}_j\right)^t\right)\right)/(1+i)^t\right\}}\right\}$$

Why Use a Systemwide Business-Case Approach?

TERM considers the benefit-cost of the entire agency rail investment versus simply considering the replacement of a single rail car. Benefits and costs are grouped into an aggregated investment evaluation and not evaluated at the level of individual asset investment actions (e.g., replacement of a segment of track) for two primary reasons: (1) lack of empirical benefits data and (2) transit asset interrelationships.

Lack of Empirical Benefits Data: The marginal benefits of transit asset reinvestment are 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 depend 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? Even though 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 apart from 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 (1) a 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 an 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:

1. TERM begins its benefit-cost assessment by considering the benefits and costs 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.

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.

3. The Step 3 B/C test provides a more realistic assessment of agency-mode benefits for those agency-modes that fail the Step 2 B/C test. Under this "partial" cost-benefit 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 preserving (versus discontinuing any reinvestment in an entire agency-mode). This partial test focuses reinvestment actions (costs) on shorter useful-life, poorer-condition assets, while simultaneously reducing service levels (benefits) until a B/C ratio of 1 is attained (with the relationship between assets renewed and supported service levels supported by high level empirical analysis). This partial benefit-cost test procedure represents a simple solution to this issue, and more sophisticated approaches to this problem should be investigated in future years.

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 versus the agency-mode user's next best alternative. The total trip cost includes both out-of-pocket costs (e.g., transit fare, station parking fee) and value of time costs (including access time, wait time, and in-vehicle travel time).

Transit Agency Benefits

In general, the primary benefit to transit agencies of reinvestment in existing assets comes from the reduction in asset O&M costs. In addition to fewer asset repair requirements, this benefit includes reductions of in-service failures (technically also a benefit to riders) and the associated costs of responding to those failures (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, greenhouse gas emissions, 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).

New Investment Components and TERM's Benefit-Cost Tests

As discussed above, the 25th C&P Report introduces three new components for estimated expansion investments (the Improve Coverage, Improve Frequency, and New Starts Pipeline components) and reintroduces two previously developed components (the Improve Average Speed and Occupancy components). It is worth noting here that, with the exception of New Starts Pipeline projects, the expansion investments generated by these new modules are included in TERM's agency-mode level cost-benefit assessments, using the same cost-benefit modules and parameters, as in all prior C&P Reports (as described above). New Starts Pipeline projects have been exempted from the test given selected projects have Full Funding Grant Agreements.

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:

- The high backlog value relative to existing funding capacity, and
- 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:

- The estimate of current backlog size is focused solely on deferred replacement needs, and thus does not include an assessment of deferred rehabilitation needs. As such, the current backlog estimate is necessarily a lower-bound estimate of the actual SGR backlog.
- The asset inventory data provide only information on asset age or overall condition. These data are sufficient to estimate replacement needs, but not rehabilitation needs.
- TERM provides estimates of future rehabilitation needs based on the typical life-cycle reinvestment needs of transit assets. However, as the underlying asset inventory data sources are not designed to report the extent to which an asset's expected rehabilitation actions have been performed, TERM has no basis on which to estimate the current level of deferred rehabilitation needs.
- TERM's backlog estimates are limited primarily to those assets owned by FTA grantees. Hence, the estimates tend to exclude the reinvestment needs of some assets that are used for transit service but not owned by a grantee. For example, it excludes some assets that are leased by the grantee, provided for service by a municipality, or provided through track access agreements. This resulting level of backlog underestimation is thought to be minor.

What Data Are Used to Support Backlog Estimation?

Backlog is estimated from two different sources:

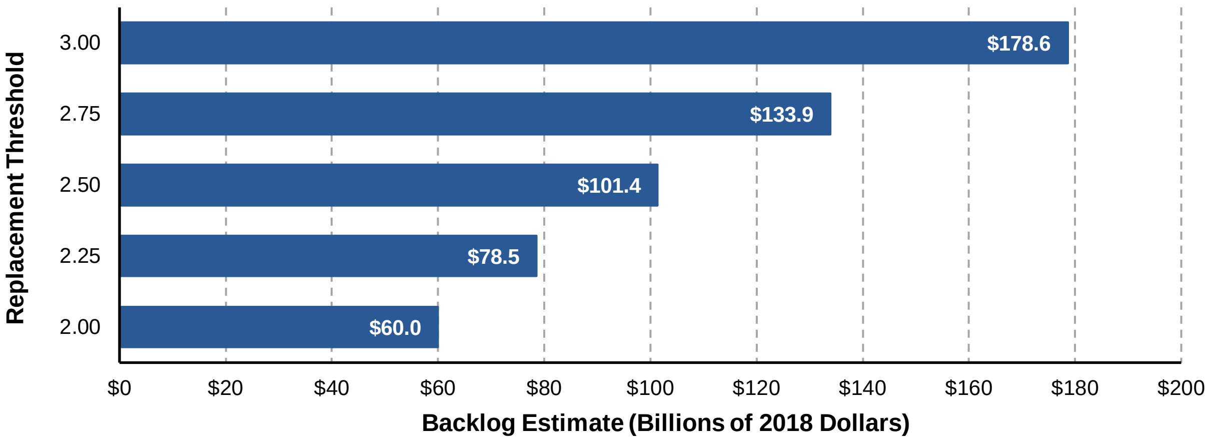
- NTD data on vehicle assets, including vehicle types, quantities, and ages of all rail cars, buses, vans, and other revenue vehicles used by grantees to provide transit service.
- Data requests to a sample of the Nation's largest (primarily rail) operators and special studies for all other asset categories.

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-20.*

Exhibit C-18: Backlog Estimate vs. Replacement Threshold



Source: Transit Economic Requirements Model.

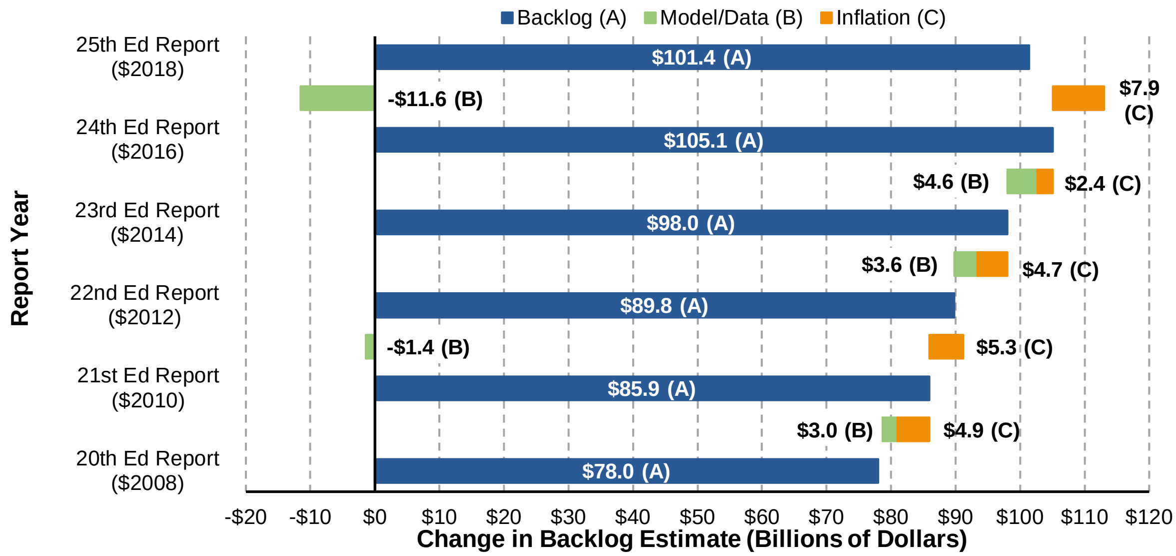
What Does the Backlog Trend Reveal?

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:

- **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-19*.
- **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.
- **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).
- **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-19: Change in Backlog Estimate Since 2008



Source: Transit Economic Requirements Model (TERM).

Additional Supporting Material

Following transmittal of this report to the Congress, seven additional online-only exhibits will be posted to the FHWA website (https://www.fhwa.dot.gov/policy/25cpr/online-only/).

Exhibit C-20 includes a data dictionary for terminology used in *Exhibits C-21* and *C-22*. *Exhibits C-21* and *C-22* contain data used in the service coverage and service frequency components of the transit investment analysis, respectively, organized by UZA. *Exhibit C-23* lists the UZAs without sufficient data to be included in this analysis. *Exhibit C-24* lists the data sources used in the expansion module. *Exhibit C-25* lists the modeling limitations and future enhancements by component.

TERM's analyses rely on a range of parameters required to assess the impacts of transit investments on transit asset conditions, performance, and the related investment benefits and costs. *Exhibit C-26* provides a listing of these parameters, including the parameter name, its purpose, current value(s) or the source of variation in values, the location where variable values are stored in the model (including the actual variable name), the data source for those values, and the year that source was published.

All TERM parameters are reviewed every two years in preparation for the biennial update of the C&P Report. That said, some of TERM's analyses depend on parameters obtained from sources that are not updated on a regular basis but are derived from one-time or periodic research efforts. Given the nature of these research sources, some parameter values have been derived from research sources that are more than a decade old. In these cases, FTA may want to conduct new analyses where variable values are likely to have been affected by changes in technology or traveler behavior.

Appendix D: Reinventing the C&P Report

Reinventing the C&P Report

Over the past decades, the C&P Report series has provided an objective assessment of current transportation 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 National Bridge Investment Analysis System (NBIAS), introduced in the 2002 C&P Report; and the Transit Economic Requirements Model (TERM), introduced in the 1997 C&P Report. These models are presented and described in Appendices A, B, and C, respectively.

As discussed in Part I: Moving a Nation, MAP-21 (the Moving Ahead for Progress in the 21st Century Act) incorporated performance management principles into the Federal-aid Highway Program. States are setting targets for several key performance measures and will report 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. It documented who uses the C&P Report, assessed the utility of the report to FHWA program offices, and identified options for presenting information more effectively. This effort identified two areas of potential report improvements: communication and methodology. It was followed by two other research projects initiated in 2014, one with the objective of enhancing communication approaches and the other aimed at improving estimation methodologies to evaluate 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, 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 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.

An ongoing effort 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 effort is to facilitate ease of use by a wider audience 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 in this 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 graphic 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 leading to improved estimation methodologies for estimating and understanding transportation investment needs.

Simulation modeling, used to forecast usage and investment needs, inherently involves tradeoffs, as the desire for detailed, reliable predictions must be balanced against data collection burdens and computational tractability. The tools and methodologies currently used in the C&P Reports reflect several analytical simplifications introduced to 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 was conducted 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 were explored to identify potential alternative methodologies and upgrades to the current BCA approach. This project included 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 was to identify practical approaches for improving the C&P Report methodology.

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, and provides an approach for evaluating non-monetary performance objectives on equal footing with monetary ones. 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.[207] It assesses the economic, environmental, social, distributional, and fiscal impacts of an investment based on both quantitative, monetized information and qualitative information at the project level. Although this approach helps guide the modeling of reliability and economic impacts, scaling the findings from individual projects to the national system and obtaining a strategic allocation of resources for infrastructure investment 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 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 evaluation of methodologies suggested that the BCA technique currently used in HERS remains an appropriate methodology for examining traffic conditions, 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 alternative refinements emerged 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. Based on information available, the research team decided to integrate the performance measures into HERS, including measures related to safety, pavement, congestion and reliability, and bridge performance. These performance measures, which are similar to values already used in BCA methods, are 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 procedure of nationwide economic analysis. Once HERS develops the ability to report costs and budgets by different performance categories (safety, congestion, and pavement), tradeoff analysis can be performed by the priority order of performance categories based on BCR score, such as increasing capacity or improving existing system. In each funding period, projects are selected based on the selected order of priority categories until the budget is exhausted. Alternatively, projects could be selected based on the priority category with the highest BCR. For example, if both congestion and pavement categories are being evaluated by HERS and the priority category is set as first pavement then congestion, the resources will be first allocated to all projects that addressing deficiencies in pavement. The remainder resources will then be dedicated to

[207] 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/.

address deficiencies in congestion. In this case, the projects to address pavement deficiencies are selected first even if its BCR is lower than that of the projects addressing congestion. Tradeoff analysis provides a useful tool to assess the impacts of different strategies in investing and shed insights into the cost and performance implications of each strategy.

Section 1116(h) of the Fixing America's Surface Transportation (FAST) Act required a biennial report describing the conditions and performance of the National Highway Freight Network, which is included in Part IV of this report. Options for enhancing freight analysis capabilities for the C&P Report are being explored as part of the effort to reinvent the C&P Report. The selected approach is to create a freight corridor sketch tool to display the freight performance measures on a national network based on the Freight Analysis Framework (FAF). This approach assigns FAF origin-destination trip tables to a simplified version of the FAF highway network, which condenses 670,000 links on Interstates and high truck volume roads to 27,000 links while maintaining good match to the more detailed FAF assignments. The process enables reporting of annual freight flows by region, functional class, and truck type, and accommodates easily extracted routing data through existing travel demand models.

The increasing deployment of connected and automated vehicles will have significant impacts on national highway conditions and performance. 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. The selected approach to incorporating C/AV analysis is to determine a combination of parameters, followed by a including market penetration rate and impact factors on system capacity, VMT, and safety. A sensitivity analysis of these parameters is performed to cover a wide range of possible scenarios and measure the associated impacts of highway conditions and performance.

FHWA also considered the feasibility of integrating needs analysis for pedestrian and cyclist infrastructure and 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 were further explored and implemented for their feasibility of being integrated into the HERS framework, 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 is actively working to enhance its investment tool capabilities to implement methodological enhancements identified as part of the Reinventing the C&P Report initiative and previous external peer reviews. FHWA has also initiated research needed to address new requirements added by the Bipartisan Infrastructure Law (BIL), enacted as the Infrastructure Investment and Jobs Act (IIJA), Pub. L. 117-58 (Nov. 15, 2021).

Moving forward, FHWA plans to initiate a new series of external outreach sessions on the C&P Report to gather feedback on what should be included in future editions.

Bipartisan Infrastructure Law

The Bipartisan Infrastructure Law, also known as the Infrastructure Investment and Jobs Act, Sec. 13006(a)(2)(F), requires DOT to expand the scope of the C&P Report to include conditions and performance of intelligent transportation systems (ITS), resilience needs, and tunnel needs. The 24th C&P Report presented data on tunnel counts; this 25th edition adds data on tunnel age. Future editions will include more information on tunnel conditions and future investment needs as models are developed to analyze them.

Some recent editions of the C&P Report have included qualitative discussions of resilience concepts. Research is underway to explore alternatives for adapting existing investment modeling tools to address resilience in a more quantitative manner, with a particular focus on the impacts of extreme weather on the transportation system and the resilience of the nation's systems to absorb, adapt, and recover from extreme events.

Although HERS considers the impacts of certain types of highway operational improvements that feature ITS, this consideration is currently implemented via a "HERS Operations Preprocessor" that does not compare their benefits and costs. Research is underway to explore options for analyzing ITS needs in a more rigorous manner to support direct comparisons with other types of highway investments.

In addition to developing and revising analytical models, addressing the new C&P Report requirements added by the Bipartisan Infrastructure Law may require the collection of additional data from asset owners. As potential data needs are identified through model research and development, DOT will work to identify how such data could be collected without putting undue burden on data reporters and how existing data systems might need to be modified to capture these additional data. The 26th edition of the C&P Report will document progress on model development and data collection and will provide estimates as to when each of the Bipartisan Infrastructure Law requirements will be fully implemented.

Peer Reviews

Routine peer reviews provide an opportunity to assess recent enhancements and to consider other changes in transportation policy focus that may have an impact on C&P analysis and reporting. FHWA invited an external panel of experts representing State departments of transportation, MPOs, academia, and transportation consulting firms to review the analytical framework of the C&P Reports in mid-2018. The peer review was organized in conjunction with the Reinventing the C&P initiative, and the panel reviewed several areas for potential improvement identified in a report entitled "Opportunities to Integrate Performance Management with National Transportation Investment Needs Estimation" that was generated as part of that initiative. The review generated a series of recommendations for research options to improve the methodologies, models, and tools in C&P reporting and the feasibility of implementation. Some enhancements to the HERS and NBIAS models initiated to address these recommendations are referenced in Appendices A and B, and others have been built into longer-term model development plans.

FHWA plans to embark on a new round of external outreach sessions to inform the development of future editions of the report. The objective of this round of engagement is to obtain feedback on what future investment scenarios to analyze and present in future C&P Reports. This will include potential modifications to the existing investment scenarios and/or the incorporation of additional supplemental scenarios that reflect recent shifts in policy goals and state planning objectives. The outreach sessions will be performed in three phases.

The first phase, planned for early 2024, will involve conducting a transportation policy symposium focused on the C&P Report. FHWA's Transportation Policy Symposia series allows the agency to hear from leading transportation policy experts on current and emerging issues and gain information and perspectives on key policy topics and potential future study areas. For this symposium, a selection of experts that routinely use the report will be asked to participate. Other transportation experts who lead initiatives in safety, pedestrian and bicycle infrastructure, freight analytics, equity, environmental justice, and resilience will be also be invited. A broad range of external organizations are expected to be represented, as the intent is to obtain feedback from a wide range of perspectives. The results of the symposium will be summarized in the 26th C&P Report, including discussions on the recommendations selected by FHWA for short- and long-term implementation. FHWA expects to debut some of the recommended future investment scenarios in the 26th edition, to the extent they can be analyzed with FHWA's current analysis tools.

Other recommended scenarios will require additional methods and resources. Therefore, the second and third phases will involve separate peer reviews of the highway models, HERS and NBIAS, planned for 2025 and 2026, respectively. Participants in these sessions will include individuals with more technical backgrounds and experience in transportation modeling, such as economists, engineers and planners who use the models for asset management planning; academic partners who have collaborated on research and software coding efforts; and other transportation representatives working with similar modeling tools. The peer review panels will be asked to consider model capabilities and data needs required to implement the investment scenarios identified during the transportation policy symposium. Reviewers will also be asked to provide feedback on recent and ongoing efforts to implement recommendations developed as part of the Reinventing the C&P initiative as well as efforts to expand model capabilities to incorporate BIL requirements. Feedback provided during the HERS and NBIAS peer reviews will be summarized in the 27th and 28th editions of the C&P Report, respectively.

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 and future 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 ultimate goal of this effort is to provide a multimodal product with cutting-edge analytics that improve users' experience.

Appendix E: Highway Freight Methodology

Highway Freight Methodology

Preface

Section 1116(a) of the Fixing America's Surface Transportation (FAST) Act (Pub. L. 114-94, 23 U.S.C. §167(h)), established the NHFN and directed FHWA to prepare a biennial report on the conditions and performance of the NHFN. Part IV of the FHWA *Conditions and Performance Report to Congress*: *25th Edition* fulfills this requirement.

National Highway Freight Network

Section 1116(a) of the Fixing America's Surface Transportation (FAST) Act (Pub. L. 114-94, 23 U.S.C. §167(h)), established the NHFN and directed FHWA to prepare a biennial report on the conditions and performance of the NHFN. Part IV of the FHWA *Conditions and Performance Report to Congress*: *25th Edition* fulfills this requirement.

The intent of the NHFN is to direct Federal resources and policies toward improving the performance of the highway portion of the U.S. freight transportation system. The NHFN consists of four component roadways: the Primary Highway Freight Network (PHFS), other Interstates not on the PHFS (non-PHFS), CRFCs, and CUFCs. NHFN mileage can fluctuate over time. The PHFS must be redesignated every five years, whereas States may designate CR/CUFCs on an ongoing basis.

Unless otherwise stated, FHWA used the NHFN dated January 1, 2021, to produce most of Part IV's core exhibits. However, performance exhibits developed with FHWA's Freight Mobility Trends (FMT) tool used a previous (2016) NHFN date that excluded CR/CUFCs. See the Performance Analysis section of this Appendix for greater detail.

Data and Analysis Overview

FHWA uses multiple data sources to report on NHFN conditions and performance because no single source contains all information needed for the analysis. Because these data sources were developed for purposes other than compiling the FHWA *Conditions and Performance Report to Congress,* there is a need to process and link data to the NHFN. The capacity for NHFN conditions and performance analysis is therefore subject to the availability, quality, and extent of the input data sources.

FHWA's FMT tool, released in 2019, was a key data source used to develop the mobility, reliability, and freight demand exhibits reported in the Highway Freight chapter's performance analysis section. The FMT tool is a freight performance analysis tool that uses truck travel data from the National Performance Management Research Data Set (NPMRDS) to provide national freight performance statistics. *Exhibit E-1* provides details about the FMT tool.

Exhibit E-1 outlines the key data sources and data years used to construct core exhibits included in Part IV. Data sources are updated on different cycles and at different times. Therefore, the exhibits included in Part IV present information from multiple data years.

Exhibit E-2 provides an overview of the conditions exhibits reported in Part IV, data source/year used, an overview of the exhibit, and a summary of why the exhibits were included.

Exhibit E-1: Key Data Sources and Years Included in this Edition

Data Source	Overview	Data Year	Relevant Exhibit(s)
FHWA Freight Mobility Trends (FMT) Tool	Dashboard providing national freight performance statistics and information on freight highway bottlenecks, as based on an analysis of the National Performance Management Research Data Set (NPMRDS).	2019 FMT, which includes: 2019 NPMRDS data[1] 2016 NHFN data (excludes CRFCs and CUFCs)	IV-17, IV-18, IV-19, IV-20, IV-21, IV-23
National Performance Management Research Data Set (NPMRDS)	National set of vehicle probe data generated by location-based devices such as mobile devices, connected automobiles, portable navigation devices, and commercial fleet sensors that includes data on speed and travel time.[2]	2019	IV-17, IV-18, IV-19, IV-20, IV-21, IV-23
Freight Analysis Framework (FAF)	Data product that integrates information from a variety of sources to produce a comprehensive picture of freight movement among States and major metropolitan areas by all modes of transportation.	2015 (for highway flow data–FAF version 4)[3]	IV-7
Highway Performance Monitoring System (HPMS)	National-level highway information system that includes data on the extent, conditions, performance, use, and operating characteristics of the Nation's highways.	2018	IV-10, IV-11, IV-12
National Bridge Inventory (NBI)	Database containing comprehensive bridge condition and inventory data from Federal agencies and State and Tribal governments, and describing all bridges located on public roads.	2020[4]	IV-14, IV-15
Fatality Analysis Reporting System (FARS)	Nationwide census generated from State records for all crashes that occur on U.S. public roadways.	2019	IV-16

[1]The FMT tool version used for this edition included the PHFS as of 2016. It excluded data on CR/CUFCs, because these segments may not be part of the NHS, change frequently with ongoing designations from States, and may not have associated NPMRDS data.

[2]NPMRDS data were not directly used for this edition; however, the NPMRDS is the data source for the FMT tool.

[3]At the time of writing, FAF version 5 included only 2017 FAF base year data. FAF data for 2018–2019, forecasted years (2020–2050), and previous base years 1997–2012 in 5-year increments will be released in later version updates. FAF version 5 will update highway flow data to 2017 but this information was unavailable at the time of writing. Part IV used FAF version 4 for highway flow data (dated to 2015).

[4]The NBI version used for Part IV included data as of December 2020. Data were filtered to include only bridges built in 2019 or earlier to align with the reporting approach used by other chapters of the FHWA Conditions and Performance Report to Congress.

Exhibit E-2: Summary of Conditions Exhibits

Analysis Area	Exhibit # and Title	Data Source/Year and Network/Year	Overview	Justification Summary
Pavement	IV-10: NHFN Pavement Ride Quality based on IRI, 2018	HPMS 2018, NHFN 2021	Reports pavement ride quality as experienced by a driver	Provides a driver perspective on pavement quality
	IV-11: NHFN Overall Pavement Condition and Individual Pavement Distresses, 2018	HPMS 2018, NHFN 2021	Reports on extent of pavement distresses (cracking, rutting, and faulting) and overall pavement condition based on these distresses	Show how pavement deteriorates over time with implications for asset management and maintenance
	IV-12: NHFN Overall Pavement Condition by Roadway Functional Class, 2018	HPMS 2018, NHFN 2021	Reports on extent of pavement distresses by roadway functional class	Shows implications of roadway class for pavement condition
Bridge	IV-14: NHFN Bridge Conditions, 2019	NBI 2020, NHFN 2021	Reports on the condition of bridge structural components (deck, substructure, superstructure) and culverts	Indicates the extent to which a bridge has deteriorated from original condition when first built
	IV-15: NHFN Bridge Conditions by Roadway Functional Class, 2019	NBI 2020, NHFN 2021	Reports on overall bridge condition, based on the bridge structural component and culvert condition for roadway functional classes	Shows implications of roadway class for bridge condition

Exhibit E-3 provides an overview of the performance indicators reported in Part IV, data source/year used, an overview of the exhibit, and a summary of why the exhibits were included.

Exhibit E-3: Summary of Performance Exhibits

Analysis Area	Exhibit Title	Data Source/Year and Network/Year	Overview	Justification Summary
Safety	IV-16: Fatal Crashes and Fatalities on the NHFN, 2014–2019	FARS 2019, NHFN 2016	Reports on fatal crashes and fatalities on the NHFN in both urban and rural areas	Indicates overall safety trends on the NHFN
Mobility	IV-17: Most Congested NHFN Corridors, 2019	FMT Tool 2019 (includes 2019 NPMRDS and 2016 NHFN without CRFCs/CUFCs)	Displays NHFN corridors with the most hours of truck delay/mile in 2019	Provides a geospatial view of the most congested NHFN corridors in 2019
	IV-18: Truck Hours of Delay per Mile for Most Congested NHFN Corridors (2017–2019)	FMT Tool 2019 (includes 2019 NPMRDS and 2016 NHFN without CRFCs/CUFCs)	For the most congested NHFN corridors, lists truck hours of delay/mile values for 2017, 2018, and 2019	Provides detail on the most congested corridors and shows a time-series comparison
	IV-19: Multimodal Freight Facilities with Surrounding Highly Congested NHS Roadways, 2019	FMT Tool 2019 (includes 2019 NPMRDS and 2016 NHFN without CRFCs/CUFCs)	Lists multimodal freight facilities (airports, border crossings, intermodal facilities, and maritime ports) where surrounding NHS roadways have high levels of delay	Provides a multimodal perspective on mobility
Reliability	IV-20: Peak Period Planning Time Index for the Most Congested NHFN Corridors (2017–2019)	FMT Tool 2019 (includes 2019 NPMRDS and 2016 NHFN without CRFCs/CUFCs)	Lists PTI for the most congested NHFN corridors	Indicates how much longer travelers need to plan to arrive at their destinations on time during peak periods, compared with when traffic is free-flowing
	IV-21: Truck Reliability Index for the Most Congested NHFN Corridors (2017–2019)	FMT Tool 2019 (includes 2019 NPMRDS and 2016 NHFN without CRFCs/CUFCs)	Lists TRI for the most congested NHFN corridors	Provides insight into the reliability of truck travel times
	IV-22: National Truck Travel Time Reliability Index on the Interstate System (2017–2019)	Evaluation of Freight Performance Measures from 2020 Mid-Period Performance Report	National TTTR index measured over the entire Interstate System	Indicates the national average of additional time that needs to be added to truck travel times on the Interstate System to ensure on-time arrival 95 percent of the time
Freight Demand	IV-23: Truck Volumes for the Most Congested NHFN Corridors, 2019	FMT Tool 2019 (includes 2019 NPMRDS and 2016 NHFN without CRFCs/CUFCs)	Lists truck volumes (average annual daily truck traffic) for most congested corridors	Shows where there are heavy truck volumes on congested corridors; however, heavier volumes do not necessarily correspond to more congested conditions

Conditions Analysis

For the conditions indicators reported in Part IV, FHWA used geospatial processes to link relevant information from various data sources to the NHFN. Specifically, FHWA used geospatial "buffers" with HPMS and NBI to identify roadway segments and bridges located within certain spatial zones of NHFN roadways. FHWA used this process because, at the time of writing, there were no reporting attributes within HPMS or NBI identifying whether a feature was part of (or located on) the NHFN. In some cases, FHWA addressed data inconsistencies through additional analysis.

NHFN Pavement Conditions

FHWA used HPMS data to prepare these exhibits on pavement conditions. HPMS is a national highway information system that includes data on the extent, conditions, performance, use, and operating characteristics of the Nation's highways.[208] State departments of transportation (DOTs) are required to submit data to HPMS on an annual basis. Data include roadway characteristics such as functional classification, pavement conditions, and speed limit.

HPMS data were used to analyze pavement conditions of all four NHFN component roadways. At the time of this writing, HPMS did not include any data elements identifying whether a roadway was located on the NHFN. To address this gap, FHWA used a geospatial information systems (GIS) process to assign relevant HPMS attributes to the NHFN. Specifically, FHWA used ArcGIS software to join linear-referenced HPMS data to the All Road Network of Linear Referenced Data (ARNOLD) shapefile and then subset this to HPMS roadways located within a 500-meter buffer of the NHFN. HPMS data were then manually reviewed. FHWA omitted segments that (in a visual inspection) were not on the NHFN.

To determine a roadway's overall pavement condition, four indicators were assessed and rated as either "good," "fair," or "poor" following criteria for these ratings established by FHWA as part of its Final Rule for Pavement and Bridge Performance Measures published on January 18, 2017 (23 CFR 490 Subparts C and D). These regulations provided NHS pavement and bridge conditions performance measures, along with minimum condition standards, target establishment, progress assessment, and reporting requirements. The regulations also provided criteria for overall pavement ratings, based on combinations of ratings for individual distresses. Part IV includes additional discussion on 23 CFR 490 Subparts C and D as well as its significance for NHFN conditions and performance reporting, and provides the criteria used for the ratings. The four indicators assessed and rated are as follows:

1. International Roughness Index (IRI) – the road roughness index measured in inches per mile. IRI is the pavement ride quality as experienced by the driver. This indicator is the most commonly used worldwide metric for evaluating and managing road systems and is the primary indicator of the utility of a roadway. On roadways where the posted speed limit is less than 40 miles per hour (mph), and data are available, the Present Serviceability Rating (PSR) can be substituted.
2. Cracking Percent – the percentage of the pavement surface with fissure or discontinuity not necessarily extending through the entire thickness of the pavement.
3. Rutting – the average depth, measured in inches, of any surface depression present in the vehicle wheel path.
4. Faulting – the average vertical displacement, measured in inches, between adjacent jointed concrete panels.

The surface type of the pavement determines which distress indicators and threshold levels were calculated for each roadway. The three pavement surface types were asphalt, jointed concrete pavement (JCP), and continuously reinforced concrete pavement (CRCP). For all three pavement types, FHWA calculated IRI using the same thresholds to determine pavement condition rating of "good," "fair," or "poor." On roadways where the posted speed limit was less than 40 mph and data were available, PSR was substituted for IRI. Cracking percent was also calculated for all three pavement types; however, each surface type uses different thresholds for each of the pavement condition ratings. For asphalt surface types, FHWA calculated the rutting condition of the pavement. For JCP surface types, FHWA calculated the faulting condition of the pavement. *Exhibit E-4* summarizes the pavement distress indicators and thresholds used for each surface type.

[208] https://www.fhwa.dot.gov/policyinformation/hpms.cfm

Exhibit E-4: Summary of Indicators and Thresholds for Pavement Surface Type

Indicator	Pavement Surface Type	Condition Rating Threshold: Good	Condition Rating Threshold: Fair	Condition Rating Threshold: Poor
IRI	All	< 95	95 to 170	> 170
PSR	All; replace IRI where speed limit < 40 mph	PSR ≥ 4.0	2.0 ≤ PSR ≤ 4.0	PSR ≤ 2.0
Cracking Percent	Asphalt	< 5	5 to 20	> 20
	JCP	< 5	5 to 15	> 15
	CRCP	< 5	5 to 10	> 10
Rutting	Asphalt	< 0.20	0.20 to 0.40	> 0.40
Faulting	JCP	< 0.10	0.10 to 0.15	> 0.15

Notes: IRI is International Roughness Index. PSR is Present Serviceability Rating. JCP is Jointed Plain Concrete. CRCP is Continuously Reinforced Concrete Pavement.

FHWA used the combination of IRI and individual pavement distress indicators and rating thresholds to determine overall pavement condition. For CRCP surface types, IRI and cracking percent were the only distress indicators used to determine the overall pavement condition. For the overall condition for CRCP surface types to be rated "good," both IRI and cracking percent must be rated "good;" for a roadway to have an overall rating as "poor," both IRI and cracking percent must be rated "poor."

For asphalt surface types, IRI, cracking percent, and rutting were used to determine the overall pavement condition. For JCP surface types, IRI, cracking percent, and faulting were used to determine the overall pavement condition. For the overall condition for asphalt or JCP surface types to be rated as "good," all three indicators must be rated as "good." For a roadway to have an overall rating as "poor," at least two of the three indicators must be rated "poor." All other combinations of indicator ratings result in an overall rating as "fair." *Exhibit E-5* summarizes individual distress indicators used to determine overall pavement condition for each surface type.

Exhibit E-5: Summary of Individual Pavement Distresses by Pavement Type

Overall Ride Quality Rating	Asphalt and JCP Three Distress Indicator Ratings: IRI, Cracking Percent, and Rutting/Faulting	CRCP Two Distress Indicator Ratings: IRI and Cracking Percent
Good	All three indicators rated "good"	Both indicators rated as "good"
Poor	Two or more indicators rated as "poor"	Both indicators rated as "poor"
Fair	All other combinations	All other combinations

Notes: IRI is International Roughness Index. JCP is Jointed Concrete Pavement. CRCP is Continuously Reinforced Concrete Pavement.

In cases where a distress indicator or IRI value was missing or unavailable in HPMS data, that condition's indicator was not reported for that roadway segment. Therefore, it was excluded from total NHFN mileage and omitted from the overall pavement conditions calculation.

The values for IRI and the three individual distress indicators reported in HPMS are based on centerline miles. Centerline miles measure a road from the start point to the end point. State DOTs use a consistent approach to calculate centerline miles, which can help ensure a more consistent analysis. For this reason, the information presented in *Exhibit IV-10* summarizing pavement ride quality as measured by IRI on the NHFN is based on the percentage of centerline miles rated as "good," "fair," or "poor." In this exhibit, about 97 percent of the total centerline NHFN mileage is represented in the IRI value.

However, centerline miles do not provide information on the number or width of roadway lanes, thus somewhat limiting their analysis. To account for the number of roadway lanes, the centerline miles were multiplied by the number of through lanes, an attribute also reported in

HPMS. Through lanes are the number of lanes designated to through traffic. Weighting the centerline miles by the number of through lanes results in total lane miles and helps to better align with the cost agencies would incur to improve existing pavement conditions. For this reason, the information presented in *Exhibits IV-11* and *IV-12* is based on the percent of total lane miles for the individual distress indicators and overall pavement condition rated as "good," "fair," or "poor." For these exhibits, about 98 percent of total NHFN lane miles are represented in the cracking value, 74 percent of total NHFN lane miles are represented in the rutting value, and 20 percent of total NHFN lane miles are represented in the faulting value.

NHFN Bridge Conditions

FHWA used National Bridge Inventory (NBI) data to prepare the bridge conditions exhibits. The NBI is an FHWA database of 628,207 bridges in the United States.[209] The NBI database was established in 1972. Since 1978, State DOTs have been required to submit annual NBI reports to FHWA. The NBI is a highly consistent set of national data for evaluating and monitoring the condition and performance of bridges that is based on National Bridge Inspection Standards (NBIS) for the proper and uniform inspection and evaluation of highway bridges.

FHWA analyzed NBI data to inventory bridge conditions on the NHFN. Because there was no data element in the NBI to identify whether a bridge was or was not located on the NHFN at the time of writing, FHWA used a GIS process to estimate the number of bridges included in the analysis. For the bridge conditions exhibits, FHWA used ArcGIS software to subset the NBI GIS layer, published by the Bureau of Transportation Statistics (BTS), to include bridges within a 100-meter buffer of the NHFN that were built prior to 2020 and were not closed or not yet open. This screen resulted in a total of 84,165 bridges.

Information presented in the bridge conditions exhibits was based on bridge deck length rather than the number of bridges on the NHFN.[210] 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. The subset of bridges included in the analysis resulted in a total bridge deck length of 26,054,406 feet.

Based on bridge length (feet), four bridge element conditions were analyzed as either "good," "fair," or "poor," in addition to the overall bridge condition:

1. Deck – the roadway or traveling surface of the bridge.
2. Superstructure – the main part of the bridge, such as the beams, that rests on the substructure.
3. Substructure – the foundation and other parts that support the superstructure.
4. Culvert – a specific type of bridge superstructure that allows water to flow through. A culvert is termed a "bridge" if its length is greater than 20 feet (or 6.1 meters).

Overall bridge condition is determined from the condition ratings of all four of these bridge elements. The Final Rule for Pavement and Bridge Performance Measures (23 CFR 490 Subparts C and D) redefined the criteria for determining structurally deficient bridges and made them equal to the criteria that classify bridges as being in "poor" condition.[211] The regulations consider only condition ratings for four structural items (deck condition, superstructure condition, substructure condition, and culvert condition). If any one of these is rated "poor," the overall bridge condition is classified as "poor." 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

[209] https://www.fhwa.dot.gov/bridge/nbi.cfm

[210] This approach differs from the bridge condition performance measures defined in the Final Rule for Pavement and Bridge Performance Measures, which are based on reporting bridge deck area.

[211] The Final Rule for Pavement and Bridge Performance Measures is available at: https://www.federalregister.gov/documents/2017/01/18/2017-00550/national-performance-management-measures-assessing-pavement-condition-for-the-national-highway.

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. A bridge is classified as "good" only if all four elements are rated as "good." The regulations only require that targets be set for National Highway System (NHS) bridges, but FHWA applied the same criteria to NHFN bridges for the exhibits in Part IV. *Exhibit E-6* summarizes the bridge conditions indicator classifications.

Exhibit E-6: Summary of Indicators and Thresholds for Bridge Conditions Elements

Conditions Metric	Rating Criteria	Good	Fair	Poor
Bridge Deck Condition	Ratings scaled from 0 "Failed' to 9 "Excellent"	≥ 7	5 to 6	≤ 4
Bridge Superstructure Condition	Ratings scaled from 0 "Failed' to 9 "Excellent"	≥ 7	5 to 6	≤ 4
Bridge Substructure Condition	Ratings scaled from 0 "Failed' to 9 "Excellent"	≥ 7	5 to 6	≤ 4
Culvert Condition	Ratings scaled from 0 "Failed' to 9 "Excellent"	≥ 7	5 to 6	≤ 4

In cases where a bridge element value was missing or not available in the NBI data, that element's condition was not reported for that roadway segment and was therefore excluded from the total bridge length mileage. It was also omitted from the overall bridge conditions indicator calculation.

The NBI, and by extension, the NBI-based exhibits in the chapter, classify roadways using the old functional classification system set by FHWA, which categorizes roadways into one of 12 functional classes. Under new guidance from FHWA as a result of the 2010 HPMS Reassessment Project, HPMS data reported starting in 2010 should use revised functional classifications that categorize roadways into one of seven functional classes. For consistency with previous editions of the highway freight chapter, the older functional classification system was used to categorize the NHFN bridges for *Exhibit IV-15*. Furthermore, the old classification system distinguished between urban and rural boundaries. How a road functions is not necessarily related to or dependent on it being urban or rural. For Part IV, the urban-rural bifurcation was retained because it supports improved understanding of bridge conditions across all functional classes and these two geographies.

Performance Analysis

This section provides details on the analysis approaches used to develop the performance exhibits included in the chapter.

Fatal Crashes and Fatalities on the NHFN

The Fatality Analysis Reporting System (FARS) is a safety database managed by the National Highway Transportation Safety Administration (NHTSA). It is a national-level census on fatal traffic crashes that includes more than 140 data elements. To be included in FARS, a crash must involve a motor vehicle traveling on a traffic way customarily open to the public and must result in either the death of a vehicle occupant or a non-occupant within 30 days of the crash date.

For *Exhibit IV-16*, FHWA used FARS data to analyze the safety performance of all four NHFN component roadways. At the time of writing, there was no data element in FARS to identify whether a fatal crash occurred on (or off) the NHFN. To address this gap, FHWA used a GIS process to assign FARS reports to the NHFN. FHWA specifically used ArcGIS software to subset FARS reports within a 180-feet buffer of the NHFN.

One of the attributes reported in FARS is functional class of roadway where the fatal crash occurred. In some cases, this can be a more accurate data element than the reported latitude and longitude coordinates of the fatal crash. Further review of FARS reports within the 180-foot buffer was applied to confirm the presence of a FARS report on the NHFN, and functional class attributes were compared in both layers. The number of fatal crashes and fatalities reported in this chapter differs from the numbers reported in previous editions because NHFN mileage has increased over time and methodologies have changed.

The designation of whether a fatal crash occurred on a roadway within an urban or rural area boundary is based on the attribute reported in FARS. Classification of urban and rural areas is based on the FHWA-approved adjusted Census boundaries of small urban and urbanized areas. According to 23 U.S.C. 101(a)(33), urban areas are those of a population of at least 5,000, in contrast to the U.S. Census Bureau's threshold of 2,500. As of 2016, NHTSA reported FARS data using the FHWA adjusted urbanized areas of geography. In some cases, a crash was classified as having occurred on an "Unknown" roadway, indicating that there was not enough information for FARS to determine whether the crash occurred within an urban or rural area boundary.

Although the NHFN was not established until 2015, FHWA included 2014 FARS reports in *Exhibit IV-16* to provide a more comprehensive timeline and align with the baseline year included in the first edition.

Freight Mobility Trends (FMT) Tool

Exhibits IV-17 to *IV-21* and *IV-23* were developed using the FHWA FMT tool. The FMT tool uses multiple data sources for multiple years to provide users with transportation performance measures specifically for trucks on the NHFN, as well as for the National Highway System (NHS) and Strategic Highway Network (STRAHNET).

The FMT tool consists of three interactive dashboards presenting national freight statistics, including data on freight bottlenecks, congestion, delay, speed, and truck volumes. One dashboard includes several mobility indicators and indices (e.g., delay/mile, planning time index, truck reliability index, and congestion costs). This dashboard allows for "filtering" on either urban or rural NHS roads, as well as different networks (including the NHFN). A second dashboard provides a ranked list and visualization of national or State freight bottlenecks (based on delay/mile). A third dashboard provides an overview of national freight corridor performance.

The FMT tool uses multiple data sources for multiple years to calculate a suite of indicators. For FHWA to create the measures reported in the FMT tool, data must be collected, conflated, and transformed multiple times to be presented at the correct level of detail. To produce *Exhibits IV-17* to *IV-21* and *IV-23*, two primary data sources were used: NPMRDS and HPMS. NPMRDS data are a national archive of observed measurements (collected 24 hours a day) of average travel times from vehicle probe data reported every five minutes on the NHS at the TMC level. HPMS data include Average Annual Daily Truck Traffic (AADTT) volumes and other required roadway inventory attributes reported to FHWA on an annual basis. FHWA used speed data from NPMRDS to calculate travel time metrics. AADTT data from HPMS were used to calculate traffic volumes. FHWA conflated NPMRDS TMC travel times to HPMS roadway segments (and associated volumes).

The FMT tool uses different roadway segmentation with sections of adjacent roadways combined to longer corridors for analysis. The basic spatial unit of analysis is the Traffic Message Channel (TMC). The TMC network is a map of the Nation's roads split into smaller segments (i.e., TMCs) based on industry agreement. Only TMCs that cover the NHS and STRAHNET networks are included in the NPMRDS network and subsequently the FMT tool. Lower functional classifications are excluded.

Datasets used in the FMT tool do not represent a single data year. Instead, due to the time it takes to process some data, datasets used in the FMT tool represent measured observations from prior years. TMC segmentation generally lags one year from the current year and maps are named with year and decimal version (e.g., 2018.2). HPMS volumes and attributes generally lag two years from when attributes and volumes were collected. NPMRDS month and year for historical travel times represent the actual month and year when observations were collected from probe data. The 2019 NPMRDS network uses the 2019 travel time data with the 2018.2 TMC map geometries conflated with 2017 HPMS volumes and attributes.

Additionally, the FMT tool uses the 2016 NHFN dataset of the PHFS and Other Interstates not on the PHFS but excludes CR/CUFCs. The CR/CUFCs are excluded from the FMT tool because these segments change frequently, may not have associated NPMRDS data or attributes, and may contain significant data quality issues. Because CR/CUFC segments change frequently, a year-over-year analysis would not be possible in many cases. CR/CUFCs represent relatively little mileage on the NHFN and would be unlikely to significantly change results in the FMT tool, even if added.

Exhibit E-7 summarizes the data sources used in the FMT tool (as of February 2021). This was the version of the FMT tool used to develop *Exhibits IV-17* to *IV-21* and *IV-23*.

Exhibit E-7: Summary of 2019 FMT Tool Data Sources, Elements, and Years

Data Source	Data Element	Year
NPMRDS	TMC Map	2018
	Travel Times	2019
HPMS	Traffic Volumes, Attributes	2017
NHFN	Attributes	2016

Congested Corridors

To develop *Exhibits IV-17*, *IV-18*, *IV-19*, *IV-21*, and *IV-23*, FHWA used NPMRDS travel time data in the FMT tool to identify the most congested corridors on the NHFN based on 2019 truck hours of delay per mile. Truck hours of delay per mile was defined as the total truck vehicle hours of delay for a section of roadway divided by the section length in miles and summed for the full year. Total vehicle hours of delay was calculated by taking the difference between the congested, or actual, travel time and the uncongested travel time for a section of roadway and multiplying it by the number of truck vehicles impacted. Uncongested travel time is the travel time at reference speed. The reference speed used for the FMT tool is based on the free-flow speed of a segment using the NPMRDS off-peak travel times.

Free-flow speed was used rather than the speed limit of a roadway because posted speed limit does not always reflect the free-flow speeds for large trucks. Free-flow speed is calculated as the 85th percentile of off-peak speeds, where off-peak is defined as Monday through Friday, 9 a.m. to 4 p.m. and 7 p.m. to 10 p.m., as well as Saturday and Sunday, 6 a.m. to 10 p.m.[212] Truck hours of delay per mile was calculated for all NHFN roadways in the FMT tool. Truck hours of delay per mile captures the degree of congestion weighted by the magnitude of truck volume.

$$Vehicle\ Hours\ of\ Delay = (Actual\ Travel\ Time - Reference\ Travel\ Time) * Truck\ Volume$$

$$Truck\ Hours\ of\ Delay\ per\ Mile = \frac{Vehicle\ Hours\ of\ Delay}{Roadway\ Length\ in\ Miles}$$

The congested corridors listed in *Exhibits IV-17*, *IV-18*, *IV-20*, *IV-21*, and *IV-23* represent 50 roadways with the largest truck hours of delay per mile in 2019. FHWA determined that for this analysis, a sample size of 50 was an adequate threshold to provide a robust perspective of freight mobility with appropriate geographic diversity among the corridor locations. These 50 corridors are the foundational element for *Exhibits IV-17*, *IV-18*, *IV-20*, *IV-21*, and *IV-23*. *Exhibit*

[212] See https://ops.fhwa.dot.gov/perf_measurement/ and https://ops.fhwa.dot.gov/perf_measurement/ucr/documentation.htm for details.

IV-17 provides a map of the most congested corridors in 2019; *Exhibits IV-18*, *IV-20*, *IV-21*, and *IV-23* provide detail on these corridors using a suite of performance indicators.

Planning Time Index

The peak period Planning Time Index (PTI) is the 95th percentile of peak travel time to the reference, or free-flow, travel time. The FMT tool defines peak period travel times as 6 a.m. to 9 a.m. and 4 p.m. to 7 p.m. on weekdays (Monday through Friday). PTI measures how much longer a total trip time will be compared to free-flow traffic periods for 95 percent of trips. PTI is based on the concept that travelers want to be on time for an important trip 19 out of 20 times. Using the 95th percentile travel time compares the travel time of the worst trip out of 20 trips to the travel time of a trip at free-flow speed. In terms of reliability, PTI can indicate variation in total travel times during peak travel periods, with lower PTI values representing less variability to free-flow conditions and higher reliability, whereas higher PTI values suggest greater variation and lower reliability.

$$Planning\ Time\ Index = \frac{95th\ Percentile\ Travel\ Time}{Reference\ Travel\ Time}$$

For *Exhibit IV-20*, PTI is calculated for the 50 most congested corridors in 2019 for 2017, 2018, and 2019. The 50 most congested corridors were selected because they had the largest truck hours of delay per mile in 2019.

Truck Reliability Index

The Truck Reliability Index (TRI) was also used to assess performance on the NHFN in Part IV. The TRI is the ratio of the 95th percentile travel time to the 50th percentile travel time for five different times during the day. Using the 95th percentile travel time compares the travel time of the worst trip out of 20 trips to the travel time of an average trip. The five periods are: morning peak (6 a.m. to 10 a.m.), midday (10 a.m. to 4 p.m.), and evening peak (4 p.m. to 8 p.m.) on weekdays, 6 a.m. to 8 p.m. on weekends, and overnight every day from 8 p.m. to 6 a.m. The TRI metric for a section of roadway is the largest ratio of the five periods.

$$Truck\ Reliability\ Index = \frac{95th\ Percetile\ Travel\ Time}{50th\ Percentile\ Travel\ Time}$$

For *Exhibit IV-21*, TRI was calculated for the 50 most congested corridors in 2019 for 2017, 2018, and 2019. The 50 most congested corridors were selected because they had the largest truck hours of delay per mile in 2019.

TRI is calculated the same as the Moving Ahead for Progress in the 21st Century (MAP-21) performance measure for Truck Travel Time Reliability (TTTR), but TRI results differ from TTTR due to differences in route segmentation and the TRI cannot be used to report TTTR. The FMT tool uses TRI because the route segmentation method allows for aggregation and the ability to report freight congestion indicators at various geographies over the entire NHS.

Truck Travel Time Reliability

Truck Travel Time Reliability (TTTR) is the national performance measure for freight movement on the Interstate System. The national TTTR measure is presented for the entire Interstate System for 2017, 2018, and 2019.

The national TTTR Index is the average additional travel time that should be added to typical truck travel times on the Interstate System to ensure on-time arrival 95 percent of the time. Higher TTTR values indicate a less reliable roadway, while lower TTTR values closer to 1.0 indicate a more reliable roadway. The TTTR Index is calculated by multiplying each Interstate segment's TTTR by its length, and then dividing the sum of all length-weighted Interstate segments by the total length of the Interstate System.

The TTTR Index is generated by dividing the 95th percentile travel time by the 50th percentile travel time for each segment of the Interstate System during specific times of the day. The five periods are: morning peak (6 a.m. to 10 a.m.), midday (10 a.m. to 4 p.m.) and evening peak (4 p.m. to 8 p.m.) on weekdays, 6 p.m. to 8 p.m. on weekends, and overnight every day from 8 p.m. to 6 a.m.

$$TTTR_i = \frac{95th\ Percentile\ Travel\ Time_i}{50th\ Percentile\ Travel\ Time_i}$$

Where *i* is the period:

6 a.m. to 10 a.m. on weekdays
10 a.m. to 4 p.m. on weekdays
4 p.m. to 8 p.m. on weekdays
6 a.m. to 8 p.m. on weekends
8 p.m. to 6 a.m. every day

The TTTR Metric for each segment of the Interstate is the largest ratio of the five periods.

Finally, the overall TTTR Measure for the entire Interstate System is then generated by multiplying each segment's TTTR Metric by its length, then dividing the sum of all length-weighted segments by the total length of Interstate. The formula is:

$$TTTR\ Measure = \frac{\sum_{i=1}^{T}(SL_i \times maxTTTR_i)}{\sum_{i=1}^{T}(SL_i)}$$

Where:

i = an Interstate reporting segment
$maxTTTR_i$ = the maximum TTTR of all five periods for segment i (nearest hundredth)
SL_i = length of segment i
T = total number of Interstate segments

Truck Volume

For *Exhibit IV-23*, FHWA used HPMS traffic volume data in the FMT tool to identify AADTT on the most congested NHFN corridors in 2019. Congestion was based on truck hours of delay per mile in 2019. Trucks are defined as vehicles of classes 4 through 13 in FHWA's 13-category vehicle classification system.

Congestion Surrounding Freight Facilities

FHWA used NPMRDS travel time data in the FMT tool to identify 2019 congestion on NHS roadways surrounding multimodal freight facilities. Congestion was based on truck hours of delay per mile in 2019. Four types of multimodal freight facilities were included in the analysis presented in *Exhibit IV-19*: freight-significant airports, maritime ports, border-crossings (U.S-side only), and intermodal yards.

The multimodal freight facility locations are represented on the NHS roadways as single points. For this exhibit, FHWA included all NHS roadways within a five-mile buffer of the multimodal freight facilities. For each multimodal freight facility type, the selected facilities represent the top 10 facilities with the largest truck hours of delay per mile in 2019 on surrounding NHS roadways. Reported congestion values for each multimodal freight facility are the average of all truck hours of delay per mile in 2019 for all NHS roadways within the five-mile buffer of a facility.

The NHS roadways included in the five-mile buffer do not necessarily lead to, or provide access to, the multimodal freight facility included in the exhibit. FHWA included the NHS roadways in the buffer because of their vicinity to the location of the multimodal freight facility. If there were no NHS roadways within the five-mile buffer, that multimodal freight facility was omitted from the analysis because there was no travel time data available to calculate the level of congestion surrounding the facility.

Critical Rural and Urban Freight Corridors

Pursuant to FAST Act Section 1116(a), States (including the District of Columbia), and in certain cases, metropolitan planning organizations (MPOs), can identify and designate public roads as CR/CUFCs. These corridors provide critical connectivity to the NHFN from freight transfer points and facilities such as intermodal and manufacturing facilities, distribution points, and other freight processing facilities. States are responsible for designating CRFCs. States can also designate CUFCs, in consultation with MPOs, in urbanized areas with populations under 500,000. In urbanized areas with populations over 500,000, MPOs are responsible for designating CUFCs in consultation with States, and for determining how to distribute CUFC mileage among urbanized areas.

While submitting CR/CUFC designations is optional, by statute, States cannot use National Highway Freight Program (NHFP) funds on a route not designated as a CR/CUFC.[213]

There are mileage limitations on the extent of CR/CUFCs. State designation of CRFCs is limited to a maximum of 150 centerline miles of highway, or 20 percent of the PHFS mileage in that State, whichever is greater. State designation of CUFCs is limited to a maximum of 75 centerline miles of highway, or 10 percent of the PHFS mileage in that State, whichever is greater.[214]

When designating a CR/CUFC, States or MPOs are required to classify corridors with at least one route identifier as defined by FHWA. There are 11 unique route identifiers: seven identifiers for CRFCs and four identifiers for CUFCs. However, States and MPOs are permitted – and generally do – assign multiple route identifiers for each submitted CR/CUFC. *Exhibits 23* and *24* provide the CR/CUFC route identifiers.

States and MPOs have flexibility to designate CR/CUFCs for any functional class of roadway, including local roads as well as planned facilities. When designating CRFCs, FHWA encourages States to consider first- or last-mile connector routes from high-volume freight corridors to key rural freight facilities. When designating CUFCs, FHWA encourages States and MPOs to consider first- or last-mile connector routes from high-volume freight corridors to freight-intensive land uses and key urban freight facilities.

CR/CUFC Route Identifier Frequency

Information in *Exhibit IV-26* was based on designated CR/CUFCs' corridor length (in miles) for each route identifier. The total mileage of a designated corridor was added to each route identifier's mileage. In the case that a State designated a corridor using more than one route identifier, mileage was counted toward each of the route identifier's total mileage. To estimate the percent of mileage assigned to a route identifier, mileage for each designated corridor's route identifiers was included in both the mileage for the route identifier (numerator) and the total mileage (denominator). As a result, the total number of miles sums to be more than the actual number of designated miles on the NHFN.

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[213] The FAST Act established the NHFP, a freight formula program designed to improve the efficient movement of freight on the NHFN, among other goals. The NHFP represented the first dedicated Federal funding source for freight transportation projects.

[214] For additional details, see https://ops.fhwa.dot.gov/fastact/crfc/sec_1116_gdnce.htm

As of January 2021, States or MPOs designated about 8 percent of corridor mileage (CRFC=3 percent; CUFC=5 percent) without a route identifier. States or MPOs designated an additional four percent of corridor mileage (CRFC=1 percent; CUFC=3 percent) using an identifier that was based on incorrect geography of the route (for example, States used a CRFC route identifier to designate a CUFC). FHWA included these incorrectly route-identified corridors in the total reported corridor mileage and the total NHFN mileage reported in *Exhibit IV-3* but excluded them from the analysis presented in *Exhibit IV-26*.

Appendix F: Macroeconomics Analysis Methodology

Description of the USAGE-Hwy Model

Estimates of improved highway performance from increases in highway investment are generated from the Highway Economic Requirements System (HERS) model. The USAGE-Hwy model translates those performance effects and the financial impacts related to funding the highway investment into implications for the national economy as measured by gross domestic product (GDP), welfare (measured primarily by consumption), employment, and wages. Additional measures of macroeconomic activity, including productivity, capital levels, and trade balances are also available. In addition, the USAGE-Hwy model has the capacity to investigate the employment impacts of those spending scenarios for different demographic groups of the U.S. workforce. Technical details on the USAGE-Hwy model can be found below.

USAGE-Hwy is a dynamic computable general equilibrium (CGE) model of the U.S. economy, developed on behalf of FHWA to expand its capacity to understand transportation-related economic activities. It is a variant of the USAGE model, developed in 2001 for the U.S. International Trade Commission. The USAGE-Hwy model has been customized to provide greater detail on transportation industries and to depict economic activities particular to transportation.

In a CGE model, the supply and demand for each commodity is determined as the outcome of optimizing behavior of economic agents. Industries are assumed to choose labor, capital, and land so as to minimize costs while operating in a competitive market, subject to technology constraints. Households purchase a particular bundle of goods in accordance with the household's preferences, relative prices, and amount of disposable income. Capital creators assemble, in a cost-minimizing manner, units of industry-specific capital for each industry. Investment is allocated across industries to maximize rates of returns to investors (e.g., households, firms). Governments operate within a fiscal federal framework. The behavior of those outside the United States is summarized by export demand curves for domestically produced goods and by supply curves for international imports. Changes in exports and imports for goods and services impact the economy's trade or current account balance with offsetting effects on its capital account. In each period or year for which the CGE model provides a solution, all economy-wide constraints must be satisfied: for each commodity the total quantity demanded by all economic agents will equal the total quantity supplied, total household spending is constrained to equal total available income, and the economy-wide demand for factors of production (e.g., labor, capital, land, natural resources) is constrained by the economy's capacity to supply these factors. In this way, changes to supply or demand for one commodity ripple through the entire economy.

Although USAGE-Hwy shares features common to all CGE models, it has been tailored to analyze the economy-wide effects of changes in highway related industries in the following ways:

- Separates highway and bridge construction and street repairs from other types of construction in its representation of industries. Those two industries would typically be aggregated together as part of a single economy-wide construction industry.
- Creates a separate private road transport industry that uses cars, household car repairs, and gasoline as inputs.
- Models separate commuter transport and vacation transport industries. Vacation transport uses inputs of private road transport, air transport, water transport, and passenger transport (e.g., buses, taxis, and trains) to provide transport services that facilitate vacation activities. Similarly, commuter transport uses these inputs to provide transport services that facilitate travel to work, shopping etc. The output of vacation transport is sold to the vacation industry, whose output is in turn sold to households. The output of commuter transport is sold directly to households.

- Uses artificial taxes on sales to commuter transport and vacation transport to represent the cost of driver time in producing automobile transportation.

USAGE-Hwy depicts the impacts of spending on highway investments through two channels: stimulus impacts from government expenditures and the impacts of improved highway performance on the productivity of industries that use highways. In the analysis conducted for this report, the HERS model is the source of estimates of highway performance impacts resulting from increased highway investment. Specifically, the HERS outputs used as shocks to the U.S. economy in USAGE-Hwy include:

- Driving time per mile traveled in passenger cars and in trucks;
- Vehicle operating costs per mile traveled in passenger cars and in trucks;
- Fuel use per mile traveled in passenger cars and in trucks;
- Road maintenance costs;
- Safety costs; and
- Road fatalities.

The productivity enhancements from highway investment, acting through several mechanisms that are discussed below, act to free up resources for other needs, which results in increased economic output, capital levels, and employment. On the other hand, the highway investment itself requires using resources that could otherwise be used for different purposes. The USAGE-Hwy model simulates those dynamics and estimates the magnitude of the net economic impacts, considering both the positive and negative impacts of highway investment.

The changes in fuel use, vehicle operating costs, and driving time for trucks are modeled as productivity shocks to the trucking industry, meaning that the trucking industry can generate the same amount of output with fewer resources, and that those resources become available to produce additional output from the trucking sector or other industries. These ripple effects are experienced by many industries due to transportation's central role in the economy. For passenger vehicles, changes in fuel use, vehicle operating costs, and driving time are modeled as productivity shocks to the private road transportation industry. In USAGE-Hwy, prices are the mechanism by which supply and demand adjust to clear the market for different commodities. The changes in relative prices due to productivity improvements in the different transport industries trigger substitutions between transport modes.

Reductions in road maintenance costs are treated as deductions from additional infrastructure investment, since both activities are likely to share the same mix of labor, capital, and other inputs. Thus, a reduction in road maintenance costs acts to lower the total cost of the investment, freeing up resources for other uses.

The HERS model produces estimates of changes in safety costs, which are the medical costs associated with injuries from road crashes and changes in traffic fatalities, which are valued using the value of statistical life (VSL) from U.S. DOT guidance.[215] The changes in demand for medical services stemming from changes in safety costs are treated as shocks to the economy. Further, the changes in safety costs are incorporated into the measure of welfare used in this analysis, as are changes in total traffic fatalities. Specifically, increases in household welfare from highway investment are calculated as the increase in consumption created by freeing up resources for other uses (after accounting for the cost of the investment itself), plus the value of passenger vehicle travel time savings, minus any increases in medical costs associated with road crashes, minus the monetized value of any increases in fatalities. In this way, USAGE-Hwy translates HERS outputs of performance and financial effects related to funding highway investment into implications for the national economy as measured in GDP, employment,

[215] U.S. Department of Transportation. "Benefit-Cost Analysis Guidance for Discretionary Grant Programs." https://www7.transportation.gov/office-policy/transportation-policy/benefit-cost-analysis-guidance-discretionary-grant-programs-0

wages, and welfare. The model also produces other measures of macroeconomic activity including productivity, capital levels, and trade balances.

The latest version of USAGE-Hwy is version 1.2, which is based on 2018 industry input-output data from the U.S. Bureau of Economic Analysis (BEA). It also incorporates data describing in-house (as opposed to for-hire) air, rail, water, and trucking industries from the 2018 Transportation Satellite Accounts published by the Bureau of Transportation Statistics (BTS).[216] The in-house transportation industries represent transportation activities undertaken by companies in non-transportation industries. For example, the transportation activities of a retailer that uses its own employees and trucks to ship goods from its warehouses to its retail stores are reflected in the in-house trucking industry in the BTS Transportation Satellite Accounts data, whereas in the BEA data these activities are included in the retail industry.[217]

In addition to the central analysis of the macroeconomic impacts of the Improve Conditions and Performance scenario compared to the Sustain 2014–2018 Spending scenario found in Chapter 7, USAGE-Hwy was used to conduct an exploratory analysis of the employment impacts from highway investment for different demographic groups of workers. The model estimates changes in employment by occupation by connecting the estimated changes in employment by industry with industry-by-occupation data produced by the Bureau of Labor Statistics (BLS).[218] The resulting estimates of changes in employment for each occupation are combined with BLS demographic data for each occupation[219] to estimate the changes in employment for different demographic groups (i.e., by sex, race, and ethnicity) from increased highway investment. This analysis is presented in Chapter 10 of this report.

This exploratory analysis at present has a few key limitations. First, this analysis necessarily assumes that the racial composition of occupations does not vary by industry. For example, 18.3 percent of Healthcare Support Occupations were Hispanic or Latino in 2018, but there is no information available to determine if that percentage varies depending on whether workers are employed in hospitals versus retirement homes, which are categorized in separate industries by BLS. Second, the analysis is static and does not account for the possibility that the demographic characteristics of an occupation may change in response to changes in demand for workers in that occupation. Third, the Transportation Satellite Account data describing in-house transportation industries is a specialized data product that is not linked to other detailed employment data and therefore industry-by-occupation employment data are not available for in-house transportation industries. Finally, the employment estimates produced by the USAGE-Hwy analysis reflect the percentage changes in employment as measured by total employee compensation in an industry, but the employment impacts explored using the BLS industry-by-occupation data reflect employment counts. Therefore, industries with higher wages receive a slightly higher weight when estimating employment dynamics than in the supplemental employment demographic analysis in the central analysis of Chapter 10. As a result of these last two limitations (the lack of industry-by-occupation data for in-house transportation industries and different weighting schemes), the employment dynamics aggregated over all demographic groups differ slightly from the total employment effect reported in the central analysis of Chapter 10.[220] Nonetheless, the analysis is useful for comparing employment impacts among demographic groups.

[216] Bureau of Transportation Statistics. “Transportation Satellite Accounts.” https://www.bts.gov/satellite-accounts

[217] The economic activities of in-house industries are added to the Make and Use matrices as separate rows and columns and then subtracted from their previous industries as characterized in the BEA data to avoid double-accounting.

[218] Bureau of Labor Statistics. “Occupational Employment and Wage Statistics.” https://www.bls.gov/oes/

[219] Bureau of Labor Statistics. “Table 11: Employed persons by detailed occupation, sex, race, and Hispanic or Latino ethnicity.” https://www.bls.gov/cps/aa2018/cpsaat11.htm

[220] Specifically, the employment dynamics reported for “all” demographic groups exhibit a more muted response to highway investment than the total employment impacts reported in the central analysis.

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