2010 Status of the Nation's Highways, Bridges, and Transit:
Conditions & Performance
REPORT TO CONGRESS

U.S. Department
of Transportation

Federal Highway
Administration

Federal Transit
Administration

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Abbreviations

AASHTO	American Association of State Highway and Transportation Officials
ACE	Altamont Commuter Express
ADA	Americans with Disabilities Act of 1990
ADT	average daily traffic
AEO	*Annual Energy Outlook 2010*
APTA	American Public Transportation Association
ATM	Active Traffic Management
BAB	Build America Bond
BAC	blood alcohol concentration
BART	San Francisco Bay Area Rapid Transit District
BCR	benefit-cost ratio
BIRM	Bridge Inspector's Reference Manual
BLS	Bureau of Labor Statistics
BPI	Bid Price Index
BRT	Bus Rapid Transit
BTS	Bureau of Transportation Statistics
BTU	British thermal unit
C&P	Conditions and Performance
CAFE	Corporate Average Fuel Economy
CAT	Climate Action Team, Climate Advisory Team
CATA	Central Arkansas Transit Authority
CATS	Charlotte Area Transit System
CDOT	Connecticut Department of Transportation
CEA	Council of Economic Advisers
CEQ	Council on Environmental Quality
CFC	chlorofluorocarbon
CFR	U.S. Code of Federal Regulations
CFS	Commodity Flow Survey
CH_4	methane
CMAQ	Congestion Mitigation and Air Quality
CMTA	Capital Metropolitan Transportation Authority
CNT	Center for Neighborhood Technology
CO_2	carbon dioxide
CO_2e	CO_2 equivalent
COT	City of Tucson
CPI	Consumer Price Index
CSS	context sensitive solution
CTA	Chicago Transit Authority
DART	Dallas Area Rapid Transit
DHS	U.S. Department of Homeland Security
DO	directly operated
DOT	Department of Transportation
DOT&PF	Alaska Department of Transportation and Public Facilities
DTC	Delaware Transit Corporation
DTS	City and County of Honolulu Department of Transportation Services
EDC	*Every Day Counts*

EIA	Energy Information Administration
EPA	U.S. Environmental Protection Agency
FAF	Freight Analysis Framework
FARS	Fatality Analysis Reporting System
FHWA	U.S. Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FPM	freight performance measurement
FTA	Federal Transit Administration
FY	fiscal year
g/dL	gram per deciliter
GARVEE	Grant Anticipation Revenue Vehicle
GCRTA	The Greater Cleveland Regional Transit Authority
GDP	gross domestic product
GHG	greenhouse gas
GIS	geographic information system
GP	general purpose
GPS	Global Positioning System
GreenLITES	Green Leadership in Transportation Environmental Sustainability
HART	Hillsborough Area Regional Transit Authority
HERS	Highway Economic Requirements System
HFC	hydrofluorocarbon
HFCS	Highway Functional Classification System
HMA	hot-mix asphalt
HOT	high-occupancy toll
HOV	high-occupancy vehicle
HPMS	Highway Performance Monitoring System
HPMS-AP	HPMS Analytical Process
HRRR	High Risk Rural Roads Program
HRT	Hampton Roads Transit
HTF	Highway Trust Fund
HUD	U.S. Department of Housing and Urban Development
ICM	Integrated Corridor Management
IDAS	ITS Deployment Analysis System
IFTWG	Intermodal Freight Technology Working Group
INVEST	Infrastructure Voluntary Evaluation Sustainability Tool
IPCC	Intergovernmental Panel on Climate Change
IRI	International Roughness Index
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
IT	Island Transit
ITS	intelligent transportation system(s)
King County Metro	King County Department of Transportation
KT	Kenosha Transit
LACMTA	Los Angeles County Metropolitan Transportation Authority
LDV	light-duty vehicle
LEED	Leadership in Energy and Environmental Design
LID	Low Impact Development
LNG	liquefied natural gas
LPG	liquefied petroleum gas
MARTA	Metropolitan Atlanta Rapid Transit Authority
MATA	Memphis Area Transit Authority
MBTA	Massachusetts Bay Transportation Authority
MCCC	Maryland Climate Change Commission
MDT	Miami-Dade Transit

Metra	Northeast Illinois Regional Commuter Railroad Corporation
METRO	Bi-State Development Agency; Metropolitan Transit Authority of Harris County, Texas; Metro Regional Transit Authority
Metrolink	Southern California Regional Rail Authority
MOVES	Motor Vehicle Emission Simulator
mpg	miles per gallon
mph	miles per hour
MPO	metropolitan planning organization
MR&R	maintenance, repair, and rehabilitation
MTA	Mass Transit Account, Metropolitan Transportation Authority, Maryland Transit Administration
MTA LIRR	MTA Long Island Rail Road
MTA-MNCR	Metro-North Commuter Railroad Company
MTS	San Diego Metropolitan Transit System
MTSI	mean time to service interruption
MUNI	San Francisco Municipal Railway
N_2O	nitrous oxide
NBI	National Bridge Inventory
NBIAS	National Bridge Investment Analysis System
NBIS	National Bridge Inspection Standards
NCHRP	National Cooperative Highway Research Program
NCTD	North County Transit District
NEPA	National Environmental Policy Act
NFT Metro	Niagara Frontier Transportation Authority
NHCCI	National Highway Construction Cost Index
NHS	National Highway System
NHTS	National Household Travel Survey
NHTSA	National Highway Traffic Safety Administration
NICTD	Northern Indiana Commuter Transportation District
NIPA	U.S. National Income and Product Accounts
NJ TRANSIT	New Jersey Transit Corporation
NNEPRA	Northern New England Passenger Rail Authority
NOAA	National Oceanic and Atmospheric Administration
NO_x	nitrogen oxide
NORTA	New Orleans Regional Transit Authority
NTD	National Transit Database
NTPP	Nonmotorized Transportation Pilot Program
NYCT	MTA New York City Transit
OMB	Office of Management and Budget
OSTP	Office of Science and Technology Policy
P3	Public-Private Partnership
PAB	Private Activity Bond
PATCO	Port Authority Transit Corporation
PATH	Port Authority Trans-Hudson Corporation
PCJPB	Peninsula Corridor Joint Powers Board
PENNDOT	Pennsylvania Department of Transportation
PFC	perfluorocarbon
PM-10	particulate matter of 10 microns in diameter or smaller
PMT	passenger miles traveled
Port Authority	Port Authority of Allegheny County
PPI	Producer Price Index
PRHTA	Puerto Rico Highway and Transportation Authority
PSR	Present Serviceability Rating

PT	purchase transportation
RAP	reclaimed asphalt pavement
RCTC	Riverside County Transportation Commission
RPTA	Regional Public Transportation Authority
RTA	Regional Transportation Authority
RTD	Denver Regional Transportation District
RTP	Regional Transportation Plan
Sacramento RT	Sacramento Regional Transit District
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users
SCS	Sustainable Communities Strategy
SEPTA	Southeastern Pennsylvania Transportation Authority
SF_6	sulfur hexafluoride
SGR	State of Good Repair
SIB	State Infrastructure Bank
SIRTOA	Staten Island Rapid Transit Operating Authority
SQC	Synthesis, Quantity, and Condition
ST	Central Puget Sound Regional Transit Authority
STRAHNET	Strategic Highway Network
SUV	sports utility vehicle
TEA-21	Transportation Equity Act for the 21st Century
TEAM	Transit Electronic Award Management
TERM	Transit Economic Requirements Model
The T	Fort Worth Transportation Authority
TIFIA	Transportation Infrastructure and Finance Innovation Act
TIGER	Transportation Investment Generating Economic Recovery
TIGGER	Transit Investment for Greenhouse Gas and Energy Reduction
TMC	traffic management center
TOD	Transit-Oriented Development
TRB	Transportation Research Board
TriMet	Tri-County Metropolitan Transportation District of Oregon
TRI-Rail	South Florida Regional Transportation Authority
TTI	Texas Transportation Institute
TVT	Traffic Volume Trends
UCR	Urban Congestion Report
UN	United Nations
U.S.C.	United States Code
U.S. DOT	United States Department of Transportation
UTA	Utah Transit Authority
UZA	urbanized area
Valley Metro	City of Phoenix Public Transit Department
V/SF	volume to service flow
VHT	vehicle-hours of travel
VII	Vehicle Infrastructure Integration
VIUS	Vehicle Inventory and Use Survey
VMT	vehicle miles traveled
VRE	Virginia Railway Express
VRM	vehicle revenue mile
VSL	variable speed limit
VTA	Santa Clara Valley Transportation Authority
WMA	warm mix asphalt
WMATA	Washington Metropolitan Area Transit Authority

Introduction

This is the ninth in a series of combined documents prepared by the U.S. Department of Transportation (DOT) to satisfy requirements for reports to Congress on the condition, performance, and future capital investment needs of the Nation's highway and transit systems. This report incorporates highway, bridge, and transit information required by 23 U.S.C. §502(h), as well as transit system information required by 49 U.S.C. §308(e). Beginning in 1993, the Department combined two separate existing report series that covered highways and transit to form this report series; prior to this, 11 reports had been issued on the condition and performance of the Nation's highway systems, starting in 1968. Five separate reports on the Nation's transit systems' performance and conditions were issued beginning in 1984.

This *2010 Status of the Nation's Highways, Bridges, and Transit: Conditions and Performance* report to Congress (C&P report) draws primarily on 2008 data. The 2008 C&P report, transmitted on January 14, 2010, was based primarily on 2006 data.

In assessing recent trends, many of the exhibits presented in this report present statistics for the primary data years reflected in the last five C&P reports (2000, 2002, 2004, 2006, and 2008). Other charts and tables cover different time periods depending on data availability and years of significance for particular data series. The data presented within this report generally reflect the latest available information as of December 2009 or the date the individual chapters were written. The prospective analyses presented in this report generally cover the 20-year period ending in 2028.

Report Purpose

This document is intended to provide decision makers with an objective appraisal of the physical conditions, operational performances, and financing mechanisms of highways, bridges, and transit systems based both on the current state of these systems and on the projected future state of these systems under a set of alternative future investment scenarios. This report offers a comprehensive, data-driven background 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 mass transit operators to provide a national-level summary. Some of the underlying data are available through the DOT's regular statistical publications. The future investment scenario analyses are developed specifically for this report and provide national-level projections 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 highlights the key findings in each individual chapter. These two sections will also be published as a separate stand-alone summary document.

The main body of the report is organized into four major sections. The six chapters in Part I, "Description of Current System," contain the core retrospective analyses of the report. Chapters 2 through 6 each include separate highway and transit sections discussing each mode in depth. This structure is intended to accommodate report users who may primarily be interested in only one of the two modes.

- **Chapter 1** provides a broad overview of the functions served by the Nation's highways and transit systems.
- **Chapter 2** describes recent trends in highway, bridge, and transit system characteristics.
- **Chapter 3** depicts the current physical conditions of highways, bridges, and transit systems.
- **Chapter 4** describes the current operational performance of highways and transit systems.
- **Chapter 5** discusses issues relating to the safety of highways and transit.
- **Chapter 6** discusses highway and transit revenue sources and expenditure patterns for all levels of government, as well as recent innovations in highway finance.

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

- **Chapter 7** projects the potential impacts of different levels of future highway, bridge, and transit capital investment on the future performance of various components of the system.
- **Chapter 8** describes selected capital investment scenarios in more detail and relates these scenarios to the current levels of capital investment for highways, bridges, and transit.
- **Chapter 9** provides supplemental analysis relating to the primary investment scenarios, comparing the future investment scenario findings to previous reports, relating past investment to the current conditions and operational performance of the system, discussing scenario implications, and exploring selected policy alternatives.
- **Chapter 10** discusses how some future highway and transit investment scenarios would be affected by changing the assumptions about travel growth and other key variables.

Part III, "Sustainable Transportation Systems," includes a set of three new chapters exploring sustainability, climate change adaptation, and livability. Some of the topics discussed have been referenced in previous editions of this report, but this edition is the first to explore these issues in a concentrated fashion.

- **Chapter 11** examines issues pertaining to the long-term environmental sustainability of the transportation system and the challenges involved in meeting the needs of the present without compromising the ability of future generations to meet their own needs.
- **Chapter 12** explores climate change adaptation, identifies potential impacts of climate change on transportation, and discusses policies and measures intended to promote effective responses in adapting to these changes.
- **Chapter 13** discusses issues pertaining to livability and efforts to foster livable communities in which transportation, housing and commercial development investments have been coordinated so that everyone has access to adequate, affordable, and environmentally sustainable travel options.

The 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 ongoing research activities and identifies potential areas for improvement in the data and analytical tools used to produce the analyses contained in this report.

Highway Data Sources

Highway conditions and performance data are derived from the Highway Performance Monitoring System (HPMS), a cooperative data/analytical effort dating from the late-1970s that involves the Federal Highway Administration (FHWA) and State and local governments. The HPMS includes a statistically drawn sample of more than 100,000 highway sections containing data on current physical and operating characteristics, as well as projections of future travel growth on a 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.

The HPMS data are collected in accordance with the *Highway Performance Monitoring System Field Manual for the Continuing Analytical and Statistical Database.* This document is designed to create a uniform and consistent database by providing standardized collection, coding, and reporting instructions for the various data items. The FHWA reviews the State-reported HPMS data for completeness, consistency, and adherence to reporting guidelines. Where necessary, and with close State cooperation, data may be adjusted to improve uniformity. The HPMS data also serve as a critical input to other studies that are cited in various parts of this report, such as the Texas Transportation Institute's *2009 Urban Mobility Report.*

State and local finance data are derived from the financial reports provided by the States to FHWA in accordance with *A Guide to Reporting Highway Statistics.* These are the same data used in compiling the annual *Highway Statistics* report. The FHWA adjusts these data to improve completeness, consistency, and uniformity. Highway safety performance data are drawn from the Fatality Analysis Reporting System (FARS).

Bridge Data Sources

The FHWA annually collects bridge inventory and inspection data from the States and incorporates the data into the National Bridge Inventory (NBI). The NBI contains information from all bridges covered by the National Bridge Inspection Standards (Title 23, Code of Federal Regulations, Part 650) 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; conditions information includes inspectors' evaluations of the primary components of a bridge, such as the deck, superstructure, and substructure. Most bridges are inspected once every 24 months. The archival NBI data sets represent the most comprehensive uniform source of information available on the conditions and performance of bridges located on public roads throughout the United States.

Transit Data Sources

Transit data are derived from the National Transit Database (NTD) and transit agency asset inventories. The NTD provides comprehensive data on the revenue sources, capital and operating expenses, basic asset holdings, service levels, annual passenger boardings, and safety data of the more than 650 urban and 1,300 rural transit operators that receive annual funding support through the Federal Transit Administration's (FTA's) Section 5309 (Urbanized Area) and Section 5311 (Rural Area) Formula Programs. Given the range of measures reported to NTD and its comprehensive coverage of U.S. transit operations, NTD is an excellent source of data for analysis of transit financial, operating, and safety performance.

However, with the exception of fleet vehicle holdings (where NTD provides comprehensive data on the composition and age of transit fleets), NTD does not provide the data required to assess the current physical condition of the Nation's transit infrastructure.

To meet this need, FTA collects transit asset inventory data from a sample of the Nation's largest rail and bus transit operators. In direct contrast to the data in either NTD or HPMS—which local and State funding grantees are required to report to FTA and FHWA, respectively, and which are subject to standardized reporting procedures—the transit asset inventory data used to assess current transit conditions are provided to FTA in response to direct requests submitted to grantees and are not subject to any reporting requirements. At present, there are no reporting requirements or reporting standards for asset inventory data.

In practice, these data requests are only made to the Nation's 20 to 30 largest transit agencies because these agencies account for roughly 85 percent of the Nation's total transit infrastructure by value. At the same time, given the slow rate of change in transit agency asset holdings over time (excluding fleet vehicles and major expansion projects), FTA only requests this data from any given agency once every 3 to 5 years. The asset inventory data collected through these requests typically document the age, quantity, and replacement costs of the grantees' asset holdings by asset type. Meanwhile the non-vehicle asset holdings of smaller operators are estimated using a combination of (1) the fleet-size and facility-count data reported to NTD and (2) the actual asset age data of a sample of smaller agencies that respond to asset inventory requests similar to those provided to the larger operators. While this method of obtaining asset data has served FTA well in the past (and the quality of the reported data has improved over time), the accuracy and comprehensiveness of FTA's estimates of current asset conditions and capital reinvestment needs would nonetheless benefit from a standardized reporting requirement comparable to those for NTD and HPMS.

Other Data Sources

This report also relies on data from a number of other sources. For example, the National Household Travel Survey (NHTS) collected by the FHWA provides information on the characteristics, volume, and proportion of passenger travel across all modes of transportation. Information on freight activity is collected by the Census Bureau through the Commodity Flow Survey and the Vehicle Inventory and Use Survey, and then merged with other data in FHWA's Freight Analysis Framework.

Investment/Performance Analytical Procedures

The earliest versions of the reports in this combined series relied exclusively on engineering-based estimates for future investment/performance analysis, which considered only the costs of transportation agencies. This philosophy failed to adequately consider another critical dimension of transportation programs, such as the impacts of transportation investments on the costs incurred by the users of the transportation system. Executive Order 12893, *Principles for Federal Infrastructure Investments,* dated January 1994, directs each executive department and agency with infrastructure responsibilities to base investments on " . . . systematic analysis of expected benefits and costs, including both quantitative and qualitative measures . . . ." New approaches have been developed to address the deficiencies in earlier versions of this report and to meet the challenge of this Executive Order. The analytical tools now used in this report have added an economic overlay to the development of future investment scenarios.

The highway investment scenarios presented in this report are developed in part from the Highway Economic Requirements System (HERS), which uses benefit-cost analysis to optimize highway investment. The HERS model quantifies user, agency, and societal costs for various types and combinations of improvements, including travel time and vehicle operating, safety, capital, maintenance, and emissions costs. Bridge investment scenario estimates are developed from the National Bridge Investment Analysis System (NBIAS) model. Unlike earlier bridge models (and similar to HERS), NBIAS incorporates benefit-cost analysis into the bridge investment/performance evaluation.

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

While HERS, NBIAS, and TERM all utilize benefit-cost analysis, their methods for implementing this analysis are very different. The highway, transit, and bridge models are all based on separate databases that are very different from one another. Each model makes use of the specific data available for its part of the transportation system and addresses issues unique to each mode. These three models have not yet evolved to the point where direct multimodal analysis is possible. For example, HERS assumes that when lanes are added to a highway, this causes highway user costs to fall, resulting 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. However, HERS does not distinguish between different sources of additional highway travel. At present, there is no truly accurate method for predicting the impact that a given level of highway investment would have on the future performance of transit systems. Likewise, TERM's benefit-cost analysis assumes that some travel shifts from automobile to transit as a result of transit investments, but cannot project these investments' impact on highways.

In interpreting the findings of this report, it is important to recognize the limitations of these analytical tools and the potential impacts of different assumptions that have been made as part of the analysis. Appendix D and the Introduction to Part II both contain information critical to contextualizing the future investment scenarios, and these issues are also discussed in Q&A boxes located in Chapters 7 through 10.

What Does it Mean to "Maintain?"

For each broad component of the transportation system considered in this report–i.e., highways, bridges, and transit–selecting a summary measure of overall conditions and performance presents a choice among various alternative metrics each of which are partial to some extent; no single metric captures all aspects of conditions and performance. The "Maintain" scenarios presented in this report each consider a level of capital investment that could keep overall conditions and performance, as measured by a particular metric, at the same level 20 years from now as it is today. The metrics selected differ among system components because the highway, bridge, and transit systems differ from each other in their characteristics, the data available to measure these characteristics are limited, and the analytical tools used to analyze these characteristics in this report differ in their capabilities.

The primary "Maintain" scenarios for highways focus on maintaining average speeds over 20 years at the base year level. (The impact on other conditions and performance metrics would vary; for example, on a systemwide basis, average pavement condition improves a little under this scenario, while average delay gets a little worse). The "Maintain" scenarios for bridges target the size of the backlog of economically justifiable bridge improvements (measured in constant dollars); and identify the level of investment needed to keep this backlog from growing above its base year level. Some of the transit scenarios include components reflecting the estimated level of investment that would be sufficient to maintain at the base year level the average occupancy rate for each transit mode, as measured by passenger miles per peak vehicle.

In each case, the investment scenarios outlined in this report represent an estimate of what level of performance could be achieved with a given level of funding, not what would be achieved with it. While the models assume that projects are prioritized based on their benefit-cost ratios, that assumption is not consistent with actual patterns of project selection and funding distribution that occur in the real world.

While the "Maintain" scenarios presented in this report focus on maintaining conditions at base-year levels, the base year is different for each edition of the report; i.e., the prevailing conditions and performance in the 2008 base year analyzed in this report differ from those for the 2006 base year presented in the 2008 edition of the report. Hence, as the level of current system conditions and performance varies over time, the investment scenarios that are based on maintaining the status quo are effectively targeting something different each time. It is important to recognize this when comparing the results of different reports in the series.

What Does it Mean to "Improve?"

In theory, spending anything more than the cost to maintain overall conditions and performance at the base year level will produce overall conditions and performance at the end of the 20-year analysis period that are an improvement over the base year level. Thus, any number of scenarios to "Improve" conditions and performance" could have been considered for this report, each associated with a particular level of capital investment. Among this range of alternatives, this report focuses on a limited number of illustrative "Improve" scenarios.

The two "Improve" scenarios for highways envision spending at levels sufficient to implement all potential capital improvement projects with benefit-cost ratios of 1.5 or 1.0, respectively. The scenarios reflecting a minimum benefit-cost ratio of 1.0 can be viewed as an "investment ceiling" above which additional investment would not be cost beneficial, even if unlimited funding were available. In reality, available funding is not unlimited, and many decisions on highway funding levels must be weighed against potential cost beneficial investments in other government programs as well as private sector investments, which can also be evaluated from a societal cost-benefit perspective. Thus, the less expensive scenario reflecting the higher minimum benefit-cost ratio of 1.5 is also included in this report as a point of reference.

One of the "Improve" scenarios presented for bridges is consistent with the highway scenario, applying a minimum benefit cost ratio of 1.0 to estimate the level of investment that would be sufficient to eliminate the backlog of economically justifiable bridge improvements by the end of 20 years. Due to limitations in data availability and current analytical modeling capabilities, the other "Improve" scenario for bridges assumes a rate of spending growth consistent with the corresponding highway scenario, rather than applying an alternative minimum benefit-cost ratio. Some of the transit scenarios include components reflecting the estimated level of investment that would be sufficient to bring transit assets up to a state of good repair.

It is important to recognize several key limitations of the "Improve" scenarios presented in this report. First, while the models assume that projects are prioritized based on their benefit-cost ratios, that assumption is not consistent with actual patterns of project selection and funding distribution that occur in practice. Consequently, if investment rose to the levels identified in the "Improve" scenarios, there are few mechanisms to ensure that these funds would be invested in projects that would be cost beneficial. As a result, the impacts on actual conditions and performance may be considerably smaller than what is projected for these scenarios. Second, these scenarios do not address practical considerations concerning whether the highway and transit construction industries would be capable of absorbing such a large increase in funding within the 20-year analysis period. Such an expansion of infrastructure investment could significantly increase the rate of inflation within these industry sectors, a factor that is not considered in the constant dollar investment analyses presented in this report. Third, the legal and political complexities frequently associated with major highway capacity projects might preclude certain improvements from being made, even if they could be justified on benefit-cost criteria.

Impact of Financing Structures on Transportation Investment/Performance Analysis

This report has traditionally identified the amount of additional spending above current levels that would be required to achieve certain performance benchmarks, without incorporating the impact of the types of revenues that would support this additional spending. This approach was in keeping with the general philosophy referenced earlier that the assignment of responsibility for the costs associated with a given scenario to any particular level of government or funding source falls beyond the legislative mandate for this report. However, the implicit assumption built into this approach has been that the financing mechanisms would not have any impact on investment scenarios themselves. In reality, raising funding from general revenue sources (such as property taxes, sales taxes, income taxes, etc.) would have different implications than raising funding from user charges (such as fuel taxes, tolls, and fares).

For this report, a set of supplemental highway investment/performance analyses has been developed to compare the implications of funding potential increases in capital spending through user charges imposed on either a per-mile or a per-gallon basis. A feedback loop has been added to the modeling process to account for the impact that changes in the "price" of travel experienced by individual system users would have on projected future travel volumes and overall system performance.

When highway users make decisions about whether, when, and where to travel, they consider both implicit costs (such as travel time and safety risk) and explicit, out-of-pocket costs (such as fuel costs and tolls). Under uncongested conditions, their use of the road will not have an appreciable effect on the costs faced by other users. As traffic volumes begin to approach the carrying capacity of the road, however, traffic congestion and delays begin to set in and travel times for all users begin to rise, with each additional vehicle making the situation progressively worse. However, individual travelers do not take into account the delays and additional costs that their use of the facility imposes on other travelers, focusing instead only on the costs that they bear themselves. To maximize net social benefits, users of congested facilities would be levied charges corresponding to the economic cost of the delay they impose on one another, thereby more efficiently spreading traffic volumes and allowing the diverse preferences of users to be expressed. In the absence of efficient pricing, options for reducing congestion externalities are limited. In addition, the efficient level of investment in highway capacity is larger under the current system of highway user charges (primarily fuel and other indirect taxes) than would be the case with full-cost pricing of highway use. This report includes supplemental analyses that explore the potential impact that the widespread adoption of congestion pricing could have on the level of investment required to achieve certain levels of future conditions and performance.

While the above discussion focuses on highway pricing, the same considerations may apply to transit investments. Anecdotal evidence suggests that transit routes in major metropolitan areas are approaching their passenger-carrying capacities during peak travel hours, with a commensurate deterioration in the quality of service. Some of this crowding could be reduced by increasing fares during peak hours. Certain considerations, however, may limit the ability of transportation authorities to price transit services more efficiently, such as the ability of the fare system to handle peak pricing, and the desire to provide transit as a low-cost service to transit-dependent riders. Additionally, the fact that overcrowded transit lines are often in corridors with heavily congested highways makes a joint solution to the pricing problems on both highways and transit more complicated to analyze, devise, and implement. Measuring the actual crowding on transit systems during peak periods, and the development of a more sophisticated crowding metric than the one currently used by FTA, are areas for further research.

Changes to C&P Report Scenarios From 2008 Edition

The selected capital investment scenarios presented in Chapter 8 are framed somewhat differently from those presented in the 2008 edition of the Conditions and Performance report. While the highway and transit scenario definitions have been modified, the changes to the transit scenarios are much more extensive.

Highway and Bridge Scenarios

The 2008 C&P report had presented two versions of each scenario in Chapter 8, based on alternative assumptions about funding mechanisms. One set assumed the imposition of user charges on a per-mile basis as needed to cover the increased investment above base year levels associated with each scenario; the other assumed the widespread adoption of congestion pricing, with positive or negative adjustments to other user charges up or down as needed to generate the level of investment needed to support each scenario. This type of analysis has been moved to Chapter 9 for this edition; the scenarios presented in Chapter 8 do not make any assumptions regarding funding mechanisms.

The 2008 C&P report included five primary scenarios; one that showed the impacts of sustaining spending at base year levels, one that estimated the level of investment needed to maintain overall conditions and performance at base year levels, and three that identified the level of investment associated with implementing all potential investments which met a specific minimum benefit-cost ratio threshold. The name and definition of the **Sustain Current Spending** scenario remains unchanged. The **Sustain Conditions and Performance scenario** has been renamed the **Maintain Conditions and Performance scenario,** and the target measure used to compute the highway portion of this scenario has been modified. The **MinBCR=1.0 scenario** has been renamed the **Improve Conditions and Performance scenario,** while the **MinBCR=1.2 scenario** has been dropped. The **MinBCR=1.5 scenario** has been renamed the **Intermediate Improvement scenario**, and the method used to compute the bridge portion of this scenario has been modified. The portion of **Improve Conditions and Performance scenario** associated with improvements to the physical conditions of highways and bridges is identified as the **State of Good Repair benchmark**.

"Maintain" Scenarios

The 2006 C&P report and several prior editions had used average user costs per VMT as a proxy for the overall conditions and performance of the highway system, and used this measure as a target for their "Maintain" scenarios. Since factors that affects average user costs other than pavement condition and traffic congestion, such as vehicle technology, were held constant in the analysis, decreases in average user costs could be directly associated with improvements in overall system conditions and performance.

This direct relationship between average user costs and system conditions and performance was broken in the 2008 C&P report, as the analysis of future user costs was modified to take into account EIA forecasts of future fuel efficiency of the vehicle fleet. Adding this refinement to the analysis created a situation in which average user costs would decline over time, even if the physical conditions and operational performance of the highway system remained unchanged. In order to net out this effect, the 2008 C&P report introduced a new metric, "adjusted user costs". This statistic was computed by recalculating user costs in the 2006 base year as though the fuel economy improvements projected through the end of the analysis period had already occurred. By netting out the impacts of the fuel economy changes, the adjusted user cost metric represents a better proxy for overall system conditions and performance, and was utilized as the metric for a key scenario in the 2008 C&P report.

One issue with the "adjusted user costs" metric is that it requires a somewhat lengthy discussion to fully explain the concept. For this edition, the "Maintain" scenario targets average speed instead. As discussed more fully in Chapter 9, the cost of maintaining average speed at base year levels is similar to that associated with maintaining adjusted average user costs, and average speed is a more readily understandable metric.

Future editions of this report may revert to using adjusted user costs more prominently or switch to highlighting some other metric, especially if the costs associated with maintaining average speed in future analyses begin to deviate significantly from those associated with maintaining adjusted user costs.

Bridge Scenarios

The bridge components of the combined highway and bridge scenarios presented in this report are generally computed in the same manner as the comparable scenarios from the 2008 C&P report. The exception is the **Intermediate Improvement scenario**. This scenario assumes that the growth of spending on bridges will be consistent with that computed for highways, unless that would result in spending that is higher than that computed for the **Improve Conditions and Performance scenario**. In contrast, the approach taken for the 2008 C&P report was to use the same bridge spending levels in both of the comparable scenarios, based on the level of investment required to address all bridge deficiencies when it is cost-beneficial to do so.

Transit Scenarios

The 2008 C&P report presented several scenarios in Chapter 8, including a **Maintain Current Funding scenario**, that has been renamed as the **Sustain Current Spending scenario** for this edition.

The 2008 C&P report also identified a **Maintain Conditions scenario**, a **Maintain Performance scenario**, an **Improve Conditions scenario** and an **Improve Performance scenario**; combinations of these scenarios were formed to identify the level of investment associated with maintaining both conditions and performance, improving conditions while maintaining performance, maintaining conditions while improving performance, and improving both conditions and performance. For both the **Cost to Maintain Conditions and Performance scenario** and the **Cost to Improve Conditions and Performance scenario**, separate versions were presented assuming the application of minimum benefit-cost ratios of 1.0 and 1.2. Another set of alternative versions of these scenarios were linked to the version of the highway scenarios assuming the widespread adoption of congestion pricing, assuming that some portion of traffic diverted by congestion pricing would shift to transit. None of these scenarios was directly continued in this edition.

This edition presents a standalone **State of Good Repair benchmark** which focuses on needs associated with existing assets only; no assessment of expansion needs is included, and the computation of this benchmark does not apply TERM's benefit-cost test. Two additional scenarios, the **Low Growth scenario** and the **High Growth scenario** incorporate both expansion needs and costs required to bring existing assets to a state of good repair; both apply the TERM benefit-cost test, differing only in the rate of future transit travel growth assumed. For system expansion needs, both of these scenarios apply a similar performance target to that used in the computation of the Maintain Performance scenario in the 2008 C&P report.

Highlights

This edition of the C&P report is based primarily on data through the year 2008; consequently, the system conditions and performance measures presented do not yet fully reflect the effects of the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU), which authorized Federal highway and transit funding for Federal fiscal years 2005 through 2009. These measures also do not reflect the impact of the American Recovery and Reinvestment Act of 2009 (Recovery Act).

Cautionary Notes on Using this Report

In order to correctly interpret the analyses presented in this report, it is important 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 does not address what future Federal surface transportation programs should look like, or what level of future surface transportation funding can or should be provided by the Federal government, State governments, local governments, the private sector, or system users. Making recommendations on policy issues such as these would go beyond the legislative mandate for the report and would violate its objectivity. Outside analysts can and do make use of 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 whole series of additional policy and technical assumptions that go well beyond what is reflected in the report itself.

The investment scenario estimates presented in this report are estimates of the performance that **could** be achieved with a given level of funding, not necessarily what **would** be achieved with it. The analytical tools used in the development of these estimates combine engineering and economic procedures, determining deficiencies based on engineering standards while applying benefit-cost analysis procedures to identify potential capital improvements to address those deficiencies that may have positive net benefits. While the models generally assume that projects are prioritized based on their benefit-cost ratios, that assumption is not consistent with actual patterns of project selection and funding distribution that occur in the real world. Consequently, the level of investment identified as the amount required to maintain a certain performance level should be viewed as **illustrative only**, and should not be considered a projection or prediction of actual condition and performance outcomes likely to result from a given level of national spending.

As in any modeling process, simplifying assumptions have been made to make analysis practical and to report within the limitations of available data. Since the ultimate decisions concerning highways, bridges, and transit systems are primarily made by their operators at the State and local level, they have a much stronger business case for collecting and retaining detailed data on individual system components. The Federal government collects selected data from States and transit operators to support this report, as well as a number of other Federal activities, but these data are not sufficiently robust to make definitive recommendations concerning specific transportation investments in specific locations. While improvements are evaluated based on benefit-cost analysis, not all external costs (such as noise pollution) or external benefits (such as the impact of transportation investments on productivity) are fully considered. Across a broad program of investment projects, such external effects may cancel each other; but, to the extent that they do not, the true "needs" may be either higher or lower than would be predicted by the models.

Highlights: Highways and Bridges

The Nation's Road Network is Extensive

The Nation's road network includes more than 4 million miles of public roadways and more than 600,000 bridges. In 2008, this network carried almost 3 trillion vehicle miles traveled (VMT).

The term "Federal-aid highways" includes roads that are generally eligible for Federal funding assistance under current law; approximately one-quarter of the Nation's 4 million miles of roadways fall into this category. (Note that certain Federal programs do allow the use of Federal funds on other roadways, under certain circumstances.) These 1 million miles of Federal-aid highways carried over five-sixths of the total VMT in 2008.

The National Highway System (NHS) includes those roads that are most important to interstate travel, economic expansion, and national defense. While the NHS makes up only 4 percent of total mileage, it carries approximately 44 percent of total VMT in the United States.

Highway Spending Has Increased

All levels of government spent a combined $182.1 billion for highway-related purposes in 2008, equivalent to almost $45 thousand per mile of roadway, or just over 6 cents per VMT. Just over half of this spending ($91.1 billion) was for capital improvements to highways and bridges; the remainder included expenditures for physical maintenance, highway and traffic services, administration, highway safety, and debt service.

Total spending on highways increased by 48.4 percent between 2000 and 2008, a 9.1 increase when adjusted for inflation. Highway construction costs generally increased more quickly than consumer prices, increasing sharply between 2004 and 2006. Highway capital expenditures increased by 48.6 percent between 2000 and 2008, equaling a 1.2 percent increase when adjusted for inflation.

Constant Dollar Conversions for Highway Expenditures

This report uses the Federal Highway Administration's (FHWA's) National Highway Construction Cost Index (NHCCI) and its predecessor, the Composite Bid Price Index (BPI), for inflation adjustments to highway capital expenditures and the Consumer Price Index (CPI) for adjustments to other types of highway expenditures.

Prior to the enactment of the Recovery Act, there had been a shift in the types of capital improvements being made by State and local governments. The portion of capital investment going for "system rehabilitation" (which includes resurfacing, rehabilitation, or reconstruction of existing highway lanes and bridges) declined from 52.7 percent in 2000 to 51.1 percent in 2008. The percentage of capital spending directed toward "system expansion" (the construction of new highways and bridges and additional lanes on existing highways) decreased from 37.4 percent to 36.8 percent over this period, while the portion used for "system enhancement" (including safety enhancements, traffic control facilities, and environmental enhancements) increased from 9.9 percent to 12.0 percent.

The portion of total highway capital spending funded by the Federal government declined from 42.6 percent in 2000 to 41.5 percent in 2008, because State and local government funding growth outpaced Federal funding growth over this period. This share is expected to rise in the near future due to the effects of the Recovery Act and various recession-related cuts at the State and local levels. Because the Federal-aid highway program is a multiple-year reimbursement program, the impact of increases in obligation levels on outlay levels phases in gradually over a number of years. (Note the terms "spending", "expenditures" and "outlays" are used interchangeably in this report).

Highway Safety Has Improved

Considerable progress has been made in reducing fatality and injury rates since 2000. Highway fatalities fell by 11.2 percent to 37,261 deaths in 2008. Data for 2009 show a continued drop to 33,808, and fell even more in 2010 to 32,788. The fatality rate per 100 million VMT declined from 1.53 in 2000 to 1.25 in 2008; preliminary 2009 figures show a further drop to 1.13 in 2009, which would be the lowest on record. Similarly, the injury rate per 100 million VMT declined from 116 in 2000 to 80 in 2008.

The 37,261 highway fatalities in 2008 included 5,282 nonmotorists killed by motor vehicle crashes. Overall nonmotorized fatalities decreased by 5.6 percent from 2000 to 2008, as an 8.1 percent decrease in pedestrian fatalities over this period was partially offset by increases in the number of bicyclists and other non-motorists killed. Highway safety remains a top priority within the U.S. Department of Transportation (DOT), and the improvement of the Nation's roadway infrastructure is an important component of the effort to reduce highway fatalities and injuries.

Operational Performance Has Stabilized in Many Areas

Over the period from 2000 to 2008, measures of urbanized area congestion developed for FHWA by the Texas Transportation Institute (TTI) show some overall improvement. The estimated percentage of travel occurring under congested conditions decreased from 27.0 percent in 2000 to 26.3 percent in 2008. The average length of congestion conditions in 2008 matches the 2000 level of 6.2 hours per day. System expansion and operational improvements since 2000 likely played a role in the stabilization of congestion. However, it is worth noting that there were reductions in highway travel in 2008 in conjunction with the recession and it is possible that congestion measures may be impacted when economic growth returns.

While urbanized areas with larger populations generally experience more congestion than smaller urbanized areas, that gap is shrinking. The share of travel occurring under congested conditions for urbanized areas of over 3 million in population decreased from 35.9 percent in 2000 to 35.4 percent in 2008, but rose from 13.4 percent to 13.7 percent over this period for urbanized areas of under 500,000 in population.

Pavement Conditions Have Improved in Many Areas

The percentage of Federal-aid Highway VMT on pavements with "good" ride quality rose from 43 percent in 2000 to 46 percent in 2008, while the share of VMT on pavements with "acceptable" ride quality (a lower standard that includes roads classified as "good") remained relatively stable at 85 percent.

While pavement ride quality has improved in both rural and urban areas over this period, overall pavement conditions in rural areas tend to be better than those in urban areas. In 2008, 62.5 percent of travel on rural Federal-aid highways was on pavements with good ride quality, while only 38.9 percent of travel on urban Federal-aid highways was on pavements meeting that standard.

While the overall pavement ride quality trend for Federal-aid highways has been positive (rising from 43 percent of VMT on "good" quality highways to 46 percent on "good" highways), these gains have occurred primarily on the Interstate System and other principal arterial routes that carry the most traffic. For lower-volume roadways classified as rural major collectors, urban minor arterials, or urban collectors, the percent of VMT on pavements with "good" ride quality declined between 2000 and 2008; the largest decline occurred on urban collectors as the share of VMT meeting this standard fell from 37.9 percent to 31.5 percent over this period.

The percentage of VMT on NHS pavements with "good" ride quality rose from 48 percent in 2000 to 57 percent in 2008. The share of VMT on NHS roads with "acceptable" ride quality increased slightly over this period, from 91 percent to 92 percent. (Note that the pavement statistics presented in this report are based on calendar year data, consistent with the annual *Highway Statistics* publication; in other DOT publications presented on a fiscal year basis, these calendar 2008 statistics appear as Fiscal Year 2009 data).

Bridge Conditions Have Improved, on Average

Bridges are considered structurally deficient if significant load-carrying elements are found to be in poor or worse condition due to deterioration and/or damage, or the adequacy of the waterway opening provided by the bridge is determined to be extremely insufficient to the point of causing intolerable traffic interruptions due to high water. That a bridge is deficient does not imply that it is likely to collapse or that it is unsafe.

Functional obsolescence is a function of the geometrics (i.e., lane width, number of lanes on the bridge, shoulder width, presence of guardrails on the approaches, etc.) of the bridge in relation to the geometrics required by current design standards. As an example, a bridge designed in the 1930s would have shoulder widths in conformance with the design standards of the 1930s, but current design standards are based on different criteria and require wider bridge shoulders to meet current safety standards. The difference between the required, current-day shoulder width and the 1930s-designed shoulder width represents a deficiency. The magnitude of these types of deficiencies determines whether a bridge is classified as functionally obsolete.

Due to the timing of data availability, the bridge statistics presented in this report are for the years 2001 to 2009, rather than for the 2000 to 2008 period presented for most other data. Bridge deficiencies are presented in three ways, relative to the number of bridges, weighted by average daily traffic, and weighted by deck area (the surface area of the bridge deck including the travel lanes, shoulders and pedestrian walkways). Weighting by deck area takes into account the size of bridges, which is significant in terms of the costs associated with replacing or rehabilitating them; weighting by average daily traffic is significant in terms of the number of people affected by bridge deficiencies.

Weighted by deck area, the percentage of NHS bridges classified as deficient declined from 30 percent in 2001 to 29 percent in 2009. About three-quarters of deficiencies on NHS bridges relate to functional obsolescence rather than to structural issues; some NHS bridges are narrower than current design standards would call for given the traffic volumes they currently carry. The percentage of deck area on all bridges (on or off the NHS) classified as deficient declined from 31 percent in 2001 to 29 percent in 2009.

While weighting by bridge deck area is useful in terms of thinking about the costs of addressing deficiencies (which would vary depending on the size of the bridge), in assessing overall bridge conditions it is also useful to consider the actual number of deficient bridges. The percentage of NHS bridges classified as deficient decreased from 23 percent in 2001 to 22 percent in 2009; the percentage of all bridges classified as deficient decreased from 30 percent to 27 percent over this period.

Future Capital Investment Scenarios

In order 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 levels by all levels of government on highways and bridges for different subsets of the overall system. These analyses cover the 20-year period from 2008 to 2028 (reflecting the impacts of spending from 2009 through 2028); the funding levels associated with all of these analyses are stated in constant 2008 dollars. Rather than assuming an immediate jump to a higher (or lower) investment level, each of these analyses assume that spending will grow by a uniform annual rate of increase (or decrease) in constant dollar terms using combined highway capital spending by all levels of government in 2008 as the starting point. Drawing upon these investment/performance analyses, a series of illustrative scenarios were selected for further exploration and presentation in more detail. The scenario criteria were applied separately to the Interstate System, the NHS, all Federal-aid highways, and the highway system overall.

The **Sustain Current Spending scenario** assumes that capital spending by all levels of government combined is sustained in constant dollar terms at 2008 levels through the year 2028. The **Maintain Conditions and Performance scenario** assumes that capital investment gradually changes in constant dollar terms over 20 years to the point at which selected measures of future conditions and performance in 2028 are maintained at 2008 levels.

The **Improve Conditions and Performance scenario** assumes that capital investment gradually rises to the point at which all potential highway and bridge investments that are estimated to be cost-beneficial (i.e., those with a benefit-cost ratio of 1.0 or higher) could be funded by 2028. The **State of Good Repair benchmark** represents the subset of this scenario that is directed toward addressing deficiencies of existing highway and bridge assets. The **Intermediate Improvement scenario** assumes that combined spending gradually rises to a point at which potential highway investments with a benefit-cost ratio of 1.5 or higher can be implemented and assumes a comparable rate of growth in bridge spending.

Systemwide Findings

Sustaining combined highway capital spending by all levels of government at its 2008 level of $91.1 billion in constant dollar terms over 20 years is projected to result in a decline in certain measures of condition and performance. Achieving the objectives of the **Maintain Conditions and Performance scenario** would require an annual spending increase of 0.97 percent above the rate of inflation, translating into an average annual investment level of $101.0 billion over 20 years, stated in constant 2008 dollars.

Achieving the objectives of the **Intermediate Conditions and Performance scenario** would require a constant dollar spending increase of 3.51 percent per year, translating into an average annual investment level of $133.5 billion. Implementing all potentially cost-beneficial improvements by 2028 under the **Improve Conditions and Performance scenario** would cost approximately $170.1 billion per year over 20 years, consistent with an annual constant dollar spending increase of 5.62 percent. As part of this scenario, approximately $85.1 billion per year is associated with addressing deficiencies on existing highways and bridges; this figure is described as the **State of Good Repair benchmark**.

Federal-Aid Highway Findings

All levels of government spent a combined $70.6 billion on capital improvements to Federal-aid highways in 2008. The average annual investment level over 20 years for the **Maintain Conditions and Performance scenario** for Federal-aid highways is $80.1 billion, compared with $103.5 billion for the **Intermediate Improvement scenario** and $134.9 billion for the **Improve Conditions and Performance scenario**. The **State of Good Repair benchmark** is estimated to be $67.8 billion per year over 20 years, stated in constant 2008 dollars.

As noted above, the **Improve Conditions and Performance scenario** would address all potential highway and bridge investments with a benefit-cost ratio of 1.00 or higher by 2028, while the **Intermediate Improvement scenario** would address highway investments with a benefit-cost ratio of 1.50 or higher. The other two scenarios also assume that investments will be implemented in order based on their benefit-cost ratios; the funding level associated with the **Maintain Conditions and Performance scenario** is estimated to be sufficient to address all potential highway improvements with a benefit-cost ratio of 2.02 or higher by 2028, while the **Sustain Current Spending scenario** could address improvements with a benefit-cost ratio of 2.42 or higher.

Under the **Sustain Current Spending scenario**, the overall conditions and performance for Federal-aid highways are expected to worsen by 2028: average pavement roughness is projected to increase by 2.8 percent, average delay per VMT is expected to rise by 6.7 percent, and the economic bridge investment backlog is projected to grow by 6.5 percent. Under the **Improve Conditions and Performance scenario**, average pavement roughness is expected to be reduced by 24.3 percent, average delay per VMT would fall by 7.7 percent, and the economic bridge investment backlog would be eliminated by 2028.

NHS and Interstate Findings

All levels of government spent a combined $42.0 billion on capital improvements to the NHS in 2008. The average annual investment level over 20 years for the **Maintain Conditions and Performance scenario** for the NHS is $38.9 billion, compared with $56.9 billion for the **Intermediate Improvement scenario** and $71.8 billion for the **Improve Conditions and Performance scenario**. The **State of Good Repair benchmark** is estimated to be $29.8 billion per year over 20 years, stated in constant 2008 dollars.

Combined Federal, State, and local capital spending on Interstate highways totaled $20.0 billion in 2008. The average annual investment level over 20 years for the **Maintain Conditions and Performance scenario** for Interstate highways is $24.3 billion, compared with $36.2 billion for the **Intermediate Improvement scenario** and $43.0 billion for the **Improve Conditions and Performance scenario**. The **State of Good Repair benchmark** is estimated to be $16.2 billion per year over 20 years, stated in constant 2008 dollars.

Additional Observations

Several supplemental analyses were also conducted with alternative assumptions in the models used to project future capital investment scenarios. For example, if overall VMT, or particularly peak-period VMT, grew more slowly than has been assumed by the State projections reflected in the scenarios, the costs to maintain and improve the system would be lower.

Similarly, improving the livability of existing communities by providing a wider array of transportation options can be an effective means to reduce the strain on existing highway facilities and reduce the need for costly additions of new highway capacity. The widespread adoption of congestion pricing would also be projected to significantly reduce the need for additional highway capacity.

Highlights: Transit

Transit is Almost Everywhere

In 2008, there were 690 agencies in urbanized areas (UZAs) and 1,396 rural transit operators that reported financial and operating data to the National Transit Database (NTD). Not all transit providers throughout the United States are included in these counts since providers that do not receive grant funds from the Federal Transit Administration (FTA) are not required to report to the NTD.

In 2008, transit services provided 10.2 billion unlinked trips and 53.7 billion passenger miles traveled (PMT). Heavy rail and motor bus modes continue to be the largest segments of both measures. Commuter rail accounts for relatively more PMT due to its greater average trip length (23.4 miles compared with 3.9 for bus, 4.8 for heavy rail, and 4.4 for light rail). Though light rail is the fastest-growing rail mode (with PMT growing at 5.7 percent per year from 2000 to 2008), it provided only 3.9 percent of transit PMT in 2008. Vanpool growth during the same period was 11.8 percent per year, substantially outpacing the 1.8 percent growth in motor bus passenger miles. However, while motor buses provided 39.5 percent of all PMT, vanpools accounted for only 1.8 percent.

Every state reported providing rural service. Rural transit operators reported 136.6 million unlinked passenger trips. Included in this total are rural transit services provided by 61 Indian tribes, which reported 417,000 unlinked passenger trips. This service was provided by 1,150 demand response systems, 494 motor bus systems, and 16 vanpool systems. A total of 304 UZA agencies also reported providing rural service at the rate of 24 million unlinked passenger trips in 2008.

Are Transit Systems in Good Repair?

Prior editions of this report included scenarios that considered the level of investment required to either (1) *maintain* the condition of existing transit assets at current levels, or (2) *improve* the condition of those assets to an overall condition of "good" (i.e., 4.0 on TERM's condition scale). For this edition, these "maintain" and "improve" conditions analyses have been replaced by a **State of Good Repair** analysis. This type of analysis better represents idealized asset management practices and, to a somewhat lesser extent, actual practices at most transit agencies.

The FTA uses a numerical rating scale ranging from 1 to 5 (detailed in Chapter 3) to describe the relative condition of transit assets. Assets are considered to be in a state of good repair when the physical condition of that asset is at or above a condition rating of 2.5. For assets below this condition rating, it is cost-effective to replace instead of rehabilitate or repair the asset. A transit system is in a state of good repair when all its assets are rated at or above this 2.5 threshold. State of Good Repair analysis estimates the investment required to replace assets that are past their useful life expectancy (that is, below the 2.5 condition rating).

Additionally, prior report editions only considered a single ridership growth projection whereas this edition assesses transit capital expansion under both low and high ridership growth outcomes. In this report edition, the **Low Growth scenario** (which is comparable to prior editions' single ridership growth projection) assumes UZA-specific rates of PMT growth projected by the Nation's MPOs. Using this projected growth rate, transit operators expect to serve 2.6 billion new riders annually by 2028. Accordingly, these MPO projections (which are financially constrained) have fallen well short of actual growth in recent years. This report adds a new **High Growth scenario** based on UZA-specific historical growth rates for the last decade, which can be extrapolated to project an additional 6.2 billion new riders by 2028.

The transit state of good repair analysis, as presented in this report and in FTA's June 2010, *National State of Good Repair Assessment,* estimates that $77.7 billion (12 percent) of the $663 billion in assets for the entire U.S. transit industry are past their expected period of reliable service. These over-age assets are particularly concentrated in the categories of rail guideway elements and train communications/control systems. Future reports in this series will monitor ongoing changes in the proportion of in-service assets that exceed their useful life and related measures of transit state of good repair.

For purposes of comparison with previous reports in this series, average asset condition estimates are also included in this report. Averages reported here are weighted by the value of the assets. Thus a $2 asset in condition 4.0 and a $1 asset in condition 2.0 have a cost-weighted average condition of 3.3 [($2*4.0+$1*2.0)/($2+$1)] representing the average condition of the investment as opposed to an un-weighted average condition of 3.0 [(4.0+2.0)/2] which would not distinguish between the different replacement values of the two assets. Comparisons with prior year reports suggest that average transit conditions have remained stable or declined slightly over the past decade (though estimated conditions have improved somewhat for vehicle fleets).

Non-vehicle transit rail assets (guideway elements, facilities, systems, and stations) represent the biggest challenge to maintaining a state of good repair. The replacement value of these assets is $143 billion, of which $19 billion is below condition 2.0 (13 percent) and $16 billion is between condition 2.0 and 3.0

(11 percent). The replacement value of train systems (power, communication, and train control equipment) is $92 billion, of which $14 billion is below condition 2.0 (15 percent) and $19 billion is between condition 2.0 and 3.0 (21 percent). Stations have a replacement value of $83 billion with only $1.5 billion below condition 2.0 (2 percent) but with $21 billion between condition 2.0 and 3.0 (21 percent). Facilities, mostly consisting of maintenance and administration buildings, have a replacement value of $32 billion with $1.4 billion below condition 2.0 (4 percent) and $7 billion between condition 2.0 and 3.0 (22 percent). The relatively large proportion of guideway and systems assets that are below condition 2.0, and finding the $36 billion investment required to replace them, represents a long-term challenge to the rail transit industry.

The Ride Hasn't Changed Much

A few of the most important goals shared by all transit operations include minimizing travel times, making efficient use of vehicle capacity, and providing reliable performance. Accordingly, the FTA collects data on average speed, how full the vehicles are (utilization) and how often they break down (mean distance between failures) to determine how well transit service meets these goals.

Average speeds for nonrail service (dominated by the bus mode) have been relatively constant since 2000. Speeds remain around 20 miles per hour (mph) in spite of increases in roadway congestion over this period. Rail service shows a slight decrease in average speed over this period (24.9 to 23.9 mph). This may be due to more crowded conditions in the heavy rail systems that dominate this category (heavy rail passenger loads have increased 7.5% over this period), track maintenance issues associated with the older systems, or both. Average speed is decreased when high passenger volumes force vehicles to exceed scheduled dwell times as they take on and discharge passengers. Bus passenger loads have not increased since 2000.

Utilization of vehicle capacity varies by mode. In 2008 vehicle occupancy as a percentage of the seating capacity was: vanpool, 57.5%; heavy rail, 48.5%; light rail, 38.3%; trolleybus, 30.4%; ferryboat, 29.2%; commuter rail, 28.3%; motor bus, 27.8%; and demand response, 12.3%. Even on crowded routes these percentages seldom exceed 50% as it is difficult to get significant ridership on trips running counter to the flow of commuters who make up the majority of most transit users. The average utilization of vehicle capacity for all modes combined has increased slightly since 2000.

Mean distance between failures has been stable over the last decade at around 7,000 miles. This indicates that the number of unscheduled delays due to mechanical failures of transit vehicles has not changed significantly. Note that the FTA does not currently collect direct measurement data on the number and lengths of passenger delays resulting from non-vehicular mechanical failures, guideway conditions (e.g., roadway congestion or rail slow zones), or related factors.

Transit is Getting Safer

Transit operators report safety information to the NTD for three major categories: incidents, injuries, and fatalities. The number of fatalities (excluding suicides and homicides) has been relatively constant for the last five years with the U.S. transit industry reporting 216 fatalities in 2008. In 2000, there were 245 fatalities reported. Additionally, due to increasing passenger miles traveled over this period, the fatality rate "per 100 million passenger miles" has been trending down. The fatality rate per 100 million passenger miles was 0.56 in 2000 and was 0.42 in 2008.

For injuries and incidents, the NTD has consistent and comparable data back to only 2004 when new definitions were promulgated. The worst year for injuries since then was 2008, with 11 percent more than in the previous year for a total of 26,228 injuries (50.43 per 100 million passenger miles).

Commuter rail reported the highest fatality rate for transit modes in 2008 (1.13 fatalities per 100 million passenger miles). Both light rail (0.77 fatalities per 100 million passenger miles) and demand response (0.83 fatalities per 100 million passenger miles) reported about half the fatalities reported in 2007. A trend toward significantly fewer fatalities may be developing in these two modes. Motor bus and heavy rail also reported relatively low numbers (heavy rail was 0.40 fatalities per 100 million passenger miles and motor bus was 0.38 fatalities per 100 million passenger miles).

Transit Funding is Up

In 2008, $52.5 billion was generated from all sources to finance transit investment and operations, compared with $30.8 billion in 2000. This is a 70 percent absolute increase or 36.3 percent in constant dollars (adjusted for inflation). Of these funds, 73.9 percent ($38.8 billion) came from public sources and 26.1 percent came from passenger fares ($11.4 billion) plus other system-generated revenue sources ($2.3 billion). The Federal share of this was $9.0 billion (23.1 percent of total public funding and 17.1 percent of all funding). The Federal share of total funding from government sources has been fairly constant, between 23 and 25 percent, since 2000 and has rarely been outside that range since 1990. Local jurisdictions provided the bulk of transit funds, $18.5 billion in 2008, or 47.5 percent of total public funds and 35.1 percent of all funding. Dedicated sales taxes were the largest sources of State and local funding; in 2008, they accounted for 30.2 percent of State transit funds and 36.0 percent of total local transit funds. In constant dollars, total public funding for transit increased 47.9 percent and funding from Federal sources increased by 37.0 percent between 2000 and 2008. Funding from State and local sources increased by 52.0 percent in constant dollars during this period.

Constant Dollar Conversions for Transit Expenditures

This report uses the Consumer Price Index (CPI) for inflation adjustments to all types of transit expenditures. (There is currently no industry-specific index for transit capital expenditures comparable to the NHCCI for highway capital expenditures.)

In 2008, $36.4 billion in funding was provided for transit operating expenses (wages, salaries, fuel, spare parts, preventive maintenance, support services, and leases). The Federal share of this has declined from the 2006 high of 8.2 percent to 7.1 percent in 2008. Similarly, the share generated from system revenues has decreased from 40.3 percent in 2006 to 37.6 percent. These decreases have been offset by the State share, which has increased from 22.5 percent in 2006 to 25.8 percent. The local share of operating expenditures has been close to 2008's 29.7 percent for several years.

The average annual increase in operating expenditures per vehicle revenue mile for all modes combined between 2000 and 2008 was 4.1 percent (current dollars) or, after adjusting for inflation, 1.5 percent (constant dollars). Operating expenditures per passenger mile for all transit modes combined increased at an average annual rate of 4.3 percent between 2000 and 2008 (from $0.44 to $0.62) in current dollars (a 1.7 percent increase in constant dollars).

Analysis of NTD reports for the largest 10 transit agencies (by ridership) shows that the growth in operating expenses is led by the cost of fringe benefits (36.0 percent of all operating costs for these agencies), which have been going up at a rate of 3.4 percent per year above inflation (constant dollars) since 2000. By comparison, average salaries and wages at these ten agencies grew at an inflation-adjusted rate of only 0.1 percent per year in that period. FTA does not collect data on the different components of fringe benefits but increases in the cost of medical insurance undoubtedly contributed to the growth in this category.

New Capital Investment Scenarios

The analyses associated with this report assess the impact of broad variations in the total level of transit capital expenditures on future transit asset conditions, the magnitude of the investment backlog, and the overall ability to meet growth in transit travel demand. Furthermore, this report features key transit investment analysis scenarios that assess the consequences of sustaining transit capital spending at current levels as well as the level of investment required to attain specific conditions and performance objectives. As with the highway and bridge analyses, all transit analyses assess investment impacts over a 20-year time period from 2008 to 2028 (reflecting the impacts of spending from 2009 through 2028) and take into account the combined levels of investment from all levels of government.

The **Sustain Current Spending scenario** assumes that spending on the preservation and expansion of transit capital assets by all levels of government is sustained in constant dollar terms at base year 2008 levels from 2009 through 2028. In contrast, the **State of Good Repair benchmark** assesses the level of spending required to bring all of the Nation's existing transit assets—including all vehicles, stations, maintenance facilities, guideway track and structures, and systems—to a state of good repair (with no assessment of investment cost-effectiveness and no consideration of transit expansion requirements). Finally, the **Low Growth** and **High Growth scenarios** consider the level of investment to address both asset state-of-good-repair and service expansion needs subject to two different potential levels of growth (and with all investments now required to pass a benefit-cost analysis). The **Low Growth scenario** assumes transit ridership will grow as projected by the Nation's metropolitan planning organizations (MPOs), while the **High Growth scenario** assumes the average rate of growth (by UZA) as experienced since 1999.

Results for All Transit Systems

All levels of government spent a combined $16.1 billion on capital improvements for the Nation's transit infrastructure and fleets in 2008, including $11.0 billion on reinvestment in existing assets and $5.1 billion on expansions to existing transit capacity. In contrast, the average annual investment level required to attain a state of good repair alone under the **State of Good Repair benchmark** is estimated to be $18.0 billion over the next 20 years (this level of investment does not consider cost effectiveness or address expansion needs). 87% of this amount is associated with the reinvestment needs of urbanized areas with over one million in population. $11.0 billion is associated with rail capital reinvestment nationally.

The level of average annual investment required to attain a state of good repair and address asset expansion to accommodate expected ridership growth is estimated to be between $20.8 billion and $24.5 billion under the **Low Growth** and **High Growth scenarios**, respectively. In addition to the roughly $16.6 billion to $17.2 billion required annually to address *cost-effective* asset preservation needs, these scenarios estimate that an additional $4.2 billion to $7.3 billion are required to support from 2.6 billion to 6.2 billion additional annual transit boardings by 2028 while maintaining current service levels (as measured by the number of riders per peak vehicle). Under both growth scenarios, about 60 percent of these amounts are associated with rail expansion needs, with the remainder devoted to the expansion needs of other transit modes (primarily bus).

Finally, the **Sustain Current Spending scenario** assesses the impact of sustaining national-level transit capital expenditures at the 2008 level (i.e., $16.1 billion) though 2028. Under these circumstances, it is projected that the size of the transit investment backlog will increase from $77.7 billion in 2008 to roughly $116.5 billion by 2028. Similarly, the proportion of assets included in the backlog will increase from about 11.7 percent to about 17.5 percent by 2028, with a related decline in average physical conditions and projected increases in both annual service failures (10 percent) and fleet maintenance costs (4 percent).

Results for Transit Systems in Urbanized Areas Over 1 Million in Population

Transit systems in the 37 Urbanized Areas (UZAs) with over one million in population account for 90.1 percent of the all transit passenger boardings in the Nation. They operate more than 90 percent of the Nation's transit assets (by replacement value), including all but a few rail systems (and these are small).

In 2008, transit agencies operating in these UZAs expended $14.8 billion on capital projects, including $10.2 billion on preservation investments intended to rehabilitate or replace existing assets, and $4.6 billion on expansion investments designed to increase service capacity. The annual investment level for these UZAs to attain a state of good repair under the **State of Good Repair benchmark** is estimated to average $15.6 billion over the next 20 years (excludes expansion needs). The additional level of average annual investment required to address both the asset expansion needs of these larger UZAs is estimated to be between $3.7 billion and $6.6 billion under the **Low Growth** and **High Growth scenarios**, respectively. In 2008 expenditures for expansion were $4.6 billion, a level that is able to meet the low growth projected increases in transit boardings while maintaining current service performance levels (as measured by the number of riders per peak vehicle).

Results for Transit Systems in Areas Under 1 Million in Population

This report includes the results of an analysis that considers the preservation and expansion needs of transit systems in all UZAs with populations of less than a million, as well as those of rural areas with existing transit service. This diverse group covers more than 500 different mid- and small-sized urbanized and rural transit operators offering only bus and/or paratransit services. This group currently accounts for less than 10 percent of all existing transit assets (by replacement value) but tends to have higher average growth in transit ridership as compared with the large UZAs.

The investment level needed for the smaller UZAs and all rural areas to attain a state of good repair under the **State of Good Repair benchmark** is estimated to average $2.4 billion over the next 20 years (excludes expansion needs), primarily for reinvestment in bus and paratransit fleets and the maintenance facilities that service those vehicles. This is significantly larger than the current investment level of $0.8 billion. The level of annual investment required to address the asset expansion needs of this group is estimated to average between $0.5 billion and $0.7 billion under the **Low Growth** and **High Growth scenarios**, respectively. As in the large UZAs, current levels of expansion investment for transit operators in this group meet the needs of the **Low Growth scenario**.

Chapter 1

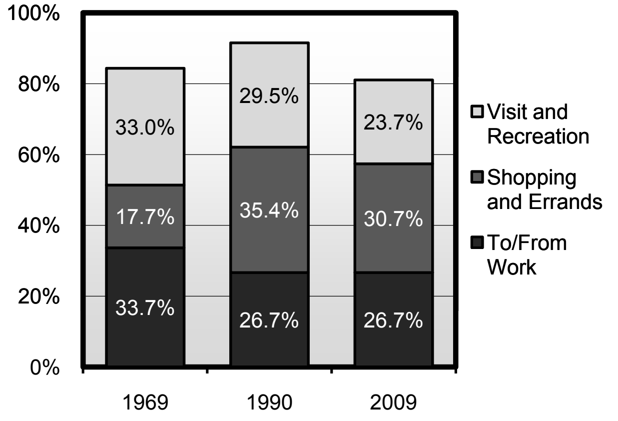
Household Travel in America

Over 300 million people in the United States make decisions about travel every day with about three-quarters of the vehicle miles traveled (VMT) on the Nation's roadways for purposes of personal travel. The household travel data cited below are drawn primarily from a sampling of Americans' daily travel habits collected in the National Household Travel Survey (NHTS).

How People Use the Transportation System

Travel to and from work accounted for 26.7 percent of household-based vehicle travel in 2009, compared with 33.7 percent in 1969; the share of trips devoted to personal visits and recreation also declined. The share of trips attributed to shopping and errands grew significantly over this period from 17.7 percent to 30.7 percent. These trips had widely different destinations than work trips and occurred at different times of day.

Percent of Household-Based Vehicle Miles by Purpose, 1969–2009



Recent data on work commute trends show an increase in telecommuting and flexible hours in the U.S. workplace. More than 36 percent of full-time workers can set or change their start time. The data show that workers are increasingly linking commuting with trips for non-work activities such as errands and shopping. These non-work trips have the potential to conflict with work commute trips and extend the a.m., p.m., and midday peak travel periods as well. Weekend travel for errands and recreation is also increasing.

While congestion used to be associated only with peak travel hours, the increasing share of trips unrelated to work presents a challenge for the operational performance of the transportation system at other times as well.

Travel to work has historically defined peak hour travel demand and in turn influenced the design of transportation infrastructure. Work trips are a critical factor to transit planning and help to determine corridors served and assess the level of transit services available. The average automobile commuter spends 22.8 minutes commuting a one-way distance of 12.6 miles; bus commuters travel a shorter average distance of 9.4 miles, but have a higher average commuting time of 48.9 minutes.

Average Commute Time and Distance by Mode

Travel Mode	Time, minutes	Distance, miles	Estimated Speed, mph
Walk	14.2	1.1	4.8
Privately Owned Vehicle	22.8	12.6	33.2
Bus	48.9	9.4	11.5
Commuter Rail	51.7	12.2	14.1

Shifting Travel Patterns

Socio-demographic changes in the United States are expected to impact travel patterns in coming years. First, while older drivers tend to reduce their daily travel relative to when they were younger, these older drivers are expected to constitute a significantly higher share of total national travel in the future as the baby boom generation ages. Second, 18 million of 150 million U.S. households are made up of new immigrants who tend to have a larger number of persons per household, a greater number of daily household trips, and less likelihood of owning a vehicle; increased immigration can have implications such as increased carpooling, walking, biking, and use of public transit. Third, population redistribution within the United States, such as shifts from the Northeast and Midwest to the Southern and Western States, has the potential to overwhelm the transportation systems in some of these redistributed areas.

Chapter 2

System Characteristics: Highways and Bridges

In 2008, a network of 4.1 million miles of public roads provided mobility for the American people. Rural areas accounted for 73.4 percent of this mileage. While urban mileage constitutes only 26.6 percent of total mileage, these roads carried 60.1 percent of the almost 3.0 trillion vehicle miles traveled (VMT) in the United States in 2008. Urban areas are defined to include all places with a population of 5,000 or greater; all other locations are classified as rural.

In 2009, 25.9 percent of the Nation's 603,310 bridges were located in urban areas; these bridges carried 76.3 percent of total bridge traffic and included 55.9 percent of the total bridge deck area.

Roadways functionally classified as rural local made up 50.2 percent of total mileage in 2008, but carried only 4.4 percent of total VMT. In contrast, the urban portion of the Interstate System made up only 0.4 percent of total mileage but carried 15.2 percent of total VMT.

Percentage of Highway Miles, Bridges, and Vehicle Miles Traveled by Functional System

Functional System	2008 Miles	2008 VMT	2009 Bridges
Rural Areas			
Interstate	0.7%	8.1%	4.2%
Other Principal Arterial	2.3%	7.4%	5.9%
Minor Arterial	3.3%	5.1%	6.4%
Major Collector	10.3%	6.2%	15.4%
Minor Collector	6.5%	1.8%	8.0%
Local	50.2%	4.4%	34.2%
Subtotal Rural	**73.4%**	**33.1%**	**74.1%**
Urban Areas			
Interstate	0.4%	16.1%	4.9%
Other Freeway and Expressway	0.3%	7.5%	3.2%
Other Principal Arterial	1.6%	15.6%	4.5%
Minor Arterial	2.6%	12.7%	4.6%
Collector	2.8%	5.9%	3.3%
Local	18.8%	9.1%	5.3%
Subtotal Urban	**26.6%**	**66.9%**	**25.9%**
Total	**100.0%**	**100.0%**	**100.0%**

Highway mileage increased at an average annual rate of 0.3 percent between 2000 and 2008, while VMT grew at an average annual rate of 1.0 percent.

In 2008, 77.4 percent of highway miles were locally owned, 19.3 percent were owned by States, and 3.2 percent were owned by the Federal government. Bridge ownership is more evenly split; in 2009, 50.2 percent of bridges were locally owned, while 48.1 percent were owned by States.

The term "Federal-aid highways" applies to the subset of the road network that is generally eligible for Federal funding assistance under most programs; this includes all functional systems except for rural minor collector, rural local, and urban local. (Certain programs have broader eligibility criteria that allow funds to be used for any type of road). Federal-aid highways represent 24.5 percent of total mileage and carry 84.7 percent of total VMT.

Highway Functional Classification System

All U.S. Roads

Rural Roads

- **Arterials**
  Principal
    - Interstate
    - Other Principal Arterial
  Minor
- **Collectors**
  Major
  Minor
- **Local**

Urban Roads

- **Arterials**
  Principal
    - Interstate
    - Other Freeway and Expressway
    - Other Principal Arterial
  Minor
- **Collectors**
- **Local**

The 162,944-mile National Highway System (NHS) includes the Nation's key corridors and carries much of its traffic. In 2008, NHS included only 4.0 percent of the Nation's total route mileage and only 6.7 percent of the Nation's total lane miles, but 44.3 percent of VMT in the Nation were on the NHS. Of the total bridges in the Nation, only 19.5 percent are on the NHS; but these bridges comprise 49.2 percent of the total bridge deck area of the Nation.

All of the Interstate System is part of the NHS, as are 83.5 percent of rural other principal arterials, 87.1 percent of urban other freeways and expressways, and 36.3 percent of urban other principal arterials.

Chapter 2

System Characteristics: Transit

Transit system coverage, capacity, and use in the United States continued to increase between 2006 and 2008. In 2008, there were 690 agencies (667 public agencies) in urbanized areas required to submit data to the National Transit Database (NTD). All but 166 of these agencies operated more than one mode. There were also 1,396 rural transit operators that reported. Urban reporters operated 658 motor bus systems, 633 demand response systems, 16 heavy rail systems, 29 commuter rail systems, and 35 light rail systems. There were also 67 transit vanpool systems, 20 ferryboat systems, 7 trolleybus systems, 4 automated guideway systems, 4 inclined plane systems, and 1 cable car system. Not all transit providers are included in these counts since those that do not receive grant funds from the Federal Transit Administration (FTA) are not required to report to the NTD.

These systems operated 73,512 motor buses, 29,833 vans, 11,367 heavy rail vehicles, 6,124 commuter rail cars, and 1,919 light rail cars. Transit providers operated 11,864 miles of track and served 3,078 stations. Light rail systems have been growing fastest since 2006, with track mileage up 5.1 percent and the number of stations served up 3.0 percent. Nonetheless, the Nation's rail system mileage is still dominated (62 percent) by commuter rail. Trends in directional route miles follow growth in track mileage and allow for comparison with nonrail modes.

Transit Urban Directional Route Miles by Mode (Millions of Miles)

Transit Mode	2000	2008	Change 2000–2008
Rail	**9,222**	**11,270**	**22.2%**
Commuter Rail	6,802	8,219	**20.8%**
Heavy Rail	1,558	1,623	**4.2%**
Light Rail	834	1,397	**67.5%**
Other Rail	29	30	**5.2%**
Nonrail	**196,858**	**212,801**	**8.1%**
Bus	195,884	211,664	**8.1%**
Ferryboat	505	682	**34.9%**
Trolleybus	469	456	**-2.8%**
Total	**206,080**	**224,071**	**8.7%**
Percent Nonrail	95.5%	95.0%	

In 2008, transit services provided 10.2 billion unlinked trips and 53.7 billion passenger miles traveled (PMT). Heavy rail and motor bus modes continue to be the largest segments of both measures. Commuter rail supports relatively more PMT due to its greater average trip length (23.4 miles compared with 3.9 for bus, 4.8 for heavy rail, and 4.4 for light rail). Light rail is the fastest-growing rail mode (with PMT growing at 5.7 percent per year between 2000 and 2008) but still provides only 3.9 percent of transit PMT in 2008. Vanpool growth during that period was 11.8 percent per year, substantially outpacing the 1.8 percent growth in motor bus passenger miles, but while motor buses provided 39.5 percent of all PMT, vanpools accounted for only 1.8 percent.

Transit Urban Passenger Miles by Mode (Millions of Miles)

Transit Mode	2000	2008	Change 2000–2008
Rail	**24,604**	**29,989**	**21.9%**
Heavy Rail	13,844	16,850	**21.7%**
Commuter Rail	9,400	11,032	**17.4%**
Light Rail	1,340	2,081	**55.3%**
Other Rail	20	26	**30.0%**
Nonrail	**20,497**	**23,723**	**15.7%**
Motor Bus	18,807	21,198	**12.7%**
Demand Response	588	844	**43.5%**
Vanpool	407	992	**143.7%**
Ferryboat	298	390	**31.0%**
Trolleybus	192	161	**-16.3%**
Other Nonrail	205	138	**-32.7%**
Total	**45,101**	**53,712**	**19.1%**
Percent Rail	54.6%	55.8%	

Rural transit operators reported 136.6 million unlinked passenger trips on 486 million vehicle revenue miles. This included 61 Indian tribes who provided 417,000 unlinked passenger trips. Rural systems provide both traditional fixed-route and demand response services, with 1,150 demand response systems, 494 motor bus systems, and 16 vanpool systems. A total of 304 urbanized area agencies also reported providing rural service at the rate of 24 million unlinked passenger trips on 37 million vehicle revenue miles in 2008. Every state reported providing rural service.

Chapter 3

System Conditions: Highways and Bridges

Poor pavement condition imposes economic costs on highway users in the form of increased wear and tear on vehicle suspensions and tires, delays associated with vehicles slowing to avoid potholes, and crashes resulting from unexpected changes in surface conditions. While transportation agencies consider many factors when assessing the overall condition of highways and bridges, surface roughness most directly affects the ride quality experienced by drivers.

On the NHS, the percentage of VMT on pavements with good ride quality has risen sharply over time, from approximately 48 percent in 2000 to about 57 percent in 2008. (These calendar year values are identified as fiscal year 2001 and 2009 values in some other U.S. DOT publications.) The VMT on NHS pavements meeting the acceptable standard of ride quality increased from 91 percent in 2000 to 92 percent in 2008.

Percent of NHS VMT on Pavements With Good and Acceptable Ride Quality, 2000–2008

	Calendar Year		
Ride Quality	**2000**	**2004**	**2008**
Good (IRI < 95)	48%	52%	57%
Acceptable (IRI ≤ 170)	91%	91%	92%

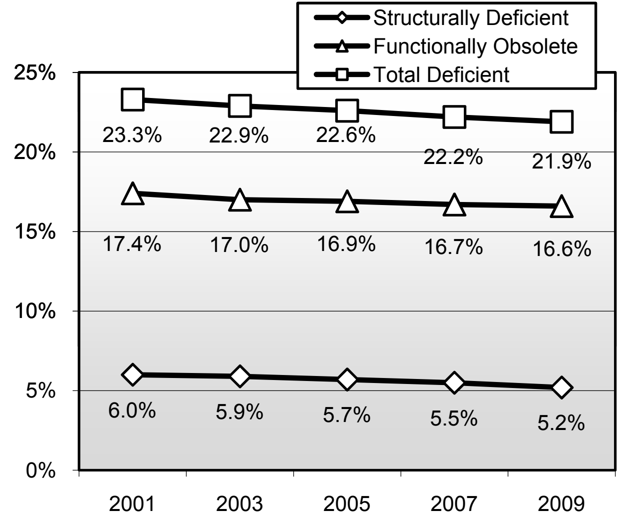
Rural NHS routes tend to have better pavement conditions than urban NHS routes. In 2008, for example, about 97.5 percent of all VMT on rural pavements was traveled on routes with acceptable ride quality. By contrast, the portion of urban NHS VMT on acceptable pavements was 89.0 percent that same year.

For Federal-aid highways as a whole, including the NHS and other arterials and collectors eligible for Federal funding, the VMT on pavements with good ride quality increased from 42.8 percent in 2000 to 46.4 percent in 2008. The VMT on pavements meeting the less stringent standard of acceptable ride quality declined slightly from 85.5 percent in 2000 to 85.4 percent in 2008.

Two terms used to summarize bridge deficiencies are “structurally deficient” and “functionally obsolete.” Structural deficiencies are characterized by deteriorated conditions of significant bridge elements and potentially reduced load-carrying capacity. A “structurally deficient” designation does not imply that a bridge is unsafe, but such bridges typically require significant maintenance and repair to remain in service, and would eventually require major rehabilitation or replacement to address the underlying deficiency. A bridge is considered “functionally obsolete” when it does not meet current design standards (for criteria such as lane width), either because the volume of traffic carried by the bridge exceeds the level anticipated when the bridge was constructed and/or the relevant design standards have been revised. Addressing functional deficiencies may require the widening or replacement of the structure. Rural bridges tend to have a higher percentage of structural deficiencies, while urban bridges have a higher incidence of functional obsolescence due to rising traffic volumes.

The share of total bridges classified as deficient (meaning the share of bridges classified as either structurally deficient or functionally obsolete) fell from 30.1 percent in 2001 to 26.5 percent in 2009. The share of NHS bridges classified as deficient fell from 23.3 percent in 2001 to 21.9 percent in 2009; this reduction was split evenly between structurally deficient and functionally obsolete bridges.

Percentage of NHS Bridges Classified as Deficient, 2001–2009



Chapter 3

System Conditions: Transit

This edition of the C&P report discusses levels of investment needed to achieve a "state of good repair" benchmark. The Federal Transit Administration (FTA) uses a numerical condition rating scale ranging from 1 to 5 (detailed in Chapter 3) to describe the relative condition of transit assets as estimated by the Transit Economic Requirements Model (TERM). Assets are considered to be in a state of good repair when the physical condition of that asset is at or above a condition rating value of 2.5 (the mid-point of the marginal range). An entire transit system is in a state of good repair when all its assets are rated at or above the 2.5 threshold rating. This report estimates the cost of replacing all assets in the national inventory that are past their useful life (that is, below the 2.5 condition rating) to be a total of $78 billion. This is 12 percent of the estimated total asset value of $663.3 billion for the entire U.S. transit industry.

2008 Replacement Value of U.S. Transit Assets (Billions of Current Dollars)

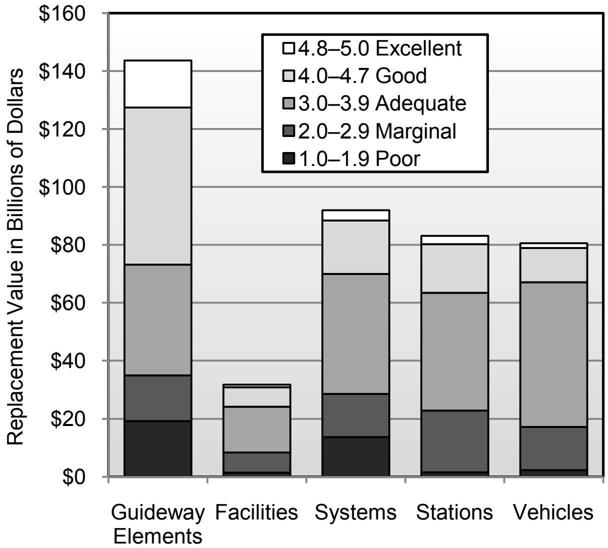
	Replacement Value			
Asset Type	**Nonrail**	**Rail**	**Joint Assets**	**Total**
Maintenance Facilities	$56.4	$33.2	$3.8	**$93.4**
Guideway Elements	$13.1	$234.5	$1.0	**$248.6**
Stations	$3.8	$84.8	$0.6	**$89.1**
Systems	$3.4	$107.5	$1.3	**$112.2**
Vehicles	$41.1	$78.5	$0.5	**$120.1**
Total	**$117.7**	**$538.6**	**$7.0**	**$663.3**

The cost-weighted average condition rating over all bus types is near the bottom of the adequate range (3.18) where it has been without appreciable change for the past decade. Average age is up slightly in all categories (except vans) as is the percentage of vehicles that is below the state of good repair replacement threshold. This is in spite of the fact that new vehicles have entered the fleet faster than at any time in the past decade. The number of vehicles reported is up 17 percent over the last 2 years. This is particularly evident with articulated buses (extra-long buses with two connected passenger compartments), which have grown in number by 25 percent. The average age of the bus fleet is now 6.2 years.

The cost-weighted average condition rating over all rail vehicles is near the middle of the adequate range (3.47) where it has been without appreciable change for the past decade. With average conditions and ages being quite stable over the last 5 years, the most significant aspect of the rail vehicle data presented here is the recent growth in the size of the fleet, which increased by 16 percent, both in total and for each of the individual modes, between 2006 and 2008. This is the largest increase observed over the past decade by far.

Non-vehicle transit rail assets represent the biggest challenge to achieving a state of good repair. The replacement value of guideway elements (track, ties, switches, ballast, tunnels, and elevated structures) is $143.6 billion, of which $19.1 billion is in poor condition (13 percent) and $15.8 billion is in marginal condition. The replacement value of train systems (power, communication, and train control equipment) is $92.0 billion, of which $13.7 billion is in poor condition (15 percent) and $18.9 billion is in marginal condition. The relatively large proportion of guideway and systems assets that are in poor condition, and the magnitude of the $38.2 billion investment required to replace them, represents a major challenge to the rail transit industry.

Distribution of Asset Physical Conditions by Asset Type for All Rail



Chapter 4

Operational Performance: Highways

Drivers continue to experience high levels of congestion on the Nation's highways, leading to travel delays, wasted fuel, and billions of dollars in congestion costs. From an economic perspective, travel time accounts for almost half of all costs experienced by highway users (other key components of user costs include vehicle operating costs and costs associated with crashes).

Three key aspects of congestion are severity, extent, and duration. **Severity** refers to the magnitude of the problem at its worst. The **extent** of congestion is the geographic area or number of people affected. **Duration** of congestion is the length of time that the traffic is congested, often referred to as the "peak period." Since there is no universally accepted definition of exactly what constitutes a congestion "problem," this report uses several metrics to explore different aspects of congestion.

The Texas Transportation Institute (TTI) collects data for 458 urban communities of different sizes across the Nation. The TTI 2009 Urban Mobility Report estimates that drivers experienced nearly 4.2 billion hours of delay and wasted approximately 2.8 billion gallons of fuel in 2007. The total congestion cost for these areas (including the implicit value that travelers place on their lost time) was $87.2 billion.

The Travel Time Index measures the amount of additional time required to make a trip during the congested peak travel period. The average value for all urbanized areas was 1.24 in 2008, indicating that a trip during the peak period would require 24 percent longer than the same trip during off-peak noncongested conditions. For example, a trip of 60 minutes during the off-peak time would require 74.4 minutes during the peak period.

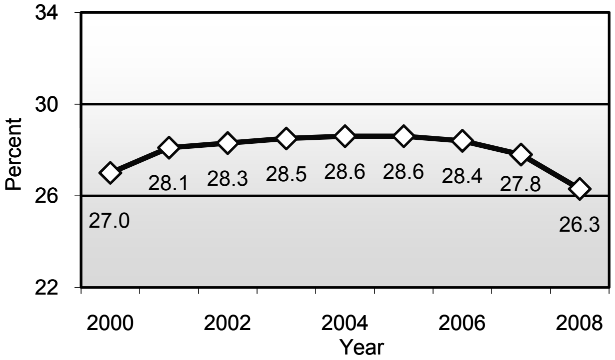
The average Travel Time Index for all urbanized areas had begun to decline in recent years, dropping below its 2000 level of 1.25. This reduction occurred primarily in areas with a population of 1 million or greater. Smaller urbanized areas did not experience the same degree of reduced congestion based on the Travel Time Index or other measures.

Travel Time Index by Urbanized Area Size, 2000–2008

Urbanized Area Population	Year 2000	Year 2004	Year 2008
Less Than 500,000	1.11	1.12	1.11
500,000 to 999,999	1.16	1.18	1.16
1 Million to 3 Million	1.24	1.26	1.23
Over 3 Million	1.36	1.39	1.35
All Urbanized Areas	**1.25**	**1.27**	**1.24**

The average daily percentage of VMT under congested conditions is a metric that indicates the portion of daily traffic on freeways and other principal arterials in an urbanized area that moves at less than free-flow speeds. After increasing from 27.0 percent to 28.6 percent in 2004, this percentage dropped to 26.3 percent in 2008. This decrease can partially be attributed to the reduction in VMT that occurred between 2006 and 2008.

Average Daily Percent of VMT Under Congested Conditions for All Urbanized Areas, 2000–2008



There are different ways in which congestion can be measured. The CEOs for Cities "Driven Apart" report suggests an alternative approach to the TTI methodology. This report is available at: http://www.ceosforcities.org/driven-apart.

A variety of strategies can contribute to reducing congestion. These include the strategic addition of new capacity, increasing the productivity of existing capacity via systems management and operations, providing transportation alternatives along congested corridors, and travel demand management through approaches such as congestion pricing.

Chapter 4

Operational Performance: Transit

Transit operational performance can be measured and evaluated using a number of different factors, including the speed of passenger travel, vehicle utilization, and service frequency.

Average operating speed in 2008 remained consistent with 2006 levels at 19.5 miles per hour across all transit modes. Average operating speed is an approximate measure of the speed experienced by transit riders and is affected by dwell times and the number of stops. The average speed of nonrail modes was 13.7 miles per hour in 2008, the same as was reported in 2000. Rail mode operating speeds have decreased from 24.9 miles per hour in 2000 to 23.9 miles per hour in 2008.

Average vehicle occupancy levels did not change significantly between 2000 and 2008. The most significant changes over that period were a 7.5 percent increase for heavy rail and a 7.6 percent decrease for light rail. Light rail decreases may be due to the addition of new capacity in that mode over this period. Several urbanized areas, including Denver, Phoenix, Seattle, Charlotte, and Salt Lake City, opened new light systems during this period of time. The nonrail modes were practically unchanged.

Adjusting for the number of seats on an average vehicle for each mode, it can be seen that, as expected, vanpool and heavy rail vehicles, on the average, run closer to capacity than other modes.

Vehicle Occupancy Averages by Mode

Transit Mode	Passenger Count	Seat Count	Percent Occupied
Demand Response	1.2	10	12.3%
Motor Bus	10.8	39	27.8%
Commuter Rail	35.7	126	28.3%
Ferryboat	118.1	405	29.2%
Trolleybus	14.3	47	30.4%
Light Rail	24.1	63	38.3%
Heavy Rail	25.7	53	48.5%
Vanpool	6.3	11	57.5%

Between 2000 and 2008, transit agencies have provided substantially more vanpool, demand response, and light rail service. These modes have far outpaced motor bus, with its 1.3 percent per year growth rate in revenue miles, and heavy rail with its 1.6 percent growth rate. Vanpool, growing at almost 12.3 percent per year, is set to become a major mode. Demand response is starting to account for a great number of service miles, though with an average of only 1.2 passengers, it is still a small contributor to the total number of passenger trips.

Change From 2000 to 2008 in Vehicle Revenue Miles by Mode (Millions of Miles)

Transit Mode	2000	2008	Change 2000–2008
Rail	879	1,053	**19.8%**
Heavy Rail	578	655	**13.3%**
Commuter Rail	248	309	**24.6%**
Light Rail	51	86	**68.6%**
Other Rail	2	3	**50.0%**
Nonrail	2,322	2,840	**22.3%**
Motor Bus	1,764	1,956	**10.9%**
Demand Response	452	688	**52.2%**
Vanpool	62	157	**153.2%**
Ferryboat	2	3	**50.0%**
Trolleybus	14	11	**-21.4%**
Other Nonrail	28	25	**-10.7%**
Total	**3,201**	**3,893**	**21.6%**

Productivity per active vehicle increased between 2000 and 2008. Vehicle in-service mileage has increased steadily from 2000 to 2008 for all the major modes. Light rail has shown particularly strong growth, though from a low starting point. Demand response has also shown a strong improvement in vehicle miles per active vehicle.

Change From 2000 to 2008 in Vehicle Revenue Miles per Active Vehicle

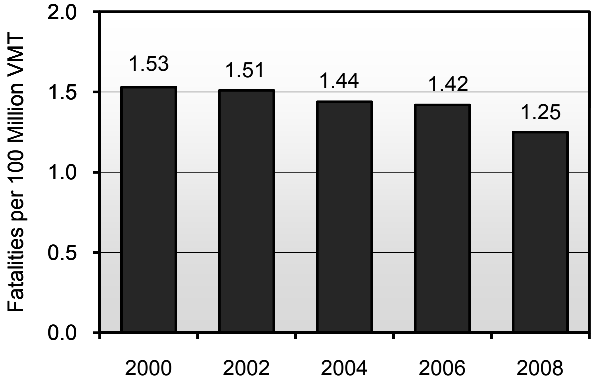
Mode	Thousands of Vehicle Revenue Miles 2000	Thousands of Vehicle Revenue Miles 2008	Average Annual Rate of Change 2008/2000
Rail	**130.2**	**147.3**	**1.6%**
Heavy Rail	55.6	57.7	0.5%
Commuter Rail	42.1	45.5	1.0%
Light Rail	32.5	44.1	3.9%
Nonrail	**101.9**	**106.5**	**0.6%**
Motor Bus	28.0	30.3	1.0%
Demand Response	17.9	21.3	2.2%
Ferryboat	24.1	21.9	-1.2%
Vanpool	12.9	14.3	1.3%
Trolleybus	18.9	18.7	-0.1%

Chapter 5

Safety: Highways

There has been considerable progress in reducing the number of highway fatalities since 1966, when Federal legislation first addressed highway safety. That year, the fatality rate was 5.50 fatalities per 100 million vehicle miles traveled (VMT). This figure dropped to 1.53 in 2000 and 1.25 in 2008. The total number of highway fatalities decreased from 41,945 in 2000 to 37,261 in 2008. (Preliminary data for 2009 indicate further declines in the fatality rate to 1.13; highway fatalities dropped to 33,808 in 2009, the lowest number since 1950.)

Highway Fatality Rates, 2000 to 2008



From 2000 to 2008, the number of fatalities on urban roadways decreased by about 1 percent from 16,113 to 15,983. During this same period, fatalities on rural roads decreased by almost 16 percent from 24,838 to 20,905. Urban Interstate highways were the safest functional system, with a fatality rate of 0.47 per 100 million VMT in 2008. Although the fatality rate on rural local roads declined from 3.45 to 3.08 per 100 million VMT from 2000 to 2008, this functional system continues to have the highest fatality rate.

Approximately 53 percent of highway fatalities in 2008 involved a roadway departure, in which a vehicle left its travel lane and crashed. While roadway design and environmental factors play a role in these types of crashes, behavioral factors such as driver intoxication, driver fatigue, driver drowsiness, and driver distraction also have a significant impact. Some roadway departures can be attributed to drivers being distracted while attempting to operate mobile devices. The U.S. DOT is leading efforts to help educate drivers and promote a greater understanding of the issue.

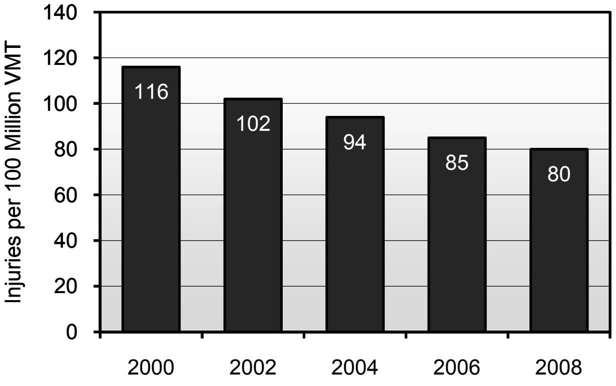
In 2008, approximately 21 percent of highway fatalities occurred at intersections. Of these fatalities, about 61 percent occurred in urban areas. Older drivers and pedestrians are particularly at risk at intersections. About 40 percent of the fatal crashes for drivers aged 80 or older and about one-third of the pedestrian deaths among people aged 70 or older occurred at intersections.

Other major crash types involve speeding and alcohol-related incidents. Speeding was a contributing factor in 31 percent of fatal crashes with 11,674 lives lost. Alcohol-related crashes continue to be a serious public safety problem that accounted for 13,846 deaths and 41 percent of fatal crashes in 2008.

In terms of vehicle type, the number of occupant fatalities that involved passenger cars decreased from 20,699 in 2000 to 14,587 in 2008. Fatalities for occupants of light trucks and large trucks also declined, while motorcycle fatalities grew by almost 83 percent over this period from 2,897 in 2000 to 5,290 in 2008.

The overall number of traffic-related injuries has decreased over time, from about 3.1 million in 2000 to about 2.3 million in 2008. In 2000, the injury rate was 116 per 100 million VMT; by 2008, the number had dropped to 80 per 100 million VMT.

Highway Injury Rates, 2000 to 2008



Chapter 5

Safety: Transit

Public transit in the United States has been and continues to be a highly safe mode of transportation, as evidenced by the statistics on incidents, injuries, and fatalities that have been reported by transit agencies for the vehicles they operate directly. Reportable safety incidents include collisions and any other type of occurrence that results in death, a reportable injury, or property damage in excess of a threshold. Since 2002, an injury has been reported only when a person has been immediately transported away from the scene of a transit incident for medical care. Any event producing a reported injury is also reported as an incident. Injuries and fatalities include those suffered by riders as well as by pedestrians, bicyclists, and people in other vehicles. Reportable security incidents include a number of serious crimes (robberies, aggravated assaults, etc.), as well as arrests and citations for minor offenses (fare evasions, trespassings, other assaults, etc.). Injuries and fatalities may occur not only while traveling on a transit vehicle, but also while boarding, alighting, or waiting for a transit vehicle or as a result of a collision with a transit vehicle or on transit property.

The definition of transit-related fatalities has remained the same. Non-homicide/non-suicide fatalities decreased from 245 in 2000 to 216 in 2008, and dropped from 0.56 per 100 million passenger miles traveled (PMT) in 2000 to 0.42 per 100 million PMT in 2008. Both the fatalities for 2008 and the rate per 100 million passenger miles demonstrate that transit is an extremely safe mode of transportation. With the fatality count steadily trending down since 2002, it experienced an unexplained increase of 30 deaths in 2007.

Data on incidents (safety and security combined) and injuries per 100 million PMT for transportation services on the five largest modes from 2004 to 2008 (excluding suicides and homicides) suggests that the highway modes (motor bus and demand response) became significantly safer in 2007 and 2008; however, given this dramatic decrease is unexplained, the data for these years may also suggest a reporting inconsistency. Data for the rail modes is volatile, but does not suggest any significant positive or negative trends over this period.

Although commuter rail has a very low number of incidents per PMT, commuter rail incidents are far more likely to result in a fatality than incidents occurring on any other mode. Most likely, this is because the average speed of commuter rail vehicles is considerably higher than the other rail modes (except vanpools). Motor buses, on the other hand, have a high number of incidents per PMT, but a lower chance of having an incident result in a fatality than almost any other mode (perhaps related to their low average speed).

Annual Transit Fatality (Non-Suicide/Homocide) Count and Rate, 2000–2008

Year	Fatality Count	Fatalities per 100 Million PMT
2000	245	0.56
2001	236	0.52
2002	249	0.55
2003	224	0.50
2004	217	0.48
2005	214	0.47
2006	213	0.44
2007	243	0.48
2008	216	0.42

Annual Transit Incidents and Injuries by Mode, 2004–2008

Analysis Parameter	2004	2005	2006	2007	2008
Incidents per 100 Million PMT					
Motor Bus	77	74	79	66	54
Heavy Rail	45	40	42	43	53
Commuter Rail	20	22	19	18	16
Light Rail	63	67	62	61	48
Demand Response	895	1,010	1,298	247	204
Injuries per 100 Million PMT					
Motor Bus	76	70	71	69	67
Heavy Rail	33	26	32	31	43
Commuter Rail	17	21	17	18	16
Light Rail	42	37	36	44	48
Demand Response	449	506	729	227	234

Chapter 6

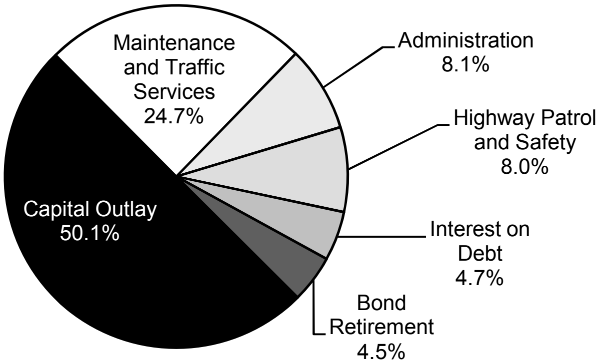
Finance: Highways

All levels of government combined generated $192.7 billion in 2008 to fund spending on highways and bridges; actual cash expenditures for highways and bridges were lower, totaling $182.1 billion in 2008. (The difference reflects amounts placed in reserve for expenditures in future years.)

Cash outlays by the Federal government for highway-related purposes were $40.0 billion (22.0 percent of the combined total), including both direct highway expenditures and amounts transferred to State and local governments for use on highways. States provided $90.6 billion (49.7 percent). Counties, cities, and other local government entities funded $51.5 billion (28.3 percent).

Of the total $182.1 billion spent for highways in 2008, $91.1 billion (50.1 percent) was used for capital investment. Spending on routine maintenance and traffic services totaled $44.9 billion (24.7 percent); administrative costs (including planning and research) were $14.7 billion; $14.6 billion was spent on highway patrol functions and safety programs; $8.5 billion was used to pay interest; and $8.2 billion was used for bond retirement.

Highway Expenditures by Type, 2008



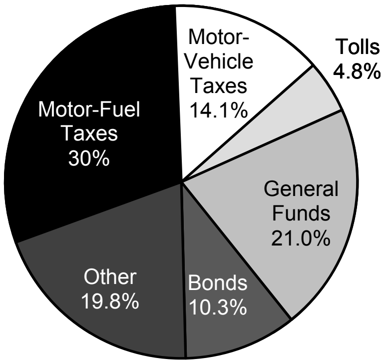
Total highway expenditures by all levels of government increased by 48.4 percent between 2000 and 2008. Local government spending grew more quickly than Federal or State spending over this period; the share of total expenditures funded by the Federal government declined from 22.4 percent in 2000 to 22.0 in 2008.

Federal cash expenditures for capital purposes outlay grew by 48.6 percent, from $26.1 billion in 2000 to $37.8 billion in 2008, while combined State and local capital investment increased by 51.5 percent. Consequently, the Federally-funded share of total capital outlay declined over this period (from 42.6 percent to 41.5 percent).

Of the total $82.7 billion of capital spending by all levels of government in 2008, $46.6 billion (51.1 percent) was used for system rehabilitation (resurfacing or replacing existing pavements and rehabilitating or replacing existing bridges). An estimated $33.6 billion (36.8 percent) was used for system expansion (constructing new roads and bridges or adding lanes to existing roads); and $11.0 billion (9.0 percent) went for system enhancements such as safety, operational, or environmental enhancements.

In 2008, $94.2 billion (48.9 percent) of the revenue generated for spending on highways and bridges came from highway-user charges—including motor-fuel taxes, motor-vehicle fees, and tolls. Other major sources of revenues for highways included general fund appropriations of $40.4 billion (21.0 percent) and bond proceeds of $19.9 billion (10.3 percent). All other sources such as property taxes, other taxes and fees, lottery proceeds, interest income, and miscellaneous receipts totaled $38.2 billion (19.8 percent).

Revenue Sources for Highways, 2008

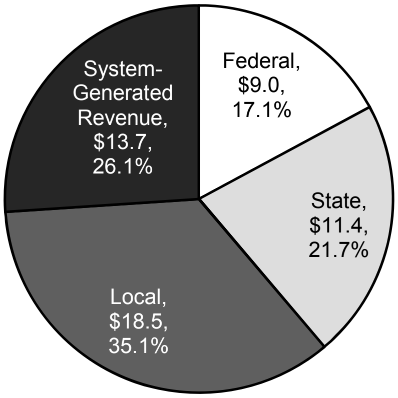


Chapter 6

Finance: Transit

In 2008, $52.5 billion was generated from all sources to finance transit investment and operations. Transit funding comes from *public funds* allocated by Federal, State, and local governments and *system-generated revenues* earned by transit agencies from the provision of transit services. Of the funds generated in 2008, 73.9 percent ($38.8 billion) came from public sources and 26.1 percent came from passenger fares ($11.4 billion) and other system-generated revenue sources ($2.3 billion). The Federal share of this was $9.0 billion (23.1 percent of total public funding and 17.1 percent of all funding). Local jurisdictions provided the bulk of transit funds, $18.5 billion in 2008, or 47.5 percent of total public funds and 35.1 percent of all funding.

2008 Public Transit Revenue Sources (Billions of Dollars)



In 2008, total public transit agency expenditures for *capital* investment were $16.1 billion and accounted for 41.5 percent of total available funds. Federal funds were $6.4 billion in 2008, 39.8 percent of total transit agency capital expenditures. State funds provided an additional 12.4 percent and local funds provided the remaining 47.8 percent of total transit agency capital expenditures. Of total 2008 transit capital expenditures, 76.4 percent ($12.3 billion) was invested in rail modes of transportation, compared with 23.6 percent ($3.8 billion) invested in nonrail modes. This investment distribution has been consistent over the last decade.

2008 Transit Capital Expenditures by Mode (Millions of Dollars)

Transit Mode	Expenditure	Percent of Total
Rail	**$12,292.5**	**76.4%**
Commuter Rail	$2,686.2	16.7%
Heavy Rail	$6,125.8	38.1%
Light Rail	$3,458.3	21.5%
Other Rail	$22.2	0.1%
Nonrail	**$3,796.3**	**23.6%**
Motor Bus	$3,355.3	20.9%
Demand Response	$263.9	1.6%
Ferryboat	$113.2	0.7%
Trolley Bus	$44.6	0.3%
Other Nonrail	$19.3	0.1%
Total	**$16,088.8**	**100.0%**

In 2008, $36.4 billion was available for transit operating expenses (wages, salaries, fuel, spare parts, preventive maintenance, support services, and leases). The Federal share of this has declined from the 2006 high of 8.2 percent to 7.1 percent. Similarly, the share generated from system revenues has decreased from 40.3 percent in 2006 to 37.6 percent. These decreases have been offset by the State share, which has increased from 22.5 percent in 2006 to 25.8 percent. The local share of operating expenditures has been close to 2008's 29.7 percent for several years.

The average annual increase in operating expenditures per vehicle revenue mile for all modes combined between 2000 and 2008 was 4.1 percent. In 2008, the average operating expenditure across all transit modes was $8.60 per vehicle revenue mile. Analysis of National Transit Database reports for the largest 10 transit agencies (by ridership) shows that the growth in operating expenses is led by the cost of fringe benefits (36.0 percent of all operating costs for these agencies), which have been going up at a rate of 3.4 percent per year above inflation (constant dollars) since 2000. By comparison, average salaries at these ten agencies grew at an inflation-adjusted rate of only 0.1 percent per year in that period. Operating expenditures per passenger mile for all transit modes combined increased at an average annual rate of 4.3 percent between 2000 and 2008 (from $0.44 to $0.62).

Part II

Investment/Performance Analysis

The methods and assumptions used to analyze future highway, bridge, and transit investment scenarios for this report have evolved over time, to incorporate current research, new data sources, and improved estimation techniques relying on economic principles.

Traditional engineering-based analytical tools focus mainly on estimating transportation agency costs and the value of resources required to maintain or improve the conditions and performance of infrastructure. This type of analytical approach can provide valuable information about the cost effectiveness of transportation system investments from the public agency perspective, including the optimal pattern of investment to minimize life-cycle costs. However, this approach does not fully consider the potential benefits to users of transportation services from maintaining or improving the conditions and performance of transportation infrastructure.

The investment/performance analyses presented in Chapters 7 through 10 were developed using the Highway Economic Requirements System (HERS), the National Bridge Investment Analysis System (NBIAS), and the Transit Economic Requirements Model (TERM). Each of these tools has a broader focus than traditional engineering-based models and takes into account the value of services that transportation infrastructure provides to its users as well as some of the impacts of transportation activity on non-users. The methodologies used to analyze investment for highways, bridges, and transit are detailed in Appendices A, B, and C.

For purposes of computing a benefit-cost ratio for a transportation project, the "cost" (the denominator) is conventionally measured as the capital expenditures required to carry out the project. The "benefits" (the numerator) are generally measured in terms of reductions in costs experienced by (1) transportation agencies (such as for maintenance), (2) users of the transportation system (such as savings in travel time or vehicle operating costs, or reductions in crashes), and (3) others who are affected by the operation of the transportation system (such as reductions in environmental or other societal costs). Increases in any of these types of costs are treated as negative benefits.

An economics-based approach will likely result in different decisions about the catalog of desirable improvements than would a purely engineering-based approach. For example, if a highway segment, bridge, or transit system is greatly underutilized, benefit-cost analysis might suggest that it would not be worthwhile to fully preserve its condition or to address its engineering deficiencies. Conversely, a model based on economic analysis might recommend additional investments to expand capacity or improve travel conditions above and beyond the levels dictated by an analysis that simply minimized engineering life-cycle costs, if doing so would provide sufficient benefits to the users of the system. These types of considerations can potentially influence the establishment of standards as to what constitutes a "State of Good Repair" for different types of transportation assets.

An economics-based approach also provides a more sophisticated method for prioritizing potential improvement options when funding is constrained. By ranking investment opportunities in order of their benefit-cost ratios, economic analysis helps provide guidance in directing limited resources toward those improvements that provide the largest benefits to transportation system users. Projects selected for implementation can be limited to those having a benefit-cost ratio above the threshold that would result in all available funds being used; projects that produce lesser net benefits can be deferred for future consideration.

HERS, NBIAS, and TERM each use benefit-cost analysis as part of their decision-making process, but their approaches are very different. Each model relies on separate databases, making use of specific data available for only one part of the transportation network and addressing issues unique to that particular mode. The models have not evolved to the point where direct multimodal analysis is possible.

Part II

Investment/Performance Analysis (continuation)

Chapter 7 analyzes the projected impacts of different levels of future capital investment on a series of measures of physical condition, operational performance, and other benefits to system users. These levels are described in terms of both average annual investment levels over 20 years, and the annual rate of increase or decrease in constant dollar investment that could generate these levels.

Chapter 8 presents a set of **illustrative** 20-year capital investment scenarios building upon the analysis presented in Chapter 7. **The Department does not endorse or recommend any particular scenario.** The investment levels associated with each scenario represent hypothetical levels of combined capital spending nationwide; the scenarios do not identify how much might be contributed by each level of government or from private sources to support such spending.

Some of these scenarios are oriented toward achieving a particular level of system performance. In considering the future system performance impacts identified for each scenario, it is important to note that they represent hypothetical models of what **could** be achievable assuming a particular level of investment rather than what **would** be achieved in reality. While the economics-based approach applied in HERS, NBIAS, and TERM would suggest that projects be implemented in order based on their benefit-cost ratios until the funding available under a given scenario is exhausted, the reality is that other factors influence Federal, State, and local decision making. If some projects with lower benefit-cost ratios were carried out in favor of projects with higher benefit-cost ratios, then the actual amount of investment required to achieve any given level of performance would be higher than the amount predicted in this report. Further, several assumptions, estimates, and projections are used to derive the investment scenarios and no effort to assess the predictive value of these models has been undertaken to date. As in any modeling process, simplifying assumptions have been adopted to make analysis practical and report within the limitations of available data.

Other scenarios are defined around funding all potential investments above a specified benefit-cost ratio threshold. It is important to note that simply increasing spending to the levels identified in these scenarios would not in itself guarantee that these funds would be expended in a cost-beneficial manner. Also, some potential capital investments selected by the models may be infeasible as a practical matter due to factors beyond those considered in the models. Because of this, the supply of feasible cost-beneficial projects could be exhausted at a lower level of investment than that indicated by these scenarios, and the projected improvements to future conditions and performance associated with these scenarios may not be fully obtainable in practice.

Chapter 9 provides supplemental scenario analyses, including comparisons of recent system performance and funding trends with projected future needs in order to identify consistencies and inconsistencies between what has occurred in the past and what is expected for the future. In addition, projections from selected prior editions are compared with actual spending and outcomes over time. Issues relating to the interpretation of scenarios, including the timing of future investment and the conversion of scenarios from constant dollars to nominal dollars, are also explored.

Chapter 9 includes a set of supplemental analyses that assume that any increases in highway and bridge spending above 2008 levels would be funded from user charges imposed on either a per-mile or a per-gallon basis. The general effect of such charges is to reduce future travel and reduce the projected level of investment needed to achieve a particular performance objective. These analyses also examine the potential impacts that the widespread adoption of congestion pricing might be expected to have on the level of investment required to achieve certain levels of future conditions and performance.

Chapter 10 explores the impact that changing some key technical assumptions could have on the overall results projected by HERS, NBIAS, and TERM.

Chapter 7

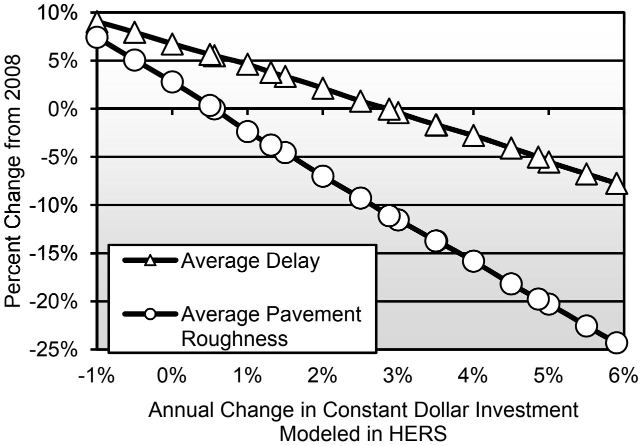
Potential Capital Investment Impacts: Highways and Bridges

Of the $91.1 billion of total capital outlay by all levels of government combined in 2008, $54.7 billion was used for types of capital improvements modeled in HERS, including pavement resurfacing, pavement reconstruction, and system expansion. (HERS models investments on Federal-aid highways only; $12.7 billion was spent on similar types of improvements to other roads.) In 2008, $12.8 billion was spent on improvement types modeled in NBIAS, including bridge repair, rehabilitation, and replacement. The remaining $11.0 billion went for system enhancements not captured by either model.

Sustaining HERS-modeled capital spending on Federal-aid highways at its base year 2008 level in constant dollar terms for 20 years (i.e., an annual change in spending of zero percent) is projected to result in a worsening of overall system performance in 2028 relative to 2008, including a 2.8 percent increase in pavement roughness, and a 6.7 percent increase in average delay per VMT; if annual spending growth were negative, HERS projects even larger increases in pavement roughness and delay by 2028.

HERS projects that if constant dollar spending were to grow by 5.90 percent per year, this would be sufficient to finance all potentially cost-beneficial capital improvements on Federal-aid highways by 2028; at this level of investment, average pavement roughness and delay are projected to improve by 24.3 percent and 7.7 percent, respectively, over the period 2008 through 2028.

Projected Changes in 2028 Highway Condition and Performance Measures Compared With 2008 Levels, for Different Spending Growth Rates Relative to 2008



The NBIAS model estimates that there was a backlog of potentially cost-beneficial bridge investments in 2008 of $121.2 billion, of which $102.1 billion was on Federal-aid highway bridges, $60.4 billion was on NHS bridges, and $38.1 billion was on Interstate System bridges. (These figures do not include costs associated with system expansion modeled separately in HERS.) In the absence of future capital investment, this backlog would grow over time as existing bridges age.

If spending by all levels of government for the types of improvements modeled in NBIAS were sustained at 2008 levels ($12.8 billion—all bridges; $9.4 billion—Federal-aid highway bridges; $5.4 billion—NHS bridges; $3.3 billion—Interstate System bridges) in constant dollar terms, NBIAS projects that this would be sufficient to reduce the backlog by 2028 for Interstate System bridges, NHS bridges, and all bridges; however, the backlog for Federal-aid highway bridges would increase by an estimated 6.5 percent, driven primarily by the subset of bridges on Federal-aid highways that are not on the NHS.

Impact of Sustaining Spending at 2008 Levels Through 2028 on Economic Bridge Investment Backlog

System Subset	2008 Bridge Backlog (Billions of 2008 Dollars)	Percent Change by 2028
Interstate Bridges	$38.1	-3.6%
NHS Bridges	$60.4	-1.8%
Federal-Aid Highway Bridges	$102.1	6.5%
All Bridges	$121.2	-11.2%

NBIAS projects that eliminating the economic bridge investment backlog and addressing new bridge deficiencies as they arise over 20 years would require an annual increase in constant dollar spending of 4.31 percent for all bridges, 5.36 percent for Federal-aid highway bridges, 4.48 percent for NHS bridges, and 4.39 percent for Interstate System bridges.

Chapter 7

Potential Capital Investment Impacts: Transit

U.S. transit agencies spent a combined $16.1 billion in 2008 on capital improvements to the Nation's transit infrastructure and vehicle fleets. This amount included $11.0 billion in the preservation (rehabilitation and replacement) of existing assets already in service and $5.1 billion to expand transit capacity—both to accommodate ridership growth and to improve performance for existing riders.

Sustaining TERM-modeled transit capital spending at these base year 2008 levels for 20 years is projected to result in an overall decline in both transit system conditions and performance. This includes an overall deterioration in the average physical condition of the Nation's stock of transit assets, with consequent performance impacts on service reliability and potentially on safety, an estimated 50 percent increase in the size of the "State of Good Repair" (SGR) backlog by 2030, and increases in vehicle crowding on the order of 5 to 30 percent (depending on the magnitude of ridership growth).

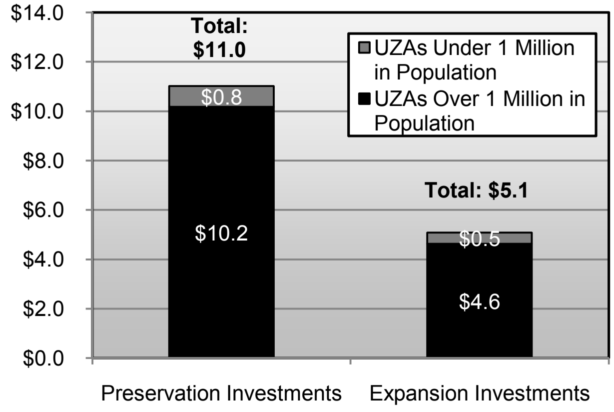
For this edition of the report, the FTA developed an **SGR benchmark** scenario which estimates the investment required to *attain* and *maintain* a state of good repair for the Nation's existing transit assets. Prior editions of this report included scenarios that were based on *maintaining* conditions or *improving* the condition of assets. Details of the new scenarios relative to past scenarios are provided in Chapter 9 and its Executive Summary.

Accordingly, for the **SGR benchmark** scenario, TERM estimates the average annual level of 20-year investment required to eliminate the existing investment backlog and bring *all* existing transit assets to the SGR benchmark to be roughly $18.0 billion (without consideration of investment cost-effectiveness) and closer to $17.0 billion if limited to those asset reinvestments passing TERM's cost-benefit analysis. Similarly, an additional $4.2 billion to $7.3 billion in annual expansion investments are required to maintain transit performance (as measured by vehicle crowding) at 2008 levels, depending on the actual rate of growth in ridership.

When limited to urbanized areas (UZAs) with populations greater than 1 million, transit agencies expended $14.8 billion on capital projects in 2008, including $10.2 billion on asset preservation and $4.6 billion on transit capacity expansion. In contrast, the average annual investment level for these UZAs to attain SGR is estimated to be $15.6 billion over the next 20 years (without consideration of investment cost effectiveness) and closer to $14.5 billion to $15.1 billion if limited to those asset reinvestments passing TERM's cost-benefit analysis. These scenarios suggest that an additional $2.6 billion to $6.1 billion are required to support projected increases in transit boardings while maintaining current service performance levels (as measured by the number of riders per peak vehicle).

Transit agencies operating outside of UZAs with populations greater than 1 million expended $1.3 billion on capital projects in 2008, including $0.8 billion on preservation and $0.5 billion on asset expansion. In contrast, the average annual investment level for these smaller UZAs and all rural areas to attain SGR is estimated to be $2.4 billion over the next 20 years (or approximately $2.0 billion if limited to those reinvestments passing TERM's benefit-cost analysis), while the level of average annual investment required to address both SGR and asset expansion needs of these smaller UZAs and rural areas is estimated to be between $2.5 billion and $2.8 billion, depending on the level of ridership growth.

2008 Transit Capital Expenditures
(Billions of Dollars)



Chapter 8

Selected Capital Investment Scenarios: Highways

This report presents a set of illustrative 20-year capital investment scenarios; this report does not endorse any of these scenarios as a target level of funding, nor does it make any recommendations concerning future levels of Federal funding. The scenarios for highways and bridges build upon separate analyses developed using HERS and NBIAS and take into account other types of capital spending that are not currently modeled. The scenario criteria were applied separately to the Interstate System, the NHS, Federal-aid highways, and the highway system as a whole.

The **Sustain Current Spending scenario** assumes that capital spending is sustained in constant dollar terms at base year 2008 levels between 2009 and 2028. (In other words, spending would rise by exactly the rate of inflation over that period).

The **Maintain Conditions and Performance scenario** assumes that capital investment gradually changes in constant dollar terms over 20 years to the point at which selected measures of highway and bridge performance in 2028 are maintained at their base year 2008 levels. The average annual investment levels associated with meeting these goals are $24.3 billion for the Interstate System, $38.9 billion for the NHS, $80.1 billion for Federal-aid highways, and $101.0 billion for all roads. The cost to maintain value identified for the NHS is lower than the $42.0 billion spent by all levels of government combined on the NHS in 2008, indicating that sustaining NHS spending at 2008 levels could result in improved overall conditions and performance on the NHS.

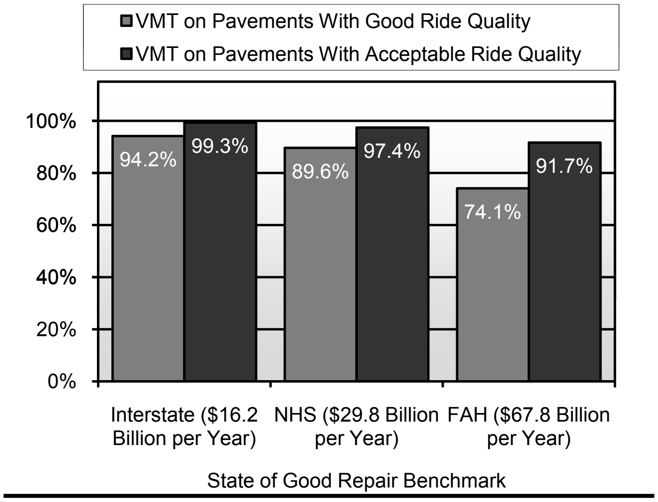
The **Improve Conditions and Performance scenario** assumes that capital investment gradually rises in constant dollar terms to the point at which all potentially cost-beneficial investments could be implemented by 2028. This scenario can be thought of as an "investment ceiling" above which it would not be cost-beneficial to invest. The average annual investment level for this scenario is $170.1 billion for all roads, 86.6 percent higher than actual spending in 2008.

Average Annual Investment Levels for Selected Highway Scenarios (Billions of 2008 Dollars)

System Subset	Sustain Current Spending	Maintain Conditions and Performance	Improve Conditions and Performance
Interstate	$20.0	$24.3	$43.0
NHS	$42.0	$38.9	$71.8
Federal-Aid Highways	$70.6	$80.1	$134.9
All Roads	$91.1	$101.0	$170.1

Of the $170.1 billion **Improve Conditions and Performance scenario** investment level for all roads, $85.1 billion (50 percent) would be directed toward improving the physical condition of existing infrastructure assets; this amount is identified as the **State of Good Repair benchmark**. The average annual **State of Good Repair benchmark** levels identified for Federal-aid highways, the NHS, and the Interstate System are $67.8 billion, $29.8 billion, and $16.2 billion, respectively. Investing at these levels could bring the share of Federal-aid highway VMT on pavements with good ride quality up from 46.4 percent in 2008 to 74.1 percent by 2028; the comparable percentages for the NHS and the Interstate System could be increased to 89.6 percent and 94.2 percent, respectively, by 2028. HERS projects that improving these measures beyond this point would not be cost-beneficial.

Impact of Investing at the State of Good Repair Benchmark Level on Pavement Ride Quality



Chapter 8

Selected Capital Investment Scenarios: Transit

This report presents a set of illustrative 20-year transit capital investment scenarios. The scenarios for transit capital needs build upon analyses developed using TERM and were applied separately to the Nation's transit assets as a whole, as well as for two separate groupings of transit operators based on the size of the UZAs they serve.

The **Sustain Current Spending scenario** assumes that capital spending is sustained in constant dollar terms at year 2008 levels between 2009 and 2028. Transit operators spent $16.1 billion on capital projects in 2008. Of this amount, $11.0 billion was devoted to the preservation of existing assets while the remaining $5.1 billion was dedicated to investment in asset expansion to support ongoing ridership growth and to improve service performance. This scenario considers the expected impact on the physical conditions and performance of the Nation's transit infrastructure if these expenditure levels are sustained in constant dollar terms. TERM analysis suggests that sustaining spending at 2008 levels would likely yield an overall decline in transit conditions, an estimated 50 percent increase in the SGR backlog by 2030, and an increase in crowding on transit passenger vehicles.

The **State of Good Repair (SGR) benchmark** estimates the level of annual capital investment required to eliminate the current transit investment backlog and then maintain all transit assets in a state of good repair thereafter, all without consideration of the cost-effectiveness of each investment (i.e., investments are not required to pass TERM's benefit-cost test under this scenario). TERM estimates this annual level of investment to be $18.0 billion for the Nation as a whole. This includes $15.6 billion for UZAs with populations greater than 1 million (with most of these funds required for rail asset reinvestment), and $2.4 billion for the remaining smaller UZAs and rural areas currently served by transit.

The **Low Growth** and **High Growth scenarios** consider the level of investment to address both asset SGR and service expansion needs subject to two differing potential levels of growth (and with all investments now required to pass a benefit-cost analysis). The **Low Growth scenario** assumes transit ridership will grow as projected by the Nation's metropolitan planning organizations (MPOs), while the **High Growth scenario** assumes the average rate of growth (by UZA) as experienced in the industry since 1999. The **Low Growth scenario** assumes that ridership will grow at an annual rate of 1.4 percent over the 20-year period from 2008 to 2028; conversely, the **High Growth scenario** assumes that ridership will increase at a rate of 2.8 percent per year over that time frame. TERM estimates this average annual level of investment to be between $20.8 billion and $24.5 billion for the Nation as a whole between 2008 and 2028, including from $16.6 billion to $17.2 billion for asset preservation and $4.2 billion to $7.3 billion for expansion needs, depending on the realized rate of ridership growth.

When limited to the UZAs with populations greater than 1 million, the average annual level of investment to address both SGR and expansion needs is $18.2 billion to $21.7 billion. The comparable range for the smaller UZAs and all rural areas with transit is $2.5 billion to $2.8 billion annually.

Annual Average Cost by Investment Scenario (2008–2028)

Mode and Asset Type	Investment (Billions of 2008 Dollars) SGR	Low Growth	High Growth
UZAs Over 1 Million in Population			
Nonrail	$4.9	$5.6	$6.9
Rail	$10.7	$12.7	$14.8
Total*	**$15.6**	**$18.2**	**$21.7**
UZAs Under 1 Million in Population and Rural			
Nonrail	$2.1	$2.4	$2.6
Rail	$0.3	$0.2	$0.2
Total*	**$2.4**	**$2.5**	**$2.8**
Total*	**$18.0**	**$20.8**	**$24.5**

** Note that totals may not sum due to rounding.*

Chapter 9

Supplemental Scenario Analysis: Highways

As noted earlier, Chapter 8 includes scenarios for selected subsets of the overall highway system. The particular analyses from Chapter 9 discussed below apply to Federal-aid highways only, not to all roads.

The goal of the **Maintain Conditions and Performance scenario** is to maintain overall conditions and performance for the lowest cost possible, without regard to how various system components might be affected. In practice, the conditions and performance of higher-ordered functional systems such as principal arterials tend to improve under this scenario, offset by some deterioration on lower-ordered systems. Maintaining pavement condition, bridge condition, and operational performance for each individual functional class would be more expensive. While the average annual investment level associated with the **Maintain Conditions and Performance scenario** for Federal-aid highways is $80.1 billion, maintaining these specific performance measures on individual functional systems would cost $88.8 billion per year.

The baseline scenarios presented in this report assume no linkages between future investment needs and the types of financing mechanisms that might be utilized to address those needs. In reality, increasing user charges to support additional future spending would have an impact on the cost of driving, and hence would affect future VMT growth. The widespread adoption of congestion pricing would have a particularly significant impact on future system performance and investment needs.

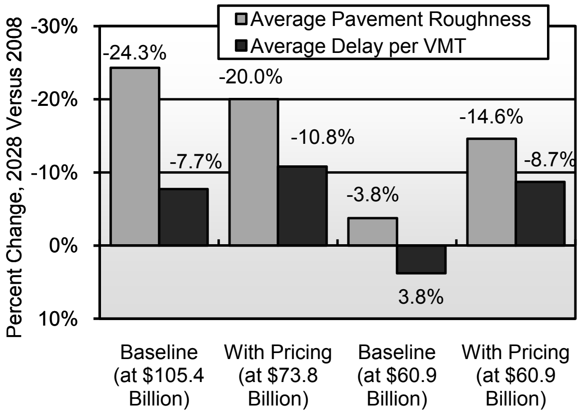
Cost of Maintaining System Components Versus Maintain Conditions and Performance Scenario for Federal-Aid Highways (Billions of 2008 Dollars)

Functional System	Cost to Maintain System Components	Maintain Conditions and Performance Scenario
Rural Arterials and Major Collectors		
Interstate	$4.2	$4.5
Other Principal Arterial	$4.2	$4.0
Minor Arterial	$5.0	$3.4
Major Collector	$7.7	$4.4
Subtotal	**$21.1**	**$16.2**
Urban Arterials and Collectors		
Interstate	$18.7	$23.5
Other Freeway and Expressway	$7.9	$10.1
Other Principal Arterial	$16.8	$12.7
Minor Arterial	$15.4	$12.4
Collector	$8.9	$5.1
Subtotal	**$67.7**	**$63.9**
All Federal-Aid Highways	**$88.8**	**$80.1**

Of the average annual investment level associated with the **Maintain Conditions and Performance scenario** for Federal-aid highways, $60.9 billion was derived from HERS. At this level of investment, HERS projects that average pavement roughness would improve by 3.8 percent, while average delay per VMT would worsen by 3.8 percent. Assuming the widespread adoption of congestion pricing, the model predicts improvements of 14.6 percent in average pavement roughness and 8.7 percent in average delay. (Under this alternative, HERS changes its mix of spending in favor of pavements, resulting in improved pavement conditions.)

Of the $134.9 billion average annual investment level for the **Improve Conditions and Performance scenario** for Federal-aid highways, $105.4 billion was derived from HERS; assuming the widespread adoption of congestion pricing, HERS projects that an average annual investment level of only $73.8 billion would be needed to address all potentially cost-beneficial improvements.

Potential Impact of Congestion Pricing on 2028 System Performance Measures Compared With 2008, for Different Average Annual Investment Levels



Chapter 9

Supplemental Scenario Analysis: Transit

Prior editions of this report included scenarios that considered the level of investment required either to (1) *maintain* the condition of existing transit assets at current levels or to (2) *improve* the condition of those assets to an overall condition of "good" (i.e., 4.0 on TERM's condition scale). For this edition, these "maintain" and "improve" conditions scenarios have been replaced by the **SGR benchmark**, which estimates the investment required to *attain* and *maintain* a state of good repair for the Nation's existing transit assets. The **SGR benchmark** is financially unconstrained and considers the level of investment required to eliminate the current investment backlog and to address all reinvestment needs as they arise such that all asset conditions remain at 2.5 or higher on TERM's condition scale. This change was found to have two key implications.

First, analysis has determined that, given a high proportion of existing long-lived assets currently in good or excellent condition, it is not realistic or rational to attempt to maintain asset conditions at current levels over the next 20 years. Assuming transit operators follow reasonable asset rehabilitation and replacement policies, asset conditions are likely to decline (even as the proportion of assets not in SGR is reduced) until *existing* transit assets attain a "steady state" average condition value that reflects a given set of rehabilitation and replacement practices.

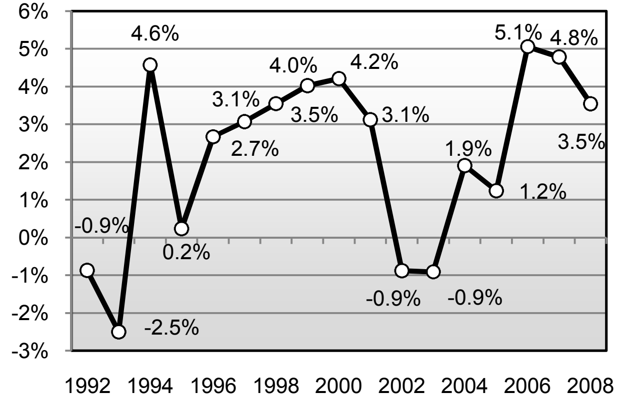
Second, only a significant and ongoing investment in expansion assets can reverse this general downward trend in conditions. Moreover, it is just this type of ongoing expansion in new transit assets over the past two decades that has tended to reduce the rate of decline in average conditions across all transit assets (both new and existing). Analysis suggests that this effect has tended to mask somewhat the underlying decline in asset conditions for *existing* (as opposed to existing plus new) transit assets.

Also in contrast to prior report editions, which only considered a single ridership growth projection, this edition assesses transit capital expansion under both low and high ridership growth outcomes. Specifically, the **Low Growth scenario** assumed UZA-specific rates of PMT growth projected by the Nation's MPOs, while the **High Growth scenario** assumed the UZA-specific average annual compound rates based on historical growth rate averages.

Analysis shows that historical rates of PMT growth have typically exceeded the MPO-projected rates of growth typically used for long-range transportation planning purposes. (In the past, the MPO-projected rates have been the only source of ridership growth estimates used to generate transit expansion needs in prior editions of this report.) For example, from 1992 to 2008, the historical compound annual PMT growth rate averaged roughly 2.1 percent compared with the 1.3 percent growth rate MPOs have projected for the upcoming 20-year period.

Given the difference between the two growth rates (and the relatively high rate of historic PMT growth as compared with other measures, such as UZA population growth), the 2.1 percent historical growth rate of PMT was identified as a reasonable input value for the **High** (or higher) **Growth scenario**. Similarly, the 1.3 percent MPO-projected growth rate was used as an input value for the **Low** (or lower) **Growth scenario**.

Annual Change in Passenger Miles Traveled, All Urbanized and Rural Areas



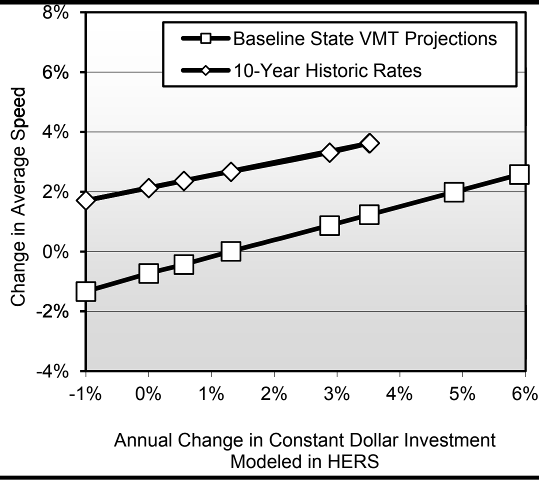
Chapter 10

Sensitivity Analysis: Highways and Bridges

States provide forecasts of future VMT for each individual HPMS sample section evaluated in HERS; for 2008, the weighted average annual VMT growth rate based on these forecasts is 1.85 percent. HERS assumes that these forecasts represent the annual growth in travel over 20 years that would occur if a constant level of service is maintained on that facility. This assumption is reflected in the baseline analysis presented in this report, for which HERS estimates that an annual constant dollar spending increase of 5.90 percent could be sufficient to fund all potentially cost-beneficial investments by 2028, translating into an average annual investment level of $105.4 billion (compared with the $54.7 billion spent in 2008 on the types of capital spending modeled in HERS).

To explore the possibility that traffic might grow more slowly than assumed, an alternative HERS analysis was conducted assuming for illustration that VMT will grow at the average annual rate of 1.23 percent, the historical average from 1998 to 2008. Modifying the input forecasts to match this VMT growth rate would reduce the benefits associated with pavement and capacity improvements, so that an annual spending increase of only 3.52 percent (translating into an average annual investment level of $80.2 billion) would be sufficient to fund all potentially cost-beneficial projects by 2028. If spending were instead sustained at 2008 levels, HERS projects that average speeds would improve by 2.1 percent under this alternative compared with a decline of 0.7 percent under the baseline assumptions.

Projected Changes in 2028 Average Speed Compared With 2008 for Different Spending Growth Rates and Two Constant Price VMT Growth Assumptions



Another sensitivity test concerns the growth rate between 2008 and 2028 in motor fuel prices relative to general rate of inflation. The baseline HERS assumption is of no difference between these rates. An alternative assumption was based on the High Oil Price case from the Energy Information Administration, *Annual Energy Outlook 2010.* In this case, the ratio of gasoline prices to the consumer price index nearly regains its 2008 level by 2012 and increases thereafter through 2028 at the equivalent of 3.4 percent annually. The change in assumption from the baseline case causes HERS to reduce its projection of future travel growth and reduces the model's estimate of the average annual investment level needed to fund all projects with a benefit-cost ratio of 1.0 or higher by 2028 to $96.9 billion.

Increases in travel time clearly impose costs on drivers, but it is difficult to precisely quantify the value of time, much less forecast changes. Increasing the baseline estimate of the value of time by 25 percent would cause HERS to attribute more benefits to projects (particularly widening projects) that would result in travel time savings. This in turn would increase the estimate of potentially cost-beneficial investment to $114.0 billion per year.

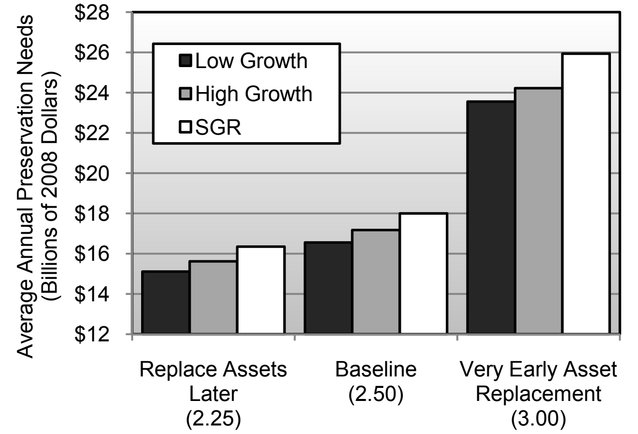
The HERS and NBIAS models each apply a discount rate to future benefits to reflect the implicit cost associated with directing resources to improve highways or bridges that could otherwise be used elsewhere in the public or private sector. Reducing the discount rate from the baseline 7 percent to 3 percent (reflecting lower interest rates) would increase the HERS estimate of the average annual investment level needed to fund all potentially cost-beneficial projects to $129.0 billion. The comparable average annual investment level projected by NBIAS for all bridges would be $24.8 billion assuming a 3 percent discount rate, about 21 percent more than the $20.5 billion baseline value computed based on a 7 percent discount rate.

Chapter 10

Sensitivity Analysis: Transit

TERM relies on a number of key input values, variations of which can significantly impact the value of TERM's capital needs projections. Each of the three unconstrained investment scenarios examined in Chapter 8—including the **SGR benchmark** and the **Low Growth** and **High Growth scenarios**—assumes that assets are replaced at a condition rating of 2.50 as determined by TERM's asset condition decay curves. Analysis suggests that each of these scenarios is sensitive to changes in this replacement condition threshold, with the sensitivity increasing disproportionally the higher the replacement condition threshold is increased. For example, reducing the condition threshold to 2.25 tends to reduce preservation needs by just under $2 billion (close to 10 percent). In contrast, increasing the threshold to 2.75 increases preservation needs by more than $3 billion (just under 20 percent), while a further threshold increase to 3.00 increases preservation needs by nearly $8 billion (over 40 percent). This increasing sensitivity reflects the fact that ongoing, equal incremental changes to the replacement condition threshold yield greater proportionate reductions in the length of the asset life cycles as higher replacement condition values are reached.

Impact of Alternative Replacement Condition Thresholds on Transit Preservation Investment Needs by Scenario



Needs estimates for scenarios employing TERM's benefit-cost analysis are also particularly sensitive to changes in capital costs (assuming no comparable increase in benefits), as these increases tend to reduce the value of the benefit-cost ratio, causing some previously acceptable projects to fail this test. For example, a 25 percent increase in capital costs increases investment costs by just under $3 billion (nearly 14 percent) for the **Low Growth scenario** and by just under $4 billion (over 15 percent) for the **High Growth scenario**. In contrast, needs under the **SGR benchmark** (which does not utilize TERM's benefit-cost test) increase by more than $4 billion (precisely 25 percent) in response to a 25 percent increase in capital costs.

The most significant source of transit investment benefits as assessed by TERM's benefit-cost analysis is the net cost savings to users of transit services, a key component of which is the value of travel time savings. Consequently, the per-hour value of travel time for transit riders is a key driver of total investment benefits for scenarios that employ TERM's benefit-cost test. For example, a doubling of the value of time increases total needs for the **Low Growth** and **High Growth scenarios** by approximately $2 to $3 billion (8 to 10 percent) due to the increase in total benefits relative to costs. Similarly, a halving of the value of time decreases total investment needs for these scenarios by approximately $3 billion each (12 to 14 percent.

Finally, TERM's benefit-cost test is responsive to the discount rate used to calculate the present value of the streams of investment costs and benefits. For example, reducing the discount rate from the base rate of 7 percent to 3 percent yields approximately $1 to $2 billion (6 to 8 percent) increase in total investment needs under the **Low Growth** and **High Growth scenarios,** respectively.

Impact of Alternative Value of Time Rates for Selected Transit Scenarios (Billions of 2008 Dollars)

Changes in Value of Time	Low Growth	High Growth
Reduce 50% ($5.60)*	$17.91	$21.51
Baseline ($11.20)*	$20.76	$24.47
Increase 100% ($22.40)*	$22.40	$26.99
Inflate to 2008 Dollars ($13.49)	$21.05	$24.87

**Multiplier values expressed in 2003 dollars.*

Chapter 11

Environmental Sustainability

The 1987 United Nations (UN) World Commission on Environment and Development defined sustainability as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." While other organizations have defined sustainability differently, a common concept that has emerged is the "triple bottom line," referring to the economy, the environment, and society. In transportation, the triple bottom line relates to sustainable solutions for the natural environmental systems surrounding the transportation system, the economic efficiency of the system, and societal needs (e.g., mobility, accessibility, and safety).

Transportation is crucial to our economy and quality of life, but the process of building, operating, and maintaining transportation systems has environmental consequences. Fostering more environmentally sustainable approaches to transportation is essential in order to avoid negative impacts in the near term and to ensure that future generations will be able to enjoy the same or better standards of living and mobility as exist today. Sustainable transportation focuses on environmental impacts such as improved energy efficiency, reduced dependence on oil, reduced greenhouse gas (GHG) emissions, and other improvements to the natural environment involving air quality and water quality.

From a sustainability perspective, the heavy reliance of the transportation system on fossil fuels is of significant concern, as they are non-renewable; generate air pollution; and contribute to the buildup of carbon dioxide (CO_2) and other GHGs, which trap heat in the Earth's atmosphere. The United States has relatively high GHG emissions per capita, even compared with other similarly affluent countries. The transportation sector consumes 29 percent of the total energy used in the United States; this represents 5 percent of global GHG emission.

Over the past four decades, progress has been made in reducing emissions of air pollutants both nationally and from the transportation sector in particular. However, many Americans continue to live in regions that exceed health-based air-quality standards. To seek more sustainable options, transportation programs will need to focus on designing, constructing, maintaining, and operating infrastructure in ways that accommodate multiple modes of transportation, promote connectivity, and minimize environmental impacts.

Establishing Sustainability Goals

At this time there is no widely recognized and accepted method for measuring sustainability in the transportation community. One of the challenges is the need to shift from operations-focused performance measures to more holistic indicators, even if they are more difficult to quantify.

At the Federal level, environmental sustainability has been adopted as a strategic goal in the U.S. DOT Strategic Plan 2010-2015. At the State level, transportation agencies are developing metrics that address various aspects of sustainability and monitoring progress toward specific goals—often in their long-range and project-level planning process. Some potential measures that have been identified for assessing progress in improving sustainability relate to reducing GHG emissions, improving system efficiency, reducing the growth of VMT, transitioning to fuel-efficient vehicles and alternative fuels, and increasing the use of recycled materials in transportation.

Sustainability in Transportation Planning

The transportation planning process provides a forum for discussion of environmental, economic, and community concerns and can facilitate the inclusion of sustainability considerations into transportation projects. One example of efforts to respond to the challenge of creating a sustainable transportation system is the increased use of context sensitive solutions (CSS). A CSS approach requires that transportation planning consider the interaction between transportation systems and tailor them to the local area's human, cultural, and natural environment.

Chapter 12

Climate Change Adaptation

Climate change has received increased attention over the last decade, with a key concern being the impact on people and the planet. For the transportation community, policies to address climate change focus on GHG mitigation and climate change adaptation. Climate change adaptation focuses on anticipating potential future changes (e.g., higher sea levels, increased temperatures, altered precipitation patterns, greater storm intensity) and the potential impact on transportation (e.g., damaged or flooded facilities).

Impacts of Climate Change Adaptation on Transportation

Research efforts regarding the potential impacts of climate change on highway infrastructure are ongoing. U.S. DOT released a report on projected changes in climate over the century, used geographical information systems to map areas with transportation infrastructure along the Atlantic coast that will be potentially vulnerable to sea level rise, and is conducting a second adaptation study focused on the Gulf Coast region. These studies identify potential climate change impacts that are widespread and modally diverse and that would stress transportation systems in ways beyond which they were designed.

Temperature and sea levels have risen in recent decades, and these rates of change may accelerate in the future as GHG concentrations rise. Climate change has the potential to cause real damage to transportation infrastructure and services.

Steps for Assessing Adaptation Needs

Transportation agencies across the Nation are addressing climate change mitigation issues at various levels; however, the issue of adapting transportation infrastructure to climate change impacts has received less widespread attention. Discussions to date have focused primarily on coastal States.

Adapting to the impacts of climate change starts with inventorying critical infrastructure, understanding potential future climate change impacts, and assessing vulnerabilities and risks.

Once adaptation needs are assessed, adaptation options can be classified in one of five broad categories. "Maintain, manage, and operate" strategies make no changes to the base transportation facility and focus on repairing damages as they occur. A "protect and strengthen" approach involves proactively strengthening a facility to meet new design standards that can withstand climate change effects. "Relocate and avoid" strategies move existing facilities to areas less threatened by climate change. An "abandon and disinvest" approach involves discontinuing service on facilities when it is no longer financially feasible to continue investment in them given current or potential threats. "Promote redundancy" strategies are aimed at adding assets that could serve as backup facilities if primary facilities fail.

Barriers to Action

A critical obstacle to creating adaptation strategies is the lack of adequate information on how and when the climate will change. Without this type of information, assessment of risk and designing development strategies are difficult. Transportation design, maintenance, and replacement will need to be more flexible to incorporate climate adaptation considerations.

Adaptation Activities

Adaptation activities are underway at both the Federal and State levels. The U.S. DOT is working to develop models to assess and identify climate change vulnerabilities and risks to critical transportation assets. Additional studies on regional impacts of climate changes are also in process.
At the State level, climate change adaptation action plans to consider necessary adaptation and mitigation strategies are being developed by several States.

Chapter 13

Livability

Fostering livable communities—places where transportation, housing, and development have been coordinated to provide access to adequate, affordable, and environmentally sustainable transportation options—is a goal of the U.S. DOT.

Transportation plays an important role in creating safer, healthier communities with the strong economies needed to support our families.

A key component of livable communities is having transportation choices. A multimodal system that integrates walking, bicycling, transit, and automobile access provides residents with more choices of where to live, work, and play. Integrating land use planning with transportation improves livability by fostering a balance of mixed-use neighborhoods that recognizes the importance of proximity, layout, and design to help keep people close to home, work, services, and recreation.

Benefits of Livable Communities

The following are some of the many benefits to considering the role of transportation in creating livable communities:

- Provides more transportation options and integrates land use planning
- Promotes healthy living
- Improves pedestrian safety
- Proves popular with citizens
- Increases economic competitiveness
- Incentivizes business investment
- Lowers transportation costs
- Saves community infrastructure costs.

HUD/DOT/EPA Partnership

In June 2009, the U.S. DOT, HUD, and EPA initiated an Interagency Partnership for Sustainable Communities (Partnership) to improve access to affordable housing, provide more transportation options, and lower transportation costs while protecting the environment in communities nationwide. The Partnership established six livability principles as follows:

- Provide more transportation choices
- Promote equitable, affordable housing
- Enhance economic competitiveness
- Support existing communities
- Coordinate policies and leverage investment
- Value communities and neighborhoods.

Livability Performance Measures

Communities across the United States have begun tracking the implementation process and accessibility outcomes of livability investments that expand transportation options. However, it is easier to articulate the benefits of livable communities than to quantify them; work is continuing to reach a consensus in terms of what data should be collected on a consistent basis nationwide to track progress in improving livability.

Given the limitations of the data that are currently available, the U.S. DOT has identified some interim measures to begin tracking progress in meeting the goal of fostering livable communities. The President's FY 2012 Budget includes the following measures and targets relating to livability:

- Increase the number of States with policies that improve transportation choices for walking and bicycling from 21 in 2010 to 23 in 2012.
- Increase access to convenient and affordable transportation choices as reflected by the average percentage change in transit boarding per transit market by 2.0 percent per year from 2010 to 2012.
- Improve access to transportation for special needs populations as reflected by the percentage of bus fleets compliant with the Americans with Disabilities Act (ADA) from 97 percent in 2007 to 98 percent in 2012 and increase the percentage of key rail stations that are ADA compliant from 93 to 95 percent between 2007 and 2012.

PART I

Description of Current System

Introduction

Chapters 1 through 6 are designed to provide a broad overview of the current status of the Nation's highway and transit systems, as well as to describe historic trends. These retrospective analyses serve as a foundation for the prospective analyses contained in Part II and other sections of the C&P report.

Chapter 1, **Household Travel in America**, provides statistics on how the American public uses the Nation's transportation system, drawing upon information gathered as part of the 2009 National Household Travel Survey (NHTS).

Chapter 2, **System Characteristics**, describes the extent and use of the Nation's highways, bridges, and transit systems.

Chapter 3, **System Conditions**, describes the current physical condition of the Nation's highways, bridges, and transit systems and how the overall physical condition of this infrastructure has changed in recent years.

Chapter 4, **Operational Performance**, analyzes how well the highway and transit infrastructure has performed in accommodating increasing demand for travel.

Chapter 5, **Safety**, describes the safety performance of highways and transit systems.

Chapter 6, **Finance**, describes the levels and types of highway and transit expenditures made by Federal, State, and local governments and identifies the sources of revenue that support these programs.

Chapter 1

Household Travel in America

Household Travel in America

Over 300 million people in the United States make decisions every day about how to travel for work, shopping, and social reasons—choices based on habits of behavior, personal and household obligations, the choices available and perception of convenience and cost. These individual decisions happen within a larger context of demographic profiles (such as life cycle); economic wherewithal (income); where individuals live; how technology is used; available transportation options; and how the transportation system is used. Personal travel accounts for roughly three-quarters of the measured vehicle miles traveled (VMT) on the Nation's roadways. Commercial and freight vehicles account for the remaining travel.

This chapter draws heavily from the National Household Travel Survey (NHTS), the Nation's authoritative source of statistical data on the travel of the American public. This survey has been conducted in 1969, 1977, 1983, 1990, 1995, 2001, and 2009. Each update in the series provides a snapshot of personal daily travel, including the number of persons and vehicles in movement through an average day by all modes (automobile, transit, bike, walk, etc.) and for all purposes. The 2009 NHTS data represent a valuable resource that can be tapped for a wide array of analyses on a variety of topics; this chapter focuses on three such topics: (1) shifting travel demand resulting from demographic factors; (2) how people use the transportation system; and (3) household vehicle use and greenhouse gas impacts.

National Household Travel Survey (NHTS) Methodology

The NHTS collects travel data from a representative sample of U.S. households to characterize personal travel patterns. The survey includes demographic characteristics of households and people and information about all vehicles in the household. Details of travel by all modes for all purposes of each household member are collected for a single assigned travel day. In this way, the NHTS traces both the interaction of household members and the use of each household vehicle throughout an average day. The data provide national and, with the 2009 survey, State-level estimates of trips and miles by travel mode, trip purpose, time of day, gender and age of traveler, and a wide range of attributes.

Much of the data presented in this section is from the NHTS data series, unless otherwise noted. Since 1990, the NHTS has been collected using a random digit dial sample of telephone households in the United States. Earlier surveys were collected in face-to-face interviews sampled from respondents to the Census Bureau's Current Population Survey.

Additional information on the NHTS is available at www.fhwa.dot.gov/policy/ohpi/nhts.

Shifting Travel Patterns

Many factors determine U.S. travel patterns. For example, travel can be affected by technological changes that allow telecommuting and on-line shopping, land-use factors that encourage density and walkable communities, social changes such as growth in social networking, and policy factors such as graduated licensing programs. All of these factors have unique and combined impacts on the travel choices of the U.S. population.

There are many challenges facing transportation policy and planning within each of these areas. While there is a great deal of uncertainty as to how travel demand will be impacted by things like the economy, housing market, and gas prices, studying current individual travel behaviors can provide insight into travel demand and future travel.

This section explores three topics to assess the changing context of travel demand in more detail:

- The aging of the U.S. population and the impact on travel demand
- Immigration and the growing diversity of the U.S. population
- Population redistribution across the United States.

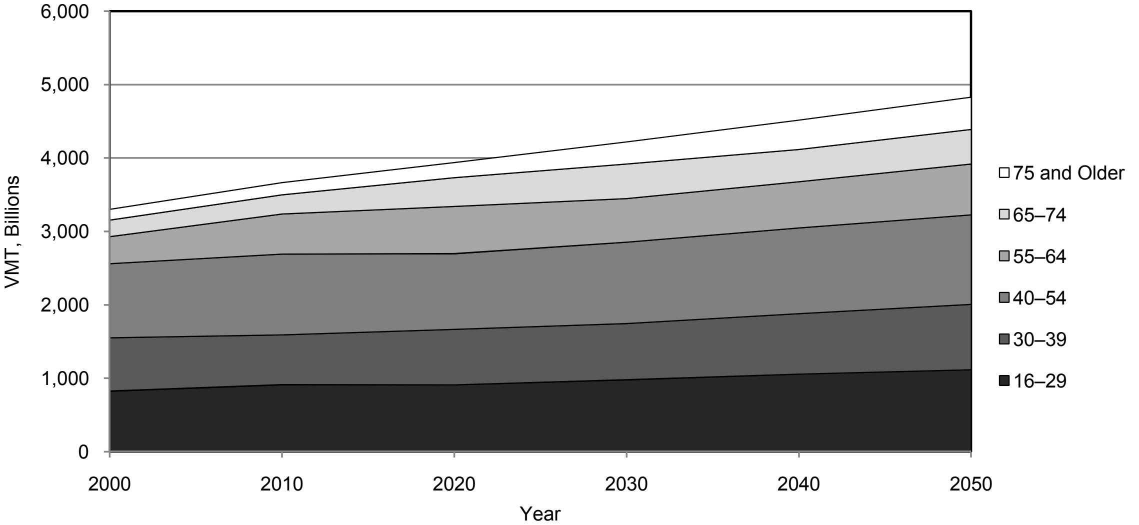
Aging of U.S. Population and Impact on Travel Demand

The aging of the population and the possible effects on travel demand has been the subject of much research and debate. In this decade, the U.S. Census Bureau estimates that the number of seniors and baby boomers will account for approximately one-third of the Nation's total population and exceed 100 million. As the population ages, some experts expect older drivers to travel fewer miles and favor non-peak travel to avoid congested travel conditions. Others foresee mode shifts—especially from single-occupant to multi-occupant vehicles—increased safety challenges, and mobility issues as more older Americans cease driving. (TRB *Conference Proceeding 27: Transportation in an Aging Society: A Decade of Experience, Technical Papers and Reports from a Conference*, 2004, http://onlinepubs.trb.org/onlinepubs/conf/reports/cp_27.pdf)

Given current population age distribution, the number of older drivers will increase in the future. *Exhibit 1-1* shows a conservative projection which assumes that typical driving patterns for older Americans will not change, and that the increase in vehicle miles is fueled by simple population growth estimates through 2050. Even if baby boomers follow historic patterns and reduce their daily travel as they age, the sheer number of added older drivers will significantly increase the number of miles and proportion of national VMT accounted for by older drivers.

Exhibit 1-1

VMT by Age Group, 2000–2050



Source: FHWA 2009 NHTS for current estimates of annual driver miles; U.S. Census Bureau for population projections.

Most researchers expect baby-boomers, especially women, to drive more miles when they age than the current elderly population because boomers are more likely to have licenses, be employed, and have a vehicle. Older Americans driving higher vehicle miles may increase their chance of accidents, change traditional time-of-day profiles of travel, and lead to more emissions because older drivers tend to drive older cars. In addition, the proportion of older drivers who are women will increase dramatically, especially women of

Hispanic and Asian ethnicity. Currently only half of older Asian and Hispanic women drive, but 80 percent of Asian and Hispanic women aged 30–54 are drivers. Increasingly, women of all races and ethnicities will become the 80-year-old drivers of the future. As the mix of drivers changes, so will their destination choices, trip lengths, auto occupancies, and vehicle choices.

Immigration and Growing Diversity of U.S. Population

The U.S. population is increasing by about 2 million people annually, about half from immigration and half from births. We are becoming more diverse in terms of race and ethnicity, and immigration is a key cause of that diversity (U.S. Census Bureau); America has always been a melting pot. As these trends continue, this diversity will impact future travel patterns.

Historically, factors that influence growth in travel beyond population growth include the age distribution of the population, auto ownership levels, licensure rates, household size, labor force participation, and real personal income per capita. African-American, Hispanic, and, to some extent, Asian households vary considerably from white households on these key factors. Common among these groups is lower auto ownership, lower household income, greater household size, and lower levels of labor force participation, lower licensure rates, and a population concentration in urban areas.

The differences in key measures of travel are shown in *Exhibit 1-2*. Households often have differences between the annual trips per household and the annual trips per person. For example, Hispanic households produce the greatest amount of travel annually (nearly 5 thousand trips), but have one of the lowest number of trips per person (1.3 thousand trips). Similarly, Asian households have the second-largest number of annual trips (3.9 thousand) and a much lower number of trips per person (1.3 thousand). White households, in comparison, average 3.7 thousand trips per household per year and 1.5 thousand trips per person, the highest level of person-based trip-making among all the demographic groups.

Exhibit 1-2

Annual Trip Rates and Vehicle Ownership by Race and Ethnicity

	Annual Trips		Vehicles
	per Household	**per Person**	**per Household**
White non-Hispanic	3,693.9	1,525.2	1.99
Black non-Hispanic	3,609.5	1,318.9	1.38
Asian non-Hispanic	3,868.6	1,342.5	1.74
Other non-Hispanic	3,506.2	1,461.4	1.90
Hispanic	4,979.5	1,327.9	1.69

Source: FHWA 2009 NHTS.

In the United States, it is difficult to discuss race and ethnicity without some discussion on immigration. The NHTS includes information on place of birth and year of entry to the United States. Immigrants, especially new immigrants, travel in significantly different ways than U.S.-born residents; however, that behavior follows a continuum from new entry to full assimilation. After 10 years living in the United States, immigrants travel much like U.S. born residents.

As shown in *Exhibit 1-3*, new immigrants (in the United States less than 10 years) differ significantly in key demographic indicators of travel. Compared with the national average, the percentage of immigrants who drive is smaller; on average, immigrants work closer to home, live in larger households, make a greater number of household trips per day, and are less likely to own vehicles.

Immigrants have a disproportionate impact on work travel, as over 80 percent of immigrants arriving in the 5 years prior to the 2000 Census were in their main working years of 16–64. In fact, new immigrants constituted all the growth in the number of workers between the ages of 16–54 during the same period.

New immigrants are much more likely to carpool, walk, bike, or use public transit for their commute to work; as they represent a growing proportion of the workforce, their commuting patterns will tend to affect the overall national trends.

NHTS data show that when looking at all trips, new immigrants are seven times as likely to use transit and are twice as likely to walk as the U.S. born population. Nineteen percent of new immigrants do not have a household vehicle as compared with 13 percent of immigrants in the United States for 11 or more years. The average percentage of U.S. born households without a vehicle is just under 8 percent. *Exhibit 1-4* shows vehicle acquisition for immigrant household by year in the United States.

As immigrants assimilate into the United States, the share of trips they make by vehicle tends to increase. Asian immigrants make a faster transition to automobile use, while Hispanic immigrants remain more likely to use transit than the U.S. born population even after 20 years in the United States. New immigrants on average are more transit dependent, having lower levels of vehicle ownership; they also tend to carpool more.

Exhibit 1-3

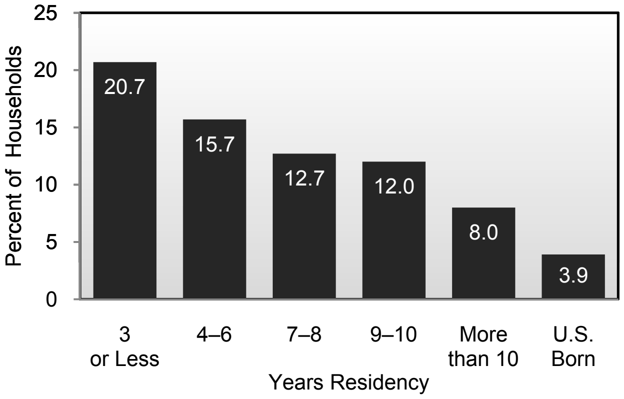
Key Demographic and Travel Characteristics of New Immigrants

Functional System	New Immigrants	National Average
Demographic Characteristics		
Average Household Size	3.6	2.6
Average Workers per Household	2.0	1.4
Average Vehicles per Household	1.3	1.7
Home Ownership	16.1%	72.3%
Travel Characteristics		
Percent Drivers (16+)	60.6%	91.5%
Usual Distance to Work (miles)	9.5	13.2
Usual Time to Work (minutes)	24.6	25.5
Average Daily Trips per Household	10.2	9.6

Source: FHWA 2009 NHTS.

Exhibit 1-4

Immigrant Households with No Vehicle by Number of Years Residency in the U.S.



Source: FHWA 2009 NHTS.

Overall Trends in Demand

Accompanying these contextual transformations are more subtle changes to some basic travel demand indicators, such as the growth in the driving-age population, vehicle saturation, changes in household structure, and a more flexible workforce. Understanding these changes will put the trends in travel demand into a context that will help develop "evidence-based" policies and initiatives.

The United States experienced a long period of growing travel demand in the last half of the Twentieth Century. This growth was a product of demographic shifts and economic bounty fueled partially by baby boomers entering the workforce, acquiring vehicles, and starting their own families, and a dramatic rise in service sector substitutes for traditional "at-home" activities such as child care and meal preparation.

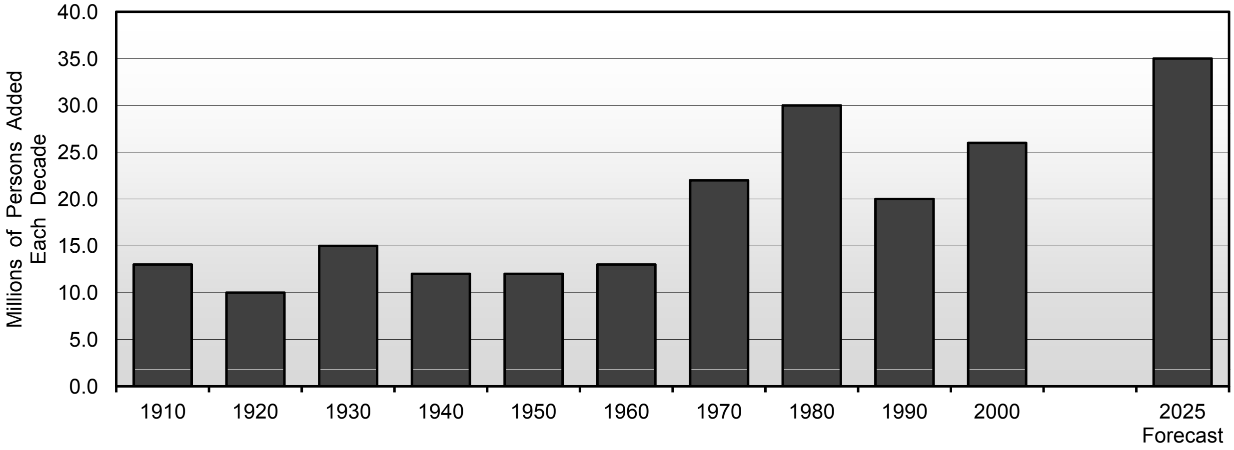
Over the four decades the NHTS has been collecting data, growth in travel demand, and especially vehicle travel, has been correlated with the following:

- Growth in the population of drivers and workers
- Increased vehicle availability
- Increased vehicle miles per driver
- More recently, shifts in household composition toward smaller and more single-family households.

The growth in drivers and workers has been dramatic. *Exhibit 1-5* shows the number of added persons 15 years and older between 1910 and 2000 and forecast for 2025. For example, in the decade from 1970 to 1980, labeled "1980" in *Exhibit 1-5*, 30 million people over 15 were added to the U.S. population, joining the 22 million added between 1960 and 1970. The decade between 1970 and 1980 added 30 million more, and the "echo boom" between 1990 and 2000 added another 25 million.

Exhibit 1-5

Number of Persons Aged 15 Years and Older Added to the U.S. Population, 1910–2000, and Forecast for 2025

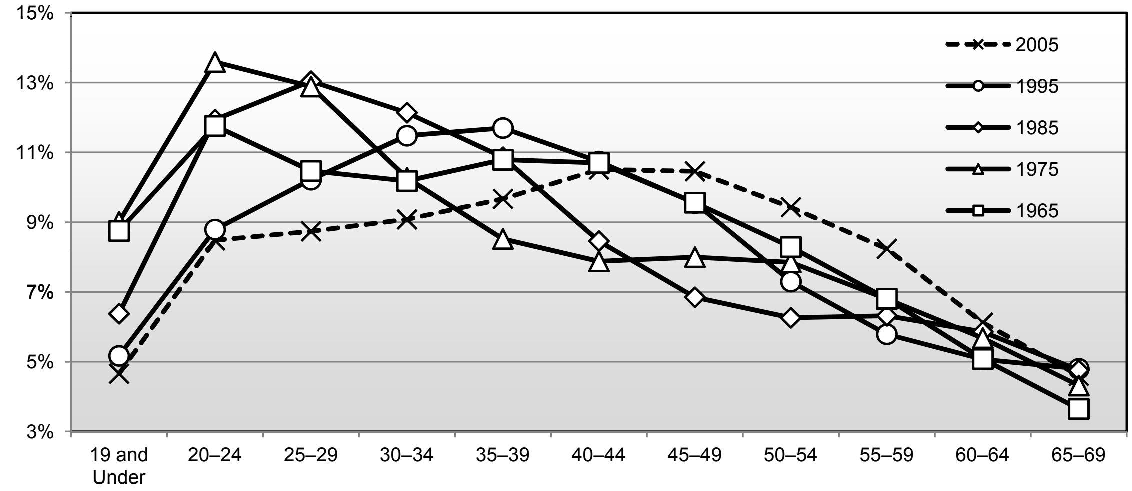


Source: U.S. Census Bureau.

The added workers and drivers resulted in tremendous growth in VMT. But now, as the population ages, the driving pool is also aging. *Exhibit 1-6* shows the percentage share of the driving population, in 10-year increments from 1965 to 2005. The baby-boomer "bulge" is clearly visible in the graph, moving rightward as this group ages over the years. The number of drivers 19 and younger peaked in 1975, when teen drivers were 11.7 million and 9 percent of driver population. In 2005, teen drivers numbered 9.3 million, but because the driving population had doubled from 100 million to 200 million, the teen share of the population declined to 4.6 percent.

Exhibit 1-6

Share of Drivers by Age Group, 1965–2005



Source: Highway Statistics, 2008.

The growth in the adult population is accompanied by a decline in the number of households with children, and a striking decline in household size. In 1960, 61 percent of the households had a father working outside the home, a homemaker mother, and three children. Today, less than one-third of U.S. households are composed of nuclear families, the lowest proportion in history. Instead:

- 28 percent are married couples with no children
- 26 percent are people living alone
- 13 percent are other structures, including roommates and unmarried partners.

The growth in vehicle availability is also dramatic. In 1969, about 70 percent of licensed drivers had access to a vehicle. In 2009, there are a sufficient number of vehicles for every licensed driver, plus some. More than 60 percent of households own two or more vehicles, and 25 percent own three or more. Overall, one-third of households have more vehicles than drivers. The correlated increases in travel demand indicators are shown in *Exhibit 1-7*.

Exhibit 1-7

Measures Related to Growth of Vehicle Travel, 1969 and 2009

	1969	2009
Total Number of Drivers	100 million	200 million
Parameter		
Average Vehicles per Licensed Driver	0.7	1.1
Average Vehicle Trips per Driver	2.3	3.3
Average Daily Person Miles per Household	61.6	95.5
Average Daily Vehicle Miles per Household	34.0	58.1
Average Household Size	3.2	2.6
Percent Single-Person Households	13%	27%

Source: FHWA NHTS data series.

All the more striking given the declines in household size is the change in per-household daily travel—more than 70 percent growth from 1969 to 2009. In 1969, there were 3.2 persons per household, compared with 2.6 in 2009. The share of single-person households has increased from 13 percent in 1969 to 27 percent in 2009.

Trip-Making and Mode-Sharing Trends

Since 1969 when the first NHTS was conducted, 45 million households have been added in the Nation, and the number of trips by each household has also grown. *Exhibit 1-8* shows the historic trend in the number of annual person trips per household by mode of travel, 1977 to 2009 (1969 did not collect walk trips). The average U.S. household currently produces 9.5 trips a day, by all modes, about 82 percent of which are vehicle trips. The remaining trips include other modes of travel such as transit, bicycling, and walking.

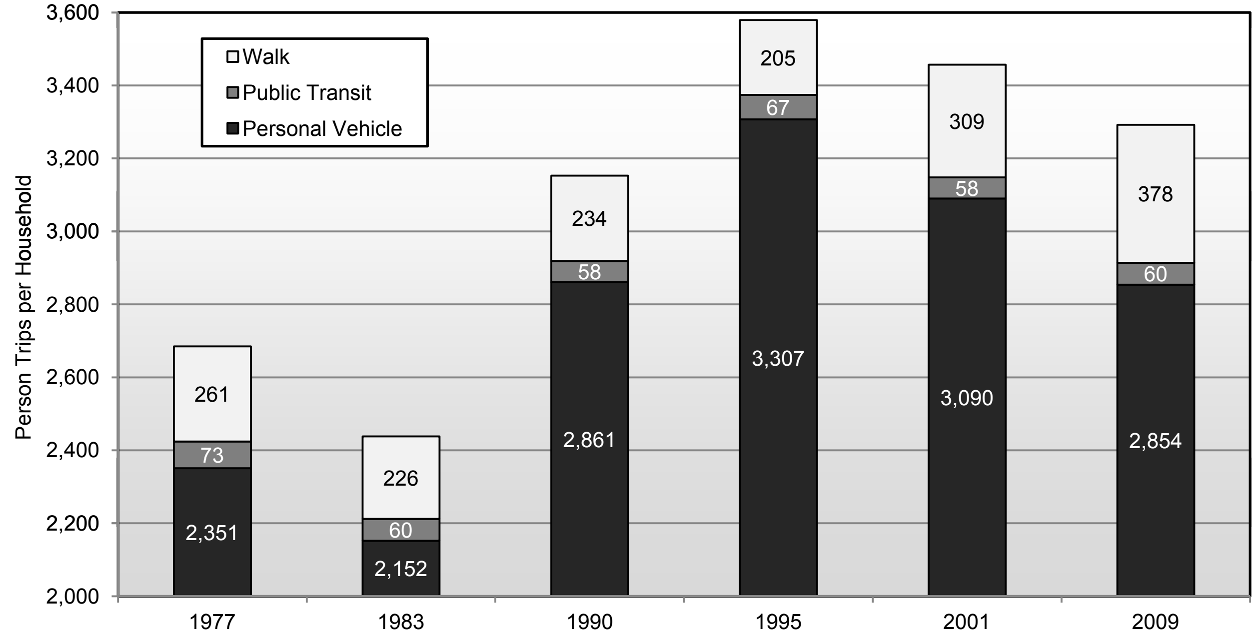
Q&A

How is a "trip" defined?

A "trip" is defined as travel directly between two anchor destinations, such as a trip from home to work. Trips can also involve a stop on the way to another destination, at which point the trip is defined as a "trip chain." An operational definition of trip chain is a sequence of trips bounded by stops of 30 minutes or less. If a stop lasts longer than 31 minutes, it becomes the terminus of the trip. Trip chains can include multiple stops such as dropping children at school and stopping for coffee, gasoline, or other errands before continuing to work or home.

Exhibit 1-8

Trends in Annual Person Trips per Household by Mode of Travel, 1977–2009



Source: FHWA NHTS data series.

The mobility offered by vehicle travel has increased the range of goods and services available within easy travel distance, but has created a number of concerns, including growing carbon emissions and oil dependency. The personal vehicle is such a ubiquitous travel mode in the United States that when people have to cease driving, because of age, for instance, it can dramatically limit their mobility options.

Increasing longevity means that more and more people age past their safe driving years. For older people who no longer drive, travel to the store, to the doctor's office, or to visit friends and family is often difficult. Suburbanization coupled with the tendency of most seniors to age in their family homes means that many older non-drivers do not have access to alternative means of transportation.

According to the 2009 NHTS, about half of non-drivers aged 65 and older do not travel at all, by any means, on an average day. There are various reasons for this lack of travel, some by choice and some from disability. About half of aging non-drivers indicate that they would like to get out more. Providing mobility options to a rising number of older non-drivers will be a planning challenge as both life expectancy and the number of older Americans grow.

How People Use the Transportation System

The United States has a vast transportation system; the extent of the Nation's highway and transit networks are discussed in detail in Chapter 2. Trips on the Interstate Highway System are almost three times longer than other trips—nearly 28 miles on average compared with just 10 miles for other vehicle trips.

Can we walk to get there?

Walking continues to be the second most common form of travel in the United States after vehicle travel. The percent of walk-only trips grew from 7 percent of all trips in 1990 to 11 percent in 2009. To obtain better information about walking, the NHTS asks about the number of walk trips "Last Week." About one-third of people in the United States report no walk trips at all in the previous week. This concerns planners and policy makers because walking contributes to health, reduces emissions, and adds to the quality of life in a community.

In addition, NHTS tracks all trips by all modes and finds that most walking trips are short trips for exercise and dog walking. As shown in *Exhibit 1-9*, more than 60 percent of trips less than ½ mile in distance are made by walking. People walk for a range of other reasons, such as shopping, escorting children to school, and walking to work. The greatest barrier to walking more is the perception of too much traffic, not enough street lighting, or wide road crossings. People are also concerned about crime, had no nearby paths or sidewalks, and were too busy to walk more often.

Exhibit 1-9

Percent of Trips Made by Vehicle and Walking

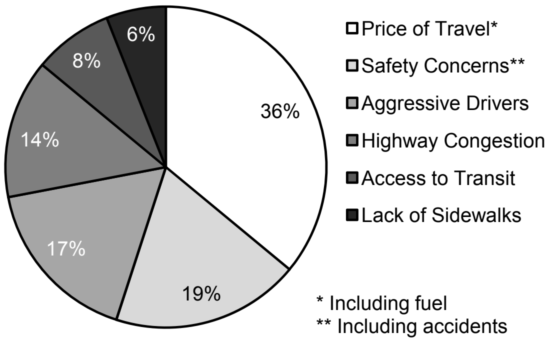
Trip Distance	Total Trips	Mode: Vehicle	Mode: Walking
Less than 1/2 mile	10%	34%	61%
Between 1/2 and 2 miles	20%	68%	23%
More than 2 miles	70%	94%	0.5%

Source: FHWA 2009 NHTS.

Exhibit 1-10 shows the issues ranked as the most important to Americans in the 2009 NHTS. *Exhibit 1-11* shows the unsurprising finding that 44 percent of vehicle trips on the Interstate/highway are commutes, while the remainder are shopping, personal business, and recreational trips. Currently, a toll is paid for about 6 percent of their trips, most often for work, but also for other purposes.

Exhibit 1-10

Most Important Issues for the Traveling Public

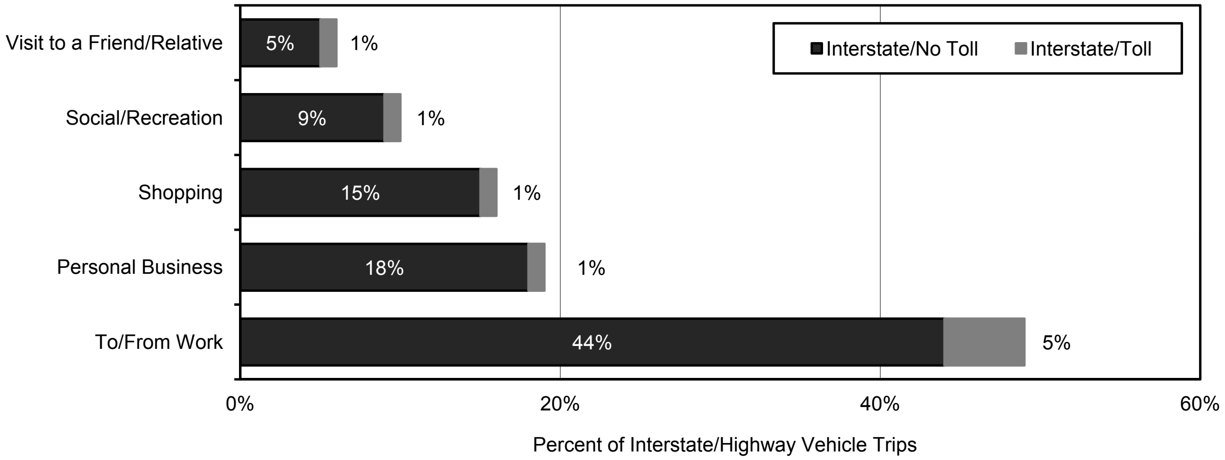


* Including fuel
** Including accidents

Source: FHWA 2009 NHTS.

Exhibit 1-11

Percent of Vehicle Trips Made on Interstates/Highways (Toll and Nontoll) for Specified Purposes

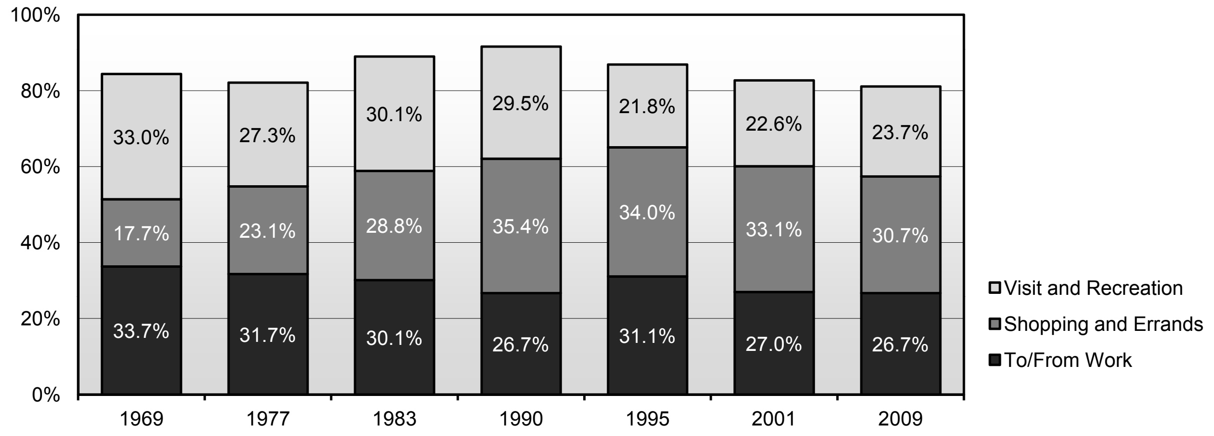


Source: FHWA 2009 NHTS.

Congestion used to be associated with peak travel hours and work trips, but now congestion affects travel for non-work purposes, such as shopping, medical visits, and recreation. Although the total amount of household-based vehicle travel has increased dramatically, the proportion of travel to work has remained relatively constant; *Exhibit 1-12* shows that travel to work accounted for 27 percent of household-based vehicle travel in 2009, compared with 34 percent in 1969. In 1969, commuting and recreational travel accounted for two-thirds of all vehicle miles. During the 1980s and 1990s, more and more vehicle miles were devoted to shopping and family errands; in the early 2000s, errands started to decline while vehicle miles for recreation increased slightly. Importantly, these non-work vehicle trips have widely different destinations, times of day, vehicle occupancies, and other characteristics that make planning and policies targeting non-work travel more complex.

Exhibit 1-12

Percent of Household-Based Vehicle Miles by Purpose, 1969–2009



Source: FHWA NHTS data series.

Work Travel

Travel to work has historically defined peak hour travel demand and, in turn, influenced the design of the transportation infrastructure. Work trips are critical to transit planning and help determine the corridors served and the levels of transit service available. The average automobile commuter spends 22.8 minutes commuting a one-way distance of 12.6 miles. Other modes of travel and variations in travel times, distances, and speeds by commute mode are shown in *Exhibit 1-13*.

Exhibit 1-13

Average Commute Time and Distance by Mode

Travel Mode	Time, minutes	Distance, miles	Estimated Speed, mph
Walk	14.2	1.1	4.8
Privately Owned Vehicle	22.8	12.6	33.2
Bus	48.9	9.4	11.5
Commuter Rail	51.7	12.2	14.1

Source: FHWA 2009 NHTS.

Data on work travel reveal two trends: more flexible hours in the workplace, including an increase in telecommuting; and workers' commutes becoming more complex, including stops for incidental purposes and the linking of work and non-work activities.

The 2009 NHTS data series shows that many workers have flexibility in work arrival times—more than 36 percent of full-time workers can "set or change their own start work time." In addition, the data series shows that nearly 12 million Americans work at home, and within urban areas the number has doubled since 1995.

Another trend in the workplace is the growing number of older workers. The 2009 NHTS shows a sharp rise in the number of people over the age of 65 who continue to work. Some of the people in "Working Retirement" may have more flexible schedules and are more likely to work at home and work part-time. Whether because of increased longevity, need for social interaction, interest in continued mental challenges, or economic reasons, more workers may decide to continue working in their 60s and 70s.

The growing flexibility of work, coupled with the power of communications technology, has potential effects on miles of travel, congestion, and travel time-of-day, characteristics that are still being studied. In addition, the typical commute is becoming more complex—for instance, trip chaining is increasing and encompassing a broader range of activities. Trip chaining has become a rational response to the burden of time and duties, such as household-sustaining activities involving child care, home care, parent care, and vehicle care. Commuters stop for a variety of reasons, such as to drop children at school or to stop at the grocery store on the way home from work. Real-life examples show that the time, location, and frequency of these other trips can be dictated by the work trip as people respond to the pressures of work and home. However, the NHTS also shows that some of the growth in trip chaining has been to grab a coffee or meal, traditional in-home activities that previously would not have involved travel.

Non-Work Travel

Over the last four decades, the greatest growth in travel has been travel not related to work. The growth in travel for shopping, family errands, and social and recreational purposes reflects the busy lives of the traveling public. In many instances the timing of these non-work trips conflicts with commute trips, such as weekend recreational trips that start Friday afternoon. Peak congestion around attractions and leisure spots can be worse than congestion in the city center at rush hour.

Shopping On-Line

More and more households are choosing to shop on-line. The FHWA 2009 NHTS indicates that one-third of adults made Internet purchases in the last month, and these purchases resulted in nearly four (3.7) deliveries a month to the average household. That equals just about 500 million deliveries of goods purchased on-line each month to U.S. households.

Distributing e-commerce goods to households is poised to create a huge new demand on the transportation system, additionally taxing the existing infrastructure to handle the capacity and speed demands of a virtual marketplace. Until recently, the fastest-growing sectors of on-line sales and services were those that do not require delivery of a product (financial services, music, games, and software) or small packaged goods that are delivered via existing third-party vehicles (books, computers, and drugs). Future growth may come from consumer demand for more everyday needs—groceries, for instance—or specialty items that require a new method of delivery and possibly are more infrastructure-dependent, such as large-scale deliveries in common carrier trucks.

American consumers demand flexibility of delivery options for on-line purchases in terms of timed slots and specified delivery days, as well as overall improvement in reliability and reduction in cost. The ability of the local and national transportation systems to accommodate demands of retailers and consumers for fast, flexible, on-time delivery of goods to households, and the potential growth in light-duty truck volumes that may accompany greater home delivery, will become an important policy and planning question in the future.

Since non-work travel has a different time-of-day profile than commuting, the growth of non-work travel affects the shoulders of the peak and midday the most, but weekend travel is also growing fast. This is changing the historical idea of the design peak—the highest volume of traffic that determines the roadway specifications—which, for some communities, occurs on Saturday afternoon rather than during weekday commuting.

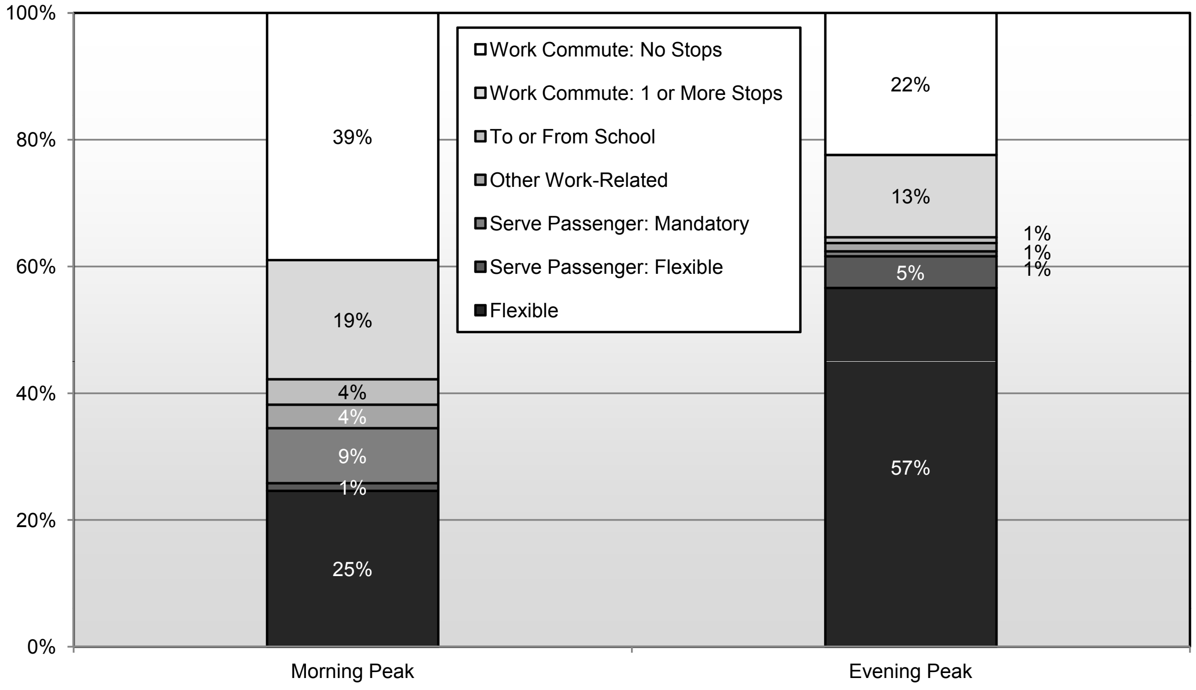
In looking only at weekday vehicle travel, about half of all travel in the combined morning and evening peak periods is not related to work—but that does not imply that all non-work travel is completely discretionary. Some non-work trips may be constrained by the individual's schedule or, in the case of medical trips, the doctor's schedule. Trips to drop someone or pick someone up may be constrained by auto availability and the schedule and purpose of the passenger. The nature of these trips, whether "flexible" or "mandatory," is subjective and based on the traveler's perception, but these two simple categories—mandatory and flexible—can be helpful for discussion.

As shown in *Exhibit 1-14*, the weekday morning peak and the weekday evening peak have very different characteristics in terms of the purpose of vehicle travel. The morning peak, between 6 and 9 a.m., is dominated by mandatory travel to work, school, and taking passengers to work and school. In contrast the evening peak, between 4 and 7 p.m., is composed of more flexible travel, such as shopping, getting a meal, and social activities. Peak travel is usually considered workday commute times; much of the morning peak travel occurs between 6 and 9 a.m. In the morning peak, mandatory travel accounts for three-quarters of all vehicle trips. Within mandatory travel, 39 percent of all vehicle trips are direct trips to or from work, 19 percent are commutes with at least one stop, 4 percent are students driving to school, and 4 percent are other trips related to work. Driving a passenger to work or school adds another 9 percent. In the evening peak, mandatory travel falls to 38 percent while flexible rises to 62 percent, including the 5 percent of drivers serving a passenger in trips not related to work or school.

These data use the trip chain file, which combines work travel into tours that can include intermediary stops for any purpose, such as getting coffee. Understanding peak period travel is vital for potential finance initiatives and congestion mitigation and air quality policies, among other important policy and planning programs.

Exhibit 1-14

Proportion of "Mandatory" and "Flexible" Morning and Evening Peak Vehicle Trips on Weekdays



Source: FHWA NHTS 2009 chained trip files (May not add to 100% due to rounding).

Household Vehicle Use and Greenhouse Gas Impacts

With concerns about the negative impact of continued growth in vehicle travel on the environment, three measures in addition to those mentioned earlier (growth in the population over 16 years old, increased vehicle availability, and growth in vehicle miles per driver) help to track the potential for increased fuel use associated with increased vehicle miles:

- Household fleet use (miles/vehicle)
- Household fleet mix (cars/trucks/sports utility vehicles (SUVs)/hybrids)
- Gas costs.

Even as the total vehicle fleet has grown by two and a half times, from 72.5 million in 1969 to well over 200 million in 2009, the value of annual miles per vehicle has remained constant: an average of 10,242 miles per vehicle in 1969 compared with 10,547 in 2009.

However, the household fleet mix has changed dramatically. The household fleet consists of passenger vehicles (cars and station wagons, vans, SUVs, and pickups) available for use in daily travel and does not normally include rental cars, company or government fleets, or taxi and delivery vehicles. Trends in the household fleet composition and use are vital to assess the impact of policies such as the "Cash for Clunkers" and the new CAFE (Corporate Average Fuel Economy) standards. Safety researchers are also keen to measure motorcycle vehicle miles traveled, as the number of motorcycle fatalities has increased in recent years. For instance, SUVs were introduced in the early 1990s and continue to be very popular. In 1995, SUVs were 6.9 percent of the fleet (this was the first year SUVs were identified in the survey); by 2009, they had grown to 19.4 percent of the fleet (*Exhibit 1-15*). On the other side of the spectrum, hybrids and smaller passenger cars rose in popularity during the gas-price spike of 2008. The most recent NHTS shows that passenger cars are a larger share of newer vehicles (0–2 years old), perhaps showing a growing demand for more fuel-efficient vehicles.

Exhibit 1-15

Percent of Household Vehicles by Vehicle Type

	Travel Survey Year					
Vehicle Type	**1977**	**1983**	**1990**	**1995**	**2001**	**2009**
Automobile	79.6%	75.9%	74.7%	64.3%	56.8%	49.9%
Van	2.8%	3.6%	5.5%	7.8%	9.0%	8.2%
SUV				6.9%	12.1%	19.4%
Pickup Truck	12.8%	15.2%	17.2%	17.7%	18.4%	17.8%
Motorcycle	2.7%	2.5%	1.3%	0.9%	2.1%	3.3%

Source: FHWA NHTS data series.

Overall, the passenger fleet continues to age as vehicles can be reliably driven well past 100,000 miles. In 1969, the average vehicle was just 5.6 years old, compared with 2009 where the average was 9.4 years. The aging fleet presents consequences, as older vehicles are generally less fuel efficient and contribute disproportionately to greenhouse gas emissions. Aging fleets also contribute to the longer lead time for introducing new technology and safety equipment. For any individual household, the GHG emissions of daily travel are based on the types of vehicles that are available for use in a household, the number of miles each vehicle is driven, the fuel efficiency in each vehicle, and usual driving patterns for each vehicle. Because the 2009 NHTS shows more aging SUVs, vans, and pickups, the proportion of CO_2 emissions from older vehicles can be expected to grow even as more efficient, newer vehicles are added to the fleet.

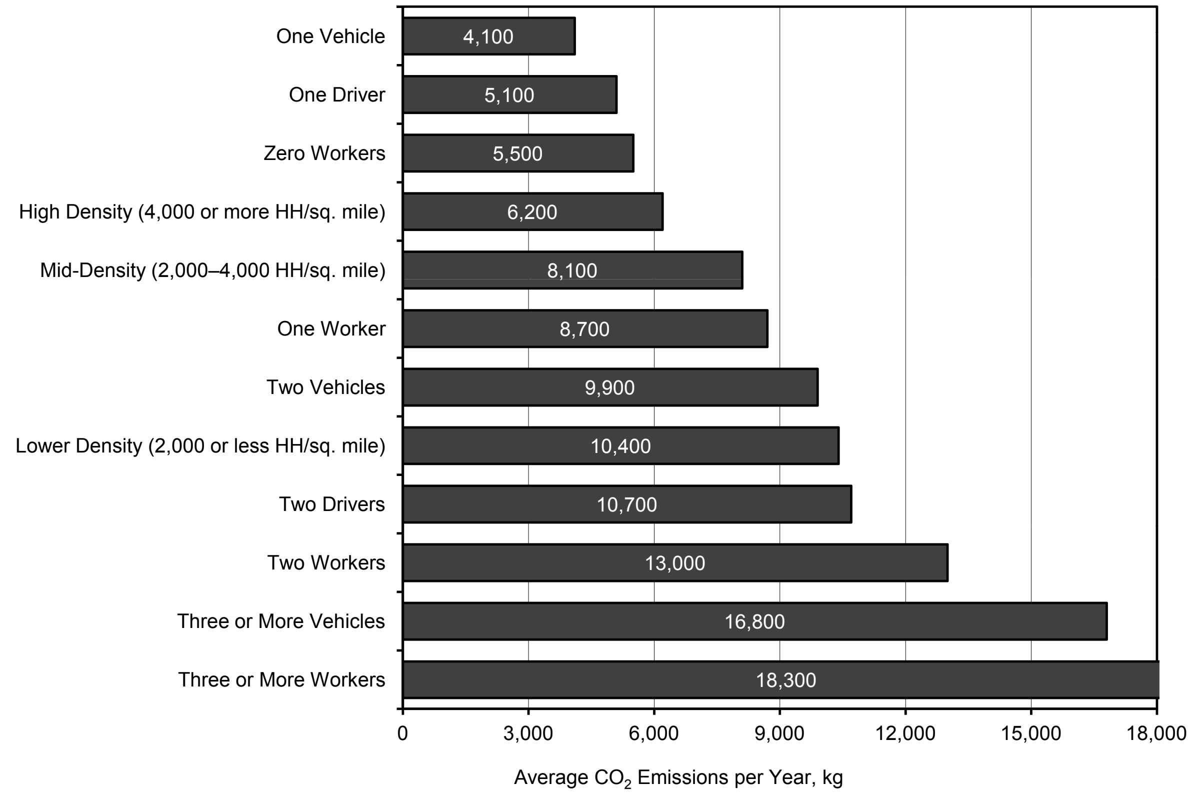
According to the NHTS, rural families drive more miles than suburban and urban households, with an average annual VMT of 28,345—well above the average of 22,418 for all households. Although a much smaller percentage of the population lives in rural locations, these families typically need to drive farther to get to places.

Also, rural families own twice as many vehicles compared to households in high density areas—and these rural vehicles are likely to be less-efficient vehicles like pickup trucks. In fact, a rural family is twice as likely to own a pickup truck (28 percent of the rural fleet mix) compared to urban households (14 percent of the fleet mix). The lower fuel efficiency of pickups combined with higher average miles of driving translates into a greater "carbon footprint" for daily travel produced from rural households.

Based on an analysis of NHTS and *Highway Statistics 2008,* VM-1 data, the average household in the lower density areas (0–2,000 housing units per square mile) produces almost two-thirds more CO_2 from daily vehicle travel than does the average household in the high density areas (urban areas of 4,000 or more housing units per square mile). However, many other factors, including socio-economic and land-use characteristics, affect the amount of CO_2 emissions by households. *Exhibit 1-16* shows a ranking of households by some factors that affect the miles driven, or are correlated to the number and type of vehicles owned, and therefore significantly affect CO_2 emissions from travel. These categories are not mutually exclusive, for example, a single household can have "three or more vehicles" and also have "two workers." In general, households with more workers and more vehicles travel more miles, emitting more CO_2 than households with fewer vehicles and fewer workers. Chapter 11 includes a more extended discussion of GHGs in the context of sustainability.

Exhibit 1-16

Average Annual CO_2 Emissions From Vehicle Travel by Household Characteristics



Source: 2009 NHTS

Chapter 2

System Characteristics

Highway System Characteristics

The Nation's highway system encompasses an extensive network of roadways that facilitates the movement of people and goods. The system supports the growth of the national economy by providing access to national and international markets and supports the defense of the Nation by providing the means for the rapid deployment of military forces and their support systems.

This section examines the characteristics of the Nation's roadways, addressing ownership, purpose, and usage. This information is presented for the National Highway System (NHS), including its Interstate Highway System component, and for the overall highway system. Separate statistics are presented for Federal-aid highways, which include those roadways that are generally eligible for Federal assistance under current law.

The statistics reported in this section rely heavily on data collected from States through the Highway Performance Monitoring System (HPMS). Note that the terms highways, roadways, and roads are generally used interchangeably in this section and elsewhere in the report. Subsequent sections within this chapter explore the characteristics of bridges and transit systems.

Are the 2008 HPMS data cited in this report fully consistent with those reported in the *Highway Statistics 2008* publication?

No. The statistics reflected in this report are based on the latest available 2008 HPMS data as of the date the chapters were written, and include revisions that were not reflected in the *Highway Statistics 2008* publication.

The HPMS database is subject to further change on an ongoing basis if States identify a need to revise their data. Such changes will be reflected in the next edition of the C&P report.

Additional information on HPMS is available at http://www.fhwa.dot.gov/policy/ohpi/hpms/index.htm.

Roads by Ownership

As shown in *Exhibit 2-1*, approximately 77.4 percent of the Nation's public road mileage was owned by local governments in 2008. In general, local governments construct and maintain these roads, although intergovernmental agreements may authorize State governments to perform construction or maintenance activities on them. In 2008, State governments owned 19.3 percent of the Nation's public road mileage. The 3.2 percent of total public road mileage under the control of the Federal government in 2008 were located primarily in National Parks and Forests, on Indian reservations, and on military bases. These figures do not reflect privately owned roads or roads not available for use by the general public.

Why does the Federal government own so many miles of road?

Approximately 30 percent of all land in the United States is owned by the Federal government. These lands have many uses: national defense; recreation; range and grazing; minerals and oil/gas extraction; timber harvest; and preservation of fish, wildlife, watersheds, wilderness, and areas of natural, scenic, scientific, or cultural value. Each use requires the presence of roads to provide access.

Roads on Indian lands provide access and mobility for tribal residents between housing and education, medical services, stores, and places of employment.

Transportation plays a key role in the way people access and enjoy their Federal lands. Use of roads by private vehicles and tour buses continues to be the primary method of travel to and within Federal and Indian lands.

Exhibit 2-1

Highway Miles by Owner and by Size of Area, 2000–2008

	2000	2002	2004	2006	2008	Annual Rate of Change 2008/2000
Rural Areas (under 5,000 in population)						
Federal	116,707	117,775	118,866	123,393	124,482	0.8%
State	663,763	664,814	683,789	669,678	632,679	-0.6%
Local	2,311,263	2,297,168	2,200,786	2,197,410	2,223,172	-0.5%
Subtotal Rural Areas	**3,091,733**	**3,079,757**	**3,003,441**	**2,990,482**	**2,980,333**	-0.5%
Urban Areas (5,000 or more in population)						
Federal	1,484	2,820	3,570	4,988	7,077	21.6%
State	111,540	111,774	132,599	150,053	151,631	3.9%
Local	746,344	787,319	857,852	887,485	920,299	2.7%
Subtotal Urbanized Areas	**859,368**	**901,913**	**994,021**	**1,042,526**	**1,079,007**	2.9%
Total Highway Miles						
Federal	118,191	120,595	122,437	128,381	131,559	1.3%
State	775,303	776,588	816,388	819,731	784,310	0.1%
Local	3,057,607	3,084,487	3,058,638	3,084,896	3,143,471	0.3%
Total	**3,951,101**	**3,981,670**	**3,997,463**	**4,033,008**	**4,059,340**	**0.3%**
Percentage of Total Highway Miles						
Federal	3.0%	3.0%	3.1%	3.2%	3.2%	
State	19.6%	19.5%	20.4%	20.3%	19.3%	
Local	77.4%	77.5%	76.5%	76.5%	77.4%	
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	

Source: Highway Performance Monitoring System (as of November 2009).

Roadways within a community with a population of 5,000 or more are classified as urban; roadways in areas outside urban boundaries are classified as rural. Some statistics in this section are presented separately for small urban areas that have populations of 5,000 to 49,999 and urbanized areas with populations over 50,000.

In 2008, the highway system in the Nation comprised nearly 4.06 million miles, compared with slightly more than 3.95 million miles in 2000. Total mileage in urban areas grew by an average annual rate of 2.9 percent between 2000 and 2008. However, highway miles in rural areas decreased at an average annual rate of 0.5 percent over the same time period.

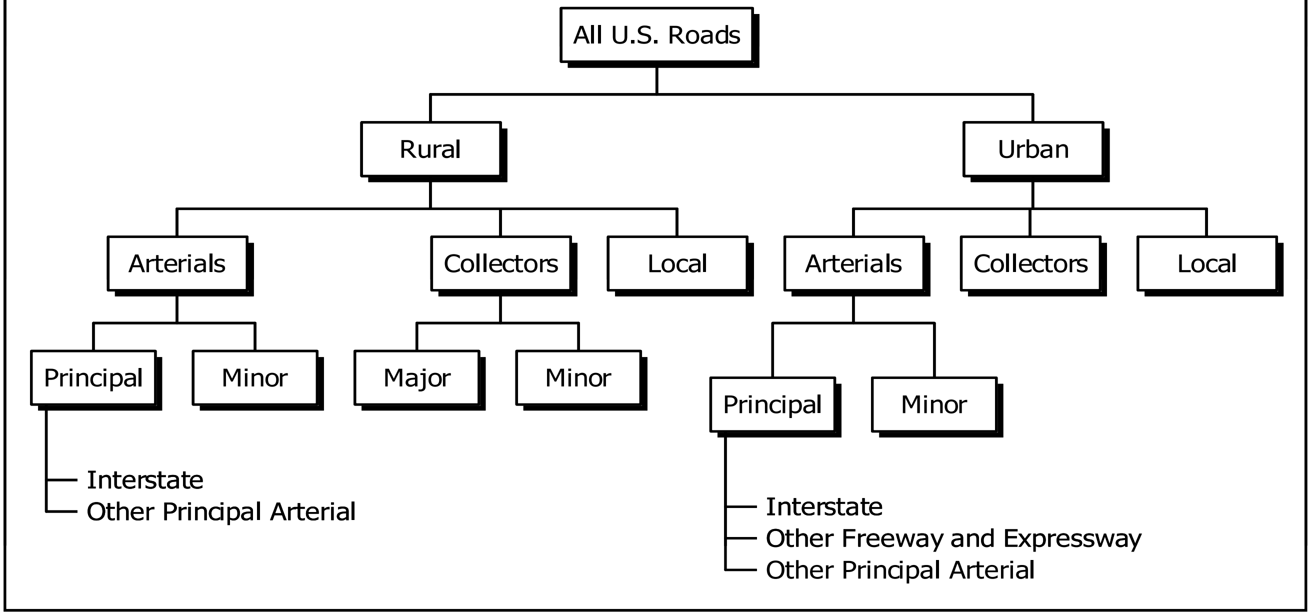
Two factors have continued to contribute to this increase in urban highway mileage, in addition to the construction of new roads. First, based on the 2000 decennial census, the boundaries of urban areas have expanded resulting in the reclassification of some mileage from rural to urban. States implemented these boundary changes in their HPMS data reporting gradually. As a result, the impact of the census-based changes on these statistics is not confined to a single year. Second, greater focus has been placed on Federal agencies to provide a more complete reporting of Federally owned mileage. As a result, reported Federal mileage in urban areas increased at an average annual rate of 21.6 percent from 2000 to 2008. This is due primarily to more accurate reporting of Department of Defense mileage on military bases within urban areas. In rural areas, Federally owned mileage increased at an annual rate of 0.8 percent over the same period.

Roads by Purpose

Roads may also be classified by the purpose they serve, which is commonly called functional classification. *Exhibit 2-2* shows the hierarchy of the Highway Functional Classification System (HFCS), which is used extensively in this report in the presentation of highway and bridge statistics.

Exhibit 2-2

Highway Functional Classification System Hierarchy



Source: FHWA Functional Classification Guidelines.

Review of Functional Classification Concepts

Roads serve two important functions: providing access and providing mobility. The better any individual segment is serving one of these functions, the worse it is at serving the other. Thus, routes on the Interstate Highway System allow a driver to travel long distances in a relatively short time, but do not allow the driver to enter each property along the way. Contrarily, a subdivision street allows a driver access to any address along its length, but does not allow the driver to travel at high speeds and is frequently interrupted by intersections that often contain traffic control devices.

Arterials provide the highest level of mobility at the highest speed for long, uninterrupted travel. Arterials typically have higher design standards than other roads because they often include multiple lanes and have some degree of access control.

The rural arterial system provides interstate and intercounty service so that all developed areas are within a reasonable distance of an arterial highway. This system is broken down into principal and minor routes, of which principal roads are more significant. Virtually all urbanized areas with more than 50,000 people and most urban areas with more than 25,000 people are connected by rural principal arterial highways. The rural principal arterial system is divided into two subgroups: Interstate highways and other principal arterials.

Similarly, in urban areas the arterial system is divided into principal and minor arterials. The urban principal arterial system includes Interstate highways, other freeways and expressways, and other principal arterials. The urban principal arterial system serves major metropolitan centers, corridors with the highest traffic volume, and those with the longest trip lengths. It carries most trips entering and leaving metropolitan areas and provides continuity for rural arterials that cross urban boundaries. Urban minor arterial routes provide service for trips of moderate length at a lower level of mobility. They connect with the urban principal arterial system and other minor arterial routes.

Collectors provide a lower degree of mobility than arterials. They are designed for travel at lower speeds and for shorter distances. Generally, collectors are two-lane roads that collect traffic from local roads and distribute it to the arterial system.

The rural collector system is stratified into two subsystems: major and minor collectors. Major collectors serve larger towns not accessed by higher-order roads, and important industrial or agricultural centers that generate significant traffic but are not served by arterials. Rural minor collectors are typically spaced at intervals consistent with population density to collect traffic from local roads and to ensure that a collector road serves all small urban areas.

In urban areas, the collector system provides traffic circulation within residential neighborhoods and commercial and industrial areas. Unlike arterials, collector roads may penetrate residential communities, distributing traffic from the arterials to the ultimate destination for many motorists. Urban collectors also channel traffic from local streets onto the arterial system. Unlike rural collectors, the urban collector system has no subclassification.

Local roads represent the largest element in the American public road system in terms of mileage. For rural and urban areas, all public road mileage below the collector system is considered local. Local roads provide basic access between residential and commercial properties, connecting with higher-order highways.

It is important to note the distinction between those roads functionally classified as local, and locally owned roads. Some roads functionally classified as local are owned by the Federal or State government, while local governments own some arterials and collectors as well as a large percentage of roads functionally classified as local.

System Characteristics

Exhibit 2-3 summarizes the percentage of highway route miles, lane miles, and vehicle miles traveled (VMT) for 2008 stratified by functional system and by population area. Route miles represent the length of a roadway, while lane miles represent the length of the roadway multiplied by the number of lanes on that roadway. As noted

Exhibit 2-3

Percentage of Highway Miles, Lane Miles, and VMT by Functional System and by Size of Area, 2008

Functional System	Miles	Lane Miles	VMT
Rural Areas (less than 5,000 in population)			
Interstate	0.7%	1.4%	8.1%
Other Principal Arterial	2.3%	2.9%	7.4%
Minor Arterial	3.3%	3.3%	5.1%
Major Collector	10.3%	9.9%	6.2%
Minor Collector	6.5%	6.2%	1.8%
Local	50.2%	47.9%	4.4%
Subtotal Rural Areas	73.4%	71.6%	33.1%
Small Urban Areas (5,000–49,999 in population)			
Interstate	0.1%	0.1%	0.9%
Other Freeway and Expressway	0.0%	0.1%	0.3%
Other Principal Arterial	0.3%	0.5%	2.1%
Minor Arterial	0.5%	0.6%	1.5%
Collector	0.6%	0.6%	0.8%
Local	3.4%	3.2%	1.1%
Subtotal Small Urban Areas	5.0%	5.1%	6.7%
Urbanized Areas (50,000 or more in population)			
Interstate	0.4%	1.0%	15.2%
Other Freeway and Expressway	0.2%	0.6%	7.2%
Other Principal Arterial	1.3%	2.2%	13.5%
Minor Arterial	2.1%	2.6%	11.2%
Collector	2.2%	2.2%	5.1%
Local	15.4%	14.7%	7.9%
Subtotal Urbanized Areas	21.6%	23.3%	60.1%
Total	100.0%	100.0%	100.0%

Source: Highway Performance Monitoring System (as of November 2009).

earlier, rural areas have populations of less than 5,000, small urban areas have populations between 5,000 and 49,999, and urbanized areas have populations of 50,000 or more.

In 2008, 73.4 percent of the Nation's highway mileage and 71.6 percent of lane miles were located in rural areas. In contrast, only 33.1 percent of the VMT occurred on roads in rural areas. Those roads classified as rural local constituted slightly over one-half of all highway mileage, but carried only 4.4 percent of total VMT. Roads in small urban areas accounted for 5.0 percent of highway mileage, 5.1 percent of lane miles, and 6.7 percent of VMT.

Only 21.6 percent of the Nation's total highway mileage and 23.3 percent of lane miles are located in urbanized areas. However, these routes carried 60.1 percent of the Nation's VMT in 2008. Urbanized Interstate System highways made up only 0.4 percent of total route mileage, but carried 15.2 percent of total VMT.

Exhibit 2-4 shows trends in public road route mileage from 2000 to 2008. Overall route mileage increased by 108,251 between 2000 and 2008, which corresponds to an annual growth rate of about 0.3 percent. The number of route miles in rural areas decreased by 111,406 between 2000 and 2008, while urban route miles increased 219,657 over the same period. Among individual functional classes, urban local roads had the largest increase in the number of miles as 159,626 were added between 2000 and 2008, while the functional class of urban collectors had the largest percentage increase of approximately 3.3 percent annually.

Exhibit 2-4

Highway Route Miles by Functional System, 2000–2008

Functional System	2000	2002	2004	2006	2008	Annual Rate of Change 2008/2000
Rural Areas (less than 5,000 in population)						
Interstate	33,152	33,107	31,477	30,615	30,227	-1.1%
Other Principal Arterial	99,023	98,945	95,998	95,009	95,002	-0.5%
Minor Arterial	137,863	137,855	135,683	135,589	135,256	-0.2%
Major Collector	433,926	431,754	420,293	419,289	418,473	-0.5%
Minor Collector	272,477	271,371	268,088	262,966	262,852	-0.4%
Local	2,115,293	2,106,725	2,051,902	2,046,796	2,038,517	-0.5%
Subtotal Rural Areas	**3,091,733**	**3,079,757**	**3,003,441**	**2,990,264**	**2,980,327**	**-0.5%**
Urban Areas (5,000 or more in population)						
Interstate	13,523	13,640	15,359	16,277	16,789	2.7%
Other Freeway and Expressway	9,196	9,377	10,305	10,817	11,401	2.7%
Other Principal Arterial	53,558	53,680	60,088	63,180	64,948	2.4%
Minor Arterial	90,302	90,922	98,447	103,678	107,182	2.2%
Collector	88,798	89,846	103,387	109,639	115,087	3.3%
Local	603,992	644,449	706,436	738,156	763,618	3.0%
Subtotal Urban Areas	**859,368**	**901,913**	**994,021**	**1,041,747**	**1,079,025**	**2.9%**
Total Highway Route Miles	**3,951,101**	**3,981,670**	**3,997,462**	**4,032,011**	**4,059,352**	**0.3%**

Source: Highway Performance Monitoring System (as of November 2009).

As noted earlier, the decline in rural route mileage can be partially attributed to changes in urban boundaries resulting from the 2000 Census. These boundary changes have also affected the classification of lane mileage and VMT.

Exhibit 2-5 shows the number of highway lane miles by functional system and by population area. Between 2000 and 2008, lane miles on the Nation's highways have grown at an average annual rate of about 0.4 percent, from 8.3 million to 8.5 million. The number of lane miles in rural areas decreased by 226,280 over this period, while the number of lane miles in urban areas increased by 489,540. Among individual functional classes, urban local roads had the largest increase in the number of lane miles with 319,246 added between 2000 and 2008, while the functional class of urban collector had the largest percentage increase of approximately 3.3 percent annually. These increases are attributable to the construction of new urban roadways, the expansion of existing urban roads, and the reclassification of rural collectors and rural local roads to urban collectors and urban local roads, respectively.

Exhibit 2-5

Highway Lane Miles by Functional System and by Size of Area, 2000–2008

Functional System	2000	2002	2004	2006	2008	Annual Rate of Change 2008/2000
Rural Areas (less than 5,000 in population)						
Interstate	135,000	135,032	128,012	124,506	122,956	-1.2%
Other Principal Arterial	253,586	256,458	249,480	248,334	250,153	-0.2%
Minor Arterial	287,750	288,391	283,173	282,397	281,071	-0.3%
Major Collector	872,672	868,977	845,513	843,262	841,353	-0.5%
Minor Collector	544,954	542,739	536,177	525,932	525,705	-0.4%
Local	4,230,588	4,213,448	4,103,804	4,093,592	4,077,032	-0.5%
Subtotal Rural Areas	**6,324,550**	**6,305,044**	**6,146,159**	**6,118,023**	**6,098,270**	**-0.5%**
Urban Areas (5,000 or more in population)						
Interstate	74,647	75,864	84,016	89,036	91,924	2.6%
Other Freeway and Expresswa	42,055	43,467	47,770	50,205	53,073	3.0%
Other Principal Arterial	187,030	188,525	210,506	221,622	228,792	2.6%
Minor Arterial	229,410	233,194	250,769	269,912	274,225	2.3%
Collector	189,839	192,115	220,177	235,240	245,262	3.3%
Local	1,207,984	1,288,898	1,412,872	1,476,314	1,527,230	3.0%
Subtotal Urban Areas	**1,930,966**	**2,022,064**	**2,226,111**	**2,342,329**	**2,420,506**	**2.9%**
Total Highway Lane Miles	**8,255,516**	**8,327,108**	**8,372,270**	**8,460,352**	**8,518,776**	**0.4%**

Source: Highway Performance Monitoring System - November 2009.

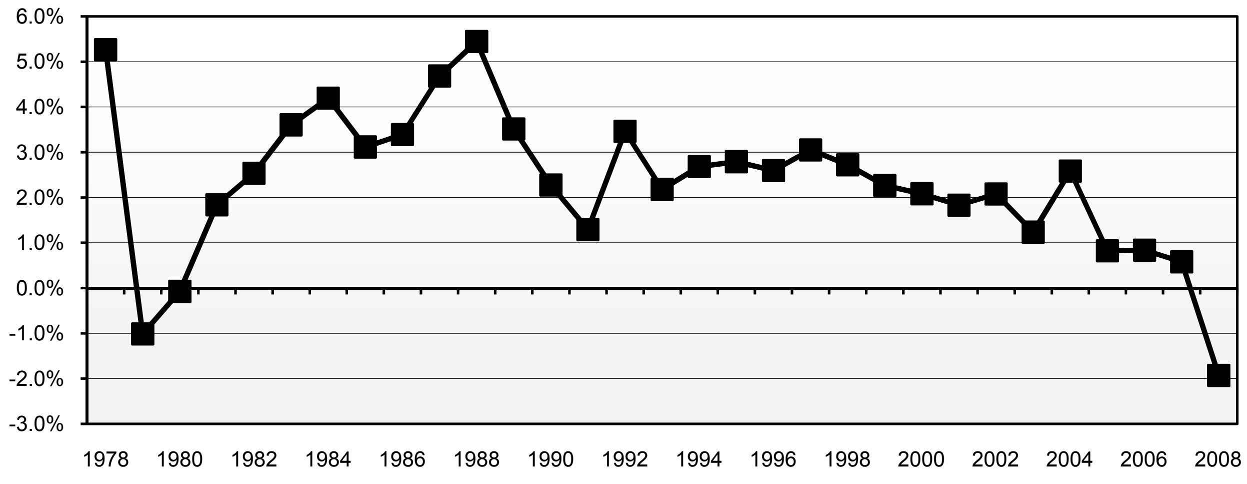
Highway Travel

This section describes highway infrastructure use, which is typically defined by highway VMT. Total VMT declined by 1.9 percent between 2007 and 2008 to 2.99 trillion, the first year-to-year decline since 1980. *Exhibit 2-6* shows annual VMT growth rates from 1978 to 2008. Highway-travel growth has typically been lower during periods of slow economic growth and/or higher fuel prices, and higher during periods of economic expansion.

Although annual VMT growth has varied somewhat from year to year, it has generally been trending downward. Annual VMT growth last exceeded 4 percent in 1988, last exceeded 3 percent in 1997, and last exceeded 2 percent in 2004. Total VMT grew by less than 1 percent per year from 2005 to 2007. Over the 30-year period from 1978 to 2008, VMT grew at an average annual rate of 2.2 percent; for the 20-year period from 1988 to 2008, VMT grew by an average 1.9 percent per year. Over the 10-year period from 1998 to 2008, VMT grew at an average annual rate of 1.2 percent; the average annual VMT growth rate dropped to 0.6 percent during the last 5 years of this period.

Exhibit 2-6

Annual VMT Growth Rates, 1978–2008



Source: Highway Statistics, various years, Tables VM-1 (50 States plus D.C.) and VM-2 (Puerto Rico).

How have economic recessions and changes in fuel prices corresponded to the changes in VMT growth rates identified in *Exhibit 2-6*?

Q&A

The Business Cycle Dating Committee of the National Bureau of Economic Research has identified periods of economic contractions from January 1980 to June 1980, July 1981 to November 1982, July 1990 to March 1991, March 2001 to November 2001, and December 2007 to June 2009. While these dates do not correspond exactly to the timing of declines in VMT growth rates over this 30-year period, they are associated with periods of weaker than average VMT growth.

In constant dollar terms, the price of regular unleaded gasoline increased by 60 percent between 1978 and 1981, contributing to the declines in VMT observed in 1979 and 1980. Unleaded gasoline prices dropped by 46 percent in constant dollar terms between 1980 and 1988, the year with the highest annual growth rate identified in *Exhibit 2-6*. These prices increased by 14 percent in constant dollar terms between 1988 to 1990, corresponding to a period of declining VMT growth, before dropping by 23 percent between 1990 and 1998. From 1998 to 2008, unleaded gasoline prices increased by 143 percent to a new all-time high; over this same period, the rate of VMT growth gradually declined, reaching a negative value in 2008.

Exhibit 2-7 shows trends in VMT by functional class and passenger miles traveled (PMT) since 2000. During the period from 2000 to 2008, VMT grew at an average annual rate of 1.0 percent per year from approximately 2.76 trillion to 2.99 trillion. Total PMT grew more quickly over this 8-year period by approximately 1.3 percent per year, rising to a total of approximately 4.9 trillion in 2008.

VMT in rural areas totaled approximately 0.99 trillion in 2008. From 2000 to 2008, travel declined on all rural functional classifications except for roads classified as rural local. Rural minor arterials experienced the largest reduction in VMT in percentage terms, declining at an average annual rate of 1.6 percent over this period. As noted earlier, the decline in rural VMT can be partially attributed to the expansion of urban boundaries resulting from the 2000 Census.

Exhibit 2-7

Vehicle Miles Traveled (VMT) and Passenger Miles Traveled (PMT), 2000–2008

Functional System	(Millions of Miles) 2000	2002	2004	2006	2008	Annual Rate of Change 2008/2000
Rural Areas (less than 5,000 in population)						
Interstate	269,533	281,461	267,397	258,324	243,693	-1.3%
Other Principal Arterial	249,177	258,009	241,282	232,224	222,555	-1.4%
Minor Arterial	172,772	177,139	169,168	162,889	152,246	-1.6%
Major Collector	210,595	214,463	200,926	193,423	186,275	-1.5%
Minor Collector	58,183	62,144	60,278	58,229	55,164	-0.7%
Local	127,560	139,892	132,474	133,378	131,796	0.4%
Subtotal Rural Areas	**1,087,820**	**1,133,107**	**1,071,524**	**1,038,467**	**991,729**	**-1.1%**
Urban Areas (5,000 or more in population)						
Interstate	397,176	412,481	459,767	482,677	481,520	2.4%
Other Freeway and Expressway	178,185	190,641	209,084	218,411	223,837	2.9%
Other Principal Arterial	401,356	410,926	453,868	470,423	465,965	1.9%
Minor Arterial	326,889	341,958	365,807	380,069	380,734	1.9%
Collector	137,007	143,621	164,330	175,516	177,665	3.3%
Local	236,051	241,721	257,617	268,394	271,329	1.8%
Subtotal Urban Areas	**1,676,664**	**1,741,348**	**1,910,473**	**1,995,489**	**2,001,050**	**2.2%**
Total VMT	**2,764,484**	**2,874,455**	**2,981,998**	**3,033,957**	**2,992,779**	**1.0%**
Total PMT*	**4,390,076**	**4,667,038**	**4,832,394**	**4,933,689**	**4,871,683**	**1.3%**

**Assumes approximately 1.59 passengers per vehicle per mile in 2000 and approximately 1.63 passengers per vehicle per mile in 2002, 2004, 2006, and 2008.*

Sources: VMT data from Highway Performance Monitoring System; PMT data from Highway Statistics, Table VM-1.

Q&A

What has happened to highway travel since 2008?

The December 2009 Traffic Volume Trends (TVT) report showed an estimated increase in VMT of 0.2 percent between 2008 and 2009. VMT on rural Interstates and other rural arterials increased by 1.3 percent, VMT on other rural roads increased by 0.7 percent, and VMT on urban Interstates increased by 0.3 percent. VMT on other urban arterials decreased by 0.2 percent, while VMT on other urban roads decreased by 0.8 percent. These estimates should be considered preliminary, and will be revised when 2009 HPMS data are available.

The TVT is a monthly report based on hourly traffic count data. These data, collected at approximately 4,000 continuous traffic-counting locations nationwide, are used to calculate the percent change in traffic for the current month compared to the same month in the previous year. Because of limited TVT sample sizes, caution should be used with these estimates.

For additional information on ongoing traffic trends, visit https://www.fhwa.dot.gov/ohim/tvtw.

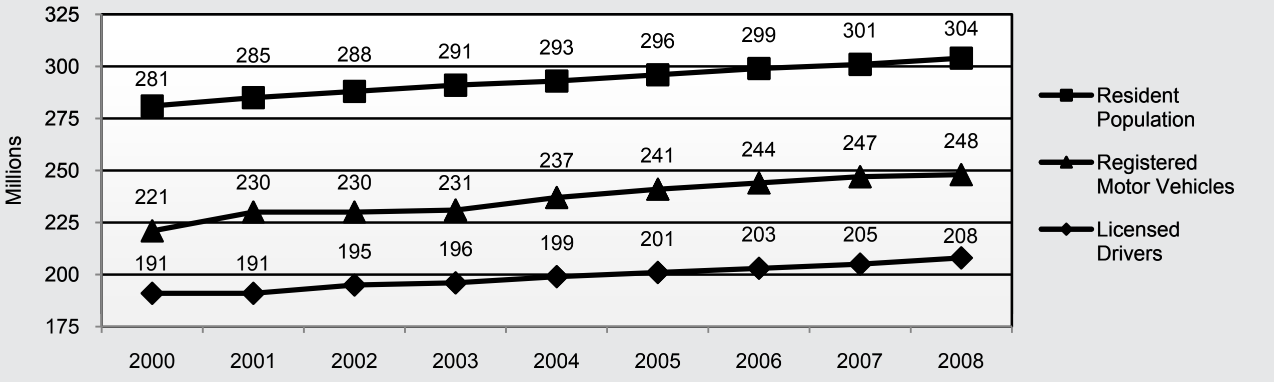
VMT in urban areas totaled approximately 2.00 trillion in 2008. Urban VMT increased at an average annual rate of 2.2 percent over this period. Urban collectors experienced the largest increase in VMT in percentage terms, growing at an average annual rate of 3.3 percent. In 2008, the urban portion of the Interstate System alone carried approximately 0.5 trillion VMT, the highest level among the functional classes.

What has happened in recent years to the size of the Nation's vehicle fleet?

From 2000 to 2008, the number of registered motor vehicles increased 12.2 percent, the resident population increased 8.2 percent, and the number of licensed drivers increased 8.9 percent. *[See Exhibit 2-8.]*

Exhibit 2-8

Licensed Drivers, Vehicle Registrations, and Resident Population, 2000–2008



Source: Highway Statistics 2008, http://www.fhwa.dot.gov/policyinformation/statistics/2008/dlchrt.cfm.

However, recently the number of registered vehicles has grown more slowly than resident population and the number of licensed drivers. From 2007 to 2008, resident population and the number of licensed drivers grew approximately 10 percent and 14.6 percent, respectively. The number of registered vehicles increased only 0.4 percent.

Exhibit 2-9 depicts highway travel by functional classification and vehicle type. Three types 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 trailers and semitrailers. Passenger vehicle travel accounted for 92.4 percent of total VMT in 2008; combination trucks accounted for 4.8 percent of VMT, and single-unit trucks accounted for the remaining 2.8 percent. The share of truck travel on the rural portion of the Interstate System is considerably higher; in 2008, single-unit and combination trucks together accounted for 19.5 percent of total VMT on the rural portion of the Interstate System.

From 2000 to 2008, travel on all functional classifications combined among all vehicle types grew fastest among single-unit trucks, at an average annual rate of 2.2 percent. Passenger vehicle travel grew by 1.0 percent per year, and combination truck traffic grew by 0.8 percent per year over the same period.

Combination truck travel and passenger vehicle travel grew more quickly on the urban portion of the Interstate System than other urban roads from 2000 to 2008. Over this period, combination truck travel on the urban portion of the Interstate System increased at an average annual rate of 3.2 percent, while passenger vehicle travel increased by 2.4 percent on the urban portion of the Interstate System. In contrast, single-unit truck travel grew more quickly on other urban roads over this period; single-unit truck VMT increased by an average of 1.9 percent annually on the urban portion of the Interstate System while increasing by 4.6 percent annually on other urban roads.

Exhibit 2-9

Highway Travel by Functional System and by Vehicle Type, 2000–2008

Functional System	2000	2002	2004	2006	2008	Annual Rate of Change 2008/2000
	(Millions of Miles)*					
Rural Interstate						
PV	215,696	225,584	212,693	206,528	195,749	-1.2%
SU	8,236	8,745	8,548	7,674	7,299	-1.5%
Combo	44,248	45,633	45,754	43,711	40,242	-1.2%
Other Arterial						
PV	378,950	391,381	367,357	354,873	335,202	-1.5%
SU	13,644	14,606	14,771	13,835	13,646	0.0%
Combo	28,005	27,818	27,817	25,791	25,426	-1.2%
Other Rural						
PV	368,096	385,340	362,662	355,582	343,556	-0.9%
SU	13,722	14,963	15,611	15,084	15,478	1.5%
Combo	12,555	14,090	15,035	13,990	13,820	1.2%
Total Rural						
PV	962,742	1,002,305	942,712	916,983	874,507	-1.2%
SU	35,602	38,314	38,930	36,593	36,423	0.3%
Combo	84,808	87,541	88,606	83,492	79,488	-0.8%
Urban Interstate						
PV	361,284	375,625	416,220	437,552	435,741	2.4%
SU	8,716	9,106	10,512	10,301	10,127	1.9%
Combo	23,465	23,887	26,481	29,430	30,223	3.2%
Other Urban						
PV	1,217,379	1,263,296	1,375,906	1,436,544	1,435,803	2.1%
SU	26,182	28,467	31,665	33,436	37,400	4.6%
Combo	26,747	27,215	30,310	29,784	33,797	3.0%
Total Urban						
PV	1,578,663	1,638,921	1,792,126	1,874,096	1,871,544	2.2%
SU	34,898	37,573	42,177	43,737	47,527	3.9%
Combo	50,212	51,102	56,791	59,214	64,020	3.1%
Total						
PV	**2,541,405**	**2,641,226**	**2,734,838**	**2,791,079**	**2,746,051**	**1.0%**
SU	**70,500**	**75,887**	**81,107**	**80,330**	**83,950**	**2.2%**
Combo	**135,020**	**138,643**	**145,397**	**142,706**	**143,508**	**0.8%**

PV = Passenger Vehicles (including buses, motorcycles and two-axle, four-tire vehicles); SU = Single-Unit Trucks (6 or more tires); Combo = Combination Trucks (trailers and semitrailers).

** Data do not include Puerto Rico.*

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

Federal-Aid Highways

The term “Federal-aid highways” includes roads that are generally eligible for Federal funding assistance under current law, which includes public roads that are not functionally classified as rural minor collector, rural local, or urban local. As shown in *Exhibit 2-10*, Federal-aid highway mileage totaled approximately 1.0 million in 2008. Federal-aid highways included 2.4 million lane miles and carried 2.5 trillion VMT in 2008. VMT on Federal-aid highways grew at an average annual rate of 1.0 percent from 2000 to 2008, outpacing the rates of increase in both highway miles and lane miles.

Exhibit 2-10

Federal-Aid Highway Miles, Lane Miles, and VMT, 2000–2008

	2000	2002	2004	2006	2008	Annual Rate of Change 2008/2000
Highway Miles	959,339	959,125	971,036	984,093	994,358	0.4%
Lane Miles	2,271,990	2,282,024	2,319,417	2,364,514	2,388,809	0.6%
VMT (millions)	2,342,690	2,430,698	2,531,629	2,573,956	2,534,490	1.0%

Source: Highway Performance Monitoring System.

The highway miles on Federal-aid highways made up 24.5 percent of the total highway miles on the Nation's roadways in 2008, while the number of lane miles on Federal-aid highways was approximately 28.0 percent of the total lane miles in the Nation. The VMT carried on Federal-aid highways made up 84.7 percent of the VMT for the Nation.

While the system characteristics information presented in this chapter is available for all functional classes, some data pertaining to system conditions and performance presented in other chapters are not available in the HPMS for roads classified as rural minor collector, rural local, or urban local. Thus, some data presented in other chapters may reflect only Federal-aid highways.

National Highway System

With the Interstate System essentially complete, the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) revised the Federal-aid highway program for the post-Interstate System era. The legislation authorized designation of an NHS that would focus Federal resources on roads that are the most important to 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.

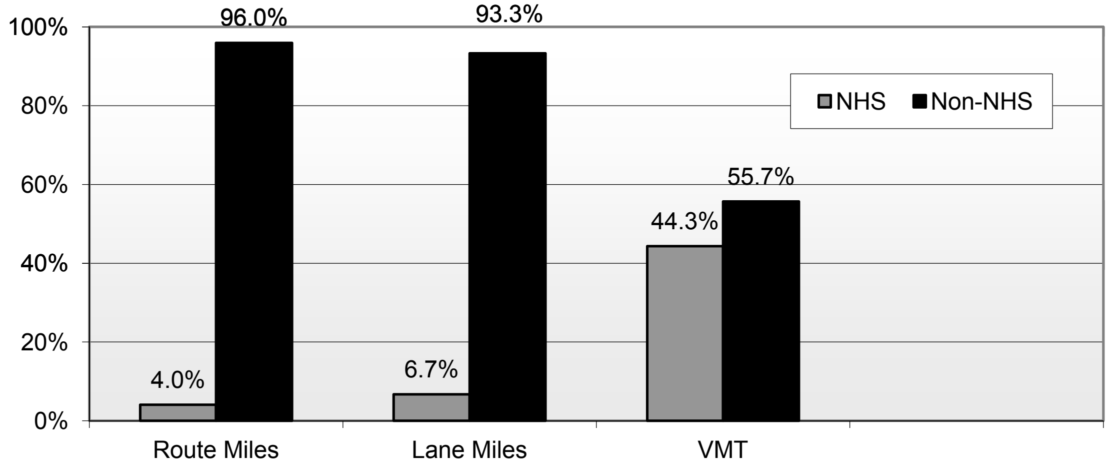
The NHS was designed to be a dynamic system able to change in response to future travel and trade demands. The Department of Transportation may approve modifications to the NHS without congressional approval. States must cooperate with local and regional officials in proposing modifications. In metropolitan areas, local and regional officials must act through metropolitan planning organizations and the State transportation department when proposing modifications. A number of such modifications are proposed and approved each year.

The NHS has five components. The first, the Interstate System, is the core of the NHS and includes the most traveled routes. The second component includes selected 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, which were not included in the National Highway System Designation Act of 1995 but are eligible for NHS funds. These roads provide access between major intermodal passenger and freight facilities and the other four subsystems making up the NHS.

Exhibit 2-11 summarizes NHS route miles, lane miles, and VMT for the NHS components. The NHS is overwhelmingly concentrated on higher functional systems. All Interstate System highways are part of the NHS, as are 83.3 percent of rural other principal arterials, 87.1 percent of urban other freeways and expressways, and 36.3 percent of urban other principal arterials. The share of minor arterials, collectors, and local roads on the NHS is relatively small. As of 2008, there were 162,944 route miles on the NHS, excluding any sections not yet open to traffic. In 2008, while only 4.0 percent of the Nation's total route mileage and 6.7 percent of the total lane miles were on the NHS, these roads carried 44.3 percent of VMT.

Exhibit 2-11

Highway Route Miles, Lane Miles, and VMT on the NHS Compared With All Roads, by Functional System, 2008

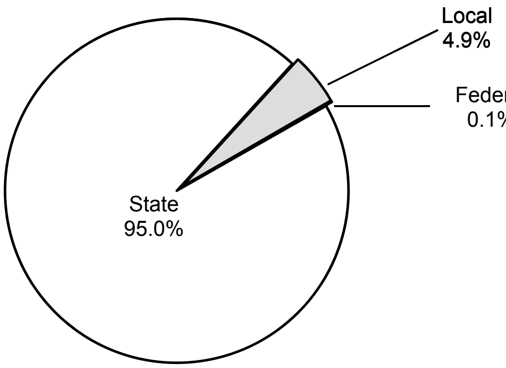


	Route Miles		Lane Miles		VMT (Millions)	
	Total on NHS	Percent of Functional System on NHS	Total on NHS	Percent of Functional System on NHS	Total on NHS	Percent of Functional System on NHS
Rural NHS						
Interstate	30,147	100.0%	122,640	100.0%	242,785	100.0%
Other Principal Arterial	78,665	83.3%	212,675	85.4%	193,116	87.1%
Minor Arterial	2,235	1.7%	5,152	1.8%	4,049	2.7%
Major Collector	664	0.2%	1,467	0.2%	1,092	0.6%
Minor Collector	17	0.0%	27	0.0%	6	0.0%
Local	23	0.0%	46	0.0%	14	0.0%
Subtotal Rural NHS	**111,751**	**3.8%**	**342,007**	**5.7%**	**441,062**	**44.6%**
Urban NHS						
Interstate	16,619	100.0%	90,954	100.0%	476,524	100.0%
Other Freeway and Expressway	9,810	87.1%	46,407	88.3%	204,855	92.1%
Other Principal Arterial	23,118	36.3%	86,092	38.2%	187,789	40.9%
Minor Arterial	1,229	1.2%	3,809	1.4%	5,921	1.6%
Collector	317	0.3%	831	0.3%	940	0.5%
Local	100	0.0%	233	0.0%	200	0.1%
Subtotal Urban NHS	**51,193**	**4.7%**	**228,093**	**9.2%**	**876,230**	**44.2%**
Total NHS	**162,944**	**4.0%**	**570,100**	**6.7%**	**1,317,292**	**44.3%**

Source: Highway Performance Monitoring System, November 2009.

Exhibit 2-12

NHS Mileage by Owner, 2008



Source: Highway Performance Monitoring System, November 2009.

Exhibit 2-12 describes the ownership of NHS mileage. Approximately 95.0 percent of route miles were State-owned in 2008. Only 4.9 percent were locally owned, and the Federal government owned the remaining 0.1 percent. In contrast, as noted earlier in this chapter, 19.3 percent of all route miles in the United States were State-owned, 77.4 percent were owned by local governments, and the Federal government owned 3.2 percent in 2008. The NHS is concentrated on higher functional systems, which tend to have higher shares of State-owned mileage.

Interstate System

With the strong support of President Dwight D. Eisenhower, the Federal-Aid Highway Act of 1956 declared that the completion of the "National System of Interstate and Defense Highways" was essential to the national interest. It made a national commitment to the completion of the Interstate System within the Federal–State partnership of the Federal-aid highway program, with the State responsible for construction to approved standards. The 1956 Act resolved the challenging issue of how to pay for construction by establishing the Highway Trust Fund to ensure that revenue from highway user taxes, such as the motor fuels tax, would be dedicated to the Interstate System and other Federal-aid highway and bridge projects.

President Eisenhower wrote in his memoirs that "more than any single action by the government since the end of the war, this one would change the face of America. Its impact on the American economy . . . was beyond calculation." The Dwight D. Eisenhower National System of Interstate and Defense Highways, as it is now called, accelerated interstate and regional commerce, enhanced the country's competitiveness in international markets, increased personal mobility, facilitated military transportation, and accelerated metropolitan development throughout the United States. Although the Interstate System accounted for only 1.2 percent of the Nation's total roadway mileage in 2008, it carried 24.2 percent of all highway travel.

Exhibit 2-13 combines data presented earlier in this section for rural and urban Interstate System highways. From 2000 to 2008, Interstate System miles grew at an average annual rate of 0.1 percent to 47,019. Over this same period, Interstate System lane miles grew by 0.3 percent annually to 214,880, and the traffic carried by the Interstate System grew by 1.1 percent per year to 0.7 trillion VMT in 2008.

Exhibit 2-13

Interstate Highway Miles, Lane Miles, and VMT, 2000–2008

	2000	2002	2004	2006	2008	Annual Rate of Change 2008/2000
Highway Miles	46,675	46,747	46,836	46,892	47,019	0.1%
Lane Miles	209,647	210,896	212,029	213,542	214,880	0.3%
VMT(millions)	666,708	693,941	727,163	741,002	725,213	1.1%

Source: Highway Performance Monitoring System, November 2009.

Freight Travel

The movement of freight dominates trucking activity and is a significant component of highway traffic. Three-fourths of VMT by trucks larger than pickups and vans is for carrying freight, with much of the rest being for empty backhauls or serving construction and utilities. Single-unit and combination trucks accounted for every fourth vehicle on almost 28,000 miles of the NHS in 2007, and 6,000 of those miles carried more than 8,500 trucks on an average day.

As shown in *Exhibit 2-14*, approximately half of trucks larger than pickups and vans typically operate locally—within 50 miles of home—and account for about 30 percent of truck VMT. In contrast, 10 percent of trucks larger than pickups and vans that operate more than 200 miles away from home account for 40 percent of truck VMT. Long-distance truck travel also accounts for nearly all freight ton miles and a large share of truck VMT. Based on the previous version of the Freight Analysis Framework (FAF version 2.3), *Exhibit 2-15* shows that almost all of the ton miles carried by trucks is among places at least 50 miles apart, and two-thirds of those ton miles cross state lines.

As reflected in *Exhibit 2-16*, trucks are a critical component of the Nation's freight transportation system, serving approximately two-thirds the value and weight of freight moved to, from, and within the United States. (It should be noted that these raw tonnage statistics do not take into account the distance these goods were moved; for example, if a container was transported 3,000 miles across the country on rail, and two miles by truck from an intermodal yard to a retail store, both rail and truck would have moved the same tonnage.)

Exhibit 2-14

Trucks and Truck Miles by Range of Operations

Location	Number of Trucks (percent)	Truck Miles (percent)
Off the road	3.3%	1.6%
50 miles or less	53.3%	29.3%
51 to 100 miles	12.4%	13.2%
101 to 200 miles	4.4%	8.1%
201 to 500 miles	4.2%	12.1%
501 miles or more	5.3%	18.4%
Not reported	13.0%	17.3%
Not applicable	4.1%	0.1%
Total	**100%**	**100%**

Note: Includes trucks registered to companies and individuals in the United States except pickups, minivans, other light vans, and sport utility vehicles. Numbers may not add to total due to rounding.

Source: U.S. Department of Commerce, Census Bureau, 2002 Vehicle Inventory and Use Survey: United States, EC02TV-US, Table 3a (Washington, DC: 2004), available at http://www.census.gov/prod/ec02/ec02tv-us.pdf as of April 24, 2008.

Exhibit 2-15

Ton Miles by Truck, 2002

Trip Type	Trip Percentage
Local (less than 50 miles)	1%
Within State	36%
To Other States	15%
From Other States	15%
Through State	34%
Total	**100%**

Note: Numbers do not add to 100 due to rounding.

Source: Freight Analysis Framework 2.3 in FHWA, Freight Facts and Figures 2009, Table 3-7.

Freight Statistics

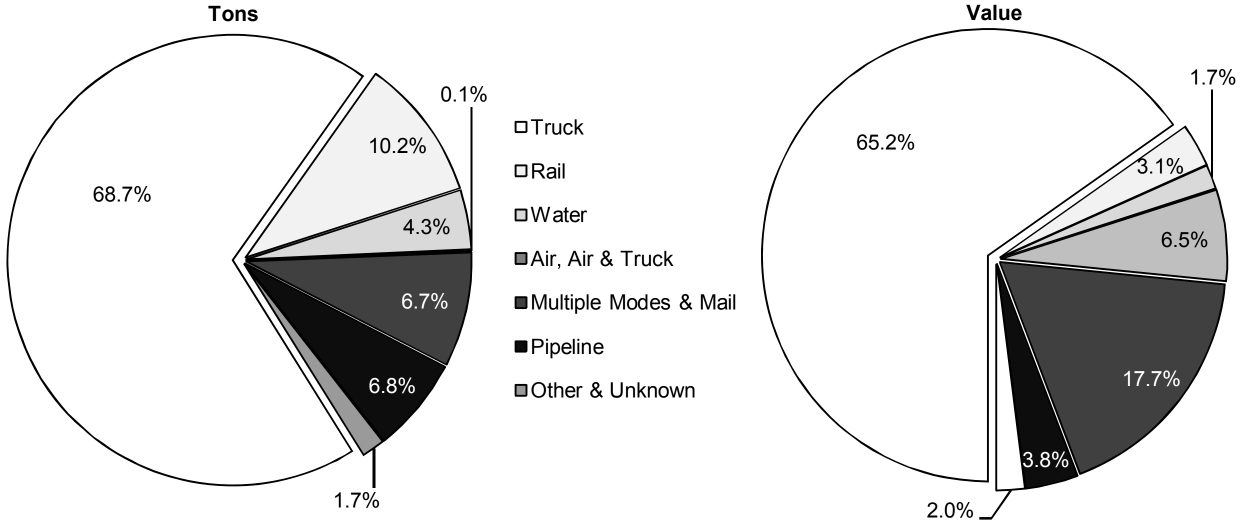
Many of the freight statistics in this section are derived from the Freight Analysis Framework (FAF) version 3 (FAF^3) and FAF version 2 (FAF^2). Both versions of the FAF include all freight flows to, from, and within the United States. FAF estimates are recalibrated every 5 years primarily with data from the Commodity Flow Survey (CFS), and are updated annually with provisional estimates. The CFS, conducted every 5 years by the Census Bureau and U.S. DOT's Bureau of Transportation Statistics, measures approximately two-thirds of the tonnage covered by the FAF. FAF^3 incorporates data from the 2007 CFS and FAF^2 was based on 2002 data.

Statistics on trucking activity are primarily from FHWA's Highway Performance Monitoring System and the Census Bureau's Vehicle Inventory and Use Survey (VIUS). The VIUS links truck size and weight, miles traveled, energy consumed, economic activity served, commodities carried, and other characteristics of significant public interest, but was discontinued after 2002. See www.ops.fhwa.dot.gov/freight/freight_analysis/faf for additional information.

Exhibit 2-16

Goods Movement by Mode, 2007

An average of 51 million tons of freight worth $45 billion was moved by the transportation system per day in 2007



Notes: Multiple Modes & Mail includes export and import shipments that move domestically by a different mode than the mode used between the port and foreign location. Data do not include imports and exports that pass through the United States from a foreign origin to a foreign destination by any mode. Numbers may not add to 100 due to rounding.

Source: U.S. Department of Transportation, Federal Highway Administration, Office of Freight Management and Operations, Freight Analysis Framework, version 3.1.

The Freight Transportation System

The FHWA's *Freight Facts and Figures 2010* publication shows that the transportation system of the United States moves nearly 51 million tons of freight worth more than $45 billion each day to meet the logistical needs of the Nation's 117 million households, 7.7 million business establishments, and 89,500 government units. The economy depends on freight transportation to link businesses with suppliers and markets throughout the Nation and the world. American farms and mines reach out to customers across and beyond the continent, using inexpensive transportation to compete against farms and mines in other countries. Domestic manufacturers increasingly use distant sources of raw materials and other inputs to produce goods for local and worldwide customers, all of which require efficient and reliable transportation to maintain a competitive advantage in a global marketplace. Wholesalers and retailers depend on fast and reliable transportation to obtain inexpensive or specialized goods through extensive supply chains. In the expanding world of e-commerce, households increasingly rely on freight transportation to deliver purchases directly to their door. Even service providers, public utilities, construction companies, and government agencies depend on freight transportation to get needed equipment and supplies from sources scattered throughout the world.

Freight Facts and Figures 2010 reports that the U.S. freight transportation system includes 9 million single-unit and combination trucks, more than 1.4 million locomotives and rail cars, and more than 40,000 marine vessels. The system operates on more than 400,000 miles of arterial highways, 140,000 miles of railroads, 13,000 miles of inland waterways and the Great Lakes-St. Lawrence Seaway system, and 1.6 million miles of petroleum and natural gas pipelines. The U.S. Army Corps of Engineers' *Waterborne Commerce of the United States 2007* publication identifies 146 ports that handle more than 1 million tons of freight per year.

The freight transportation system is more than equipment and facilities. As reported in *Freight Facts and Figures 2010*, freight transportation establishments with payrolls primarily serving for-hire transportation and warehousing employ 4.2 million workers. Truck drivers account for the largest freight transportation occupation in the U.S. numbering 2.4 million in 2009. Other freight transportation occupations included other rail and water vehicle operators, as well as other freight transportation-related occupations such as equipment manufacturing, equipment maintenance, and other transportation support service providers.

The projections shown in *Exhibit 2-17* estimate that the tonnage of commodities moved by truck will increase by nearly 70 percent between 2009 and 2040. The demand for freight movement grows with population, with production of goods for domestic consumption and export activity, and with shifting supply chains for each sector of the economy. Sectors such as agriculture and mining originate substantial freight, particularly bulk products. The manufacturing and wholesale trade sectors are both destinations and origins of freight movement, including both bulk inputs to basic industries and retail goods going to and from manufacturing and distribution centers. The construction sector consumes sand and gravel, steel, sheet rock, and other heavy materials; public utilities consume bulk energy products; and the retail trade and service sectors consume vast quantities of high-value, time-sensitive goods. As shown in *Exhibit 2-18*, by tonnage, trucks carry almost 90 percent of high-value goods and over 70 percent of the time-sensitive bulk goods.

Exhibit 2-17

Weight of Shipments by Transportation Mode (Millions of Tons)

Mode	2007	2009	2040 Projected	Compound Annual Growth, 2009–2040
Truck	12,766	10,868	18,445	1.7%
Rail	1,894	1,689	2,408	1.2%
Water	794	734	1,143	1.4%
Air, Air & Truck	13	11	41	4.3%
Multiple Modes & Mail*	1,531	1,336	3,119	2.8%
Pipeline	1,270	1,220	1,509	0.7%
Other & Unknown	313	265	440	1.6%
Total	**18,581**	**16,122**	**27,104**	**1.7%**

** In this table, Multiple Modes & Mail includes export and import shipments that move domestically by a different mode than the mode used between the port and foreign location.*

Note: Data do not include imports and exports that pass through the United States from a foreign origin to a foreign destination by any mode. Numbers may not add to total due to rounding.

Source: U.S. Department of Transportation, Federal Highway Administration, Office of Freight Management and Operations, Freight Analysis Framework, version 3.1, 2010.

Growth in freight tonnage drives long-term growth in truck VMT. *Freight Facts and Figures 2010* shows that, from 1980 to 2008, combination truck VMT more than doubled and the VMT for single-unit trucks grew by about 95 percent. VMT decreased slightly for both types of trucks in 2008.

Exhibit 2-18

The Spectrum of Freight Moved in 2007

	Commodity Type	
Parameter	**High Value/Time Sensitive**	**Bulk**
Top Three Commodity Classes	Machinery Electronics Mixed Freight	Gravel Cereal Grains Coal
Share of Total Tons	13%	85%
Share of Total Value	65%	30%
Key Performance Variables	Reliability Speed Flexibilty	Reliability Cost
Share of Tons by Domestic Mode	87% Truck 5% Multiple Modes and Mail 4% Rail	71% Truck 12% Rail 9% Pipeline 4% Multiple Modes and Mail 3% Water
Share of Value by Domestic Mode	70% Truck 16% Multiple Modes and Mail 10% Air 2% Rail	71% Truck 12% Pipeline 7% Multiple Modes and Mail 6% Rail 2% Water

Source: U.S. Department of Transportation, Federal Highway Administration, Office of Freight Management and Operations, Freight Analysis Framework, version 3.1, 2010.

Freight Highways

The National Network is approximately 200,000 miles of public roads designated under the Surface Transportation Assistance Act of 1982 (Public Law 97-424) that requires States to allow trucks of certain specific sizes and configurations on the "Interstate System and those portions of the Federal-aid Primary System ... serving to link principal cities and densely developed portions of the States ... utilized extensively by large vehicles for interstate commerce." Required conventional combination trucks are up to 102 inches wide and include tractors with a single semitrailer up to 48 feet in length or with two 28-foot trailers. Most States currently allow conventional combinations with single trailers up to 53 feet in length.

Q&A

What corridors are included in the National Network and where are the routes designated as major freight corridors located?

With approximately 200,000 miles, the National Network is extensive. A map of the network is available in the *Freight Facts and Figures 2009* or online at: http://ops.fhwa.dot.gov/freight/freight_analysis/nat_freight_stats/docs/09factsfigures/figure3_3.htm.

Likewise, the 27,500 miles of the National Network that carry the largest concentration of freight are identified as major freight corridors. A map of the major U.S. freight corridors can be found in the *FHWA Freight Story, 2008,* or online at: http://ops.fhwa.dot.gov/freight/freight_analysis/freight_story/major.htm.

The National Network has not changed significantly since it was designated in 1982 and is especially important for maintaining truck access to ports and industrial activities in central cities and supporting interstate commerce by regulating the size of trucks.

Freight Transportation and the Cost of Goods

Geographic access of communities to the major freight corridors and performance of the major freight corridors help reduce the cost of goods to the benefit of consumers and businesses, which in turn stimulates economic activity and creates jobs. While deregulation and other factors lowered the cost of freight transportation for a given level of service over the past four decades, congestion, rising fuel prices, environmental constraints, and other factors could increase the cost of moving all goods in the years ahead. If these factors are not mitigated, then the increased cost of moving freight will be felt throughout the economy, affecting businesses and households alike.

The long and often vulnerable supply chains of high-value, time-sensitive commodities are particularly sensitive to congestion. Congestion results in enormous costs to shippers, carriers, and the economy. For example, Nike spends an additional $4 million per week to carry an extra 7 to 14 days of inventory to compensate for shipping delays.[1] One day of delay requires APL's eastbound trans-Pacific services to increase its use of containers and chassis by 1,300, which adds $4 million in costs per year.[2] A week-long disruption to container movements through the Ports of Los Angeles and Long Beach could cost the national economy between $65 million and $150 million per day.[3] Freight bottlenecks on highways throughout the United States cause more than 243 million hours of delay to truckers annually.[4] At a delay cost of $26.70 per hour, the conservative value used by the FHWA's Highway Economic Requirements System model for estimating national highway costs and benefits, these bottlenecks cost truckers about $6.5 billion per year.

Congestion costs are compounded by continuing increases in operating costs per mile and per hour. The cost of highway diesel fuel more than doubled in constant dollars over the decade ending in 2010 and would have quadrupled if the peak in 2008 had continued.[5] Future labor costs are projected to increase at a faster rate than in the past in response to the growing shortage of truck drivers.[6] To attract and retain more drivers, carriers will reduce the number of hours drivers are on the road, which will in turn increase operating costs. Railroads also are facing labor recruitment challenges.[7] Beyond fuel and labor, truck operating costs are affected by needed repairs to damaged equipment caused by deteriorating roads; taxes and tolls to pay for repair of infrastructure; and insurance and additional equipment required to meet security, safety, and environmental requirements.

Increased costs to carriers are reflected eventually in increased prices paid for freight transportation. Between 2003 and 2008, prices increased 23 percent for truck transportation, 49 percent for rail transportation, 28 percent for scheduled air freight, 27 percent for water transportation, 37 percent for pipeline transportation of crude petroleum, 22 percent for other pipeline transportation, and 12 percent for freight transportation support activities.[8]

When the entire economy is taken into account, transportation services contribute about 5 percent to the production of the gross domestic product (GDP).[9] For-hire and in-house trucking provide more than one-half of this contribution. The importance of transportation varies by economic sector. For example, $1 of final demand for agricultural products requires 14.2 cents in transportation services, compared with 9.1 cents for manufactured goods and about 8 cents for mining products.[10] An increase in transportation cost affects inexpensive bulk commodities more than high-value, time-sensitive commodities that have higher margins. In either case, an increase in transportation costs will ripple through all these industries, affecting not only the cost of goods from all economic sectors but also markets for the goods.

[1] John Isabell, "Maritime and Infrastructure Impact on Nike's Inbound Delivery Supply Chain," TRB Freight Roundtable, October 24, 2006 www.trb.org/conferences/FDM/Isabell.pdf.

[2] John Bowe, "The High Cost of Congestion," TRB Freight Roundtable, October 24, 2006 www.trb.org/conferences/FDM/Bowe.pdf.

[3] U.S. Congressional Budget Office, *The Economic Costs of Disruptions in Container Shipments*, March 26, 2006 www.cbo.gov/ftpdocs/71xx/doc7106/03-29-Container_Shipments.pdf.

[4] FHWA, *An Initial Assessment of Freight Bottlenecks on Highways*, October 2005 www.fhwa.dot.gov/policy/otps/bottlenecks.

[5] FHWA, *Freight Facts and Figures 2010*, figure 5-2, page 57.

[6] America Trucking Associations, *The U.S. Truck Driver Shortage: Analysis and Forecasts*, 2005 www.truckline.com/StateIndustry/Documents/ATADriverShortageStudy05.pdf.

[7] Federal Railroad Administration, *An Examination of Employee Recruitment and Retention in the U.S. Railroad Industry*, 2007 www.fra.dot.gov/us/content/1891.

[8] FHWA, *Freight Facts and Figures 2010*, table 4-5, page 50.

[9] FHWA, *Freight Facts and Figures 2010*, page 45.

[10] DOT, Bureau of Transportation Statistics, "The Economic Importance of Transportation Services: Highlights of the Transportation Satellite Accounts," BTS/98-TS4R, April 1998, figure 2, page 5.

The National Network and the NHS are approximately 200,000 miles in length, but the National Network includes 65,000 miles of highway beyond the NHS and the NHS includes 50,000 miles not on the National Network. Both the National Network and the NHS were created for the purpose of supporting interstate commerce. However, the National Network seeks to regulate the size of trucks while the NHS focuses on Federal investments.

Only a small portion of the National Network and the NHS carries the largest concentrations of freight flows. The Federal Highway Administration (FHWA) has identified approximately 27,500 miles of major freight corridors. Interstate highways account for more than 95 percent of the mileage of these major freight corridors. The corridors account for about 60 percent of the length of the Interstate System and less than 17 percent of the National Network.

Freight Challenges

The challenges of moving the Nation's freight cheaply and reliably on an increasingly constrained infrastructure without affecting safety and degrading the environment are substantial, and traditional strategies to support passenger travel may not apply. The freight transportation challenge differs from that of urban commuting and other passenger travel in several ways:

- Freight often moves long distances through localities and responds to distant economic demands, while the majority of passenger travel occurs between local origins and destinations. Freight movement often creates local problems without local benefits.
- Freight movements fluctuate more quickly and in greater relative amounts than passenger travel. While both passenger travel and freight respond to long-term demographic change, freight responds more quickly than passenger travel to short-term economic fluctuations. Fluctuations can be national or local. The addition or loss of just one major business can dramatically change the level of freight activity in a locality.
- Freight movement is heterogeneous compared with passenger travel. Patterns of passenger travel tend to be very similar across metropolitan areas and among large economic and social strata. The freight transportation demands of farms, steel mills, and clothing boutiques differ radically from one another. Solutions aimed at average conditions are less likely to work because the freight demands of economic sectors vary widely.
- Improvements targeted at freight demand are needed because freight accounts for a larger share of VMT on the transportation system and improvements targeted at general traffic or passenger travel are less likely to aid the flow of freight as an incidental by-product.

Local public action is difficult to marshal because freight traffic and the benefits of serving that traffic rarely stay within a single political jurisdiction. One-half of the weight and two-thirds of the value of all freight movements cross a State or international boundary. Federal legislation established metropolitan planning organizations (MPOs) four decades ago to coordinate transportation planning and investment across State and local lines within urban areas, but freight corridors extend well beyond even the largest metropolitan regions and usually involve several States. Creative and ad hoc arrangements are often required through pooled-fund studies and multi-State coalitions to plan and invest in freight corridors that span regions and even the continent, but there are few institutional arrangements that coordinate this activity. One example of a more established multi-State arrangement is the I-95 Corridor Coalition. Additional information about this coalition and similar groups can be found at www.ops.fhwa.dot.gov/freight/corridor_coal.htm.

Challenges for Freight Transportation: Congestion

Congestion affects economic productivity in several ways. American businesses require more operators and equipment to deliver goods when shipping takes longer, more inventory when deliveries are unreliable, and more distribution centers to reach markets quickly when traffic is slow. Likewise, both businesses and households are affected by sluggish traffic on the ground and in the air, reducing the number of workers and job sites within easy reach of any location. The growth in freight is a major contributor to congestion in urban areas and on intercity routes, and congestion affects the timeliness and reliability of freight transportation. Long-distance freight movements are often a significant contributor to local congestion, and local congestion typically impedes freight to the detriment of local and distant economic activity.

Growing freight demand increases recurring congestion at freight bottlenecks, places where freight and passenger service conflict with one another, and where there is not enough room for local pickup and delivery. Congested freight hubs include international gateways such as ports, airports, and border crossings, and major domestic terminals and transfer points such as Chicago's rail yards. Bottlenecks between freight hubs are caused by converging traffic at highway intersections and railroad junctions, steep grades on highways and rail lines, lane reductions on highways and single-track portions of railroads, and locks and constrained channels on waterways. A preliminary study for the FHWA identified intersections in large cities, where both personal vehicles and trucks clog the road, as the largest highway freight bottlenecks.[1]

As passenger cars and trucks compete for space on the highway system, commuter and intercity passenger trains compete with freight trains for space on the railroad network. Rail freight is growing at the same time that rising fuel prices and environmental concerns are encouraging greater use of commuter and high-speed rail.

Congestion also is caused by restrictions on freight movement, such as the lack of space for trucks in dense urban areas and limited delivery and pickup times at ports, terminals, and shipper loading docks. One estimate of urban congestion attributes 947,000 hours of vehicle delay to delivery trucks parked at curbside in dense urban areas where office buildings and stores lack off-street loading facilities.[2] Limitations on delivery times place significant demands on highway rest areas when large numbers of trucks park outside major metropolitan areas waiting for their destination to open and accept their shipments.[3]

Bottlenecks cause recurring, predictable congestion in selected locations while the temporary loss of capacity, or nonrecurring congestion, is widespread and less predictable. Sources of nonrecurring delay include incidents, weather, work zones, and other disruptions. These nonrecurring, often-unpredictable, sources of highway delay have been estimated to exceed delay from recurring congestion.[4] Weather, maintenance activities, and incidents have similar effects on aviation, railroads, pipelines, and waterways. Aviation is regularly disrupted by local weather delays; and inland waterways are closed by regional flooding, droughts, and ice.

Chapter 4 includes a broader discussion of highway congestion.

[1] FHWA, *An Initial Assessment of Freight Bottlenecks on Highways*, October 2005 www.fhwa.dot.gov/policy/otps/bottlenecks.

[2] Oak Ridge National Laboratory, *Temporary Losses of Highway Capacity and Impacts on Performance: Phase 2*, 2004, table 36, page 88 www-cta.ornl.gov/cta/Publications/Reports/ORNL_TM_2004_209.pdf.

[3] FHWA, *Study of Adequacy of Commercial Truck Parking Facilities*, 2002 www.tfhrc.gov/safety/pubs/01158.

[4] Oak Ridge National Laboratory, *Temporary Losses of Highway Capacity and Impacts on Performance: Phase 2*, 2004, table 41, page 101 www-cta.ornl.gov/cta/Publications/Reports/ORNL_TM_2004_209.pdf.

The growing needs of freight transportation can bring into focus conflicts between interstate and local interests. Many communities do not want the noise and other aspects of trucks and trains that pass through with little benefit to the locality, but those transits can have a huge impact on national freight movement and regional economies.

Beyond the challenges of intergovernmental coordination, freight transportation raises additional issues involving the relationships between public and private sectors. Virtually all carriers and many freight facilities are privately owned. *Freight Facts and Figures 2010* shows that the private sector owns $1.07 trillion

Challenges for Freight Transportation: Safety, Energy, and the Environment

Freight transportation is not just an issue of throughput and congestion. The growth in freight movement has heightened public concerns about safety, energy consumption, and the environment.

Highways and railroads account for nearly all fatalities and injuries involving freight transportation. Most of these fatalities involve people who are not part of the freight transportation industry, such as trespassers at railroad facilities and occupants of other vehicles killed in crashes involving large trucks. The FHWA's *Freight Facts and Figures 2010* publication shows that, of the 33,808 highway fatalities in 2009, 1.5 percent were occupants of large trucks and 8.5 percent were others killed in crashes involving large trucks (the remaining 90 percent of fatalities were attributed to other types of personal and commercial vehicles). Chapter 5 discusses highway safety in more detail.

According to *Freight Facts and Figures 2010* single-unit and combination trucks accounted for 22 percent of all gasoline, diesel, and other fuels consumed by motor vehicles, and 69 percent of the fuel consumed by freight transportation in 2008. Fuel consumption by trucks resulted in three-fourths of the 522.6 million metric tons of carbon dioxide (CO_2) equivalent generated by freight transportation, and freight accounted for 28 percent of transportation's contribution to this major greenhouse gas. Trucks and other heavy vehicles are also a major contributor to air quality problems related to nitrogen oxide (NO_x) (33 percent of all mobile sources) and particulate matter of 10 microns in diameter or smaller (PM-10) (23.3 percent of all mobile sources). Freight modes combined account for 49 percent of all mobile sources of NO_x and 36 percent of all mobile sources of PM-10.

Environmental issues involving freight transportation go well beyond emissions. Disposal of dredge spoil, the mud and silt that must be removed to deepen water channels for commercial vessels, is a major challenge for allowing larger ships to berth. Land use and water quality concerns are raised against all types of freight facilities, and invasive species can spread through freight movement. Issues relating to environmental sustainability are discussed in Chapter 11.

Incidents involving hazardous materials exacerbate public concern and cause real disruption. *Freight Facts and Figures 2010* shows that, of the 14,777 accident-related hazardous materials transportation incidents in 2009, highways accounted for 12,691, air accounted for 1,357, and rail accounted for 641. The railcar fire in the Howard Street tunnel under Baltimore City in 2001 illustrates the perceived and real problems of transporting hazardous materials. This incident, which occurred on tracks next to a major league baseball stadium at game time during the evening rush hour, forced the evacuation of thousands of people and closed businesses in much of downtown Baltimore. A vital railroad link between the Northeast and the South, as well as a local rail transit line and all east-west arterial streets through downtown, were closed for an extended period.

in transportation equipment plus $681.2 billion in transportation structures. In comparison, public agencies own $502 billion in transportation equipment plus $2.47 trillion in highways. Freight railroad facilities and services are owned almost entirely by the private sector, while trucks owned by the private sector operate over public highways. Likewise, air cargo services owned by the private sector operate in public airways and mostly at public airports. Privately owned ships operate over public waterways and at both public and private port facilities. Most pipelines are privately owned but significantly controlled by public regulation. In the public sector, virtually all truck routes are owned by State or local governments, and airports and harbors are typically owned by regional or local authorities. Air and water navigation is typically handled at the Federal level, and safety is regulated by all levels of government. As a consequence of this mixed ownership and management, most solutions to freight problems require joint action by both public and private sectors. Financial, planning, and other institutional mechanisms for developing and implementing joint efforts have been limited, inhibiting effective measures to improve the performance and minimize the public costs of the freight transportation system.

Framework for a National Freight Policy

To establish a better understanding of the freight challenge and freight activities by all levels of government and the private sector, the Transportation Research Board convened individuals from transportation providers, shippers, State agencies, port authorities, and the U.S. Department of Transportation (DOT) to form a Freight Transportation Industry Roundtable. Members of the roundtable developed an initial Framework for a National Freight Policy to identify freight activities and focus those activities toward common objectives. The framework continues to evolve within the DOT as part of its outreach to members of the freight community.

The objectives and strategies of the framework summarize a large number of tactics and activities, including the freight programs that were launched under the Safe, Accountable, Flexible, Efficient Transportation Act: A Legacy for Users (SAFETEA-LU). SAFETEA-LU authorized $4.6 billion for freight-oriented infrastructure investments, expanded eligibility for freight projects under previous programs, modified the tax code to encourage up to $15 billion in private investment, initiated a program to enhance the capacity of the freight profession, and launched the National Cooperative Freight Research Program.

SAFETEA-LU and local recognition of freight challenges have stimulated a variety of freight plans, investments, and management initiatives in State departments of transportation, MPOs, port authorities, and the private sector. Several State departments of transportation have begun collaborative planning efforts for multistate freight corridors; and public-private partnerships such as the Intermodal Freight Technology Working Group (IFTWG) have been established to pursue creative financial and technological options for improving the efficiency, safety, and security of freight movement. These activities and their relationship to the Framework for a National Freight Policy are described in the FHWA's *Freight Story 2008*.

Freight challenges are not new, but their ongoing importance and increased complexity warrant creative solutions by all with a stake in the vitality of the American economy. Enhanced freight planning, improved institutional arrangements for multi-State freight projects, and performance management requirements are among proposed responses to freight challenges being considered through reauthorization of the Federal-aid highway program.

Bridge System Characteristics

The National Bridge Inventory (NBI) contains records for 603,310 bridges longer than 20 feet (6.1 meters) in total length located on public roads in the United States in 2009. Information concerning the Nation's bridges is collected on a regular basis in accordance with the National Bridge Inspection Standards. These standards are discussed in more detail in Chapter 3.

This section presents information on the characteristics of the Nation's bridges, including ownership, deck area, the amount of traffic carried, and the functional classification of roadways on which bridges are located.

Q&A

Why do the bridge statistics presented in this report cover the period from 2001 to 2009, rather than the 2000 to 2008 data presented for highways?

This report is based on the latest available data at the time the writing of each chapter commenced; in the case of bridge data, it covers information in the National Bridge Inventory as of October 2009. Final 2009 numbers would reflect information in the NBI as of December 2009.

However, it should be noted that the majority of bridges are inspected once every 24 months. Therefore, the "2009" NBI data actually reflect the conditions of individual bridges from late 2007 through late 2009, or late 2008 on average.

In contrast, the HPMS data cited earlier in this chapter were based on annual reports entered into the system in 2009, which reflected the system as of the end of 2008; these data are commonly referred to as "2008" HPMS data.

Bridges by Owner

Exhibit 2-19 identifies bridges by owner. The majority of State and local bridges are owned by highway agencies. However, some bridges are owned by State or local park, forest, and reservation agencies; toll authorities; and other State or local agencies. At the Federal level, bridge ownership is spread across a number of agencies; many such bridges are owned by units within the Department of Interior and by the Department of Defense. A small number (less than 1 percent) of bridges carrying public roadways are owned by private entities. Bridges carrying railroads are not included in the database unless they also carry a public road or cross a public road where information of certain features, such as vertical or horizontal clearances, is required for management of the highway system.

Q&A

How do the bridge ownership percentages compare with the road ownership percentages?

In 2009, bridge ownership was nearly equally divided between State (slightly more than 48.6 percent) and local (slightly more than 50.2 percent) agencies. As noted earlier, the majority of roadways were owned by local agencies (77.4 percent) in 2008.

Exhibit 2-19

Bridges by Owner, 2001–2009

Owner	2001	2003	2005	2007	2009	Annual Rate of Change 2009/2001
Federal	8,769	8,437	8,276	8,404	8,452	-0.5%
State	278,504	281,684	283,644	286,623	290,062	0.5%
Local	299,224	299,499	301,162	302,921	303,014	0.2%
Private	2,302	1,511	1,435	1,451	1,426	-5.8%
Unknown/Unclassified	1,354	1,206	1,151	481	356	-15.4%
Total	**590,153**	**592,337**	**595,668**	**599,880**	**603,310**	**0.3%**

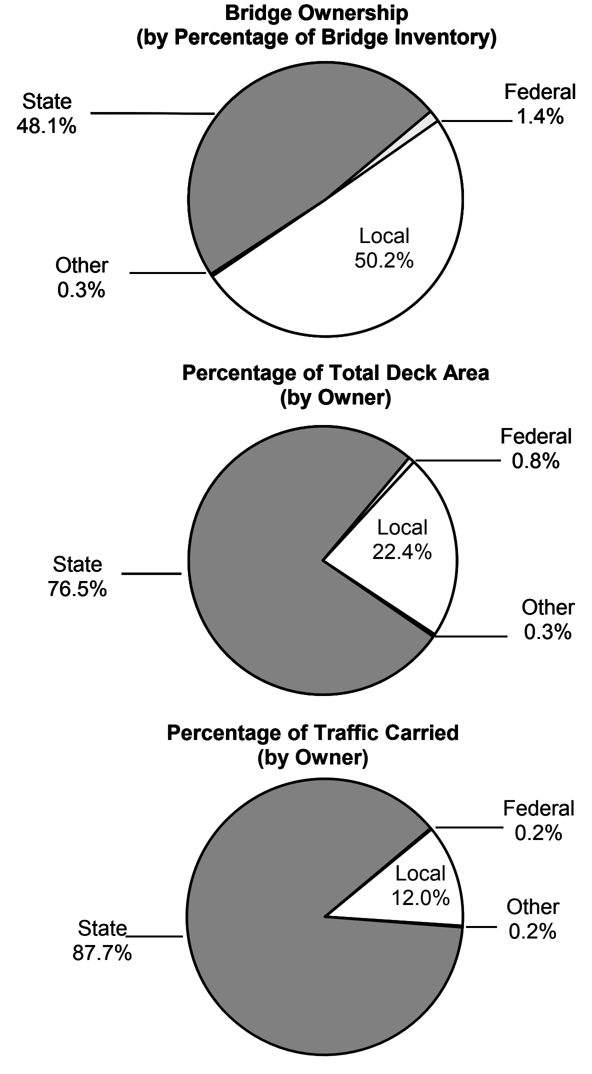
Source: National Bridge Inventory as of October 2009.

Between 2001 and 2009, the total number of bridges grew at an average annual rate of 0.3 percent to 603,310. This increase has been concentrated in State-owned and locally owned bridges; the number of bridges owned by the Federal government and private entities decreased over this period. Of note is the steady reduction in the number of bridges recorded as unknown/unclassified from 1,354 in 2001 to 356 in 2009. The reduction is the result of the continued efforts to properly and accurately record data for all bridges on the Nation's roadways.

In 2009, State agencies owned 290,062 bridges, while local agencies owned 303,014. While these numbers are relatively even in terms of raw counts, it is important to recognize that State agencies own a disproportionate amount of larger bridges with higher traffic volumes. As shown in *Exhibit 2-20*, while States owned 48.1 percent of total bridges in 2009, these bridges constituted 76.5 percent of total bridge deck area and carried 87.7 percent of total bridge traffic. In 2009, State agencies were responsible for the maintenance and operation of more than 3.4 times the deck area of local agencies. In addition, bridges owned by State agencies carried more than 7.3 times the traffic of bridges owned by local agencies.

Exhibit 2-20

Bridge Inventory Characteristics for Ownership, Traffic, and Deck Area, 2009



Source: National Bridge Inventory as of October 2009.

Bridges by Functional Classification

Highway functional classifications are maintained in the NBI according to the hierarchy used for highway systems previously described in this chapter. The number of bridges by functional classification is summarized and compared with previous years in *Exhibit 2-21.*

As noted earlier in this chapter, changes in urban area boundaries resulting from the 2000 Census have led to reductions in the number of rural bridges. The number of bridges on all rural functional classifications has shown, for the most part, a steady decline since 2001, while the number of urban bridges on all functional classifications has, in the majority of years, shown an unbroken increase. The number of bridges on urban collectors has increased at an average annual rate of 3.3 percent between 2001 and 2009, increasing the fastest among the functional classes identified.

Exhibit 2-22 shows the relationship between bridges among various rural and urban functional classes. In 2009, there were approximately 2.9 rural bridges for every 1 urban bridge. However, urban bridges carried more than 3.2 times the ADT of rural bridges and comprised slightly less than 1.3 times the deck area of rural bridges.

In 2009, the 206,127 bridges on roads classified as rural local constituted 34.2 percent of the total number of bridges, but accounted for only 9.6 percent of total bridge deck area and carried only 1.4 percent of total bridge traffic. In contrast, the 29,743 urban Interstate System bridges made up only 4.9 percent of total bridges, but accounted for 19.3 percent of total bridge deck area and carried 35.8 percent of total bridge ADT.

Interstate bridges in urban areas carried almost 3.9 times the ADT carried by rural interstate bridges in 2009. In fact, the ADT carried on urban Interstate System bridges was more than 1.5 times the ADT carried on all rural bridges combined in 2009.

Exhibit 2-21

Number of Bridges by Functional System, 2001–2009

Functional System	2001	2003	2005	2007	2009	Annual Rate of Change 2009/2001
Rural						
Interstate	27,579	27,769	26,946	26,134	25,268	-1.1%
Other Arterial	75,335	76,064	75,273	74,616	74,506	-0.1%
Collector	143,517	143,457	142,869	141,679	141,053	-0.2%
Local	209,845	209,218	207,866	206,165	206,127	-0.2%
Subtotal Rural	456,276	456,508	452,954	448,594	446,954	-0.3%
Urban						
Interstate	27,875	27,601	28,566	29,309	29,743	0.8%
Other Arterial	64,074	65,451	68,625	72,567	74,797	2.0%
Collector	15,405	15,278	16,873	18,629	19,992	3.3%
Local	26,043	27,085	28,344	30,666	31,773	2.5%
Subtotal Urban	133,397	135,415	142,408	151,171	156,305	2.0%
Not coded	480	415	306	115	51	-24.4%
Total	**590,153**	**592,338**	**595,668**	**599,880**	**603,310**	**0.3%**

Source: National Bridge Inventory as of October 2009.

Exhibit 2-22

Bridges by Functional System Weighted by Numbers, ADT, and Deck Area, 2009

Functional System	Number of Bridges	Percent by Total Number	Percent of Total Deck Area	Percent of Total ADT
Rural				
Interstate	25,268	4.2%	7.1%	9.2%
Other Principal Arterial	35,699	5.9%	8.7%	5.8%
Minor Arterial	38,807	6.4%	6.1%	3.3%
Major Collector	93,036	15.4%	9.3%	3.2%
Minor Collector	48,017	8.0%	3.3%	0.8%
Local	206,127	34.2%	9.6%	1.4%
Subtotal Rural	**446,954**	**74.1%**	**44.1%**	**23.7%**
Urban				
Interstate	29,743	4.9%	19.3%	35.8%
Other Freeways & Expressways	19,512	3.2%	10.6%	16.1%
Other Principal Arterial	27,442	4.5%	11.3%	11.9%
Minor Arterial	27,843	4.6%	7.4%	7.3%
Collector	19,992	3.3%	3.6%	2.7%
Local	31,773	5.3%	3.8%	2.4%
Subtotal Urban	**156,305**	**25.9%**	**55.9%**	**76.3%**
Unclassified	51	0.0%		
Total	**603,310**	**100.0%**	**100.0%**	**100.0%**

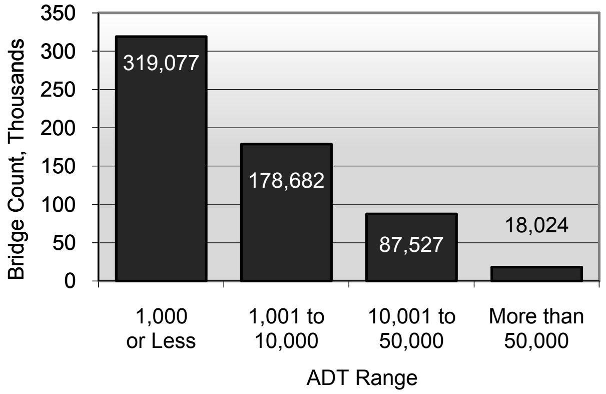
Source: National Bridge Inventory as of October 2009.

Bridges by Traffic Volume

As shown in *Exhibit 2-23*, many bridges carry relatively low volumes of traffic on a typical day. Approximately 319,077 bridges, 52.9 percent of the total bridges in the Nation, have an ADT of 1,000 or less. An additional 178,682 bridges, 29.6 percent of all bridges, have an ADT between 1,001 and 10,000. Only 18,024 of the Nation's bridges, or 3.0 percent, have an ADT higher than 50,000. The remaining 87,527 bridges, 14.5 percent, have an ADT between 10,001 and 50,000.

Exhibit 2-23

Number of Bridges by ADT, 2009



Source: National Bridge Inventory as of October 2009.

NHS Bridges

Exhibit 2-24 shows that the 117,510 bridges on the National Highway System (NHS) as of 2009 constituted 19.5 percent of total bridges in the Nation, but included 49.2 percent of total bridge deck area and carried 71.0 percent of total bridge traffic. Taken together, rural and urban Interstate bridges accounted for 9.1 percent of the total bridges, but carried 45.1 percent of total bridge traffic in 2009. As referenced earlier in this chapter, the NHS includes the entire Interstate System, as well as additional critical routes. The STRAHNET system, including Interstate highways and other routes critical to national defense, included 67,843 bridges in 2009. All STRAHNET routes, including STRAHNET connectors, are included as part of the NHS.

Exhibit 2-24

Interstate, STRAHNET, and NHS Bridges Weighted by Numbers, ADT, and Deck Area, 2009

Federal System *	Number of Bridges	Percent by Total Number of Bridges	Percent of Total Deck Area	Percent of Total ADT
Interstate System	55,011	9.1%	26.3%	45.1%
STRAHNET	67,843	11.2%	30.8%	49.9%
National Highway System	117,510	19.5%	49.2%	71.0%

** The NHS includes all of STRAHNET; STRAHNET includes the entire Interstate System.*

Source: National Bridge Inventory as of October 2009.

Transit System Characteristics

System History

The first transit systems in the United States date to the late 19th century. These were privately owned, for-profit businesses that were instrumental in defining the urban communities of that time. By the postwar period, competition from the private automobile was making it impossible for transit businesses to operate at a profit. As they 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, which established the agency now known as the Federal Transit Administration (FTA) to administer Federal funding for transit systems. The Act also changed the character of the industry by specifying that Federal funds for transit were to be given to public agencies rather than private firms; this accelerated transit systems' transition from private to public ownership and operation. The Act also required local governments to contribute matching funds in order to receive Federal aid for transit services, setting the stage for the multilevel governmental partnerships that continues to characterize the transit industry today.

State governments' involvement in the provision of transit services is generally through financial support and performance oversight. In some cases, States have undertaken outright ownership and operation of transit services; six States—Connecticut, Delaware, Massachusetts, Maryland, Pennsylvania, and Washington—own and operate transit systems directly.

Colorful Transit Vocabulary

Modal network refers to a system of routes and stops served by one type of transit technology; this could be a bus network, a light rail network, a ferry network, or a demand response system. Transit operators often maintain several different modal networks, most often motor bus systems augmented with demand response service.

Articulated bus is an extra-long (54 ft. to 60 ft.) bus with two connected passenger compartments. The rear body section is connected to the main body by a joint mechanism that allows the vehicles to bend when in operation for sharp turns and curves and yet have a continuous interior.

Automated Guideway Systems are driverless, rubber-tire vehicles usually running alone or in pairs on a single broad concrete rail, typical of most airport trains.

Demand response service usually consists of passenger cars, vans, or small buses operating in response to calls from passengers or their agents to the transit operator, who then dispatches a vehicle to pick up the passengers and transport them to their destinations. The vehicles do not operate over a fixed route or on a fixed schedule, except on a temporary basis to satisfy a special need. A vehicle may be dispatched to pick up several passengers at different pickup points before taking them to their respective destinations.

Públicos or "public cars" are typically 17-passenger vans that serve towns throughout Puerto Rico, stopping in each community's main plaza or at a destination requested by a passenger. They operate without a set schedule, primarily during the day; the public service commission fixes routes and fares. Some routes have vehicles in good condition, with air-conditioning, workable radios, and seats without holes. San Juan-based Público companies include Blue Line for trips to Aguadilla and the northwest coast, Choferes Unidos de Ponce for Ponce, Línea Caborrojeña for Cabo Rojo and the southwest coast, Línea Boricua for the interior and the southwest, Línea Sultana for Mayagüez and the west coast, and Terminal de Transportación Pública for Fajardo and the east.

Jitneys are generally small-capacity vehicles that follow a rough service route, but can go slightly out of their way to pick up and drop off passengers. In many U.S. cities (e.g., Pittsburgh and Detroit), the term "jitney" refers to an unlicensed taxicab. In some U.S. jurisdictions, the limit to a jitney is seven passengers.

Revenue service is the time when a vehicle is actively providing service to the general public and carrying passengers or at least available to them. Revenue from fares is not necessary because vehicles are considered to be in revenue service even when the ride is free.

In 1962, the United States Congress passed legislation that required the formation of metropolitan planning organizations (MPOs) for urbanized areas with populations greater than 50,000. MPOs are composed of State and local officials who work to address the transportation planning needs of an urbanized area at a regional level. Twenty-nine years later, the Intermodal Surface Transportation Efficiency Act of 1991 made MPO coordination an essential prerequisite for Federal funding of many transit projects.

State and local transit agencies have evolved into a number of different institutional models. A transit provider may be a unit of a regional transportation agency; may be operated directly by the State, county, or city government; or may be an independent agency with an elected or appointed Board of Governors. Transit operators can provide service directly with their own equipment or they may purchase transit services through an agreement with a contractor. All public transit services must be open to the general public without discrimination and meet the accessibility requirements of the Americans with Disabilities Act of 1990 (ADA).

System Infrastructure

Urban Transit Agencies

In 2008, there were 690 agencies in urbanized areas that were required to submit data to the National Transit Database (NTD), of which 667 were public agencies, including six State departments of transportation (DOTs). The remaining 23 agencies were either private operators or independent agencies (e.g., nonprofit organizations). Of the 690 agencies, 116 received either a reporting exemption for operating nine or fewer vehicles or a temporary reporting waiver. The remaining 574 reporting agencies provided service on 1,479 separate modal networks; all but 166 agencies operated more than one mode. In 2008, there were an additional 1,396 transit operators serving rural areas. Not all transit providers are included in these counts because those that do not receive grant funds from the FTA are not required to report to the NTD. Some, but not all, agencies report anyway, as this can help their region receive more Federal transit funding.

The Nation's motor bus and demand response systems are much more extensive than the Nation's rail transit system. In 2008, there were 658 motor bus systems and 633 demand response systems in urban areas, compared with 17 heavy rail systems, 29 commuter rail systems, and 35 light rail systems. While motor bus and demand response systems were found in every major urbanized area in the United States, 84 urbanized areas were served by at least one of the three primary rail modes, including 55 by commuter rail, 25 by light rail, and 24 by heavy rail (listed in *Exhibit 2-25*). In addition to these modes, there were 67 publicly operated transit vanpool systems, 20 ferryboat systems, seven trolleybus systems, four automated guideway systems, four inclined plane systems, and one cable car system operating in urbanized areas of the United States and its territories.

The transit statistics presented in this report also include the San Francisco Cable Car, the Seattle Monorail, the Roosevelt Island Aerial Tramway in New York, and the Alaska Railroad (which is a combination of long-distance passenger rail, sightseeing, and freight transportation services.)

Exhibit 2-25

Rail Modes Serving Urbanized Areas, by State

Mode: Heavy Rail

Rail System Name	City	State	Vehicles
Los Angeles County Metropolitan Transportation Authority (LACMTA)	Los Angeles	CA	70
San Francisco Bay Area Rapid Transit District (BART)	Oakland	CA	540
Santa Clara Valley Transportation Authority (VTA)	San Jose	CA	
Washington Metropolitan Area Transit Authority (WMATA)	Washington	DC	830
Miami-Dade Transit (MDT)	Miami	FL	98
Metropolitan Atlanta Rapid Transit Authority (MARTA)	Atlanta	GA	188
City and County of Honolulu Department of Transportation Services (DTS)	Honolulu	HI	
Chicago Transit Authority (CTA)	Chicago	IL	1,016
Massachusetts Bay Transportation Authority (MBTA)	Boston	MA	320
Maryland Transit Administration (MTA)	Baltimore	MD	54
Port Authority Trans-Hudson Corporation (PATH)	Jersey City	NJ	266
Port Authority Transit Corporation (PATCO)	Lindenwold	NJ	84
MTA New York City Transit (NYCT)	New York	NY	5,288
Staten Island Rapid Transit Operating Authority (SIRTOA)	Staten Island	NY	46
The Greater Cleveland Regional Transit Authority (GCRTA)	Cleveland	OH	22
Southeastern Pennsylvania Transportation Authority (SEPTA)	Philadelphia	PA	278
Puerto Rico Highway and Transportation Authority (PRHTA)	San Juan	PR	40

Mode: Commuter Rail

Rail System Name	City	State	Vehicles
Altamont Commuter Express (ACE)	Stockton	CA	18
North County Transit District (NCTD)	Oceanside	CA	26
Peninsula Corridor Joint Powers Board (PCJPB)	San Carlos	CA	96
Riverside County Transportation Commission (RCTC)	Riverside	CA	
Southern California Regional Rail Authority (Metrolink)	Los Angeles	CA	173
Connecticut Department of Transportation (CDOT)	Newington	CT	22
Delaware Transit Corporation (DTC)	Dover	DE	
South Florida Regional Transportation Authority (TRI-Rail)	Pompano Beach	FL	34
Northeast Illinois Regional Commuter Railroad Corporation (Metra)	Chicago	IL	1,056
Northern Indiana Commuter Transportation District (NICTD)	Chesterton	IN	66
Massachusetts Bay Transportation Authority (MBTA)	Boston	MA	419
Maryland Transit Administration (MTA)	Baltimore	MD	132
Northern New England Passenger Rail Authority (NNEPRA)	Portland	ME	14
Metro Transit	Minneapolis	MN	
New Jersey Transit Corporation (NJ TRANSIT)	Newark	NJ	944
Metro-North Commuter Railroad Company (MTA-MNCR)	New York	NY	1,089
MTA Long Island Rail Road (MTA LIRR)	Jamaica	NY	1,018
Metro Regional Transit Authority (Metro)	Akron	OH	
Tri-County Metropolitan Transportation District of Oregon (TriMet)	Portland	OR	
Pennsylvania Department of Transportation (PENNDOT)	Harrisburg	PA	20
Southeastern Pennsylvania Transportation Authority (SEPTA)	Philadelphia	PA	315
Regional Transportation Authority (RTA)	Nashville	TN	5
Capital Metropolitan Transportation Authority (CMTA)	Austin	TX	
Dallas Area Rapid Transit (DART)	Dallas	TX	21
Fort Worth Transportation Authority (The T)	Fort Worth	TX	15
Metropolitan Transit Authority of Harris County, Texas (Metro)	Houston	TX	
Utah Transit Authority (UTA)	Salt Lake City	UT	18
Virginia Railway Express (VRE)	Alexandria	VA	78
Central Puget Sound Regional Transit Authority (ST)	Seattle	WA	38

Exhibit 2-25

Rail Modes Serving Urbanized Areas, by State (Continued)

Mode: Light Rail

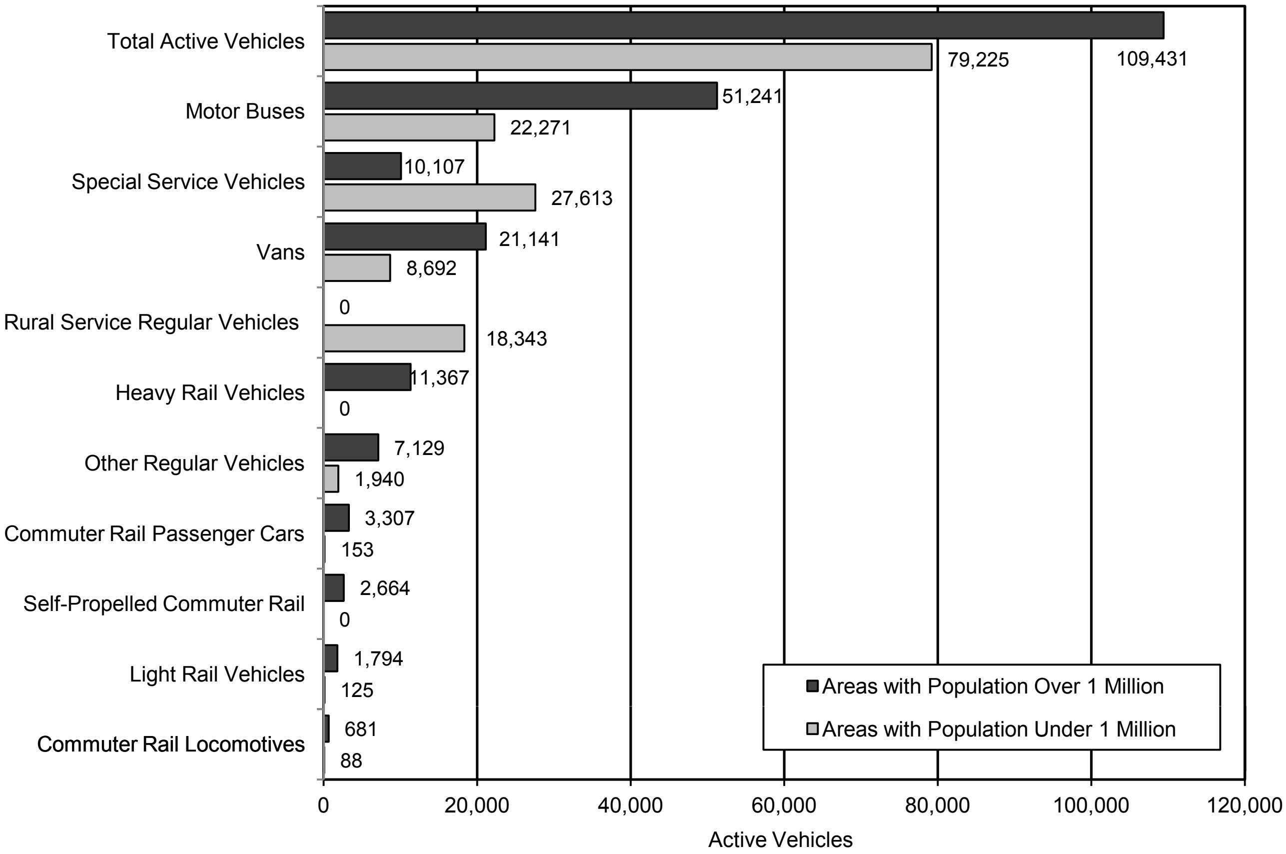
Rail System Name	City	State	Vehicles
Central Arkansas Transit Authority (CATA)	Little Rock	AR	3
City of Phoenix Public Transit Department (Valley Metro)	Phoenix	AZ	
City of Tucson (COT)	Tucson	AZ	
Regional Public Transportation Authority (RPTA)	Phoenix	AZ	
Los Angeles County Metropolitan Transportation Authority (LACMTA)	Los Angeles	CA	102
North County Transit District (NCTD)	Oceanside	CA	4
Sacramento Regional Transit District (Sacramento RT)	Sacramento	CA	56
San Diego Metropolitan Transit System (MTS)	San Diego	CA	93
San Francisco Municipal Railway (MUNI)	San Francisco	CA	139
Santa Clara Valley Transportation Authority (VTA)	San Jose	CA	54
Denver Regional Transportation District (RTD)	Denver	CO	101
Hillsborough Area Regional Transit Authority (HART)	Tampa	FL	8
New Orleans Regional Transit Authority (NORTA)	New Orleans	LA	22
Massachusetts Bay Transportation Authority (MBTA)	Boston	MA	152
Maryland Transit Administration (MTA)	Baltimore	MD	36
Metro Transit	Minneapolis	MN	27
Bi-State Development Agency (METRO)	St. Louis	MO	56
Charlotte Area Transit System (CATS)	Charlotte	NC	19
New Jersey Transit Corporation (NJ TRANSIT)	Newark	NJ	17
New Jersey Transit Corporation (NJ TRANSIT)	Newark	NJ	59
Niagara Frontier Transportation Authority (NFT Metro)	Buffalo	NY	23
The Greater Cleveland Regional Transit Authority (GCRTA)	Cleveland	OH	17
Tri-County Metropolitan Transportation District of Oregon (TriMet)	Portland	OR	85
Port Authority of Allegheny County (Port Authority)	Pittsburgh	PA	51
Southeastern Pennsylvania Transportation Authority (SEPTA)	Philadelphia	PA	127
Memphis Area Transit Authority (MATA)	Memphis	TN	12
Dallas Area Rapid Transit (DART)	Dallas	TX	85
Island Transit (IT)	Galveston	TX	4
Metropolitan Transit Authority of Harris County, Texas (Metro)	Houston	TX	17
Utah Transit Authority (UTA)	Salt Lake City	UT	46
Hampton Roads Transit (HRT)	Hampton	VA	
Central Puget Sound Regional Transit Authority (ST)	Seattle	WA	2
Central Puget Sound Regional Transit Authority (ST)	Seattle	WA	
King County Department of Transportation (King County Metro)	Seattle	WA	2
Kenosha Transit (KT)	Kenosha	WI	3

Transit Fleet

Exhibit 2-26 provides an overview of the Nation's 188,656 transit vehicles in 2008 by type of vehicle and size of urbanized area. Although some types of vehicles are specific to certain modes, many vehicles—particularly small buses and vans—are used by several different transit modes. For example, vans may be used to provide vanpool, demand response, Público, or motor bus services.

Exhibit 2-26

Transit Active Fleet by Vehicle Type, 2008



Notes:

1: "Other Regular Vehicles" includes aerial tramway vehicles, Alaska railroad vehicles, automated guideway vehicles, automobiles, cable cars, ferryboats, inclinded plane vehicles, jitneys, Públicos, taxicabs, and trolleybuses.

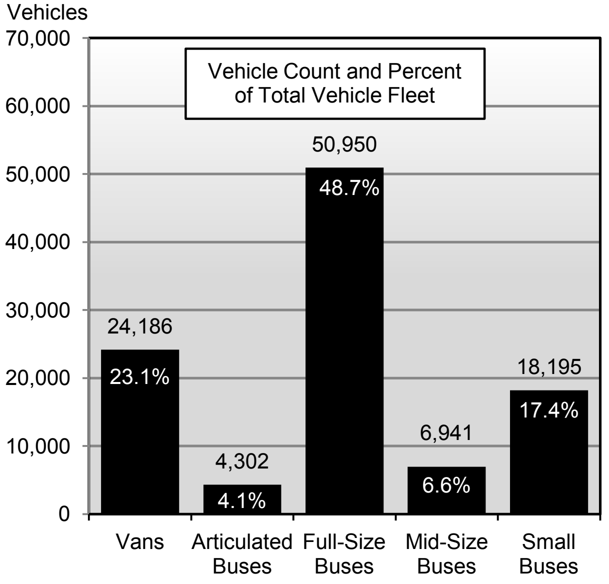
2: Source for "Special Service Vehicles" is the FTA, Fiscal Year Trends Report on the Use of Section 5310 Elderly and Persons with Disabilities Program Funds, 2002.

Source: National Transit Database except where otherwise noted.

Exhibit 2-27 shows the composition of the Nation's urban transit road vehicle fleet in 2008. Almost half of these vehicles, 48.7 percent, are full-sized motor buses. Additional information on trends in the number and condition of vehicles over time is included in Chapter 3.

Exhibit 2-27

Composition of Urban Transit Road Vehicle Fleet, 2008



Source: Transit Economic Requirements Model and National Transit Database.

Track, Stations, and Maintenance Facilities

Maintenance facility counts are broken down by mode and by size of the urbanized areas in *Exhibit 2-28*. Additional data on the age and condition of these facilities is included in Chapter 3.

Exhibit 2-28

Maintenance Facilities for Directly Operated Services, 2008

	Population Category		
Maintenance Facility Type[1]	**Over 1 Million**	**Under 1 Million**	**Total**
Heavy Rail	59	0	59
Commuter Rail	49	1	50
Light Rail	38	6	44
Other Rail [2]	3	4	7
Motorbus	302	242	544
Demand Response	34	78	112
Ferryboat	7	0	7
Other Nonrail [3]	6	5	11
Total Urban Maintenance Facilities	497	336	833
Rural Transit [4]		510	510
Total Maintenance Facilities	497	846	1,343

[1] *Includes owned and leased facilities.*
[2] *Alaska railroad, automated guideway, cable car, inclined plane, and monorail.*
[3] *Aerial tramway, jitney, Público, and vanpool.*
[4] *Vehicles owned by operators receiving funding from FTA as directed by 49 USC Section 5311. These funds are for transit services in areas with populations of less than 50,000. (Section 5311 Status of Rural Public Transportation 2000, Community Transportation Association of America, April 2001.)*

Source: National Transit Database.

As shown in *Exhibit 2-29*, in 2008, transit providers operated 11,864 miles of track and served 3,078 stations, compared with 11,796 miles of track and 3,053 stations in 2006. Expansion in light rail track mileage (5.1 percent) and stations (3.0 percent) accounted for most of the increase, a trend that continues from the recent past. 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 2-29

Transit Rail Mileage and Stations, 2008

	Population Category		
	Over 1 Million	**Under 1 Million**	**Total**
Urbanized Area Track Mileage			
Heavy Rail	2,277	0	2,277
Commuter Rail	7,012	395	7,407
Light Rail	1,459	80	1,539
Other Rail and Tramway*	24	618	641
Total Urbanized Area Track Mileage	**10,772**	**1,092**	**11,864**
Urbanized Area Transit Rail Stations Count			
Heavy Rail	1,041	0	1,041
Commuter Rail	1,147	42	1,189
Light Rail	716	71	787
Other Rail and Tramway	39	22	61
Total Urbanized Area Transit Rail Stations	**2,943**	**135**	**3,078**

** Alaska railroad, automated guideway, cable car, inclined plane, monorail, and aerial tramway.*

Source: National Transit Database.

System Coverage: Urban Directional Route Miles

The extent of the coverage 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; even though opposite-direction transit routes may use the same road or track, they are counted separately. Data associated with route miles are not collected for demand response and vanpool modes, since these transit modes do not travel along specific predetermined routes. Route miles data are also not collected for jitney services, since these transit modes often have highly variable route structures.

Exhibit 2-30 enumerates directional route miles by mode over the past 8 years. Growth in both rail (22.2 percent) and nonrail (8.1 percent) route miles is evident over this period. The average 6.7 percent rate of annual growth for light rail clearly outpaces the rate of growth for all other modes.

Exhibit 2-30

Transit Urban Directional Route Miles, 2000–2008

Transit Mode	Route Miles 2000	2002	2004	2006	2008	Average Annual Rate of Change 2008/2000
Rail	**9,222**	**9,484**	**9,782**	**10,865**	**11,270**	**2.5%**
Commuter Rail [1]	6,802	6,923	6,968	7,930	8,219	2.4%
Heavy Rail	1,558	1,572	1,597	1,623	1,623	0.5%
Light Rail	834	960	1,187	1,280	1,397	6.7%
Other Rail [2]	29	30	30	31	30	0.6%
Nonrail [3]	**196,858**	**225,820**	**216,619**	**223,489**	**212,801**	**1.0%**
Bus	195,884	224,838	215,571	222,445	211,664	1.0%
Ferryboat	505	513	623	620	682	3.8%
Trolleybus	469	468	425	424	456	-0.4%
Total	**206,080**	**235,304**	**226,401**	**234,354**	**224,071**	**1.1%**
Percent Nonrail	95.5%	96.0%	95.7%	95.4%	95.0%	

[1] *Includes Alaska rail.*

[2] *Automated guideway, inclined plane, cable car, and monorail.*

[3] *Excludes jitney, Público, and vanpool.*

Source: National Transit Database.

System Capacity

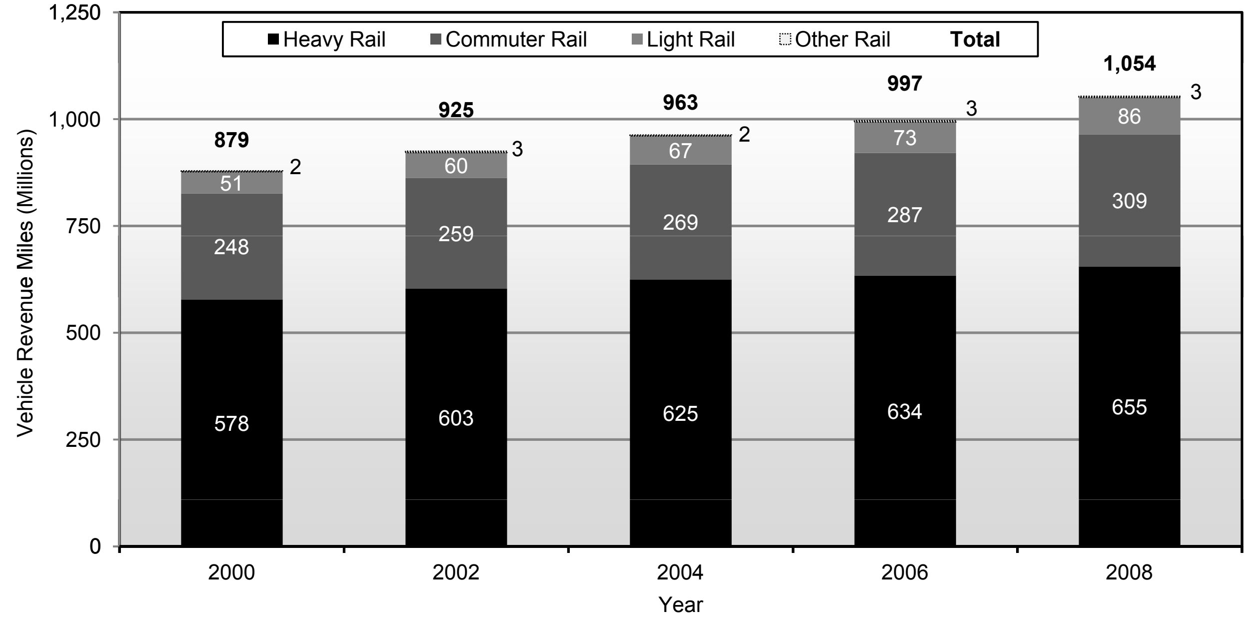
Transit system capacity, particularly in cross-modal comparisons, is typically measured by capacity-equivalent vehicle revenue miles (VRMs). Capacity-equivalent VRMs measure the distance traveled by transit vehicles in revenue service and adjust them by the passenger-carrying capacity of each transit vehicle type, with the average carrying capacity of motor 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 2.5 times more people than a full-size bus provides 2.5 capacity-equivalent miles for each revenue mile it travels.

Exhibit 2-31 shows reported VRMs, unadjusted by passenger-carrying capacity. These numbers are of interest because they show the actual number of miles traveled by each mode in revenue service. Unadjusted VRMs provided by both bus services and rail services show consistent growth, with light rail and vanpool miles growing somewhat faster growth than the other modes. Overall, the number of VRMs is up by 20.0 percent since 2000.

The 2008 capacity-equivalent factors for each mode are shown in *Exhibit 2-32*. Unadjusted VRMs for each mode are multiplied by a capacity-equivalent factor in order 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 2008 was 39 seated and 23 standing for a total of 62 riders.

Exhibit 2-31

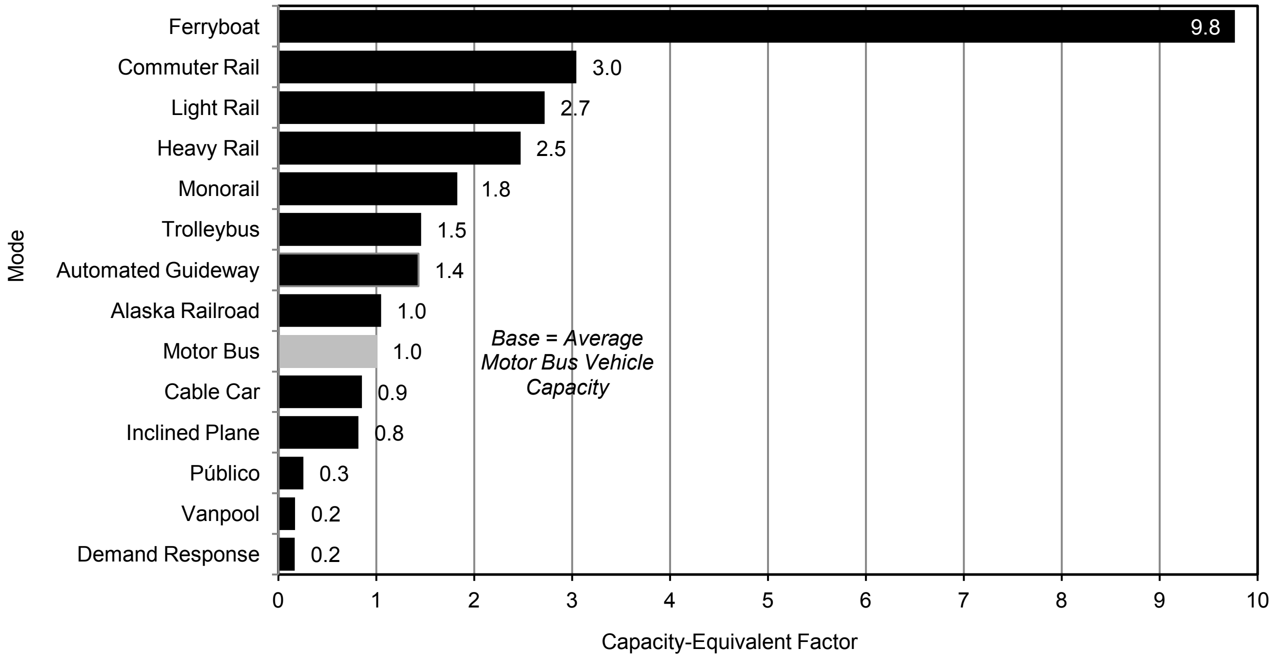
Rail Vehicle Revenue Miles, 2000–2008



Source: National Transit Database.

Exhibit 2-32

2008 Capacity-Equivalent Factors by Mode



Source: National Transit Database.

Total capacity-equivalent VRMs are shown in *Exhibit 2-33*. The most rapid expansion in capacity-equivalent VRMs in the period from 2000 to 2008 has been for vanpools, followed by light rail and then commuter rail. Total capacity-equivalent revenue miles have increased from 3,954 in 2000 to 4,953 in 2008, an increase of 25.3 percent.

Exhibit 2-33

Capacity-Equivalent Revenue Vehicle Miles, 2000–2008

	Vehicle Miles (Millions)					Average Annual Rate of Change
Transit Mode	**2000**	**2002**	**2004**	**2006**	**2008**	**2008/2000**
Rail	**2,046**	**2,274**	**2,413**	**2,681**	**2,799**	**4.0%**
Heavy Rail	1,321	1,469	1,546	1,648	1,621	2.6%
Commuter Rail	595	652	685	832	940	5.9%
Light Rail	127	150	179	197	235	8.0%
Other Rail	3	3	3	4	3	0.5%
Nonrail	**1,908**	**2,037**	**2,064**	**2,118**	**2,154**	**1.5%**
Motor Bus	1,764	1,864	1,885	1,910	1,956	1.3%
Demand Response	76	100	101	121	115	5.4%
Vanpool	11	15	15	22	27	11.3%
Ferryboat	30	32	32	37	32	0.9%
Trolleybus	20	20	20	19	16	-2.4%
Other Nonrail	7	7	12	10	6	-1.6%
Total	**3,954**	**4,311**	**4,478**	**4,800**	**4,953**	**2.9%**

Source: National Transit Database.

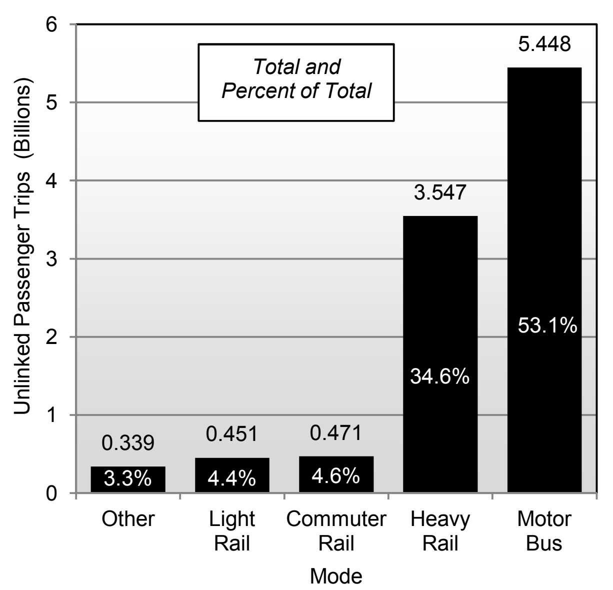
Ridership

There are two primary measures of transit ridership—unlinked passenger trips and passenger miles traveled (PMT). An unlinked passenger trip, sometimes called a boarding, is defined as a journey on *one* transit vehicle. PMT is calculated on the basis of unlinked passenger trips and estimates of average trip length. Either measure provides an appropriate time series since average trip lengths, by mode, have not changed substantially over time. Comparisons across modes, however, may differ substantially depending on which measure is used due to large differences in the average trip length for the different modes.

Exhibit 2-34 and *Exhibit 2-35* show the distribution of unlinked passenger trips and PMT by mode. In 2008, transit services provided 10.2 billion unlinked trips and 53.7 billion PMT. Heavy rail and motorbus modes continue to be the largest segments of both measures. Commuter rail supports relatively more PMT due to its greater average trip length (23.4 miles compared to 3.9 for bus, 4.8 for heavy rail, and 4.4 for light rail).

Exhibit 2-34

2008 Unlinked Passenger Trips

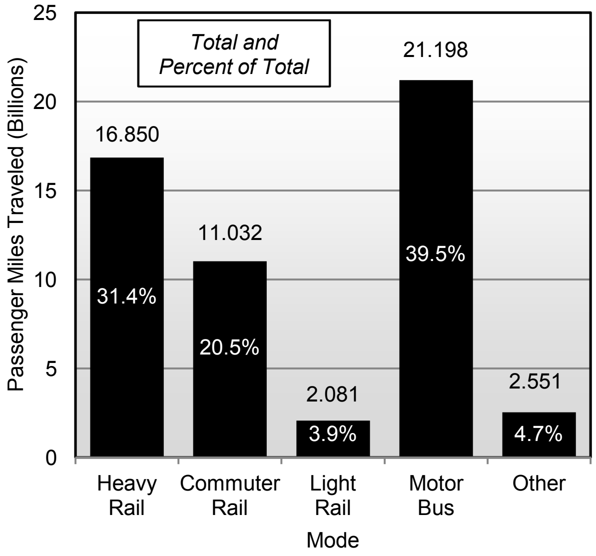


Note: "Other" includes Alaska railroad, automated guideway, cable car, demand response, ferryboat, inclined plane, monorail, Público, and trolleybus.

Source: National Transit Database.

Exhibit 2-35

2008 Passenger Miles Traveled



Note: "Other" includes Alaska railroad, automated guideway, cable car, demand response, ferryboat, inclined plane, monorail, Público, and trolleybus.

Source: National Transit Database.

Exhibit 2-36 provides total PMT for selected years between 2000 and 2008, showing steady growth in all the major modes. Demand response, light rail, and vanpool modes grew at the fastest rates. Demand response (up 4.6 percent per year) has undoubtedly benefited from ADA requirements. Light rail (up 5.7 percent per year) had enjoyed increased capacity during this period due to expansions and addition of new systems.

Exhibit 2-36

Transit Urban Passenger Miles, 2000–2008

	Passenger Miles (Millions)					Average Annual Rate of Change
Transit Mode	**2000**	**2002**	**2004**	**2006**	**2008**	**2008/2000**
Rail	**24,604**	**24,617**	**25,667**	**26,972**	**29,989**	**2.5%**
Heavy Rail	13,844	13,663	14,354	14,721	16,850	2.5%
Commuter Rail	9,400	9,500	9,715	10,359	11,032	2.0%
Light Rail	1,340	1,432	1,576	1,866	2,081	5.7%
Other Rail[1]	20	22	22	25	26	3.3%
Nonrail	**20,497**	**21,328**	**20,879**	**22,533**	**23,723**	**1.8%**
Motor Bus	18,807	19,527	18,921	20,390	21,198	1.5%
Demand Response	588	651	704	753	844	4.6%
Vanpool	407	455	459	689	992	11.8%
Ferryboat	298	301	357	360	390	3.4%
Trolleybus	192	188	173	164	161	-2.2%
Other Nonrail[2]	205	206	265	176	138	-4.8%
Total	**45,101**	**45,945**	**46,546**	**49,504**	**53,712**	**2.2%**
Percent Rail	54.6%	53.6%	55.1%	54.5%	55.8%	

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

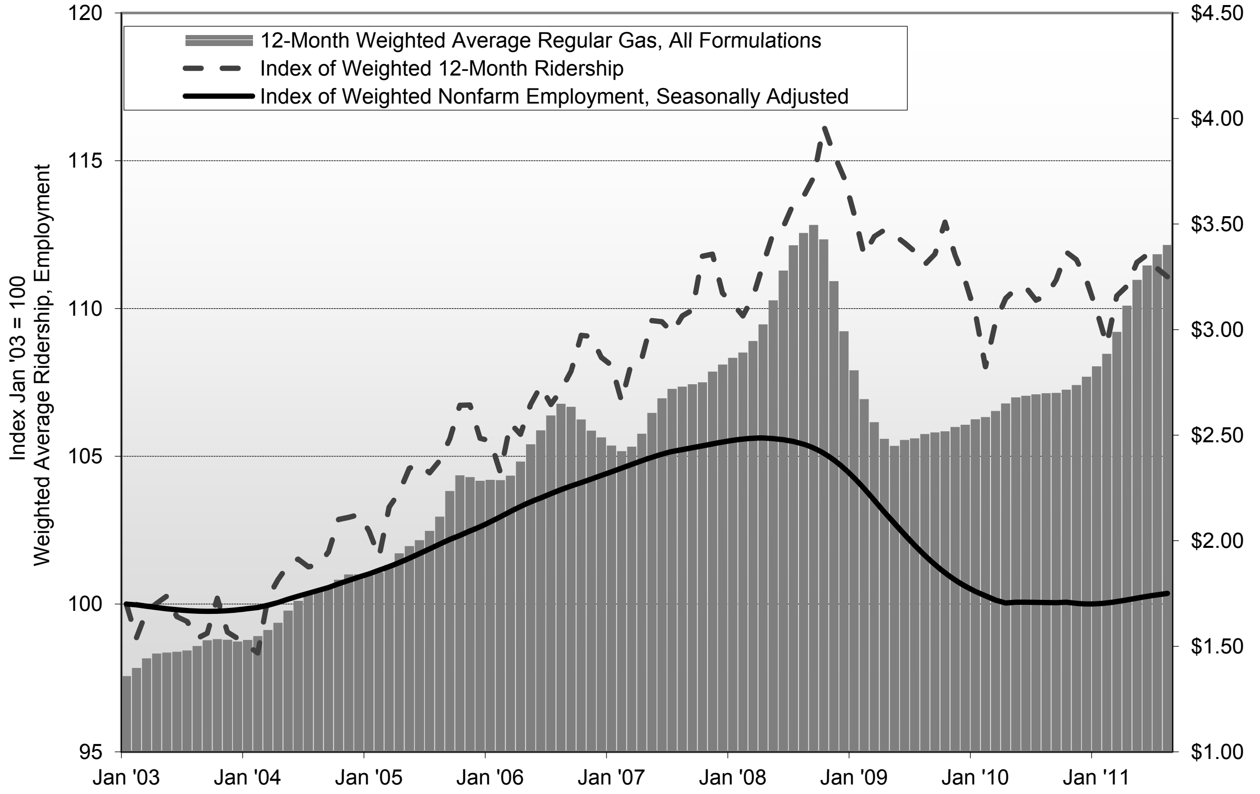
[2] *Aerial tramway and Público.*

Source: National Transit Database.

Vanpool's rapidly increasing popularity (up 11.8 percent per year), particularly the surge between 2006 and 2008 (up 20 percent per year), can be partially attributed to rising gas prices. Regular gasoline sold for more than $4 per gallon in July of 2008. *Exhibit 2-37* shows the complex relationship between transit ridership, gasoline price, and unemployment using 12-month exponential moving averages (e.g., weighted averages) to smooth out the monthly volatility in transit ridership and fuel prices.

Exhibit 2-37

Transit Ridership Versus Employment



Source: National Transit Database, U.S. Energy Information Administration's Gas Pump Data History, and Bureau of Labor Statistics' Employment Data.

On the most basic level, the effectiveness of transit operations can be gauged by the demand for transit services. People choose to use transit if it meets their needs as well as, or better than, the alternatives. These choices occur in an economic context in which the need for transportation and the cost of that transportation are constantly changing due to factors that have nothing to do with transit.

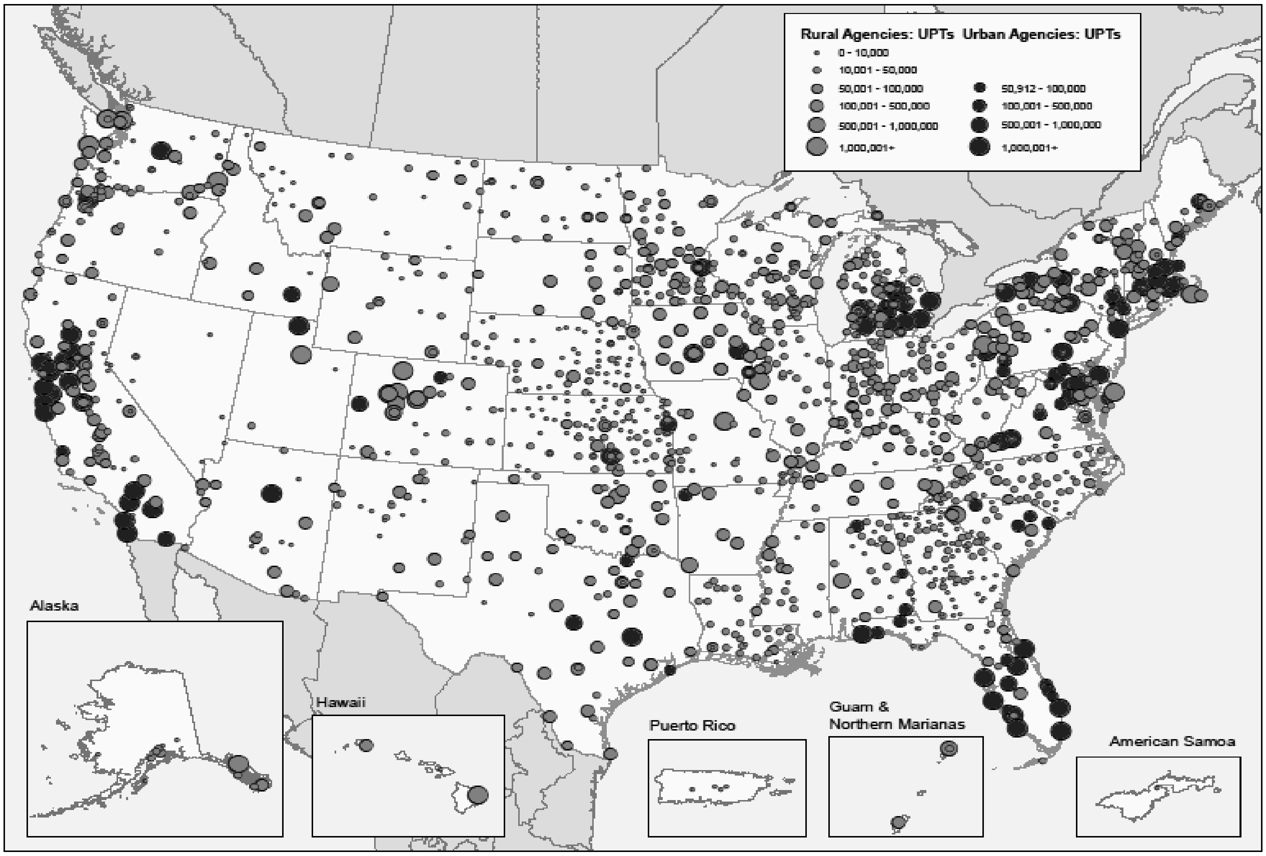
Rural Transit Systems (Section 5311 Providers)

FTA first instituted rural data reporting to the NTD in 2006. In 2008, 1,396 transit operators reported providing rural service. They reported 136.6 million unlinked passenger trips and 486 million vehicle revenue miles. This included 61 Indian tribes who provided 417,000 unlinked passenger trips. Urbanized area agencies, of which there are 304, also reported providing rural service that added another 24 million unlinked passenger trips and 37 million vehicle revenue miles.

The data indicates that rural transit service has been growing rapidly; but, because the NTD is still adding rural reporters, this can't yet be quantified. The data also indicates every State and four territories provides some form of rural transit service, as shown in *Exhibit 2-38*.

Exhibit 2-38

Distribution of Rural and Urban Unlinked Passenger Trips Across the United States

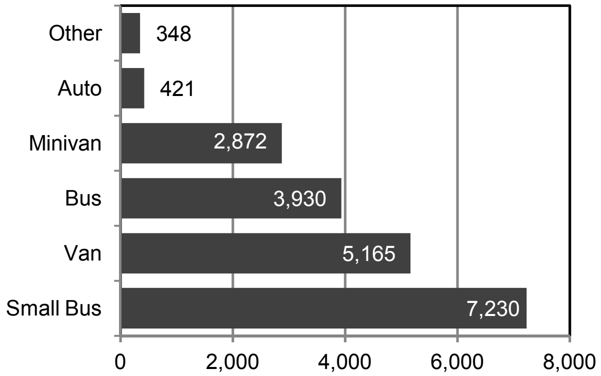


Source: National Transit Database.

Rural systems provide both traditional fixed-route and demand response services, with 1,150 demand response services, 494 motor bus services, and 16 vanpool services. They reported 19,966 vehicles in 2008. *Exhibit 2-39* shows the number of rural transit vehicles in service.

Exhibit 2-39

2008 Rural Transit Vehicles



Source: National Transit Database.

Transit System Characteristics for Americans With Disabilities and the Elderly

The ADA is intended to ensure that persons with disabilities have access to the same facilities and services as other Americans, including transit vehicles and facilities. This equality of access is brought about through the upgrading of transit vehicles and facilities on regular routes, through the provision of demand response transit service for those individuals who are still unable to use regular transit service, and through special service vehicles operated by private entities and some public organizations, often with the assistance of FTA funding.

Since the passage of the ADA in 1990, transit operators have been working to upgrade their regular vehicle fleets and improve their demand response services in order to meet the ADA's requirement to provide persons with disabilities a level of service comparable to that of fixed-route systems. U.S. DOT regulations provide minimum guidelines and accessibility standards for buses; vans; and heavy, light, and commuter rail vehicles. For example, commuter rail transportation systems are required to have at least one accessible car per train and all new cars must be accessible. The ADA deems it discriminatory for a public entity providing a fixed-route transit service to provide disabled individuals with services that are inferior to those provided to nondisabled individuals.

The overall percentage of transit vehicles that are ADA-compliant has not significantly changed in recent years. In 2008, 79.0 percent of all transit vehicles reported in the NTD were ADA-compliant. This percentage has decreased slightly from 80.2 percent in 2006, although it is significantly greater than the 73.3 percent reported for 2000. The percentage of vehicles compliant with the ADA for each mode is shown in *Exhibit 2-40.*

Exhibit 2-40

Urban Transit Operators' ADA Vehicle Fleets by Mode, 2008

Transit Mode	Active Vehicles	ADA-Compliant Vehicles	Percent of Active Vehicles ADA-Compliant
Rail			
Heavy Rail	11,367	10,990	96.7%
Commuter Rail	6,078	3,738	61.5%
Light Rail	1,957	1,600	81.8%
Alaska Railroad	44	27	61.4%
Automated Guideway	54	54	100.0%
Cable Car	40	0	0.0%
Inclined Plane	8	6	75.0%
Monorail	8	8	100.0%
Total Rail	**19,556**	**16,423**	**84.0%**
Nonrail			
Motor Bus	64,647	63,669	98.5%
Demand Response	32,248	23,165	71.8%
Vanpool	10,970	222	2.0%
Ferryboat	151	130	86.1%
Trolleybus	601	599	99.7%
Público	3,718	0	0.0%
Total Nonrail	**112,335**	**87,785**	**78.1%**
Total All Modes	**131,891**	**104,208**	**79.0%**

Source: National Transit Database.

In addition to the services provided by urban transit operators, a recent survey by the University of Montana found that, in 2002, there were 4,836 private and nonprofit agencies that received FTA Section 5310 funding for the provision of "special" transit services (i.e., demand response) to persons with disabilities and the elderly. These providers include religious organizations, senior citizen centers, rehabilitation centers, the American Red Cross, nursing homes, community action centers, sheltered workshops, and coordinated human services transportation providers.

In 2002, the most recent year for which data are available, these providers were estimated to be using 37,720 special service vehicles. Approximately 62 percent of these special service providers were in rural areas, and 38 percent were in urbanized areas. Data collected by FTA show that approximately 76 percent of the vehicles purchased in FY 2002 were wheelchair accessible, about the same as in the previous few years.

In 2008, 73.7 percent of total transit stations were ADA-compliant. This is up from the 2006 count, in which 71.9 percent were compliant. Earlier data on this issue may not be comparable to data provided in this report due to improvements in reporting quality. The ADA requires that new transit facilities and alterations to existing facilities be accessible to the disabled. *Exhibit 2-41* gives data on the number of urban transit ADA stations by mode.

Exhibit 2-41

Urban Transit Operators' ADA-Compliant Stations by Mode, 2008

Transit Mode	Total Stations	ADA Compliant Stations	Percent of Stations ADA Compliant
Rail			
Heavy Rail	1,041	508	48.8%
Commuter Rail	1,189	753	63.3%
Light Rail	787	665	84.5%
Alaska Railroad	10	10	100.0%
Automated Guideway	41	40	97.6%
Inclined Plane	8	7	87.5%
Monorail	2	2	100.0%
Total Rail	**3,078**	**1,985**	**64.5%**
Nonrail			
Motor Bus	1,346	1,258	93.5%
Ferryboat	81	78	96.3%
Trolleybus	5	5	100.0%
Total Nonrail	**1,432**	**1,341**	**93.6%**
Total All Modes	**4,510**	**3,326**	**73.7%**

Source: National Transit Database.

Under the ADA, FTA was given responsibility for identifying "key rail stations" and facilitating the accessibility of these stations to disabled persons by July 26, 1993. Key rail stations are identified on the basis of the following criteria:

- The number of passengers boarding at the key station exceeds the average number of passengers boarding on the rail system as a whole 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.

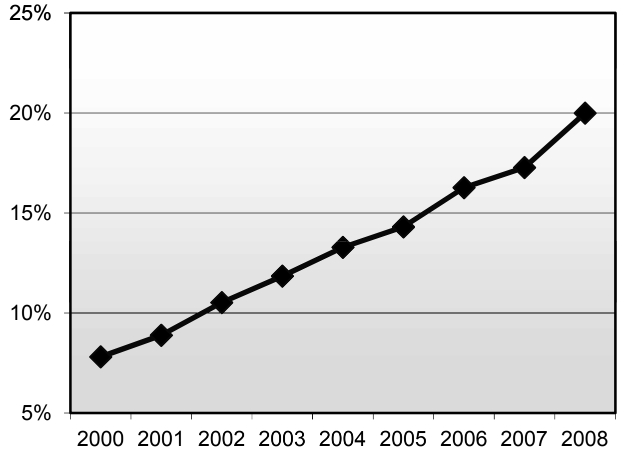
Although ADA legislation required all key stations to be accessible by July 26, 1993, the U.S. DOT ADA regulation in Title 49—Code of Federal Regulations (CFR), Part 37.47(c)(2), permitted the FTA Administrator to grant extensions up to July 26, 2020, for stations requiring extraordinarily expensive structural modifications to bring them into compliance. In 2008, there were 687 key rail stations, of which 27 stations (3.9 percent) were under FTA-approved time extensions. The total number of key rail stations has changed slightly over the years as certain stations have closed. As of June 24, 2010, of the 680 key rail stations, 648 stations are accessible and compliant or accessible but not fully compliant (95.2 percent). "Accessible but not fully compliant" means that these stations are functionally accessible (i.e., persons with disabilities, including wheelchair users, can make use of the station), but there are still minor outstanding issues that must be addressed in order to be fully compliant; these usually involve things like missing or mislocated signage and parking-lot striping errors. There are 32 key rail stations that are not yet compliant and are in the planning, design, or construction stage at this time. Of these, 15 stations are under FTA-approved time extensions up to 2020 (as provided under 49 CFR §37.47(c)(2)), eight of which will expire by June 26, 2012. FTA continues to focus its attention on the 17 stations that are not fully accessible and are not under a time extension, as well as on the 15 stations with time extensions that will be expiring in the coming years.

Transit System Characteristics: Special Interests

Exhibit 2-42 presents an increase in the share of alternative fuel buses from 7.8 percent in 2000 to 20.0 percent in 2008. In 2008, 12.9 percent of buses used compressed natural gas, 5.2 percent used biodiesel, and 1.8 percent used liquefied natural or petroleum gas. Conventional fuel buses, which make up the majority of the U.S. bus fleet, utilized diesel fuel and gasoline.

Exhibit 2-42

Change in Percentage of Urban Bus Fleet Using Alternative Fuels, 2000–2008



Source: National Transit Database.

Chapter 3

System Conditions

Road Conditions

The condition of roadway pavements can affect the costs associated with both passenger travel and freight transportation. Poor road surfaces cause additional wear and tear on vehicle suspensions, wheels, and tires. When vehicles slow down in heavy traffic for potholes or very rough pavement, this can create significant queuing and subsequent delay. Unexpected changes in surface conditions can also increase the frequency of crashes. Inadequate road surfaces can reduce road friction, which affects the stopping ability and maneuverability of vehicles.

This section examines the physical conditions of the Nation's roadways, addressing both roadway surface conditions and other condition measures. This information is presented for Federal-aid highways only, as pavement data are not collected in the Highway Performance Monitoring System (HPMS) for those roads functionally classified as rural minor collectors, rural local, or urban local. Separate statistics are presented for the National Highway System (NHS).

Subsequent sections within this chapter explore the physical conditions of bridges and transit systems. Operational performance trends are discussed separately in Chapter 4, while Chapter 5 explores various safety performance measures. Other aspects of system performance pertaining to livability and sustainability are discussed in Part III.

Q&A

What are some factors that should be considered in defining a "State of Good Repair" for transportation assets?

There is broad consensus that our Nation's transportation infrastructure falls short of a "State of Good Repair"; there is, however, no nationally accepted definition of exactly how the term should be defined in the context of various types of transportation assets.

The condition of some asset types have traditionally been measured by multiple quantitative indicators, which are often weighted differently in the assessment process of different transportation asset owners. Other kinds of assets have traditionally been measured using a single qualitative rating, but this introduces subjectivity into the assessment process, as different asset owners, or different individual raters, might apply such rating criteria differently. Thus, while a "State of Good Repair" goal is conducive to measurement, identifying investments that provide the greatest utility in meeting this goal would require consideration of a broad range of metrics within the context of sound asset management principles. Investment decisions should take into account the life-cycle costs of potential alternatives, including the capital costs, maintenance costs, and user costs associated with alternative strategies.

In establishing performance targets for individual assets, it is important to consider how different metrics would reasonably be expected to vary over the asset's life cycle in response to an analytically sound pattern of capital and maintenance actions. It is important that target thresholds be set at levels high enough to measure overall progress, but not so high that they might inadvertently produce suboptimal decision making.

Another key consideration in setting performance targets is how particular assets are utilized. The physical condition of a heavily used asset will, by definition, impact more users than that of a lightly used asset. Applying higher performance standards to heavily used assets would help to capture their greater impact on the traveling public. Also, in selecting potential measures to target, it is important to recognize that some aspects of asset condition have more direct impact on system users than others. Ideally, the performance measures selected for a given type of asset would roughly reflect the weighting of agency costs and user costs that would be determined as part of a full life-cycle cost analysis for that type of asset.

Other fundamental questions to be answered are whether a particular asset is still serving the purpose for which it was originally intended, and whether the long-term benefits that it provides exceed the cost of keeping the asset in service. Simply because a previous decision was made to invest in an asset should not automatically mean that the asset should be kept in a "State of Good Repair" in perpetuity, without considering the merits of the alternative possibility of taking the asset out of service.

Pavement Terminology and Measurements

The pavement condition ratings presented in this section are derived from one of two measures: the International Roughness Index (IRI) or the Present Serviceability Rating (PSR). The IRI measures the cumulative deviation from a smooth surface in inches per mile. The PSR is a subjective rating system based on a scale of 0 to 5. The HPMS coding instructions recommend the reporting of IRI data for all facility types, but permit States to instead provide PSR data for roadway sections classified as rural major collectors, urban minor arterials, or urban collectors. The Federal Highway Administration (FHWA) adopted the IRI for the higher functional classifications because it is an objective measurement and is generally accepted worldwide as a pavement roughness measurement. The IRI system results in more consistent data for trend analyses and cross jurisdiction comparisons.

Q&A

What are some measures of pavement condition other than IRI?

Other principal measures of pavement condition or distress such as rutting, cracking, and faulting exist, but are not currently reported in HPMS. However, the HPMS reporting requirements have been modified to collect information on these distresses and other pavement-related data. This additional information should be available in time to be included in the 2012 C&P Report.

In addition to allowing more robust assessments of the current state of the Nation's pavements, these new data will support the use of enhanced pavement deterioration equations in the HERS model, which will provide refined projections of future pavement conditions.

For this report, a conversion table was used to translate PSR values into equivalent IRI values to classify mileage. *Exhibit 3-1* contains a description of qualitative pavement condition terms used in this report and corresponding quantitative PSR and IRI values. The translation between PSR and IRI is not exact; IRI values are based on objective measurements of pavement roughness, while PSR is a subjective evaluation of a broader range of pavement characteristics. The term "good ride quality" applies to pavements with an IRI value of less than 95 inches per mile. The term "acceptable ride quality" applies to pavements with an IRI value of less than or equal to 170 inches per mile, which includes those pavements classified as having good ride quality. It is important to note that the specific IRI values associated with good ride quality and acceptable ride quality were adopted by the FHWA as pavement condition indicators for NHS; while these values are applied to all Federal-aid highways in this report, States and local governments may have different standards of what constitutes "acceptable" pavement conditions, particularly for lower volume roadways that are not part of the NHS.

Exhibit 3-1

Pavement Condition Criteria

	All Functional Classifications	
Ride Quality Terms*	**IRI Rating**	**PSR Rating**
Good	< 95	≥ 3.5
Acceptable	≤ 170	≥ 2.5

** The rating thresholds for "good" and "acceptable" ride quality used in this report were initially determined for use in assessing pavements on the NHS. Some transportation agencies may use less stringent standards for lower functional classification roadways.*

Source: Highway Performance Monitoring System (HPMS).

Implications of Pavement Ride Quality for Highway Users

Among the three major components of highway user costs measured in this report (travel time costs, vehicle operating costs, and crash costs), pavement condition has the most direct impact on vehicle operating costs in the form of increased wear and tear on vehicles and repair costs. Poor pavement can also impact travel time costs to the extent that road conditions force drivers to reduce speed and can have an impact on crash rates. Highway user costs are discussed in more detail in Chapter 7.

Because the terms "good ride quality" and "acceptable ride quality" are defined based on a range of IRI values, the impact that pavements classified in these categories have on highway user costs varies. In general, pavements falling below the acceptable ride quality threshold would tend to have greater impacts on user costs than those classified as having acceptable or good ride quality. However, the relative impacts on user costs of a pavement with an IRI of 169 (acceptable) compared with a pavement with an IRI of 171 (not acceptable) would not be significant. The same would be true for pavements just above or below the good ride quality standard (an IRI of less than or equal to 95).

The impact of pavement ride quality on user costs will tend to be higher on the higher functional classification roadways such as Interstate System highways than on the roadways with lower functional classifications such as connectors. Vehicle speed can significantly influence the impact that poor ride quality has on highway user costs. For example, a vehicle encountering a pothole at 55 miles per hour on an Interstate highway would experience relatively more wear and tear than a vehicle encountering an identical pothole on a collector at 25 miles per hour.

Poor ride quality would also tend to have a greater impact on Interstate highways due to their higher traffic volumes. The Interstate System supports the movement of passenger vehicles and trucks at relatively high speeds across the Nation. Poor ride quality can cause drivers to travel at a lower speed than the facility is otherwise capable of supporting, thereby increasing the time of individual trips and adding to congestion. In the case of freight movement, this reduction in travel speed would add to the cost of the delivery of goods. Conversely, because traffic volumes and average speeds on collectors are lower to begin with, poor ride quality on such facilities would not have as great an impact on vehicle speeds as comparable conditions would on higher functional classification roadways.

Q&A

What goals were established by the Department of Transportation for pavement ride quality?

The Department of Transportation's *FY 2009 Performance and Accountability Report* presented an FY 2009 target of 57 percent for the share of travel on the NHS on pavements with good ride quality.

Pavement Ride Quality on the National Highway System

As shown in *Exhibit 3-2,* the share of VMT on NHS pavements with acceptable ride quality has changed very little from approximately 91 percent in 2000 to approximately 92 percent in 2008. However, the share of VMT on NHS pavements meeting the more rigorous standard of good ride quality has risen sharply over time, from approximately 48 percent in 2000 to approximately 57 percent in 2008. As noted above, the percentage of pavements with good ride quality is a subset of the percentage of pavements with acceptable ride quality.

Exhibit 3-2

Percent of NHS VMT on Pavements With Good and Acceptable Ride Quality, 2000–2008

Calendar Year	**2000**	**2002**	**2004**	**2006**	**2008**
Fiscal Year *	**2001**	**2003**	**2005**	**2007**	**2009**
Good (IRI < 95)	48%	50%	52%	57%	57%
Acceptable (IRI ≤ 170)	91%	91%	91%	93%	92%

**The pavement data in this section reflect conditions as of December 31 of each year, as reported in HPMS. In this report, these values are presented on a calendar year basis, consistent with the annual* Highway Statistics *publication. Some other Departmental documents, such as the* FY 2009 Performance and Accountability Report*, are based on a Federal fiscal year basis; values as of December 31 in one calendar year fall into the next fiscal year. For example, the 57 percent figure identified as "good" for calendar year 2008 in this exhibit, is reported as a fiscal year 2009 value in the* FY 2009 Performance and Accountability Report*.*

Source: Highway Performance Monitoring System as of November 2009.

As shown in *Exhibit 3-3*, rural NHS routes tend to have better pavement conditions than urban NHS routes. The share of rural VMT on NHS pavements providing good ride quality increased from 63.6 percent in 2000 to 74.5 percent in 2008. The share of NHS VMT on pavements with good ride quality in urban areas increased from 37.9 percent in 2000 to 47.9 percent in 2008.

Exhibit 3-3

Percent of VMT on NHS Pavements With Good and Acceptable Ride Quality in Rural and Urban Areas, 2000–2008

	2000	2002	2004	2006	2008
Rural					
Good (IRI < 95)	63.6%	66.6%	68.0%	73.6%	74.5%
Acceptable (IRI ≤ 170)	96.8%	96.9%	97.0%	97.8%	97.5%
Urban					
Good (IRI < 95)	37.9%	38.6%	42.5%	47.7%	47.9%
Acceptable (IRI ≤ 170)	87.0%	86.1%	86.9%	90.0%	89.0%

Source: Highway Performance Monitoring System as of November 2009.

The portion of VMT on rural pavements meeting the standard of acceptable ride quality increased slightly from 96.8 percent in 2000 to 97.5 percent in 2008. The share of urban NHS VMT on acceptable pavements rose from 87.0 percent in 2000 to 89.0 percent in 2008.

Pavement Ride Quality on Federal-Aid Highways

The HPMS collects ride quality data only for Federal-aid highways, which include all functional classes except for rural minor collectors, rural local, and urban local. As described in Chapter 2, these three functional classifications account for approximately three-fourths of the total mileage on the Nation's system, but carry less than one-sixth of the total daily VMT on the Nation's roadway system. Because the focus of this report is on VMT-based measures of ride quality rather than mileage-based measures, the omission of these functional classes from the statistics in this section is less significant.

As shown in *Exhibit 3-4*, for those functional classes on which data are collected, the VMT on pavements with good ride quality increased from 42.8 percent in 2000 to 46.4 percent in 2008. The VMT on pavements meeting the standard of acceptable (which includes the category of good) remained about the same at 85.5 percent in 2000 and 85.4 percent in 2008.

As noted in Chapter 2, rural areas contain about three-fourths of road miles, but support only about one-third of annual national VMT. Consequently, pavement conditions in urban areas have a greater impact on the VMT-weighted measure shown in *Exhibit 3-4* than do pavement conditions in rural areas. Pavement conditions are generally better in rural areas. For those functional systems for which data are available, the share of rural VMT on pavements with good ride quality rose from 55.2 percent in 2000 to 62.5 percent in 2008, while the portion of urban VMT on pavements with good ride quality increased from 35.0 percent to 38.9 percent in 2008. The share of VMT on pavements with acceptable ride quality rose slightly from 2000 to 2008 in both rural and urban areas.

Pavement Ride Quality by Functional Classification

While the percentage of both rural and urban VMT on pavements with good ride quality rose from 2000 to 2008, this improvement was concentrated among the higher-order functional systems. *Exhibit 3-4* shows that the share of VMT on pavements with good ride quality declined over this period for rural major collectors, urban minor arterials, and urban collectors. The largest decline occurred on urban collectors, as the portion of VMT on pavements with good ride quality dropped from 37.9 percent in 2000 to 31.5 percent in 2008.

The percentage of VMT on pavements with acceptable ride quality fell slightly from 2000 to 2008, driven by reductions in the percentages for the rural portion of the Interstate System, urban minor arterials, and urban collectors. The share of VMT on pavements with acceptable ride quality rose for each of the other functional systems included in *Exhibit 3-4.* The portion of urban collector VMT on pavements with acceptable ride quality dropped from 76.1 percent to 72.0 percent over this 8-year period, the largest decline among any functional system.

Exhibit 3-4

Percent of VMT on Pavements With Good and Acceptable Ride Quality, by Functional System, 2000–2008

	2000	2002	2004	2006	2008
Functional System			**Percent Good**		
Rural Interstate	69.6%	72.2%	73.7%	78.6%	79.0%
Rural Principal Arterial	56.8%	60.2%	61.0%	66.8%	68.4%
Rural Minor Arterial	48.9%	51.0%	51.5%	56.3%	56.2%
Rural Major Collector	39.9%	42.4%	40.3%	39.8%	39.0%
Subtotal Rural	**55.2%**	**58.0%**	**58.3%**	**62.2%**	**62.5%**
Urban Interstate	43.6%	45.0%	49.4%	54.0%	55.7%
Urban Other Freeway & Expressway	32.4%	33.6%	38.8%	45.3%	44.4%
Urban Other Principal Arterial	26.9%	25.7%	26.5%	28.8%	26.9%
Urban Minor Arterial	34.4%	34.1%	32.3%	33.6%	32.5%
Urban Collector	37.9%	35.5%	35.7%	34.1%	31.5%
Subtotal Urban	**35.0%**	**34.9%**	**36.6%**	**39.5%**	**38.9%**
Total Good *	**42.8%**	**43.8%**	**44.2%**	**47.0%**	**46.4%**
Functional System			**Percent Acceptable**		
Rural Interstate	97.4%	97.3%	97.8%	98.2%	97.3%
Rural Principal Arterial	96.0%	96.2%	96.1%	97.0%	97.6%
Rural Minor Arterial	93.1%	93.8%	94.3%	95.1%	94.5%
Rural Major Collector	86.9%	87.6%	88.5%	87.8%	88.3%
Subtotal Rural	**93.8%**	**94.1%**	**94.5%**	**94.9%**	**94.8%**
Urban Interstate	91.2%	89.6%	90.3%	92.7%	91.9%
Urban Other Freeway & Expressway	87.2%	87.8%	87.7%	92.1%	91.4%
Urban Other Principal Arterial	71.0%	71.0%	72.6%	73.8%	72.4%
Urban Minor Arterial	76.5%	76.3%	73.8%	75.6%	75.5%
Urban Collector	76.1%	74.6%	72.6%	72.6%	72.0%
Subtotal Urban	**80.3%**	**79.8%**	**79.7%**	**81.7%**	**85.4%**
Total Acceptable *	**85.5%**	**85.3%**	**84.9%**	**86.0%**	**85.4%**

** Totals shown reflect Federal-aid highways only and exclude roads classified as rural minor collector, rural local, or urban local, for which pavement data are not reported in HPMS.*

Source: Highway Performance Monitoring System as of December 2009.

Interstate Pavement Ride Quality

Among all of the functional systems identified in *Exhibit 3-4*, the rural portion of the Interstate System had the highest percentage of VMT on pavements with good ride quality in 2008, at 79.0 percent. The share of urban Interstate System VMT on pavements with good ride quality from 2000 to 2008 rose from 43.6 percent to 55.7 percent, which represented the largest increase among the functional systems for which data are available.

A total of 97.3 percent of all VMT on the rural portion of the Interstate System occurred on pavements with acceptable ride quality. On the urban portion of the Interstate System, the share of urban Interstate System VMT occurring on pavements with good and acceptable ride quality in 2008 was 55.7 percent and 91.9 percent, respectively.

Pavement Ride Quality by Mileage

Exhibit 3-5 shows the pavement ride quality by functional classification from 2000 to 2008 based on mileage, rather than on VMT. On a mileage basis, the percentage of pavements with both good and acceptable ride quality declined from 2000 to 2008. Consistent with the VMT-weighted figures presented earlier, the share of pavements with good ride quality declined for rural major collectors, urban minor arterials, and urban collectors. However, since these functional systems constitute a greater share of total mileage than total travel, these declines had a relatively larger impact on the totals presented in *Exhibit 3-5* than on those presented in *Exhibit 3-4*.

Exhibit 3-5

Percent of Mileage With Acceptable and Good Ride Quality, by Functional System, 2000–2008

	2000	2002	2004	2006	2008
Functional System	**Percent Good**				
Rural Interstate	68.5%	71.9%	72.9%	77.2%	78.2%
Rural Principal Arterial	57.4%	60.9%	60.1%	65.3%	66.5%
Rural Minor Arterial	47.7%	50.2%	47.6%	53.3%	53.3%
Rural Major Collector	36.2%	43.1%	36.3%	35.1%	34.0%
Subtotal Rural	**46.5%**	**50.9%**	**47.0%**	**45.4%**	**44.9%**
Urban Interstate	50.0%	50.9%	55.0%	59.3%	61.4%
Urban Other Freeway & Expressway	38.7%	40.9%	44.6%	50.2%	50.6%
Urban Other Principal Arterial	26.9%	25.7%	26.2%	29.7%	27.4%
Urban Minor Arterial	37.7%	38.8%	35.7%	33.0%	32.1%
Urban Collector	31.0%	33.4%	31.2%	30.1%	28.3%
Subtotal Urban	**33.6%**	**34.3%**	**33.6%**	**33.3%**	**32.0%**
Total Good *	**43.2%**	**46.6%**	**43.1%**	**41.5%**	**40.7%**
Functional System	**Percent Acceptable**				
Rural Interstate	97.8%	97.8%	98.0%	98.0%	98.0%
Rural Principal Arterial	96.0%	96.6%	95.8%	96.7%	97.1%
Rural Minor Arterial	92.0%	93.8%	93.9%	94.0%	94.1%
Rural Major Collector	82.1%	85.9%	85.8%	84.5%	85.1%
Subtotal Rural	**89.0%**	**91.0%**	**90.9%**	**89.0%**	**89.4%**
Urban Interstate	93.4%	92.2%	92.6%	94.5%	94.4%
Urban Other Freeway & Expressway	89.0%	89.5%	90.2%	93.2%	93.3%
Urban Other Principal Arterial	71.3%	71.1%	72.7%	74.4%	73.1%
Urban Minor Arterial	78.7%	77.3%	76.0%	75.0%	74.7%
Urban Collector	75.3%	75.9%	73.5%	67.9%	68.0%
Subtotal Urban	**77.3%**	**76.9%**	**76.5%**	**74.0%**	**73.6%**
Total Acceptable *	**86.0%**	**87.4%**	**86.6%**	**84.2%**	**84.2%**

** Totals shown reflect Federal-aid highways only and exclude roads classified as rural minor collector, rural local, or urban local, for which pavement data are not reported in HPMS.*
Source: Highway Performance Monitoring System as of December 2009.

Lane Width

Lane width affects capacity and safety; narrow lanes have a lower capacity and can affect the frequency of crashes. As with roadway alignment, lane width is more crucial on those functional classifications with higher travel volumes.

Currently, higher functional systems such as the Interstate System are expected to have 12-foot lanes. Approximately 98.8 percent of all Interstate System highways had lane widths of 12 feet or greater in 2008. As shown in *Exhibit 3-6,* approximately 99.0 percent of rural Interstate System miles and 98.4 percent of urban Interstate System miles have minimum 12-foot lane widths.

Exhibit 3-6

Lane Width by Functional Class, 2008

	≥ 12 foot	11 foot	10 foot	9 foot	< 9 foot
Rural					
Interstate	99.0%	1.0%	0.0%	0.0%	0.0%
Other Principal Arterial	89.9%	8.4%	1.4%	0.2%	0.1%
Minor Arterial	70.9%	18.9%	9.2%	0.8%	0.1%
Major Collector	39.8%	26.7%	25.4%	6.2%	1.8%
Urban					
Interstate	98.4%	1.4%	0.1%	0.1%	0.0%
Other Freeway & Expressway	94.3%	5.1%	0.6%	0.0%	0.0%
Other Principal Arterial	82.0%	12.7%	4.8%	0.3%	0.3%
Minor Arterial	66.5%	18.8%	12.3%	1.7%	0.6%
Collector	52.5%	19.3%	20.4%	5.9%	1.9%

Source: Highway Performance Monitoring System as of December 2009.

A slight majority (52.5 percent) of urban collectors have lane widths of 12 feet or greater, but approximately one-fifth have 11-foot lanes, and about one-fifth have 10-foot lanes. Among rural major collectors, 39.8 percent have lane widths of 12 feet or greater, but approximately one-fourth have 11-foot lanes and one-fourth have 10-foot lanes. Roughly one in every 13 miles on rural major collectors has lane widths of 9 feet or less.

Roadway Alignment

The term "Roadway Alignment" refers to the curvature and grade of a roadway; i.e., the extent to which it swings from side to side, and points up or down. The term "Horizontal Alignment" relates to curvature, while the term "Vertical Alignment" relates to gradient. Alignment adequacy affects the level of service and safety of the highway system. Inadequate alignment may result in speed reductions and impaired sight distance. In particular, trucks are affected by inadequate vertical alignment with regard to speed. Alignment adequacy is evaluated on a scale from Code 1 (best) to Code 4 (worst).

Alignment adequacy is more important on roads with higher travel speeds and/or higher volumes (e.g., the Interstate System). Alignment is generally not a major issue in urban areas; therefore, only rural alignment statistics are presented in this section. The amount of change in roadway alignment over time is gradual and occurs only during major reconstruction of existing roadways. New roadways are constructed to meet current vertical and horizontal alignment criteria and therefore do not generally have alignment problems, except under very extreme conditions.

As shown in *Exhibit 3-7,* approximately 95.6 percent of rural Interstate System miles are classified as Code 1 for horizontal alignment and 92.7 percent as Code 1 for vertical alignment. In contrast, the percentage of rural minor arterial miles classified as Code 1 for horizontal and vertical alignment, respectively, are only 72.8 percent and 55.1 percent.

Exhibit 3-7

Rural Alignment by Functional Class, 2008

	Code 1	Code 2	Code 3	Code 4
Horizontal				
Interstate	95.6%	0.4%	1.2%	2.8%
Other Principal Arterial	77.9%	8.5%	5.0%	8.6%
Minor Arterial	72.8%	6.3%	7.5%	13.5%
Major Collector	88.0%	0.9%	0.9%	10.3%
Vertical				
Interstate	92.7%	6.0%	0.8%	0.5%
Other Principal Arterial	67.4%	21.3%	6.2%	5.1%
Minor Arterial	55.1%	23.6%	13.2%	8.1%
Major Collector	63.6%	21.1%	9.9%	5.4%

Code 1	All curves and grades meet appropriate design standards.
Code 2	Some curves or grades are below design standards for new construction, but curves can be negotiated safely at prevailing speed limits. Truck speed is not substantially affected.
Code 3	Infrequent curves or grades occur that impair sight distance or severely affect truck speeds. May have reduced speed limits.
Code 4	Frequent grades occur that impair sight distance or severely affect truck speeds. Generally, curves are unsafe or uncomfortable at prevailing speed limit, or the speed limit is severely restricted due to the design speed limits of the curves.

Source: Highway Performance Monitoring System as of December 2009.

Bridge System Conditions

The data used to evaluate the condition of the Nation's bridges is drawn from the National Bridge Inventory (NBI) and reflects information gathered by the States during their periodic safety inspection of bridges. Bridge inspectors are trained to inspect bridges based on, as a minimum, the criteria in the National Bridge Inspection Standards (NBIS). Regular inspections are required for all 603,310 bridges with spans of more than 20 feet (6.1 meters) located on public roads.

Some of the statistics presented in this section are based on actual bridge counts, while others are weighted by bridge deck area (taking bridge size into account) or by average daily traffic (ADT). ADT represents the number of vehicles crossing a structure on a typical day, but does not reflect the length of the structure crossed. In contrast, the VMT-weighted figures for pavements presented in the previous section take into account both the number of vehicles and the distance they travel.

How often are the bridges inspected?

Most bridges in the NBI are inspected once every 24 months. Structures with advanced deterioration or other conditions warranting close monitoring may be inspected more frequently. Certain types of structures in satisfactory or better condition as well as other factors, including but not limited to structure type and description, structure age, and structure load rating, may receive an exemption from the 24-month inspection cycle. With FHWA approval, these structures may be inspected at intervals that do not exceed 48 months. A discussion of the criteria can be found in Technical Advisory 5140.21, subparagraph 7 of *Varying the Frequency of Routine Inspection* (http://staffnet/pgc/results.cfm?id=2341)

Approximately 83 percent of bridges are inspected once every 24 months, 12 percent are inspected on a 12-month cycle, and 5 percent are inspected on a maximum 48-month cycle.

All data presented in this section are from the NBI database as of October 2009. As noted in Chapter 2, since a majority of bridges are inspected once every 24 months, the "2009" NBI data actually reflect the condition of individual bridges from late 2007 through late 2009, or late 2008 on average.

Bridge Ratings and Classifications

From the information collected through the inspection process, assessments are performed to determine the adequacy of a structure to service the current structural and functional demands; factors considered include load-carrying capacity, deck geometry, clearances, waterway adequacy, and approach roadway alignment. Structural assessments together with ratings of the physical condition of key bridge components determine whether a bridge should be classified as "**structurally deficient.**" Functional adequacy is assessed by comparing the existing geometric configurations and design load carrying capacities to current standards and demands. Disparities between the actual and preferred configurations are used to determine whether a bridge should be classified as "**functionally obsolete.**"

What makes a bridge structurally deficient, and are structurally deficient bridges unsafe?

Structurally deficient bridges are **not** inherently unsafe.

Bridges are considered structurally deficient if significant load-carrying elements are found to be in poor or worse condition due to deterioration and/or damage, or the adequacy of the waterway opening provided by the bridge is determined to be extremely insufficient to the point of causing intolerable roadway traffic interruptions.

The classification of a bridge as structurally deficient does not imply that it is likely to collapse or that it is unsafe. By conducting properly scheduled inspections, unsafe conditions may be identified; if the bridge is determined to be unsafe, the structure must be closed. A deficient bridge, when left open to traffic, typically requires significant maintenance and repair to remain in service and eventual rehabilitation or replacement to address deficiencies. To remain in service, structurally deficient bridges often have weight limits that restrict the gross weight of vehicles using the bridges to less than the maximum weight typically allowed by statute.

Condition Ratings

The primary considerations in classifying structural deficiencies are the bridge component condition ratings. The NBI database contains condition ratings on the three primary components of a bridge: the deck, superstructure, and substructure. The bridge deck is the surface on which vehicles travel and is supported by the superstructure. The superstructure transfers the load of the deck and bridge traffic to the substructure, which provides support for the entire bridge.

Condition ratings have been established to measure the state of bridge components over time in a consistent and uniform manner. Bridge inspectors assign condition ratings by evaluating the severity of any deterioration of bridge components relative to their as-built condition, and the extent to which this deterioration affects the performance of the component being rated. These ratings provide an overall characterization of the general condition of the entire component being rated; the condition of specific individual bridge elements may be higher or lower. *Exhibit 3-8* describes the bridge condition ratings in more detail.

Q&A

How does a bridge become functionally obsolete?

Functional obsolescence is a function of the geometrics of the bridge in relation to the geometrics required by current design standards. While structural deficiencies are generally the result of deterioration of the conditions of the bridge components, functional obsolescence generally results from changing traffic demands on the structure. Facilities, including bridges, are designed to conform to the design standards in place at the time they are designed. Over time, improvements are made to the design requirements. As an example, a bridge designed in the 1930s would have shoulder widths in conformance with the design standards of the 1930s, but current design standards are based on different criteria and require wider bridge shoulders to meet current safety standards. The difference between the required, current-day shoulder width and the 1930s' designed shoulder width represents a deficiency. The magnitude of these types of deficiencies determines whether a bridge is classified as functionally obsolete.

Exhibit 3-8

Bridge Condition Rating Categories

Rating	Condition Category	Description*
9	Excellent	
8	Very Good	No problems noted.
7	Good	Some minor problems.
6	Satisfactory	Structural elements show some minor deterioration.
5	Fair	All primary structural elements are sound but may have minor section loss, cracking, spalling, or scour.
4	Poor	Advanced section loss, deterioration, spalling, or scour.
3	Serious	Loss of section, deterioration, spalling, or scour have seriously affected primary structural components. Local failures are possible. Fatigue cracks in steel or shear cracks in concrete may be present.
2	Critical	Advanced deterioration of primary structural elements. Fatigue cracks in steel or shear cracks in concrete may be present or scour may have removed substructure support. Unless closely monitored, it may be necessary to close the bridge until corrective action is taken.
1	Imminent Failure	Major deterioration or section loss present in critical structural components, or obvious loss present in critical structural components, or obvious vertical or horizontal movement affecting structural stability. Bridge is closed to traffic, but corrective action may be sufficient to put the bridge back in light service.
0	Failed	Bridge is out of service and is beyond corrective action.

**The term "section loss" is defined in The Bridge Inspector's Reference Manual (BIRM) Publication No. FHWA NHI 03-001 as the loss of a (bridge) member's cross-sectional area usually by corrosion or decay. A "spall" is a depression in a concrete member resulting from the separation and removal of a volume of the surface concrete. Spalls can be caused by corroding reinforcement, friction from thermal movement, and overstress. The term "scour" refers to the erosion of streambed or bank material around bridge supports due to flowing water.*

Source: Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges, Report No. FHWA-PD-96-001.

The condition ratings for bridges in the Nation are shown in *Exhibit 3-9.* When a primary component of a structure has a rating of 4 or lower, it is considered to be structurally deficient. A structural deficiency does not indicate that a bridge is unsafe but instead indicates the extent to which a bridge has depreciated from its original condition when first built. Once bridge components become structurally deficient, the bridge may experience reduced performance in the form of lane closures or load limits. Bridges with components in such disrepair that there is a safety risk are closed to traffic.

Approximately 58.9 percent of the bridges rated had bridge decks in good (7) or better condition. Weighting bridges by deck area changes this value to 59.4 percent, suggesting that larger bridges are in slightly better shape on average; the corresponding value weighted by ADT is 55.6 percent, suggesting that bridge decks on heavily traveled bridges are in slightly worse shape on average. The share of bridge decks rated as poor (4) or worse was 5.5 percent based on raw bridge counts or weighted by ADT; the corresponding figure weighted by deck area was 5.0 percent.

Weighted by deck area, the share of bridge superstructures rated as good (7) or better was

Exhibit 3-9

Bridge Condition Ratings, 2009

Deck Rating Distribution

Rating *	Bridge Count	Deck Area Weighting	ADT Weighting
9	4.0%	2.9%	2.0%
8	17.4%	15.2%	11.3%
7	37.5%	41.3%	42.2%
6	23.2%	24.9%	26.5%
5	12.4%	10.7%	12.4%
4	4.0%	3.7%	4.1%
3	1.0%	1.0%	1.2%
2	0.3%	0.1%	0.1%
1	0.1%	0.1%	0.1%
0	0.2%	0.1%	0.0%

Superstructure Rating Distribution

Rating*	Bridge Count	Deck Area Weighting	ADT Weighting
9	4.6%	3.8%	2.7%
8	22.8%	24.8%	22.4%
7	34.0%	36.8%	41.9%
6	21.4%	21.1%	21.9%
5	11.6%	9.8%	8.6%
4	3.9%	2.9%	2.1%
3	1.1%	0.6%	0.4%
2	0.3%	0.2%	0.1%
1	0.1%	0.0%	0.0%
0	0.2%	0.1%	0.0%

Substructure Rating Distribution

Rating*	Bridge Count	Deck Area Weighting	ADT Weighting
9	4.3%	3.4%	2.2%
8	17.5%	17.0%	12.6%
7	36.0%	44.4%	51.2%
6	22.7%	22.1%	23.2%
5	12.5%	9.6%	8.5%
4	4.9%	2.8%	1.9%
3	1.3%	0.5%	0.2%
2	0.5%	0.1%	0.0%
1	0.1%	0.0%	0.0%
0	0.2%	0.1%	0.0%

** Percentages are based on deck ratings for 468,466 bridges, superstructure ratings for 473,116 bridges, and substructure ratings for 473,305 bridges. These percentages exclude 124,823 culverts (self-contained units located under roadway fill that do not have a deck, superstructure, or substructure), other structures for which these ratings are nonapplicable, and other structures for which no value was coded.*

Source: National Bridge Inventory, October 2009.

Q&A

What is the condition of the culverts included in the NBI?

There are 129,351 culverts reflected in the NBI. Culverts are self-contained units located under roadway fill, typically constructed of concrete or corrugated steel. Multiple pipes or boxes placed side by side are considered to be a structure and are included in the NBI if they span a total length in excess of 6.1 meters and carry a public roadway. As these structures lack decks, superstructures, and substructures, culverts are rated based on their overall condition as a whole. *Exhibit 3-10* shows the distribution of culvert condition ratings.

Exhibit 3-10

Culvert Condition Ratings, 2009

Rating	Number of Culverts	Percent
9	4,517	3.5%
8	24,674	19.1%
7	55,875	43.2%
6	32,845	25.4%
5	8,771	6.8%
4	2,106	1.6%
3	457	0.4%
2	67	0.1%
1	7	0.0%
0	32	0.0%
Total	**129,351**	**100.0%**

Source: National Bridge Inventory, October 2009.

65.4 percent, while the comparable value for bridge substructures was 64.8 percent. The share of bridge superstructures weighted by deck area rated as poor or worse was 3.8 percent, compared to 3.5 percent for bridge substructures. The percentages shown in *Exhibit 3-9* do not reflect culverts, which do not have a deck, superstructure or substructure, but instead are self contained units typically located under roadway fill.

Appraisal Ratings

Appraisal ratings are based on an evaluation of bridge characteristics relative to the current standards used for highway and bridge design. Such ratings factor into the classification of bridges as structurally deficient or functionally obsolete. *Exhibit 3-11* describes appraisal rating codes in more detail.

Exhibit 3-11

Bridge Appraisal Rating Categories

Rating	Description
N	Not applicable.
9	Superior to present desirable criteria.
8	Equal to present desirable criteria.
7	Better than present minimum criteria.
6	Equal to present minimum criteria.
5	Somewhat better than minimum adequacy to tolerate being left in place as-is.
4	Meets minimum tolerable limits to be left in place as-is.
3	Basically intolerable requiring a high priority of corrective action.
2	Basically intolerable requiring a high priority of replacement.
1	This value of rating code is not used.
0	Bridge closed.

Source: Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges, Report No. FHWA-PD-96-001.

Structural Evaluation and Waterway Adequacy Ratings

Load-carrying capacity does not influence the assignment of the condition ratings referenced above, but it does factor into the structural evaluation appraisal rating. This is calculated according to the capacity ratings for various categories of traffic in terms of ADT. A structural evaluation rating of 3 indicates that the load-carrying capacity does not meet current design standards, but can be mitigated through corrective action; in this case, the bridge is classified as functionally obsolete. A structural evaluation rating of 2 or lower indicates that the load-carrying capacity is too low and the structure should be replaced; in this case, the bridge is classified as structurally deficient. Again, neither rating is indicative of a bridge that is unsafe but rather a measure of the bridge's original design and the extent of the bridge's depreciation relative to current design standards.

The waterway adequacy appraisal rating describes the size of the opening of the structure with respect to the passage of water flow under the bridge. This rating, which considers the potential for a structure to be submerged during a flood event and the potential inconvenience to the traveling public, is based on criteria assigned by functional classification. Bridges with waterway adequacy appraisal ratings of 3 are classified as functionally obsolete, while those with waterway adequacy appraisal ratings of 2 or lower are classified as structurally deficient.

Exhibit 3-12 shows the distribution of structural evaluation and waterway adequacy ratings. Approximately 6.9 percent of bridges received a structural evaluation rating of 3 or less. Weighting bridges by deck area reduces this value to 3.2 percent; the comparable ADT-weighted figure is 1.6 percent. This suggests that larger, more heavily traveled bridges have fewer problems in terms of load-carrying capacity than smaller less-traveled bridges, on average. Only 1.0 percent of structures spanning waterways received a waterway adequacy rating of 3 or less; the comparable figures weighted by deck area and weighted by ADT were both 0.3 percent.

Reporting Deficient Deck Area

The FHWA is exploring alternate methods of reporting total deficient bridge deck area. Under the current method, the total deck area on deficient bridges is divided by the total deck area of all bridges for a particular year. As new bridges are constructed, their area is included in the denominator of this computation; even if the total deck area on deficient bridges remained constant from one year to the next, the increase in the total deck area of all bridges would cause the deck-area weighted percent of deficient bridges to decrease. Concerns have been raised that this method can inadvertently mask relevant changes to the condition of existing bridges.

Exhibit 3-12

Structural Evaluation and Waterway Adequacy Appraisal Ratings, 2009

	Structural Evaluation			Waterway Adequacy		
Rating*	Structures	Weighted by Deck Area	Weighted by ADT	Structures	Weighted by Deck Area	Weighted by ADT
9	1.7%	1.7%	1.1%	11.0%	24.6%	20.1%
8	13.7%	12.9%	10.6%	35.6%	45.0%	43.3%
7	26.4%	34.7%	40.1%	22.6%	12.8%	13.7%
6	25.3%	26.0%	28.2%	20.9%	13.3%	18.5%
5	16.3%	15.3%	14.0%	5.3%	2.8%	2.7%
4	9.6%	6.2%	4.5%	3.6%	1.2%	1.3%
3	2.3%	1.7%	1.0%	0.7%	0.2%	0.2%
2	4.0%	1.3%	0.5%	0.1%	0.0%	0.0%
1	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0	0.6%	0.2%	0.1%	0.2%	0.1%	0.0%

** Percentages are based on structural evaluation ratings for 597,266 bridges and waterway adequacy ratings for 501,043 bridges. Bridges that are not over a waterway are not rated for waterway adequacy.*

Source: National Bridge Inventory, October 2009

Deck Geometry, Underclearance, and Approach Alignment Ratings

While load-carrying capacity and waterway adequacy can trigger the classification of a bridge as functionally obsolete, the primary considerations in determining functional obsolescence are functional and geometric-based appraisal ratings, including the deck geometry appraisal rating, the underclearance appraisal rating, and the approach roadway alignment appraisal rating.

Deck geometry ratings reflect the width of the bridge, the minimum vertical clearance over the bridge, the ADT, the number of lanes carried by the structure, whether two-way or one-way traffic is serviced, and the functional classification of the structure. As noted above, appraisal ratings are based on an evaluation of bridge characteristics relative to the current standards used for highway and bridge design; thus, the deck geometry rating is based in part on the difference between the actual width of the structure and the current design standard for the width of a structure with the same characteristics as the bridge being rated.

Underclearance appraisals consider both the vertical and horizontal underclearances as measured from the roadway or railway to the nearest bridge component. The functional classification of the underpassing route is considered, along with its Federal-aid designation and defense categorization (i.e., whether the bridge crosses over a Strategic Highway Network STRAHNET route).

Approach alignment ratings differ from the deck geometry and underclearance appraisal ratings in that, rather than comparing approach roadway alignment with current standards, they are determined by comparing the existing approach roadway alignment to the bridge to the general alignment for the section of highway the bridge is on. Deficiencies are identified where the bridge route does not function adequately because of alignment disparities.

Exhibit 3-13 shows the distribution of appraisal ratings for deck geometry, underclearance, and approach alignment. Approximately 8.6 percent of bridges received a deck geometry rating of 2 or lower, indicating problems that generally would not be correctable unless the structure were replaced. The comparable figure weighted by ADT is 10.8 percent because deck geometry adequacy is more of a problem on higher-traveled routes, on average. Approximately 0.3 percent of approach alignments were rated 2 or lower; for those bridges for which underclearance adequacy was evaluated, 3.1 percent were rated 2 or lower.

Exhibit 3-13

Bridge Appraisal Ratings Based on Geometry and Function, 2009

Deck Geometry Rating Distribution

Rating*	Bridge Count	Deck Area Weighting	ADT Weighting
9	8.9%	21.2%	31.0%
8	2.2%	2.4%	2.0%
7	11.3%	14.4%	12.4%
6	20.7%	16.4%	13.5%
5	22.6%	15.8%	11.7%
4	18.4%	16.5%	14.7%
3	7.2%	4.8%	4.0%
2	8.5%	8.5%	10.8%
1	0.0%	0.0%	0.0%
0	0.1%	0.1%	0.0%

Approach Alignment Rating Distribution

Rating*	Bridge Count	Deck Area Weighting	ADT Weighting
9	2.7%	3.5%	5.4%
8	62.4%	73.2%	79.2%
7	12.3%	10.0%	7.9%
6	14.4%	8.9%	5.5%
5	3.8%	2.1%	1.1%
4	2.8%	1.5%	0.8%
3	1.4%	0.6%	0.2%
2	0.2%	0.1%	0.0%
1	0.0%	0.0%	0.0%
0	0.1%	0.0%	0.0%

Underclearance Rating Distribution

Rating*	Bridge Count	Deck Area Weighting	ADT Weighting
9	10.4%	12.3%	9.1%
8	2.0%	2.0%	1.6%
7	9.1%	8.3%	7.8%
6	17.3%	16.7%	17.1%
5	16.2%	14.2%	15.0%
4	20.3%	19.3%	23.5%
3	21.6%	24.2%	23.4%
2	3.0%	2.9%	2.4%
1	0.0%	0.0%	0.0%
0	0.1%	0.1%	0.0%

** Percentages are based on deck geometry ratings for 519,386 structures, approach alignment ratings for 602,100 structures, and underclearance ratings for 101,860 structures. Underclearance adequacy is rated only for those bridges crossing over a highway or railroad.*

Source: National Bridge Inventory, October 2009.

Condition and Appraisal Ratings Relative to Structurally Deficient/ Functionally Obsolete Designations

The discussion of condition and appraisal ratings above identifies some specific trigger values that will result in the designation of a bridge as structurally deficient or functionally obsolete. However, it is important to note that condition and appraisal ratings are not cumulative; for example, a single bridge may have multiple deficiencies that each would warrant a classification of functionally obsolete.

Bridges may have both structural problems that would warrant a classification of structurally deficient and functional issues that would warrant a classification of functionally obsolete. However, when summary NBI bridge condition metrics are presented, bridges are reported as being in one of three mutually exclusive categories—structurally deficient, functionally obsolete, or non-deficient. The standard NBI data reporting convention is that **if a bridge meets the criteria to be classified as both structurally deficient and functionally obsolete, it is identified only as structurally deficient**, because structural deficiencies are considered more critical. Thus, while a significant percentage of bridges classified as structurally deficient will also have functional issues in need of correction, bridges classified as functionally obsolete do not have significant structural deficiencies.

Bridge Conditions on the NHS

Exhibit 3-14 identifies the percent of bridges on the National Highway System (NHS) classified as structurally deficient or functionally obsolete based on the number of bridges, bridges weighted by deck area, and bridges weighted by ADT. The FHWA has adopted deck-area weighting for use in agency performance planning in recognition of the significant logistical and financial challenges that may be involved in addressing deficiencies on larger bridges. The total number of NHS bridges for individual years are identified in Chapter 2.

Approximately 21.9 percent of the 117,510 NHS bridges were classified as deficient in 2009; the comparable values weighted by ADT and deck area were 26.2 percent and 29.2 percent, respectively. This suggests that there is a greater-than-average concentration of deficiencies on heavily traveled and larger bridges, respectively.

The share of NHS bridges weighted by deck area that are classified as structurally deficient decreased from 8.4 percent in 2001 to 8.2 percent in 2009, while the deck-area weighted share classified as functionally obsolete decreased from 22.0 percent to 21.0 percent over the same period. NHS routes tend to carry significantly more traffic than the average road, and functional obsolescence remains a significant challenge on NHS bridges.

Exhibit 3-14

NHS Bridge Deficiences, 2001–2009

	Percentage of Deficient Bridges by Year				
Analysis Approach	**2001**	**2003**	**2005**	**2007**	**2009**
Weighted By Deck Area					
Structurally Deficient	8.4%	8.8%	8.5%	8.4%	8.2%
Functionally Obsolete	22.0%	20.9%	21.3%	21.3%	21.0%
Total Deficient	**30.4%**	**29.7%**	**29.8%**	**29.7%**	**29.2%**
Weighted By ADT					
Structurally Deficient	7.2%	7.1%	6.6%	6.5%	6.2%
Functionally Obsolete	20.5%	20.0%	20.2%	20.2%	20.0%
Total Deficient	**27.7%**	**27.1%**	**26.8%**	**26.7%**	**26.2%**
By Bridge Count					
Structurally Deficient	6.0%	5.9%	5.7%	5.5%	5.2%
Functionally Obsolete	17.4%	17.0%	16.9%	16.7%	16.6%
Total Deficient	**23.3%**	**22.9%**	**22.6%**	**22.2%**	**21.9%**

Source: National Bridge Inventory, October 2009.

Systemwide Bridge Conditions

Exhibit 3-15 identifies the percentage of all bridges classified as structurally deficient or functionally obsolete based on the number of bridges, bridges weighted by deck area, and bridges weighted by ADT. The total number of bridges has grown over time; totals for individual years are identified in Chapter 2.

Q&A

What goals were established by the Department of Transportation for NHS bridges?

The Department of Transportation's *FY 2009 Performance and Accountability Report* presented a fiscal year (FY) 2009 target of 29.0 percent for the share of deck area on NHS bridges rated as deficient.

Based on raw bridge counts, approximately 12.0 percent of bridges were classified as structurally deficient in 2009, and 14.5 percent were classified as functionally obsolete. Weighted by deck area, the comparable shares were 9.3 percent structurally deficient and 20.2 percent functionally obsolete. The differences are even more pronounced when bridges are weighted by ADT, as this adjustment results in a structural deficient share of 7.0 percent and a functionally obsolete share of 21.7 percent.

Since 2001, the total share of deficient bridges weighted by deck area has decreased from 31.3 percent to 29.4 percent, representing an overall improvement in the condition of the Nation's bridges. Whether considering raw bridge counts, deck-area-weighted values, or ADT-weighted values, more progress was made during this period in reducing the percentage of structurally deficient bridges than in reducing the share of functionally obsolete bridges.

Exhibit 3-15

Systemwide Bridge Deficiencies, 2001–2009

	Percentage of Deficient Bridges by Year				
Analysis Approach	**2001**	**2003**	**2005**	**2007**	**2009**
Weighted By Deck Area					
Structurally Deficient	10.5%	10.3%	9.8%	9.5%	9.3%
Functionally Obsolete	20.9%	20.4%	20.7%	20.6%	20.2%
Total Deficient	**31.3%**	**30.8%**	**30.5%**	**30.1%**	**29.4%**
Weighted By ADT					
Structurally Deficient	8.1%	7.9%	7.4%	7.3%	7.0%
Functionally Obsolete	22.4%	22.0%	22.0%	22.0%	21.7%
Total Deficient	**30.5%**	**29.9%**	**29.4%**	**29.4%**	**28.7%**
By Bridge Count					
Structurally Deficient	14.6%	13.9%	13.1%	12.3%	12.0%
Functionally Obsolete	15.5%	15.3%	15.1%	14.8%	14.5%
Total Deficient	**30.1%**	**29.1%**	**28.2%**	**27.2%**	**26.5%**

Source: National Bridge Inventory, October 2009.

Rural and Urban Deficient Bridges by Functional Classification

Based on the number of bridges, the total percentage of structurally deficient and functionally obsolete bridges on the Nation's roadways decreased from 30.1 percent in 2001 to 26.5 percent in 2009. The percentage of structurally deficient bridges for most functional classes decreased from 2001 to 2009, with the exception of rural Interstate System bridges. As shown in *Exhibit 3-16*, the share of rural Interstate System bridges classified as structurally deficient increased from 4.1 percent to 4.5 percent over this period. The share of bridges classified as functionally obsolete decreased for most functional classes except for urban collectors, which experienced an increase from 28.1 percent in 2001 to 28.3 percent in 2009.

Exhibit 3-16

Bridge Deficiences by Functional Class, 2001–2009

	Percentage of Structurally Deficient Bridges by Year				
Functional System	**2001**	**2003**	**2005**	**2007**	**2009**
Rural					
Interstate	4.1%	4.4%	4.2%	4.4%	4.5%
Other Principal Arterial	5.6%	5.5%	5.3%	5.0%	4.7%
Minor Arterial	8.7%	8.6%	8.4%	8.2%	7.8%
Major Collector	12.3%	12.1%	11.4%	10.8%	10.5%
Minor Collector	14.6%	14.0%	13.0%	12.5%	12.4%
Local	22.7%	21.4%	19.9%	18.7%	18.3%
Subtotal Rural	**16.0%**	**15.2%**	**14.3%**	**13.5%**	**13.3%**
Urban					
Interstate	6.5%	6.5%	6.2%	6.0%	5.8%
Other Freeway and Expressway	6.5%	6.3%	5.9%	6.0%	5.4%
Other Principal Arterial	10.0%	9.5%	9.1%	8.7%	8.3%
Minor Arterial	11.0%	10.6%	10.3%	10.0%	9.5%
Collector	12.0%	11.4%	11.3%	11.0%	10.3%
Local	12.6%	11.8%	11.6%	10.9%	10.6%
Subtotal Urban	**9.8%**	**9.4%**	**9.1%**	**8.8%**	**8.4%**

	Percentage of Functionally Obsolete Bridges by Year				
Functional System	**2001**	**2003**	**2005**	**2007**	**2009**
Rural					
Interstate	12.8%	12.8%	12.5%	11.7%	11.7%
Other Principal Arterial	10.8%	10.0%	9.6%	9.1%	8.8%
Minor Arterial	12.6%	11.7%	11.3%	10.8%	10.3%
Major Collector	11.3%	11.2%	10.9%	10.3%	9.7%
Minor Collector	12.5%	12.2%	12.0%	11.6%	11.1%
Local	13.7%	13.3%	13.0%	12.5%	12.0%
Subtotal Rural	**12.7%**	**12.3%**	**12.0%**	**11.5%**	**11.0%**
Urban					
Interstate	23.4%	22.9%	23.6%	23.8%	23.2%
Other Freeway and Expressway	24.2%	23.6%	23.3%	22.8%	22.3%
Other Principal Arterial	25.3%	25.5%	24.8%	24.5%	24.1%
Minor Arterial	29.7%	29.4%	29.0%	29.4%	28.9%
Collector	28.1%	28.6%	28.9%	28.5%	28.3%
Local	21.5%	21.9%	22.1%	21.5%	21.1%
Subtotal Urban	**25.1%**	**25.1%**	**25.1%**	**24.9%**	**24.5%**

Source: National Bridge Inventory, October 2009.

Among the individual functional classes, the highest percentage observed in 2009 for structurally deficient bridges was 18.3 percent for rural minor collectors; despite the increase noted above, the rural portion of the Interstate System had the lowest percentage of structurally deficient bridges. Urban minor arterials had the highest share of functionally obsolete bridges, 28.9 percent in 2009, while only 8.8 percent of rural other principal arterials were classified as functionally obsolete.

Deficient Bridges by Owner

Bridge deficiencies by ownership are examined in *Exhibit 3-17*. Each State has the responsibility for inspection of all bridges in that State except for tribally or Federally owned bridges. The agency that owns a bridge is responsible for its maintenance and operation. Interagency agreements may be formed, such as those between State highway agencies and localities. In these cases, a secondary agency (such as the State) performs maintenance and operation work under agreement with the owner. However, such agreements do not transfer ownership and, therefore, do not negate the responsibilities of the bridge owners for maintenance and operation in compliance with Federal and State requirements.

Exhibit 3-17

Bridge Deficiencies by Owner, 2009

	Federal	State	Local	Private/ Other*	Total
Count					
Total Bridges	8,452	290,062	303,014	1,782	603,310
Total Deficient	2,293	71,680	84,766	1,120	159,859
Structurally Deficient	762	23,919	47,161	559	72,401
Functionally Obsolete	1,531	47,761	37,605	561	87,458
Percentages					
Percent of Total Inventory Owned	1.4%	48.1%	50.2%	0.3%	100.0%
Percent Deficient	27.1%	24.7%	28.0%	62.9%	26.5%
Percent Structurally Deficient	9.0%	8.2%	15.6%	31.4%	12.0%
Percent Functionally Obsolete	18.1%	16.5%	12.4%	31.5%	14.5%

** Note that these data only reflect bridges for which inspection reports were submitted to the NBI. An unknown number of privately owned bridges are omitted.*

Source: National Bridge Inventory, October 2009.

While the number of privately owned bridges reported in the NBI is relatively small, at 0.3 percent of the total number of bridges, about 62.9 percent of them were classified as deficient in 2009. State-owned bridges had the lowest share of structurally deficient bridges in 2009, at approximately 8.2 percent. Bridges owned by local governments had the lowest share of functionally obsolete bridges, at only 12.4 percent. These findings are consistent with the types of bridges owned by the different levels of government; local governments tend to own smaller bridges with lower traffic levels than average, for which functional obsolescence is less of an issue.

Historic Bridges on the Nation's Roadways

Of the 603,310 bridges in the National Bridge Inventory, 1,767 (0.29 percent) are registered as historic and an additional 3,846 (0.64 percent) are eligible to be registered. Some historic bridges carry significant traffic volumes; over 17 percent of the bridges on the historic register are on principal arterials.

Bridges do not have to be extremely old to be classified as historic. Approximately 9.5 percent of the registered historic bridges are 50 years in age or less, well within the typical useful lifespan of a bridge; approximately 4.1 percent are 10 years old or less.

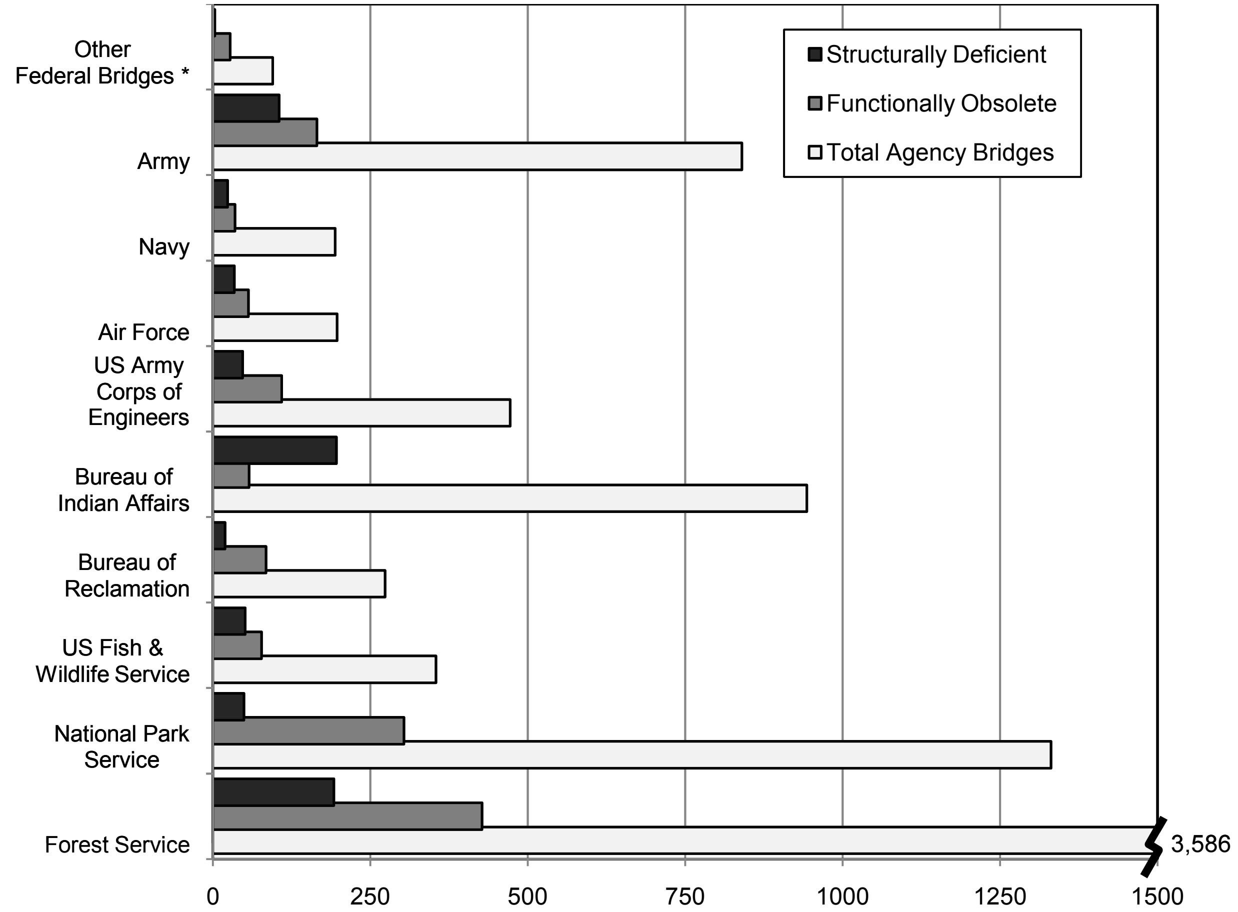
Of the registered historic bridges, 33.3 percent of them have current ratings that cause them to be classified as structurally deficient while 40.2 percent are classified as functionally obsolete. At some time, it will be necessary to take mitigation actions on those bridges classified as structurally deficient; however, mitigation actions on the bridges classified as functionally obsolete may not be possible due to the historic classification. These bridges are still open to vehicular traffic even though, in some cases, heavy trucks and similar vehicles may not be allowed to use a particular historic bridge.

How are Federal bridge deficiencies distributed among various Federal agencies? Q&A

Exhibit 3-18 illustrates the status of bridges for individual Federal agencies as of 2009. Among these agencies, the Forest Service owns the most bridges (3,586) and has the most functionally obsolete bridges in its inventory (427). The National Park Service also owns a significant number of bridges classified as functionally obsolete (303). The Bureau of Indian Affairs owns the most bridges classified as structurally deficient (196), slightly more than the number owned by the Forest Service (192).

Exhibit 3-18

Status of the Federal Bridge Inventory, 2009



** Includes bridges owned by the General Services Administration, the National Aeronautics and Space Administration, the Department of Energy, the Pentagon Reservation, the Department of Agriculture, the National Security Agency, the National Zoo, Washington Airports, and the Tennessee Valley Authority.*

Source: National Bridge Inventory.

Bridges by Age

Exhibit 3-19 identifies the age composition of Interstate System bridges, NHS bridges, and all bridges combined. As of 2009, approximately 38.1 percent of the Nation's bridges were between 26 and 50 years old; this share is higher for NHS bridges, 54.6 percent, while 71.1 percent of the Interstate bridges fell into this age range. The clustering of bridges in this age range has potential implications in terms of long-term bridge rehabilitation and replacement strategies because the need for such actions may be concentrated within certain time periods rather than being spread out evenly, which might be the case if the original construction of bridges had been spread out more evenly over time. However, a number of other variables such as maintenance practices and environmental conditions also affect when future capital investments might be needed.

Exhibit 3-19

Bridges by Age Range, as of 2009

	All Bridges		NHS Bridges		Interstate Bridges	
Age Range	**Count**	**Percent**	**Count**	**Percent**	**Count**	**Percent**
0–10 Years	68,406	11.3%	12,028	10.2%	3,537	6.4%
11–25 Years	123,860	20.5%	19,026	16.2%	5,878	10.7%
26–50 Years	230,128	38.1%	64,116	54.6%	39,137	71.1%
51–75 Years	121,543	20.1%	17,811	15.2%	6,253	11.4%
76–100 Years	49,122	8.1%	4,284	3.6%	168	0.3%
>100 Years	9,865	1.6%	194	0.2%	9	0.0%
Not reported	386	0.1%	51	0.0%	29	0.1%
Total	**603,310**	**100.0%**	**117,510**	**100.0%**	**55,011**	**100.0%**

Source: National Bridge Inventory, October 2009.

Exhibit 3-20 identifies the distribution of bridge deficiencies within the age ranges presented in *Exhibit 3-19*. The percent of bridges classified as either structurally deficient or functionally obsolete generally tends to rise as bridges age. Among Interstate System bridges, 22.8 percent of the bridges constructed between 26 and 50 years ago were classified as deficient; this share rose to 35.2 percent for Interstate System bridges constructed between 51 and 75 years ago. Note that some existing bridges were absorbed into the Interstate System at the time it was designated; some of these structures remain in service today.

The age of a bridge structure is one indicator of its serviceability. However, a combination of several factors impacts the serviceability of a structure, including the original type of design; the frequency, timeliness, effectiveness, and appropriateness of the maintenance activities implemented over the life of the structure; the loading the structure has been subject to 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.

Q&A

Why are there bridges less than ten years old that are classified as deficient?

Current laws and regulations permit the building of bridges off the Federal-aid system to design standards (width, clearance, etc.) that may be less than the minimum current design standards for bridges on the Federal-aid system. Newly constructed, replaced, or major rehabilitated bridges built to lesser design standards are often classified as functionally obsolete once they are open to traffic.

Also, design exceptions for less than the minimum current standards for bridges on the Federal-aid system are sometimes approved depending on the circumstances. Physical constraints within urban areas can limit the size of a new bridge, thus resulting in a relatively young deficient bridge. Additionally, extreme events such as earthquakes can render a new bridge structurally deficient.

The FHWA established the "10-Year Rule" for determining a bridge's eligibility for Federal funds after new construction, replacement, or major rehabilitation has taken place. Bridges that have been newly constructed, replaced, or had major rehabilitation within the past 10 years are not eligible for Federal funds and are not used to apportion Highway Bridge Program funds.

The 10-Year Rule encourages States to address all the deficiencies of a bridge at one time rather than separately, which results in multiple traffic disruptions and additional costs. The rule also assists in preventing intentional manipulation of the apportionment process of Highway Bridge Program funds. Without it, States could minimize the amount of improvements on deficient bridges to maintain them in a safe condition but still in a deficient classification, so that their deck areas would still contribute to a stable or increased apportionment of Highway Bridge Program funds.

It should be noted that some standard NBI data reports on structurally deficient and functionally obsolete bridges, including those used in the C&P report prior to the 2008 edition, exclude bridges that fall under the 10-Year Rule, which has the effect of reducing the apparent number of deficient bridges.

Exhibit 3-20

Bridge Deficiencies by Period Built, as of 2009

Age Range of All Bridges	Bridge Count	Structurally Deficient		Functionally Obsolete		All Deficient	
		Count	Percent	Count	Percent	Count	Percent
0–10 Years	68,406	552	0.8%	6,507	9.5%	7,059	10.3%
11–25 Years	123,860	3,183	2.6%	11,325	9.1%	14,508	11.7%
26–50 Years	230,128	22,720	9.9%	32,357	14.1%	55,077	23.9%
51–75 Years	121,543	26,244	21.6%	23,836	19.6%	50,080	41.2%
76–100 Years	49,122	15,668	31.9%	10,882	22.2%	26,550	54.0%
>100 Years	9,865	3,993	40.5%	2,455	24.9%	6,448	65.4%
Null	386	41	10.6%	96	24.9%	137	35.5%
Total	**603,310**	**72,401**	**12.0%**	**87,458**	**14.5%**	**159,859**	**26.5%**

Age Range of NHS Bridges	Bridge Count	Structurally Deficient		Functionally Obsolete		All Deficient	
		Count	Percent	Count	Percent	Count	Percent
0–10 Years	12,028	60	0.5%	1,458	12.1%	1,518	12.6%
11–25 Years	19,026	142	0.7%	1,960	10.3%	2,102	11.0%
26–50 Years	64,116	3,609	5.6%	10,829	16.9%	14,438	22.5%
51–75 Years	17,811	1,709	9.6%	4,367	24.5%	6,076	34.1%
76–100 Years	4,284	579	13.5%	865	20.2%	1,444	33.7%
>100 Years	194	49	25.3%	59	30.4%	108	55.7%
Null	51	4	7.8%	20	39.2%	24	47.1%
Total	**117,510**	**6,152**	**5.2%**	**19,558**	**16.6%**	**25,710**	**21.9%**

Age Range of Interstate Bridges	Bridge Count	Structurally Deficient		Functionally Obsolete		All Deficient	
		Count	Percent	Count	Percent	Count	Percent
0–10 Years	3,537	27	0.8%	634	17.9%	661	18.7%
11–25 Years	5,878	63	1.1%	806	13.7%	869	14.8%
26–50 Years	39,137	2,212	5.7%	6,709	17.1%	8,921	22.8%
51–75 Years	6,253	529	8.5%	1,669	26.7%	2,198	35.2%
76–100 Years	168	18	10.7%	24	14.3%	42	25.0%
>100 Years	9	2	22.2%	1	11.1%	3	33.3%
Null	29	0	0.0%	15	51.7%	15	51.7%
Total	**55,011**	**2,851**	**5.2%**	**9,858**	**17.9%**	**12,709**	**23.1%**

Source: National Bridge Inventory, October 2009.

As an example, two structures built at the same time, using the same design standards, and in the same climate area can have very different serviceability levels. The first structure may have had increasing loads due to increased heavy truck traffic, did not have any maintenance of the deck or the substructure, and did not have any rehabilitation work. The second structure may have had the same increases in heavy truck traffic but received correctly timed preventive maintenance activities on all parts of the structure and proper rehabilitation activities. In this case, the first structure would have a very low serviceability level while the second structure would have a high serviceability level.

Transit System Conditions

The condition and performance of the U.S. transit infrastructure should ideally be evaluated by how well it supports the objectives of the transit agencies that operate it. Presumably these include fast, safe, and comfortable service that charges reasonable fares, requires a minimal subsidy from taxpayers, and takes people where they want to go. However, the degree to which transit service meets these objectives is difficult to quantify and involves trade-offs that are outside the scope of Federal responsibility. This section reports on the quantity, age, and physical condition of transit assets because these factors determine how well the infrastructure can support any agency's objectives and set a foundation for uniform, consistent measurement. The assets in question include vehicles, stations, guideways, rail yards, administrative facilities, maintenance facilities, maintenance equipment, power systems, signaling systems, communication systems, and structures that carry both elevated and subterranean guideways. Chapter 4 addresses issues relating to the operational performance of transit systems.

The Federal Transit Administration (FTA) uses a numerical condition rating scale ranging from 1 to 5, detailed in *Exhibit 3-21*, 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. At the other end of the scale, a rating of 1.0 to 1.9, or "poor," indicates that the asset needs immediate repair and is not capable of supporting satisfactory transit service.

Exhibit 3-21

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.

FTA uses the Transit Economic Requirements Model (TERM) to estimate the conditions of transit assets. 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 an estimate of vehicle maintenance history and major rehabilitation expenditures in addition to vehicle age; the conditions of wayside control systems and track are based on an estimate of use (revenue miles per mile of track) in addition to age. For the purposes of this report, the state of good repair was defined using TERM's numerical condition rating scale. Specifically, this report considers an asset to be in a state of good repair when the physical condition of that asset is at or above a condition rating value of 2.5 (the mid-point of the marginal range). An entire transit system would be in a state of good repair if all of its assets have an estimated condition value of 2.5 or higher. The **State of Good Repair benchmark** presented in Chapter 8 represents the level of investment required to attain and maintain a state of good repair by rehabilitating or replacing all assets with estimated condition ratings that are less than this minimum condition value.

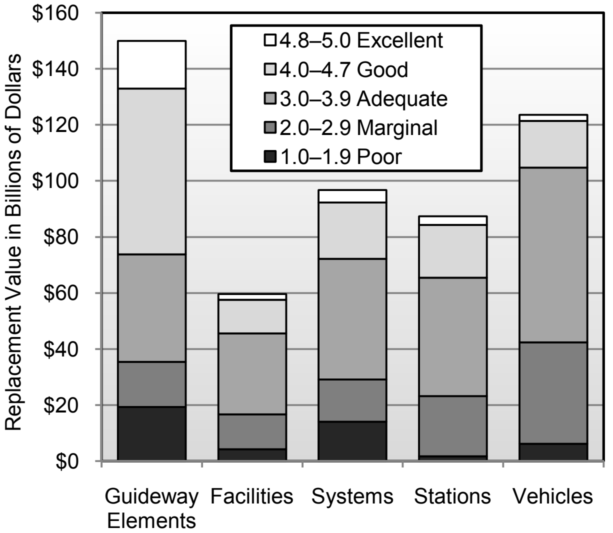
Typical deterioration schedules for vehicles, maintenance facilities, stations, train control systems, electric power systems, and communication systems have been estimated by FTA through special on-site engineering surveys. Transit vehicle conditions also reflect the most recently available information on vehicle age, use, and level of maintenance from the National Transit Database (NTD); the information used in this edition of the C&P report is from 2008. Age information is available on a vehicle-by-vehicle basis from the NTD and collected for all other assets through special surveys. Average maintenance expenditures and major rehabilitation expenditures by vehicle are also available on agency and modal bases. For the purpose of calculating conditions, agency maintenance and rehabilitation expenditures for a particular mode are assumed to be the same average value for all vehicles operated by that agency in that mode. Because agency maintenance expenditures may 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. The methods used to calculate deterioration schedules and the sources of the data on which deterioration schedules are based are discussed in Appendix C.

Condition estimates in each edition of the C&P report are based on contemporary updated asset inventory information and reflect updates in TERM's asset inventory data. Annual data from the NTD were used to update asset records for the Nation's transit vehicle fleets. In addition, updated asset inventory data were collected from more than 40 of the Nation's largest rail and bus transit agencies to support analysis of non-vehicle needs. Since this data is not collected annually it is not possible to provide accurate time series analysis of non-vehicle assets. FTA is working to develop improved data in this area. Appendix C provides a more detailed discussion of TERM's data sources. *Exhibit 3-22* shows the distribution of asset conditions, by replacement value, across major categories of assets for the entire U.S. transit industry.

Exhibit 3-22

Distribution of Asset Physical Conditions by Asset Type for All Modes



Source: Transit Economic Requirements Model.

Condition estimates for assets in this report are weighted by the replacement value of each asset. This takes into account the fact that assets vary substantially in replacement value. So, a $1 million railcar in poor condition is a much bigger problem than a $1 thousand turnstile in similar condition. As an example of the calculation involved, consider: the cost-weighted average of a $100 asset in condition 2 and a $50 asset in condition 4 would be (100x2+50x4)/(100+50) = 2.67. The unweighted average would be (2+4)/2 = 3.

The Replacement Value of U.S. Transit Assets

The total replacement value of the transit infrastructure in the United States was estimated at $663.3 billion in 2008. These estimates, presented in *Exhibit 3-23*, are based on asset inventory information contained in TERM. The data collected for these efforts represent a significant improvement in data availability in terms of asset inventories and unit costs, and are significantly more comprehensive than data used in previous C&P reports. The estimates are reported in 2008 dollars. They exclude the value of assets that belong to special service operators that do not report to the NTD. Rail

Exhibit 3-23

Estimated Replacement Value of the Nation's Transit Assets, 2008

	Replacement Value (Billions of 2008 Dollars)			
Transit Asset	**Nonrail**	**Rail**	**Joint Assets**	**Total**
Maintenance Facilities	$56.4	$33.2	$3.8	$93.4
Guideway Elements	$13.1	$234.5	$1.0	$248.6
Stations	$3.8	$84.8	$0.6	$89.1
Systems	$3.4	$107.5	$1.3	$112.2
Vehicles	$41.1	$78.5	$0.5	$120.1
Total	**$117.7**	**$538.6**	**$7.0**	**$663.3**

Source: Transit Economic Requirements Model.

assets totaled $538.6 billion, more than 80 percent of all transit assets. Nonrail assets were estimated at $117.7 billion. Joint assets totaled $7.0 billion; they consist of assets that serve more than one mode within a single agency and can include administrative facilities, intermodal transfer centers, agency communications systems (e.g., telephone, radios, and computer networks), and vehicles used by agency management (e.g., vans and automobiles).

Bus Vehicles (Urban Areas)

Bus vehicle age and condition information is reported according to vehicle type for 2000 to 2008 in *Exhibit 3-24.* The average condition rating for all bus types (calculated as the weighted average of bus asset conditions, weighted by asset replacement value) is near the bottom of the adequate range where it has been without appreciable change for the last decade. Average age is up slightly in all categories (except vans) as is

Exhibit 3-24

Urban Transit Bus Fleet Count, Age, and Condition, 2000–2008

Bus Fleet Component	2000	2002	2004	2006	2008
Articulated Buses					
Fleet Count	2,002	2,799	3,074	3,445	4,302
Average Age (Years)	6.6	7.2	5.0	5.3	6.3
Average Condition Rating	3.52	3.25	3.50	3.51	3.30
Below Condition 2.50 (Percent)	24.9%	16.6%	5.0%	2.1%	2.6%
Full-Size Buses					
Fleet Count	46,380	46,573	46,139	46,714	51,083
Average Age (Years)	8.1	7.5	7.2	7.4	7.9
Average Condition Rating	3.16	3.19	3.19	3.21	3.10
Below Condition 2.50 (Percent)	14.5%	13.1%	12.3%	11.3%	15.2%
Mid-Size Buses					
Fleet Count	7,203	7,269	7,114	6,844	7,009
Average Age (Years)	5.5	8.4	8.1	8.2	8.3
Average Condition Rating	3.44	3.11	3.13	3.08	3.06
Below Condition 2.50 (Percent)	8.3%	14.1%	13.2%	14.2%	12.4%
Small Buses					
Fleet Count	8,646	14,857	15,972	16,156	19,366
Average Age (Years)	4.2	4.5	4.6	5.1	5.1
Average Condition Rating	3.60	3.39	3.49	3.37	3.38
Below Condition 2.50 (Percent)	2.2%	8.8%	10.1%	10.3%	11.6%
Vans					
Fleet Count	14,583	17,147	18,713	19,515	26,823
Average Age (Years)	3.2	3.2	3.3	3.0	3.2
Average Condition Rating	3.84	3.74	3.75	3.77	3.76
Below Condition 2.50 (Percent)	0.2%	7.2%	6.7%	8.4%	8.0%
Total Bus					
Total Fleet Count	**78,814**	**88,645**	**91,012**	**92,674**	**108,583**
Weighted Average Age (Years)	6.5	6.2	6.0	6.0	6.2
Weighted Average Condition Rating	3.28	3.24	3.26	3.26	3.18
Below Condition 2.50 (Percent)	10.2%	11.8%	10.6%	10.4%	12.1%

Sources: Transit Economic Requirements Model and National Transit Database.

the percentage of vehicles below the state of good repair replacement threshold. For an asset with a 14-year life expectancy, like a full-size transit bus, structured asset management practices would typically indicate replacement of about 7 percent of fleet every year. About twice that many full-sized buses need replacement, with the result that the industry is slightly behind in keeping up with replacement needs.

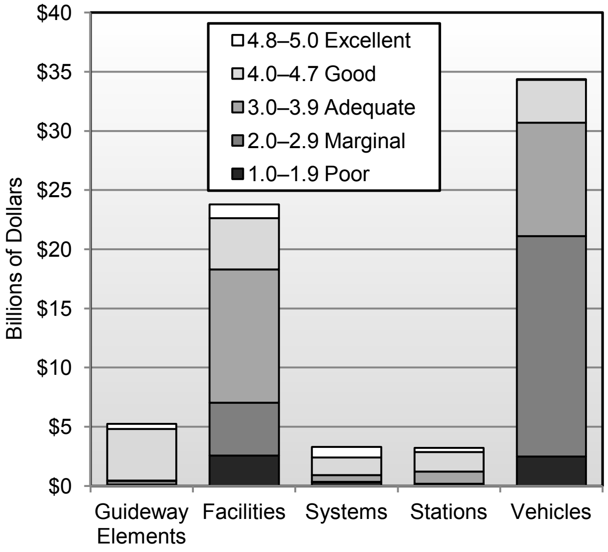
The number of vehicles reported is up 17 percent over the past 2 years—more growth than has been seen at any time in the last decade. This is particularly evident with articulated buses, whose numbers have grown by 25 percent. Discontinuities in the data for full-sized and mid-sized buses between 2000 and 2002 were caused by changes in the classification system that moved many older buses to the mid-sized category.

Other Bus Assets (Urban Areas)

The more comprehensive capital asset data described above allow us to report a more complete picture of the overall condition of bus-related assets. *Exhibit 3-25* shows TERM estimates of current conditions for the major categories of bus assets. Vehicles constitute half of all bus assets and maintenance facilities make up another third. Thirty percent of bus maintenance facilities are rated below condition 3.0. This finding stands in sharp contrast to the statistics for other types of U.S. bus transit assets, which show much lower percentages, and implies a major shortfall in reinvestment in such facilities. This is consistent with the common agency practice of prioritizing investments in "customer-facing" assets, such as vehicles, over those that customers never see, such as maintenance facilities.

Exhibit 3-25

Distribution of Estimated Asset Conditions by Asset Type for Bus



Source: Transit Economic Requirements Model.

Rail Vehicles

The NTD collects annual data on all rail vehicles; this data is shown in *Exhibit 3-26* broken down by the major categories of rail vehicle. With life expectancies in excess of 25 years, structured asset management practices would typically indicate replacement of about 4 percent of these vehicles annually, which is the amount currently seen in need of replacement (condition below 2.5). Even so, with these vehicles costing about $1 million each, and with a fleet of 23,463 vehicles, annual replacement costs should total about $1 billion. Because average conditions and ages have been quite stable over the last 5 years, the most significant aspect of this data is the recent growth in the vehicle fleet. The number of rail vehicles increased by 16 percent, in total and for each of the individual modes, between 2006 and 2008. This is the largest 2-year increase that has occurred over the past decade by far.

Exhibit 3-26

Urban Transit Rail Fleet Count, Age, and Average Estimated Condition Rating, 2000–2008

	2000	2002	2004	2006	2008
Commuter Rail Locomotives					
Fleet Count	576	709	710	740	991
Average Age (Years)	15.24	17.2	17.8	16.7	17.6
Average Condition Rating	4.51	3.72	3.72	3.98	3.89
Below Condition 2.50 (Percent)	5.7%	0.0%	0.0%	0.0%	0.0%
Commuter Rail Passenger Coaches					
Fleet Count	2,743	2,985	3,513	3,671	4,897
Average Age (Years)	17.49	19.2	17.7	16.8	17.7
Average Condition Rating	4.28	3.67	3.78	4.07	3.95
Below Condition 2.50 (Percent)	10.8%	0.0%	0.0%	0.0%	0.0%
Commuter Rail Self-Propelled Passenger Coaches					
Fleet Count	2,466	2,389	2,470	2,933	2,665
Average Age (Years)	25.24	27.1	23.6	14.7	17.9
Average Condition Rating	4.07	3.50	3.69	3.81	3.84
Below Condition 2.50 (Percent)	4.1%	0.0%	0.0%	0.0%	0.0%
Heavy Rail					
Fleet Count	10,028	11,093	11,046	11,075	12,759
Average Age (Years)	23.1	19.8	19.8	22.3	21.0
Average Condition Rating	3.21	3.39	3.35	3.28	3.34
Below Condition 2.50 (Percent)	4.8%	6.1%	5.6%	5.5%	6.1%
Light Rail					
Fleet Count	1,335	1,637	1,884	1,832	2,151
Average Age (Years)	15.8	17.85	16.5	14.6	17.1
Average Condition Rating	3.6	3.53	3.60	3.70	3.57
Below Condition 2.50 (Percent)	8.4%	11.8%	9.3%	6.4%	7.1%
Total Rail					
Total Fleet Count	**17,148**	**18,813**	**19,623**	**20,251**	**23,463**
Weighted Average Age (Years)	21.66	20.37	19.5	19.3	20.1
Weighted Average Condition Rating	3.53	3.47	3.51	3.55	3.47
Below Condition 2.50 (Percent)	6.0%	4.6%	4.1%	3.6%	4.0%

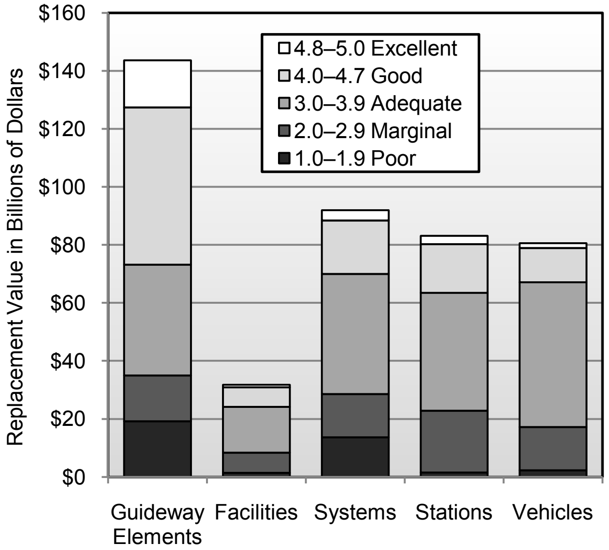
Sources: Transit Economic Requirements Model and National Transit Database.

Other Rail Assets

Non-vehicle transit rail assets can be divided into four general categories: guideway elements, facilities, systems, and stations. TERM estimates of the condition distribution for each of these categories as shown in *Exhibit 3-27*. The largest category by replacement value is guideway elements. These consist of tracks, ties, switches, ballasts, tunnels, and elevated structures. The replacement value of this category is $143.6 billion, of which $19.1 billion is rated below condition 2.0 (13 percent) and $15.8 billion is rated between condition 2.0 and 3.0. The next-largest category is systems, which consist of power, communication, and train control equipment. Assets in this category have a replacement value of $92.0 billion, of which $13.7 billion is rated below condition 2.0 (15 percent) and $18.9 billion is rated between condition 2.0 and 3.0. Stations have a replacement value of $83.0 billion with only $1.5 billion rated below condition 2.0 and $21.4 billion rated between condition 2.0 and 3.0. Facilities, mostly consisting of maintenance and administration buildings, have a replacement value of $31.8 billion with $1.4 billion rated below condition 2.0 and $6.9 billion rated between condition 2.0 and 3.0. The relatively large proportion of guideway and systems assets that are rated below condition 2.0, and the magnitude of the $38.2 billion investment required to replace them, represents a major challenge to the rail transit industry.

Exhibit 3-27

Distribution of Asset Physical Conditions by Asset Type for All Rail

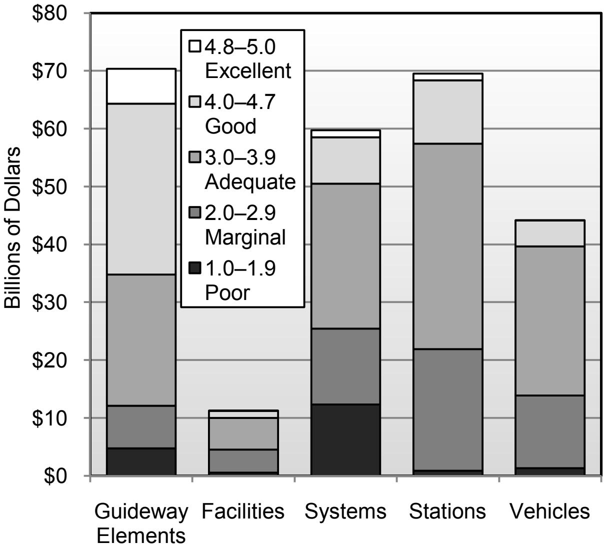


Source: Transit Economic Requirements Model.

Rail transit consists of heavy rail (urban dedicated guideway), light rail (operates in mixed traffic), and commuter rail (suburban passenger rail) modes. Almost half of rail transit vehicles are in heavy rail systems. Heavy rail represents $255 billion (59 percent) of the total transit rail replacement cost of $430 billion. Some of the Nation's oldest and largest transit systems are served by heavy rail (Boston, New York, Washington, San Francisco, Philadelphia, and Chicago). The distribution of asset conditions in U.S. heavy rail is shown in *Exhibit 3-28*. Most notable is the relatively larger proportion of the total replacement value that is in station and system assets and that 21 percent of system assets are rated below condition 2.0.

Exhibit 3-28

Distribution of Asset Physical Conditions by Asset Type for Heavy Rail



Source: Transit Economic Requirements Model.

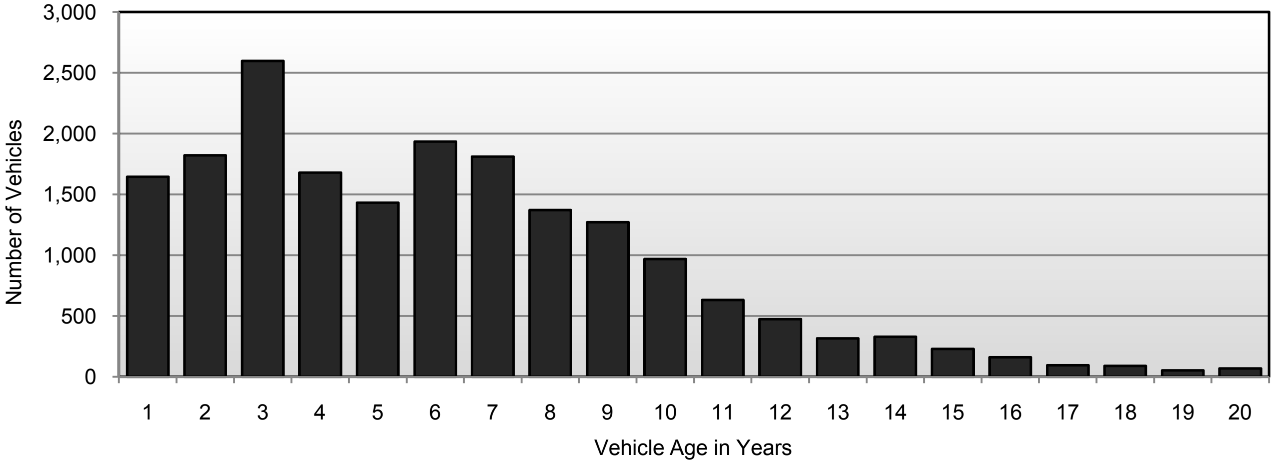
Rural Transit Vehicles and Facilities

Because rail transit does not serve rural areas, all rural transit vehicles are buses, vans, or other small passenger vehicles (see Chapter 2). Data on the number and age of rural vehicles and the number of maintenance facilities is now collected in the NTD, allowing FTA to report more accurately on rural transit conditions and on the 676 rural maintenance facilities that were reported. The age distribution of rural transit vehicles is summarized in *Exhibit 3-29*.

For 2008, data reported to the NTD indicated that 9.2 percent of rural buses and 19.2 percent of rural vans were past their life expectancy (14 years for buses and 8 years for vans). The rural transit fleet had an average age of 6.2 years in 2008; buses, with an average age of 6.3 years, were older than vans, which had an average age of 5.4 years. Half of the overall fleet was more than 5 years old.

Exhibit 3-29

Age of Rural Vehicles



Source: National Transit Database.

Chapter 4

Operational Performance

Highway Operational Performance

Virtually all road users have experienced traffic congestion, some more than others. They also have an intuitive sense of what causes congestion. Americans know it makes a difference in their lives because it makes them wait in their cars, losing the opportunity to do other things. Congestion also can influence where people choose to live and work, often limiting the range of feasible choices to households and workers.

The business community understands congestion as a problem that can increase costs. Retailers, manufacturers, and shippers have to adjust their operating practices to compensate for time wasted in traffic. Because of congestion, transporting goods and services to their destinations takes longer.

Allowing for unexpected delays makes congestion even more problematic. Individuals must allow more time to arrive at important appointments. When calculating the time to travel to a given location, they must add a "buffer factor." Often, this means that they arrive early and, once again, must wait. Unreliable travel times can also affect businesses by forcing them to carry larger inventories to guard against delays in deliveries.

This section describes the dimensions and magnitude of the congestion problem in U.S. cities, which has grown over time in both its depth and reach across the country. Also included is a discussion of the impact that congestion has on freight movement; additional discussion of highway freight transportation is provided in Chapter 2. This section concludes by presenting several strategies and approaches that can be used to reduce congestion on our Nation's highways. A subsequent section within this chapter describes issues pertaining to transit operational performance.

Causes of Congestion

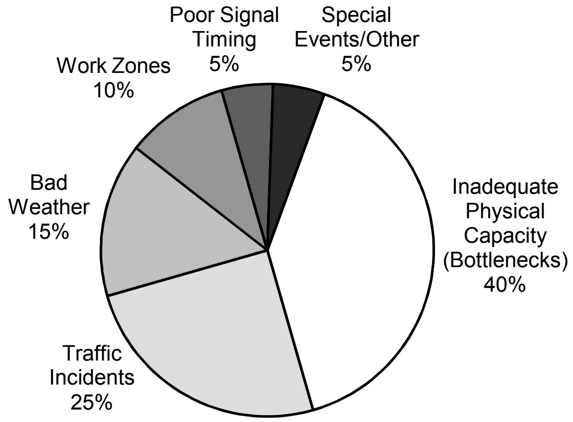
Congestion generally reflects a fundamental imbalance of supply and demand. During hours of peak usage of the transportation facilities most desirable to motorists, the supply of roadway capacity is insufficient to meet the demand for those facilities. Economists have long understood that such an imbalance stems from inefficient pricing, where the true costs of usage are not reflected in prices paid by the users. For example, travelers are not generally charged for the impact their trip will have on others using the same facility (e.g., increased levels of congestion) or on other members of society (e.g., increased air pollution). In fact, in this country, access to highway travel, for the most part, is rationed by traveler delay.

The imbalance of supply and demand leading to congestion is impacted by the absolute volume of traffic (e.g., demand) on a given facility relative to its physical capacity (e.g., supply). Looking at traffic congestion from a demand perspective means considering how many vehicles compete for space on a particular facility at a given time. The demand for a facility is a function of individual decisions as to when, where, how, and even whether highway travel will take place.

On the supply side, congestion is primarily a function of the physical characteristics of the facility and events that limit the availability of this capacity. Congestion driven by supply-side considerations is characterized as either "recurring" or "nonrecurring." This distinction is useful in helping transportation professionals devise strategies that will either mitigate or reduce congestion. Recurring congestion happens in roughly the same time and place on the same days of the week. It results when physical capacity is simply not adequate to accommodate demand during peak periods. On the other hand, nonrecurring congestion is caused by events such as work zone activity, traffic incidents, and bad weather. Obviously, when these nonrecurring events occur on an already congested facility, the impacts are magnified. *Exhibit 4-1* shows the estimated percentages of on the road congestion caused by different factors.

Exhibit 4-1

Sources of Congestion



Source: Federal Highway Administration.

Congestion Measurement

There is no universally accepted definition or measurement of exactly what constitutes a congestion "problem." The public's perception seems to be that congestion is getting worse, and it is by many measures. However, the perception of what constitutes a congestion problem varies from place to place. Traffic conditions that may be considered a congestion problem in a city of 300,000 may be perceived differently in a city of 3 million, based on differing congestion histories and driver expectations. These differences of opinion make it difficult to arrive at a consensus of what congestion means, the effect it has on the public, its costs, how to measure it, and how best to correct or reduce it. Because of this uncertainty, transportation professionals examine congestion from several perspectives.

Three key aspects of congestion are severity, extent, and duration. The **severity** of congestion refers to the magnitude of the problem or the degree of congestion experienced by drivers. The **extent** of congestion is defined by the geographic area or number of people affected. The **duration** of congestion is the length of time that the roadway is congested, often referred to as the "peak period" of traffic flow.

Texas Transportation Institute Performance Measures

The Texas Transportation Institute (TTI) has studied congestion trends since 1982. Its study results are published annually in the Urban Mobility Report, which is cited nationwide for its list of congestion delays and potential solutions in the Nation's busiest cities. The Federal Highway Administration (FHWA) coordinates with TTI to establish and refine the performance metrics of congestion that provide a better indication of congestion's level of impact on the Nation's communities. Since 1982, the data source for the calculations in the Urban Mobility Report has been the FHWA Highway Performance Monitoring System (HPMS).

Alternate Congestion Measurement Approach

The CEOs for Cities report, "Driven Apart," suggests an alternative approach to the Texas Transportation Institute's (TTI) approach to measuring congestion. Their alternative is built on the basic premise that it would be better to have trip-based measures rather than facility-based measures (as TTI's are), especially for supporting Livable Communities. The full "Driven Apart" report may be found at http://www.ceosforcities.org/driven-apart.

This section draws upon data computed by TTI for the FHWA using a methodology consistent with the 2009 TTI Urban Mobility report. This analysis combines information on 458 urban communities with a total population of 213 million or slightly more than 70.7 percent of the Nation's population in 2007.

TTI divides the communities in the Urban Mobility report into four groups based on population size. In the 2009 report, 377 urbanized areas had populations of less than 500,000 and were classified as "Small," 35 areas had populations between 500,000 and 999,999 and were classified as "Medium," 29 areas with populations between 1 million and 3 million were classified as "Large," and 17 areas had populations greater than 3 million and were classified as "Very Large." These shorthand terms have been adopted in this section for clarity. However, it should be noted that they are not consistent with the population break of 200,000 frequently used in other FHWA applications to distinguish "Small Urbanized Areas" from "Large Urbanized Areas." (Transportation Management Areas with a population greater than 200,000 are subject to additional transportation planning requirements beyond those of smaller urbanized areas.)

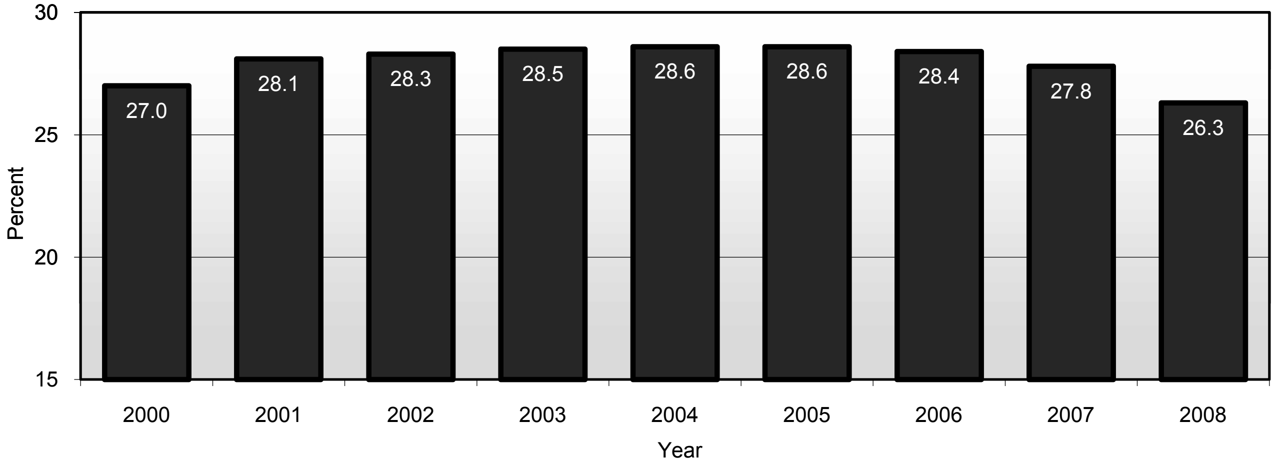
As urban areas increase in size, they will migrate between the four categories used by TTI to define population groups. This adjustment due to population change can have a significant impact on the results for a particular group. TTI recalculates the measures for each group for each year of data.

Average Daily Percentage of Vehicle Miles Traveled Under Congested Conditions

The average daily percent of vehicles miles traveled (VMT) under congested conditions is defined as the percentage of daily traffic on freeways and principal arterials in urbanized areas moving at less than free-flow speeds. Based on the TTI calculations, *Exhibit 4-2* shows that this measure of extent and duration of congestion increased from 27.0 percent in 2000 to 28.6 percent in 2004, before dropping to 26.3 percent in 2008. As noted in Chapter 2, total VMT declined between 2006 and 2008, making it easier for existing highway facilities to accommodate the lesser demand.

Exhibit 4-2

Average Daily Percentage of VMT Under Congested Conditions for All Urbanized Areas, 2000–2008



Source: Texas Transportation Institute.

Exhibit 4-3 shows the trend of VMT under congested conditions broken down by population area size. From 2000 to 2008, the value for this measure of congestion increased for both the Small (population less than 500,000) and Medium (population 500,000 to 999,999) categories, suggesting an overall decline in operational performance in these types of urbanized areas. Over the same period, this measure of congestion decreased in Large (population 1 million to 3 million) and Very Large (population more than 3 million), suggesting some stabilization of operational performance in these urbanized areas. The percentage of VMT under congested conditions decreased from 2006 to 2008 for each of these urbanized area population categories.

Exhibit 4-3

Average Daily Percentage of VMT Under Congested Conditions, by Urbanized Area Size, 2000–2008

Urbanized Area Population	2000	2002	2004	2006	2008
Small (less than 500,000)	13.4%	14.4%	15.8%	15.9%	13.7%
Medium (500,000 to 999,999)	20.2%	22.6%	22.4%	22.4%	21.3%
Large (1 million to 3 million)	27.9%	28.7%	29.2%	29.6%	27.7%
Very Large (more than 3 million)	35.9%	37.2%	38.0%	37.9%	35.4%
All Urbanized Areas	**27.0%**	**28.3%**	**28.6%**	**28.4%**	**26.3%**

Source: Texas Transportation Institute.

Travel Time Index

The Travel Time Index measures the additional time required to make a trip during the congested peak travel period rather than during the off-peak period in non-congested conditions, and indicates the severity and duration of congestion. The additional time required is a result of increased traffic volumes on the roadway and the additional delay caused by crashes, poor weather, special events, or other nonrecurring incidents.

Exhibit 4-4 shows changes in the national average of the Travel Time Index for all urbanized area categories evaluated by TTI. The value of 1.24 in 2008 indicates that a trip during the peak period will require 24 percent more travel time than if the same trip were made during off-peak non-congested periods. For example, a trip of 60 minutes during the off-peak time would require 74.4 minutes during the peak period when roadway usage is higher. The Travel Time Index for the Small and Medium categories in 2008 was the same as in 2000, while that for the Large and Very Large categories declined slightly over this period.

Exhibit 4-4

Travel Time Index by Urbanized Area Size, 2000–2008

Urbanized Area Population	2000	2002	2004	2006	2008
Small (less than 500,000)	1.11	1.17	1.12	1.13	1.11
Medium (500,000 to 999,999)	1.16	1.17	1.18	1.18	1.16
Large (1 million to 3 million)	1.24	1.25	1.26	1.25	1.23
Very Large (more than 3 million)	1.36	1.39	1.39	1.37	1.35
All Urbanized Areas	**1.25**	**1.27**	**1.27**	**1.26**	**1.24**

Source: Texas Transportation Institute.

Average Length of Congested Conditions

The average length of congested conditions, shown in *Exhibit 4-5,* is a measure of the duration of congestion. This is the number of hours during a 24-hour period when traffic is operating under congested conditions, combining what is commonly thought of as the "morning rush hours" and the "evening rush hours."

Exhibit 4-5

Average Length of Congested Conditions, Urbanized Areas, 2000–2008

	Hours				
Urbanized Area Population	**2000**	**2002**	**2004**	**2006**	**2008**
Small (less than 500,000)	4.2	4.3	4.6	4.5	4.2
Medium (500,000 to 999,999)	5.5	5.6	5.7	5.7	5.4
Large (1 million to 3 million)	6.5	6.6	6.6	6.6	6.4
Very Large (more than 3 million)	7.5	7.6	7.7	7.6	7.5
All Urbanized Areas	**6.2**	**6.4**	**6.4**	**6.4**	**6.2**

Source: Texas Transportation Institute.

The average urbanized area experienced 6.2 hours of congestion per 24-hour period in 2008, approximately the same as in 2000. Over this period, Medium and Large urbanized areas experienced slight decreases in their average daily length of congestion.

In the past, recurring congestion tended to occur only in one direction—toward downtown in the morning and away from it in the evening. Today, two-directional congestion is common, particularly on routes serving several major activity centers dispersed in suburban areas around the most congested metropolitan areas.

Cost of Congestion From TTI Urban Mobility Report

Congestion has an adverse impact on the American economy, which values speed, reliability, and efficiency. The problem is of particular concern to firms involved in logistics and distribution. As just-in-time delivery increases, firms need an integrated transportation network that allows for the reliable, predictable shipment of goods. If travel time increases or reliability decreases, businesses will need to increase average inventory levels to compensate, which will increase storage costs. Congestion, then, imposes a real economic cost for businesses and these costs will continue to impact consumer prices.

As shown in *Exhibit 4-6*, the TTI 2009 Urban Mobility Report estimates that drivers experienced 4.2 billion hours of delay and wasted approximately 2.8 billion gallons of fuel during delays in 2007. The total congestion cost for these areas, including wasted fuel and time, was estimated to be approximately $87.2 billion. Each of these values is over four times higher than the comparable estimates for 1982, reflecting a significant increase in congestion over this 25-year period.

Exhibit 4-6

National Congestion Measures, 1982–2007

Year	Total Delay (Billions of Hours)	Total Fuel Wasted (Billions of Gallons)	Total Cost (Billions of 2007 Dollars)
1982	0.79	0.50	$16.7
1983	0.87	0.54	$18.0
1984	0.95	0.60	$19.7
1985	1.10	0.70	$22.6
1986	1.27	0.81	$25.2
1987	1.41	0.92	$27.9
1988	1.62	1.06	$32.0
1989	1.78	1.17	$35.3
1990	1.88	1.25	$37.3
1991	1.90	1.29	$38.1
1992	2.05	1.37	$40.6
1993	2.17	1.43	$42.6
1994	2.26	1.49	$44.3
1995	2.42	1.61	$47.8
1996	2.58	1.72	$51.0
1997	2.73	1.82	$53.6
1998	2.83	1.91	$55.0
1999	3.04	2.05	$58.9
2000	3.18	2.14	$63.1
2001	3.33	2.25	$65.7
2002	3.52	2.38	$69.3
2003	3.73	2.53	$73.3
2004	3.97	2.69	$79.4
2005	4.18	2.82	$85.6
2006	4.20	2.85	$87.1
2007	4.16	2.81	$87.2

Source: Texas Transportation Institute 2009 Urban Mobility Report.

Effect of Congestion on Freight Travel

FHWA's Office of Freight Management and Operations is leading a freight performance measurement (FPM) research initiative that focuses on measuring average operating speeds and travel time reliability on freight significant corridors and on crossing time and crossing time reliability at major U.S. international land border crossings. Measures are based primarily on vehicle location and time data from communication technology used by the freight industry. Through this initiative, FHWA directly measures operating speeds and reliability on major truck routes by tracking more than 500,000 trucks. Average truck speeds drop below 55 miles per hour near major urban areas, border crossings and gateways, and in mountainous terrain.

The data produced through the FPM initiative enables FHWA to analyze freight system performance (truck speed and travel time reliability) by location, date, and time of day. As an example, *Exhibit 4-7* demonstrates how the data can be used to example freight performance in peak versus nonpeak period hours, drawing upon information gathered from January through March of 2009. As would be expected, average speeds in the peak period between 6 a.m. and 9 a.m. and between 4 p.m. and 7 p.m. are lower than those recorded in the nonpeak period between 10 a.m. and 2 p.m. on all routes.

Freight Performance Measurement

FHWA has been collecting and analyzing data for freight significant Interstate corridors since 2004. FHWA plans to continue to collect travel time information on 25 interstate corridors and 15 U.S./Canada land border crossings at least through September 2011. Key objectives of the current FPM research program are to expand on the existing data sources, further develop and refine methods for analyzing data, derive national measures of congestion and reliability, analyze freight bottlenecks and intermodal connectors and develop data products and tools that will assist DOT, FHWA, and State and local transportation agencies in addressing surface transportation congestion. A Web tool for disseminating FPM data on the 25 study corridors, www.freightperformance.org, provides an example of the types of tools FHWA will develop. The goal is to evolve the research into a credible freight data source that can be used to continuously measure freight performance and inform the development of strategies and tactics for managing and relieving freight congestion.

Exhibit 4-7

Average Truck Speeds on Selected Interstate Highways, 2009

		Average Speed*				Average Speed	
Interstate Route	**Average Operating Speed**	**Peak Period**	**Nonpeak Period**	**Interstate Route**	**Average Operating Speed**	**Peak Period**	**Nonpeak Period**
5	52.8	52.1	53.1	**70**	56.8	56.5	57.1
10	57.4	56.7	57.6	**75**	56.7	56.1	57.0
15	56.7	56.2	56.9	**76**	54.5	54.5	54.8
20	59.2	58.8	59.3	**77**	54.7	54.3	55.1
24	57.2	56.6	57.4	**80**	57.7	57.4	57.9
25	59.0	58.5	59.3	**81**	56.6	56.6	56.8
26	53.7	53.3	54.6	**84**	54.2	53.3	54.9
35	56.8	56.0	57.0	**85**	57.3	56.5	57.4
40	58.6	58.4	58.8	**87**	54.1	53.8	54.5
45	54.9	53.9	55.4	**90**	57.1	56.8	57.4
55	57.0	56.8	57.2	**91**	53.4	52.9	54.2
65	57.9	57.3	58.2	**94**	56.7	56.2	56.8
				95	56.2	55.2	56.3

Both urban and rural areas were combined to determine the speeds shown. This procedure reduces the impact of urban congestion on average speeds. Average speeds are available separated by urban and rural areas on request from the U.S. Department of Transportation, Federal Highway Administration, Office of Freight Management and Operations.

Source: U.S. Department of Transportation, Federal Highway Administration, Office of Freight Management and Operations, Performance Measurement Program, 2009.

Emerging Operational Performance Measures

Substantial research supports the use of delay as a measure of congestion. Delay is certainly important; it exacts a substantial cost from the traveler and, consequently, from the consumer. However, it does not tell the complete story. Moreover, there currently is no direct measure of delay that can be collected both consistently and inexpensively.

Reliability is another important characteristic of any transportation system, one that industry in particular requires for efficient production. If a given trip requires 1 hour on one day and 1.5 hours on another day, an industry that is increasingly reliant on just-in-time delivery suffers. To compensate for variable trip times required to deliver products, an industry may be required to carry greater inventory than would otherwise be necessary, thereby incurring higher costs. Travel time reliability is a measure of congestion easily understood by a wide variety of audiences, and is one of the more direct measures of the effects of congestion on the highway user. However, additional research is needed to determine what measures should be used to describe congestion and what data will be required to supply these measures.

System Reliability

Travel time reliability measures are relatively new, but a few have proven useful, especially at the local level. Such measures typically compare high-delay days with average-delay days. The simplest method identifies days that exceed the 90th or 95th percentile in terms of travel times and estimates how bad delay will be on specific routes during the worst one or two travel days each month.

The Buffer Index measures the percentage of extra time travelers must add to their average peak-hour travel time to allow for congestion delays and arrive at a location on time about 95 percent of the time. The Planning Time Index represents the total travel time that is necessary to ensure on-time arrival, including both the average travel time and the additional travel time included in the Buffer Index. Generally, the Buffer Index goes up during peak periods, when congestion occurs, indicating a reliability problem.

The Planning Time Index is especially useful because it uses a numeric scale which can be directly compared to the numeric scale of the Travel Time Index presented earlier in this chapter. While data are not currently available to support these measures at the national level, data in the 2009 TTI Urban Mobility Report were collected on planning time indicators for 19 metropolitan regions. The comparison of the Travel Time Index (in average conditions) and the Planning Time Index (for an important trip) for these 19 metropolitan areas suggest that while travelers can expect a peak-period trip to take 1.14 to 1.48 times longer than a nonpeak-period trip on average; for important trips, they should plan on needing 1.43 to 2.07 times longer in order to arrive on time approximately 95 percent of the time.

The importance of reliability is underscored by a November 2004 study, *Temporary Losses of Highway Capacity and Impacts on Performance: Phase 2*, produced for the FHWA by the Oak Ridge National Laboratory. Temporary capacity losses due to work zones, crashes, breakdowns, adverse weather, suboptimal signal timing, toll collection facilities, and railroad crossings caused more than 3.5 billion vehicle-hours of delay on U.S. freeways and principal arterials in 1999. For journeys on regularly congested highways during peak commuting periods, temporary capacity losses added 6 hours of delay for every 1,000 miles of travel. Americans suffer 2.5 hours of delay per 1,000 miles of travel from temporary capacity loss for journeys on roads that do not experience recurring congestion.

FHWA Urban Congestion Report

The Urban Congestion Report (UCR) is produced quarterly and characterizes emerging traffic congestion and reliability trends at the national and city level. The reports utilize archived traffic operations data gathered from State DOTs and a private traffic information company. The reports are currently using data from 23 urban areas in the Nation. The production of these reports is a cooperative effort between the Texas Transportation Institute and FHWA. The UCR data are also being used to report Travel Time Reliability in metropolitan areas for the FHWA Strategic Plan, which is available at http://www.fhwa.dot.gov/policy/fhplan.html#measurement.

The UCR includes only those roadways that are instrumented with traffic sensors for the purposes of real-time traffic management and/or traveler information. In many cities, this typically includes the most congested parts of the freeway system. Currently, congestion information on arterial streets is not included.

The congestion information presented in these reports may not be representative of the entire roadway system in any particular city. Construction may affect the roadways that are included in this report. The congestion and reliability trends are calculated by comparing the most recent 3 months this year to the same 3 months last year. Only instrumented roadways that provided data in both years are included in the UCR. Further information can be found at http://ops.fhwa.dot.gov/perf_measurement/ucr/.

Congestion Reduction Strategies

In considering solutions to the congestion problem, it might be useful to think of the transportation system as a limited resource, for which there is an imbalance between supply and demand. Society has several options to address this situation: make more of it (add new capacity), use it more productively (operate the system at peak condition and performance), provide alternatives to highway travel, and/or create an efficient transportation market (use congestion pricing to balance supply and demand).

Making More of It: Strategic Addition of Capacity

The traditional approach to dealing with congestion is to expand the capacity of the road network. At the beginning of the Interstate era, Federal funding provided incentives to build new highways that offered significant improvements in speed, safety, and traffic-carrying capabilities. As traffic levels increased over time, many of these roads have been widened or rebuilt with higher capacity.

The demand for new highway capacity not only is increasing, but also is dynamic in nature and location. For example, locations that were rural communities in the early 1960s are now major metropolitan areas. Increases and shifts in international trade have created new trade routes and have expanded freight access requirements at seaports and major cargo hubs. The investment analyses of Part II of this report include significant discussion of the potential impact of alternative levels of system expansion on operational performance.

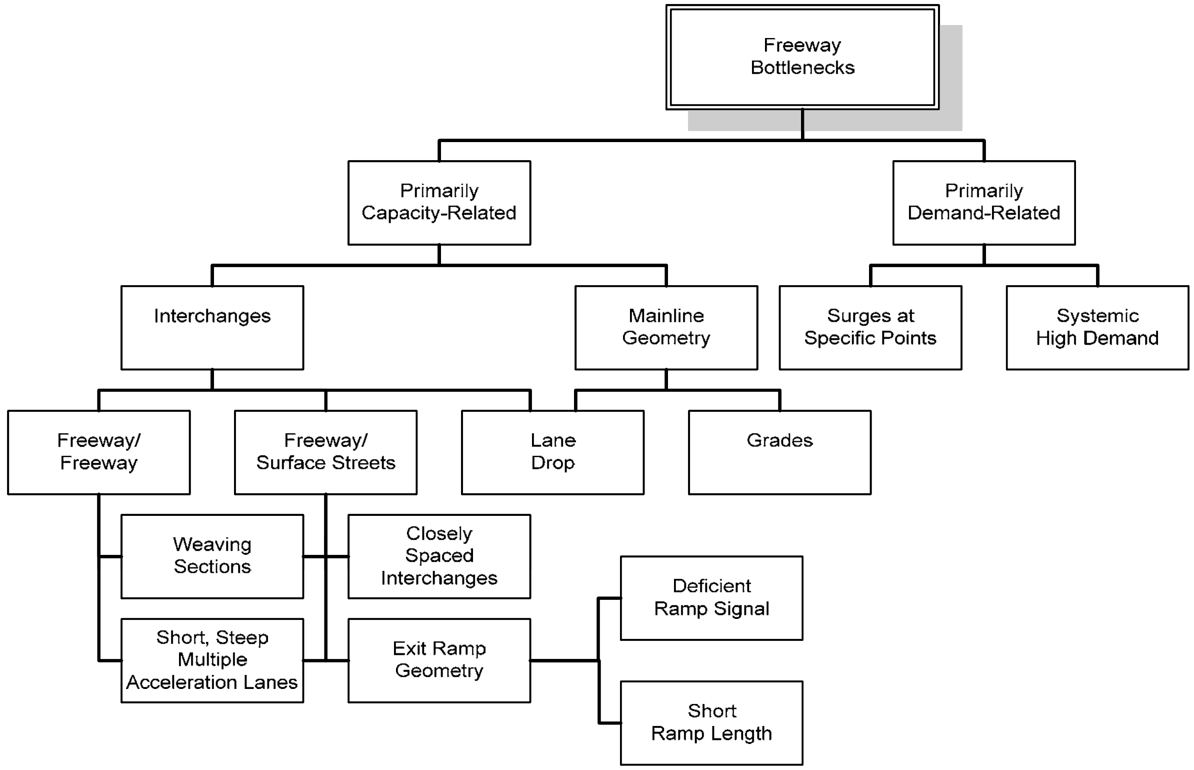
Many capacity expansion projects are aimed at relieving bottlenecks. Traffic bottlenecks are specific roadway locations that routinely and predictably experience congestion because traffic volumes exceed capacity during periods of heavy demand. Bottlenecks are characterized by queues upstream and freely flowing traffic downstream. They may be compared to a storm pipe that can carry only so much water—during floods the excess water just backs up behind it, much the same as traffic at bottleneck locations. However, the situation is even worse for traffic. Once the traffic flow breaks down to stop-and-go conditions, capacity is actually reduced—fewer cars can get through the bottleneck because of the extra turbulence.

The severity of congestion at a bottleneck is related to its physical design. Some facilities were originally constructed many years ago using designs that are now considered to be antiquated. Others that have been built to extremely high design specifications are simply overwhelmed by high traffic volumes. Whatever the root cause, operational conflicts can occur at lane drops (where one or more traffic lanes are lost), weaving areas (where traffic must merge across one or more lanes to access entry or exit ramps), freeway on-ramps, freeway-to-freeway interchanges, and abrupt changes in highway alignment (such as sharp curves and hills).

Exhibit 4-8 summarizes various root causes of freeway bottlenecks by category. Factors contributing to bottlenecks can be classified as being primarily demand-related or primarily capacity-related. Demand-

Exhibit 4-8

Fault Tree for Freeway Bottlenecks



Source: Federal Highway Administration.

related causes include both localized surges in traffic volumes at specific points and systemic high demand across an entire facility, corridor, or region. Capacity-related causes include items associated with mainline roadway geometry (grades, lane drops) and interchange design (lane drops, weaving sections, acceleration lanes, interchange spacing, ramp geometry, ramp signals, and ramp lengths). Multiple factors may contribute to causing a bottleneck at a particular location.

Bottlenecks have been the focus of transportation improvements—and of travelers' concerns—for many years. On much of the urban highway system, there are specific points that are notorious for causing congestion on a daily basis. These locations—which can be a single interchange (usually freeway-to-freeway), a series of closely spaced interchanges, or lane drops—are focal points for congestion in corridors. Major bottlenecks tend to dominate congestion in corridors where they exist.

Some bottlenecks, particularly those involving large freeway-to-freeway interchanges, can be addressed through major construction projects. Although costly, such projects can provide congestion relief to motorists. For most other bottlenecks, however, applying operational and low-cost infrastructure solutions also may relieve congestion at much lower cost. Such strategies may include the following:

- Using a short section of shoulder as an additional travel lane during peak periods
- Restriping merge or diverge areas to better match demand
- Reducing lane widths to add a travel and/or auxiliary lane through restriping
- Modifying weaving areas (e.g., adding collector/distributor or through lanes)
- Metering or closing entrance ramps
- Adjusting speed limits when congestion thresholds are exceeded and congestion and queue formation is impending (known as speed harmonization)
- Encouraging "zippering," the merging by alternating vehicles from two different lanes, to promote fair and smooth merges
- Designating reversible lanes to accommodate the prevailing direction of traffic flow during morning and evening peaks.

Using It More Productively: System Management and Operations

Capacity constraints arise when physical capacity is insufficient and when capacity is temporarily reduced due to traffic incidents, work zones, inclement weather, or special events. As traffic volumes have grown over time relative to physical capacity, the system has become less able to absorb "surprise"—or nonrecurring—events. In the realm of managing the highway system, the margin for error is very small and continues to decline. Operational strategies can make a major contribution to effective performance of the highway system at a much lower cost than capacity expansion because they enable quicker recovery when disruptions occur and help maximize system performance in the first place.

Such strategies include managing temporary disruptions in a way that will return the system to full capacity quickly; ensuring more effective day-to-day operations through coordinated and up-to-date traffic signal timing and operational improvements to relieve bottlenecks; and providing real-time information about the system so that travelers can decide immediately when, where, and how to travel and transportation agencies can adjust immediately to improve system operations.

Q&A

How do management and operations strategies help achieve livability and climate change goals?

As the transportation community brings livability and climate change issues into better focus, the relationship of these with management and operations strategies is becoming more apparent. Although these strategies clearly have a direct impact on reducing congestion, there currently is somewhat less of a general understanding of how they can contribute to more livable communities and reductions in greenhouse gas (GHG) emissions.

With regard to livability, management and operations strategies can help reduce congestion and delays in communities through better operation of traffic signals and more timely and effective response to traffic incidents and adverse weather conditions. Improved traffic control can enhance the safety of pedestrians and bicyclists, particularly at intersections. Traveler information strategies can provide the means for residents to make more informed mode and travel choices. And implementation of congestion pricing strategies can both reduce congestion and fund and encourage the use of alternative transportation modes.

With regard to reducing GHG emissions, there are many management and operations strategies that reduce harmful emissions. These include freeway management (e.g., ramp metering), traffic incident management, road weather management, arterial management (e.g., more efficient traffic signal timing), real-time traveler information, and implementation of pricing strategies to reduce congestion. Though research on GHG reduction opportunities from management and operations strategies is limited, evaluation of individual strategies suggest the potential of a 10 percent to 20 percent reduction in GHG emissions in congested metropolitan areas if a concerted effort to implement these strategies is pursued.

Livability and Sustainability are discussed in more detail in Part III of this report.

Real-Time Traveler Information

Real-time traveler information enables travelers to decide how they will use (or not use) the transportation system, influencing the choices that people make about how, when, where, whether, and which way they travel to their destinations. Real-time information enables motorists to manage the uncertainty of travel during congested conditions by leaving earlier or later, taking alternative routes, or even postponing discretionary trips. Transportation agencies also can use the information to better manage and improve the system. Traveler information on traffic conditions, transit service, parking availability, and weather conditions is being delivered through various means, including Web sites, dynamic message signs, email and text message alerts, and highway advisory radio.

The development and establishment of 511 Traveler Information Systems to provide access to highway and travel conditions information in all parts of the Nation have been identified as key elements in implementing a successful national operations strategy. Such systems use the 511 telephone number dedicated by the Federal Communications Commission for relaying information to travelers. At the end of 2009, there were 41 active systems in 36 States, providing access to nearly 200 million people, or about 66 percent of the U.S. population.

Traffic Incident Management

As indicated in *Exhibit 4-1*, traffic incidents cause approximately 25 percent of all congestion; each minute of lane blockage creates 4 minutes of congestion after the incident is cleared. Traffic incident management is a planned and coordinated process to detect, respond to, and remove traffic incidents and restore capacity as safely and quickly as possible. Effectively managing traffic incidents requires cooperation among organizations that often have conflicting on-scene priorities and operating cultures. For example, transportation agencies must interact with a variety of public and private sector partners, including law enforcement, fire and rescue, emergency medical services, public safety communications, emergency management, towing and recovery, hazardous materials contractors, traffic information media, and traffic

Real-Time System Management Information Program

Section 1201 of SAFETEA-LU requires the U.S. DOT to "establish a real-time system management information program to provide, in all States, the capability to monitor, in real time, the traffic and travel conditions of the major highways of the United States and to share that information to improve the security of the surface transportation system, to address congestion problems, to support improved response to weather events and surface transportation incidents, and to facilitate national and regional highway traveler information."

Through the Section 1201 program, agencies will be able to anticipate changes and events and take remedial actions, and provide road users with information to make better travel-related decisions. The specific goal of the program is to establish in all States the capability to share data on system performance nationwide. Significant opportunities exist for private sector involvement or partnering in implementation of this program, including information gathering, data processing, and information dissemination. Toward this end, the FHWA published an interim guidance on data-sharing specifications and data exchange formats in 2007.

In May 2006, FHWA issued a notice in the *Federal Register* requesting comments on the proposed program goals, definitions for various parameters, the current status of related activities in the States, and implementation issues to guide development of the Real-Time System Management Information Program. In January 2009, FHWA published a notice of proposed rulemaking in the *Federal Register* to implement the Real-Time System Management Information Program. Based on comments received from State DOTs and other representatives of the private sector and national associations, FHWA is developing a final rule and anticipates issuing it in 2010.

management centers (TMCs). Promoting more aggressive and widespread traffic incident management is an important strategy to lessen the effects of nonrecurring congestion as well as provide a safer driving environment.

Real-time information is particularly critical for effective incident management. Information is necessary for locating and clearing crashes, stalled vehicles, spilled loads, and other highway debris. Efficient and rapid response, effective management of resources at the incident, and area-wide traffic control all depend on the rapid exchange of accurate and clear information among the responding parties. This exchange requires communications standards and institutional coordination among all the parties involved in responding to and clearing traffic incidents. (It should be noted that the term "incident delay" is sometimes used to refer to delay associated with non-recurring sources more broadly, including traffic incidents, work zones, and weather-related delays).

Work Zone Mobility

Work zones are second only to incidents as a source of delay from temporary capacity loss. Effective work zone management requires fundamental changes in the way reconstruction and maintenance projects are planned, estimated, designed, bid, and implemented. A comprehensive approach to work zone management requires minimizing work zone consequences, serving the customer around the clock, making use of real-time information, and aggressively pursuing public information and outreach.

Road Weather Management

Adverse weather is the third most common source of delay from temporary capacity loss. Although the weather cannot be changed, its effects on highway safety and operations can be reduced. Today, it is possible to predict weather changes and identify threats to the highway system with much greater precision through the use of roadside weather-monitoring equipment linked to TMCs. More precise weather information can be used to adjust speed limits and traffic signal timing; pretreat roads with anti-icing materials; pre-position trucks for deicing, sanding, or plowing; and inform travelers of changing roadway conditions.

Traffic Signal Timing and Coordination

Another source of congestion is outdated or poor signal timing at intersections. When signal timing is not updated to accommodate changes in traffic patterns, drivers may be subjected to unnecessary stops and delays. Outdated signal timing accounts for an estimated 10 percent of the total delay on major roadways, and a far greater percentage on local roadways.

Signal timing can be improved in several ways, with varying levels of complexity. At the most basic level, old signal timing plans can be updated based on more recent traffic counts. Signal controls can be upgraded, from simple signals actuated by traffic to sophisticated adaptive or even predictive computer-based controls. Interconnecting and coordinating traffic signals through a central master control can achieve the maximum benefits from traffic signal optimization.

Intelligent Transportation Systems

The range of technologies used to advance highway system operations are often referred to collectively as Intelligent Transportation Systems (ITS). They include electronic toll payment, roadway surveillance systems, and advanced traveler information systems. Such systems are being used around the country to improve the operational efficiency and safety of the transportation system. The impetus to employ ITS is growing as technology improves, congestion increases, and building new roads and bridges becomes more difficult and expensive. Many of these technologies are discussed in the highway investment analyses of Part II.

Freeway and Arterial Management Technologies. ITS technologies are being deployed to actively manage freeways and arterials in many places around the country. Ramp metering on freeways is used to regulate the flow of traffic entering a facility to increase vehicle throughput and speeds. In the Minneapolis-St. Paul region, ramp metering increased vehicle throughput by 30 percent and average speeds in the peak period by 60 percent. Adaptive signal control is another type of ITS that adjusts traffic signal timing based on real-time traffic demand. In Los Angeles, where nearly 2,500 of the more than 4,000 traffic signals use adaptive signal control, delay at intersections with these systems is reduced by an average of 10 percent.

Transportation Management Centers. A TMC coordinates the use of ITS. A TMC is typically a central location for bringing together multiple agencies, jurisdictions, and control systems for managing traffic and transit, incident and emergency response, and traveler information. Transportation management technology includes closed-circuit television cameras, dynamic message signs, synchronized traffic signals, vehicle-flow sensors, highway advisory radio, and other high-tech devices.

Active Traffic Management and Integrated Corridor Management. Active Traffic Management (ATM) is a system-centered approach to transportation management. ATM is concerned with the flow and balance within the transportation system and incorporates demand management, traffic flow management, and supply management measures. Although ATM can range from the simple to the complex, proactive management of both demand and supply greatly enhances the ability of transportation agencies to maximize the use of available highway resources including parallel routes, off-peak lanes, high-occupancy vehicle (HOV) lanes, and transit services. This approach to congestion management is a more holistic approach that can include the current U.S. application of managed lane strategies in congested freeway corridors. It is the next step in congestion management.

Integrated Corridor Management (ICM) is active traffic management at the corridor level. It focuses heavily on travel demand management and load balancing across facilities and modes. With ICM, the various institutional partner agencies manage the transportation corridor as a system. The corridor is managed as an integrated asset in order to improve travel time reliability and predictability. In an ICM corridor, because of proactive multimodal management of infrastructure assets by institutional partners, travelers can receive information that encompasses the entire transportation network. They can dynamically shift to alternative transportation options in response to changing traffic conditions.

IntelliDrive^{SM}. In the future, vehicles communicating with other vehicles, with the roadside, and with other devices may offer significant crash prevention and congestion relief. Under the IntelliDrive^{SM} concept being pursued by U.S. Department of Transportation (DOT), data transmitted from the roadside to the vehicle could warn a driver that it is not safe to enter an intersection. Information about traffic signal timing could be sent to vehicles to allow them to navigate arterial streets more efficiently with fewer stops. Vehicles could also serve as data collectors, anonymously transmitting traffic and road condition information from every major road. This information would allow transportation agencies to implement active strategies to relieve traffic congestion.

Providing Better Transportation Choices

In addition to managing the supply of highways, agencies may be able to affect demand for highway travel by providing attractive alternative transportation choices that meet travelers' transportation needs at a reduced cost. The availability of less expensive travel alternatives can provide travelers with choices of location, route, time, and mode that may be more attractive than highway travel, especially under congested conditions.

Providing exclusive lanes for HOVs during peak hours is another means of providing incentives for transportation system users to reduce their use of scarce highway capacity by sharing rides in carpools, vanpools, or buses. Bike lanes and streetscape improvements can encourage the use of non-motorized travel modes. Other tools for enhancing the attractiveness and efficiency of travel alternatives include park-and-ride facilities, guaranteed ride home programs, tax-advantaged transit benefit programs, and transit-supportive local land use controls.

Other strategies are focused on shifting the times of travel or reducing the frequency and distance of trips altogether. Flexible work schedules, compressed workweeks, telecommuting, satellite work centers, and encouragement of mixed-use development (combining residential, commercial, and office uses in a single development) are among several options available to employers and public agencies in achieving such goals.

Traveler information systems are increasingly seen as an important tool for encouraging efficient travel choices by consumers. Online travel planning tools can help system users understand the likely congestion cost of travel in advance and then choose the routes and combination of modes that will most cost effectively meet their travel needs. Online tools can also be used to match carpool drivers and passengers. Real-time travel information can be used to notify travelers of traffic conditions, parking availability at remote transit stations, or even expected travel times on alternative modes.

Creating an Efficient Transportation Market: Road Pricing

Building new facilities and better management and operation of existing roads do not address one of congestion's root causes: that most travelers do not pay the full cost of receiving transportation services. As discussed in the introduction to Part II, when making travel decisions, travelers generally consider only their own travel times and vehicle operating costs; they do not consider the effects that their trips will have on others using the same facilities. Congestion often returns to newly constructed facilities, and facilities with state-of-the-art operating practices remain congested as users respond to increases in road supply and efficiency by shifting from a less satisfactory alternatives and/or making desired trips that they might otherwise have postponed or forgone. In the absence of road pricing mechanisms, highway travel—a notably inefficient market—is distributed according to the amount of time users are willing to wait.

Congestion pricing—charging a toll during peak hours in order to bring supply and demand back into balance—relies on market forces and recognizes that trip values vary by individual, depending on time, location, destination, and cost, and more broadly among individuals, depending on personal preference and access to alternative travel options. Congestion prices can be set at levels that reflect the cost of delay that the traveler imposes on others. Travelers are encouraged to eliminate some lower value trips or take them at different times, or to choose alternate routes or modes of transportation, such as transit or carpooling.

Congestion pricing can take many forms. Presently, variable pricing is typically applied on a limited access facility (such as a bridge or highway) or in a congestion charging zone around a central business district (such as the cordon pricing zones in Stockholm, Singapore, and London). In the future, charging using global positioning systems or dedicated short-range communication technologies may make it feasible to efficiently price entire road networks.

Variable pricing can also be used to make more efficient use of existing transportation infrastructure. This provides users with the benefits of reduced congestion but at a much lower cost than adding new capacity or new technologies. For example, in Miami, Florida, as a part of the U.S. DOT Urban Partnership Program, the single HOV lane on I-95 was converted into two express lanes based on the high-occupancy toll (HOT) concept. Since the opening of the 95 Express project on December 5, 2008, the facility has serviced over 6 million vehicle trips and generated an estimated monthly toll revenue of more than $400,000. In recent surveys, 76 percent of users believe that the express lanes offer a more reliable trip than the un-tolled general purpose (GP) lanes. In addition, speeds in the GP lanes are 21 mph faster than in 2008, while the express lanes have operated at speeds in excess of 45 mph 95.4 percent of the time during the p.m. peak hours and 55.5 percent at all other times.

The 95 Express project also enhanced and expanded the Bus Rapid Transit (BRT) service on I-95 from I-395 in downtown Miami to Broward Boulevard in Fort Lauderdale. Eligibility requirements to travel toll-free in the 95 Express lanes were changed from unregistered two or more persons per vehicle (2+) to registered carpools and vanpools of three or more persons (3+) and registered hybrid vehicles. Motorcycles and emergency vehicles are permitted to use the lanes for free without registering, as are public transit vehicles, school buses, and other over-the-road coaches. Unregistered vehicles participating in the SunPass prepaid toll program are permitted to travel on 95 Express lanes for a fee in order to ensure a high probability of operating speeds of 45 mph or greater.

Congestion pricing strategies such as this retain the incentive for carpool and transit use while also reducing traffic levels in the general purpose lanes. Congestion pricing concepts can also be applied to parking. When parking is made available too cheaply, it can encourage inefficiently high levels of auto use. Underpriced parking can also contribute to localized congestion during high demand periods as motorists search for available parking spaces. Variable pricing of parking can address both of these contributors to congestion.

Transit Operational Performance

Basic goals shared by all transit operations include minimizing travel times, making efficient use of vehicle capacity, and providing reliable performance. The FTA collects data on average speed, how full the vehicles are (utilization) and how often they break down (average distance between failures) to characterize how well transit service meets these goals. These data are reported here. Though safety is also an operational issue, safety data are reported in Chapter 5, which specifically reports safety information.

More subjective customer satisfaction issues, such as how easy it is to access transit service (accessibility), and how well that service meets a community's needs, are harder to measure. Data from the FHWA 2009 National Household Travel Survey, reported here, provide some insights but are not available on an annual basis and so does not support time series analysis. The FTA is investigating the feasibility of maintaining a database of bus stops and train stations, along with their service frequencies and other characteristics, to facilitate analysis of these issues. It is also funding research to develop measures of the degree to which transit systems contribute to the livability and sustainability of our communities. The results of this work will appear in this series of reports in future years.

New technology has allowed progressive transit agencies to report service metrics on their Web sites. Since this is a relatively new practice, measures that are standardized across the industry have not yet been developed. Industry associations are addressing this issue but for now there is no generally recognized set of standards. The FTA has proposed to perform a meta-data analysis of on-time-arrival data as posted on Web sites for major transit agencies for the next report in this series.

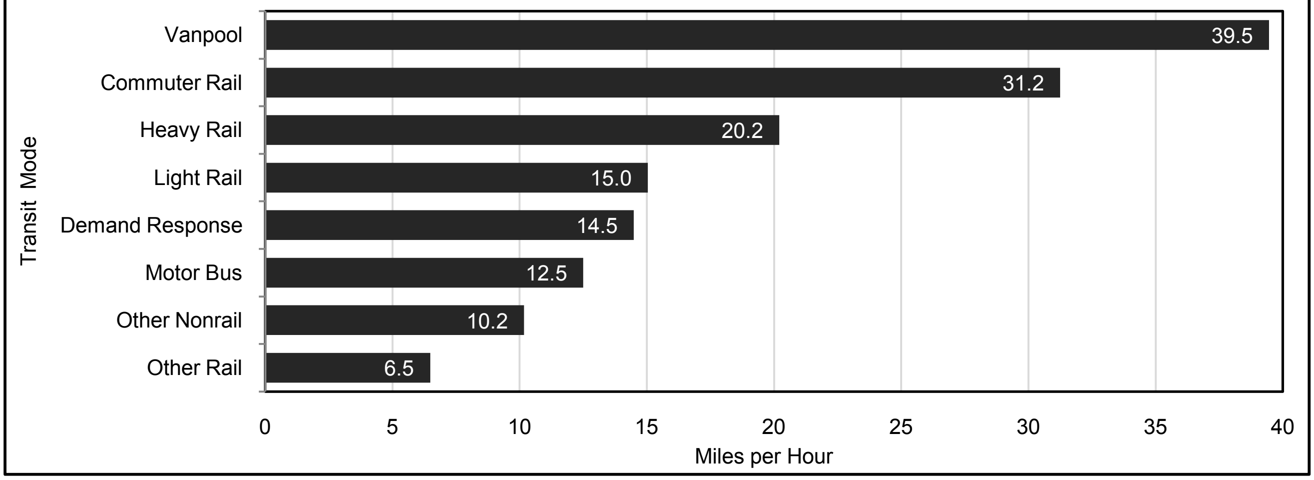
The following analysis presents data on average operating speeds, average number of passengers per vehicle, average percentage of seats occupied per vehicle, average distance traveled per vehicle, and mean distance between failures for vehicles. Average speed, seats occupied, and distance between failures address efficiency and customer service issues; passengers per vehicle and miles per vehicle are primarily efficiency measures. Financial efficiency metrics, including operating expenditures per revenue mile or passenger mile, are discussed in Chapter 6.

Average Operating (Passenger-Carrying) Speeds

Average vehicle operating speed is an approximate measure of the speed experienced by transit riders; it is not a measure of the operating speed of transit vehicles between stops. More specifically, average operating speed is a measure of the speed passengers experience from the time they enter a transit vehicle to the time they exit it, including dwell times at stops. It does not include the time passengers spend waiting or transferring. Average vehicle operating speed is calculated for each mode by dividing annual vehicle revenue miles by annual vehicle revenue hours for each agency in each mode, weighted by the passenger miles traveled (PMT) for each agency within the mode, as reported to the NTD. In cases where an agency contracts with a service provider, as well as provides the service directly, the speeds for each of these services within a mode are calculated and weighted separately. The results of these average speed calculations are presented in *Exhibit 4-9*.

Exhibit 4-9

Average Transit Passenger-Carrying Speed, 2008



Notes: Other Nonrail *includes Publico and trolleybus;* Other Rail *includes Alaska railroad, automated guideway, cable car, inclined plane, and monorail.*

Source: National Transit Database.

The average speed of a transit mode is strongly affected by the number of stops it makes. Motor bus service, which typically makes frequent stops, has a relatively low average speed. In contrast, commuter rail has high sustained speeds between infrequent stops, and thus a relatively high average speed. Vanpools also travel at high speeds, usually with only a few stops at each end of the route. Modes using exclusive guideway 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 light rail, which often shares its guideway with mixed traffic.

Exhibit 4-10 provides average speed data for each year from 2000 to 2008 for all rail modes, all nonrail modes, and all modes combined. These average speeds are based on the average speed of each agency-mode weighted by the amount of PMT on that agency-mode. Decreases in average speed can be due to more crowded conditions—which cause longer dwell times because vehicles take on and discharge larger numbers of passengers—or to roadway congestion (bus) or track maintenance issues (rail). Average speeds for nonrail service (dominated by the bus mode) are virtually constant over the last several years. Rail service shows a slight decrease in average speed which could be due to crowding, maintenance issues, or both.

Exhibit 4-10

Passenger-Mile Weighted Average Operating Speed by Mode

	Average Speed, Miles per Hour		
Year	Rail	Nonrail	All Modes
2000	24.9	13.7	19.6
2001	25.2	13.7	19.6
2002	25.3	13.7	19.6
2003	25.4	13.9	20.1
2004	25.0	14.0	20.1
2005	24.0	13.5	19.2
2006	24.0	13.6	19.3
2007	24.1	13.5	19.6
2008	23.9	13.7	19.5

Source: National Transit Database.

Vehicle Use

Vehicle Occupancy

Exhibit 4-11 shows vehicle occupancy by mode for selected years from 2000 to 2008. Vehicle occupancy is calculated by dividing PMT by vehicle revenue miles (VRMs) resulting in the average number of people carried in a transit vehicle. Aside from a possibly significant increase in heavy rail occupancy in 2008, these numbers do not indicate a meaningful increasing or decreasing trend.

Exhibit 4-11

Unadjusted Vehicle Occupancy: Passengers per Transit Vehicle, 2000–2008

Mode	2000	2002	2004	2006	2008
Rail					
Heavy Rail	23.9	22.6	23.0	23.2	25.7
Commuter Rail	37.9	36.7	36.1	36.1	35.7
Light Rail	26.1	23.9	23.7	25.5	24.1
Other Rail[1]	8.4	8.4	10.4	8.4	9.3
Nonrail					
Motor Bus	10.7	10.5	10.0	10.8	10.8
Demand Response	1.3	1.2	1.3	1.3	1.2
Ferryboat	120.1	112.1	119.5	130.7	118.1
Trolleybus	13.8	14.1	13.3	13.9	14.3
Vanpool	6.6	6.4	5.9	6.3	6.3
Other Nonrail[2]	7.3	7.9	5.8	7.8	8.2

[1] *Alaska railroad, automated guideway, cable car, inclined plane, and monorail.*
[2] *Aerial tramway and Público.*

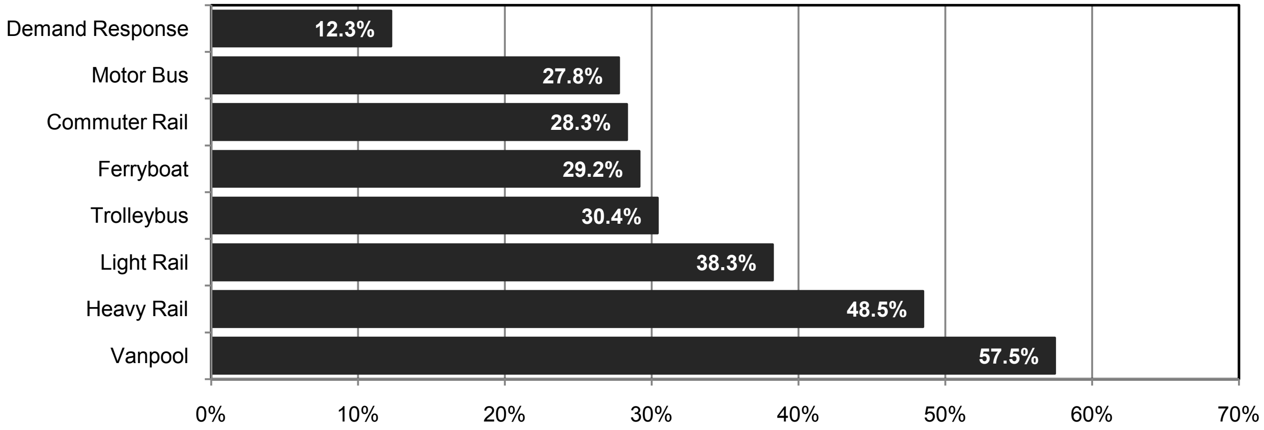
Source: National Transit Database.

With vehicle capacities varying by mode, *Exhibit 4-12* shows the 2008 vehicle occupancy as a percentage of the seating capacity for an average vehicle in each mode (based on the average number of seats reported per vehicle in 2008: vanpool, 11; heavy rail, 53; light rail, 63; trolleybus, 47; ferryboat, 405; commuter rail, 126; motor bus, 39; demand response, 10). For example, as shown in *Exhibit 4-11*, the average occupancy for a bus in 2008 was 10.8 riders and the average full-size bus seats 39 people. This occupancy, as a percentage of seating capacity, is 27.8 percent. Some modes also have substantial standing capacity that is not considered here, but which can allow the "percentage of seats occupied" measure to exceed 100 percent for a full vehicle.

Although, on the average, it appears that there is considerable excess capacity in all these modes, it should be noted that commuting patterns make it difficult to fill vehicles returning to the suburbs from downtown employment centers during the morning rush hours and, likewise, to fill vehicles going downtown in the

Exhibit 4-12

Percentage of Seats Occupied



Source: National Transit Database.

evening rush. Vehicles also tend to be relatively empty at the beginning and ends of their routes. For many commuter routes, a vehicle that is crush-loaded (e.g., filled to maximum capacity) on part of the trip may still only achieve an average occupancy of around 25 percent.

Revenue Miles per Active Vehicle (Service Use)

Vehicle service use, the average distance traveled per vehicle in service, can be measured by VRMs per vehicle in active service. *Exhibit 4-13* provides vehicle service use by mode for selected years from 2000 to 2008. Heavy rail, generally offering long hours of frequent service, had the highest vehicle use during this period and displays a clear trend of gradually increasing service use per vehicle. Vehicle service use for light rail also appears to show an increasing trend. Vehicle service use for nonrail modes appears to be stable over the past few years with no apparent trends in either direction.

Exhibit 4-13

Vehicle Service Utilization: Vehicle Revenue Miles per Active Vehicle by Mode

	Thousands of Revenue Vehicle Miles					Average Annual Rate of Change
Mode	**2000**	**2002**	**2004**	**2006**	**2008**	**2008/2000**
Rail						
Heavy Rail	55.6	55.1	57.0	57.2	57.7	0.5%
Commuter Rail	42.1	43.9	41.1	43.0	45.5	1.0%
Light Rail	32.5	41.1	39.9	39.9	44.1	3.9%
Nonrail						
Motor Bus	28.0	29.9	30.2	30.2	30.3	1.0%
Demand Response	17.9	21.1	20.1	21.7	21.3	2.2%
Ferryboat	24.1	24.4	24.9	24.8	21.9	-1.2%
Vanpool	12.9	13.6	14.1	13.7	14.3	1.3%
Trolleybus	18.9	20.3	21.1	19.1	18.7	-0.1%

Source: National Transit Database.

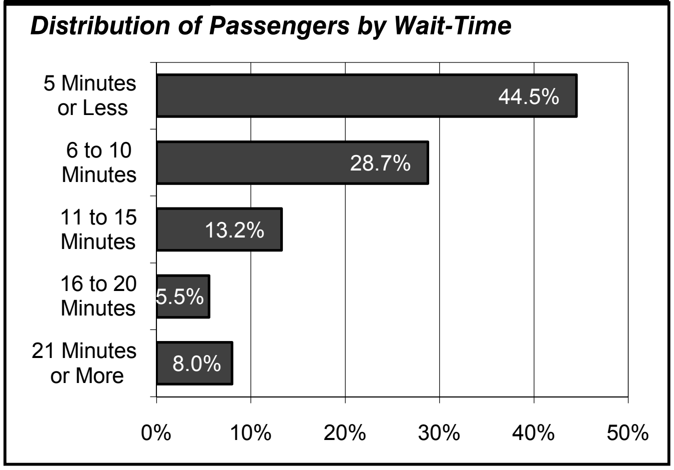
Frequency and Reliability of Service

The frequency of transit service varies considerably according to location and time of day. Transit service is more frequent in urban areas and during rush hours—namely, where and when the demand for transit is highest. Studies have found that transit passengers consider the time spent waiting for a transit vehicle to be less well spent than the time spent traveling in a transit vehicle. The higher the degree of uncertainty in waiting times, the less attractive transit becomes as a means of transportation and the fewer users transit will attract. Further, when scheduled service is offered less frequently, reliability becomes more important to users.

Exhibit 4-14 shows findings on wait-times from the 2009 National Household Travel Survey (NHTS) by the FHWA, the most recent nationwide survey of this information. The NHTS found that 44.5 percent of all passengers who ride transit wait 5 minutes or less and 73.2 percent wait 10 minutes or less. The NHTS also found that 8.0 percent of all passengers wait more than 20 minutes. A number of factors influence passenger wait-times, including the frequency of service, the reliability of service, and passengers' awareness of timetables. These factors are also interrelated. For example, passengers may intentionally arrive earlier for service that is infrequent, compared with equally reliable services that are more frequent. Overall, waiting times of 5 minutes or less are clearly associated with good service that is either frequent, reliably provided according to a schedule, or both. Waiting times of 5 to 10 minutes are most likely consistent with adequate levels of service that are both reasonably frequent and generally reliable. Waiting times of 20 minutes or more indicate that service is likely both infrequent and unreliable.

Exhibit 4-14

Distribution of Passengers by Wait-Time

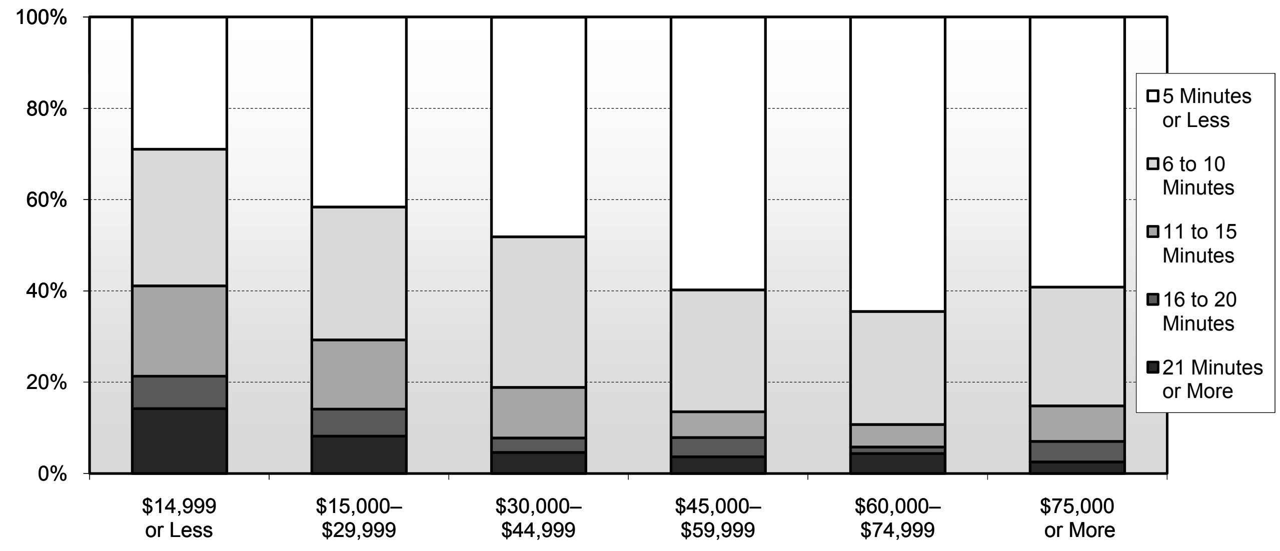


Source: National Household Travel Survey, FHWA, 2009.

Waiting time is also correlated with income, as shown in *Exhibit 4-15*. Passengers from households with annual incomes of $30,000 or more are much more likely to report a waiting time of 5 minutes or less than passengers from households with incomes of less than $30,000. Additionally, passengers from households with more than $45,000 in annual income report almost never waiting more than 15 minutes for transit. This disparity is in large part due to the fact that high income riders tend to be "choice" riders who primarily ride transit on modes, routes, and at times of day when the service is frequent and reliable—and who generally substitute the use of personal automobiles for trips when these conditions aren't met. In contrast, passengers with lower incomes are more likely to use transit for basic mobility and have more limited alternative means of travel, therefore using transit even when the service is not as frequent or reliable as they may prefer.

Exhibit 4-15

Passenger Wait-Time According to Household Income

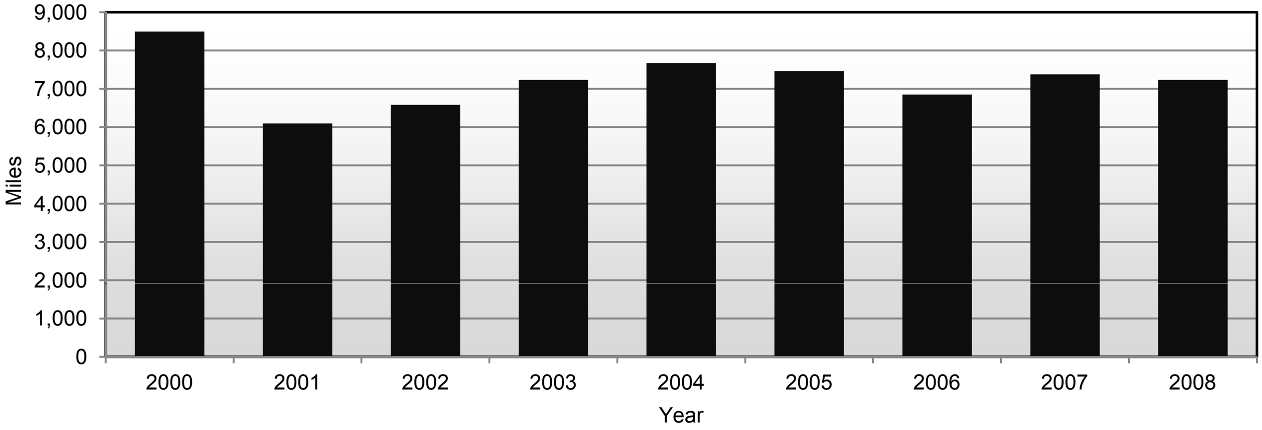


Source: National Household Travel Survey, FHWA, 2009.

Average distance between failures, as shown in *Exhibit 4-16,* has been relatively stable since 2003 at around 7,000 miles. This indicates that the number of unscheduled delays due to mechanical failure of transit vehicles has not increased. The FTA does not collect data on delays due to guideway conditions; this would include congestion for roads and slow zones (due to system or rail problems) for track. These delays are not considered to be as much of a problem as delays caused by vehicle failure. This is an issue that the FTA will be addressing as part of its State of Good Repair work in the future.

Exhibit 4-16

Average Distance Between Failures



Source: National Transit Database.

Chapter 5

Safety

Highway Safety

This section describes the safety of the Nation's highway system. It looks at fatalities and injuries on highway functional systems, across vehicle types, and among different segments of the population. It also examines contributing factors to fatal crashes. Fatalities and injuries for bicyclists and pedestrians caused by collisions with vehicles are included in the statistics presented, along with those for vehicle occupants.

Three operating administrations within the U.S. Department of Transportation (DOT) have responsibility for addressing highway safety. The U.S. Federal Highway Administration (FHWA) focuses on infrastructure safety design and operations. The National Highway Traffic Safety Administration (NHTSA) has responsibility for overseeing vehicle safety standards and administering driver behavior programs. The Federal Motor Carrier Safety Administration (FMCSA) has the mission to reduce crashes, injuries, and fatalities involving large trucks and buses.

Statistics in this section are primarily drawn from the Fatality Analysis Reporting System (FARS). The FARS is maintained by NHTSA, which has a cooperative agreement with States to provide information on fatal crashes. Police crash reports, death certificates, and other documents provide data that are tabulated daily and included in the FARS. For consistency with other sections of this report, safety statistics in this section were compiled during the fall of 2009 and represent a "snapshot in time" during the preparation of this report, which is why they may not precisely correspond to other reports completed during the last year.

NHTSA publishes an annual Traffic Safety Facts report that comprehensively describes safety characteristics on the highway transportation network. FMCSA publishes similar reports on a regular basis, specific to truck- and bus-related crashes.

Overall Fatalities and Injuries

There were more than 5.8 million police-reported motor vehicle crashes in the United States in 2008. Fewer than 1 percent (0.6 percent or 34,017) of these crashes were severe enough to result in a fatality, while 28.1 percent (approximately 1.63 million) resulted in injuries and 71.4 percent (approximately 4.15 million) resulted in property damage only, as shown in *Exhibit 5-1*.

Exhibit 5-1

Crashes by Severity, 2000–2008

	Crash Severity							
	Fatal		Injury		Property Damage Only		Total Crashes	
Year	Number	Percent	Number	Percent	Number	Percent	Number	Percent
2000	37,526	0.6	2,070,000	32.4	4,286,000	67.0	6,394,000	100.0
2001	37,862	0.6	2,003,000	31.7	4,282,000	67.7	6,323,000	100.0
2002	38,491	0.6	1,929,000	30.5	4,348,000	68.8	4,349,000	100.0
2003	38,477	0.6	1,925,000	30.4	4,365,000	69.0	6,328,000	100.0
2004	38,444	0.6	1,862,000	30.1	4,281,000	69.3	6,181,000	100.0
2005	39,252	0.6	1,816,000	29.5	4,304,000	69.9	6,159,000	100.0
2006	38,588	0.6	1,746,000	29.2	4,189,000	70.1	5,973,000	100.0
2007	37,435	0.6	1,711,000	28.4	4,275,000	71.0	6,024,000	100.0
2008	34,017	0.6	1,630,000	28.1	4,146,000	71.4	5,811,000	100.0

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

Exhibit 5-2 describes the considerable improvement in highway safety since Federal legislation first addressed the issue in 1966. That year, the fatality rate was 5.50 fatalities per 100 million vehicle miles traveled (VMT). By 2008, the fatality rate had declined to 1.25 per 100 million VMT. This sharp decline in the fatality rate occurred even as the number of licensed drivers doubled over that same period.

Exhibit 5-2

Summary of Fatality and Injury Rates, 1966–2008

Year	Fatalities	Resident Population (Thousands)	Fatality Rate per 100,000 Population	Licensed Drivers (Thousands)	Fatality Rate per 100 Million VMT	Injured	Injury Rate per 100,000 Population	Injury Rate per 100 Million VMT
1966	50,894	196,560	25.89	100,998	5.50			
1968	52,725	200,706	26.27	105,410	5.20			
1970	52,627	205,052	25.67	111,543	4.74			
1972	54,589	209,896	26.01	118,414	4.30			
1974	45,196	213,854	21.13	125,427	3.50			
1976	45,523	218,035	20.88	134,036	3.25			
1978	50,331	222,585	22.61	140,844	3.26			
1980	51,091	227,225	22.48	145,295	3.35			
1982	43,945	231,664	18.97	150,234	1.76			
1984	44,257	235,825	18.77	155,424	2.57			
1986	46,087	240,133	19.19	159,486	2.51			
1988	47,087	244,499	19.26	162,854	2.32	3,416,000	1,397	169
1990	44,599	249,439	17.88	167,015	2.08	3,231,000	1,295	151
1992	39,250	254,995	15.39	173,125	1.75	3,070,000	1,204	137
1994	40,716	260,327	15.64	175,403	1.73	3,266,000	1,255	139
1996	42,065	265,229	15.86	179,539	1.69	3,483,000	1,313	140
1998	41,501	270,248	15.36	184,861	1.58	3,192,000	1,181	121
2000	41,945	282,192	14.86	190,625	1.53	3,189,000	1,130	116
2002	43,005	288,126	14.93	194,602	1.51	2,926,000	1,017	102
2004	42,836	293,638	14.59	198,889	1.44	2,788,000	952	94
2006	42,708	299,398	14.24	202,810	1.42	2,575,000	863	85
2008	37,261	304,060	12.25	208,321	1.25	2,346,000	771	80

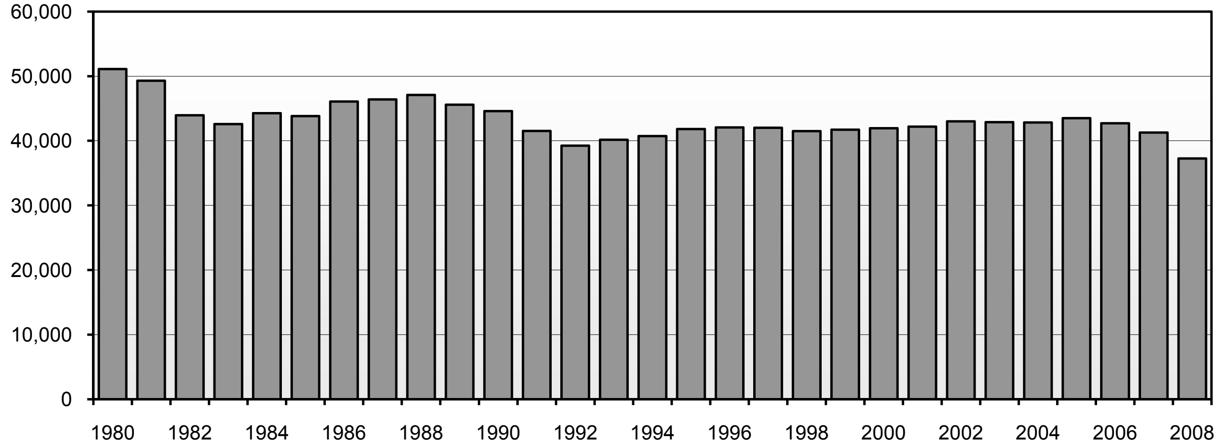
Source: Fatality Analysis Reporting System/National Center for Statistics and Analysis, NHTSA.

While the overall number of fatalities dropped by more than 20 percent in 20 years (between 1988 and 2008), the overall number of traffic-related injuries also decreased by more than 31 percent during that same period (from 3,416,000 to 2,346,000). Injuries increased between 1992 and 1996, but have steadily declined since then. In 1988, the injury rate was 169 per 100 million VMT; by 2008, the number had dropped (by more than 52 percent) to 80 per 100 million VMT.

The overall number of traffic deaths also decreased between 1966 and 2008. In 1966, there were 50,894 traffic deaths. Fatalities reached their highest point in 1972 with 54,589 fatalities, then declined sharply following the implementation of a national speed limit, reaching a record low point of 39,250 fatalities in 1992. Between 1992 and 2006, there was more limited progress in reducing the number of fatalities. The number of fatalities generally increased year-to-year from 1992 to 2006, when 42,708 Americans lost their lives in crashes. However, in 2008, there was a record low number of fatalities (37,261), the lowest number since 1966. *Exhibit 5-3* and *Exhibit 5-4* compare the number of fatalities with fatality rates between 1980 and 2008.

Exhibit 5-3

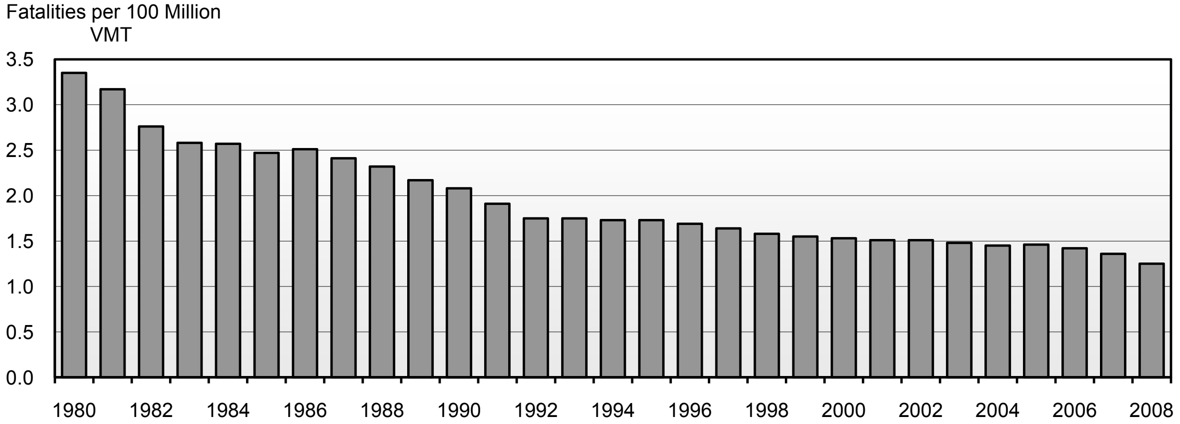
Fatalities, 1980–2008



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

Exhibit 5-4

Fatality Rates, 1980–2008



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

Q&A

What information is available for highway fatalities in 2009?

In 2009, highway deaths fell to 33,808 for the year, a 9.7 percent decrease from 2008, and the lowest number since 1950. The record-breaking decline in traffic fatalities occurred even while estimated VMT in 2009 increased by 0.2 percent over 2008 levels. For the first time in 11 years, motorcycle fatalities also declined by 24 percent, with a reduction of 850 deaths from the previous year.

In addition, 2009 saw the lowest fatality and injury rates ever recorded with 1.13 deaths per 100 million VMT traveled in 2009, compared with 1.26 deaths for 2008.

Additional information on the 2009 data can be found in the latest version of the *Traffic Safety Facts,* which can be viewed at http://www-nrd.nhtsa.dot.gov/Pubs/811363.pdf. The information provided throughout this chapter as well as the information used to compile the *NHTSA Traffic Safety Facts* draws primarily from the Fatality Analysis Reporting System (FARS). The FARS contains data on the fatal traffic crashes submitted by the 50 States, the District of Columbia, and Puerto Rico.

Fatalities by Functional Class

Exhibit 5-5 and *Exhibit 5-6* show the number of fatalities and fatality rates by rural and urban functional system between 2000 and 2008. These exhibits show the distinction between fatalities and fatality rates.

Exhibit 5-5

Fatalities by Functional System, 2000–2008

Functional System	2000	2002	2004	2006	2008	Percent Change 2008/2000
Rural Areas (under 5,000 in population)						
Interstate	3,254	3,298	3,227	2,887	2,416	-25.8%
Other Principal Arterial	4,917	4,894	5,167	4,554	4,358	-11.4%
Minor Arterial	4,090	4,467	5,043	4,346	3,515	-14.1%
Major Collector	5,501	6,014	5,568	5,675	5,068	-7.9%
Minor Collector	1,808	2,003	1,787	1,650	1,423	-21.3%
Local	4,414	5,059	4,162	4,294	4,027	-8.8%
Unknown Rural	854	161	225	240	98	-88.5%
Subtotal Rural	**24,838**	**25,896**	**25,179**	**23,646**	**20,905**	**-15.8%**
Urban Areas (5,000 or more in population)						
Interstate	2,419	2,482	2,602	2,663	2,259	-6.6%
Other Freeway and Expressway	1,364	1,506	1,673	1,690	1,505	10.3%
Other Principal Arterial	4,948	5,124	4,847	5,447	4,446	-10.1%
Minor Arterial	3,211	3,218	3,573	3,807	3,105	-3.3%
Collector	1,001	1,151	1,385	1,513	1,239	23.8%
Local	2,912	3,497	3,290	3,622	3,402	16.8%
Unknown Urban	258	35	211	49	27	-89.5%
Subtotal Urban	**16,113**	**17,013**	**17,581**	**18,791**	**15,983**	**-0.8%**
Unknown Rural or Urban	994	96	76	271	373	-62.5%
Total Highway Fatalities	**41,945**	**43,005**	**42,836**	**42,708**	**37,261**	**-11.2%**

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

As shown in *Exhibit 5-5*, the absolute number of fatalities grew slightly between 2000 and 2006 and then declined to 37,261 deaths in 2008. During this period (from 2000 to 2008), the number of fatalities on urban roads decreased from 16,113 to 15,983 (a reduction of almost 1 percent). At the same time, the number of fatalities on rural roads decreased from 24,838 to 20,905 (a reduction of almost 16 percent). In 2008, fatalities from urban crashes accounted for 43 percent of all fatalities, while those resulting from rural crashes accounted for 56 percent.[1] The fatality rate, however, decreased on both urban and rural roads since 2000, due in part to a combination of safety countermeasures and programs introduced by DOT and State partners, as well as a decrease in VMT between 2007 and 2008.

What steps are being taken to improve safety on the Nation's rural roads? Q&A

Rural road safety is a particular concern, as the majority of highway fatalities take place on rural roads. FHWA works closely with highway safety partners at the National, State, and local levels to highlight available options to help reduce highway fatalities and injuries on the nation's rural roads. There are a variety of initiatives currently underway to address issues relating to rural road safety. These include assistance to rural road owners, partners and stakeholders through forums, workshops, a web-based clearinghouse, publishing guidelines and peer-to-peer technical support.

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[1] As shown in *Exhibit 5-5*, about 1 percent of crashes were not classified as either urban or rural.

High Risk Rural Roads (HRRR) Program

SAFETEA-LU created HRRR to help improve rural road safety by funding rural construction and operational improvement projects, such as adding or expanding shoulders, straightening dangerous curves, and improving hazardous intersections. FHWA developed additional information on the program which can be found in the *Guide for High Risk Rural Road Program Implementation,* available at http://safety.fhwa.dot.gov/local_rural/training/fhwasa10012/fhwasa10012.pdf.

Rural Safety Innovation Program

FHWA launched this program in 2008 to improve rural road safety. Twenty-one rural safety projects were selected in 14 States, 3 counties, and 2 parishes to receive a total of $14.7 million. Nine projects focused on application of low-cost safety countermeasures and 12 focused on applying an Intelligent Transportation System to improve rural safety. As projects are completed and evaluated, good practices will be shared with the rural road safety community.

Exhibit 5-6 shows the fatality rates for every urban and rural functional system between 2000 and 2008. Urban Interstate highways were the safest functional system, with a fatality rate of 0.47 per 100 million VMT in 2008. Among urban roads, Interstate highways and other principal arterials recorded the sharpest declines in fatality rates over this 8-year period, as each experienced an overall reduction of approximately 23 percent.

Exhibit 5-6

Fatality Rates by Functional System, 2000–2008 (per 100 Million VMT)

Functional System	2000	2002	2004	2006	2008	Percent Change 2008/2000
Rural Areas (under 5,000 in population)						
Interstate	1.21	1.18	1.21	1.12	0.99	-18.2%
Other Principal Arterial	1.98	1.90	2.14	1.96	1.96	-1.0%
Minor Arterial	2.38	2.53	2.99	2.67	2.31	-2.9%
Major Collector	2.63	2.82	2.77	2.94	2.72	3.4%
Minor Collector	3.12	3.26	2.97	2.84	2.59	-17.0%
Local	3.45	3.63	3.14	3.22	3.06	-11.3%
Subtotal Rural	**2.34**	**2.30**	**2.36**	**2.29**	**2.13**	**-9.0%**
Urban Areas (5,000 or more in population)						
Interstate	0.61	0.61	0.57	0.56	0.47	-23.0%
Other Freeway and Expressway	0.77	0.79	0.80	0.78	0.68	-11.7%
Other Principal Arterial	1.24	1.25	1.08	1.17	0.96	-22.6%
Minor Arterial	0.99	0.95	0.99	1.01	0.82	-17.2%
Collector	0.74	0.81	0.85	0.87	0.71	-4.1%
Local	1.24	1.46	1.29	1.36	1.26	1.6%
Subtotal Urban	**0.99**	**0.99**	**0.93**	**0.96**	**0.81**	**-18.2%**
Total Highway Fatality Rate	**1.53**	**1.51**	**1.45**	**1.42**	**1.25**	**-18.3%**

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

The overall fatality rate decreased by 9 percent on rural roads between 2000 and 2008. Among rural roads, Interstate highways and minor collectors recorded the sharpest declines in fatality rates over this period. The fatality rate for rural minor collectors in 2008 was 17 percent lower than in 2000. Likewise, the fatality rate for rural Interstates dropped by 18 percent over the same

Rural Highway Knowledge Resource Program

Initiated in 2009, this $1.2-million program addresses the issue of local and rural safety through outreach and the demonstration and evaluation of innovative solutions. Outreach is aimed at actively engaging public decision makers through workshops and forums, providing easy-to-understand technical information and guidance, improving the Rural Highway Safety Clearinghouse, and providing peer-to-peer technical support.

period. Despite the overall decrease in fatality rate on both urban and rural functional systems, rural roads are far more dangerous than their urban counterparts. A number of factors collectively result in this rural road safety challenge, such as greater curvature and obstacles close to the roadway, designs that contribute to roadway departure, and higher levels of speeding on nonseparated roadways.

Rural Safety Clearinghouse and Center of Excellence for Rural Safety

Established in June 2008, this web-based clearinghouse at http://www.ruralhighwaysafety.org links to a growing collection of rural road safety documents and resources. Another rural safety website is the Center for Excellence in Rural Safety at http://www.ruralsafety.umn.edu. The University of Minnesota developed the site through sponsorship by the FHWA and funding by SAFETEA-LU Section 5309.

Emergency Response Time in Rural Areas

The *2008 NHTSA Traffic Safety Facts: Rural/Urban Comparison* publication indicates: "In 2008, 24,175 drivers were killed in fatal crashes. Of those, 64 percent of rural and 51 percent of urban drivers died at the scene. Data also shows that 39 percent of all drivers killed were transported to the hospital and 6 percent of these drivers died en route. Unfortunately, rural drivers represented 52 percent of drivers who died en route to the hospital versus 48 percent of urban drivers."

Timely emergency response and treatment can be challenging in rural areas, which has an impact on fatality rates. The December 2006 NHTSA publication, *Traffic Crashes Take Their Toll on America's Rural Roads,* indicates that it takes emergency personnel an average of 19 minutes to arrive at a crash scene in a rural area, compared with 7 minutes in an urban area. The total time from occurrence of a crash to arrival at the hospital averages 53 minutes in rural areas in contrast to 36 minutes in urban areas.

The time to get a crash victim emergency care and transported to a hospital is critical as many medical experts consider the first 60 minutes after the occurrence of a trauma the "golden hour" and the most critical time period for saving lives.

Highway Fatalities by Major Crash Type or Contributing Factors

The total economic cost of crashes was estimated at $230.6 billion in 2000. Motor vehicle crashes cost society an estimated $7,300 per second. When a crash occurs, it is generally the result of numerous contributing factors. Driver, roadway, and vehicle factors all have an impact on the safety of the Nation's highway system. The FHWA is focused on reducing four types of roadway-related crashes: roadway departures and intersection incidents, pedestrian, and speeding-related crashes. *Exhibit 5-7* shows data for these crash types between 2000 and 2008. These categories are not mutually exclusive; the fatalities shown in *Exhibit 5-7* can involve a combination of factors—intersection- and pedestrian-related, for example—so that some fatalities appear in more than one category.

Exhibit 5-7

Highway Fatalities by Crash Type, 2000–2008

	2000	2002	2004	2006	2008	Percent Change 2008/2000
Roadway Departures[1, 2]	23,046	25,415	22,340	22,665	19,794	-14.1%
Intersection-Related[1]	8,689	9,273	9,176	8,850	7,772	-10.6%
Pedestrian-Related[1]	4,763	4,851	4,675	4,795	4,378	-8.1%
Speeding-Related[1]	12,552	13,799	13,291	13,609	11,674	-7.0%

[1] Some fatalities may overlap; for example, some intersection-related fatalities may involve pedestrians.

[2] Definition for roadway departure crashes was modified beginning in 2004.

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

Roadway Departures

In 2008, there were 19,794 fatalities related to a vehicle leaving the roadway and crashing. In some cases, the vehicle crossed the centerline and struck another vehicle, hitting it head-on or sideswiping it. In other cases, the vehicle left the roadway and struck one or more man-made or natural objects, such as utility poles, embankments, guardrails, trees, or parked vehicles.

Roadway departures occur because of human factors, roadway design factors, and environmental factors. Human factors include driving while intoxicated, driver distraction, driver fatigue, and driver drowsiness. It is widely recognized that drunk drivers can create hazardous driving conditions, but a drowsy driver can be as dangerous as a drunk driver.

Q&A

What's happening regarding distracted driving prevention at USDOT?

The USDOT is leading an effort to share knowledge and promote a greater understanding of the issue pertaining to distracted driving.

In September 2010, the Department convened the second National Distracted Driving Summit. The Summit brought together leading transportation officials, safety experts, researchers, industry representatives, and victims of distraction-related crashes to take stock of progress made, reassess the challenges still faced, and determine steps that should be taken moving forward in national anti-distracted driving efforts.

USDOT has also called on State and local governments to help to reduce fatalities and crashes by making distracted driving part of their state highway plans.

Public service announcements have been aired across the Nation to educate drivers and remind them to keep their focus on the roads. In addition, USDOT has launched a website, www.distraction.gov, where the public can locate information and resources on the issue.

Some roadway departures can be attributed to drivers being distracted while attempting to operate mobile devices in their vehicles, causing them to drift out of the lane and off the road. Research shows that using a cell phone while driving can pose a serious cognitive distraction that degrades driver performance. Distracted driving can be caused by anything that makes drivers take their eyes off the road or hands off the steering wheel, or that interrupts concentration. In 2008, a total of 5,870 fatalities and 515,000 injuries involved distracted driving. This accounts for 16 percent of total fatalities in 2008. Even the use of hands-free devices can impair drivers' reaction times. The available research indicates that operating either a hands-free or hand-held cell phone can present cognitive distraction significant enough to degrade a driver's performance, potentially causing a driver to miss key visual and audio cues needed to avoid a crash.

The majority of roadway departure crashes happen at night. About two-thirds of roadway departure fatalities occur on rural roads. Rural highways are often not as well-lit as urban roadways and are often designed with narrow travel lanes, sharp roadway curvatures, or unimproved shoulders. Environmental factors including inclement weather such as fog, snow, smoke, or dust storms can also decrease the visibility of pavement markings or roadway curvature. In 2008, about 17 percent of all crashes were attributed at least in part to weather conditions. Of the 19,794 total roadway departure fatalities that occurred in 2008, more than 45 percent involved the rollover of a passenger vehicle.

As shown in *Exhibit 5-8*, the total number of fatalities in rollover crashes has decreased, from 9,962 in 2000 to 9,007 in 2008 (a decrease of about 10 percent), with the number of fatalities varying by vehicle type. While the number of fatalities in rollovers among cars decreased, from 4,549 in 2000 to 3,640 in 2008 (a 20 percent decrease), the number of fatalities in rollovers among light (sport) utility trucks grew from 2,064 in 2000 to 2,414 in 2008 (an increase of 17 percent) at the same time the fatality rate from rollovers in light utility trucks decreased from 9.61 to 5.96 while the number of these vehicles almost doubled. The number of fatalities in rollovers among pickup trucks for the same period decreased by more than 5 percent (from 2,558 in 2000 to 2,424 in 2008). Among vans, fatalities related to rollover crashes decreased by 33 percent (from 770 in 2000 to 515 in 2008).

In 2008 fatal crashes in which a rollover occurred, the occupant fatality rate for light pickup trucks was six per 100,000 registered vehicles. Likewise, the rate per 100,000 registered vehicles was almost six for light utility trucks, three for other light trucks, and almost three for vans. Passenger cars had the lowest fatality rate for rollover crashes, when compared with other vehicle types.

Intersections

Of the 37,261 fatalities that occurred in 2008, about 21 percent—7,772—occurred at intersections, of which at least 39.2 percent were at rural intersections and at least 60.8 percent urban, as shown in *Exhibit 5-9*.

Intersection-related crashes accounted for nearly 40 percent of all police-reported crashes and approximately 47 percent of all people injured in 2008. Older drivers and pedestrians are particularly at risk at intersections; 40 percent of the traffic fatalities among drivers aged 80 or older and more than one-third of the pedestrian deaths among people aged 70 or older were intersection-related.

There are more than 3 million intersections in the United States, including both signalized and nonsignalized (e.g., those controlled by stop or yield signs); and many factors may contribute to unsafe conditions at these areas. Road designs may be inadequate for current traffic levels or traffic signals may not be optimally programmed. Approximately one-third of signalized intersection fatalities involve red-light running.

Intersection Safety – Law Enforcement

Education and law enforcement are important components of intersection safety. Automated enforcement at red lights is increasingly being used in States and cities to supplement limited police manpower. It is believed that red-light cameras are presently being used in more than 400 communities in the United States.

Exhibit 5-8

Comparison of Number of Fatalities and Fatality Rates for Vehicles Involved in Rollover Crashes, 2000 and 2008

	Fatalities	Registered Passenger Vehicles	Fatality Rate per 100,000 Registered Vehicles
2000			
Passenger Cars	4,549	133,621,420	3.40
Light Pickup Trucks	2,558	38,216,835	6.69
Light Utility Trucks	2,064	21,466,592	9.61
Vans	770	17,250,102	4.46
Other Light Trucks	21	863,298	2.43
Total	**9,962**	**211,418,247**	**4.71**
2008			
Passenger Cars	3,640	137,079,843	2.66
Light Pickup Trucks	2,424	40,158,416	6.04
Light Utility Trucks	2,414	40,519,012	5.96
Vans	515	18,445,139	2.79
Other Light Trucks	14	447,765	3.13
Total	**9,007**	**236,650,175**	**3.81**
Percent Change	**-9.6%**	**11.9%**	

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

Exhibit 5-9

Intersection-Related Fatalities by Functional System, 2008

	Fatalities	
	Count	Percent of Total
Rural Areas (under 5,000 in population)		
Principal Arterials	851	11.1%
Minor Arterials	630	8.2%
Collectors (Major and Minor)	915	11.9%
Locals	612	8.0%
Subtotal Rural Areas	**3,008**	**39.2%**
Urban Areas (5,000 or more in population)		
Principal Arterials	2,088	27.2%
Minor Arterials	1,136	14.8%
Collectors (Major and Minor)	405	5.3%
Locals	1,031	13.4%
Subtotal Urban Areas	**4,660**	**60.8%**
Total Highway Fatalities*	**7,668**	**100.0%**

** Total excludes 104 intersection-related fatalities not identified by functional class.*

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

How are Federal, State, and local transportation agencies working to improve intersection safety?

Q&A

Engineering improvements can greatly enhance safety at intersections. At stop-controlled intersections, adding advance warning signs on each approach, doubling up advance warning and stop signs, and making the signs larger have all been shown to assist motorists in recognizing that there is an intersection ahead. Adding flashing beacons to the signs further enhances recognition of an intersection and the driver's action that is required. Providing turn lanes may be warranted on the major road at stop-controlled intersections.

Intersection Safety—Roundabouts

Increased usage of modern roundabouts, which offer substantial safety and operational benefits over traditional intersections, are being promoted as a proven safety countermeasure. The AASHTO *Highway Safety Manual* includes Crash Modification Factors that show the overall safety effectiveness of roundabouts at over 40 percent fewer crashes and nearly 80 percent fewer injuries and fatalities as compared with stop- and signal-controlled intersections. It is estimated that there are currently between 1,500 and 2,000 roundabouts in the United States, with the number increasing steadily. More information on roundabouts can be found in the comprehensive national reference, *Roundabouts: An Informational Guide*, *Second Edition,* located at (http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_672.pdf).

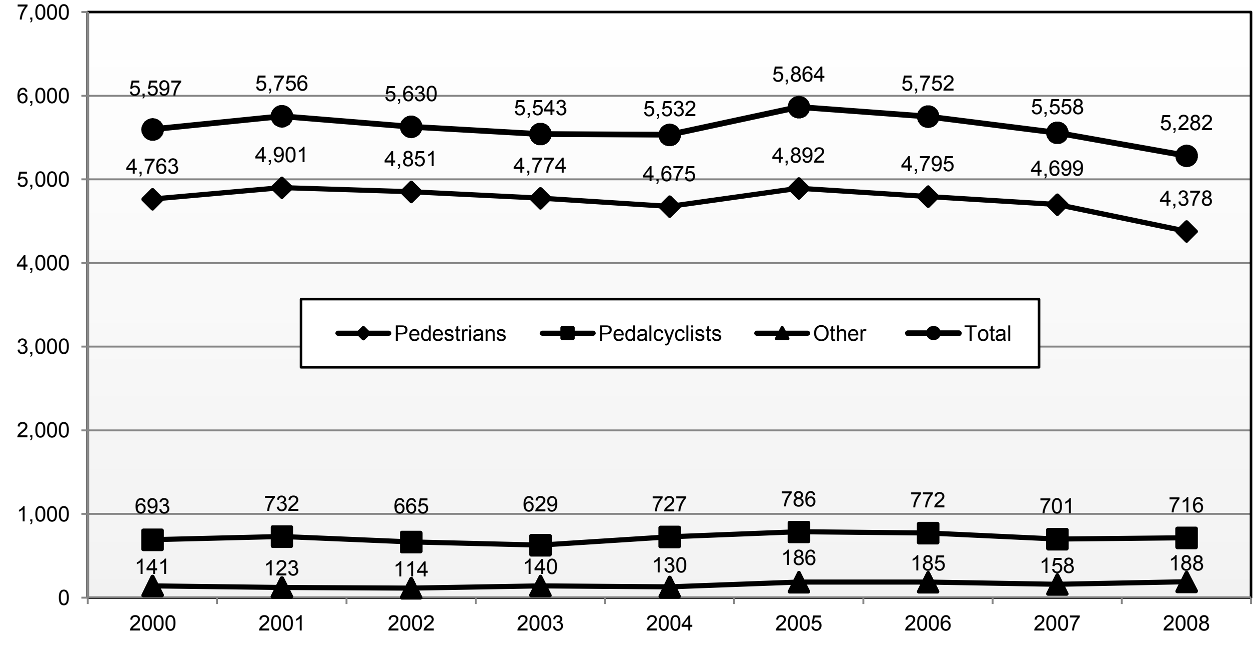
Pedestrians and Other Nonmotorists

Exhibit 5-10 displays nonmotorist traffic fatalities that occurred between 2000 and 2008. For the purposes of this report, the term "nonmotorist" refers to pedestrians, pedalcyclists (such as bicyclists), and other nonmotorists (such as skateboarders and roller skaters).

The number of nonmotorist fatalities decreased from 5,597 in 2000 to 5,282 in 2008, a 5.6 percent decrease in 8 years. While the number of pedestrians killed by motor vehicle crashes has decreased by 8 percent over this period, the number of pedalcyclists and other nonmotorists killed has increased by 3 percent and

Exhibit 5-10

Pedestrian and Other Nonmotorist Traffic Fatalities, 2000–2008



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

33 percent, respectively. Still, in 2008, 82.8 percent of all nonmotorist fatalities were pedestrians. About 13.5 percent were pedalcyclists, and the remaining 3.5 percent were other nonmotorists. More than 13 percent of the nonmotorist crash fatalities were alcohol-related in 2008, where a driver or motorcycle operator had a blood alcohol concentration (BAC) of 0.08 gram per deciliter (g/dL) or greater.

The number of nonmotorists injured in crashes in 2008 was 130,000. This constitutes almost 6 percent of total crash-related injuries. Pedestrians represented 53 percent (69,000) of these injuries, while pedalcyclists represented 40 percent (52,000). Of the total injuries sustained by nonmotorists, 16 percent were incapacitating injuries (21,000), usually defined as inability to walk, drive, or continue other normal activities.

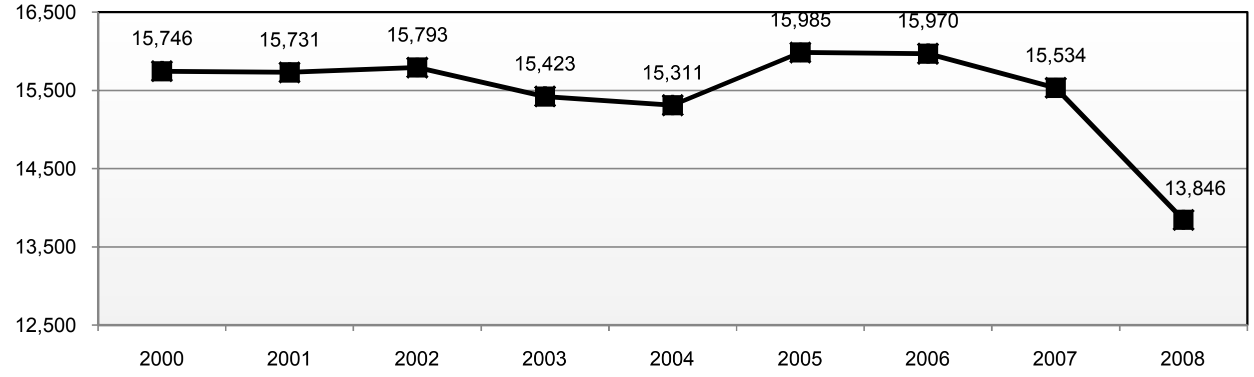
Alcohol

Alcohol-related driving is a serious public safety problem in the United States. In 2008, 13,846 Americans were killed in alcohol-related crashes on the Nation's highways. The NHTSA estimates that alcohol was involved in 41 percent of fatal crashes in 2008.

Exhibit 5-11 shows the number of fatalities attributable to alcohol between 2000 and 2008. Trends remained somewhat consistent in the number of alcohol-related fatalities during the period between 2000 and 2007; the number of alcohol-related fatalities declined by 10.9 percent from 2007 to 2008.

Exhibit 5-11

Alcohol-Related Fatalities, 2000–2008



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

Impaired Driving

The U.S. DOT works to discourage impaired driving through a three-pronged strategy: high-visibility law enforcement and education, enhanced prosecution and adjudication, and medical screening and brief intervention for alcohol abuse problems. Special emphasis is placed on reaching high-risk populations, including those under age 21, those 21–34, repeat offenders, and high-BAC (blood alcohol concentration) offenders.

In 2008, there were 13,846 fatalities in which either the driver or motorcycle operator had a BAC of 0.01 g/dL or greater. Of all fatalities attributable to alcohol in 2008, 27 percent occurred between the hours of midnight and 3 a.m.; alcohol-related fatalities represent 64 percent of all fatalities that occurred during those hours. Of the fatalities from crashes that involved a driver with a BAC of 0.08 g/dL (alcohol-impaired) or higher, 43 percent (3,432) involved a driver between the ages of 21 and 34 years old. The age group of drivers 20 and younger made up 9 percent of the total. Underage drinking and driving continues to be a major problem, despite years of education and law enforcement programs.

Speeding

Speeding is one of the most prevalent factors contributing to traffic crashes. The economic cost to society of speeding-related crashes is estimated by NHTSA to be $40.4 billion per year. In 2008, speeding was a contributing factor in 31 percent of all fatal crashes; 11,674 lives were lost in speeding-related crashes. In 2008, 35 percent of all motorcycle riders involved in fatal crashes were speeding, compared with 23 percent for passenger car drivers, 19 percent for light-truck drivers, and 8 percent for large-truck drivers.

In 2000, the cost of speeding-related crashes was estimated to be $76,865 per minute or $1,281 per second. Speeding reduces a driver's ability to steer safely around curves or objects in the roadway, extends the distance necessary to stop a vehicle, and increases the distance a vehicle travels while the driver reacts to a dangerous situation.

For drivers involved in fatal crashes, young males are the most likely to be speeding. The relative proportion of speeding-related crashes to all crashes decreases with increasing driver age. In 2008, 37 percent of male drivers in the 15- to 24-year-old age groups who were involved in fatal crashes were reported to be speeding at the time of the crash.

As shown by cases for which blood alcohol data are available, alcohol involvement is prevalent for drivers involved in speeding-related crashes. In 2008, 41 percent of drivers with a BAC of 0.08 g/dL or higher involved in fatal crashes were speeding, compared with only 15 percent of drivers with a BAC of 0.00 g/dL involved in fatal crashes. In 2008, 27 percent of the speeding drivers under age 21 who were involved in fatal crashes also had a BAC of 0.08 g/dL or higher. In contrast, only 12 percent of the nonspeeding drivers under age 21 involved in fatal crashes in 2008 had a BAC of 0.08 g/dL or higher.

Many speeding-related crashes are coupled with poor weather conditions. Speeding was a factor in 54 percent of the fatal crashes that occurred when there was snow or slush on the road and in 59 percent of those that occurred on icy roads. Speeding was a factor in 35 percent of those that occurred on wet roads.

Nearly one-half of all fatal crashes in 2008 occurred on roads with posted speed limits of 55 miles per hour or more, as compared with 23 percent of injury crashes and 23 percent of property-damage-only crashes. Although much of the public concern about speed-related crashes focuses on high-speed roadways, speeding is a safety concern on all roads. In 2008, about 22 percent (10,812) of drivers involved in fatal crashes were cited for driving too fast for conditions or in excess of posted speed limits—the second-highest driver factor cited for all fatal crashes.

While speeding has often been seen as a prevalent occurrence on major highways, 88 percent of speeding-related fatalities occurred on roads that were not Interstate System highways in 2008.

Crashes and Fatalities by Vehicle Type

Exhibit 5-12 shows the breakdown of occupant fatalities by vehicle type from 2000 to 2008. The number of occupant fatalities that involved passenger cars decreased from 20,699 in 2000 to 14,587 in 2008 (a decrease of 30 percent).

The number of occupant fatalities in light trucks decreased from 11,528 in 2000 to 10,764 in 2008 (a decrease of 6.6 percent). There were approximately 768,000 light-truck occupants injured in 2008, down from 886,566 in 2000.

The number of occupant fatalities in large trucks decreased by 10 percent, from 754 in 2000 to 677 in 2008. While occupants of large trucks represent less than 2 percent of all highway fatalities, total fatalities from crashes that involve large trucks (including both the occupants of large trucks and others killed in crashes involving large trucks) account for more than 11 percent of all highway fatalities. The number of all other

Exhibit 5-12

Fatalities for Vehicle Occupants by Type of Vehicle, 2000–2008

Type of Vehicle	2000	2002	2004	2006	2008	Percent Change 2008/2000
Motorists						
Passenger Cars	20,699	20,569	19,192	17,800	14,587	-29.5%
Light Trucks	11,528	12,273	12,674	12,722	10,764	-6.6%
Large Trucks	754	689	766	805	677	-10.2%
Motorcycles	2,897	3,270	4,028	4,810	5,290	82.6%
Buses	22	45	42	27	67	204.5%
Other and Unknown Vehicles	448	529	602	738	594	32.6%
Nonmotorists						
Pedestrians	4,763	4,851	4,675	4,784	4,378	-8.1%
Pedalcyclists	693	665	727	773	716	3.3%
Other and Unknown	141	114	130	183	188	33.3%
Total	**41,945**	**43,005**	**42,836**	**42,642**	**37,261**	**-11.2%**

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

vehicle occupants killed in crashes involving a large truck decreased by 24 percent, from 4,114 in 2000 to 3,139 in 2008. Approximately 90,000 people were injured in crashes involving large trucks in 2008.

The most significant, consistent increase in fatalities among vehicle types involved those who ride motorcycles. The number of motorcyclists who died in crashes increased each year between 2000 and 2008, rising by almost 83 percent over 8 years from 2,897 to 5,290. Motorcycle crashes are frequently speed-related. Speed is two times more likely to be a factor in fatal motorcycle crashes than in passenger car or light truck crashes. Studies also have shown that alcohol is more likely to be a factor in motorcycle crashes than in passenger car or light truck crashes.

Exhibit 5-13 describes the breakdown of occupant injuries between 2000 and 2008. The number of injuries decreased for passenger cars, buses, light trucks, and large trucks during that period. Injuries for motorcycle riders drastically increased during this same period, rising from 57,723 to approximately 96,000, an increase of more than 66 percent over 8 years.

Exhibit 5-13

Injuries for Vehicle Occupants by Type of Vehicle, 2000–2008

Type of Vehicle	2000	2002	2004	2006	2008	Percent Change 2008/2000
Motorists						
Passenger Cars	2,051,609	1,804,788	1,642,549	1,474,536	1,304,000	-36.4%
Light Trucks	886,566	879,338	900,171	856,896	768,000	-13.4%
Large Trucks	30,832	26,242	27,287	22,815	23,000	-25.4%
Motorcycles	57,723	64,713	76,379	87,652	96,000	66.3%
Buses	17,769	18,819	16,410	9,839	15,000	-15.6%
Other and Unknown Vehicles	10,120	6,187	7,262	10,843	9,000	-11.1%
Nonmotorists						
Pedestrians	78,000	71,000	68,000	61,000	69,000	-11.5%
Pedalcyclists	51,000	48,000	41,000	44,000	52,000	2.0%
Other and Unknown Vehicles	5,000	7,000	9,000	7,000	9,000	80.0%
Total	**3,188,619**	**2,926,087**	**2,788,058**	**2,574,581**	**2,345,000**	**-26.5%**

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

What are the recent trends for motorcycle fatalities and injuries per VMT?

While motorcycle fatalities increased consistently between 2000 and 2008, the year 2005 had the highest rate of fatalities per 100 million VMT within this time period. The 2005 rate of 43.77 fatalities per 100 million VMT was approximately 58 percent higher than the 2000 rate of 27.67. As shown in *Exhibit 5-14*, the rate of motorcycle fatalities per 100 million VMT was 36.62 in 2008. While this represents a 16 percent decrease from the 2005 rate, it is an increase of 32 percent over the 2000 rate.

The number of motorcycle injuries rose from 2000 to 2007, peaking at 103,000, dropping to 96,000 in 2008. The rate of motorcycle injuries per 100 million VMT peaked in 2005 at 835; this is 52 percent higher than the 2000 rate of 551. The rate of motorcycle injuries per 100 million VMT in 2008 was 663. This is a decrease of 21 percent from the 2005 peak but remains a 20 percent increase over the 2000 rate.

Exhibit 5-14

Motorcycle Fatalities and Injuries per 100 Million VMT, 2000–2008

Year	Fatality Rate per 100 Million VMT	Injury Rate per 100 Million VMT
2000	27.67	551
2001	33.17	625
2002	34.23	677
2003	38.78	701
2004	39.79	755
2005	43.77	835
2006	40.14	727
2007	37.99	756
2008	36.62	663

Source: Fatality Analysis Reporting System/National Center for Statistics and Analysis, and the General Estimates System for Injuries, NHTSA.

Transit Safety

Transit operators report safety information to the National Transit Database for three major categories: incidents, injuries, and fatalities. In 2002, the Federal Transit Administration revised the definitions of an "incident" and an "injury." Given that there is no "statistical bridge" across the change in definitions, this chapter provides only injury and incident data from 2002 onward. Data on injuries and incidents prior to 2002, which are not comparable with the new data, are available in the 2004 C&P Report.

An incident is recorded by a transit agency for a variety of events occurring on transit property or vehicles, involving transit vehicles, or to persons using the transit system. Included among these is any event that results in significant property damage, one or more reported injuries, one or more reported fatalities, or some combination thereof. Since 2002, the definition of "significant property damage" has been total property damage in excess of $7,500 (in current-year dollars, not indexed to inflation).

Since 2002, an injury has been reported only when a person has been immediately transported away from the scene of a transit incident for medical care. Any event producing a reported injury is also reported as an incident.

The definition of a transit-related fatality was not revised in 2002. A transit-related fatality is reported for any death occurring within 30 days of a transit incident which is confirmed to be a result of that incident. Fatality data are provided from 2000 through 2008.

Injuries and fatalities include those suffered by riders, as well as those suffered by pedestrians, bicyclists, and people in other vehicles. Injuries and fatalities may occur while traveling on transit or while boarding, alighting, or waiting for transit vehicles to arrive. An injury or fatality may also occur while not using transit, such as in the cases of being struck by a transit vehicle or, in the case of a collision, in a transit station parking lot.

Q&A

What sort of events result in a recorded transit incident?

A transit agency records an incident for any event occurring on transit property, onboard 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 in excess of $7,500
- An evacuation for life safety reasons
- A mainline derailment (i.e., occurring on a revenue service line, regardless of whether the vehicle was in service or out of service)
- A fire.

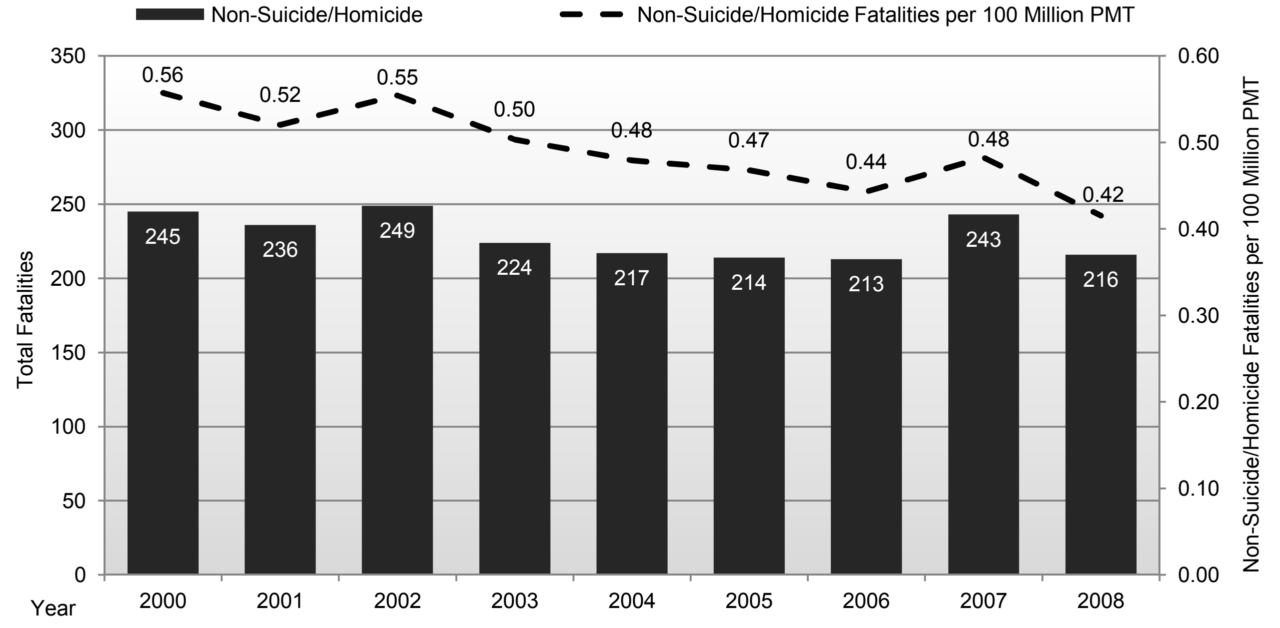
Additionally, an incident is recorded by a transit agency whenever one of the following security situations occurs on transit property, onboard or involving transit vehicles, or to persons using the transit system:

- A robbery, burglary, or theft
- A rape
- A suicide or attempted suicide
- An aggravated assault
- An arrest or citation, such as for trespassing, vandalism, fare evasion, or assault
- A bomb threat
- A bombing
- A release of chemical, biological, nuclear, or radiological materials
- A cybersecurity incident
- A hijacking
- A nonviolent civil disturbance that results in the disruption of transit service
- A sabotage.

Exhibit 5-15 shows annual fatalities for transit services in both absolute numbers and adjusted according to the number of passenger miles traveled (PMT) in each year for 2000 to 2008. Fatality numbers include reported incidents on commuter rail, heavy rail, light rail, demand response, and motor bus but exclude suicides and homicides. Both the count of 216 fatalities for 2008 and the rate of 0.42 fatalities per 100 million passenger miles demonstrate that transit is an extremely safe mode of transportation. With the fatality count steadily trending down since 2002, it experienced an unexplained increase of 30 deaths in 2007. This significant increase was not the result of any single incident. The fatality count in 2008 dropped back to the pre-2007 levels in spite of the September 13, 2008, collision between a Metrolink commuter train and a Union Pacific freight train in Chatsworth, California, that killed 25 and injured 135.

Exhibit 5-15

Annual Transit Fatalities (Non-Suicide/Homicide), 2000–2008



Note: Exhibit includes data for commuter rail, demand response, heavy rail, light rail, and motor bus. Also, fatality totals include both directly operated (DO) and purchase transportation (PT) service types.

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

Exhibit 5-16 provides total incidents and injuries both in absolute terms and per 100 million PMT. A trend toward fewer incidents is apparent over the most recent 3 years, but there is no comparable downward trend in injuries. It is notable that the injury rate was low in 2007, even though the fatality rate was high that year. *Exhibit 5-17* lists injuries and fatalities for the most significant light and heavy rail transit accidents for 2008, 2009, and 2010. As this exhibit indicates, the total injuries and fatalities in this time period are due to numerous accidents and no one accident accounts for the majority of the total; therefore, increases in annual injury and fatality

Exhibit 5-16

Annual Incidents and Injuries, 2004–2008

	Incidents		Injuries	
Year	**Total**	**Per 100 Million PMT**	**Total**	**Per 100 Million PMT**
2004	24,031	58.00	20,439	49.33
2005	23,578	56.71	19,201	46.18
2006	25,572	59.07	20,857	48.17
2007	25,525	50.67	23,567	45.32
2008	24,898	47.88	26,228	50.43

Note: Exhibit includes data for commuter rail, demand response, heavy rail, light rail, and motor bus.

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

Exhibit 5-17

Injuries and Fatalities for Significant Accidents, 2008–2010

Agency	Date	Mode	Injuries	Fatalities
Washington Metropolitan Area Transit Authority	3-Oct-09	Heavy Rail	70	9
Miami-Dade Transit	4-Mar-09	Heavy Rail	3	3
MTA New York City Transit	2-Apr-10	Heavy Rail	3	2
Utah Transit Authority	28-Mar-10	Light Rail	4	2
Washington Metropolitan Area Transit Authority	16-Feb-10	Heavy Rail	2	2
Maryland Transit Administration	10-Aug-09	Light Rail	2	2
Chicago Transit Authority	23-May-08	Heavy Rail	20	2
Massachusetts Bay Transportation Authority	1-Oct-09	Light Rail	49	0
San Francisco Municipal Railway	23-Feb-10	Light Rail	40	0
The Greater Cleveland Regional Transit Authority	5-Oct-10	Heavy Rail	25	0

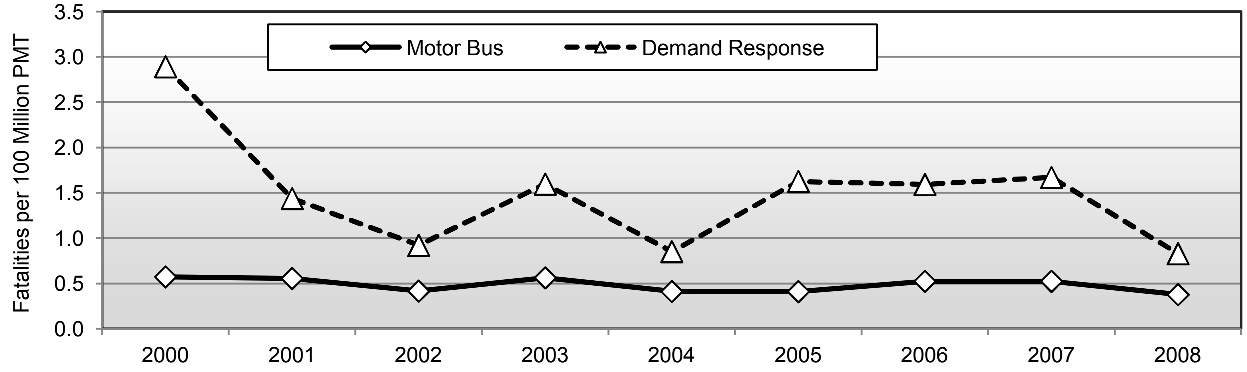
Source: National Transit Database.

rates are not merely the result of one or two bad incidents. However, multi-injury incidents (like the above-mentioned Chatsworth collision) must account for the absolute number of injuries being greater than the number of incidents in 2008.

Exhibit 5-18 shows fatality rates per 100 million PMT for motor bus and demand response (excluding suicides and homicides). The data indicate demand response experienced a significant decrease in fatality rates in 2008 while motor bus experienced a less dramatic decrease. Absolute fatalities are not comparable across modes because of the wide range of passenger miles traveled on each mode and are therefore not provided. *Exhibit 5-19* shows fatality rates per 100 million PMT for commuter rail, heavy rail, and light rail (excluding suicides and homicides). While no trends are apparent in this data, it appears to indicate that heavy rail is the statistically safest mode of travel.

Exhibit 5-18

Annual Transit Fatality Rates by Highway Mode, 2000–2008

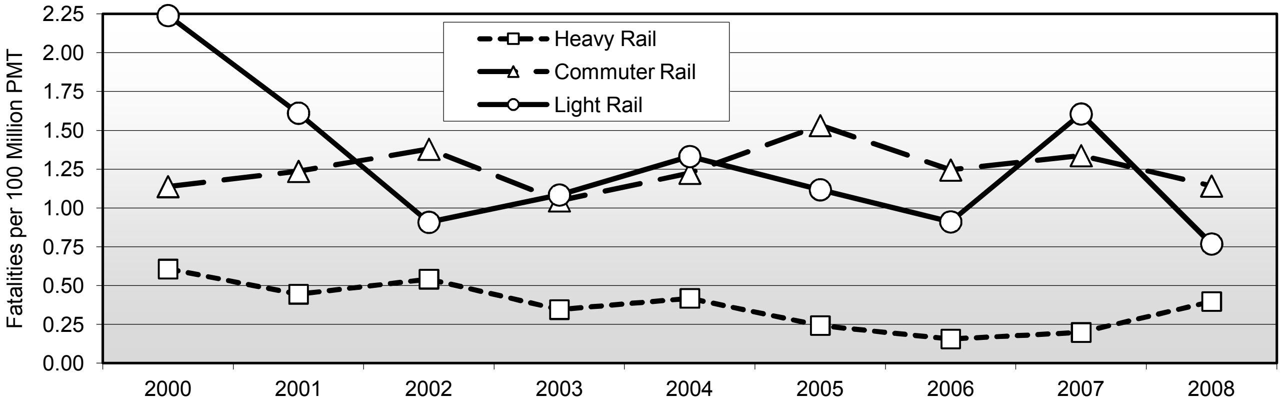


Note: Fatality totals include both DO and PT service types.

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

Exhibit 5-19

Annual Fatality Rates by Rail Mode, 2000–2008



Note: Fatality totals include both DO and PT service types.

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

Exhibit 5-20 provides data on incidents and injuries per 100 million PMT for transportation services on the five largest modes from 2004 to 2008 (excluding suicides and homicides). This data suggests that the highway modes (motor bus and demand response) became significantly safer in 2007 and 2008; however, given this dramatic decrease is unexplained, the data for these years may also suggest a reporting inconsistency. Data for the rail modes is volatile, but does not suggest any significant positive or negative trends over this period.

Exhibit 5-20

Transit Incidents and Injuries by Mode, 2004–2008

Analysis Parameter	2004	2005	2006	2007	2008
Incidents per 100 Million PMT					
Motor Bus	77.31	74.31	78.71	66.02	54.15
Heavy Rail	44.57	39.79	42.24	43.15	52.83
Commuter Rail	20.13	21.51	18.84	17.93	16.18
Light Rail	63.15	67.37	61.62	61.18	48.48
Demand Response	895.24	1,010.24	1,298.07	247.39	204.28
Injuries per 100 Million PMT					
Motor Bus	75.56	70.08	70.84	68.57	66.89
Heavy Rail	32.88	26.17	32.41	31.08	43.11
Commuter Rail	16.84	21.05	16.50	17.60	16.31
Light Rail	41.84	36.59	35.76	43.67	48.34
Demand Response	448.50	506.00	729.47	227.33	234.50

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

Exhibit 5-21 shows the number of fatalities per 100 incidents for each of the five largest transit modes from 2004 to 2008. This metric does not represent the percentage of incidents that are fatal, as some incidents result in multiple fatalities. The metric does, however, show the likelihood that a fatality will result from an incident. Although commuter rail has a very low number of incidents per PMT (as indicated in *Exhibit 5-20*), commuter rail incidents are far more likely to result in a fatality than incidents occurring

Exhibit 5-21

Fatalities per 100 Incidents by Mode, 2004–2008

Mode	2004	2005	2006	2007	2008
Motor Bus	0.63	0.63	0.76	0.79	0.70
Heavy Rail	0.96	0.61	0.37	0.46	0.75
Commuter Rail	6.86	8.16	7.52	7.46	7.06
Light Rail	2.24	1.68	1.50	2.62	1.59
Demand Response	0.29	0.50	0.43	0.68	0.41

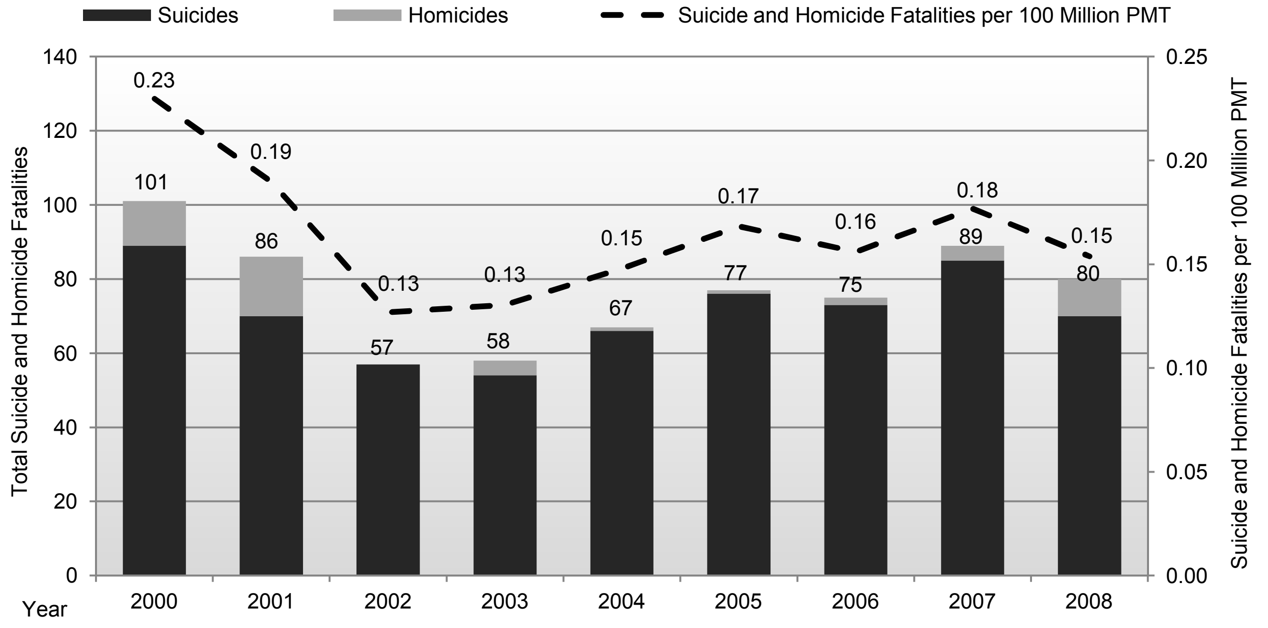
Source: National Transit Database—Transit Safety and Security Statistics and Analysis Reporting.

on any other mode. Most likely, this is because the average speed of commuter rail vehicles is considerably higher than the other modes (except vanpools). Motor buses, on the other hand, have a high number of incidents per PMT, but a lower chance of having an incident result in a fatality than almost any other mode (perhaps related to their low average speed). While light rail and motor bus modes of transit have similar numbers of incidents per PMT, an incident on light rail is approximately 2.3 times more likely to produce a fatality than an incident on a motor bus, based on 2008 data. It is possible that this is a result of the higher mass and longer stopping distance of light rail vehicles relative to motorbuses. It could also be that light rail vehicles attract more suicide attempts, some of which may not be recognizable as such and are not excluded from the fatality count.

Suicides and homicides represented about a quarter of transit fatalities in 2008, perhaps a bit more since it is possible not all suicide attempts are recognized as such. Data on these fatalities since 2000 are shown in *Exhibit 5-22*, which indicates a modest upward trend.

Exhibit 5-22

Annual Transit Suicide and Homicide Fatalities, 2000–2008



Note: Exhibit includes data for commuter rail, demand response, heavy rail, light rail, and motor bus. Also, fatality totals include both DO and PT service types.

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

Chapter 6

Finance

Highway Finance

This section presents a detailed look at highway finance trends, beginning with revenue sources that support public investment in highways and bridges across all levels of government. This is followed by a detailed analysis of highway expenditures in general and highway capital outlay. A separate section within this chapter explores the financing of transit systems.

Revenue Sources for Highways

As shown in *Exhibit 6-1*, all levels of government combined generated $192.7 billion in 2008 to fund spending on highway and bridges. Actual cash expenditures during the same year for highways and bridges were lower, totaling $182.1 billion. The difference was placed in reserves for expenditure in future years.

The $1.9 billion difference between total revenues and total expenditures in the "Federal" column in *Exhibit 6-1* corresponds to an increase in the cash balance in the Highway Account of the Highway Trust Fund (HTF) of that amount in

Private Sector Financing

Financing for highways comes from both the public and private sectors. The private sector has increasingly played a role in the delivery of highway infrastructure, but the vast majority of funding is still provided by the public sector. The financial statistics presented in this chapter are predominantly drawn from State reports based on State and local accounting systems. Figures in these systems can include some private sector investment; where it does, these amounts are generally classified as "other receipts." For additional information on private sector investment in highways, see http://www.fhwa.dot.gov/ipd/p3/index.htm.

Exhibit 6-1

Government Revenue Sources for Highways, 2008

	Highway Revenue, Billions of Dollars				
Source	**Federal**	**State**	**Local**	**Total**	**Percent**
User Charges*					
Motor-Fuel Taxes	$26.2	$30.0	$1.5	$57.7	29.9%
Motor-Vehicle Taxes and Fees	$4.7	$21.4	$1.1	$27.2	14.1%
Tolls	$0.0	$7.5	$1.8	$9.3	4.8%
Subtotal	**$30.8**	**$59.0**	**$4.3**	**$94.2**	**48.9%**
Other					
Property Taxes and Assessments	$0.0	$0.0	$8.3	$8.3	4.3%
General Fund Appropriations	$10.6	$6.8	$23.0	$40.4	21.0%
Other Taxes and Fees	$0.5	$7.0	$5.0	$12.4	6.5%
Investment Income and Other Receipts	$0.0	$10.6	$6.8	$17.5	9.1%
Bond Issue Proceeds	$0.0	$14.3	$5.7	$19.9	10.3%
Subtotal	**$11.1**	**$38.7**	**$48.8**	**$98.6**	**51.1%**
Total Revenues	**$41.9**	**$97.7**	**$53.1**	**$192.7**	**100.0%**
Funds Drawn From (or Placed in) Reserves	($1.9)	($7.1)	($1.6)	($10.7)	-5.5%
Total Expenditures Funded During 2008	**$40.0**	**$90.6**	**$51.5**	**$182.1**	**94.5%**

** Amounts shown represent only the portion of user charges that are used to fund highway spending; a portion of the revenue generated by motor-fuel taxes, motor-vehicle taxes and fees, and tolls is used for mass transit and other nonhighway purposes. Gross receipts generated by user charges totaled $122.1 billion in 2008.*

Sources: Highway Statistics 2008, Table HF-10, and unpublished FHWA data.

2008. However, it is important to note that these revenues include a legislatively mandated transfer of $8.0 billion from the Federal General Fund to the HTF in September 2008. The annual proceeds from the taxes and fees dedicated to the Highway Account of the HTF have fallen below annual expenditures in recent years; additional transfers of general revenues to the HTF have subsequently occurred in FY 2009 and FY 2010 to keep the account solvent. In 2008, 48.9 percent of the total revenues for highway and bridges were provided from highway-user charges—including motor-fuel taxes, motor-vehicle taxes and fees, and tolls. The remaining 51.1 percent of revenues came from a number of sources, including local property taxes and assessments, other dedicated taxes, general funds, bond issues, investment income, and other miscellaneous sources.

The degree to which highway programs are funded by highway-user charges differs widely among the different levels of government. At the Federal level, $30.8 billion (73.6 percent) of highway revenues came from motor-fuel and motor-vehicle taxes in 2008. (It should be noted that this share was unusually low due to the transfer of general revenues to the HTF in 2008; from 1985 through 2007, the share of highway revenues at the Federal level derived from motor-fuel and motor-vehicle taxes exceeded 90 percent in each year.) The remaining $11.1 billion in revenues at the Federal level came from general fund appropriations, other taxes and fees (timber sales, mineral leases, etc.), and other receipts (interest income, fines and penalties, etc.); this includes the transfer of general revenues to the HTF, as well as additional revenues that cover highway-related activities of various Federal agencies that are not funded by the HTF.

Debt Financing Tools

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

Three innovative debt instrument tools—Grant Anticipation Revenue Vehicles (GARVEEs), Private Activity Bonds (PABs), and Build America Bonds (BABs)—provide further borrowing opportunities. A GARVEE is a debt financing instrument—such as a bond, note, certificate, mortgage, lease, or other debt financing technique—that has a pledge of future Federal-aid funding. PABs are debt instruments issued by State or local governments on behalf of a private entity for highway and freight transfer projects, allowing a private project sponsor to benefit from the lower financing costs of tax-exempt municipal bonds. BABs, which were authorized by the American Recovery and Reinvestment Act (Recovery Act), are taxable bonds that are eligible for an interest rate subsidy paid directly from the U.S. Treasury. The Recovery Act allows States and local governments to issue BABs through December 2010. Additional information on Federal debt financing tools is available at http://www.fhwa.dot.gov/ipd/finance/tools_programs/federal_debt_financing/index.htm.

At the State level, highway-user charges provided $59.0 billion or 60.4 percent of total highway revenues in 2008. Bond sales were another significant source of funding, contributing $14.3 billion (14.6 percent) toward total State highway revenues.

Many States do not permit local governments to impose motor-fuel and motor-vehicle taxes, or they cap them at relatively low levels. Therefore, at the local government level, only $4.3 billion (8.2 percent) of highway funding was provided by highway-user charges in 2008. General fund appropriations contributed $23.0 billion (43.3 percent) toward total local highway revenues, while property taxes generated $8.3 billion (15.7 percent).

The "Investment Income and Other Receipts" category in *Exhibit 6-1* includes development fees and special district assessments. Other private sector investment in highways would also be reflected in this category, to the extent that such investment is captured in State and local accounting systems.

Federal Credit Assistance

Federal credit assistance for surface transportation improvements can take one of two forms: loans, where project sponsors borrow Federal highway funds directly from a State DOT or the Federal government; and credit enhancements, where a State DOT or the Federal government makes Federal funds available on a contingent (or standby) basis. Credit enhancement helps reduce risk to investors and thus allows project sponsors to borrow at lower interest rates. Loans can provide the capital necessary to proceed with a project, and reduce the amount of capital borrowed from other sources, and may also serve a credit enhancement function by reducing the risk borne by other investors. Federal tools currently available to project sponsors include the Transportation Infrastructure and Finance Innovation Act (TIFIA) program, State Infrastructure Bank (SIB) programs, and Section 129 loans.

The TIFIA Credit Program provides Federal credit assistance in the form of direct loans, loan guarantees, and standby lines of credit to finance surface transportation projects of national and regional significance. A TIFIA project must pledge repayment in whole or in part with dedicated revenue sources such as tolls, user fees, special assessments (taxes), or other non-Federal sources. SIBs are State-run revolving funds that provide loans, credit enhancements, and other forms of non-grant assistance to surface transportation projects. SIBs can be capitalized with regularly apportioned Federal-aid funds. Section 129 loans allow States to lend apportioned Federal-aid highway funds to toll and non-toll projects generating dedicated revenue streams. Additional information on credit assistance tools is available at http://www.fhwa.dot.gov/ipd/finance/tools_programs/federal_credit_assistance/index.htm.

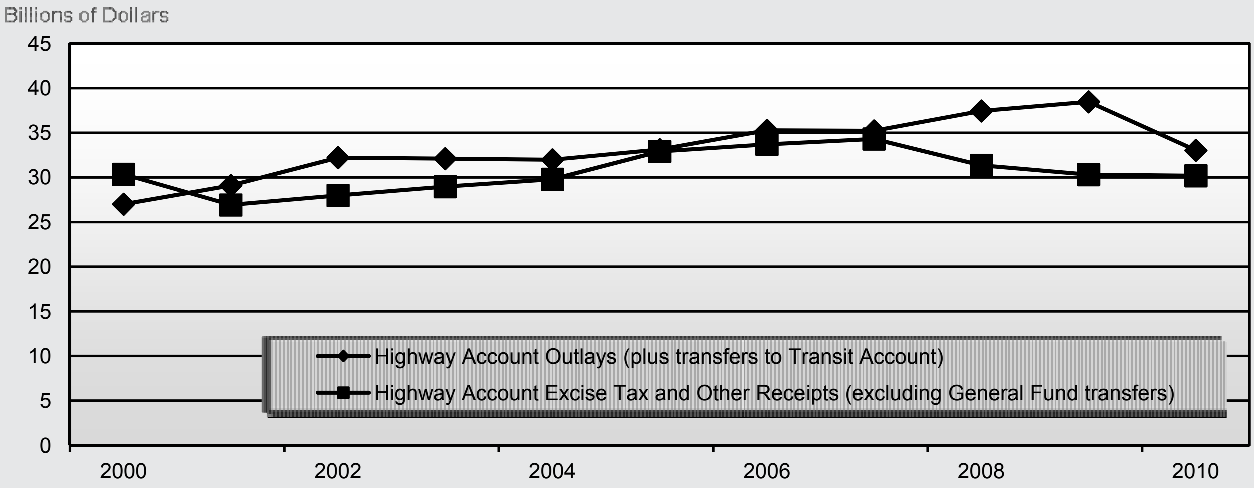
How long has it been since excise tax revenue deposited into the Highway Account exceeded expenditures?

The last time that annual net receipts credited to the Highway Account of the HTF exceeded annual expenditures from the Highway Account was in 2000. As shown in *Exhibit 6-2*, for each year since 2000, total annual receipts to the Highway Account from excise taxes and other income (such as interest income and motor carrier safety fines and penalties) have been lower than the annual expenditures from the Highway Account (including amounts transferred to the Transit Account).

To help maintain a positive cash balance in the HTF, three transfers from the General Fund to the HTF were legislatively mandated in FY 2008, FY 2009, and FY 2010. From FY 2007 to FY 2010, gross excise tax receipts from gasoline, diesel and special motor fuels, tires, trucks and trailers, and the heavy vehicle use tax all declined.

Exhibit 6-2

Highway Trust Fund Highway Account Receipts and Outlays, Fiscal Years 2000–2010



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

Were all revenues generated by motor-fuel taxes, motor-vehicle taxes and fees, and tolls in 2008 used for highways?

No. The $94.2 billion identified as highway-user charges in *Exhibit 6-3* represents only 77.1 percent of total highway-user revenue, defined as all revenue generated by motor-fuel taxes, motor-vehicle taxes, and tolls. *Exhibit 6-3* shows that combined highway-user revenue collected in 2008 by all levels of government totaled $122.1 billion.

In 2008, $15.3 billion of highway-user revenue was used for transit, and $12.7 billion was used for other purposes, such as ports, schools, collection costs, and general government activities. The $0.3 billion shown as Federal highway-user revenue used for other purposes reflects the difference between total collections in 2008 and the amounts deposited into the HTF during FY 2008. Much of this difference is attributable to the proceeds of 0.1 cent of the motor-fuel tax being deposited into the Leaking Underground Storage Tank trust fund.

Exhibit 6-3

Disposition of Highway-User Revenue by Level of Government, 2008

	Revenue, Billions of Dollars			
	Federal	**State**	**Local**	**Total**
Highways	$30.8	$59.0	$4.3	$94.2
Transit	$5.4	$8.8	$1.0	$15.3
Other	$0.3	$12.3	$0.1	$12.7
Total Collected	**$36.6**	**$80.1**	**$5.4**	**$122.1**

Sources: Highway Statistics 2008, Table HF-10, and unpublished FHWA data.

The $5.4 billion shown as Federal highway-user revenue used for transit includes deposits into the Transit Account of the HTF, as well as deposits into the Highway Account of the HTF that States elected to use for transit purposes.

Public-Private Partnerships

Public-Private Partnerships (P3s) are contractual agreements formed between a public agency and a private sector entity that allow for greater private sector participation in the delivery and financing of transportation projects. Typically, this participation involves the private sector taking on additional project risks, such as design, finance, long-term operation, maintenance, or traffic revenue. P3s are undertaken for a variety of purposes, including monetizing the value of existing assets, developing new transportation facilities, or rehabilitating or expanding existing facilities. While P3s may offer certain advantages, such as increased financing capacity and reduced costs, the public sector still must identify a source of revenue for the project, in order to provide a return to the private partner's involvement, and must ensure that the goals and interests of the public are adequately secured. Additional information on P3s is available at http://www.fhwa.dot.gov/ipd/p3/index.htm.

Revenue Trends

Since the passage of the Federal-Aid Highway Act of 1956 and the establishment of the HTF, user charges such as motor-fuel and motor-vehicle tax receipts have consistently provided a majority of the combined revenues raised for highway and bridge programs by all levels of government.

Exhibit 6-4 shows the trends for highway revenue sources by all levels of government between 2000 and 2008. While motor-fuel and motor-vehicle taxes continue to account for a large percentage of highway funding, revenues from this source grew at an average annual rate of only 1.5 percent over this period, well below the 4.9 percent average annual rate for all types of highway revenues. In contrast, revenues from "Investment Income and Other Receipts" and "Other Taxes and Fees" increased at average annual rates of 11.4 percent and 10.2 percent, respectively, between 2000 and 2008. The "General Fund Appropriations" category showed a 9.7 percent average annual increase between 2000 and 2008; a portion of this increase is attributable to the transfer of Federal general revenues to the HTF referenced earlier.

Exhibit 6-4

Government Revenue Sources for Highways, 2000–2008

Source	Highway Revenue, Billions of Dollars 2000	2002	2004	2006	2008	Annual Rate of Change 2008/2000
Motor-Fuel and Motor-Vehicle Taxes	$75.6	$73.1	$76.4	$85.4	$84.9	1.5%
Tolls	$5.7	$6.6	$6.6	$8.3	$9.3	6.2%
Property Taxes and Assessments	$6.1	$6.5	$7.5	$9.0	$8.3	3.9%
General Fund Appropriations	$19.3	$20.3	$23.6	$28.3	$40.4	9.7%
Other Taxes and Fees	$5.7	$7.5	$7.9	$10.1	$12.4	10.2%
Investment Income and Other Receipts	$7.3	$8.1	$7.6	$9.7	$17.5	11.4%
Bond Issue Proceeds	$11.3	$12.7	$15.8	$18.3	$19.9	7.4%
Total Revenues	**$131.1**	**$134.8**	**$145.3**	**$169.0**	**$192.7**	**4.9%**

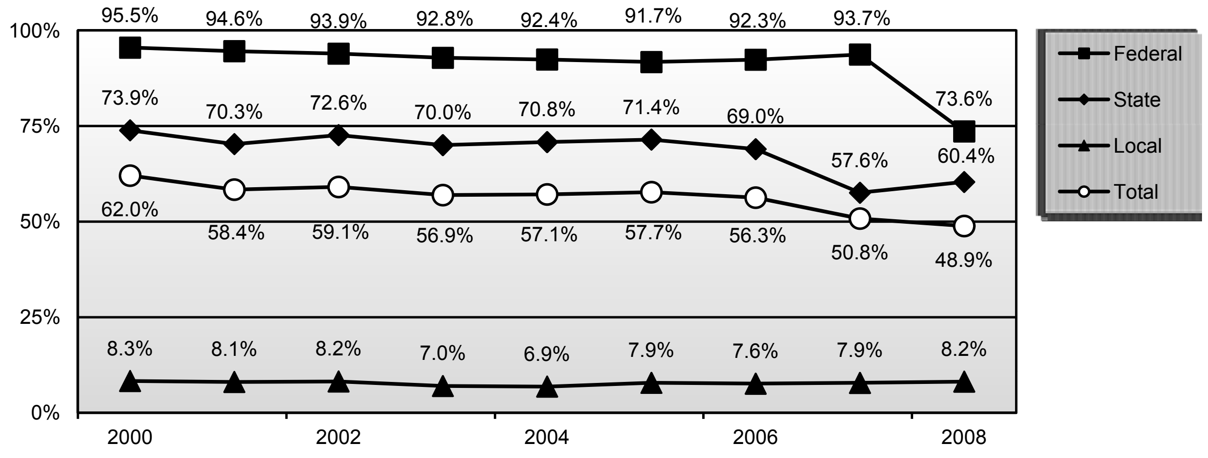
Sources: Highway Statistics, various years, Tables HF-10A and HF-10.

As shown in *Exhibit 6-5*, the percentage of Federal highway revenue derived from user charges declined from 95.5 percent in 2000 to 93.7 percent in 2006, followed by a steep drop to 73.6 percent in 2008 attributable to the transfer of general revenues to the HTF. At the State government level, the portion of highway funding from user charges has also declined, dropping from 73.9 percent to 60.4 percent over this period. States diversified their highway revenue sources of this period and relied more heavily on debt financing.

Highway-user charges have never been as significant a source of highway revenue at the local government level as at the Federal or State levels. The share of local government highway revenues derived from highway-user charges was 8.3 percent in 2000, decreasing to 6.9 percent in 2004, and then increasing to 8.2 percent in 2008.

Exhibit 6-5

Percent of Highway Revenue Derived From User Charges, Each Level of Government, 2000–2008



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

Highway Expenditures

As indicated earlier in *Exhibit 6-1*, total expenditures for highways in 2008 equaled $182.1 billion. *Exhibit 6-6* classifies this total by type of expenditure and level of government. The “Federal,” “State,” and “Local” columns in *Exhibit 6-6* indicate which level of government made the direct expenditures, while the

Exhibit 6-6

Direct Expenditures for Highways, by Expending Agencies and by Type, 2008

	Highway Expenditures, Billions of Dollars				
	Federal	**State**	**Local**	**Total**	**Percent**
Expenditures by Type					
Capital Outlay	**$0.7**	**$67.5**	**$22.9**	**$91.1**	**50.1%**
Noncapital Expenditures					
Maintenance	$0.5	$13.0	$18.7	$32.1	17.6%
Highway and Traffic Services	$0.0	$7.5	$5.3	$12.8	7.1%
Administration	$1.7	$8.2	$4.9	$14.7	8.1%
Highway Patrol and Safety	$0.0	$7.7	$6.9	$14.6	8.0%
Interest on Debt	$0.0	$6.0	$2.5	$8.5	4.7%
Subtotal	**$2.2**	**$42.3**	**$38.2**	**$82.7**	**45.4%**
Total, Current Expenditures	**$2.9**	**$109.9**	**$61.1**	**$173.9**	**95.5%**
Bond Retirement	**$0.0**	**$4.3**	**$3.9**	**$8.2**	**4.5%**
Total, All Expenditures	**$2.9**	**$114.2**	**$65.0**	**$182.1**	**100.0%**
Funding Sources for Capital Outlay					
Funded by Federal Government*	*$0.7*	*$36.0*	*$1.1*	*$37.8*	***41.5%***
Funded by State or Local Govt's*	*$0.0*	*$31.5*	*$21.8*	*$53.3*	*58.5%*
Total	***$0.7***	***$67.5***	***$22.9***	***$91.1***	***100.0%***
Funding Sources for Total Expenditures					
Funded by Federal Government*	*$2.9*	*$36.0*	*$1.1*	*$40.0*	***22.0%***
Funded by State Governments*	*$0.0*	*$75.7*	*$14.8*	*$90.6*	*49.7%*
Funded by Local Governments*	*$0.0*	*$2.4*	*$49.1*	*$51.5*	*28.3%*
Total	***$2.9***	***$114.1***	***$65.0***	***$182.1***	***100.0%***

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

Sources: Highway Statistics 2008, Table HF-10, and unpublished FHWA data.

How was the $40.0 billion figure for Federal contributions to total highway expenditures derived, and why does this figure differ from amounts that appear in other documents (e.g., the President's Budget)?

Q&A

The Federal expenditures shown in this report are intended to reflect the highway-related activities of all Federal agencies, rather than just those of the traditional transportation agencies such as FHWA. The figures shown in this report draw from the same source data presented in Tables HF-10 and HF-10A in the annual *Highway Statistics* publication, which are linked to data for highway expenditures on an agency-by-agency basis at the Federal level presented in Tables FA-5 and FA-5R. These data represent cash outlays, rather than obligations (which are more relevant in terms of the annual Federal budget) or authorizations (which are more relevant in terms of multiyear authorization bills). Since the financial data reported by State and local governments are compiled on a cash basis, this report uses the same basis for Federal expenditures to ensure consistency.

These Federal spending figures rely on data from a mix of Federal, State, and local sources; in some cases, the *Highway Statistics* tables capture Federal funding for highways that is not otherwise tracked at the Federal level. For example, under current law, 25 percent of the receipts derived from Federal timber sales are to be paid to States for public roads and schools in the counties where forests are situated. At the time these payments are made, it is often unknown what portion will ultimately be used for roads as opposed to schools; however, once States have expended these funds, they report to FHWA what portion was used for roads so that this information may be included.

Note that the Federal highway funding figures in this report exclude any amounts funded from the Highway Account of the Federal HTF that were used for transit purposes as identified in *Highway Statistics.* Such amounts would appear as Federal funding for transit in this report.

The $37.8 billion Federal contribution to total capital expenditures represents total Federal highway expenditures of $40.0 billion, less direct Federal expenditures for noncapital purposes such as maintenance on Federally owned roads, administrative costs, and research.

rows "Funding Sources for Capital Outlay" and "Funding Sources for Total Expenditures" indicate the level of government that provided the funding for those expenditures. Note that all amounts cited as "expenditures," "spending," or "outlays" in this report represent cash expenditures rather than authorizations or obligations.

While the Federal government funded $40.0 billion of total highway expenditures in 2008, the majority of the Federal government's contribution to highways consists of transfers to State and local governments. Direct Federal spending on capital outlay, maintenance, administration, and research amounted to only $2.9 billion. The remaining $37.1 billion was in the form of transfers to State and local governments.

State governments combined $36.0 billion of Federal funds with $75.7 billion of State funds and $2.4 billion of local funds to make direct expenditures of $114.1 billion (62.6 percent). Local governments combined $1.1 billion of Federal funds with $14.8 billion of State funds and $49.1 billion of local funds to make direct expenditures of $65.0 billion (35.6 percent).

Types of Highway Expenditures

Exhibit 6-6 classifies highway expenditure by type. Total highway expenditures are divided into two categories: bond retirement, which represents the costs associated with paying off the principal of bonds issued in the past to support highway spending; and current expenditures, which include all spending that has a direct impact on the highway system today. Current expenditures are further subdivided into capital outlay and noncapital expenditures.

Q&A

What is the distinction between "total expenditures" and "current expenditures"?

The difference relates to expenditures for bond retirement, which are not included as part of current expenditures. When looking at cash outlays for a particular year, total expenditures is more relevant, as it measures the full scope of highway-related activity. However, when summing expenditures across years, it is sometimes more appropriate to use current expenditures. For example, if bonds were issued to pay for a capital project, and retired 20 years later, then summing total expenditures over 20 years would effectively capture this transaction twice, as both the initial capital expenditure and the retirement of the bonds would be included. In such instances, summing current expenditures over time (excluding bond retirement) may provide a more accurate reflection of cumulative investment.

It should be noted that refunding bond transactions (bonds issued in the current year to immediately retire bonds issued in previous years) are excluded from both the total revenue and total expenditure figures presented in this chapter.

Highway capital outlay consists of those expenditures associated with highway improvements. Improvements include land acquisition and other right-of-way costs; preliminary and construction engineering; new construction, reconstruction, resurfacing, rehabilitation, and restoration; and installation of guardrails, fencing, signs, and signals. Noncapital highway expenditures include maintenance of highways, highway and traffic services, administration, highway law enforcement, highway behavioral safety, and interest on debt.

Q&A

What basis is used for distinguishing between capital expenditures and maintenance expenditures?

The classification of the revenue and expenditure items in this report is based on definitions contained in *A Guide to Reporting Highway Statistics,* the instructional manual for States providing financial data for the *Highway Statistics* publication.

Other definitions of maintenance are used by different organizations. Some resurfacing, restoration, and rehabilitation projects that meet this report's definition of capital outlay might be classified as maintenance activities in internal State or local accounting systems.

As shown in *Exhibit 6-6*, in 2008 all levels of government spent $91.1 billion (50.1 percent) of highway expenditures on capital outlay. Additional information on types of capital outlay and the distribution of capital outlay by type of highway facility is presented later in this chapter. Combined spending on maintenance and traffic services of $45.0 billion represented 24.7 percent on total highway expenditures.

Expressed as a percentage, most Federal funding for highways goes for capital outlay; noncapital expenditures are funded primarily by State and local governments. The Federal government funded 41.5 percent of capital outlay in 2008, but only 22.0 percent of total highway expenditures.

How are "maintenance" and "highway and traffic services" defined in this report?

Maintenance in this report includes routine and regular expenditures required to keep the highway surface, shoulders, roadsides, structures, and traffic control devices in usable condition. This includes completing spot patching and crack sealing of roadways and bridge decks and maintaining and repairing highway utilities and safety devices such as route markers, signs, guardrails, fence, signals, and highway lighting.

Highway and traffic services include activities designed to improve the operation and appearance of the roadway. This includes items such as the operation of traffic control systems, snow and ice removal, highway beautification, litter pickup, mowing, toll collection, and air quality monitoring.

In terms of direct expenditures by expending agency, State expenditures represent a majority of total spending for each type of expenditure except for maintenance. Local governments spent $18.7 billion on maintenance in 2008, which is 58.2 percent of total maintenance spending by all levels of government combined.

Expenditure and Funding Trends

Exhibit 6-7 shows highway expenditures by all levels of government between 2000 and 2008. Total highway expenditures grew by 48.4 percent (5.1 percent per year) in nominal dollar terms over this period, rising from $122.7 billion to $182.1 billion. Capital outlay by all levels of government increased by 48.6 percent (5.1 percent per year) in nominal dollar terms over the same period, from $61.3 billion to $91.1 billion. Highway patrol and safety expenditures rose more slowly than other types of expenditures, increasing at an average annual rate of 3.5 percent per year; interest on debt grew more quickly than other types, growing by 8.0 percent annually.

Exhibit 6-7

Expenditures for Highways by Type, All Units of Government, 2000–2008

	Highway Expenditures, Billions of Dollars					Annual Rate of Change
Expenditure Type	**2000**	**2002**	**2004**	**2006**	**2008**	**2008/2000**
Capital Outlay	$61.3	$68.2	$70.3	$80.2	$91.1	5.1%
Maintenance and Traffic Services	$30.6	$33.2	$36.3	$40.8	$45.0	4.9%
Administration	$10.0	$10.7	$12.7	$13.1	$14.7	4.9%
Highway Patrol and Safety	$11.0	$11.7	$14.3	$14.7	$14.6	3.5%
Interest on Debt	$4.6	$5.4	$5.8	$6.6	$8.5	8.0%
Total, Current Expenditures	$117.6	$129.1	$139.5	$155.5	$173.9	5.0%
Bond Retirement	$5.1	$6.8	$8.0	$8.1	$8.2	6.1%
Total, All Expenditures	**$122.7**	**$135.9**	**$147.5**	**$163.5**	**$182.1**	**5.1%**

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

As shown in *Exhibit 6-8,* the portion of total highway expenditures funded by the Federal government declined from 22.4 percent in 2000 to 22.0 percent in 2008, peaking in 2004 before gradually declining. While Federally funded capital outlay grew by 44.8 percent (4.7 percent per year) from $26.1 billion in 2000 to $37.8 billion in 2008, State and local capital investment increased even faster, by 51.5 percent (5.3 percent annually), from $35.2 billion to $53.3 billion. Consequently, the Federal share of capital outlay declined over this period, from 42.6 percent to 41.5 percent.

Exhibit 6-8

Funding for Highways by Level of Government, 2000–2008

	Highway Funding, Billions of Dollars					Annual Rate of Change
	2000	**2002**	**2004**	**2006**	**2008**	**2008/2000**
Capital Outlay						
Funded by Federal Government	$26.1	$31.5	$30.8	$34.6	$37.8	4.7%
Funded by State or Local Govt's	$35.2	$36.7	$39.5	$45.6	$53.3	5.3%
Total	**$61.3**	**$68.2**	**$70.3**	**$80.2**	**$91.1**	**5.1%**
Federal Share	42.6%	46.1%	43.8%	43.1%	41.5%	
Total Expenditures						
Funded by Federal Government	$27.5	$32.8	$33.1	$36.3	$40.0	4.8%
Funded by State Governments	$62.7	$69.0	$72.8	$77.4	$90.6	4.7%
Funded by Local Governments	$32.6	$34.1	$41.6	$49.8	$51.5	5.9%
Total	**$122.7**	**$135.9**	**$147.5**	**$163.5**	**$182.1**	**5.1%**
Federal Share	22.4%	24.1%	22.4%	22.2%	22.0%	

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

Constant Dollar Expenditures

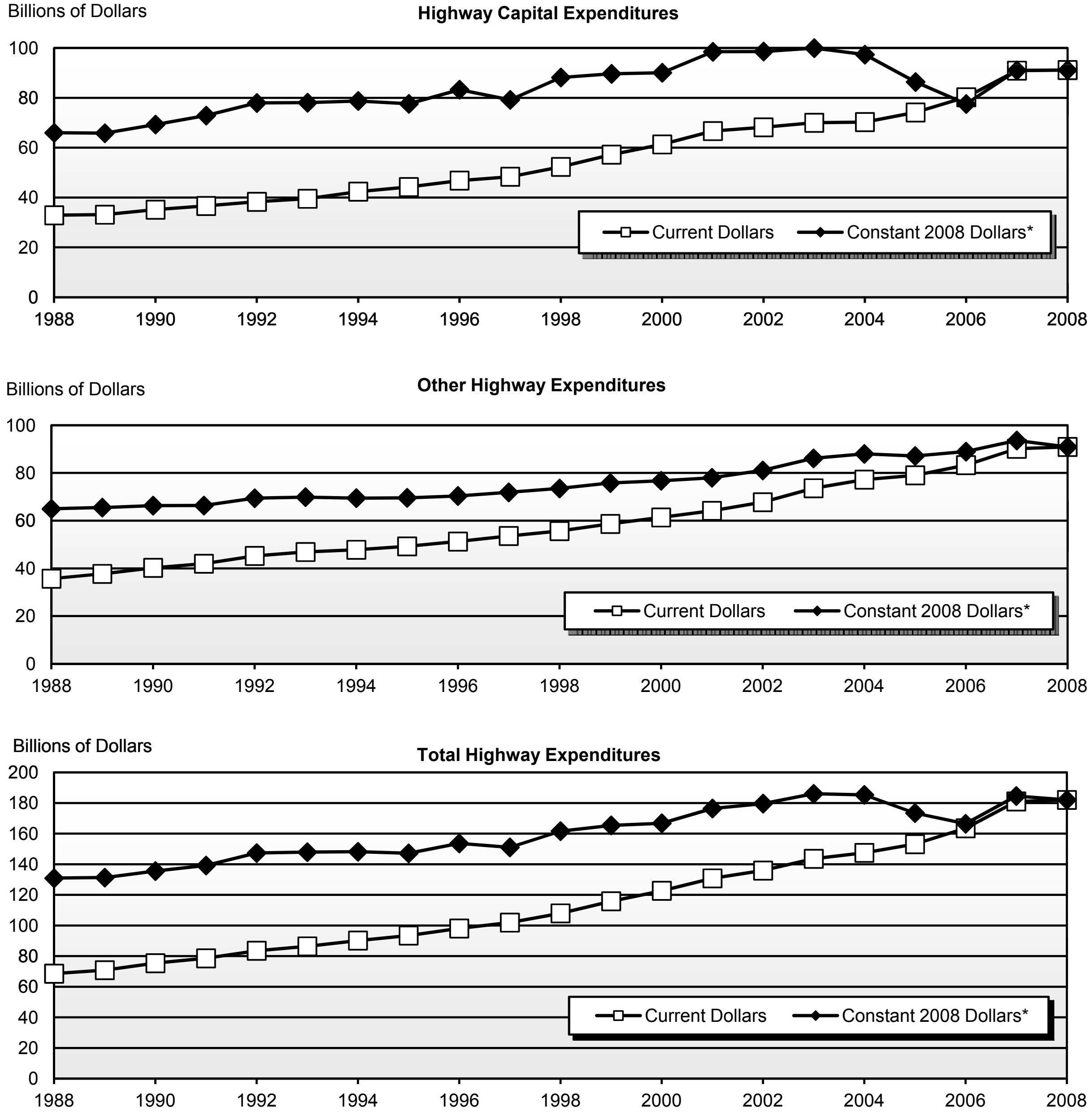
There are significant differences in the types of inputs of materials and labor that are associated with different types of highway expenditures; for example, on a dollar-per-dollar basis, highway maintenance activities are generally more labor intensive than highway construction activities. This report uses different indices for converting nominal dollar highway spending to constant dollars for capital and noncapital expenditures. For constant dollar conversions for highway capital expenditures, the Federal Highway Administration (FHWA) Composite Bid Price Index (BPI) is used through the year 2006, the last year for which this index was produced. Capital expenditure conversions for subsequent years rely on a new index, the FHWA National Highway Construction Cost Index (NHCCI). Constant dollar conversions for other types of highway expenditures are based on the Bureau of Labor Statistics' Consumer Price Index (CPI).

For some historic periods, highway construction costs as measured by the BPI and NHCCI have grown faster than the CPI; in others, the CPI has grown faster. Industry-specific indices such as the BPI and NHCCI tend to be more volatile than the CPI, which reflects general trends within the overall economy. This volatility was demonstrated in the period between 2004 and 2006, as sharp increases in the prices of materials such as steel, asphalt, and cement caused the BPI to increase by 43.3 percent, compared with a 6.7 percent increase in the CPI.

Exhibit 6-9 compares highway expenditures in current (nominal) and constant (real) dollars over time. While total highway expenditures have grown in current dollar terms in each year from 1988 through 2008, constant dollar expenditures show a different pattern. Within this 20-year period, total highway spending peaked in constant dollar terms in 2003 and has subsequently declined. A similar pattern is evident for highway capital outlay, which was virtually unchanged in nominal dollar spending from 2003 to 2004 and

Exhibit 6-9

Highway Capital, Noncapital, and Total Expenditures in Current and Constant 2008 Dollars, All Units of Government, 1988–2008



** Constant dollar conversions for highway capital expenditures were made using the FHWA BPI through the year 2006, and the FHWA NHCCI in subsequent years. Constant dollar conversions for other types of highway spending were made using the Bureau of Labor Statistics' CPI.*

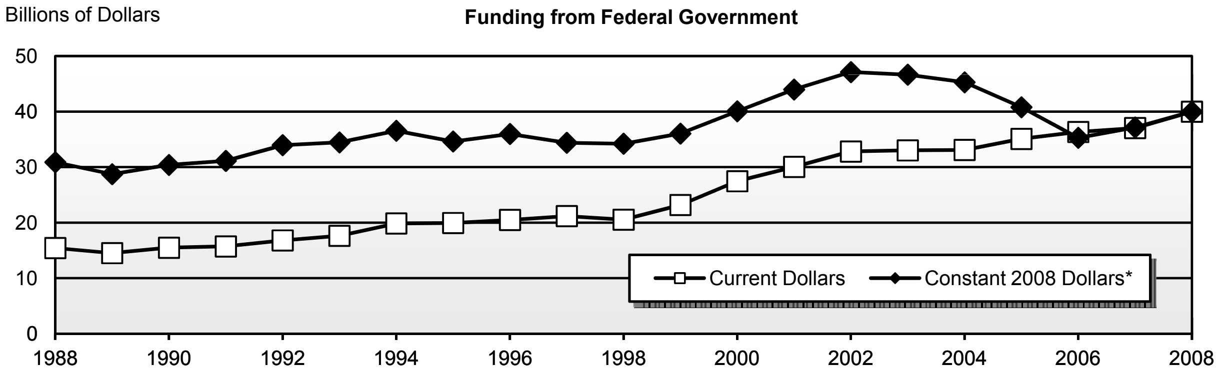
grew by less than the rate of construction costs in subsequent years. Noncapital expenditures have grown more steadily over time in constant dollar terms.

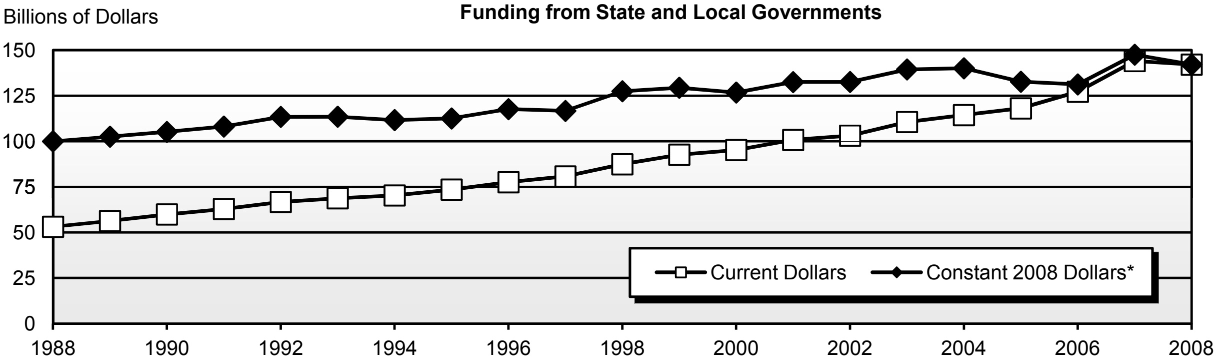
From 1988 to 2008, highway capital spending increased at an average annual rate of 1.6 percent in constant dollar terms, slightly below the 1.7 percent annual constant dollar growth rate for total highway expenditures. More recently, for the 8-year period from 2000 to 2008, highway capital outlay grew by 1.2 percent (0.1 percent per year) in constant dollar terms, while total highway expenditures grew by 9.1 percent (1.1 percent annually) in constant dollars.

Exhibit 6-10 shows highway expenditures in current (nominal) and constant (real) dollars between 1988 and 2008 at the Federal government level and for State and local governments combined. Within this period, Federally funded highway expenditures peaked in 2002 in constant dollar terms, while non-Federal constant dollar expenditures peaked in 2007. As indicated earlier, most Federal highway funding goes for capital outlay, and highway construction costs as reflected in the BPI and NHCCI have risen more quickly in recent years than has the CPI.

Exhibit 6-10

Highway Expenditures Funded by Federal and Non-Federal Sources, in Current and Constant 2008 Dollars, 1988–2008


Funding from Federal Government


Funding from State and Local Governments

***Constant dollar conversions for highway capital expenditures were made using the FHWA BPI through the year 2006, and the FHWA NHCCI in subsequent years. 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/.

From 1988 to 2008, Federally funded highway expenditures increased at an average annual rate of 1.3 percent in constant dollar terms; State and local constant-dollar highway expenditures grew more quickly, increasing by 1.8 percent per year on average. For the 8-year period from 2000 to 2008, highway expenditures funded by the Federal government fell by 0.2 percent (0.0 percent per year) in constant dollar terms. Highway expenditures funded by State and local sources grew by 12.1 percent (1.4 percent annually) over this same period.

Highway Capital Outlay

As discussed earlier in the chapter, while the Federal government funds a significant portion of total capital outlay, most of the Federal contribution comes in the form of transfers to State and local governments for expenditure. Of the $91.1 billion in combined capital outlay by all levels of government in 2008, State governments directly spent $67.5 billion; this figure includes State projects funded with State funds, Federal funds, and/or local funds. Approximately $59.8 billion of direct State expenditures went for roads that are functionally classified as arterials or collectors; the remainder went for roads classified as rural local or urban local. Chapter 2 provides more detail on functional classification definition.

Capital Outlay by Improvement Type

States provide the FHWA with detailed data on what they spend on arterials and collectors, classifying capital outlay on each functional system into 17 improvement types. For this report, these improvement types have been allocated among three broad categories: system rehabilitation, system expansion, and system enhancement.

Q&A

How are "system rehabilitation," "system expansion," and "system enhancement" defined in this report?

System rehabilitation consists of capital improvements on existing roads and bridges that are 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 to be related to reconstructing or improving existing lanes. System rehabilitation does not include routine maintenance costs. As shown in *Exhibit 6-6*, an additional $32.1 billion was spent by all levels of government in 2008 on routine maintenance.

System expansion includes construction of new roads and new bridges and addition of new lanes to existing roads. This includes all "New Construction," "New Bridge," "Major Widening," and most of the costs associated with "Reconstruction-Added Capacity," except for the portion of these expenditures estimated to be related to improving the existing lanes of a facility. As used in this report, "System Expansion" is the functional equivalent to "Capacity Expansion" used in some previous editions. The term was modified because some system rehabilitation and system enhancement improvements may result in added capacity without the addition of new lanes.

System enhancement includes safety enhancements, traffic operations improvements such as the installation of intelligent transportation systems, and environmental enhancements.

Exhibit 6-11 shows the distribution of the $59.8 billion in State expenditures on arterials and collectors by improvement type and demonstrates how this funding was grouped among these three major categories. No comparably detailed data for local expenditures or direct expenditures by Federal agencies are available; the distribution of such spending was estimated, based on the State expenditure patterns. An estimated $72.2 billion was expended in 2008 by all levels of government on capital improvements to arterials and collectors.

Exhibit 6-11 also shows an estimated distribution of capital outlay by improvement type on all roadways and bridges for all levels of government combined. The improvement type breakdown for the $91.1 billion in total capital outlay includes estimates for roads classified as rural local and urban local. This distribution was estimated based on State expenditure patterns on lower-ordered functional systems such as rural minor collectors, rural major collectors, and urban collectors.

In 2008, about $46.6 billion was spent on system rehabilitation (51.1 percent of total capital outlay). As defined in this report, system rehabilitation activities include capital improvements on existing roads and bridges that are designed to preserve the existing pavement and bridge infrastructure. These improvements do not include routine maintenance.

About $17.7 billion—19.4 percent of total capital outlay—was spent on the construction of new roads and bridges in 2008. An additional $15.9 billion, or 17.4 percent, was used to add lanes to existing roads. Another $11.0 billion, or 12.0 percent, was spent on system enhancement, including safety enhancements, traffic operations improvements, and environmental enhancements.

Exhibit 6-11

Highway Capital Outlay by Improvement Type, 2008

	Distribution of Capital Outlay, Billions of Dollars				
		System Expansion			
Type of Expenditure	**System Rehabilitation**	**New Roads and Bridges**	**Existing Roads**	**System Enhancements**	**Total Outlay**
Direct State Expenditures on Arterials and Collectors					
Right-of-Way		$1.9	$1.9		$3.8
Engineering	$4.0	$1.3	$1.3	$0.7	$7.4
New Construction		$8.0			$8.0
Relocation			$1.0		$1.0
Reconstruction—Added Capacity	$2.2		$5.0		$7.2
Reconstruction—No Added Capacity	$3.5				$3.5
Major Widening			$2.9		$2.9
Minor Widening	$1.4				$1.4
Restoration and Rehabilitation	$10.9				$10.9
Resurfacing	$0.3				$0.3
New Bridge		$0.9			$0.9
Bridge Replacement	$4.0				$4.0
Major Bridge Rehabilitation	$2.2				$2.2
Minor Bridge Work	$1.9				$1.9
Safety				$1.9	$1.9
Traffic Management/Engineering				$1.2	$1.2
Environmental and Other				$1.5	$1.5
Total, State Arterials and Collectors	**$30.3**	**$12.1**	**$12.1**	**$5.2**	**$59.8**
Total, Arterials and Collectors, All Jurisdictions (estimated)*					
Highways and Other	$26.9	$12.9	$14.6	$6.8	$61.2
Bridges	$9.9	$1.0			$11.0
Total, Arterials and Collectors	**$36.8**	**$14.0**	**$14.6**	**$6.8**	**$72.2**
Total Capital Outlay on All Systems (estimated)*					
Highways and Other	$33.8	$16.2	$15.9	$11.0	$76.8
Bridges	$12.8	$1.5			$14.3
Total, All Systems	**$46.6**	**$17.7**	**$15.9**	**$11.0**	**$91.1**
Percent of Total	**51.1%**	**19.4%**	**17.4%**	**12.0%**	**100.0%**

**Improvement type distribution was estimated based on State arterial and collector data.*

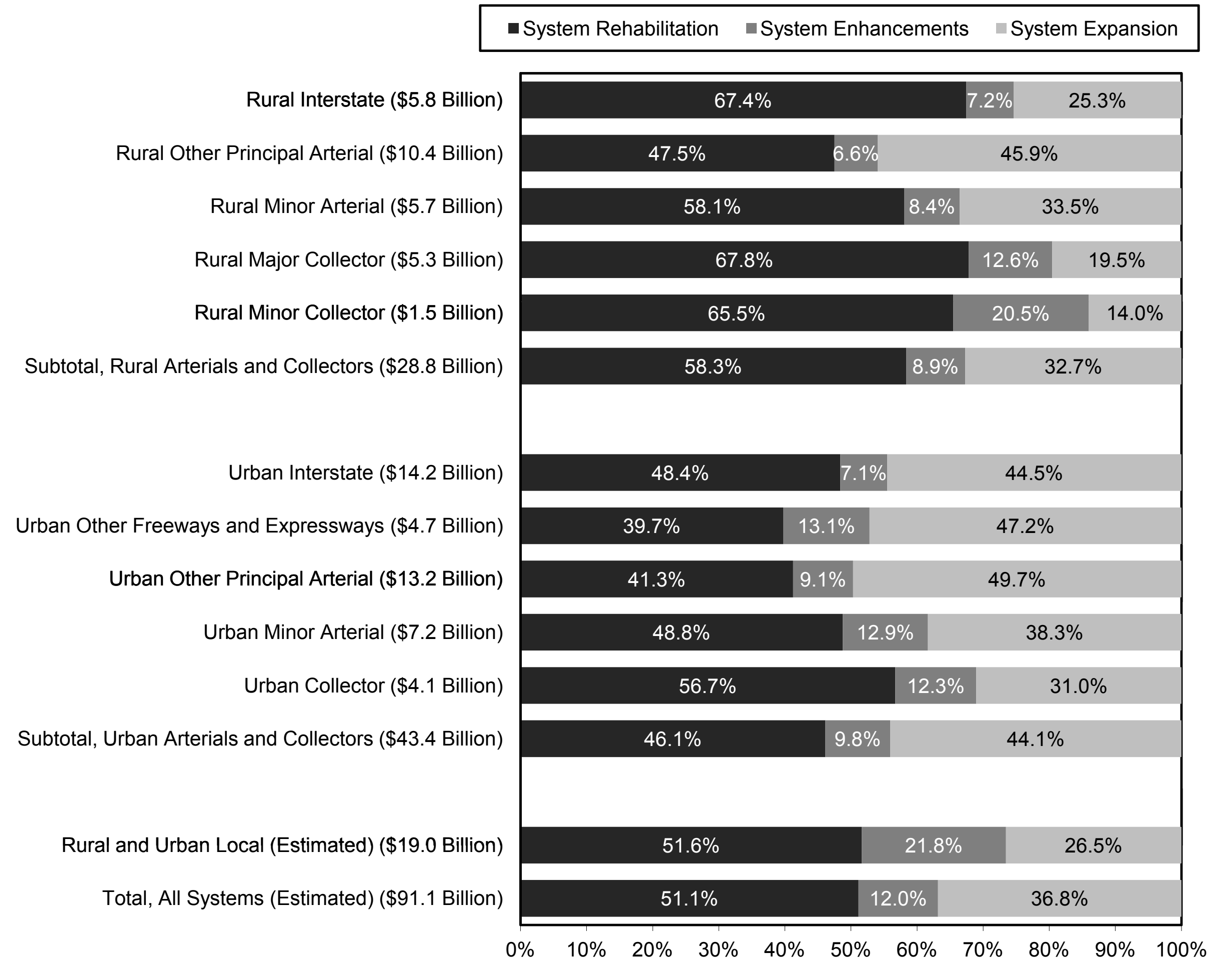
Sources: Highway Statistics 2008, Table SF-12A, and unpublished FHWA data.

Exhibit 6-12 shows the distribution of capital outlay by improvement type for individual functional systems. The portion of capital outlay spent on system rehabilitation ranges from 39.7 percent on urban other freeways and expressways to 67.8 percent on rural major collectors. Overall, system rehabilitation's share of capital spending on arterials and collectors in rural areas (58.3 percent) was greater than in urban areas (46.1 percent).

System expansion expenditures also vary significantly by functional class. The portion of capital used for lane additions, new roads, and new bridges is highest on urban other principal arterials, at 49.7 percent. In contrast, only 14.0 percent of capital outlay on rural minor collectors went for system expansion.

Exhibit 6-12

Distribution of Capital Outlay by Improvement Type and Functional System, 2008



Sources: Highway Statistics 2008, Table SF-12A, and unpublished FHWA data.

Exhibit 6-13 provides information on capital outlay by improvement type between 2000 and 2008. System rehabilitation expenditures grew at an average annual rate of 4.7 percent over this period, from $32.3 billion in 2000 to $46.6 billion in 2008. System expansion grew by 4.9 percent annually, from $23.0 billion in 2000 to $33.6 billion by 2008. Spending on system enhancements grew more quickly than overall highway spending, rising from $6.1 billion in 2000 to $11.0 billion by 2008, an increase of 7.7 percent per year.

Q&A

How have constant dollar expenditures for different capital improvement types grown in recent years?

As noted earlier in this section, total capital outlay by all levels of government grew at an average annual rate of 0.1 percent from 2000 to 2008. System rehabilitation expenditures fell by 0.2 percent per year in constant dollar terms over this period, while system expansion expenditures fell by 0.1 percent annually. Expenditures for system enhancements grew by 2.6 percent per year in constant dollar terms from 2000 to 2008.

Exhibit 6-13

Capital Outlay on All Roads by Improvement Type, 2000–2008

Improvement Type	Capital Outlay, Billions of Dollars 2000	2002	2004	2006	2008	Annual Rate of Change 2008/2000
System Rehabilitation						
Highway	$25.0	$25.5	$26.7	$31.0	$33.8	3.8%
Bridge	$7.3	$10.7	$9.6	$10.3	$12.8	7.3%
Subtotal	**$32.3**	**$36.2**	**$36.3**	**$41.3**	**$46.6**	**4.7%**
System Expansion						
Additions to Existing Roadways	$11.4	$11.9	$12.1	$14.0	$15.9	4.2%
New Routes	$10.5	$11.4	$12.6	$15.2	$16.2	5.6%
New Bridges	$1.1	$1.1	$1.4	$1.2	$1.5	3.9%
Subtotal	**$23.0**	**$24.4**	**$26.1**	**$30.4**	**$33.6**	**4.9%**
System Enhancements	**$6.1**	**$7.6**	**$7.8**	**$8.5**	**$11.0**	**7.7%**
Total	**$61.3**	**$68.2**	**$70.3**	**$80.2**	**$91.1**	**5.1%**
Percent of Total Capital Outlay						
System Rehabilitation	52.7%	53.1%	51.7%	51.5%	51.1%	
System Expansion	37.4%	35.8%	37.1%	37.9%	36.8%	
System Enhancements	9.9%	11.1%	11.2%	10.6%	12.0%	

Sources: Highway Statistics 2008, Table SF-12A, and unpublished FHWA data.

As system rehabilitation grew more slowly than these other two categories, its share of total capital spending fell from 52.7 percent in 2000 to 51.1 percent in 2008. Over this same period, the portion of total capital spending devoted to system expansion fell from 37.4 percent to 36.8 percent, while system enhancements' share of total capital outlay rose from 9.9 percent to 12.0 percent.

Capital Outlay on Federal-Aid Highways

As discussed in Chapter 2, the term "Federal-aid highways" includes roads that are generally eligible for Federal funding assistance under current law. This includes all public roads that are not functionally classified as rural minor collector, rural local, or urban local. As shown in *Exhibit 6-14*, capital outlay on Federal-aid highways increased by 4.9 percent per year from 2000 to 2008, rising from $48.3 billion to $70.6 billion. Capital outlay on Federal-aid highways represents approximately 77.5 percent of the $91.1 billion of combined capital outlay by all levels of government in 2008.

The share of capital outlay on Federal-aid highways directed toward system rehabilitation fell from 51.4 percent to 50.7 percent over this period, while the portion directed toward system expansion fell from 40.8 percent to 40.1 percent. System enhancement expenditures rose from 7.8 percent in 2000 to 9.2 percent in 2008.

Capital Outlay on the National Highway System

The National Highway System (NHS), which is described more fully in Chapter 2, includes the Interstate Highway System and other roads important to the Nation's economy, defense, and mobility. As shown in *Exhibit 6-15*, capital outlay on the NHS grew from $29.9 billion in 2000 to $42.0 billion in 2008, equating to an average annual increase of 4.3 percent. System rehabilitation expenditures of $20.4 billion constituted 48.5 percent of total NHS capital spending in 2008. The $18.4 billion spent for system expansion

Exhibit 6-14

Capital Outlay on Federal-Aid Highways, by Improvement Type, 2000–2008

	Capital Outlay, Billions of Dollars					Annual Rate of Change
Improvement Type	**2000**	**2002**	**2004**	**2006**	**2008**	**2008/2000**
System Rehabilitation						
Highway	$19.3	$19.6	$19.4	$22.9	$26.4	3.9%
Bridge	$5.5	$8.3	$7.2	$7.7	$9.4	7.0%
Subtotal	**$24.8**	**$27.9**	**$26.6**	**$30.6**	**$35.8**	**4.7%**
System Expansion						
Additions to Existing Roadways	$10.4	$11.0	$11.6	$12.9	$14.4	4.2%
New Routes	$8.4	$9.1	$9.8	$12.0	$12.9	5.4%
New Bridges	$0.9	$0.9	$1.2	$0.9	$1.0	1.4%
Subtotal	**$19.7**	**$21.0**	**$22.6**	**$25.9**	**$28.3**	**4.6%**
System Enhancements	**$3.8**	**$4.8**	**$5.0**	**$5.5**	**$6.5**	**7.1%**
Total	**$48.3**	**$53.7**	**$54.2**	**$61.9**	**$70.6**	**4.9%**
Percent of Total Capital Outlay						
System Rehabilitation	51.4%	52.0%	49.1%	49.3%	50.7%	
System Expansion	40.8%	39.1%	41.6%	41.9%	40.1%	
System Enhancements	7.8%	8.9%	9.3%	8.8%	9.2%	

Sources: Highway Statistics 2008, Table SF-12A, and unpublished FHWA data.

Exhibit 6-15

Capital Outlay on the NHS, by Improvement Type, 2000–2008

	Capital Outlay, Billions of Dollars					Annual Rate of Change
Improvement Type	**2000**	**2002**	**2004**	**2006**	**2008**	**2008/2000**
System Rehabilitation						
Highway	$11.1	$10.6	$9.5	$12.3	$15.0	3.8%
Bridge	$3.1	$4.5	$4.0	$4.3	$5.4	7.4%
Subtotal	**$14.2**	**$15.1**	**$13.5**	**$16.6**	**$20.4**	**4.6%**
System Expansion						
Additions to Existing Roadways	$6.4	$7.1	$7.1	$8.1	$9.2	4.7%
New Routes	$6.6	$6.7	$6.8	$8.9	$8.6	3.4%
New Bridges	$0.8	$0.6	$0.9	$0.7	$0.6	-3.8%
Subtotal	**$13.7**	**$14.5**	**$14.8**	**$17.7**	**$18.4**	**3.7%**
System Enhancements	**$2.0**	**$2.8**	**$2.8**	**$2.8**	**$3.3**	**6.6%**
Total	**$29.9**	**$32.4**	**$31.1**	**$37.2**	**$42.0**	**4.3%**
Percent of Total Capital Outlay						
System Rehabilitation	47.5%	46.7%	43.5%	44.7%	48.5%	
System Expansion	46.0%	44.7%	47.6%	47.7%	43.7%	
System Enhancements	6.6%	8.7%	8.9%	7.6%	7.8%	

Sources: Highway Statistics 2008, Table SF-12B, and unpublished FHWA data.

represented 43.7 percent of total NHS capital spending, while the $3.3 billion spent for NHS system enhancements constituted 7.8 percent.

The $42.0 billion spent for capital improvements to the NHS in 2008 constituted 46.1 percent of the $91.1 billion that all governments expended on highway capital projects that year.

Capital Outlay on the Interstate Highway System

Of the $91.1 billion spent for highway capital outlay by all levels of government in 2008, approximately 22.0 percent was used on the Interstate highway system component of the NHS. *Exhibit 6-16* describes how the $20.0 billion of Interstate capital spending in 2008 was distributed by type of improvement. In 2008, all levels of government combined directed 53.9 percent of their Interstate-related expenditures to system rehabilitation, 38.9 percent to system expansion, and 7.1 percent to system enhancements. Total capital outlay on the Interstate system increased at an average annual rate of 4.7 percent between 2000 and 2008.

Exhibit 6-16

Capital Outlay on the Interstate System, by Improvement Type, 2000–2008

	Capital Outlay, Billions of Dollars					Annual Rate of Change
Improvement Type	**2000**	**2002**	**2004**	**2006**	**2008**	**2008/2000**
System Rehabilitation						
Highway	$5.8	$5.5	$4.7	$5.8	$7.5	3.2%
Bridge	$1.6	$2.4	$2.3	$2.5	$3.3	9.4%
Subtotal	**$7.4**	**$8.0**	**$7.0**	**$8.3**	**$10.8**	**4.8%**
System Expansion						
Additions to Existing Roadways	$2.5	$3.2	$2.9	$3.2	$4.5	7.9%
New Routes	$2.6	$2.5	$2.5	$3.5	$3.0	1.8%
New Bridges	$0.4	$0.2	$0.2	$0.3	$0.3	-3.7%
Subtotal	**$5.5**	**$5.9**	**$5.6**	**$7.1**	**$7.8**	**4.5%**
System Enhancements	**$0.9**	**$1.4**	**$1.1**	**$1.2**	**$1.4**	**5.6%**
Total	**$13.8**	**$15.3**	**$13.7**	**$16.5**	**$20.0**	**4.7%**
Percent of Total Capital Outlay						
System Rehabilitation	53.7%	52.1%	50.8%	49.9%	53.9%	
System Expansion	39.6%	38.5%	40.9%	42.6%	38.9%	
System Enhancements	6.7%	9.4%	8.3%	7.4%	7.1%	

Sources: Highway Statistics 2008, Table SF-12A, and unpublished FHWA data.

Transit Finance

Transit funding comes from two major sources: public funds allocated by Federal, State, and local governments, and system-generated revenues earned from the provision of transit services. As shown in *Exhibit 6-17*, the total amount available for transit financing in 2008 was $52.5 billion. Federal funding for transit includes fuel taxes dedicated to transit from the Mass Transit Account (MTA) of the Highway Trust Fund (HTF), as well as undedicated taxes allocated from Federal general fund appropriations. State and local governments also provide funding for transit from their general fund appropriations, as well as from fuel, income, sales, property, and other unspecified taxes, specific percentages of which may be dedicated to transit. These percentages vary considerably among taxing jurisdictions and by type of tax. Other public funds from sources such as toll revenues and general transportation funds may also be used to fund transit. System-generated revenues are composed principally of passenger fares, although additional revenues are also earned by transit systems from advertising and concessions, park-and-ride lots, investment income, and rental of excess property and equipment.

Exhibit 6-17

2008 Revenue Sources for Transit Financing

	Transit Financing (Millions of Dollars)				
	Federal	**State**	**Local**	**Total**	**Percent**
Public Funds	**$8,986.3**	**$11,388.8**	**$18,455.3**	**$38,830.4**	**73.9%**
General Fund	$1,797.3	$3,204.2	$4,345.2	$9,346.7	17.8%
Fuel Tax	$7,189.0	$724.3	$204.0	$8,117.3	15.5%
Income Tax		$1,075.7	$99.2	$1,174.9	2.2%
Sales Tax		$3,434.6	$6,649.1	$10,083.7	19.2%
Property Tax		$0.1	$849.1	$849.2	1.6%
Other Dedicated Taxes		$1,056.0	$906.8	$1,962.8	3.7%
Other Public Funds		$1,893.9	$5,401.9	$7,295.8	13.9%
System-Generated Revenue				**$13,685.1**	**26.1%**
Passenger Fares				$11,378.4	21.7%
Other Revenue				$2,306.7	4.4%
Total, All Sources				**$52,515.5**	**100.0%**

Source: National Transit Database.

Level and Composition of Transit Funding

Exhibit 6-18 breaks down the sources of total transit funding. In 2008, public funds of $38.8 billion were available for transit and accounted for 73.9 percent of total transit funding. Of this amount, Federal funding was $9.0 billion, accounting for 23.1 percent of total public funding and for 17.1 percent of all funding from both public and nonpublic sources. State funding was $11.4 billion, accounting for 29.3 percent of total public funds and 21.7 percent of all funding. Local jurisdictions provided the bulk of transit funds, $18.5 billion in 2008, or 47.5 percent of total public funds and 35.1 percent of all funding. System-generated revenues were $13.7 billion, 26.1 percent of all funding.

What type of dedicated funding does mass transit receive from Federal highway-user fees? Q&A

In 1983 the MTA was established within the HTF. It is funded by 2.86 cents of Federal highway-user fees on gasohol, diesel and kerosene fuel, and other special fuels (benzol, benzene, and naphtha). Since 1997 the Federal fuel tax on a gallon of gasoline has been 18.4 cents and the tax on a gallon of diesel has been 24.4 cents.

The MTA also receives 2.13 cents of the user fee on liquefied petroleum gas (LPG) and 1.86 cents of the user fee on liquefied natural gas (LNG). The MTA does not receive any of the nonfuel revenues (such as heavy vehicle use taxes) that accrue to the HTF.

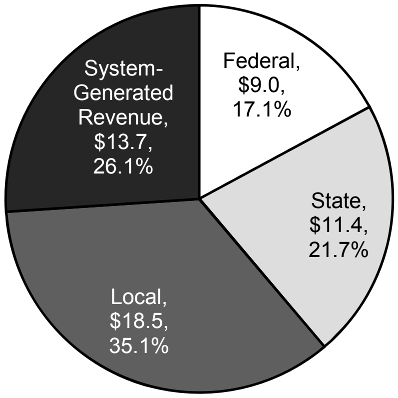
Since the passage of the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU), only the Formula and Bus Grants Program is funded from the MTA. Prior to SAFETEA-LU, MTA funded other FTA programs.

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 HTF's MTA. General revenue sources include income taxes, corporate taxes, tariffs, fees, and other government income not required by statute to be accounted for in a separate fund. The MTA, a trust fund for capital projects in transit, is the largest source of Federal funding for transit. Eighty-two percent of the funds authorized for transit by the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) ($37.2 billion) were derived from the MTA. Funding from the MTA in nominal dollars increased from $0.5 billion in 1983 to $7.2 billion in 2008.

Exhibit 6-18

2008 Public Transit Revenue Sources (Billions of Dollars)



Source: National Transit Database.

The Department of Homeland Security (DHS) provides funding for projects aimed at improving transit security. In 2008, DHS provided a total of $350.1 million to transit service providers.

Since 1973, Federal surface transportation authorization statutes have contained flexible funding provisions that enable transfers from certain highway funds to transit programs and vice versa. Transfers are subject to State and regional/local discretion, and priorities are established through statewide transportation planning processes. All States and territories within the United States participate in the flexible funding program except Kansas, North Dakota, South Dakota, and Wyoming. The amount of flexible funding transferred from highways to transit fluctuates from year to year and is drawn from several different sources.

The Surface Transportation Program is the largest source of funds from the Federal Highway Administration (FHWA). Funding is at 80 percent of Federal share and may be used for all capital and maintenance projects eligible for funds under current Federal Transit Administration (FTA) programs, and may not be used for operating assistance. Several transit projects are also earmarked under TEA-21 and SAFETEA-LU as high-priority projects. FHWA has requested that they be administered by FTA.

Congestion Mitigation and Air Quality (CMAQ) Improvement Program funds are used to support transportation 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.

What are Flex Funds?

In FY 2008, $1.4 billion in flexible funds/transfers were available to FTA for obligation. Of that total, $957.3 million (67.0 percent) was transferred in FY 2008; the remaining available $472.5 million (33.0 percent) was the un-obligated carryover or recovery of prior year transfers. Thirty-nine states transferred flexible funds during FY 2008 and obligations totaled $1.1 billion. Once transferred, these funds take on the characteristics of the program in which they are received and are included in the figures reported across various programs. Obligations in FY 2008 were:

- Urbanized Area Formula: $938.6 million (87.4 percent);
- Capital: $45.6 million (4.2 percent);
- Elderly and Persons with Disabilities: $67.8 million (6.3 percent); and
- Non-urbanized Area Formula: $21.9 million (2.0 percent).

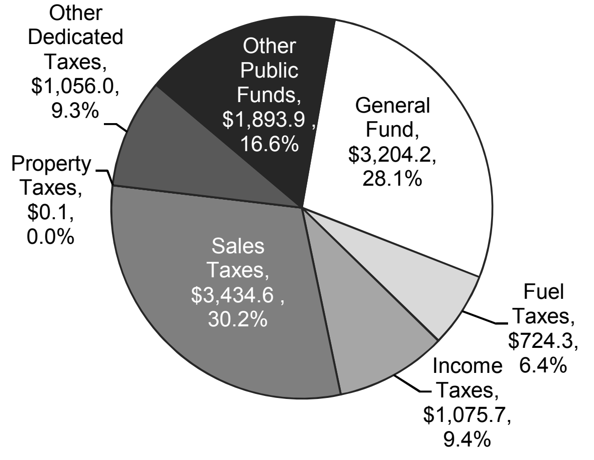
Since the program's initiation in FY 1992, a total of $15.0 billion has been transferred from highways to transit.

State and Local Funding

General funds and other dedicated public funds (vehicle licensing and registration fees, communications access fees, surcharges and taxes, lottery and casino receipts, and the proceeds from property and asset sales) are important sources of funding for transit at both the State and local levels. State and local transit funding sources are shown in *Exhibits 6-19* and *6-20*. Sales taxes are the most common source of dedicated funding for transit at both the State and local levels. In 2008, they accounted for 30.2 percent of total State and 36.0 percent of total local funding for transit. Other important sources of dedicated transit funding at both the State and local levels included income and property taxes. Dedicated income taxes are a more frequent source of transit funds at the State level, whereas dedicated property taxes are a more frequent source at the local level.

Exhibit 6-19

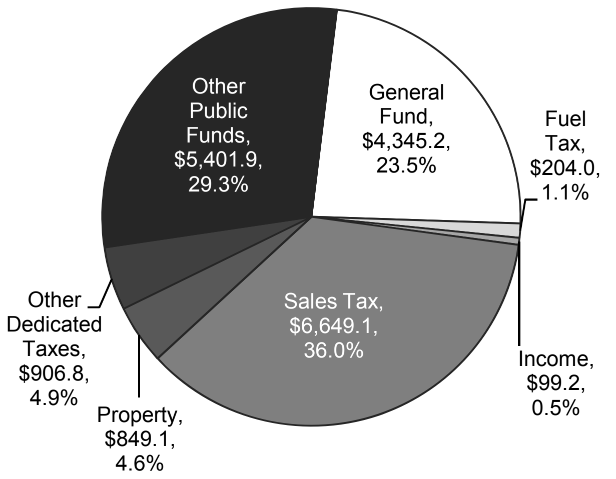
2008 State Sources of Transit Funding (Millions of Dollars)



Source: National Transit Database.

Exhibit 6-20

2008 Local Sources of Transit Funding (Millions of Dollars)



Source: National Transit Database.

System-Generated Funds

In 2008, system-generated funds were $13.7 billion and provided 26.1 percent of total transit funding. Passenger fares contributed $11.4 billion, accounting for 21.7 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.

Exhibit 6-21 shows average fares and costs, on a per mile basis, for the nation's ten largest transit agencies since 2000. After adjusting for inflation (constant dollars) there has been no increase in fares per mile over this period while the average cost per mile has increased by 7.0 percent. This has resulted in an 8.0 percent decrease in the "fare recovery ratio," which is the percentage of operating costs covered by passenger fares. The 2008 fare recovery ratio for these ten agencies was 36.8 percent. Since these are all rail agencies, and rail systems tend to have lower operating costs per passenger mile, this is a higher fare recovery ratio than would be found for most bus or demand response operations. In many cases municipalities operating these systems have determined that it is more cost-effective for them to provide free service as fare collection is expensive and fares for these operations are generally kept low.

Exhibit 6-21

Average Fares and Costs per Mile—Top 10 Transit Systems, 2000–2008

										% Increase	
Top 10 Systems*	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2000–2008**	**Average Annual**
Average Fare per Mile (Constant Dollars)	$3.71	$3.71	$3.50	$3.42	$3.56	$3.58	$3.66	$3.68	$3.70	0%	0.0%
Average Fare per Mile (Current Year Dollars)	$3.03	$3.10	$2.98	$2.97	$3.16	$3.29	$3.47	$3.59	$3.70	22%	2.5%
Average Cost per Mile (Constant Dollars)	$9.45	$9.70	$9.60	$9.63	$9.79	$9.97	$10.06	$10.43	$10.15	7%	0.9%
Average Cost per Mile (Current Year Dollars)	$7.72	$8.11	$8.15	$8.35	$8.71	$9.15	$9.55	$10.19	$10.15	31%	3.5%
Average Recovery Ratio	40.2%	39.2%	38.0%	36.6%	36.9%	36.4%	36.6%	35.5%	36.8%	-8%	-1.1%

**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, Metropolitan Atlanta Rapid Transit Authority, Maryland Transit Administration.*

Source: National Transit Database.

Trends in Public Funding

Between 2000 and 2008, public funding for transit increased at an average annual rate of 10.6 percent; Federal funding increased at an average annual rate of 8.9 percent, and State and local funding grew at an average annual rate of 11.2 percent. These data are presented in *Exhibit 6-22*.

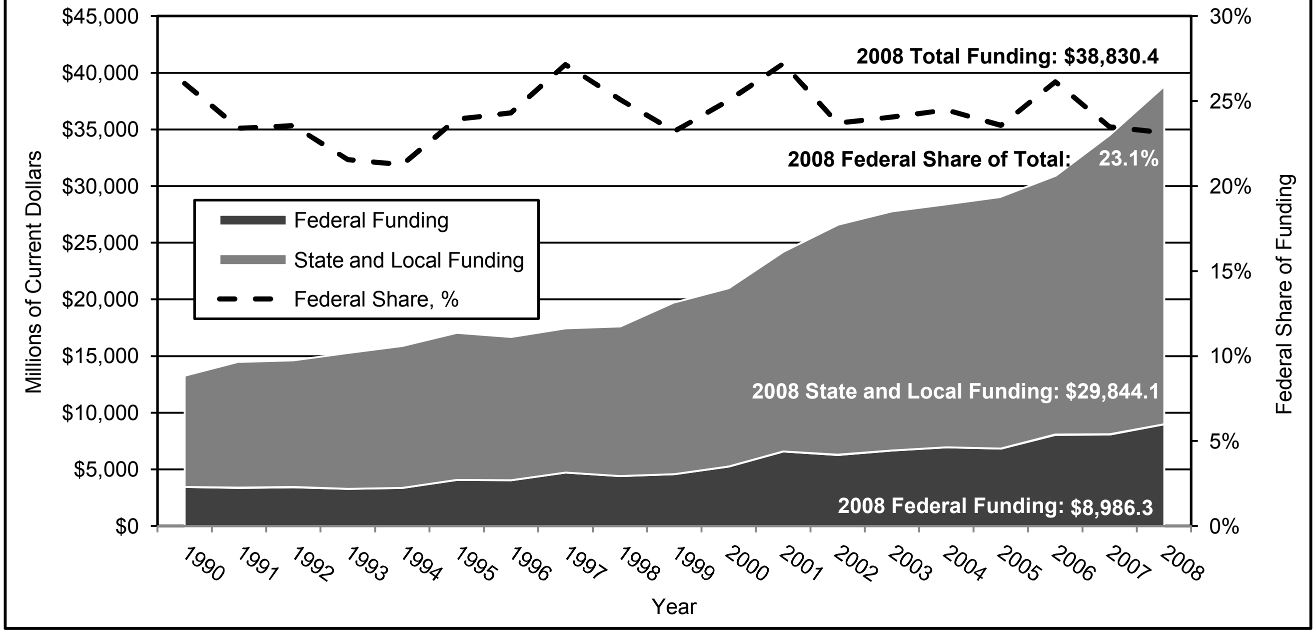
Federal funding for transit, as a percentage of total public funding for transit from Federal, State, and local sources combined, reached a peak of 42.9 percent in the late 1970s, and declined to near its present value by the early 1990's as State and local funding increased. *Exhibit 6-22* shows that, since 1990, the Federal government has provided between 21.3 and 27.2 percent of total public funding for transit; in 2008, it provided 23.1 percent of these funds.

Funding in Current and Constant Dollars

Total funding for transit in current and constant dollar terms since 1990 is presented in *Exhibit 6-23*. Total public funding for transit reached its highest level of $38.8 billion in 2008. After adjusting for inflation (constant dollars) this was 20.2 percent higher than in 2006. Between 2006 and 2008 Federal funding increased from $8.1 billion to $9.0 billion (11.1 percent) in current dollars. In constant dollars this represents a 5.7 percent increase. In current dollars State and local funding increased from $22.8 billion in 2006 to $29.8 billion in 2008 (30.7 percent). In constant dollars this represents a 25.3 percent increase.

Exhibit 6-22

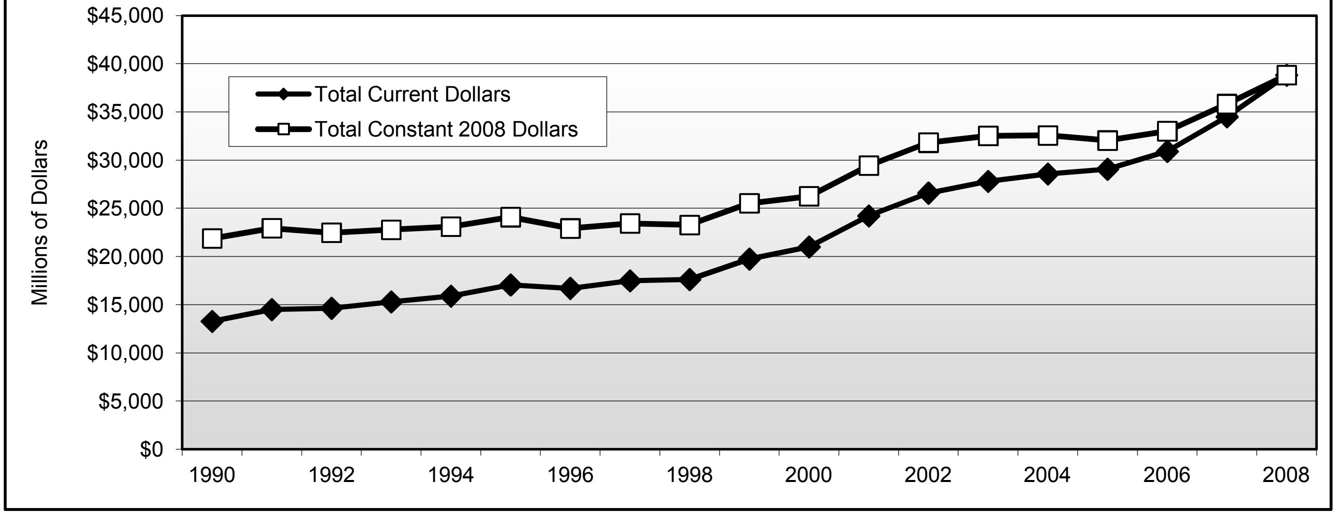
Public Funding for Transit by Government Jurisdiction, 1990–2008



Source: National Transit Database.

Exhibit 6-23

Current and Constant 2008 Dollar Funding for Public Transportation



Source: National Transit Database.

Capital Funding and Expenditures

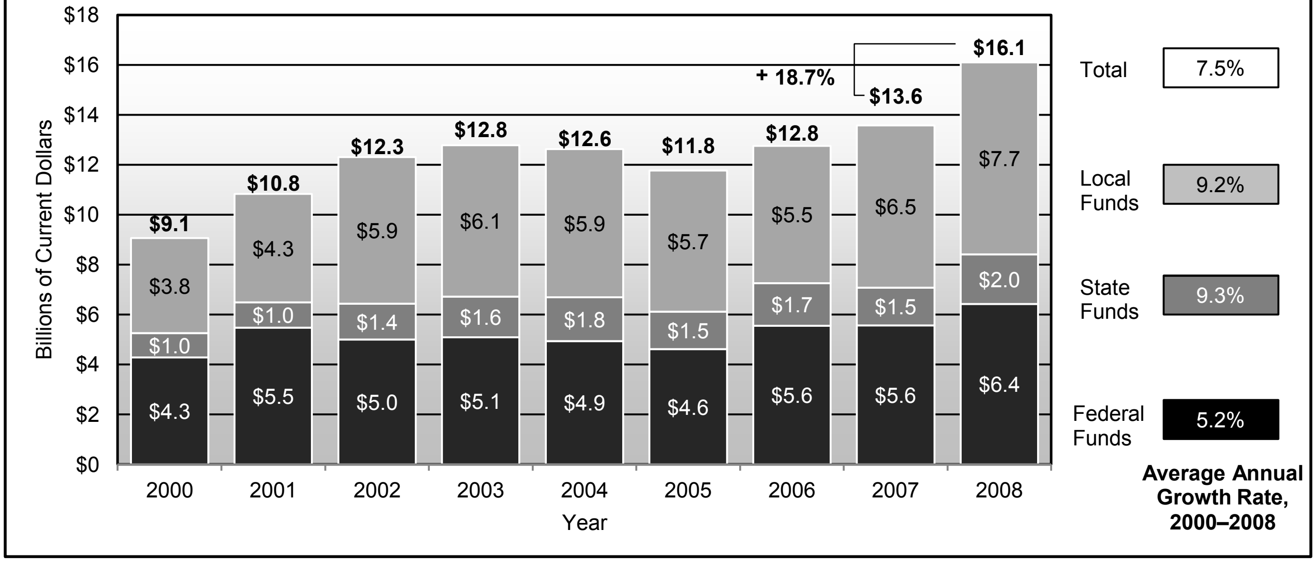
Funding for capital investments by transit operators in the United States comes primarily from public sources. Capital investment funds for transit are also generated through innovative finance programs.

Capital investments include the design and construction of new transit systems, extensions of existing systems ("New Starts"), and the modernization or replacement of existing assets. Capital investment expenditures can be for the acquisition, renovation, and repair of rolling stock (i.e., buses, railcars, locomotives, and service vehicles) or fixed assets (which include fixed guideway systems, terminals, and stations, as well as maintenance and administrative facilities).

In 2008, total public transit agency expenditures for capital investment were $16.1 billion in current dollars and accounted for 41.5 percent of total available funds as shown in *Exhibit 6-24*. Federal funds were $6.4 billion in 2008, 39.8 percent of total transit agency capital expenditures. State funds provided an additional 12.4 percent and local funds provided the remaining 47.8 percent of total transit agency capital expenditures.

Exhibit 6-24

Sources of Funds for Transit Capital Expenditures, 2000–2008



Source: National Transit Database.

As shown in *Exhibit 6-25*, rail modes require a higher percentage of total transit capital investment than bus modes because of the higher cost of building fixed guideways and rail stations and because bus systems typically do not pay to build or maintain the roads they run on. In 2008, $12.3 billion, or 76.4 percent of total transit capital expenditures, were invested in rail modes of transportation, compared with $3.8 billion, or 23.6 percent of the total, which was invested in nonrail modes. This investment distribution has been consistent over the last decade.

Exhibit 6-25 shows the capital investment expenditures by asset type in 2008. Fluctuations in the levels of capital investment in different types of transit assets reflect normal rehabilitation and replacement cycles, as well as new investment. Capital investment expenditures have only been reported to the National Transit Database (NTD) at the level of detail in *Exhibit 6-25* since 2002.

Guideway investment was $5.7 billion in 2008; investment in systems was $1.1 billion. Guideway includes at-grade rail, elevated and subway structures, tunnels, bridges, track and power systems for all rail modes, and paved highway lanes dedicated to buses. Investment in systems by transit operators includes groups of devices or objects forming a network, most notably for train control, signaling, and communications.

Investment in rolling stock in 2008 was $4.4 billion, investment in stations was $2.2 billion, and investment in maintenance facilities was $1.8 billion. Rolling stock includes the bodies and chassis of transit vehicles and their attached fixtures and appliances, but does not include fare collection equipment and revenue vehicle movement control equipment such as radios. Stations include station buildings, platforms, shelters, parking and other forms of access, and crime prevention and security equipment at stations. Facilities

Exhibit 6-25

2008 Transit Capital Expenditures by Mode and Type

	Rail Capital Expenditures, Millions of Dollars				
Type	**Commuter Rail**	**Heavy Rail**	**Light Rail**	**Other Rail [1]**	**Total Rail**
Guideway	$1,021.6	$2,134.0	$2,363.3	$6.7	**$5,525.6**
Rolling Stock	$683.9	$1,206.8	$485.7	$4.7	**$2,381.1**
Systems	$104.5	$621.1	$72.1	$3.1	**$800.8**
Maintenance Facilities	$306.7	$823.5	$121.9	$3.5	**$1,255.6**
Stations	$441.6	$1,049.9	$288.5	$1.8	**$1,781.8**
Fare Revenue Collection Equipment	$10.9	$91.6	$14.0	$0.0	**$116.5**
Administrative Buildings	$3.7	$46.9	$1.0	$0.0	**$51.6**
Other Vehicles	$11.9	$28.0	$5.1	$0.2	**$45.2**
Other Capital Expenditures [2]	$101.4	$124.0	$106.7	$2.2	**$334.3**
Total	**$2,686.2**	**$6,125.8**	**$3,458.3**	**$22.2**	**$12,292.5**
Percent of Total	16.7%	38.1%	21.5%	0.1%	**76.4%**

	Nonrail Capital Expenditures, Millions of Dollars					
Type	**Motor Bus**	**Demand Response**	**Ferryboat**	**Trolleybus**	**Other Nonrail [3]**	**Total Nonrail**
Guideway	$154.7	$0.0	$0.0	$12.0	$0.0	**$166.7**
Rolling Stock	$1,682.9	$191.0	$57.6	$29.0	$17.7	**$1,978.2**
Systems	$233.6	$14.0	$1.0	$1.1	$0.0	**$249.7**
Maintenance Facilities	$527.7	$32.9	$3.2	$0.3	$0.0	**$564.1**
Stations	$313.1	$7.2	$48.7	$0.0	$0.7	**$369.7**
Fare Revenue Collection Equipment	$89.9	$0.1	$0.1	$0.0	$0.0	**$90.1**
Administrative Buildings	$137.1	$7.2	$0.6	$1.0	$0.1	**$146.0**
Other Vehicles	$47.4	$2.8	$0.0	$0.9	$0.0	**$51.1**
Other Capital Expenditures [2]	$168.9	$8.7	$2.0	$0.3	$0.8	**$180.7**
Total	**$3,355.3**	**$263.9**	**$113.2**	**$44.6**	**$19.3**	**$3,796.3**
Percent of Total	20.9%	1.6%	0.7%	0.3%	0.1%	**23.6%**

Type	**Total Expenditures, Millions of Dollars for Rail and Nonrail Modes**	**Percent of Total**
Guideway	**$5,692.3**	**35.4%**
Rolling Stock	**$4,359.3**	**27.1%**
Systems	**$1,050.5**	**6.5%**
Maintenance Facilities	**$1,819.7**	**11.3%**
Stations	**$2,151.5**	**13.4%**
Fare Revenue Collection Equipment	**$206.6**	**1.3%**
Administrative Buildings	**$197.6**	**1.2%**
Other Vehicles	**$96.3**	**0.6%**
Other Capital Expenditures [2]	**$515.0**	**3.2%**
Total	**$16,088.8**	**100.0%**

---

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

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

[3] *Jitney, Público, and vanpool.*

Source: National Transit Database.

include the purchase, construction, and rehabilitation of administrative and maintenance facilities. Facilities also include investment in building structures, climate control, parking, yard track, vehicle and facilities maintenance equipment, furniture, office equipment, and computer systems.

Other capital includes capital costs associated with general administration facilities, furniture, equipment that is not an integral part of buildings and structures, data processing equipment (including computers and peripheral devices whose sole use is in data processing operations), and shelters located at on-street bus stops.

Q&A

What are "New Starts?"

Projects involving the construction of new fixed guideway systems are known as "New Starts." Title 49 USC Section 5309 provides for the allocation of funds for the design and construction of new transit systems and extensions to current systems ("New Starts"), among other purposes. To receive FTA capital investment funds for a New Starts project, the proposed project must emerge from the metropolitan and/or statewide planning process. A rigorous series of planning and project development requirements must be completed in order for a project to qualify for this funding. Local officials are required to analyze the benefits, costs, and other impacts of alternative transportation strategies before deciding upon a locally preferred alternative. FTA evaluates proposed projects on the basis of financial criteria and project justification criteria as prescribed by statute. Initial planning efforts are not funded through the Section 5309 program, but may be funded through Section 5303, Metropolitan Planning; Section 5339, Alternatives Analysis; or Section 5307, Urbanized Area Formula Grants programs.

Under current law, Federal funding may account for up to 80 percent of a New Starts funding requirement. Generally, the Federal share of such projects now averages about 50 percent of the total project cost.

Operating Expenditures

Transit operating expenditures include wages, salaries, fuel, spare parts, preventive maintenance, support services, and certain leases used in providing transit service. As shown in *Exhibit 6-26*, $36.4 billion was available for operating expenses in 2008, the Federal share of which has declined from the 2006 high of 8.2 percent to 7.1 percent. The share generated from system revenues decreased from 40.3 percent in 2006 to 37.6 percent. These decreases have been offset by the State share, which has increased from 22.5 percent in 2006 to 25.8 percent. The local share of operating expenditures has been close to 2008's 29.7 percent for several years.

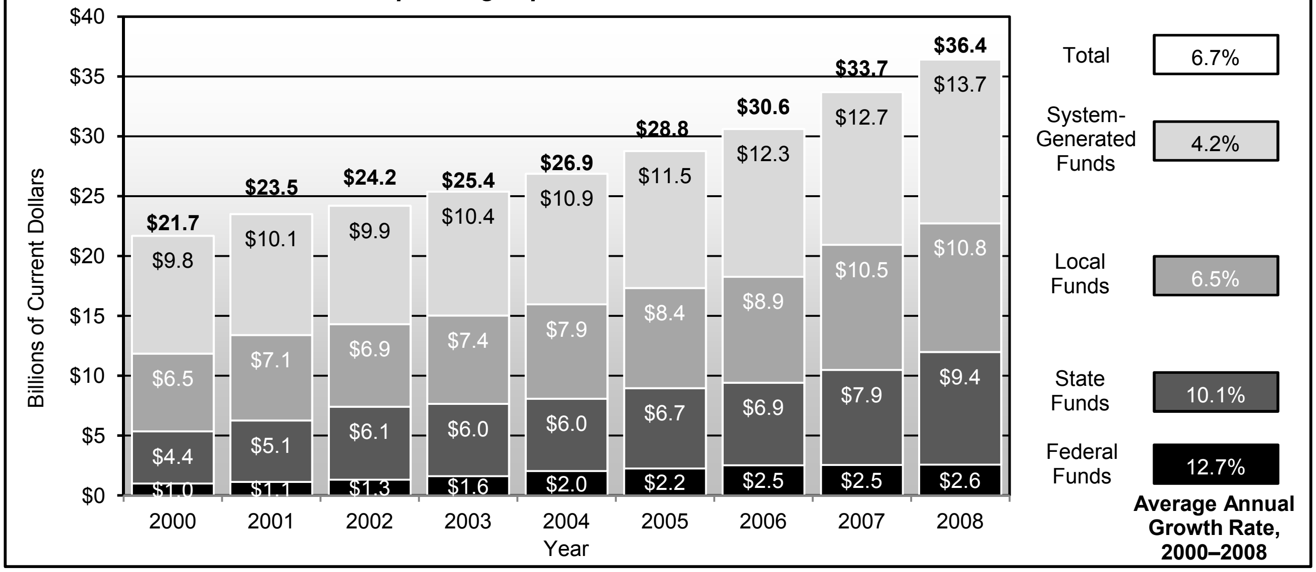
Q&A

What happens after the census?

TEA-21 mandated that Federal funding to transit systems in urbanized areas with populations over 200,000 be used only for capital expenses and preventive maintenance, and not for operating expenses. Formula grant funds to urbanized areas with populations of less than 200,000 were still allowed to be used for operating expenses. As a result of the 2000 census, 56 areas were reclassified as urbanized areas with populations of more than 200,000. (These reclassifications were announced by the Census Department in May 2002.) Transit agencies operating in these areas were slated to lose their eligibility to use Federal formula funding to finance transit operations starting in FY 2003. The Transit Operating Flexibility Act of 2002 amended Section 5307 of 49 USC to allow transit systems that were in these areas to continue to use their formula funds for operating expenses as well as for capital expenses in FY 2003, despite their change in status. This change was extended by the Surface Transportation Extension Act of 2003. Under SAFETEA-LU these transit agencies may continue to use formula funds for operating expenses in FY 2005 at 100 percent of their FY 2002 apportionment, in FY 2006 at 50 percent of their FY 2002 apportionment, and in FY 2007 at 25 percent of their FY 2002 apportionment. The impact of the 2010 census will not be known until the 2012 apportionment, and similar legislative responses to any reclassifications have yet to be considered.

Exhibit 6-26

Sources of Funds for Transit Operating Expenditures, 2000–2008



Source: National Transit Database.

Operating Expenditures by Transit Mode

As shown in *Exhibit 6-27*, transit operators' actual operating expenditures were $33.5 billion in 2008. These expenditures increased at an average annual rate of 6.6 percent between 2000 and 2008 (4.0 percent in constant dollars). Light rail and demand response modes have experienced the largest percentage increase in operating expenditures during this period. This is due to relatively greater investment in new light rail and demand response capacity over the past 10 years.

Exhibit 6-27

Transit Operating Expenditures by Mode, 2000–2008

	Expenditures, Millions of Current Dollars						
Year	**Motor Bus**	**Heavy Rail**	**Commuter Rail**	**Light Rail**	**Demand Response**	**Other**	**Total**
2000	$11,026.4	$3,930.8	$2,679.0	$592.1	$1,225.4	$549.3	**$20,003.1**
2001	$11,814.0	$4,180.1	$2,853.7	$676.5	$1,409.9	$594.7	**$21,528.8**
2002	$12,585.7	$4,267.5	$2,994.7	$778.3	$1,635.7	$643.4	**$22,905.1**
2003	$13,315.8	$4,446.2	$3,172.7	$753.7	$1,778.7	$718.0	**$24,185.2**
2004	$13,789.5	$4,734.2	$3,436.4	$826.1	$1,902.0	$738.6	**$25,426.8**
2005	$14,665.8	$5,144.8	$3,657.1	$978.1	$2,071.2	$720.8	**$27,237.8**
2006	$15,796.5	$5,287.5	$3,764.9	$1,070.1	$2,285.9	$819.7	**$29,024.6**
2007	$16,811.9	$5,888.3	$4,000.9	$1,162.8	$2,538.6	$901.0	**$31,303.5**
2008	$17,963.2	$6,128.5	$4,293.8	$1,258.5	$2,860.8	$974.6	**$33,479.4**
Percent of Total							
2000	55.1%	19.7%	13.4%	3.0%	6.1%	2.7%	**100.0%**
2008	53.7%	18.3%	12.8%	3.8%	8.5%	2.9%	**100.0%**
Average Annual Growth Rate							
2008/2000	6.3%	5.7%	6.1%	9.9%	11.2%	7.4%	**6.6%**

Source: National Transit Database.

Operating Expenditures by Type of Cost

In 2008, $18.0 billion—or 53.8 percent of total transit operating expenditures—went toward vehicle operations. Smaller amounts were expended on maintenance and administration; these expenses, which have virtually been the same for several years now, are broken down across cost categories in *Exhibit 6-28.*

Road and rail operations have inherently different cost structures because, in most cases roads are not paid for by the transit provider, but tracks are. Thus 59.1 percent of total operations expenditures for bus transit and 65.4 percent of total operations expenditures for demand response were spent for actual operation of the vehicles, only 42.7 percent of rail operations expenditures were spent on the operation of rail vehicles. A significantly higher percentage of expenditures for rail modes of transportation are classified as non-vehicle maintenance, corresponding to the repair and maintenance costs of fixed guideway systems.

Exhibit 6-28

2008 Operating Expenditures by Mode and Type of Cost

	Distribution of Expenditures, Millions of Dollars (Percent)								Totals, Millions of Dollars (Percent)	
Mode	**Vehicle Operations**		**Vehicle Maintenance**		**Nonvehicle Maintenance**		**General Administration**			
Motor Bus	$10,613.6	58.9%	$3,696.4	55.8%	$758.1	22.2%	$2,895.0	53.4%	**$17,963.1**	**53.7%**
Heavy Rail	$2,639.0	14.7%	$1,089.3	16.4%	$1,583.9	46.3%	$816.5	15.1%	**$6,128.7**	**18.3%**
Commuter Rail	$1,810.2	10.0%	$1,067.1	16.1%	$714.9	20.9%	$701.7	13.0%	**$4,293.9**	**12.8%**
Light Rail	$535.6	3.0%	$270.9	4.1%	$219.9	6.4%	$232.1	4.3%	**$1,258.5**	**3.8%**
Demand Response	$1,873.5	10.4%	$352.2	5.3%	$72.6	2.1%	$562.4	10.4%	**$2,860.7**	**8.5%**
Other	$540.1	3.0%	$153.5	2.3%	$70.4	2.1%	$210.5	3.9%	**$974.5**	**2.9%**
Total	**$18,012.0**	**100.0%**	**$6,629.4**	**100.0%**	**$3,419.8**	**100.0%**	**$5,418.2**	**100.0%**	**$33,479.4**	**100.0%**
Percent of All Modes	53.8%		19.8%		10.2%		16.2%		**100.0%**	

Source: National Transit Database.

Operating Expenditures per Vehicle Revenue Mile

Operating expenditures per vehicle revenue mile (VRM) is one measure of financial or cost efficiency. It shows the expense of operating a transit vehicle in revenue service. As shown in *Exhibit 6-29*, operating expenditures per VRM for all transit modes combined was $8.60 in 2008; the average annual increase in operating expenditures per VRM for all modes combined between 2000 and 2008 was 4.1 percent (1.5 percent after adjusting for inflation).

As shown in *Exhibit 6-30,* analysis of NTD reports for the largest 10 transit agencies (by ridership) shows that the growth in operating expenses is led by the cost of fringe benefits (36.0 percent of all operating costs for these agencies), which have been going up at a rate of 3.4 percent per year above inflation (constant dollars) since 2000. By comparison, average salaries at these ten agencies grew at an inflation-adjusted rate of only 0.1 percent per year in that period. FTA does not collect data on the different components of fringe benefits but increases in the cost of medical insurance undoubtedly contribute to the growth in this category.

Operating expenditures per capacity-equivalent VRM is a better measure of comparing cost efficiency among modes than operating expenditures per VRM because it adjusts for passenger-carrying capacities.

Exhibit 6-29

Operating Expenditures per Vehicle Revenue Mile, 2000–2008 (Current Dollars)

Year	Motor Bus[1]	Heavy Rail	Commuter Rail	Light Rail	Demand Response	Other[2]	Total
2000	$6.25	$6.80	$10.81	$11.51	$2.71	$5.05	**$6.25**
2001	$6.49	$7.07	$11.28	$12.72	$2.88	$5.41	**$6.49**
2002	$6.75	$7.07	$11.56	$12.98	$3.11	$5.59	**$6.68**
2003	$7.08	$7.27	$12.11	$12.25	$3.27	$6.37	**$6.96**
2004	$7.32	$7.58	$12.79	$12.40	$3.39	$5.21	**$7.17**
2005	$7.78	$8.20	$13.20	$14.40	$3.50	$4.66	**$7.56**
2006	$8.27	$8.34	$13.12	$14.66	$3.77	$5.13	**$7.31**
2007	$8.70	$9.22	$13.48	$14.12	$3.94	$5.17	**$8.31**
2008	$9.18	$9.35	$13.89	$14.58	$4.16	$4.89	**$8.60**
Average	**$7.54**	**$7.88**	**$12.47**	**$13.29**	**$3.41**	**$5.27**	**$7.26**
Average Annual Rate of Change							
2008/2000	4.9%	4.1%	3.2%	3.0%	5.5%	-0.4%	**4.1%**

[1] Note that annual changes in operating expense per capacity-equivalent VRM and unadjusted motor bus operating expenditures are consistent with those shown in Exhibit 6-31.

[2] Automated guideway, Alaska railroad, cable car, ferryboat, inclined plane, monorail, Público, trolleybus, and vanpool.

Source: National Transit Database.

Exhibit 6-30

Growth in Operating Costs—Top 10 Transit Systems, 2000–2008

Top 10 Systems*	Average Cost, Constant Dollars									% Increase	
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2000–2008	Average Annual
Fare per Mile	$3.71	$3.71	$3.50	$3.42	$3.56	$3.58	$3.66	$3.68	$3.70	0%	0.0%
Cost per Mile	$9.45	$9.70	$9.60	$9.63	$9.79	$9.97	$10.06	$10.43	$10.15	7%	0.9%
Labor Cost per Mile	$7.90	$7.99	$8.11	$8.27	$8.36	$8.33	$8.46	$8.80	$8.82	12%	1.4%
Salaries per Mile	$5.11	$5.11	$5.08	$5.06	$5.02	$4.91	$4.97	$5.07	$5.17	1%	0.1%
Fringe Benefits per Mile	$2.80	$2.88	$3.03	$3.21	$3.34	$3.42	$3.49	$3.73	$3.65	31%	3.4%

**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, Metropolitan Atlanta Rapid Transit Authority, and Maryland Transit Administration.*

Source: National Transit Database.

As demonstrated by the data in *Exhibit 6-31*, rail systems are more cost efficient in providing service than nonrail systems, once investment in rail infrastructure has been completed. Based on operating costs alone, heavy rail is the most efficient at providing transit service, and demand response systems are the least efficient. Annual changes in operating expense per capacity-equivalent VRM are not comparable across modes because average capacities for all vehicle types are adjusted separately each year based on reported fleet averages.

Exhibit 6-31

Operating Expenditures per Capacity-Equivalent Vehicle Revenue Mile by Mode, 2000–2008 (Current Dollars)

Year	Motor Bus[1]	Heavy Rail	Commuter Rail	Light Rail	Demand Response	Other[2]	Total
2000	$6.25	$2.88	$4.64	$4.57	$15.05	$7.71	**$5.15**
2001	$6.49	$3.00	$4.84	$5.05	$15.97	$8.53	**$5.24**
2002	$6.75	$3.00	$4.96	$5.15	$17.30	$8.43	**$5.31**
2003	$7.08	$2.93	$4.75	$4.55	$18.16	$9.57	**$5.49**
2004	$7.32	$3.06	$5.02	$4.61	$19.93	$9.10	**$5.68**
2005	$7.78	$3.30	$4.31	$5.23	$21.08	$8.66	**$6.01**
2006	$8.27	$3.35	$4.28	$5.32	$22.71	$9.91	**$6.29**
2007	$8.70	$3.73	$4.43	$5.19	$23.47	$10.01	**$6.45**
2008	$9.18	$3.78	$4.57	$5.36	$24.80	$12.91	**$6.77**
Average	**$7.54**	**$3.23**	**$4.64**	**$5.00**	**$19.83**	**$9.43**	**$5.82**
Average Annual Rate of Change							
2008/2000	4.9%	3.5%	-0.2%	2.0%	6.4%	6.7%	**3.5%**

[1] *Note that annual changes in operating expense per capacity-equivalent VRM and unadjusted motor bus operating expenditures are consistent with those shown in Exhibit 6-29.*

[2] *Automated guideway, cable car, ferryboat, inclined plane, jitney, monorail, Público, tramway, trolleybus, and vanpool.*

Source: National Transit Database.

Operating Expenditures per Passenger Mile

Operating expense per passenger mile is an indicator of the cost effectiveness of providing a transit service. It shows the relationship between service inputs as expressed by operating expenses and service consumption as expressed by passenger miles traveled. Operating expenditures per passenger mile for all transit modes combined increased at an average annual rate of 4.3 percent between 2000 and 2008 (from $0.44 to $0.62). These data are shown in *Exhibit 6-32*.

Exhibit 6-32

Operating Expenditures per Passenger Mile, 2000–2008 (Current Dollars)

Year	Motor Bus	Heavy Rail	Commuter Rail	Light Rail	Demand Response	Other*	Total
2000	$0.59	$0.28	$0.29	$0.44	$2.09	$0.49	**$0.44**
2001	$0.60	$0.29	$0.30	$0.47	$2.25	$0.52	**$0.46**
2002	$0.64	$0.31	$0.32	$0.54	$2.51	$0.55	**$0.50**
2003	$0.69	$0.33	$0.33	$0.55	$2.58	$0.56	**$0.53**
2004	$0.73	$0.33	$0.35	$0.56	$2.70	$0.53	**$0.55**
2005	$0.76	$0.36	$0.39	$0.58	$2.80	$0.52	**$0.58**
2006	$0.77	$0.36	$0.36	$0.57	$3.03	$0.58	**$0.59**
2007	$0.82	$0.36	$0.36	$0.60	$3.26	$0.60	**$0.60**
2008	$0.85	$0.36	$0.39	$0.60	$3.39	$0.57	**$0.62**
Average	**$0.72**	**$0.33**	**$0.34**	**$0.55**	**$2.74**	**$0.55**	**$0.54**
Average Annual Rate of Change							
2008/2000	4.7%	3.1%	4.0%	4.0%	6.3%	1.9%	**4.3%**

* *Automated guideway, cable car, ferryboat, inclined plane, jitney, monorail, Público, trolleybus, aerial tramway, and vanpool.*

Source: National Transit Database.

Farebox Recovery Ratios

The farebox recovery ratio represents farebox revenues as a percentage of total transit operating costs. It measures users' contributions to the variable cost of providing transit services and is influenced by the number of riders, fare structure, and rider profile. Low regular fares, the high availability and use of discounted fares, and high transfer rates tend to result in lower farebox recovery ratios. Farebox recovery ratios for 2004 to 2008 are provided in *Exhibit 6-33*. The average farebox recovery ratio over this period for all transit modes combined was 34.6 percent; heavy rail had the highest average farebox recovery ratio at 59.4 percent. Farebox recovery ratios for total costs are not provided because capital investment costs are not spread evenly across years. Rail modes have farebox recovery ratios for total costs that are significantly lower than for operating costs alone because of these modes' high level of capital costs.

Exhibit 6-33

Farebox Recovery Ratio by Mode, 2004–2008

Year	Motor Bus	Heavy Rail	Commuter Rail	Light Rail	Demand Response	Other[2]	Total
2004[1]	27.9%	61.3%	47.0%	26.2%	9.6%	36.2%	**35.5%**
2005[1]	27.6%	58.4%	47.2%	25.4%	9.5%	35.0%	**34.8%**
2006[1]	26.6%	60.9%	49.4%	27.4%	9.3%	34.3%	**34.8%**
2007	26.6%	56.8%	49.5%	26.6%	8.2%	35.3%	**34.0%**
2008	26.3%	59.4%	50.3%	29.3%	7.5%	32.7%	**34.1%**
Average	**27.0%**	**59.4%**	**48.7%**	**27.0%**	**8.8%**	**34.7%**	**34.6%**

[1] Note that the ratios presented in this exhibit were calculated differently than the ratios presented in the 2008 C&P Report and are therefore not totally comparable. The ratios presented here were calculated using data from NTD data table 26, "Fares per Passenger and Recovery Ratio," which is available at www.ntdprogram.gov/ntdprogram/data.htm.

[2] Automated guideway, Alaska railroad, cable car, ferryboat, inclined plane, jitney, monorail, Público, trolleybus, aerial tramway, and vanpool.

Source: National Transit Database.

Rural Transit

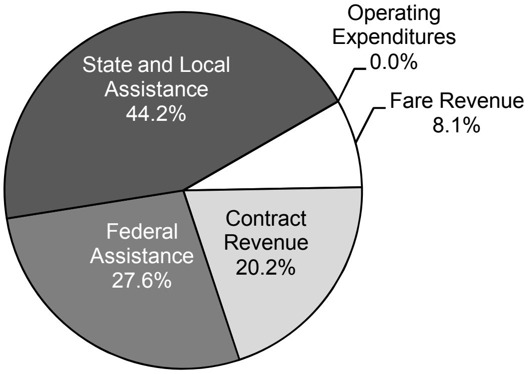
Since 1978, the Federal government has contributed to the financing of transit in rural areas (i.e., areas with populations of less than 50,000). These rural areas are estimated to account for approximately 36 percent of the U.S. population and 38 percent of the transit-dependent population.

Funding for rural transit is currently provided through 49 USC Section 5311, which replaced Section 18 of the Urban Mass Transit Act in 1994. Rural transit funding was increased substantially with passage of TEA-21 and has continued to increase under SAFETEA-LU. Federal funding for rural transit was $240 million in the last year of TEA-21, FY 2004, and reached $465 million in FY 2009 under SAFETEA-LU. States may transfer additional funds to rural transit from highway projects, transit projects, or formula transit funds for small urbanized areas.

As shown in *Exhibit 6-34*, 27.6 percent of rural transit authorities' operating budgets come from Federal Assistance funds. State and local governments cover 44.2 percent of their rural transit operating budgets through a combination of dedicated State and local taxes, appropriations from State general revenues, and allocations from other city and county funds. 20.2 percent of rural transit operating budgets comes from contract revenue, defined as reimbursement from a private entity (profit or non-profit) for the provision of transit service. Fares accounted for only 8.1 percent, close to the average farebox recovery rate for demand response service (which constitutes most of rural transit). In 2008, the total value of rural transit operating budgets reported to the NTD was $1.06 billion.

Exhibit 6-34

Rural Transit Operators' Budget Sources for Operating Expenditures, 2008



Source: National Transit Database.

PART II

Investment/Performance Analysis

Introduction

Chapters 7 through 10 present and analyze future capital investment scenario estimates for highways, bridges, and transit. These chapters provide general investment benchmarks as a basis for the development and evaluation of transportation policy and program options. The 20-year investment scenario estimates shown in these chapters reflect the total capital investment from all sources that is projected to be required to achieve certain levels of performance. **They do not directly address specific public or private revenue sources that might be used to finance the investment under each scenario, nor do they identify how much might be contributed by each level of government.**

These four investment-related chapters include the following analyses:

Chapter 7, **Potential Capital Investment Impacts**, analyzes the projected impacts of alternative levels of future investment on measures of physical condition, operational performance, and other benefits to system users. Each alternative pertains to investment over the 20-year period 2009 to 2028, and is presented both as an annual average level of investment and as the annual rates of increase or decrease in investment that would produce that annual average. Both the level and rate of growth in investment are measured using constant 2008 dollars.

Chapter 8, **Selected Capital Investment Scenarios**, examines several scenarios distilled from the investment alternatives considered in Chapter 7. Some of the scenarios are oriented around maintaining different aspects of system condition and performance or achieving a specified minimum level of performance, while others link to broader measures of system user benefits. The scenarios included in this chapter are intended to be illustrative and do not represent comprehensive alternative transportation policies; the Department does not endorse any of these scenarios as a target level of investment.

Chapter 9, **Supplemental Scenario Analysis**, explores some of the implications of the scenarios presented in Chapter 8 and contains some additional policy-oriented analyses addressing issues not covered in Chapters 7 and 8. As part of this analysis, recent condition, performance, and finance trends are compared with projected future needs in order to identify consistencies and inconsistencies between what has occurred in the past and what is projected to occur in the future.

Chapter 10, **Sensitivity Analysis**, explores the impact that changing some of the key technical assumptions underlying the analyses presented in Chapters 7 and 8 would have on the projections at alternative levels of capital investment. The investment scenario projections in this report are developed using models that evaluate current system condition and operational performance and make 20-year projections based on assumptions about future travel growth and a variety of engineering and economic variables. The accuracy of these projections depends, in large part, on the underlying assumptions used in the analysis. The uncertainty inherent in the estimates is further discussed below.

Unlike Chapters 1 through 6, which largely include highway and transit statistics drawn from other sources, the investment scenario projections presented in these chapters (and the models used to create the projections) were developed exclusively for the C&P report. The procedures for developing the investment scenario estimates have evolved over time to incorporate new research, new data sources, and improved estimation techniques relying on economic principles. The methodologies used to analyze investment for highways, bridges, and transit are discussed in greater detail in Appendices A, B, and C.

The combination of engineering and economic analysis in this part of the report is consistent with the movement of transportation agencies toward asset management, value engineering, and greater consideration of cost effectiveness in decision making. The economic approach to transportation investment is discussed in greater detail at the end of this section.

Capital Investment Scenarios

The 20-year capital investment scenario projections shown in this report reflect complex technical analyses that attempt to predict the impact that capital investment may have on the future conditions and performance of the transportation system. These scenarios are intended to be illustrative, and the U.S. Department of Transportation does not endorse any of them as a target level of investment. Where practical, supplemental information has been included to describe the impacts of other possible investment levels.

This report does not attempt to address issues of cost responsibility. The investment scenarios predict the impact that particular levels of combined Federal, State, local, and private investment might have on the overall conditions and performance of highways, bridges, and transit. While Chapter 6 provides information on what portion of highway investment has come from different revenue sources in the past, the report does not make specific recommendations about how much could or should be contributed by each level of government or the private sector in the future.

Some of the scenarios presented in this report are defined around achieving a particular level of system performance. In considering the future system performance impacts identified for each scenario, it is important to note that they represent what **could** be achievable assuming a particular level of investment, rather than what **would** be achieved. The models used in the development of the scenarios focus on engineering impacts and benefits and generally assume that, within a fixed budget constraint, potential capital projects with higher benefits relative to their costs would be carried out before those with lower benefit-cost ratios. In actual practice, other factors can and do affect project selection. Further, models used to generate estimates of investment levels rely on a variety of additional assumptions and their predictive power has never been tested. Therefore, these estimates are for illustrative and comparative purposes only. Other scenarios are defined around funding all potential capital investments with benefit-cost ratios above a specified threshold. It is important to note that simply increasing spending to the levels identified in these scenarios would not in itself guarantee that these funds would actually be expended in a cost-beneficial manner.

Also, some potential capital investments selected by the models, regardless of their economic merits or impact on conditions and performance, may be infeasible for political or other reasons. As a result, the supply of feasible cost-beneficial projects could be lower than the levels estimated by the modeling assumptions of some scenarios.

Highway and Bridge Investment Scenarios

Future investments in highways and bridges are analyzed independently by separate models and techniques for a variety of alternative funding levels in Chapter 7, and the results are combined for the selected investment scenarios presented in Chapter 8. The National Bridge Investment Analysis System (NBIAS) considers investments related to bridge repair, rehabilitation, and replacement. Investments for capacity expansion and the highway resurfacing and reconstruction component of system rehabilitation are modeled by the Highway Economic Requirements System (HERS). While this model was primarily designed to analyze highway segments, HERS also factors in the costs of expanding bridges and other structures when deciding whether to add lanes to a highway segment. The costs reported for the investment scenarios in Chapter 8 also include adjustments made using external procedures described in that chapter, allowing elements of system rehabilitation, system expansion, and system enhancement that are not modeled in NBIAS or HERS to be reflected in the estimates. The investment scenario estimates shown should thus reflect the size of the total highway capital investment program that is projected to be required in order to meet the performance goals specified in the scenarios.

Chapter 8 applies a consistent set of performance criteria in creating parallel scenarios to separately analyze investment needs for all Federal-aid highways, all roads (systemwide), the National Highway System, and the Interstate System. The statistics for Federal-aid highways are presented more prominently in this edition; due to data limitations, these estimates are considered to be more reliable than the comparable systemwide statistics for all roads. The Highway Performance Monitoring System (HPMS) database on which the HERS model relies includes detailed information only on Federal-aid highways; for the scenarios based on all roads, separate estimates must be generated for roads functionally classified as rural minor collectors, rural local, or urban local.

The **Sustain Current Spending scenario** projects the potential impacts of sustaining capital spending at 2008 base year levels in constant dollar terms over the 20-year period 2009 through 2028. The **Maintain Conditions and Performance scenario** assumes that combined highway capital investment by all levels of government gradually changes in constant dollar terms over 20 years to the point at which selected performance indicators in 2028 are maintained at their 2008 base year levels. For this edition, these indicators are average speed (as computed by HERS) and the backlog of potential cost-beneficial bridge investments (as computed by NBIAS). It should be noted that the version of this scenario presented in the 2008 C&P report used a different HERS indicator, adjusted average user costs. The impact of this change is discussed in Chapters 9.

The investment levels for the **Improve Conditions and Performance scenario** are determined by identifying the highest rate of annual spending growth for which potentially cost-beneficial highway and bridge improvements can be identified. This scenario represents an "investment ceiling" above which it would not be cost-beneficial to invest, even if available funding were unlimited. The portion of this scenario directed toward addressing engineering deficiencies on pavements and bridges is described as the **State of Good Repair benchmark**.

The **Intermediate Improvement scenario** is included in Chapter 8 in recognition that any investment above the level of the **Maintain Conditions and Performance scenario** described above should theoretically improve conditions and performance. The HERS portion of this scenario reflects a level of investment at which all potential improvements with a benefit-cost ratio of 1.5 or higher could be funded (in contrast to the **Improve Conditions and Performance scenario**, which utilizes a minimum benefit-cost ratio of 1.0). The NBIAS portion of this scenario assumes the same annual rate of spending as computed in HERS, which would be sufficient to reduce (but not eliminate) the backlog of potential cost-beneficial bridge investments by 2028.

Supporting Analyses for Highway and Bridge Investment

In addition to supporting the primary Chapter 8 scenarios described above, the investment alternatives presented in Chapter 7 identify the levels of investment associated with maintaining two other performance indicators —average pavement roughness and average delay per vehicle miles traveled (VMT)—and the level of investment at which all potential improvements with a minimum benefit-cost ratio of 1.2 or higher could be funded. The impacts of a gradual decline in constant dollar spending of 1 percent per year are also explored.

Chapter 9 includes a supplemental analysis that focuses on maintaining specific performance indicators for individual highway functional systems. This analysis combines three elements: (1) the level of system expansion expenditures associated with maintaining average delay per VMT, (2) the level of system rehabilitation expenditures associated with maintaining average pavement roughness, and (3) the level of system rehabilitation expenditures associated with maintaining the economic investment backlog for bridges.

(In contrast, the **Maintain Conditions and Performance scenario** described above focuses on maintaining more general indicators for the system as a whole).

Chapter 9 also includes supplemental analyses discussing the potential impacts of alternative deployment rates for Intelligent Transportation Systems (ITS) and operations strategies, as well as alternative bridge management strategies. The potential impacts of alternative financing mechanisms, including congestion pricing, on future travel demand and systemwide performance are explored as well. Chapter 10 includes analyses of the potential impacts of alternative future VMT growth rates.

These supporting analyses provide both insights into the implications of the primary scenarios presented in Chapter 8 and the tools needed for readers to construct their own alternative scenarios using different assumptions.

Transit Investment Scenarios

The transit section of Chapter 7 evaluates the impact of varying levels of capital investment on various measures of condition and performance, while the transit section of Chapter 8 provides a more in-depth analysis of specific investment scenarios.

The **Sustain Current Spending scenario** projects the potential impacts of sustaining preservation and expansion spending at 2008 base year levels in constant dollar terms over the 20-year period of 2009 through 2028. The scenario applies benefit-cost analysis to prioritize investments within this constrained budget target.

The **State of Good Repair benchmark** projects the level of investment needed to bring all assets to a state of good repair over the next 20 years, defined as asset condition ratings of 2.5 or higher on a 5-point scale. This scenario is focused solely on the preservation of existing assets and does not apply a benefit-cost screen.

The **Low Growth scenario** adds a system expansion component on top of the system preservation needs associated with the **State of Good Repair benchmark**. The goal of this scenario is to preserve existing assets and expand the transit asset base to support projected ridership growth over 20 years as forecast by metropolitan planning organizations (MPOs). The **High Growth scenario** incorporates a more extensive expansion of the existing transit asset base to support a higher annual rate of growth consistent with that experienced between 1999 and 2008. Both of these scenarios incorporate a benefit-cost test for evaluating potential investments.

It should be noted that the transit scenarios presented in this edition are significantly different than those presented in the 2008 C&P report. These differences are discussed in Chapter 9.

Comparisons Between Report Editions

In making comparisons between the capital investment scenarios presented in different editions of the C&P report, several considerations should be taken into account:

- Scenario definitions have been modified over time. (As noted above, the definitions of several transit scenarios and one of the highway scenarios have been modified since the 2008 C&P report).
- The analytical tools and data used in generating the scenarios have been refined and improved over time.
- The base year of the analysis advances two years between successive editions of this biennial report. Over this period many real-world factors change that 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). While this issue is relevant to all scenarios, it is particularly significant for scenarios aimed at maintaining base year conditions.

Selected comparisons of the capital investment scenarios from this report with those from previous editions are presented in Chapter 9. (Comparable analyses were presented in Chapter 8 of the 2008 C&P report). Chapter 9 also includes analyses that look back at the scenarios presented in selected previous editions to see how their projections of future conditions and performance have lined up with what has actually occurred over time, taking into account factors such as changes in capital spending and travel growth.

The Economic Approach to Transportation Investment Analysis

The methods and assumptions used to analyze future highway, bridge, and transit investment scenarios are continuously evolving. Since the beginning of the highway report series in 1968, innovations in analytical methods, new empirical evidence, and changes in transportation planning objectives have combined to encourage the development and application of improved data and analytical techniques. Estimates of future highway investment requirements, as reported in the 1968 *National Highway Needs Report to Congress*, began as a combined “wish list” of State highway “needs.” As the focus of national highway investment changed from system expansion to management of the existing system during the 1970s, national engineering standards were defined and applied to identify system deficiencies, and the investments necessary to remedy these deficiencies were estimated. By the end of the decade, a comprehensive database, the HPMS, had been developed to monitor highway system conditions and performance nationwide.

By the early 1980s, a sophisticated simulation model, the HPMS Analytical Process (HPMS-AP), was available to evaluate the impact of alternative investment strategies on system conditions and performance. The procedures used in the HPMS-AP were based on engineering principles. Engineering standards were applied to determine which system attributes were considered deficient, and improvement option packages were developed using standard engineering practices to potentially correct given deficiencies, but without consideration of comparative economic benefits and costs.

In 1988, the Federal Highway Administration embarked on a long-term research and development effort to produce an alternative simulation procedure combining engineering principles with economic analysis, culminating with the development of the HERS. The HERS model was first utilized to develop one of the two highway investment scenarios presented in the 1995 C&P Report. In subsequent reports, HERS has been used to develop all of the highway investment scenarios.

Executive Order 12893, “Principles for Federal Infrastructure Investments,” issued on January 26, 1994, directs that Federal infrastructure investments be selected on the basis of a systematic analysis of expected benefits and costs. This order provided additional momentum for the shift toward developing analytical tools that incorporate economic analysis into the evaluation of investment requirements.

In the 1997 C&P Report, the Federal Transit Administration introduced TERM, which was used to develop both of the transit investment scenarios. TERM incorporates benefit-cost analysis into its determination of transit investment levels.

The 2002 C&P Report introduced the NBIAS, incorporating economic analysis into bridge investment modeling for the first time.

Economic Focus Versus Engineering Focus

The economic approach to transportation investment relies fundamentally upon an analysis and comparison of the benefits and costs of potential investments. By providing benefits whose value exceeds their costs, projects that offer "net benefits" have the potential to increase societal welfare and are thus considered to be "good" or "economic" investments from a public welfare perspective. In a benefit-cost ratio, the cost of an investment in transportation infrastructure (the denominator) is conventionally measured by the capital expenditures required to carry out the project. The benefits of transportation capital investments are generally characterized as reductions in costs borne by transportation agencies (such as for maintenance), users of the transportation system (such as savings in travel time and vehicle operating costs), and others who are affected by the operation of the transportation system (such as those with health impacts or property damage costs).

Traditional engineering-based analytical tools focus mainly on estimating transportation agency costs and the value of resources required to maintain or improve the condition and performance of infrastructure. This type of analytical approach can provide valuable information about the cost effectiveness of transportation system investments from the public agency perspective, including the optimal pattern of investment to minimize life-cycle costs. However, this approach does not fully consider the potential benefits to users of transportation services from maintaining or improving the condition and performance of transportation infrastructure.

By incorporating the value of services that transportation infrastructure provides to its users, the HERS, TERM, and NBIAS models each have a broader focus than traditional engineering-based models. They also attempt to take into account some of the impacts that transportation activity has on non-users and recognize how investments in transportation infrastructure can alter the costs of these impacts. By expanding the scope of benefits considered in their analyses, these models are able to yield an improved understanding of existing and future investment needs for the Nation's surface transportation system.

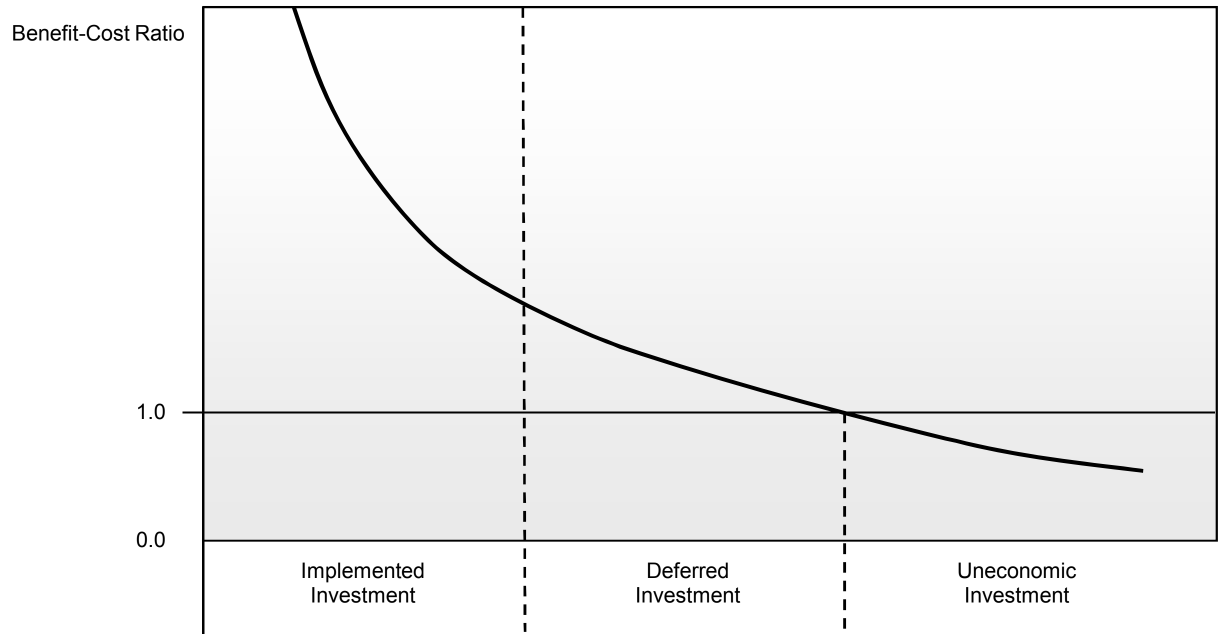
Using this economics-based approach to analyze potential transportation investment is likely to result in different decisions about the catalog of desirable improvements than would be made using a purely engineering-based approach. For example, if a highway segment, bridge, or transit system is greatly underutilized, benefit-cost analysis might suggest that it would not be worthwhile to fully preserve its condition or to address its engineering deficiencies. Conversely, a model based on economic analysis might recommend additional investments to expand capacity or improve travel conditions above and beyond the levels dictated by an analysis that simply minimized engineering life-cycle costs, if doing so would provide sufficient benefits to the users of the system.

The economics-based approach also provides a more sophisticated method for prioritizing potential improvement options when funding is constrained. By identifying investment opportunities according to the net benefits they offer, economic analysis helps to provide guidance in directing limited transportation capital investment resources toward the types of system improvements that can together provide the largest benefits to transportation system users. Such an approach, which is applied in HERS, is illustrated in *Exhibit II-1*. Projects are ranked in order by their benefit-cost ratios and are then successively implemented until the funding constraint is reached. Projects that would produce lesser net benefits would be deferred for reconsideration in the future.

One implication of prioritizing potential projects in this manner is that the marginal and average benefit-cost ratios associated with a program of improvements will decline as the overall level of investment rises. As the relative returns on potential highway, bridge, and transit investments decline, it becomes more likely that competing potential public or private sector investments will yield more net benefits to society.

Exhibit II-1

Economically Efficient Investment



Theoretically, sufficient funding could be made available to implement all projects passing the benefit-cost test. Projects that do not meet this threshold (because they do not offer positive net benefits and thus cannot increase total net benefits provided by transportation system infrastructure) should not be selected or implemented, even if unlimited funding were available.

It should be noted that some benefits of transportation investments can be difficult to measure, including those pertaining to livability and sustainability.

Financing Mechanisms and Investment Analysis

As discussed in Chapter 6, highway user revenues (including fuel taxes, motor-vehicle fees, and tolls) are the primary source of funding for highway-related expenditures in the United States. This is particularly true for expenditures funded by the Federal government, which are predominantly drawn from user charges and are devoted primarily to capital outlay; but it is also a significant factor for State and local government expenditures. Private sector investment in highways is also dependent on revenue streams (primarily tolls) from users of the privately financed facilities. By raising the out-of-pocket costs of highway travel to users, highway user charges tend to reduce the demand for use of the system, and thereby reduce the amount of investment that would be required to achieve a given level of condition and performance, or to exhaust all cost-beneficial investments. The potential reductions in investment levels are naturally greater for user charges designed to limit demand for the particular uses of the system that are main drivers of investment needs. For investment in system expansion, the main driver is peak-period congestion, which could potentially be reduced through peak-period congestion charges. For investment in highway rehabilitation, a principal driver is pavement damage from heavy trucks, which could potentially be reduced by differentiated charges on heavy truck VMT. The HERS model has been adapted to support analysis of the link between broad types of alternative financing mechanisms and projected future investment/performance relationships.

Chapter 9 includes a set of supplemental analyses that assume that any increases in highway and bridge capital investment above 2008 levels would be funded from user charges imposed on either a per-mile basis (such as a fixed-rate toll) or a per-gallon basis (such as the motor-fuel tax). The general effect of such charges is to reduce future VMT and reduce the projected level of investment needed to achieve a particular performance objective.

The sources of funding for transit-related expenditures have traditionally been more diverse than those for highways because passenger fares, fuel taxes, sales taxes, and other public funding mechanisms all play a significant role in financing transit. Consequently, the linkages between financing mechanisms and future investment/performance relationships discussed above for highways are less critical from the transit perspective and are not directly modeled in the transit investment analysis presented in this report. The analysis of potential bridge investment relationships also do not directly consider such linkages.

Congestion Pricing

When highway users make decisions about whether, when, and where to travel, they consider both the implicit costs (such as travel time and safety risk) and explicit, out-of-pocket costs (such as fuel costs and tolls) of the trip. Under normal operating conditions, their use of the road will not have an appreciable effect on the costs faced by other users. As traffic volumes begin to approach the carrying capacity of the road, however, traffic congestion and delays begin to set in; travel times for all users begin to rise, with each additional vehicle making the situation progressively worse. However, individual travelers are not likely to take into account the delays and additional costs that their use of the facility imposes on other travelers, focusing instead only on the costs that they bear themselves. Economists refer to this divergence between the costs an individual user bears and the total added costs each additional user imposes as a congestion externality. Ignoring this externality is likely to result in an inefficiently high level of use of congested facilities, resulting in a loss of some of their potential benefits to users.

If one ignores the costs of implementing and operating a system of congestion charges, then the optimal congestion charges—those that would maximize net societal benefits—would be calculated for each mile of travel on congested facilities to precisely equal the cost of the delay that mile of travel imposes on society. By “internalizing” the congestion externality, such charges would induce adjustments to travel patterns, including re-scheduling of trips away from the peak, that would reduce (but not necessarily eliminate) congestion delay. Although these adjustments would entail costs to society—for example, commuters who alter their work schedule to avoid traveling during the peak period may suffer such inconveniences as disruptions to child-care arrangements and preferred sleep/wake times—when congestion charges are set optimally, these costs are less than the benefits from reduced delay. The same is true if one takes account of the costs of implementing and operating a congestion pricing system; however, since these costs increase with the target level of precision, the optimal congestion charge for a particular mile of travel may now approximate, rather than precisely equal, the delay cost that mile of travel imposes on society. (If the costs of implementation and operation are sufficiently high in a given location, that may reduce the optimal congestion charge for that location to zero).

The HERS model has been adapted to provide quantitative estimates of the impact that more efficient pricing could have on future highway investment/performance relationships. The analytical procedures assume congestion pricing would be implemented universally on all congested roads, but do not incorporate the costs of implementing and operating this system. The rates set for individual facilities are based on the marginal cost that each user of the facility imposes on all others during the peak travel period.

Chapter 9 includes a set of supplemental analyses projecting the potential impacts of adopting universal congestion pricing. Some of these analyses are linked to the analyses described in the "Financing Mechanisms and Investment Analysis" section above and assume that congestion pricing revenues would be available to support any additional investment needed for a particular highway investment scenario and would be supplemented by additional fixed rate user charges if necessary. To the extent that the revenues from variable rate user charges would exceed the amount needed to support a given highway investment scenario, the excess revenues were assumed to be rebated to users in the form of reductions in existing fixed rate user charges. It should be noted, however, that the actual disposition of congestion pricing revenues would be at the discretion of the entity that imposes the charges, and that such revenues could instead be used to support additional investment in transit systems to accommodate travelers who might opt to change transportation modes in response to the adoption of congestion pricing, or for a variety of other transportation or nontransportation purposes.

The analysis of congestion pricing presented in this report focus mainly on their potential impacts on future investment/performance relationships, particularly in regard to the amount of combined public and private investment that might be needed to achieve particular outcomes in terms of future system performance. This report does not address social equity concerns about congestion pricing. This report also does not explore the mechanics of computing or assessing economically optimal rates on a real-time basis. However, significant advances in recent years in tolling technology have reduced both the operating costs of toll collection and the delays experienced by users from stopping or slowing down at collection points. Other advances have made it possible to charge different toll rates during different time periods, in some cases varying the price dynamically with real-time traffic conditions. While some of these technologies require extensive roadway infrastructure (and would thus likely be deployed only on high-volume, limited access roads), other in-vehicle technologies using global positioning system devices are being developed that could make it possible to assess fees on virtually any roadway. The HERS methodology for estimating the impacts of congestion pricing is presented in greater detail in Appendix A. The current approach has some technical limitations and does not fully address the network effects associated with drivers diverting to other roads. Consequently, this report does not include any analyses of the potential impacts of partial implementation of congestion pricing on selected facilities.

While most transit routes have excess capacity (measured either in terms of passengers per vehicle or vehicles per route mile), some heavily used lines in major metropolitan areas do approach their passenger-carrying capacities during peak travel hours, with commensurate deterioration in the quality of service. As with highways, some of this overcrowding relates to the underpricing of transit service during rush hours. These overcrowded transit lines are often in corridors with heavily congested highway service, making a joint solution to the pricing problems on both highways and transit not only more important to consider, but also more complicated to analyze, devise, and implement.

Multimodal Analysis

The HERS, TERM, and NBIAS all use a consistent approach for determining the value of travel time and the value of reducing transportation injuries and fatalities, which are key variables in any economic analysis of transportation investment. While HERS, TERM, and NBIAS all use benefit-cost analysis, their methods for implementing this analysis are very different. The highway, transit, and bridge models each rely on separate databases, making use of the specific data available for each mode of the transportation system and addressing issues unique to that mode.

These three models have not yet evolved to the point where direct multimodal analysis would be possible. For example, HERS assumes that, when lanes are added to a highway, highway user costs will initially fall, resulting in additional highway travel. Some of the increased use of the expanded facility would result from newly generated travel, while some would be the result of travel shifting from transit to highways. However, HERS is unable to distinguish between these different sources of additional highway travel. At present, there is no direct way to analyze the impact that a given level of highway investment in a particular location would have on the transit investment in that vicinity (or vice versa). Opportunities for future development of HERS, TERM, and NBIAS, including efforts to allow feedback between the models, are discussed in Appendix D.

Uncertainty in Transportation Investment Modeling

The three investment analysis models used in this report are deterministic rather than probabilistic, meaning that they provide a single projected value of total investment for a given scenario rather than a range of likely values. As a result, it is possible to make only general statements about the limitations of these projections, based on the characteristics of the process used to develop them, rather than giving specific information about confidence intervals.

As in any modeling process, simplifying assumptions have been adopted to make analysis practical and to meet the limitations of available data. While potential highway improvements are evaluated based on benefit-cost analysis, not all external costs (such as noise pollution) or external benefits (including certain net favorable impacts of highway improvements on productivity and competition in the economy) that may be considered in the actual selection process for individual projects are reflected in the investment models. Across a broad program of investment projects, such external effects may fully or partially cancel each other out; but, to the extent that they do not, the "true" level of investment required to achieve a particular goal may be either higher or lower than those predicted by the model. Some projects that HERS, TERM, or NBIAS view as economically justifiable may not be after more careful scrutiny, while other projects that the models would reject might actually be justifiable if these other factors were considered.

While it is not possible to present precise confidence ranges for the estimates found in this report, it is possible to examine the sensitivity of the estimates to changes in some of the key parameters underlying the models. Such analyses are presented in Chapter 10 and include discussions of alternative discount rates, alternative valuations of time saved and lives saved, alternative assumptions about fuel prices and average fuel economy, and alternative assumptions about future travel demand and its sensitivity to changes in the price of traveling. Chapter 10 also includes a discussion of the theoretical implications of each of these key input variables and their implications in conducting benefit-cost analysis.

Chapter 7

Potential Capital Investment Impacts

Potential Highway Capital Investment Impacts

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 within this chapter provides comparable information for different types of potential future transit investments.

The analyses in this section focus on the types of investment within the scopes of the Highway Economic Requirements System (HERS) and the National Bridge Investment Analysis System (NBIAS), and form the building blocks for the capital investment scenarios presented in Chapter 8. The accuracy of the projections in this chapter depends on the validity of the technical assumptions underlying the analysis, some of which are varied in the sensitivity analysis in Chapter 10. Of particular importance are the sensitivity analyses concerning the trend rate at which vehicle miles traveled (VMT) would grow in the absence of any change in average user cost of travel (in constant dollars). In this report's HERS analyses, the baseline assumption is that total VMT would grow over the analysis period at the rate implied by the projections in the Highway Performance Monitoring System (HPMS). If the projected VMT growth rate were lower, the level of performance that would be associated with any particular level of future highway capital investment would tend to be better than that depicted in the exhibits in this chapter.

The analyses presented in this section do not make any explicit assumptions regarding how future investment in highways might be funded. Chapter 9 includes an analysis of the impacts that alternative funding arrangements might have on travel demand and the level of investment needed to achieve certain levels of system performance.

Highway Economic Requirements System

Simulations conducted with the HERS model provide the basis for this report's analysis of investment in highway resurfacing and reconstruction as well as for highway and bridge capacity expansion. HERS

Q&A

How closely does the HERS model simulate the actual project selection processes of State and local highway agencies?

The process of project selection in HERS differs from reality in several respects. HERS assumes that the allocation of total national spending on highway investment will be "economically efficient," meaning that the projects selected will be the set that maximizes total benefits to society. The model takes no account of the division of funding authority among States and localities. It could, for example, program a large increase in highway investment in a State that lacks the needed budgetary resources. The model also ignores the influence on project selection decisions of evaluation criteria other than economic efficiency, such as perceptions of fairness and political considerations. To the extent that these other factors shape the project selection decisions, HERS may underestimate the level of investment needed to achieve a given performance or conditions target, such as maintaining average speed.

In addition, HERS lacks access to the full array of information that governments would need to determine what is economically efficient. It relies on the HPMS database, which provides only a limited amount of information on each sampled highway section. For example, while the HPMS includes information regarding feasibility of adding lanes to each highway section, it does not currently include information on impediments to widening or feasibility of alternative approaches to added capacity in a given location (construction of parallel routes, double-decking, tunneling, investments in other transportation modes, etc.). This issue is discussed further in Appendix A.

employs incremental benefit-cost analysis to evaluate highway improvements based on data from the Highway Performance Monitoring System. The HPMS includes State-supplied information on current roadway characteristics, conditions, and performance and anticipated future travel growth for a nationwide sample of more than 120,000 highway sections. HERS analyzes individual sample sections only as a step toward providing results at the national level; the model does not provide definitive improvement recommendations for individual sections.

Simulations with the HERS model start by evaluating the current state of the highway system using data from the HPMS sample. These data provide information on pavements, roadway geometry, traffic volume and composition (percent trucks), and other characteristics of the sampled highway sections. For sections with one or more deficiencies identified, the model then considers potential improvements, including resurfacing, reconstruction, alignment improvements, and widening or adding travel lanes. HERS selects the improvement (or combination of improvements) with the greatest net benefits, where benefits are defined as reductions in direct highway user costs, agency costs for road maintenance, and societal costs from vehicle emissions of greenhouse gases and other pollutants. (The model uses estimates of emission costs that include damage to property and human health and, in the case of greenhouse gases, certain other potential impacts such as loss of outdoor recreation amenities.) The model allocates investment funding only to the sections where at least one of the potential improvements are projected to produce benefits exceeding construction costs. Appendix A contains a more detailed description of the project selection and implementation process used by HERS.

Operations Strategies

Starting with the 2004 C&P Report, the HERS model has considered the impacts of certain types of highway operational improvements, in which intelligent transportation systems (ITS) feature prominently. The types of strategies currently evaluated by HERS include:

- Freeway management (ramp metering, electronic roadway monitoring, variable message signs, integrated corridor management, variable speed limits, queue warning systems, lane controls)
- Incident management (incident detection, verification, and response)
- Arterial management (upgraded signal control, electronic monitoring, variable message signs)
- Traveler information (511 systems and advanced in-vehicle navigation systems with real-time traveler information)

Appendix A describes these strategies in more detail and their treatment in the HERS model. It is important to note that HERS does not subject these types of investments to benefit-cost analysis and does not directly analyze tradeoffs between them and the pavement improvements and widening options also considered by the model. Instead, operations strategies are modeled via a separate preprocessor that estimates their impact on the performance of highway sections where they are deployed. The analyses presented in this chapter assume a package of investments representing the continuation of existing deployment trends, while a supplemental analysis presented in Chapter 9 considers the impacts of a more aggressive deployment pattern.

Travel Demand Elasticity

One of the key features of the economic analysis in HERS is the modeling of 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 average user cost per VMT. The model applies this elasticity to the forecasts of future travel (VMT) found in the HPMS sample data. For each highway segment, HERS assumes that the traffic forecast pertains to a future in which average conditions and performance are maintained, and highway user costs therefore remain at the current level. Any change that HERS projects in user cost relative to current level will, through the mechanism of the travel demand elasticity, affect the model's projection for future travel growth. For any highway investment scenario that predicts average user cost to decrease, the projected growth rate will be higher than the baseline rate derived from HPMS. For scenarios in which highway user cost increases, the projected VMT growth rate will tend to be lower than the baseline rate. Chapter 10 includes a discussion of how varying the assumptions about the travel demand elasticity affects the projected VMT growth rates associated with different levels of highway capital investment.

National Bridge Investment Analysis System

The scenario estimates relating to bridge repair and replacement shown in this report are derived primarily from NBIAS. This model incorporates analytical methods from the Pontis bridge management system first developed by the FHWA in 1989, and now owned and licensed by the American Association of State Highway and Transportation Officials. NBIAS also incorporates additional economic criteria into its analytical procedures. NBIAS can process detailed structural data on individual bridge elements or, if such information is not available, the model can synthesize such data from the general condition ratings reported for all bridges in the National Bridge Inventory (NBI); the NBIAS simulations conducted for this report have used only the NBI database.

The NBIAS model uses a probabilistic approach to model bridge deterioration for each synthesized bridge element. It relies on a set of transition probabilities to project the likelihood that an element will deteriorate from one condition state to another over a given period of time. The model then determines an optimal set of repair and rehabilitation actions to take for each bridge element, based on the condition of the element. NBIAS can also apply preservation policies at the individual bridge level and directly compare the costs and benefits of performing rehabilitation or repair work relative to completely replacing the bridge.

To estimate functional improvement needs, NBIAS applies a set of improvement standards and costs to each bridge in the NBI. The model then identifies potential improvements—such as widening existing bridge lanes, raising bridges to increase vertical clearances, and strengthening bridges to increase load-carrying capacity—and evaluates their potential benefits and costs. The NBIAS model is discussed in more detail in Appendix B.

Types of Capital Spending Projected by HERS and NBIAS

The types of investments evaluated by HERS and NBIAS can be related to the system of highway functional classification introduced in Chapter 2 and to the broad categories of capital improvements introduced in Chapter 6 (system rehabilitation, system expansion, and system enhancement). NBIAS relies on the NBI database, which covers bridges on all highway functional classes, and evaluates improvements that generally fall within the system rehabilitation category.

HERS evaluates pavement improvements—resurfacing or reconstruction—and highway widening; the types of improvements included in these categories roughly correspond to system rehabilitation and system expansion as described in Chapter 6. In estimating the per-mile costs of widening improvements, HERS recognizes a typical number of bridges and other structures that would need to be modified. 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 the nine highway functional classes for which the HPMS sample provides data. Excluded are the functional classes comprising the roads generally not eligible for Federal aid: rural minor collectors, rural local roads, and urban local roads.

The term "non-modeled spending" refers in this report to spending on highway and bridge capital improvements not evaluated in HERS or NBIAS; while these types of spending are absent from the analyses presented in this chapter, the capital investment scenarios presented in Chapter 8 are adjusted to account for

How closely do the types of capital improvements modeled in HERS and NBIAS correspond to the specific capital improvement type categories presented in Chapter 6?

Q&A

Exhibit 6-9 in Chapter 6 provides a crosswalk between a series of specific capital improvement types for which data are routinely collected from the States, and three major summary categories: system rehabilitation, system expansion, and system enhancement.

The "reconstruction without added capacity," "restoration and rehabilitation," and "resurfacing" capital improvement types included within the system rehabilitation category in Chapter 6 correspond well to the types of capital improvements modeled in HERS. "Reconstruction with added capacity" is split between the system rehabilitation and system expansion categories in Chapter 6 and must also be split between these categories in the HERS output.

Among the improvement types classified in the system expansion category in Chapter 6, "major widening" lines up best with types of improvements modeled in HERS, because such improvements are generally motivated by a desire to address congestion on a facility. The "relocation" improvement type is also a relatively good fit, although some relocation improvements are motivated more by safety concerns than congestion concerns and might not be captured in the HERS analysis.

While HERS does not directly model the construction of new roads and bridges, many such investments are motivated by a desire to alleviate congestion on existing facilities in a corridor, and thus would be captured indirectly by the HERS analysis in the form of additional normal-cost or high-cost lanes. As described in Appendix A, the costs per mile assumed in HERS for high-cost lanes are based on typical costs of tunneling, double-decking, or building parallel routes, depending on the functional class and area population size for the section being analyzed. To the extent that investments in the "new construction" and "new bridge" improvement types identified in Chapter 6 are motivated by desires to encourage economic development or accomplish other goals aside from the reduction of congestion on the existing highway network, such investments would not be captured in the HERS analysis.

The "bridge replacement," "major bridge rehabilitation," and "minor bridge work" categories included as part of the system rehabilitation category in Chapter 6 generally correspond to the types of capital improvements for bridges modeled in NBIAS. However, the expenditure data may include work on bridge approaches and ancillary improvements that would not be captured in the modeling.

The "safety," "traffic management/engineering," and "environmental and other" capital improvement types identified as part of the system enhancement category in Chapter 6 are treated as if they are not captured in the HERS or NBIAS analyses. However, some safety deficiencies may be addressed as part of broader pavement and capacity improvements modeled in HERS. Also, 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 6.

them. Non-modeled spending includes capital improvements on highway classes omitted from the HPMS sample and, hence, the HERS model. Development of future investment scenarios for the highway system as a whole thus requires separate estimation outside the HERS modeling process.

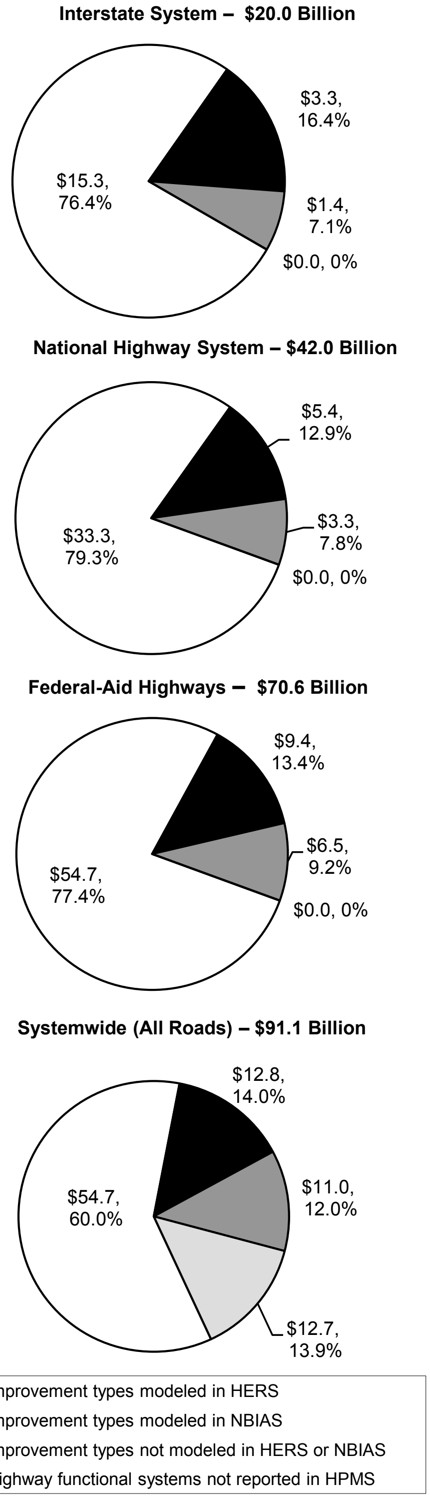
Non-modeled spending also includes types of capital expenditures classified in Chapter 6 as system enhancements, which neither HERS nor NBIAS currently evaluate. Although HERS incorporates assumptions about future operations investments, whose capital components would be classified as system enhancements, the model does not directly evaluate the need for these deployments. In addition, the HERS model does not identify specific safety-oriented investment opportunities, but instead considers the ancillary safety impacts of capital investments that are directed primarily toward system rehabilitation or capacity expansion. This limitation of the model owes to the HPMS database containing no information on the location of crashes or of safety devices such as guardrails or rumble strips.

Exhibit 7-1 shows that systemwide in 2008, highway capital spending amounted to $91.1 billion, of which 60.0 percent ($54.7 billion) went for types of improvements modeled in HERS and 14.0 percent ($12.8 billion) went for types of improvement modeled in NBIAS. The other 26.0 percent that went for non-modeled highway capital spending included system enhancement expenditures (12.1 percent) and capital improvements to classes of highways not reported in HPMS (13.9 percent).

Since the HPMS sample data are available for Federal-aid highways, the percentage of capital improvements classified as non-modeled spending is lower for Federal-aid highways than is the case systemwide. Of the $70.6 billion spent by all levels of government on capital improvements to Federal-aid highways in 2008, 77.4 percent fell within the scope of HERS, 13.4 percent fell within the scope of NBIAS, and 9.2 percent was for spending captured by neither model. The percent distribution is similar for the National Highway System (NHS) and for the Interstate Highway System.

Exhibit 7-1

Portion of 2008 Capital Expenditures Equivalent to Investment Types Modeled in HERS and NBIAS (Billions of Dollars)



Sources: Highway Statistics 2008, Table SF-12A, and unpublished FHWA data.

Alternative Levels of Future Capital Investment Analyzed

The HERS and NBIAS analyses presented in this chapter each assumes that capital investment within the scope of the model will grow over the 20 years at a constant annual percentage rate, which could be positive, negative, or zero. The starting point for each analysis is the level of investment in 2008, and since future levels are measured in constant 2008 dollars, the percent rates of growth are real (inflation-adjusted). This "ramped" approach to analyzing alternative investment levels was introduced in the 2008 C&P Report. Previous editions had either assumed a fixed amount would be spent in each year or set funding levels based on benefit-cost ratios, which tended to front-load the investment within the 20-year analysis period. Chapter 9 includes an analysis of the impacts on conditions and performance of these alternative investment timing patterns, as well as an example of how the ramping approach impacts year-by-year funding levels for some of the highway investment scenarios presented in Chapter 8.

The objective of the analyses presented in this chapter is to provide a quantitative picture of potential highway and bridge system outcomes under alternative assumptions about the rate of ramped investment growth. The particular investment levels identified were selected from among the results of a much larger number of model simulations. **Each investment level shown corresponds to a particular target outcome, such as funding all potential capital improvements with a benefit-cost ratio above a certain threshold or attaining a certain performance standard for highways or bridges.** While each of the particular rates of change selected has some specific analytical significance, the analyses presented in this chapter do not constitute complete investment scenarios, but rather form the building blocks for such scenarios, which are presented in Chapter 8.

Impacts of Federal-Aid Highway Investments Modeled by HERS

Exhibit 7-1 shows that of total capital spending of $91.1 billion on all roads in 2008, $54.7 billion was utilized on Federal-aid highways for the types of improvements modeled in HERS. This section projects the potential impacts on system performance of raising or lowering this amount within the scope of HERS at various annual rates over 20 years. The rates considered are "real," meaning that they measure spending in constant 2008 dollars. *Exhibit 7-2* shows the eight alternative funding growth rates for Federal-aid highways that were selected for further analysis in this chapter, along with the associated funding levels and marginal benefit-cost ratios. In this and previous C&P reports, the analysis follows the HERS convention of a 20-year analysis period divided into four 5-year subperiods.

The marginal benefit cost-ratio in a funding period is the lowest benefit-cost ratio among all the improvements implemented in that period. In *Exhibit 7-2*, this ratio is generally higher for earlier than for later subperiods, resulting in the minimum BCR over the entire analysis period, shown in the last column, equaling the marginal BCR in the last subperiod. This pattern reflects the tendency in the HERS model for the most worthwhile improvements to be implemented first. The exception to this pattern occurs when funding is assumed to decline at an annual real rate of negative 1.00 percent; in this case, the relative scarcity of funding toward the end of the analysis period limits what can be implemented to relatively high return projects.

Exhibit 7-3 describes the significance of the particular eight funding levels (out of the hundreds of levels analyzed) selected for presentation in this chapter. In the first three rows, average annual spending over the 20-year analysis period is targeted to the attainment of a specific minimum BCR value over that period. As explained in the introduction to Part II of this report, HERS ranks potential projects in order of BCR and implements them until the funding constraint is reached. The highest level of spending shown in *Exhibit 7-3*, which corresponds to annual rate of growth in real spending of 5.90 percent, is the estimate of what would be sufficient to finance all potential capital improvements up to a BCR cutoff of 1.00. As shown in *Exhibit 7-2*, meeting this target would require an estimated $2.1 trillion over the analysis period (an average annual of $105 billion over the 20 years); applying the more restrictive minimum BCR targets of 1.20 and 1.50 would require, respectively, 11 percent and 24 percent less than this amount ($1.9 trillion and $1.6 trillion over the analysis period).

The rates of funding growth shown in the next three rows of *Exhibit 7-3* are geared toward achieving a specific level of performance for a particular indicator for 2028. For example, the 1.31 percent growth rate in funding corresponds to maintaining average highway speed on Federal-aid highways at the 2008 level. (The connections between funding growth rates and performance indicators are identifiable from the exhibits presented later in this section). The other two rates of funding growth in *Exhibit 7-3* are based on historical patterns. The zero growth rate would set average annual spending over 2009–2028 at the actual level of spending in 2008. In the last row of *Exhibit 7-3*, the funding growth rate of negative 1.0 percent is the minimum average annual rate of growth in real highway investment over any 20-year period since 1921 (reflecting the period from 1925 to 1945).

Further evident in *Exhibit 7-3* is the inverse relationship described in the introduction to Part II between the minimum BCR and the level of investment. *Exhibit 7-4* graphs this inverse relationship as well as that between the average 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 lowest level of investment considered, $986 billion over 20 years, the average BCR of 5.16 exceeds the minimum BCR of 2.72.

Exhibit 7-2

Benefit-Cost Ratio Cutoff Points Associated With Different Possible Funding Levels for Federal-Aid Highways

Annual Percent Change in HERS Capital Spending	Spending Modeled in HERS (Billions of 2008 Dollars)						Marginal BCR[2]				Minimum BCR
	Cumulative					Average Annual Spending[1] 2009 to 2028					
	5-Year 2009 to 2013	5-Year 2014 to 2018	5-Year 2019 to 2023	5-Year 2024 to 2028	20-Year 2009 to 2028		5-Year 2009 to 2013	5-Year 2014 to 2018	5-Year 2019 to 2023	5-Year 2024 to 2028	20-Year 2009 to 2028
5.90%	$326	$434	$578	$770	$2,108	$105.4	2.32	1.84	1.34	**1.00**	1.00
4.86%	$316	$401	$508	$644	$1,868	$93.4	2.38	1.99	1.52	**1.20**	1.20
3.51%	$304	$361	$429	$509	$1,602	$80.1	2.45	2.18	1.76	**1.50**	1.50
2.88%	$298	$343	$396	$456	$1,493	$74.7	2.48	2.27	1.89	**1.64**	1.64
1.31%	$284	$303	$324	$346	$1,257	$62.9	2.58	2.52	2.22	**2.02**	2.02
0.56%	$278	$286	$294	$302	$1,160	$58.0	2.62	2.65	2.40	**2.24**	2.24
0.00%	$273	$273	$273	$273	$1,094	**$54.7**	2.66	2.76	2.52	**2.42**	2.42
-1.00%	$265	$252	$240	$228	$986	$49.3	**2.72**	2.93	2.79	2.74	2.72

[1] *The amounts shown represent the average annual investment over 20 years that would occur if annual investment grows in constant dollar terms by the percentage shown in each row of the first column.*

[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 and also shown in the last column, are the smallest of the marginal BCRs across the funding periods.*

Source: Highway Economic Requirements System.

Exhibit 7-3

Description of Eight Alternative HERS-Modeled Investment Levels Selected for Further Analysis

HERS-Modeled Capital Investment		Minimum BCR Cutoff[2]	Funding Level Description
Annual Percent Change in Spending	Average Annual Spending[1] (Billions of 2008 Dollars)		
5.90%	$105.4	1.00	Minimum BCR=1.0
4.86%	$93.4	1.20	Minimum BCR=1.2
3.51%	$80.1	1.50	Minimum BCR=1.5
2.88%	$74.7	1.64	Average Delay per VMT in 2028 Matches 2008 Level
1.31%	$62.9	2.02	Average Speed per VMT in 2028 Matches 2008 Level
0.56%	$58.0	2.24	Average IRI in 2028 Matches 2008 Level
0.00%	**$54.7**	2.42	Investment Sustained in Constant Dollar Terms at 2008 Level
-1.00%	$49.3	2.74	1 Percent Real Decline in Investment per Year[3]

[1] *The amounts shown represent the average annual investment over 20 years that would occur if annual investment grows in constant dollar terms by the percentage shown in each row of the first column.*

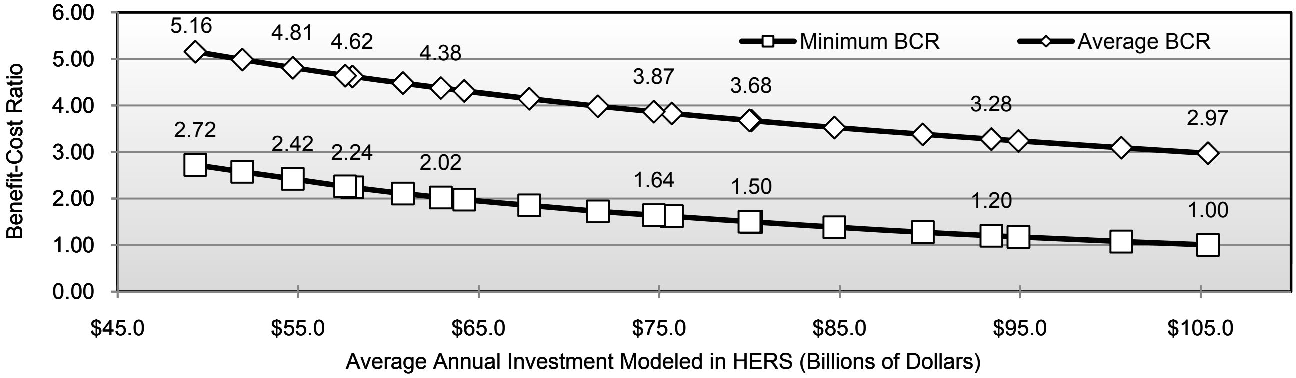
[2] *The minimum BCR represents the lowest benefit-cost ratio for any project implemented by HERS during the 20-year analysis period at the level of funding shown.*

[3] *This investment level was selected to acknowledge that highway capital spending does not always grow in real terms. Between 1925 and 1945, real spending fell at an average annual rate of approximately 1.0 percent. This was the lowest rate experienced over any 20-year period since highway finance data collection began in 1921.*

Source: Highway Economic Requirements System.

Exhibit 7-4

Minimum and Average Benefit-Cost Ratios for Different Possible Funding Levels for Federal-Aid Highways



Note: The eight minimum BCR points that are labeled correspond to the eight investment levels presented in Exhibit 7-3. 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 both naturally tend to decline as the level of investment analyzed rises.

Source: Highway Economic Requirements System.

Shaping the results for average user cost and measures of highway performance examined below is the operation of the elasticity feature in HERS. On congested sections of highway, the initial congestion relief afforded by an increase in capacity will reduce the costs of travel to highway users, of which the largest component is the cost of travel time. The reduction in user cost, in turn, will stimulate demand for travel on the affected sections as travelers adjust in various ways—for example, changing route or mode of travel, or even the total amount of travel undertaken—and this increased demand undoes a portion of the initial congestion relief. More broadly, any initial reduction in user cost of travel, whether brought about by an increase in the physical capacity of a highway or, say, a decline in gasoline prices, will induce much the same sort of casual chain. (Conversely, any initial increase in user costs will start a causal chain with effects in the opposite direction). By capturing these demand offsets to initial impacts on highway user costs, the operation of the elasticity feature in HERS (described earlier in this chapter) allows estimation of the net impacts. The elasticity feature operates likewise with respect to improvements in pavement quality by allowing for induced traffic that adds to pavement wear.

Q&A

Can the average BCRs presented in *Exhibit 7-4* be used to accurately estimate total net benefits associated with different levels of investment?

No. It is important to recognize that the base case system conditions at the time each set of investments is made will influence the benefit-cost ratios calculated. The BCRs for the alternative investment levels are most directly comparable for the first 5-year analysis period, since each analysis uses current conditions as a starting point. However, for subsequent periods, the base case depends on the improvements made in the previous period(s). For those analyses in which investment levels are rising over time, the base case conditions will be better than in those analyses where investment levels are falling, which will influence the calculated benefit-cost ratios. Simply multiplying the average BCR over 20 years by total investment over 20 years does not take into account these different base conditions within the analysis period.

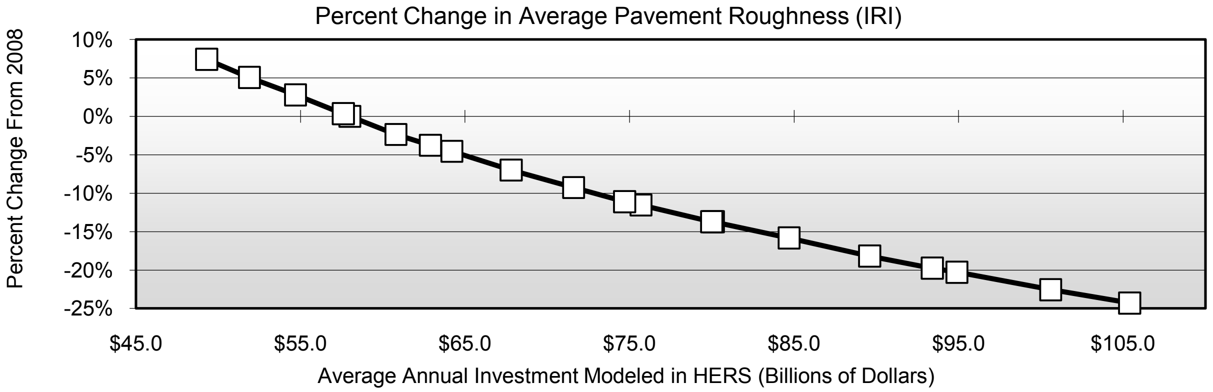
It is also important to note that the BCRs capture only the benefits associated with the investments that are made and do not reflect the additional costs experienced by users and agencies on highway sections that are not improved. A better indication of the benefits associated with each investment level is provided by the findings for highway user costs presented later in this chapter.

Impact of Future Investment on Highway Pavement Ride Quality

The primary measure in HERS of highway physical condition, pavement ride quality, is based on the International Roughness Index (IRI) defined in Chapter 3. The HERS analyses presented in this report focus on VMT-weighted IRI values; the average IRI values shown thus reflect the pavement ride quality experienced on a typical mile of travel. *Exhibit 7-5* shows how the HERS projections for the average IRI on Federal-aid highways vary with the total amount of HERS-modeled investment. Of particular relevance is the amount invested in system rehabilitation, which is more consequential for pavement roughness than investment in system expansion.

Exhibit 7-5

Projected 2028 Pavement Ride Quality Indicators on Federal-Aid Highways Compared With 2008, for Different Possible Funding Levels



HERS-Modeled Capital Investment			**Projected Impact of HERS-Modeled Capital Investment on Federal-Aid Highways**[3]				
Annual Percent Change in Spending	**Average Annual Spending (Billions of 2008 Dollars)**		**Percent of 2028 VMT on Roads With...**[4]		**Average IRI (VMT-Weighted)**		**Minimum BCR Cutoff**[5]
	Total Spending[1]	**System Rehabilitation**[2]	**IRI<95**	**IRI<170**	**Projected 2028 Level**	**Change Relative to Baseline**	
5.90%	$105.4	$50.7	74.1%	91.7%	86.6	-24.3%	1.00
4.86%	$93.4	$46.0	71.0%	90.1%	91.8	-19.8%	1.20
3.51%	$80.1	$40.2	66.6%	88.0%	98.7	-13.7%	1.50
2.88%	$74.7	$38.1	64.6%	87.1%	101.7	-11.1%	1.64
1.31%	$62.9	$32.7	59.4%	84.6%	110.1	-3.8%	2.02
0.56%	$58.0	$30.5	56.9%	83.3%	114.4	**0.0%**	2.24
0.00%	$54.7	$29.0	55.0%	82.4%	117.6	2.8%	2.42
-1.00%	$49.3	$26.5	52.1%	81.0%	122.9	7.4%	2.72
2008 Baseline Values:			**46.9%**	**85.2%**	**114.4**		

[1] The amounts shown represent the average annual investment over 20 years by all levels of government combined that would occur if such spending grows annually in constant dollar terms by the percentage shown in each row of the first column.

[2] The portion of HERS-modeled spending directed toward system rehabilitation varies by funding level and is not directly linked to actual spending for this purpose in the baseline year.

[3] 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.

[4] As discussed in Chapter 3, IRI values of 95 and 170 inches per mile, respectively, are the thresholds associated with "good" and "acceptable" pavement ride quality on the NHS.

[5] The minimum BCR cutoff represents the lowest BCR for any project implemented by HERS at the level of funding shown.

Source: Highway Economic Requirements System.

Sustaining spending in constant dollars at the $54.7 billion invested in the 2008 base year is projected to cause average pavement roughness to increase between that year and 2028 by an estimated 2.8 percent. A larger deterioration, 7.4 percent, is projected for the case where investment would decrease by 1.0 percent annually. To maintain average pavement roughness at the 2008 level would require the amount invested in highways to increase at an estimated 0.56 percent annual rate in constant dollar terms. At sufficiently higher spending levels, improvements in pavement quality become significant. At the highest rate of funding growth considered, the average pavement roughness is projected to decline 24.3 percent over the 20 years analyzed.

Exhibit 7-5 also shows the HERS projections for the percentage of travel occurring on pavements with ride quality that would be rated good or acceptable based on the IRI thresholds set in Chapter 3. For the case where real highway spending per year remains constant from 2008 to 2028, HERS projects the percentage of VMT occurring on pavements with good ride quality (IRI≤95) would increase from 46.9 percent to 55.0 percent. At the same time, the model projects the percentage of VMT occurring on pavement with acceptable ride quality (IRI≤170) to decrease by 2.8 points, from 85.2 percent to 82.4 percent. It should be noted that even if highway investment is assumed to increase at a rate sufficient to implement all cost-beneficial investment, HERS projects that only 91.7 percent of travel in 2028 would occur on pavement with acceptable ride quality. As noted in Chapter 3, the IRI threshold of 170 used to identify acceptable ride quality was originally set to measure performance on the NHS and may not fully reflect an acceptable standard for non-NHS routes, which tend to have lower travel volumes and speeds.

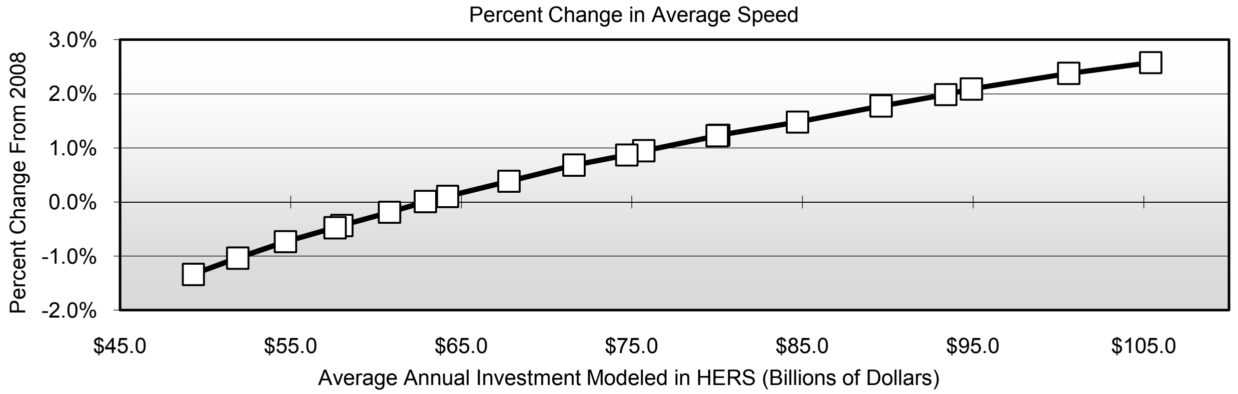
Impact of Future Investment on Highway Operational Performance

Among the HERS indicators of a highway section's operational performance is the peak ratio of volume to service flow (V/SF). A ratio above 0.80 has traditionally been associated with congested conditions, and above 0.95 with severe congestion. *Exhibit 7-6* shows for alternative levels of investment the projected percentages of Federal-aid highway travel in 2028 that will occur on sections where peak V/SF ratios exceed these thresholds. Also presented is the portion of each investment level that HERS programs for capacity expansion (such as the widening of existing highways or building new routes in existing corridors), as such spending affects the amount of delay more directly than does investment in system rehabilitation.

Exhibit 7-6 indicates that if real annual investment in highways continued at the 2008 level through 2028, the percentage of VMT occurring on congested roads would increase over that period from 22.1 percent to 36.1 percent, and on severely congested roads from 11.8 percent to 19.9 percent. Although increasing the rate of investment in highways would stem part of this deterioration, even the highest level of investment that could be economically justified would not prevent deterioration from occurring. Funding all improvements with a BCR above 1.0 would entail an annual investment in capacity expansion averaging $54.7 billion over the 20-year analysis period. Consistent with the consensus in economics that eliminating all congestion is not cost-beneficial, the amount of congestion projected for the end of the period, 2028, is nevertheless substantial, with 29.7 percent of VMT occurring on congested sections. Yet consistent with a strategy of concentrating investment on mitigating the worst congestion, HERS also projects that funding all improvements with a BCR greater than 1.0 would increase average speed on Federal-aid highways by 2.6 percent, from 43.2 miles per hour (mph) in 2008 to 44.3 mph in 2028. In comparison, with zero growth in annual spending assumed, average speed is projected to decrease over the same period by 0.4 mph; annual real growth in investment of 1.31 percent is estimated to be required to maintain average speed at the 2008 level.

Exhibit 7-6

Projected 2028 Highway Operational Performance Indicators on Federal-Aid Highways Compared With 2008, for Different Possible Funding Levels



HERS-Modeled Capital Investment			Projected Impact of HERS-Modeled Capital Investment on Federal-Aid Highways[3]				Minimum BCR Cutoff[5]
Annual Percent Change in Spending	Average Annual Spending (Billions of 2008 Dollars)		Percent of 2028 VMT on Roads With...[4]		Average Speed		
	Total Spending[1]	System Expansion[2]	V/SF > 0.80	V/SF > 0.95	Projected 2028 Level (mph)	Change Relative to Baseline	
5.90%	$105.4	$54.7	29.7%	12.9%	44.3	2.6%	1.00
4.86%	$93.4	$47.4	31.3%	14.3%	44.0	2.0%	1.20
3.51%	$80.1	$39.9	32.9%	16.1%	43.7	1.2%	1.50
2.88%	$74.7	$36.6	33.6%	16.9%	43.5	0.9%	1.64
1.31%	$62.9	$30.1	35.0%	18.5%	43.2	**0.0%**	2.02
0.56%	$58.0	$27.5	35.6%	19.3%	43.0	-0.4%	2.24
0.00%	$54.7	$25.7	36.1%	19.9%	42.8	-0.7%	2.42
-1.00%	$49.3	$22.8	36.8%	20.8%	42.6	-1.3%	2.72
2008 Baseline Values:			**22.1%**	**11.8%**	**43.2**		

[1] The amounts shown represent the average annual investment over 20 years by all levels of government combined that would occur if such spending grows annually in constant dollar terms by the percentage shown in each row of the first column.

[2] The portion of HERS-modeled spending directed toward system expansion varies by funding level and is not directly linked to actual spending for this purpose in the baseline year.

[3] 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.

[4] As discussed in Chapter 4, V/SF ratios of 0.80 and 0.95, respectively, are thresholds commonly associated with congested conditions and severely congested conditions.

[5] The minimum BCR cutoff represents the lowest BCR for any project implemented by HERS at the level of funding shown.

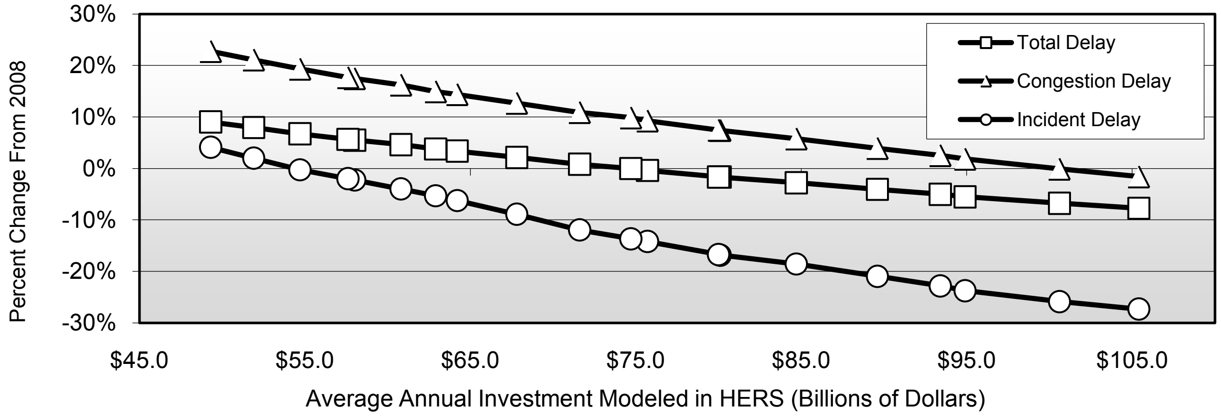
Source: Highway Economic Requirements System.

Congestion Delay and Incident Delay

As noted above, the HERS model assumes the continuation of existing trends in the deployment of certain system management and operations strategies. Among these strategies are several, such as freeway incident management programs, that can be expected to mitigate delay associated with isolated incidents more than the delay associated with recurring congestion ("congestion delay"). In line with this, the HERS projections reported in *Exhibit 7-7* show the amount of incident delay decreasing relative to congestion delay over the 2008–2028 period. For the case where investment within the scope of HERS is sustained in real terms at its 2008 level, the model projects incident delay on Federal-aid highways to be slightly lower in 2028 than in

Exhibit 7-7

Projected Changes in 2028 Highway Travel Delay on Federal-Aid Highways Compared With 2008, for Different Possible Funding Levels



HERS-Modeled Capital Investment			Projected Impact of HERS-Modeled Capital Investment on Federal-Aid Highways[3]				
Annual Percent Change in Spending	Average Annual Spending (Billions of 2008 Dollars)		Annual Hours of Delay per Vehicle[4]	Percent Change Relative to Baseline			Minimum BCR Cutoff[5]
	Total Spending[1]	System Expansion[2]		Total Delay per VMT	Congestion Delay per VMT	Incident Delay per VMT	
5.90%	$105.4	$54.7	46.5	-7.7%	-1.6%	-27.3%	1.00
4.86%	$93.4	$47.4	47.9	-5.0%	2.5%	-22.8%	1.20
3.51%	$80.1	$39.9	49.5	-1.7%	7.4%	-16.8%	1.50
2.88%	$74.7	$36.6	50.4	**0.0%**	9.9%	-13.7%	1.64
1.31%	$62.9	$30.1	52.3	3.8%	14.9%	-5.3%	2.02
0.56%	$58.0	$27.5	53.2	5.5%	17.5%	-2.3%	2.24
0.00%	$54.7	$25.7	53.8	6.7%	19.3%	-0.3%	2.42
-1.00%	$49.3	$22.8	54.9	9.0%	22.8%	4.1%	2.72
2008 Baseline Values:			**50.4**				

[1] The amounts shown represent the average annual investment over 20 years by all levels of government combined that would occur if such spending grows annually in constant dollar terms by the percentage shown in each row of the first column.

[2] The portion of HERS-modeled spending directed toward system expansion varies by funding level and is not directly linked to actual spending for this purpose in the baseline year.

[3] 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.

[4] The values shown were computed by multiplying HERS estimates of average delay per VMT by 11,619, the average VMT per registered vehicle in the 2008 base year. 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.

[5] The minimum BCR cutoff represents the lowest BCR for any project implemented by HERS at the level of funding shown.

Sources: Highway Economic Requirements System; Highway Statistics 2008, Table VM-1.

2008 (down 0.3 percent), and congestion delay to be 19.3 percent higher. The highest level of investment considered would fund all cost-beneficial improvements at an average annual expenditure of $50.7 billion greater than what was actually spent in 2008 ($105.4 billion vs. $54.7 billion) and is projected to reduce both types of delay. Again, however, the outlook from these projections is much better for incident delay, down 27.3 percent, than for congestion delay, for which a 1.6 percent decrease is predicted.

For the case where real highway spending continues at the 2008 level, HERS projects that from 2008 to 2028 overall delay per VMT will increase 6.7 percent, which equates to 3.4 hours per vehicle per year. In the projections assuming that real spending declines by 1.00 percent annually, the corresponding increases in overall delay are still larger, at 9.0 percent and 4.5 annual hours per vehicle. Alternatively, when spending increases at an annual rate of 5.90 percent, enough to fund all cost-beneficial improvements, HERS projects a 7.7 percent reduction in delay from 2008 to 2028, which equates to 3.9 fewer hours per year relative to the 2008 baseline.

Impact of Future Investment on Highway User Costs

The HERS model defines benefits as reductions in highway user costs, agency costs, and societal costs of vehicle emissions. In measuring the highway user costs, the model includes the costs of travel time, vehicle operation, and crashes, but excludes from vehicle operating costs taxes imposed on highway users (such as motor fuel taxes and vehicle registration fees). As discussed in the introduction to this report's Part II, the exclusion of these taxes conforms with the principle in benefit-cost analysis of measuring the costs of transportation inputs at their opportunity cost to society. The exclusion also makes the measure of user costs more of an indicator of highway conditions and performance, of which the amount paid in highway-user taxes provides no indication.

Impact on User Cost Components

Crash costs form the smallest of the three categories of highway user costs, with an estimated 12 percent share in the 2008 base year, compared with 49 percent for travel time costs. Although highway trips always consume traveler time and resources for vehicle operation, only a small fraction involve crashes. In addition, most crashes are non-catastrophic: particularly on urban highways, many involve only damage to property without anyone being injured.

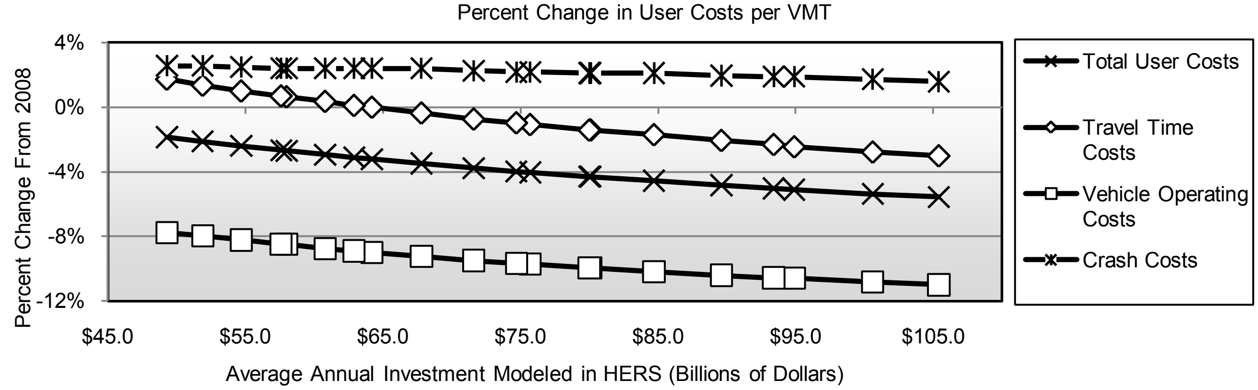
Crashes also emerge from the HERS projections as the component of user costs least sensitive to the assumptions on the rate at which highway investment increases over the 2009–2028 analysis period. As shown in *Exhibit 7-8*, for Federal-aid highways, altering this rate from the lowest rate considered (-1.00 percent) to the highest (+5.90 percent) reduces the crash costs per VMT projected for 2028, but only by 1.0 percentage points. The highway investment totals are limited, however, to the types of improvements that the HERS model evaluates, which are geared toward system rehabilitation and expansion. Since the HPMS lacks detailed information on the current location and characteristics of safety-related features (e.g., guardrail, rumble strips, roundabouts, yellow change intervals at signals), safety-focused investments are not evaluated. However, the findings do not imply that investing more in highways, including spending more on safety projects, makes little difference to highway safety.

For the other components of user cost, the same comparison between spending levels shows much larger differences in the projection for 2028. Moving from the lowest to highest levels adds $56.1 billion ($105.4 billion vs. $49.3 billion) to the annual average spending and results in a travel time cost per VMT in 2028 that is 4.7 percentage points lower (+1.7 percent vs. -3.0 percent). For vehicle operating costs, the estimated impact on the value projected for 2028 is a reduction of 3.2 percentage points.

At all levels of investment considered in *Exhibit 7-8*, the projections are for vehicle operating cost per mile to decline from 2008 to 2028. Even at the lowest rate of spending growth, which would reduce spending by 1.0 percent each year, the projection is for a 7.8 percent decline. The reason for this sizable decrease is that the analysis assumes substantial increases in average vehicle fuel economy over the future. Forecasts of fuel economy were taken from the Energy Information Administration's publication, *Annual Energy Outlook 2010* (Early Release). EIA's forecasts incorporate the effect of recent changes in Corporate Average Fuel Economy (CAFE) standards and the establishment in 2010 of Federal standards for vehicle emissions of greenhouse gases under the provisions of the Clean Air Act.

Exhibit 7-8

Projected Changes in 2028 Highway User Costs on Federal-Aid Highways Compared With 2008 Levels, for Different Possible Funding Levels



HERS-Modeled Capital Investment		Projected Impact of HERS-Modeled Capital Investment on Federal-Aid Highways[2]					
Annual Percent Change in Spending	Average Annual Spending[1] (Billions of 2008 Dollars)	Average Total User Costs per VMT	Percent Change Relative to Baseline Average per VMT				Minimum BCR Cutoff[4]
			Total User Costs	Travel Time Costs	Vehicle Operating Costs	Crash Costs[3]	
5.90%	$105.4	$1.067	-5.6%	-3.0%	-11.0%	1.6%	1.00
4.86%	$93.4	$1.073	-5.0%	-2.3%	-10.6%	1.9%	1.20
3.51%	$80.1	$1.081	-4.3%	-1.4%	-10.0%	2.1%	1.50
2.88%	$74.7	$1.085	-4.0%	-1.0%	-9.7%	2.2%	1.64
1.31%	$62.9	$1.095	-3.1%	0.1%	-8.9%	2.4%	2.02
0.56%	$58.0	$1.100	-2.7%	0.6%	-8.5%	2.4%	2.24
0.00%	$54.7	$1.103	-2.4%	1.0%	-8.2%	2.5%	2.42
-1.00%	$49.3	$1.109	-1.8%	1.7%	-7.8%	2.6%	2.72
2008 Baseline Values:		**$1.130**					

[1] The amounts shown represent the average annual investment over 20 years by all levels of government combined that would occur if such spending grows annually in constant dollar terms by the percentage shown in each row of the first column.

[2] 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.

[3] The HPMS does not contain the type of detail that would be needed to conduct an analysis of targeted safety enhancements. The crash costs estimated by the HERS model represent ancillary impacts associated with pavement and capacity improvements and are heavily influenced by traffic volume and speed.

[4] The minimum BCR cutoff represents the lowest BCR for any project implemented by HERS at the level of funding shown.

Source: Highway Economic Requirements System.

Impact on Overall User Cost

For all highway user costs combined, HERS projects that at any of the investment levels considered, the per mile cost of travel will be lower in 2028 than 2008. Even at the lowest level of investment considered, an average of $49.3 billion per year, the projection is for user costs per VMT to decrease from $1.130 (i.e., 113.0 cents) to $1.109 because of the expected improvements in fuel economy. At higher levels of investment, the projections for 2028 are for still sharper reductions in user costs relative to 2008. At the highest level shown in *Exhibit 7-8*, an average of $105.4 billion per year, average user costs per VMT in 2028 are projected to be $1.067. Thus, according to these projections, investing at the maximum rather

What changes in CAFE standards have recently been adopted, and what impacts are these changes expected to have?

Q&A

The Energy Independence and Security Act of 2007 (Public Law 110-140) included several provisions to increase the fuel efficiency of the American motor vehicle fleet, including a requirement to raise CAFE standards. On March 30, 2009, the U.S. Department of Transportation (DOT) established higher CAFE standards for passenger vehicles and light trucks produced during model year 2011; on May 7, 2010, DOT and the U.S. Environmental Protection Agency jointly adopted fuel efficiency standards for cars and light trucks to be produced during model years 2012 through 2016. For passenger cars, these new standards will increase required fuel economy from the current 27.5 miles per gallon to 37.8 miles per gallon by 2016. For light trucks, the proposal would increase fuel economy from 23.5 miles per gallon in 2010 to 28.8 miles per gallon in 2016. The impacts of these standards on the fuel economy of the overall vehicle fleet will continue to be felt for many years beyond 2016, as new vehicles meeting the higher fuel economy requirements gradually replace older, less fuel-efficient vehicles.

In announcing the new standards, the DOT estimated that they would save nearly 61 billion gallons of fuel and reduce carbon dioxide emissions by 655 million metric tons over the lifetimes of cars and light trucks produced in 2012 through 2016. The Department also estimated that the plan would save the Nation's drivers nearly $180 billion in fuel costs over the lifetimes of the vehicles covered by its most recent CAFE rule.

The 2009 and 2010 CAFE rules build on two previous changes that increased the mileage requirements for light trucks beginning with model year 2005.

than the minimum level considered, which would entail slightly more than a doubling of expenditure, would result in user costs per mile at the end of the period being reduced by 4.2 cents, or 3.6 percent. For the case where real investment in Federal-aid highways is sustained at the 2008 level, HERS projects highway user costs in 2028 to average $1.10 per mile, which translates to savings of 0.6 percent relative to the projection assuming future investment at the lowest level in *Exhibit 7-8*.

Although the results indicate that additional investment reduces user costs by only a small percentage, *Exhibit 7-9* shows that on Federal-aid highways the total dollar savings are large relative to the increment in investment. To allow measurement of these savings without conflating the impact of highway investment on VMT (operating through the demand elasticity), *Exhibit 7-9* computes the average VMT projected for 2028 across all levels of future investment. The estimated savings shown in the last column are calculated for each level of investment by multiplying this average VMT, 3.687 trillion, by the projected 2008–2028 reduction in average user cost per VMT. The resulting estimate of savings in user costs ranges from $231.9 billion at the maximum level of investment considered to $77.1 billion at the minimum level of investment. The difference between these figures, $154.8 billion, is the estimated savings in highway user costs in a single year, 2028, attributable to additional investment averaging $56.1 billion per year over the preceding 20 years. Alternatively, comparing the maximum level of investment with zero growth in investment, the corresponding estimates are savings of $132.0 billion in 2028 versus an additional investment of $50.7 billion per year.

Adjustment for Fuel Economy Improvements

The 2006 C&P report and several prior editions had used average user costs per VMT as a proxy for the overall conditions and performance of the highway system. Since factors that affect average user costs other than pavement condition and traffic congestion, such as vehicle technology, were held constant in the analysis, decreases in average user costs could be directly associated with improvements in overall system conditions and performance.

Exhibit 7-9

Analysis of User Cost Savings in 2028 Relative to 2008 at Average VMT Projected for 2028, Federal-Aid Highways

HERS-Modeled Capital Investment		Projected 2028 VMT on Federal-Aid Highways (Trillions of VMT)[2]	Average Total User Costs per VMT (2008 Dollars)		Estimated 2028 User Cost Savings at Average VMT Projection for 2028 (Billions of 2008 Dollars)[3]	Minimum BCR Cutoff[4]
Annual Percent Change in Spending	Average Annual Spending[1] (Billions of 2008 Dollars)		2028	Change Relative to Baseline		
5.90%	$105.4	3.724	$1.067	-$0.063	-$231.9	1.00
4.86%	$93.4	3.714	$1.073	-$0.057	-$209.4	1.20
3.51%	$80.1	3.700	$1.081	-$0.049	-$179.6	1.50
2.88%	$74.7	3.694	$1.085	-$0.045	-$165.9	1.64
1.31%	$62.9	3.677	$1.095	-$0.035	-$129.8	2.02
0.56%	$58.0	3.670	$1.100	-$0.031	-$112.5	2.24
0.00%	$54.7	3.664	$1.103	-$0.027	-$99.9	2.42
-1.00%	$49.3	3.655	$1.109	-$0.021	-$77.1	2.72
Projected 2028 Average:		**3.687**				
2008 Baseline Values:		**2.520**	**$1.130**			

[1] The amounts shown represent the average annual investment over 20 years by all levels of government combined that would occur if such spending grows annually in constant dollar terms by the percentage shown in each row of the first column.

[2] 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.

[3] The implied user cost savings for 2028 were computed by multiplying projected 2028 VMT by the reduction in average user costs per VMT relative to the 2008 baseline. Part of these savings are attributable to improvements in fuel economy resulting from changes to CAFE standards, rather than to the capital investment modeled in HERS.

[4] The minimum BCR cutoff represents the lowest BCR for any project implemented by HERS at the level of funding shown.

Source: Highway Economic Requirements System.

This direct relationship between average user costs and system conditions and performance was broken in the 2008 C&P report, as the analysis of future user costs was modified to take into account EIA forecasts of future fuel efficiency of the vehicle fleet. Adding this refinement to the analysis created a situation in which average user costs would decline over time, even if the physical conditions and operational performance of the highway system remained unchanged. In order to counteract this effect, the 2008 C&P report introduced a new metric, "adjusted user costs." This statistic was computed by recalculating user costs in the 2006 base year as though the fuel economy improvements projected through the end of the analysis period had already occurred. By netting out the impacts of the fuel economy changes, the adjusted user cost metric represents a better proxy for overall system conditions and performance, and was utilized as the metric for a key scenario in the 2008 C&P report.

In the present report, the HERS estimate of average user costs in 2008 has already been noted to be $1.130 (i.e., 113.0 cents) per VMT. The corresponding figure for adjusted user costs, modified as if the improvements in future fuel economy projected by EIA (roughly 28.2 percent for cars and 13.7 percent for trucks) had already occurred in 2008, is $1.096 per VMT or 3.1 percent lower. *Exhibit 7-10* indicates that meeting a target of maintaining user costs through 2028 at the adjusted 2008 level of $1.096 per VMT would require investment in system preservation and expansion on Federal-aid highways to increase at an average annual rate of 1.20 percent. This rate of spending growth is quite close to the 1.31 percent

Exhibit 7-10

Alternative Scenario Targets for Federal-Aid Highways: Maintaining Adjusted User Costs Versus Maintaining Average Speed

HERS-Modeled Capital Investment				Percent Change in Average User Costs per VMT			
Annual Percent Change in Spending	**Average Annual Spending[1] (Billions of 2008 Dollars)**	**Average Total User Costs per VMT in 2028 (2008 Dollars)**	**Average Speed in 2028 (mph)**	**Relative to Baseline**	**Relative to Adjusted Baseline**	**Percent Change in Average Speed Relative to Baseline**	**Minimum BCR Cutoff[3]**
5.90%	$105.4	$1.067	44.3	-5.6%	-2.6%	2.6%	1.00
4.86%	$93.4	$1.073	44.0	-5.0%	-2.0%	2.0%	1.20
3.51%	$80.1	$1.081	43.7	-4.3%	-1.3%	1.2%	1.50
2.88%	$74.7	$1.085	43.5	-4.0%	-1.0%	0.9%	1.64
1.31%	$62.9	$1.095	43.2	-3.1%	-0.1%	**0.0%**	2.02
1.20%	$62.1	$1.096	43.1	-3.1%	**0.0%**	-0.1%	2.06
0.56%	$58.0	$1.100	43.0	-2.7%	0.7%	-0.4%	2.24
0.00%	$54.7	$1.103	42.8	-2.4%	0.7%	-0.7%	2.42
-1.00%	$49.3	$1.109	42.6	-1.8%	1.2%	-1.3%	2.72
2008 Baseline Values:		**$1.130**	**43.2**				
2008 Adjusted Baseline:[2]		**$1.096**					

[1] The amounts shown represent the average annual investment over 20 years by all levels of government combined that would occur if such spending grows annually in constant dollar terms by the percentage shown in each row of the first column.

[2] The adjusted baseline value estimates what 2008 user costs might have been had the fuel economy improvements assumed in HERS for the year 2028 occurred in the 2008 base year. This statistic is meant to offset the effects of changes in CAFE standards to more directly show the impact of highway investment on user costs.

[3] The minimum BCR cutoff represents the lowest BCR for any project implemented by HERS at the level of funding shown.

Source: Highway Economic Requirements System.

per annum estimated to be required for the alternative performance target of maintaining average network speed at the 2008 level. Since the average annual investment levels associated with maintaining these two metrics is relatively similar ($62.9 billion for average speed versus $62.1 billion for adjusted user costs), and the concept of average speed is easier to explain, this edition focuses more on the results for average speed in developing the scenarios presented in Chapter 8.

Future editions of this report may revert to using adjusted user costs more prominently or switch to highlighting some other metric, especially if the costs associated with maintaining average speed in future analyses begin to deviate significantly from those associated with maintaining adjusted user costs. It should be noted that average speed also corresponds to one of the transit performance measures used in the Transit Economic Requirements Model, which is discussed later in this chapter.

Impacts of NHS Investments Modeled by HERS

As described in Chapter 2, the NHS includes the Interstate System as well as other routes most critical to national defense, mobility, and commerce. This section examines the total spending modeled in HERS, identifying the portion of this investment that is directed by the model to the NHS, and the impacts that such investment could have on future NHS conditions and performance.

HERS allocates a portion of future investment to the NHS based on the model's engineering and economic criteria, which give funding priority to high-BCR projects. As in this chapter's preceding sections, this section considers levels of total investment in Federal-aid highways that are each based on a particular target. However, whereas the targets in the preceding sections pertained to Federal-aid highways as a whole, this section adds targets that are NHS-specific.

Exhibit 7-11 shows these investment levels and portion that HERS allocates to the NHS. In the first three rows, the target is to implement all improvements on Federal-aid highways, including the NHS portion, that have a BCR above a certain minimum. Similarly, most of the other targets represented in *Exhibit 7-11* pertain to measures of performance or spending growth on Federal-aid highways as a whole. However, since the NHS is only a subset of Federal-aid highways, achieving a certain target for Federal-aid highways, such as maintaining average speed at the 2008 level, will generally not result in the same target being met for the NHS.

Exhibit 7-11

Alternative Funding Levels Analyzed for the NHS in HERS

HERS-Modeled Capital Investment			Computed Average Annual Percent Change in HERS NHS Spending Relative to 2008[3]	Minimum BCR Cutoff[4]
Annual Percent Change in Spending	Average Annual Spending (Billions of 2008 Dollars)			
	Total Spending[1]	Spending on NHS[2]		
5.90%	$105.4	$57.3	4.91%	1.00
4.86%	$93.4	$51.7	4.02%	1.20
3.51%	$80.1	$45.1	2.80%	1.50
2.88%	$74.7	$42.2	2.19%	1.64
1.31%	$62.9	$36.1	0.75%	2.02
0.56%	$58.0	$33.5	0.05%	2.24
0.51%	$57.7	$33.3	**0.00%**	2.26
0.00%	$54.7	$31.8	-0.45%	2.42
-0.25%	$53.3	$31.0	-0.71%	2.49
-0.42%	$52.3	$30.4	-0.87%	2.55
-1.00%	$49.3	$28.8	-1.41%	2.72
-2.57%	$42.1	$24.8	-2.92%	2.83
2008 Baseline Value:		**$33.3**		

[1] The amounts shown represent the average annual investment over 20 years by all levels of government combined that would occur if such spending grows annually in constant dollar terms by the percentage shown in each row of the first column.

[2] The portion of HERS-modeled spending directed toward the NHS varies by funding level and is not directly linked to actual spending on the NHS in the baseline year.

[3] The amounts shown represent the average annual growth rate in NHS spending that would generate a cumulative 20-year spending level consistent with the average annual HERS-modeled NHS investment levels identified. These values are computed from the results of these HERS analyses rather than having been assumed as part of the inputs to the HERS analyses.

[4] The minimum BCR cutoff represents the lowest BCR for any project implemented by HERS at the level of funding shown.

Source: Highway Economic Requirements System.

Exhibit 7-11 also considers four alternative targets for maintaining particular NHS-specific measures at their 2008 levels. Three of these alternative targets would maintain certain measures of NHS performance: average speed, average delay per VMT, and average IRI. The associated levels of total average annual spending (on both the NHS and other Federal-aid highways) are $53.3 billion, $52.3 billion, and $42.1 billion; since these are all less than the $54.7 billion spent in 2008, the corresponding rates of annual percent change over the 2008–2028 period are all negative: -0.25 percent, -0.42 percent, and -2.57 percent, respectively. In the simulations with the NHS-specific targets, HERS allocates to the NHS the amount needed to meet these targets without the same target being achieved for other Federal-aid highways. The fourth alternative target is to sustain average annual spending on the NHS at the 2008 level of $33.3 billion per year. For HERS to allocate this distribution of spending to the NHS based on benefit-cost criteria, the total level of spending on all Federal-aid highways would need to be increasing by 0.51 percent annually, which translates into an average annual investment on Federal-aid highways of $57.7 billion per year.

Alternatively, when the target is to implement all cost-beneficial improvements, HERS programs $57.3 billion for the NHS, or 54.4 percent out of a $105.4 billion total. At lower levels of total investment, the portion of investment that HERS directs to the NHS increases somewhat, up to 58.9 percent at the lowest investment total considered (which averages $42.1 billion per year). At each level, however, the share of investment that HERS programs for the NHS is smaller than the 60.1 percent share that the NHS actually received in the base year ($33.3 billion out of a $54.7 billion total).

Impact of Future Investment on NHS Pavement Ride Quality

As the BCR cutoff for funding highway projects (the "minimum BCR") is reduced, the amount that HERS programs for investment in highways increases. *Exhibit 7-12* shows the variation in the amount programmed for the NHS and the associated change in future pavement ride quality as measured by the IRI. Central to the results is the amount that HERS programs for NHS rehabilitation projects. Although investment in system expansion reduces roughness by adding new, smooth lanes, system rehabilitation investments tend to have a significantly greater impact. At a BCR cutoff of 2.26, HERS programs for the NHS an average of $33.3 billion per year in real capital spending, the same as the 2008 level; of this amount, the model programs an average of $13.7 billion for rehabilitation projects. At these levels, the model projects that in 2028 pavements with an IRI value below 95, which is the criterion in Chapter 3 for rating ride quality as "good," will carry 73.6 percent of VMT on the NHS, up from the 56.4 percent estimated for 2008. The results also indicate that bringing this percentage above 89.6 percent would not be cost-beneficial: the capital and work zone delay costs entailed would outweigh the benefits from reduced vehicle operating and other user costs.

Exhibit 7-12 also indicates that average ride quality on the NHS could be sustained at the 2008 level if capital spending on the NHS were to decrease at the equivalent of 2.92 percent annually (constant dollars). Such a decrease would follow what appears to have been a substantial increase in real spending on the NHS that occurred between 2006 (the base year for the 2008 C&P Report) and 2008 (the base year for this report). (The National Highway Construction Cost Index decreased over that period; using that index to convert nominal to real spending, the estimated increase in real spending was 22 percent).

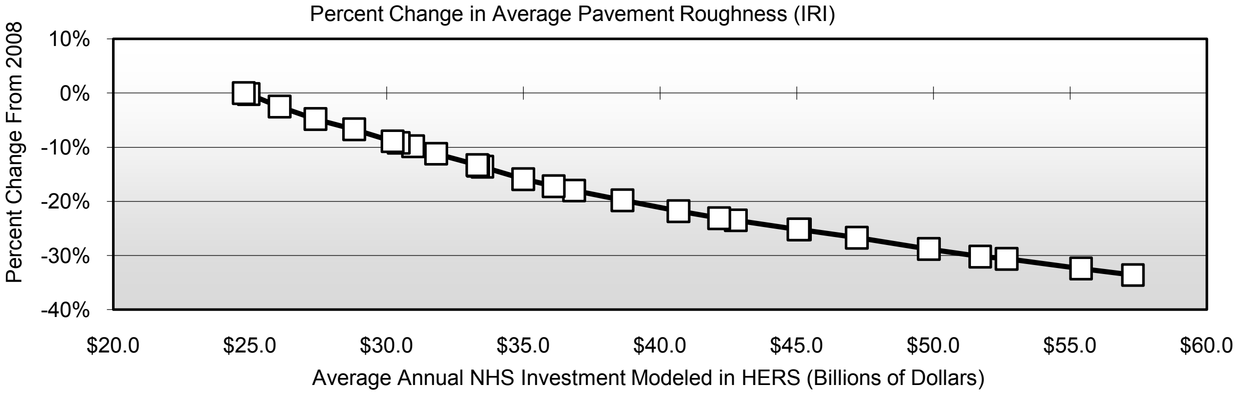
Impact of Future Investment on NHS Travel Times and User Costs

Exhibit 7-13 presents HERS projections for average delay and user costs on the NHS at alternative levels of investment. Also presented is the portion of the NHS investment that HERS programs for system expansion. In the case where HERS programs for NHS investment over 2009–2028 an annual average amount equal to the 2008 level of $33.3 billion (constant dollars), the model allocates $19.6 billion of this amount to system expansion. At these levels, the model projections for the NHS from 2008 to 2028 show average speed decreasing from 52.7 mph to 53.1 mph and average delay per VMT decreasing by 2.9 percent. HERS also predicts that maintaining average speed at the 2008 level could be achieved with constant-dollar investment in the NHS decreasing at an annual equivalent of about 0.87 percent.

Another indication from *Exhibit 7-13* is that implementing all cost-beneficial widening and rehabilitation improvements to the NHS (minimum BCR=1.00) would substantially improve NHS performance. According to the HERS projections, if investment in the NHS increased by 4.91 percent annually in constant dollar terms, average speed on the NHS would increase from 52.7 mph in 2008 to 55.7 mph in 2028, while average delay per VMT would fall 26.3 percent.

Exhibit 7-12

Projected 2028 Pavement Ride Quality Indicators on the NHS Compared With 2008, for Different Possible Funding Levels



	HERS-Modeled NHS Capital Investment			Projected Impact of HERS-Modeled Capital Investment on the NHS			
	Computed Average Annual Percent Change in Spending[1]	Average Annual Spending (Billions of 2008 Dollars)		Percent of 2028 VMT on Roads With...[4]		Average IRI	
Minimum BCR Cutoff		Total Spending[2]	System Rehabilitation[3]	IRI<95	IRI<170	Projected 2028 Level	Change Relative to Baseline
1.00	4.91%	$57.3	$20.9	89.6%	97.4%	66.4	-33.6%
1.20	4.02%	$51.7	$19.4	86.9%	96.8%	69.8	-30.2%
1.50	2.80%	$45.1	$17.4	83.0%	95.8%	74.8	-25.2%
1.64	2.19%	$42.2	$16.6	81.1%	95.5%	76.9	-23.1%
2.02	0.75%	$36.1	$14.6	76.1%	94.3%	82.8	-17.2%
2.24	0.05%	$33.5	$13.8	73.8%	93.7%	86.4	-13.6%
2.26	**0.00%**	$33.3	$13.7	73.6%	93.6%	86.6	-13.4%
2.42	-0.45%	$31.8	$13.2	72.0%	93.2%	88.8	-11.2%
2.49	-0.71%	$31.0	$12.9	71.3%	92.9%	90.2	-9.8%
2.55	-0.87%	$30.4	$12.7	70.8%	92.8%	90.8	-9.2%
2.72	-1.41%	$28.8	$12.2	69.1%	92.4%	93.3	-6.7%
2.83	-2.92%	$24.8	$10.8	64.4%	91.1%	100.0	**0.0%**
2008 Baseline Values:				**56.4%**	**91.4%**	**100.0**	

[1] The amounts shown represent the average annual growth rate in NHS spending that would generate a cumulative 20-year spending level consistent with the average annual HERS-modeled NHS investment levels identified in the third column.

[2] The amounts shown represent the average annual investment over 20 years by all levels of government combined on the NHS for the HERS analysis with the minimum BCR cutoff identified in each row of the first column. Exhibit 7-11 associates these NHS investment levels with the broader HERS analyses from which they were derived.

[3] The portion of HERS-modeled spending directed toward system rehabilitation varies by funding level and is not directly linked to actual spending for this purpose in the baseline year.

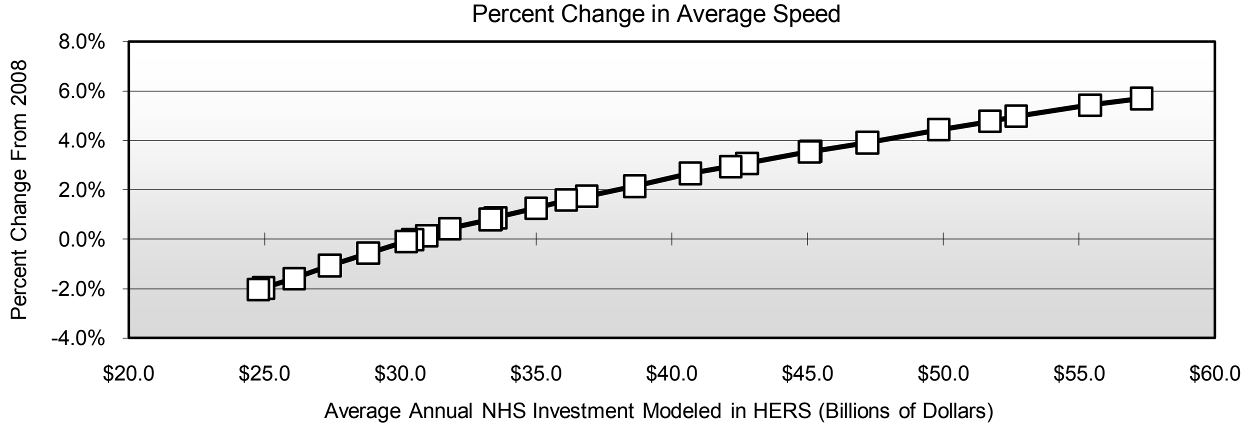
[4] As discussed in Chapter 3, IRI values of 95 and 170 inches per mile, respectively, are the thresholds associated with "good" and "acceptable" pavement ride quality on the NHS.

Source: Highway Economic Requirements System.

At all the BCR cutoffs considered, HERS projects average user cost per VMT on the NHS would decline over the 20-year analysis period. The decline ranges from 2.9 percent at the highest cutoff, which has NHS capital spending decreasing at the equivalent of 2.92 percent annually, to 8.2 percent when all cost-beneficial projects are funded (minimum BCR=1.00). A significant portion of these declines can be attributed to the projected improvements in vehicle fuel technology (see above discussion under "Adjustment for Fuel Economy Improvements").

Exhibit 7-13

Projected Changes in 2028 Speed, Delay, and Highway User Costs on the NHS Compared With 2008, for Different Possible Funding Levels



	HERS-Modeled NHS Capital Investment			Projected Impact of HERS-Modeled Capital Investment on the NHS			
Minimum BCR Cutoff	**Computed Average Annual Percent Change in Spending[1]**	**Average Annual Spending (Billions of 2008 Dollars)**		**Percent Change Relative to Baseline per VMT**		**Average Speed**	
		Total Spending[2]	**System Expansion[3]**	**Average User Costs**	**Average Delay**	**Projected 2028 Level (mph)**	**Change Relative to Baseline**
1.00	4.91%	$57.3	$36.4	-8.2%	-26.3%	55.7	5.7%
1.20	4.02%	$51.7	$32.3	-7.6%	-21.9%	55.2	4.8%
1.50	2.80%	$45.1	$27.7	-6.8%	-16.1%	54.5	3.6%
1.64	2.19%	$42.2	$25.6	-6.4%	-13.0%	54.2	2.9%
2.02	0.75%	$36.1	$21.5	-5.4%	-6.1%	53.5	1.6%
2.24	0.05%	$33.5	$19.7	-5.0%	-3.1%	53.1	0.9%
2.26	**0.00%**	$33.3	$19.6	-4.9%	-2.9%	53.1	0.8%
2.42	-0.45%	$31.8	$18.7	-4.6%	-1.2%	52.9	0.4%
2.49	-0.71%	$31.0	$18.1	-4.4%	-0.1%	52.7	0.1%
2.55	-0.87%	$30.4	$17.7	-4.3%	0.7%	52.7	**0.0%**
2.72	-1.41%	$28.8	$16.6	-3.9%	3.2%	52.4	-0.6%
2.83	-2.92%	$24.8	$13.9	-2.9%	10.2%	51.6	-2.0%
				2008 Baseline Values:		**52.7**	

[1] The amounts shown represent the average annual growth rate in NHS spending that would generate a cumulative 20-year spending level consistent with the average annual HERS-modeled NHS investment levels identified in the third column.

[2] The amounts shown represent the average annual investment over 20 years by all levels of government combined on the NHS for the HERS analysis with the minimum BCR cutoff identified in each row of the first column. Exhibit 7-11 associates these NHS investment levels with the broader HERS analyses from which they were derived.

[3] The portion of HERS-modeled spending directed toward system expansion varies by funding level and is not directly linked to actual spending for this purpose in the baseline year. System expansion expenditures have a more direct impact on delay and speed, while both system expansion and system rehabilitation expenditures impact highway user costs.

Source: Highway Economic Requirements System.

Impacts of Interstate System Investments Modeled by HERS

The Interstate System, unlike the broader NHS of which it is a part, has standard design and signing requirements, which makes it the most recognizable subset of the highway network. This section examines the amount of investment that HERS directs to the Interstate System, and the potential impacts of this investment on future Interstate System conditions and performance.

Exhibit 7-14 identifies the alternative funding levels analyzed for the Interstate System in HERS for this analysis. These levels were selected in a manner comparable to that described for the NHS earlier (and summarized in *Exhibit 7-11*), except that in place of the four investment levels targeted to achieving a particular outcome on the NHS, *Exhibit 7-14* considers investment levels geared toward achieving the same targets on the Interstate System. These targets would maintain at the 2008 level either the average annual amount invested in the Interstate System or a measure of the system's performance: average speed, average delay, average pavement roughness, or average annual capital spending in constant dollars. Apart from these four targets pertaining to the Interstate System, all the investment levels in *Exhibit 7-14* pertain to the previously considered targets for Federal-aid highways. The portion of total investment in Federal-aid highways that HERS directs to the Interstate System is determined by the model's optimization rules. When the target is to implement all cost-beneficial improvements, HERS programs $34.6 billion for the Interstate System, or about one-third of the $105.4 billion total on all Federal-aid highways. At lower levels of total investment, the portion that HERS directs to the Interstate System increases somewhat, up to 39.8 percent at the lowest investment total considered (which averages $38.2 billion per year). At each level, however, the share of investment that HERS programs for the Interstate System exceeds the 28.0 percent share that the Interstate System actually received in the base year ($15.3 billion out of a $54.7 billion total). When the target is to sustain average annual investment in the Interstate System at the 2008 level (0.00 percent growth), total funding for Federal-aid highways must decrease at a 3.47 percent annual rate for HERS to allocate out of that total the target amount for the Interstate System. In this case, HERS allocates to the Interstate System an annual average of $15.3 billion out of $38.5 billion for all Federal-aid highways.

Exhibit 7-14

Alternative Funding Levels Analyzed for the Interstate System in HERS

Annual Percent Change in HERS Capital Spending	Average Annual HERS-Modeled Capital Investment (Billions of 2008 Dollars)		Computed Average Annual Percent Change in HERS Interstate Spending Relative to 2008[3]	Minimum BCR Cutoff
	Total Spending[1]	Spending on Interstates[2]		
5.90%	$105.4	$34.6	7.27%	1.00
4.86%	$93.4	$31.8	6.55%	1.20
3.51%	$80.1	$28.3	5.54%	1.50
2.88%	$74.7	$26.5	4.99%	1.64
1.31%	$62.9	$23.0	3.75%	2.02
0.56%	$58.0	$21.6	3.18%	2.24
0.00%	$54.7	$20.6	2.77%	2.42
-0.65%	$51.1	$19.3	2.17%	2.63
-1.12%	$48.7	$18.5	1.78%	2.73
-2.50%	$42.4	$16.5	0.74%	2.83
-3.47%	$38.5	$15.3	**0.00%**	2.90
-3.57%	$38.2	$15.2	-0.05%	2.90
2008 Baseline Value:		**$15.3**		

[1] The amounts shown represent the average annual investment over 20 years by all levels of government combined that would occur if such spending grows annually in constant dollar terms by the percentage shown in each row of the first column.

[2] The portion of HERS-modeled spending directed toward Interstate highways varies by funding level and is not directly linked to actual spending on the Interstate highways in the baseline year.

[3] The amounts shown represent the average annual growth rate in NHS spending that would generate a cumulative 20-year spending level consistent with the average annual HERS-modeled NHS investment levels identified. These values are computed from the results of these HERS analyses rather than having been assumed as part of the inputs to the HERS analyses.

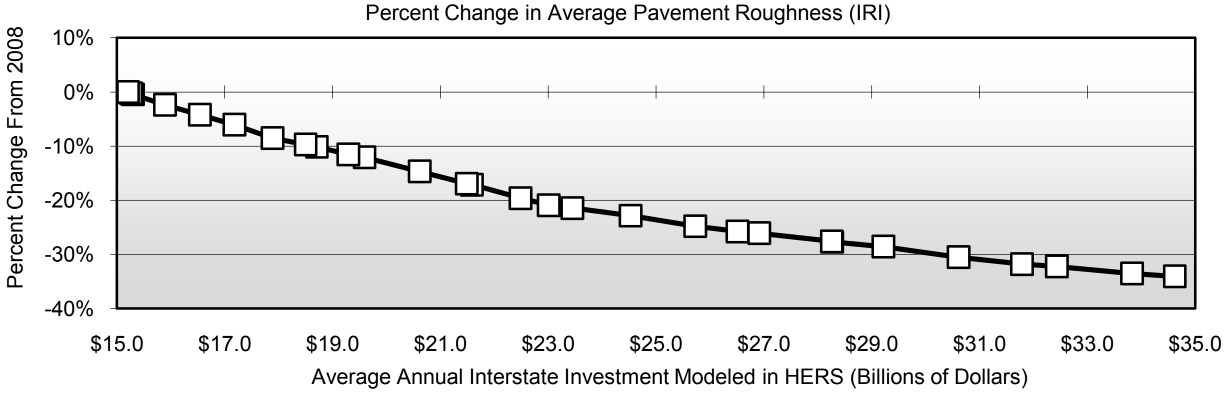
Source: Highway Economic Requirements System.

Impact of Future Investment on Interstate Pavement Ride Quality

Exhibit 7-15 shows how pavement ride quality (based on the IRI defined in Chapter 3) of the Interstate System could be affected by the total amount invested in types of capital improvements modeled in HERS, particularly Interstate System rehabilitation expenditures. When investment in the Interstate System remains at the $15.3 billion spent in 2008, HERS allocates $6.0 billion of this annual amount to system rehabilitation expenditure (*Exhibit 7-15*). At these levels, the projections for 2028 are for 72.4 percent of

Exhibit 7-15

Projected 2028 Pavement Ride Quality Indicators on the Interstate System Compared With 2008, for Different Possible Funding Levels



	HERS-Modeled Interstate Capital Investment			Projected Impact of HERS-Modeled Capital Investment on the Interstate System			
	Computed	Average Annual Spending (Billions of 2008 Dollars)		Percent of 2028 VMT on Roads With...[4]		Average IRI	
Minimum BCR Cutoff	Average Annual Percent Change in Spending[1]	Total Spending[2]	System Rehabilitation[3]	IRI<95	IRI<170	Projected 2028 Level	Change Relative to Baseline
1.00	7.27%	$34.6	$10.9	94.2%	99.3%	61.2	-34.1%
1.20	6.55%	$31.8	$10.4	92.5%	99.1%	63.3	-31.8%
1.50	5.54%	$28.3	$9.6	89.8%	98.3%	67.1	-27.7%
1.64	4.99%	$26.5	$9.2	88.3%	98.0%	68.9	-25.8%
2.02	3.75%	$23.0	$8.3	84.7%	97.2%	73.4	-20.9%
2.24	3.18%	$21.6	$7.9	82.8%	96.7%	76.9	-17.1%
2.42	2.77%	$20.6	$7.6	81.4%	96.1%	79.2	-14.7%
2.63	2.17%	$19.3	$7.2	79.7%	95.6%	82.1	-11.5%
2.73	1.78%	$18.5	$7.0	78.6%	95.4%	83.8	-9.7%
2.83	0.74%	$16.5	$6.5	75.3%	94.6%	88.9	-4.2%
2.90	**0.00%**	$15.3	$6.0	72.4%	93.9%	92.4	-0.4%
2.90	-0.05%	$15.2	$6.0	72.1%	93.8%	92.8	**0.0%**
			2008 Baseline Values:	**63.9%**	**93.4%**	**92.8**	

[1] The amounts shown represent the average annual growth rate in spending on the Interstate Highway System that would generate a cumulative 20-year spending level consistent with the average annual HERS-modeled Interstate investment levels identified in the third column.

[2] The amounts shown represent the average annual investment over 20 years by all levels of government combined on the Interstate Highway System for the HERS analysis with the minimum BCR cutoff identified in each row of the first column. Exhibit 7-14 associates these Interstate investment levels with the broader HERS analyses from which they were derived.

[3] The portion of HERS-modeled spending directed toward system rehabilitation varies by funding level and is not directly linked to actual spending for this purpose in the baseline year.

[4] As discussed in Chapter 3, IRI values of 95 and 170 inches per mile, respectively, are the thresholds associated with "good" and "acceptable" pavement ride quality on the NHS.

Source: Highway Economic Requirements System.

Interstate System travel to occur on pavements with "good" quality (IRI below 95) and 93.9 percent to occur on pavements with "acceptable" quality (IRI below 170). The increase in these percentages above the 2008 values of 63.9 percent and 93.4 percent, respectively, indicates an overall improvement in the Interstate System pavement quality.

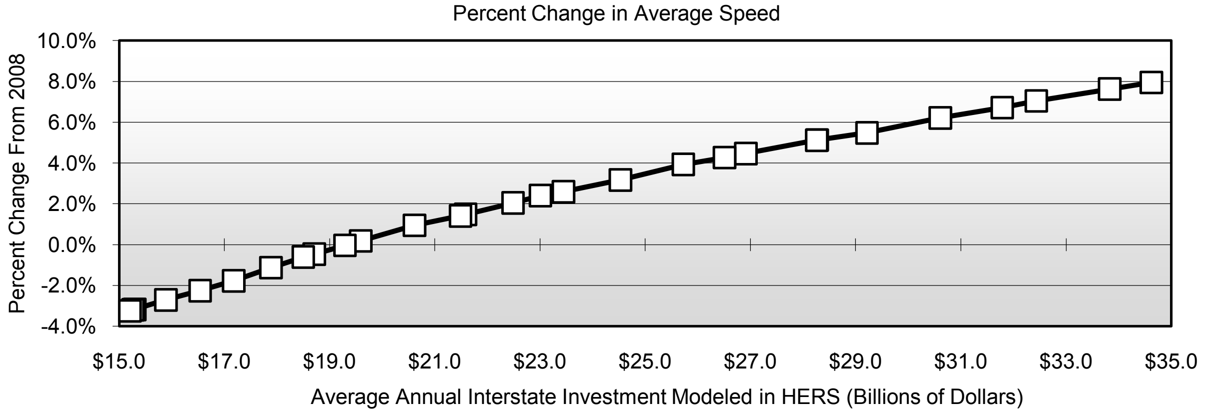
Implementation of all cost-beneficial improvements (minimum BCR=1.00) would improve pavement quality on the Interstate System to the economically justifiable extent. In this case, the average IRI on the Interstate System is projected to fall from 92.8 in 2008 to 61.2 in 2028, an improvement of 34.1 percent.

Impact of Future Investment on Interstate System Travel Times and User Costs

The impact of future investment on Interstate System travel times and user costs depends especially on the amount invested in Interstate System expansion. As shown in *Exhibit 7-16*, when total investment in Interstate System improvements within the scope of HERS is assumed to continue at the 2008 rate (minimum BCR=2.90), HERS allocates $9.3 billion for Interstate System expansion, and average system speed is projected to decrease from 60.1 mph in 2008 to 58.2 mph in 2028. With average speed lower, average delay for travel on the Interstate System increases 13.4 percent. At the limits of the investment levels

Exhibit 7-16

Projected Changes in 2028 Speed, Delay, and Highway User Costs on the Interstate System Compared With 2008, for Different Possible Funding Levels



	HERS-Modeled Interstate Capital Investment			Projected Impact of HERS-Modeled Capital Investment on the Interstate System			
	Computed	Average Annual Spending (Billions of 2008 Dollars)		Percent Change Relative to Baseline per VMT		Average Speed	
Minimum BCR Cutoff	**Average Annual Percent Change in Spending[1]**	**Total Spending[2]**	**System Expansion[3]**	**Average User Costs**	**Average Delay**	**Projected 2028 Level (mph)**	**Change Relative to Baseline**
1.00	7.27%	$34.6	$23.7	-9.4%	-41.5%	64.8	8.0%
1.20	6.55%	$31.8	$21.4	-8.8%	-35.3%	64.1	6.7%
1.50	5.54%	$28.3	$18.7	-8.0%	-27.8%	63.1	5.1%
1.64	4.99%	$26.5	$17.3	-7.5%	-23.3%	62.6	4.3%
2.02	3.75%	$23.0	$14.7	-6.5%	-13.5%	61.5	2.4%
2.24	3.18%	$21.6	$13.7	-5.9%	-9.8%	61.0	1.5%
2.42	2.77%	$20.6	$13.0	-5.6%	-7.5%	60.6	0.9%
2.63	2.17%	$19.3	$12.0	-5.0%	-2.9%	60.0	**0.0%**
2.73	1.78%	$18.5	$11.5	-4.7%	-0.2%	59.7	-0.6%
2.83	0.74%	$16.5	$10.1	-3.7%	8.2%	58.7	-2.3%
2.90	**0.00%**	$15.3	$9.3	-3.1%	13.4%	58.2	-3.2%
2.90	-0.05%	$15.2	$9.2	-3.1%	13.7%	58.1	-3.2%
				2008 Baseline Values:		**60.1**	

[1] The amounts shown represent the average annual growth rate in spending on the Interstate Highway System that would generate a cumulative 20-year spending level consistent with the average annual HERS-modeled Interstate investment levels identified in the third column.

[2] The amounts shown represent the average annual investment over 20 years by all levels of government combined on the Interstate Highway System for the HERS analysis with the minimum BCR cutoff identified in each row of the first column.
Exhibit 7-14 associates these Interstate investment levels with the broader HERS analyses from which they were derived.

[3] The portion of HERS-modeled spending directed toward system expansion varies by funding level and is not directly linked to actual spending for this purpose in the baseline year. System expansion expenditures have a more direct impact on delay and speed, while both system expansion and system rehabilitation expenditures impact highway user costs.

Source: Highway Economic Requirements System.

presented in *Exhibit 7-16*, the changes in travel time and delay are more pronounced. At one extreme where the Interstate System receives the average $34.6 billion per year that HERS estimates is required to fund all cost-beneficial improvements, projections for the Interstate System in 2028 are for speed to average 64.8 mph and for delay per VMT to average 41.5 percent less than in 2008. At the other extreme, *Exhibit 7-16* shows total investment within the scope of HERS decreasing over the 20-year analysis period by 1.00 percent per year, and average delay per VMT on the Interstate System increasing by 13.7 percent.

The projections for average user costs on the Interstate System show declines between 3.1 percent and 9.4 percent over 20 years, depending on the level of investment. Again, the projected improvements in vehicle fuel efficiency contribute significantly to these results.

Impacts of Systemwide Investments Modeled by NBIAS

Early in this chapter, *Exhibit 7-1* showed that of the $91.1 billion invested in highways in 2008, $12.8 billion was used for bridge system rehabilitation (repair and replacement). In using the NBIAS model to project conditions and performance of the Nation's bridges over 20 years, this section considers the alternatives of continuing to invest in bridge rehabilitation at this level and at higher or lower levels. The expenditures modeled pertain only to bridge system rehabilitation; expenditures associated with bridge system expansion are modeled separately as part of the capacity expansion analysis in the HERS model. (The NBIAS-modeled investments presented here should be considered as additive to the HERS-modeled investments presented above; each of the capital investment scenarios presented in Chapter 8 combines one of the HERS analyses with one of the NBIAS analyses, and makes adjustments to account for non-modeled spending).

Impact of Future Investment on Overall Bridge Conditions

The NBIAS model considers bridge deficiencies at the level of individual bridge elements based on engineering criteria and computes an initial value for the cost of a set of corrective actions that would address all such deficiencies. NBIAS tracks this "backlog" of potential bridge improvements over time, recomputing it to account for corrective actions taken and for the ongoing deterioration of bridge elements. A portion of this engineering-based backlog represents potential corrective actions that would not pass a benefit-cost test and thus would not be implemented by the model, even if available funding were unlimited. Such potential actions are not included in the statistics presented in this chapter, which focuses on the backlog of actions for which benefits would exceed the costs, and the total cost of their full implementation. Changes in this "economic" bridge investment backlog can be viewed as a proxy for changes in overall bridge conditions.

Q&A

How does the NBIAS definition of bridge deficiencies compare with the information on structurally deficient bridges reported in Chapter 3?

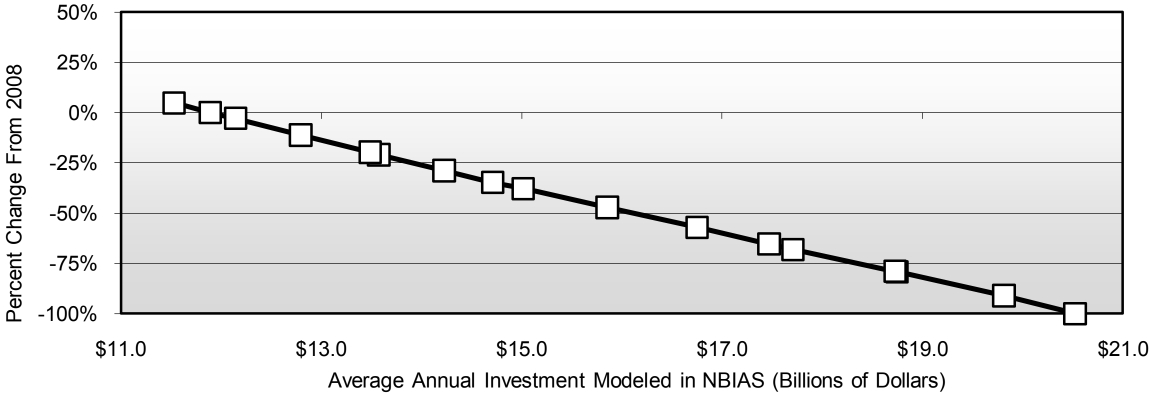
NBIAS considers bridge deficiencies and corrective improvements at the level of individual bridge elements. The economic backlog of bridge deficiencies estimated by NBIAS thus consists of the cost of all improvements to bridge elements that would be justified on both engineering and economic grounds. It includes many improvements on bridges with certain components that may warrant repair, rehabilitation, or replacement, but whose overall condition is not sufficiently deteriorated for them to be classified as structurally deficient.

The corrective actions recommended by NBIAS would include those aimed at addressing structural deficiencies, as well as some functional deficiencies. System expansion needs for both highways and bridges are addressed separately as part of the HERS model analysis.

Exhibit 7-17 describes how the economic backlog of system rehabilitation investments for bridges could be influenced by the total amount invested in the types of capital improvements modeled in NBIAS. NBIAS estimates the size of the backlog in 2008 to be $121.2 billion; the model projects that if combined spending on the types of capital improvements modeled in NBIAS were sustained at the 2008 level of $12.8 billion in constant dollar terms, the economic bridge backlog could be reduced by 11.2 percent to $107.6 billion in 2028. Less funding would be needed to maintain the backlog at its 2008 level; NBIAS projects that an average annual investment level of $11.9 billion would be sufficient to prevent the backlog from rising. To eliminate the backlog by 2028, NBIAS projects that an average annual investment of $20.5 billion (investment increasing by 4.31 percent annually) would be needed. Investment above this level would not be considered cost-beneficial.

Exhibit 7-17

Projected Changes in 2028 Economic Bridge Investment Backlog for All Bridges Compared With 2008, for Different Possible Funding Levels



NBIAS-Modeled Capital Investment		Projected Impact of NBIAS-Modeled Capital Investment on All Bridges				
		Economic Bridge Investment Backlog for System Rehabilitation in 2028 (Billions of 2008 Dollars)[2]				
Annual Percent Change in Spending	Average Annual Spending[1] (Billions of 2008 Dollars)	Replacement	Improvement[3]	Rehabilitation and Repair	Total	Change Relative to Baseline
4.31%	$20.5	$0.0	$0.0	$0.0	$0.0	**-100.0%**
3.51%	$18.7	$13.1	$1.0	$11.2	$25.3	-79.1%
2.88%	$17.5	$24.6	$1.9	$15.5	$42.0	-65.3%
1.31%	$14.7	$55.9	$3.1	$20.1	$79.1	-34.7%
0.56%	$13.6	$71.2	$3.5	$21.1	$95.8	-20.9%
0.00%	$12.8	$82.2	$3.7	$21.7	$107.6	-11.2%
-0.70%	$11.9	$94.9	$3.9	$22.4	$121.2	**0.0%**
-1.00%	$11.5	$100.6	$3.9	$22.6	$127.1	4.9%
			2008 Baseline Value:		**$121.2**	

[1] The amounts shown represent the average annual investment over 20 years by all levels of government combined that would occur if annual investment grows in constant dollar terms by the percentage shown in each row of the first column.

[2] The amounts shown do not reflect system expansion needs; the bridge components of such needs are addressed as part of the HERS model analysis.

[3] Includes raising, strengthening, and widening investments.

Source: National Bridge Investment Analysis System.

Exhibit 7-17 also identifies the portions of the economic backlog associated with bridge replacement, bridge improvement, and bridge rehabilitation and repair. The bridge improvement portion includes the raising, strengthening, and widening of existing bridges. The bridge replacement portion accounts for most of the backlog because the high capital costs of replacement projects frequently make their benefit-cost ratios lower than for potential improvement, rehabilitation, or repair actions. As a result, NBIAS tends to defer these investments when available funding is constrained.

Impacts of Federal-Aid Highway Investments Modeled by NBIAS

For the bridges on Federal-aid highways, *Exhibit 7-18* shows how variation in the amount invested over the analysis period affects the NBIAS projection for the economic backlog of investment in 2028. With this investment assumed to average $9.4 billion per year—what was actually spent on Federal-aid highway bridges in 2008—the backlog projected for 2028 exceeds the $102.1 billion backlog estimated for 2008 by 6.5 percent. To stop the backlog from growing above the 2008 level, investment would need to grow by approximately 0.40 percent per year, which equates to an average annual investment level of $9.8 billion. Eliminating the backlog by 2028 would require that spending on Federal-aid highway bridges increase 5.36 percent per year in constant dollar terms.

Exhibit 7-18

Projected Changes in 2028 Economic Bridge Investment Backlog on Federal-Aid Highways Compared With 2008, for Different Possible Funding Levels

NBIAS-Modeled Capital Investment on Federal-Aid Highway Bridges		Projected Impact of NBIAS-Modeled Capital Investments on Federal-Aid Highway Bridges	
Annual Percent Change in Spending	Average Annual Spending[1] (Billions of 2008 Dollars)	Economic Bridge Investment Backlog for System Rehabilitation[2]	
		2028 (Billions of 2008 Dollars)	Change Relative to Baseline
5.36%	$17.1	**$0.0**	**-100.0%**
4.86%	$16.1	$13.6	-86.6%
3.51%	$13.8	$45.2	-55.7%
2.88%	$12.9	$58.1	-43.1%
1.31%	$10.8	$87.4	-14.4%
0.56%	$10.0	$99.9	-2.1%
0.40%	$9.8	$102.1	**0.0%**
0.00%	$9.4	$108.7	6.5%
-1.00%	$8.5	$123.7	21.2%
2008 Baseline Value:		**$102.1**	

[1] The amounts shown represent the average annual investment over 20 years on bridges located on Federal-aid highways that would occur if annual investment grows in constant dollar terms by the percentage shown in each row of the first column. Bridges on roadways functionally classified as rural minor collector, rural local, and urban local are not included in these figures.

[2] The amounts shown do not reflect system expansion needs; the bridge components of such needs are addressed as part of the HERS model analysis.

Source: National Bridge Investment Analysis System.

It should be noted that the NBIAS analyses presented for bridges on Federal-aid highways in this section, as well as those for NHS bridges and Interstate System bridges described below, were each conducted on these specific subsets of the total bridge population, rather than as part of a larger analysis of all bridges. The annual percent changes in spending identified in the exhibits reflect the actual change in investment assumed for each individual year. In contrast, the HERS analyses of the NHS and Interstate highways presented earlier used a different approach, in which the amounts spent on these systems were extracted from analyses of all Federal-aid highways over 20 years, and equivalent annual percent changes were derived.

Impacts of NHS Investments Modeled by NBIAS

NBIAS estimates the economic backlog of NHS bridge system rehabilitation investments to have been $60.4 billion in 2008. All levels of government combined spent $5.4 billion in 2008 on the NHS capital improvements of the types that NBIAS models; as shown in *Exhibit 7-19,* the model projects that if this level of investment were sustained over 20 years in constant dollar terms, the NHS bridge backlog would decrease by 1.8 percent. Eliminating the economic backlog by 2028 is estimated to require an annual spending increase of 4.48 percent in constant dollar terms; which equates to an average annual investment level of $8.9 billion in 2008 dollars.

Exhibit 7-19

Projected Changes in 2028 Economic Bridge Investment Backlog on the NHS Compared With 2008, for Different Possible Funding Levels

NBIAS-Modeled Capital Investment on NHS Bridges		Projected Impact of NBIAS-Modeled Capital Investments on NHS Bridges	
		Economic Bridge Investment Backlog for System Rehabilitation[2]	
Annual Percent Change in Spending	Average Annual Spending[1] (Billions of 2008 Dollars)	2028 (Billions of 2008 Dollars)	Change Relative to Baseline
4.48%	$8.9	**$0.0**	**-100.0%**
4.02%	$8.4	$7.8	-87.0%
2.80%	$7.3	$26.1	-56.7%
2.19%	$6.9	$33.9	-43.8%
0.75%	$5.9	$51.5	-14.8%
0.05%	$5.5	$58.7	-2.8%
0.00%	$5.4	$59.3	-1.8%
-0.09%	$5.4	$60.4	**0.0%**
-0.45%	$5.2	$63.9	5.8%
-0.71%	$5.0	$66.5	10.1%
-0.87%	$5.0	$67.9	12.4%
-1.41%	$4.7	$72.7	20.5%
-2.92%	$4.0	$84.8	40.5%
2008 Baseline Value:		**$60.4**	

[1] The amounts shown represent the average annual investment over 20 years on NHS bridges that would occur if annual investment grows in constant dollar terms by the percentage shown in each row of the first column.

[2] The amounts shown do not reflect system expansion needs; the bridge components of such needs are addressed as part of the HERS model analysis.

Source: National Bridge Investment Analysis System.

Impacts of Interstate Investments Modeled by NBIAS

Exhibit 7-20 describes for Interstate System bridges how the economic backlog projected for 2028 varies with the assumed total expenditure on these bridges for the types of capital improvements modeled in NBIAS. Sustaining this expenditure over 20 years at the 2008 level of $3.3 billion in constant dollar terms is projected to reduce the backlog by 3.6 percent below the $38.1 billion estimated for 2008, or by $1.4 billion. If spending were to increase over this period by 4.39 percent annually, this could completely eliminate the backlog by 2028.

Exhibit 7-20

Projected Changes in 2028 Economic Bridge Investment Backlog on the Interstate System Compared With 2008, for Different Possible Funding Levels

NBIAS-Modeled Capital Investment on Interstate Bridges		Projected Impact of NBIAS-Modeled Capital Investments on Interstate Bridges	
Annual Percent Change in Spending	Average Annual Spending[1] (Billions of 2008 Dollars)	Economic Bridge Investment Backlog for System Rehabilitation[2]	
		2028 (Billions of 2008 Dollars)	Change Relative to Baseline
4.39%	$5.3	**$0.0**	**-100.0%**
3.75%	$5.0	$6.1	-84.0%
3.18%	$4.6	$11.8	-69.0%
2.77%	$4.4	$15.5	-59.4%
2.17%	$4.2	$20.6	-45.9%
1.78%	$4.0	$23.6	-38.1%
0.74%	$3.6	$31.9	-16.1%
0.00%	$3.3	$36.7	-3.6%
-0.05%	$3.3	$37.0	-2.7%
-0.18%	$3.2	$38.1	0.0%
-1.00%	$3.0	$42.8	12.4%
2008 Baseline Value:		**$38.1**	

[1] The amounts shown represent the average annual investment over 20 years on Interstate bridges that would occur if annual investment grows in constant dollar terms by the percentage shown in each row of the first column.

[2] The amounts shown do not reflect system expansion needs; the bridge components of such needs are addressed as part of the HERS model analysis.

Source: National Bridge Investment Analysis System.

Potential Transit Capital Investment Impacts

This section examines how different types and levels of annual capital investments would likely affect transit system condition and performance by the year 2028. It begins with an overview of the types of capital spending projected by the U.S. Federal Transit Administration's (FTA's) Transit Economic Requirements Model (TERM), which is the primary analysis tool used to assess transit investment needs and impacts in Part II of this report. The section then examines how variations in the level of annual capital spending are likely to impact future transit conditions and performance—both at the national level and for urbanized areas (UZAs) with populations greater than 1 million.

Types of Capital Spending Projected by TERM

TERM is an analysis tool that uses engineering and economic concepts to forecast total capital investment needs for the U.S. transit industry over a 20-year time horizon. Specifically, TERM is designed to forecast the following types of investment needs:

- **Preservation:** The level of investment in the rehabilitation and replacement of existing transit capital assets required to attain specific investment goals (e.g., to attain a "state of good repair") subject to potentially limited capital funding.
- **Expansion:** The level of investment in the expansion of transit fleets, facilities, and rail networks required to (1) support projected growth in transit demand (i.e., maintain performance); and (2) improve existing service quality and speed (i.e., improve performance).

TERM also includes a benefit-cost test that is applied for most analysis scenarios to determine which investments are cost effective and which are not. For scenarios that apply the benefit-cost test (as described in Chapter 8), TERM reports investment costs only for those investments that pass the test.

The data used to support TERM's needs estimates are derived from a variety of sources—including asset inventory data provided by local transit agencies (at FTA's request), fleet investment and transit performance data obtained from the National Transit Database (NTD), and transit travel demand forecast data provided by metropolitan planning organizations (MPOs). Appendix C contains a detailed description of the analysis methodology used by TERM.

Preservation Investments

TERM estimates current and future preservation investment needs by first assessing the age and current condition of the Nation's existing stock of transit assets (the results of this analysis were presented in Chapter 3 of this report). TERM then uses this information to assess both current reinvestment needs (i.e., the reinvestment "backlog") as well as the expected level of ongoing investment required to meet the life-cycle needs of the Nation's transit assets over the next 20 years—including all required rehabilitation and replacement activities.

Condition Based Reinvestment: Rather than relying on age alone in assessing the timing and cost of current and future reinvestment activities, TERM uses a set of empirical asset deterioration curves that estimate asset condition (both current and future) as a function of asset type, age, past rehabilitation

What types of capital spending are not modeled by TERM?

TERM does not project all types of capital spending undertaken by U.S. transit agencies. Specifically, the model does not forecast capital expenditures:

- Aimed at improving the safety or security of a transit asset or system beyond existing levels
- That address the needs of transportation services for elderly persons or persons with disabilities funded under FTA's Section 5310 program
- For significant functional improvements (e.g., such as replacement of an existing maintenance facility with a larger and better-equipped structure) to existing transit assets. In other words, TERM replaces most assets "in-kind."

It is important to note that, while TERM does not forecast the types of expenditures described above, some of these investment types (but not all) are included in the actual capital expenditures accounted for in this report, which are taken from information submitted to the NTD by local transit agencies.

activities, and potentially past maintenance and utilization levels as well (depending on asset type). The timing of specific rehabilitation and replacement activities is determined by an asset's estimated condition at the start of each year over the 20-year forecast horizon, with asset condition declining as the asset ages, triggering reinvestment events at different levels of deterioration and leading ultimately to outright replacement.

What is the significance of the *Replace at Condition 2.5* threshold?

The *Replace at Condition 2.5* threshold has been applied in earlier FTA studies, including the *Rail Modernization Study* (released in April 2009) and the *National State of Good Repair Assessment* (released in June 2010). A state of good repair, for the purposes of these studies, was defined using TERM's numerically based condition rating scale of 1 to 5 (poor to excellent) for evaluating transit asset conditions. An asset or a transit system is considered to be in a state of good repair if the asset or system has an estimated condition value of 2.5 or higher (the midpoint between adequate and marginal). The level of investment required to attain and maintain a state of good repair is therefore that amount required to rehabilitate and replace all assets with estimated condition ratings that are less than this minimum condition value.

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 of the rehabilitation and replacement needs identified by the model, at the time those investment needs come due (hence, there is no appreciable investment backlog with unconstrained analyses after any initial deferred investment is addressed). In contrast, when TERM is run in a financially constrained mode, there may not be sufficient funding to cover the reinvestment needs of all assets, in which case some reinvestment activities are deferred until a future period in which sufficient funds become available. The lack of sufficient funds to address all reinvestment needs for some or all years of the 20-year model run results in varying levels of investment backlog over this time period. Most analyses presented in this chapter were completed using funding constraints. Similarly, TERM's ability to estimate asset conditions—both current and future—provides the ability to assess how future asset conditions are likely to change (either improve or decline) given varying levels of capital reinvestment. Finally, note that TERM's benefit-cost analysis is utilized to determine the order in which reinvestment activities are completed when funding capacity is limited, with those investments with the highest benefit-cost ratio addressed first.

Expansion Investments

In addition to ongoing reinvestment in existing assets, most transit agencies also invest in the expansion of their vehicle fleets, maintenance facilities, fixed guideway, and other assets. Investments in expansion assets can be thought of as serving two distinct purposes. First, the demand for transit services typically increases over time in line with population growth, employment, and other factors. To maintain current levels of performance in the face of expanding demand, transit operators must similarly expand the capacity of their services (e.g., by increasing the number of vehicles in their fleets). Failure to accommodate this demand would result in increased vehicle crowding, increased dwell times at passenger stops, and decreased operating speeds for existing services. Second, transit operators also invest in expansion projects with the aim of improving current service performance. Such improvements include capital expansion projects (e.g., a new light rail segment) to reduce vehicle crowding or increase average operating speeds. TERM is designed to assess investment needs and impacts for both types of expansion investments.

Expansion Investments: Maintain Performance

To assess the level of investment required to maintain existing service quality, TERM estimates the rate of growth in transit vehicle fleets required to maintain current vehicle occupancy levels given the projected growth rate in transit passenger miles. In addition to assessing the level of investment in new fleet vehicles required to support this growth, TERM also forecasts investments in the expansion of other assets needed to support projected fleet growth, including bus maintenance facilities and, in the case of rail systems, additional investment in guideway, track work, stations, maintenance facilities, train control, and traction power systems. Asset expansion investment needs are assessed for all agencies reporting to the NTD on a mode-by-mode basis. However,TERM does not invest in asset expansion for those agency-modes with low ridership (per vehicle) as compared with the national average.

Expansion Investments: Improve Performance

In prior editions of the C&P report, TERM was used to estimate the level of investment required to improve current transit performance by both (1) reducing crowding in higher utilization transit systems and (2) expanding existing investment in rail as a means of improving average operating speeds in UZAs with average operating speeds (across all transit modes) well below the national average. For this edition, the impact of increased investment on system performance is assessed by developing TERM scenarios where the rate of investment in transit asset expansion exceeds the projected rate of growth in transit passenger miles. This difference between the rate of asset expansion and actual growth in travel demand represents projected long-term reductions in in-vehicle crowding and potential increases in average operating speed.

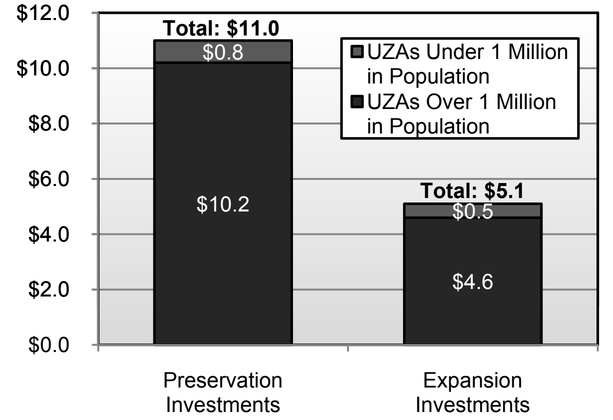
Recent Investment in Transit Preservation and Expansion

Exhibit 7-21 shows the broad composition of the 2008 spending by U.S. transit agencies on capital projects that correspond to the investment types modeled in TERM. Of the total spending amounting to $16.1 billion, $11.0 billion or 68.5 percent was devoted to preserving existing assets, and the rest was spent on expansion investments.

As expected, preservation and expansion spending were concentrated in the large urban systems. In combination, UZAs with populations greater than 1 million in 2008 accounted for 92.4 percent of preservation spending and 91.1 percent of expansion spending. Other urbanized areas and rural areas accounted for the rest.

Exhibit 7-21

2008 Transit Capital Expenditures (Billions of Dollars)



Source: National Transit Database.

Impacts of Systemwide Investments Modeled by TERM

This section uses TERM analyses to assess how different levels of investment in the preservation and expansion of the Nation's transit asset base can be expected to impact transit conditions and performance over the next 20 years. A key objective here is to place a broad range of potential future investment levels—and the consequences of those levels of investment—within the context of both the current expenditures on transit preservation and expansion and of some potential investment goals (e.g., attainment of a SGR (state of good repair) within 20 years). More specifically, these analyses consider the impact of different levels of transit capital expenditures on the following:

- **Preservation Investments**—(1) Average condition rating of U.S. transit assets and (2) SGR backlog
- **Expansion Investments**—Additional ridership (boardings) capacity.

Each of these analyses is completed first at the national level (the remainder of this section) and then repeated (in the following section) for two different segments of UZAs including the following:

- UZAs with populations greater than 1 million
- All other UZAs and rural areas with existing transit services.

Impact of Preservation Investments on Transit Conditions and Backlog

This subsection considers the expected impact of varying levels of aggregate capital reinvestment by all levels of government on the future physical condition and investment backlog (as of 2028) for the Nation's existing stock of transit assets.

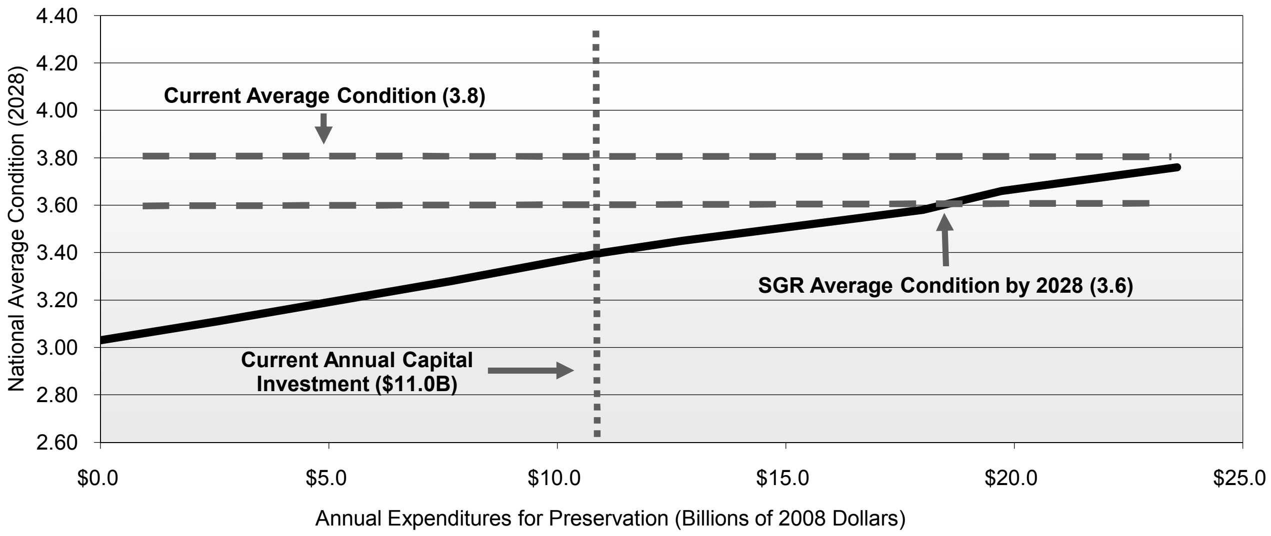
Transit Conditions: *Exhibit 7-22* presents the estimated impact of differing levels of annual rehabilitation and replacement investments on the average physical condition of all existing assets, nationwide, as of 2028. The line chart shows ongoing improvements to the overall condition of the Nation's existing transit asset base from increasing levels of transit capital reinvestment. It should be emphasized here that average condition provides a measure of asset conditions in the aggregate. Hence, while overall conditions improve with additional expenditures, it should nonetheless be expected that the condition of some individual assets will still deteriorate (given the length of asset lives and the timing of their replacement cycles) while the condition of other assets will improve. The value of the aggregate measure lies in providing an overall, single measure of aggregate conditions. Moreover, given the relationship between asset condition and asset reliability, any general improvement in overall asset conditions should also be associated with related improvements to service quality, reliability, and potentially safety as well.

The table portion of *Exhibit 7-22* presents the same investment and average condition information as in the chart. This table also presents the impact of reinvestment on asset conditions for five key transit asset categories (i.e., guideway and track, facilities, systems, stations, and vehicles) as well as the average annual percent change in constant dollar funding from 2008's level to achieve each projected condition level.

Further review of *Exhibit 7-22* reveals several observations. First, note that none of the selected reinvestment rates presented (including the current level of reinvestment, which was $11.0 billion in 2008) is sufficient to maintain aggregate conditions at or near the current national average condition rating of 3.8. Even the highest reinvestment rate presented here of $23.6 billion annually (replacement at condition rating 3.0), which represents a fairly aggressive reinvestment rate, is not quite sufficient to maintain aggregate conditions at current levels. A primary factor driving this result is the ongoing expansion investment in new rail systems over the past several decades, which has tended to maintain or even increase the average

Exhibit 7-22

Impact of Preservation Investment on 2028 Transit Conditions (All Urbanized and Rural Areas)



		Average Transit Conditions in 2028						
		Asset Categories						
Average Annual Percent Change vs. 2008	Average Annual Investment (Billions of 2008 Dollars) Total Capital Outlay	Guideway	Facilities	Systems	Stations	Vehicles	All Transit Assets	Notes
7.0%	$23.6	3.72	3.89	3.76	3.78	3.66	3.76	Unconstrained, Replace at 3.00
5.5%	$19.7	3.69	3.52	3.64	3.76	3.50	3.66	Unconstrained, Replace at 2.75
4.7%	$18.0	3.63	3.17	3.56	3.75	3.43	3.58	Unconstrained, Replace at 2.50
1.4%	$12.7	3.47	2.85	3.46	3.74	3.24	3.45	Maintain Current Backlog
0.0%	$11.0	3.40	2.82	3.37	3.73	3.13	3.40	2008 Capital Expenditures
-3.8%	$7.7	3.33	2.70	3.20	3.71	2.72	3.28	
-20.4%	$2.5	3.18	2.61	2.63	3.67	2.53	3.11	
na	$0.0	3.12	2.58	2.59	3.65	2.25	3.03	

Note that the conditions of individual transit assets are estimated using TERM's asset decay curves, which estimate asset conditions on a scale of 5 (excellent) through 1 (poor), as described earlier in this chapter and in Appendix C of this report. The average national condition is the weighted average of the condition of all assets nationwide, weighted by the estimated replacement cost of each asset.

Note that this preservation analysis is intended to consider reinvestment needs for only existing transit assets (as of 2008), not expansion assets to be added to the existing capital stock in future years.

Source: Transit Economic Requirements Model.

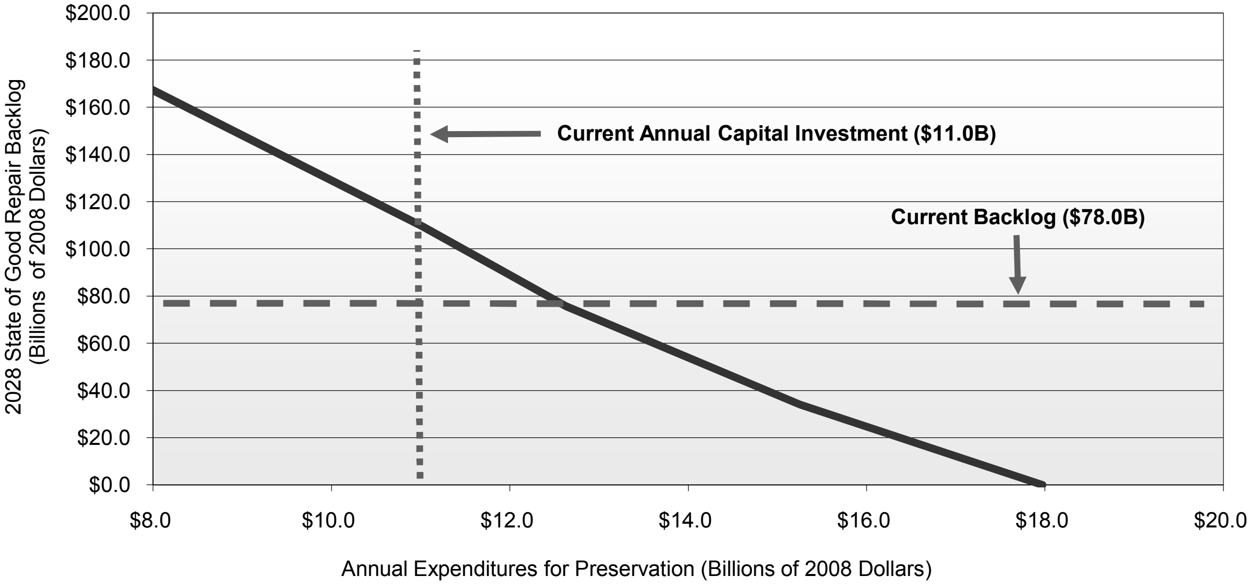
condition rating of assets nationwide (despite the ongoing deterioration of older assets) but has also resulted in an average condition rating that is not sustainable in the long term (i.e., without including the influence of further expansion investments or replacing assets at an unreasonably early age). Second, note that reinvestment at roughly $18.0 billion annually is required to attain a condition of SGR by 2028 and that this level of reinvestment is estimated to yield an average condition value of roughly 3.6 by 2028. Given the definition of the SGR benchmark (described in more detail in Chapter 8), which seeks to eliminate the existing investment backlog and then address all subsequent rehabilitation and replacement activities "on-time" thereafter, the 3.6 value could be considered representative of the expected long-term average condition of a well-maintained and financially unconstrained national transit system. Hence, an average condition value of roughly 3.6 represents a more reasonable long-term condition target for existing transit infrastructure than the current aggregate rating of 3.8.

A third and final observation is that a significant level of reinvestment is required to alter the estimated 2028 average condition measure by a point or more. This result is also driven in part by a large proportion of transit assets with expected useful lives of up to 80 years or more that will not require significant reinvestment over the 20-year period of analysis (regardless of the level of reinvestment). These assets tend to contribute a high weighting in the average condition measure, making the measure somewhat insensitive to the rate of reinvestment (note that a high proportion of reinvestment activity is focused on the replacement of those assets with relatively shorter useful lives, such as vehicles).

Transit Backlog: In contrast to the analysis above, which considers the impact of capital reinvestment on the average condition of *all* transit assets, *Exhibit 7-23* focuses on the impact of reinvestment on those assets most in need of reinvestment. Specifically, *Exhibit 7-23* presents the estimated impact of differing levels of annual capital reinvestment on the expected size of the investment backlog in 2028. The investment backlog is defined here as the level of investment required to bring all of the Nation's assets to a SGR (including the replacement of those assets that currently exceed their useful lives and the performance of all major rehabilitation activities that are currently past due). If future reinvestment rates are insufficient to address ongoing reinvestment needs as they arise, then the size of the backlog will tend to increase over time. In contrast, reinvestment at a rate above that required to address new needs as they arise will ultimately result in elimination of the existing backlog. Note that the current SGR investment backlog is estimated to be roughly $78.0 billion (see Chapter 8).

Exhibit 7-23

Impact of Preservation Investment on 2028 Transit SGR Backlog (All Urbanized and Rural Areas)



Average Annual Percent Change vs. 2008	Average Annual Investment (Billions of 2008 Dollars)	Average Condition Rating in 2028	Backlog in 2028 (Billions of 2008 Dollars)	Percent Change From Current Backlog	Funding Level Description
4.6%	$18.0	3.58	$0.0	-100.0%	SGR Scenario
3.1%	$15.3	3.53	$34.0	-55.1%	
1.3%	$12.6	3.45	$75.7	0.0%	Maintain Current Backlog
0.0%	$11.0	3.38	$109.5	44.6%	2008 Capital Expenditures
-3.8%	$7.7	3.28	$173.4	129.0%	

Note that for this report, assets are considered past their useful lives once their estimated condition in TERM falls below condition 2.50.

Source: Transit Economic Requirements Model.

As shown in *Exhibit 7-23,* TERM analysis suggests that the current rate of capital reinvestment of $11.0 billion is insufficient to keep pace with ongoing rehabilitation and replacement needs and, if maintained over the next 20 years, would result in a larger SGR backlog of roughly $109.5 billion by 2028. In contrast, increasing the rate of reinvestment to an annual average of roughly $18.0 billion will completely eliminate the backlog by 2028. Finally, the annual level of reinvestment would need to be increased to roughly $13.0 billion to maintain the backlog at roughly its current size.

Impact of Expansion Investments on Transit Ridership

While capital spending on preservation primarily benefits the physical condition of existing transit assets, expansion investments are typically undertaken to expand the asset base to accommodate projected growth in ridership and potentially to improve service performance for existing transit system users.

Exhibit 7-24 shows the relationship between aggregated annual capital spending by all levels of government on expansion investments and the additional number of annual passenger boardings that transit systems would be able to support by 2028. More precisely, this chart presents the level of expansion investment required to ensure that transit vehicle occupancy rates are maintained at current levels over the next two decades for a broad range of the potential rates of growth in transit passenger miles traveled (PMT). As the upward sloping curve of the chart indicates, higher levels of investment are required to support greater numbers of additional riders at a constant level of service. If investment levels are insufficient to fully support the projected growth in ridership, then vehicle occupancy rates will tend to increase, leading to increased crowding on high utilization systems and potentially leading to increased dwell times at stops, reduced average operating speeds, and increased rates of vehicle wear. Conversely, if the rate of transit capacity expansion exceeds the actual rate of ridership growth, then occupancy rates will tend to decline and service performance would likely also improve.

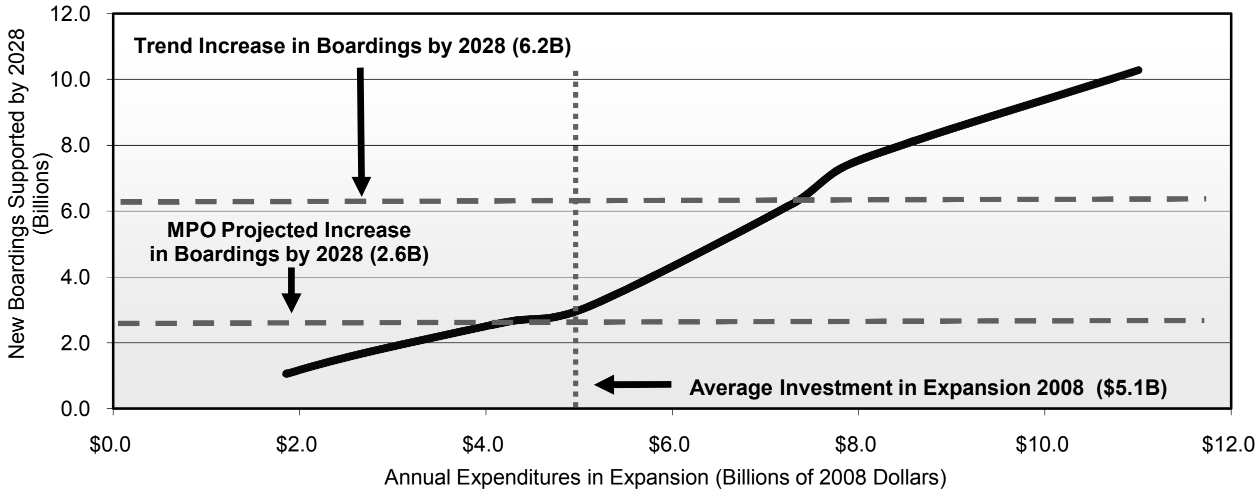
The findings presented in *Exhibit 7-24* suggest the following trends. First, the recent rate of investment in asset expansion ($5.1 billion in 2008) could support roughly 3.1 billion additional boardings by 2028 (approximately a 1.6 percent annual growth in ridership). This amount is greater than that required to support the level of growth projected by the Nation's MPOs (roughly 1.1 percent when adjusted to exclude expansion investments that do not pass TERM's benefit-cost test). As discussed in further detail in Chapter 9, MPO projections of transit growth (which are financially constrained) have typically fallen well short of actual growth in recent years. Assuming the actual rate of ridership growth is closer to the trend rate of growth for the last decade, then an average of $7.3 billion in annual transit capital expansion investment would be required over the next 20 years to support an additional 6.2 billion annual boardings (again after excluding expansion investments that do not pass TERM's benefit-cost test). Hence, while the existing levels of transit capital expansion investment may be sufficient to maintain current service performance (i.e., vehicle occupancy rates) if ridership growth is relatively low, this level of investment is roughly two-thirds of that required to support a level of ridership growth consistent with that experienced over the most recent 10-year period.

Impacts of UZA-Level Investments Modeled by TERM

The remainder of this chapter focuses on how different levels of annual capital investment in the U.S. transit infrastructure affect urbanized areas with dissimilar transit investment needs. Specifically, this section explores the impact of capital expenditures by transit agencies sorted into two distinct UZA groupings: (1) the UZAs with populations greater than 1 million and (2) all other urbanized and rural areas with existing transit services.

Exhibit 7-24

New Ridership Supported in 2028 by Expansion Investments (All Urbanized and Rural Areas)



Average Annual Percent Change vs. 2008	Average Annual Investment (Billions of 2008 Dollars)	Total New Boardings by 2028: New Riders Supported (Billions of Annual Boardings)	Total New Boardings by 2028: Average Annual Growth in Boardings*	Funding Level Description
7.1%	$11.0	10.28	3.5%	
4.3%	$8.0	7.52	2.8%	
3.5%	$7.3	6.23	2.4%	Trend Growth in PMT (1999 through 2008)
0.0%	$5.1	3.07	1.6%	Capital Expenditure for 2008
-2.0%	$4.2	2.62	1.1%	MPO Projected Increase in PMT
-7.2%	$2.7	1.66	0.7%	
-11.8%	$1.9	1.06	0.5%	

* *As compared with total urban ridership in 2008; only includes increases covered by investments passing TERM's benefit-cost test.*

Note that 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). Note, however, that 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.

UZAs Over 1 Million in Population

The Nation's largest UZAs own and operate the majority of the Nation's existing transit assets. These UZAs also typically have the highest levels of investment in older rail assets.

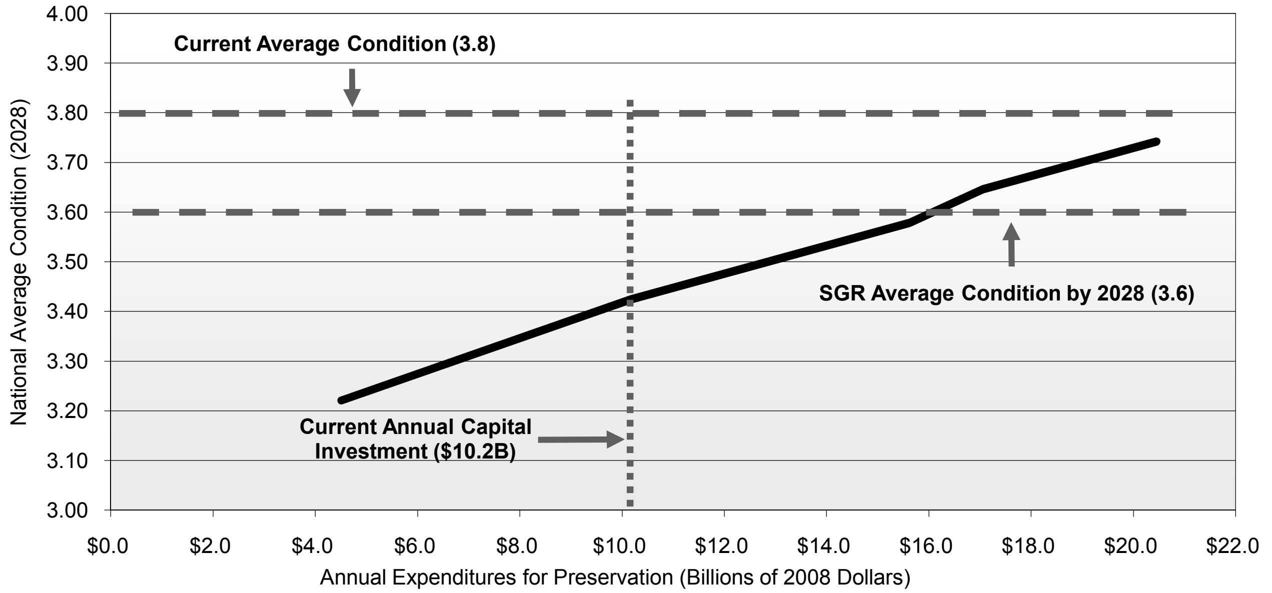
In 2008, transit agencies operating in UZAs with populations greater than 1 million expended $14.8 billion on capital projects, consisting of $10.2 billion on preservation investments intended to rehabilitate or replace existing assets, and $4.6 billion on expansion investments designed to increase service capacity. Following is a discussion of the transit asset preservation and expansion needs of these UZAs with populations greater than 1 million.

Preservation Investments

Exhibit 7-25 shows the estimated impact of varying levels of preservation investments on the future condition of existing transit assets located in UZAs with populations greater than 1 million. As with the earlier chart covering the entire industry, this chart clearly indicates that the current average condition rating for transit assets located in the largest UZAs is not sustainable in the long term without replacing assets on a fairly aggressive schedule (i.e., replacement at condition 3.0 or earlier). At the same time, the 2008 level of reinvestment ($10.2 billion) is less than that required to attain a SGR ($15.6 billion), with the latter supporting a more sustainable long-term average condition rating of roughly 3.6.

Exhibit 7-25

Impact of Preservation Investment on 2028 Transit Conditions (Over 1 Million in Population)



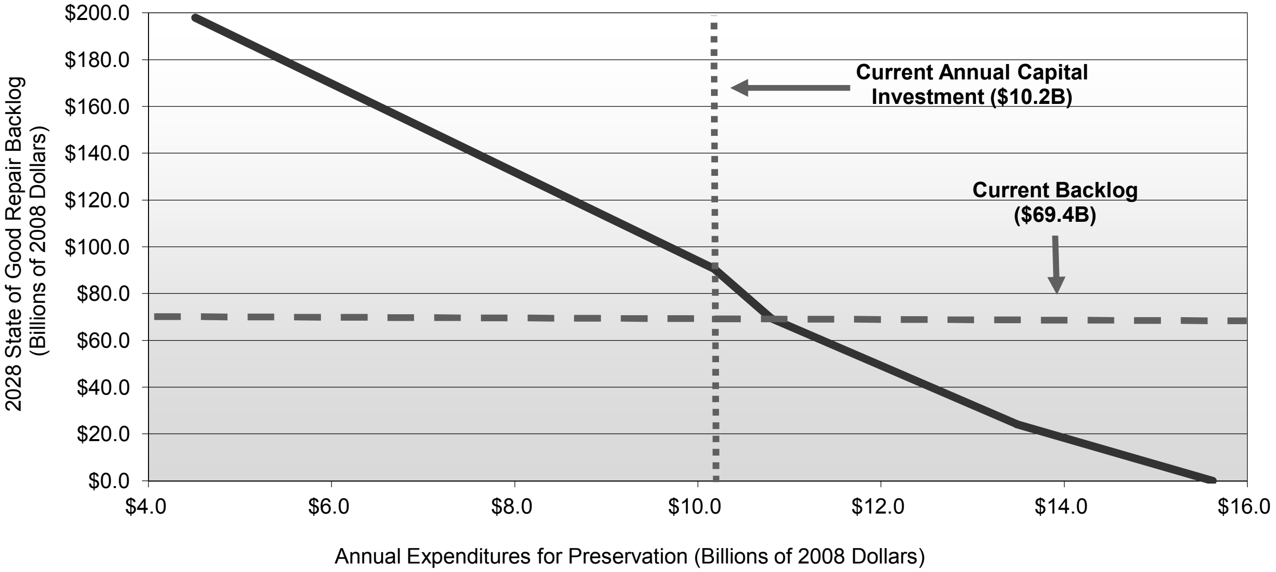
Average Annual Percent Change vs. 2008	Average Annual Investment (Billions of 2008 Dollars) Total Capital Outlay	Average Transit Conditions in 2028						Notes
		Asset Categories					All Transit Assets	
		Guideway	Facilities	Systems	Stations	Vehicles		
5.9%	$20.5	3.68	3.91	3.76	3.78	3.66	3.74	Unconstrained, Replace at 3.00
4.3%	$17.1	3.65	3.41	3.63	3.76	3.52	3.65	Unconstrained, Replace at 2.75
3.5%	$15.6	3.58	3.15	3.55	3.75	3.45	3.58	Unconstrained, Replace at 2.50 (SGR)
0.0%	$10.2	3.38	2.92	3.37	3.73	3.16	3.42	2008 Capital Expenditures
-10.6%	$4.5	3.22	2.75	2.78	3.70	2.80	3.22	

Source: Transit Economic Requirements Model.

As shown in *Exhibit 7-26,* the 2008 level of capital reinvestment of $10.2 billion for the largest UZAs is insufficient to keep pace with ongoing rehabilitation and replacement needs and, if maintained over the next 20 years, would result in a larger SGR backlog of roughly $90.7 billion by 2028 as compared with the current $69.4 billion. In contrast, increasing the rate of reinvestment to an annual average of roughly $15.6 billion will completely eliminate the entire backlog by 2028. The annual level of reinvestment would need to be increased to roughly $10.8 billion to maintain the backlog at roughly its current size.

Exhibit 7-26

Impact of Preservation Investment on 2028 Transit SGR Backlog (Over 1 Million in Population)



Average Annual Percent Change vs. 2008	Average Annual Investment (Billions of 2008 Dollars)	Replacement Condition	Average Condition Rating in 2028	Backlog in 2028 (Billions of 2008 Dollars)	Funding Level Description
3.5%	$15.6	2.50	3.58	$0.0	SGR Scenario
2.3%	$13.5	2.50	3.56	$24.2	
0.4%	$10.8	2.50	3.48	$69.4	Current Backlog
0.0%	$10.2	2.50	3.42	$90.7	2008 Capital Expenditures
-10.6%	$4.5	2.50	3.22	$197.9	

Source: Transit Economic Requirements Model.

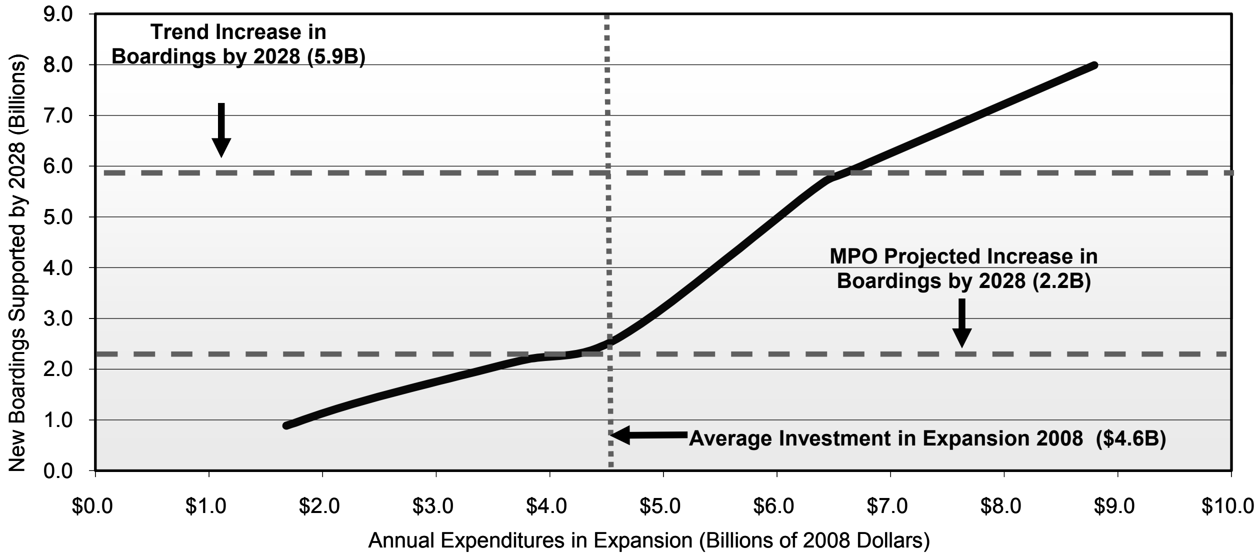
Expansion Investments

While UZAs with populations greater than 1 million tend to be dominated by cities with slower rates of increase in population and transit ridership (e.g., Boston, Philadelphia, and Chicago), this group also includes urbanized areas—including Los Angeles, Atlanta, Seattle, and other smaller cities—expected to experience relatively high rates of growth in transit boardings and PMT over the next two decades. Given the high numbers of existing riders and transit capacity in these higher-growth, large UZAs, they will require significant increases in expansion investments to maintain current service performance over this time period.

Exhibit 7-27 presents estimates of the level of expansion investment required to support varying levels of growth in transit demand while maintaining current performance levels (as measured by vehicle capacity utilization) for these larger UZAs. Note that the 2008 level of investment for these UZAs ($4.6 billion) was more than that required to support the rate of increase in transit demand as projected by the Nation's MPOs (low growth) but well short of that required to support a rate of growth comparable to the trend rate of increase as experienced over the most recent decade.

Exhibit 7-27

New Ridership Supported in 2028 by Expansion Investments (Over 1 Million in Population)



Average Annual Percent Change vs. 2008	Average Annual Investment (Billions of 2008 Dollars)	Total New Boardings by 2028		Funding Level Description
		New Riders Supported (Billions of Annual Boardings)	Average Annual Growth in Boardings*	
11.1%	$8.8	7.99	3.2%	
9.8%	$6.6	5.91	2.5%	Trend Growth in PMT (1999 through 2008)
8.3%	$6.4	5.63	2.4%	
5.9%	$4.6	2.65	1.3%	Capital Expenditure for 2008
4.6%	$3.7	2.15	1.1%	MPO Projected Increase in PMT
0.0%	$2.4	1.38	0.7%	
-3.1%	$1.7	0.89	0.5%	

* *As compared with total urban ridership in 2008; only includes increases covered by investments passing TERM's benefit-cost test.*

Source: Transit Economic Requirements Model.

Other Urbanized and Rural Areas

The following analysis considers the combined preservation and expansion needs of UZAs under 1 million and those of all rural areas with existing transit service. This diverse group therefore includes a large number of mid- and small-sized urbanized and rural transit operators offering only bus and/or paratransit services.

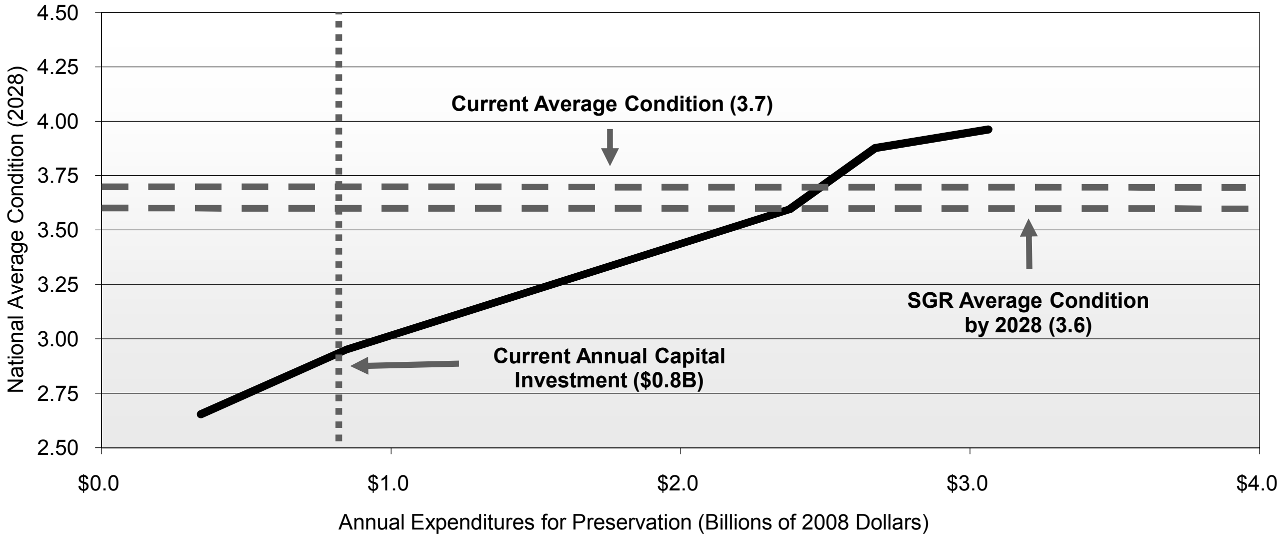
In 2008, transit agencies operating outside of the largest UZAs expended $1.3 billion on capital projects, consisting of $0.8 billion on preservation investments intended to rehabilitate or replace existing assets, and $0.5 billion on expansion investments designed to increase service capacity. Following is a discussion of the transit asset preservation and expansion needs of transit agencies in these areas.

Preservation Investments

Exhibit 7-28 shows the estimated impact of varying levels of preservation investments on the future condition of existing transit assets located in UZAs with populations less than 1 million and in rural areas. As with the earlier analyses for the largest UZAs, this chart also indicates that the current average condition rating for transit assets in these smaller urbanized and rural areas is not sustainable in the long term without replacing assets on a fairly aggressive schedule (i.e., replacement at condition 3.0 or earlier). At the same time, the 2008 level of reinvestment ($0.8 billion) is significantly less than that required to attain a SGR ($2.4 billion), with the latter supporting a more sustainable long-term average condition rating of roughly 3.6.

Exhibit 7-28

Impact of Preservation Investment on 2028 Transit Conditions (Under 1 Million in Population)



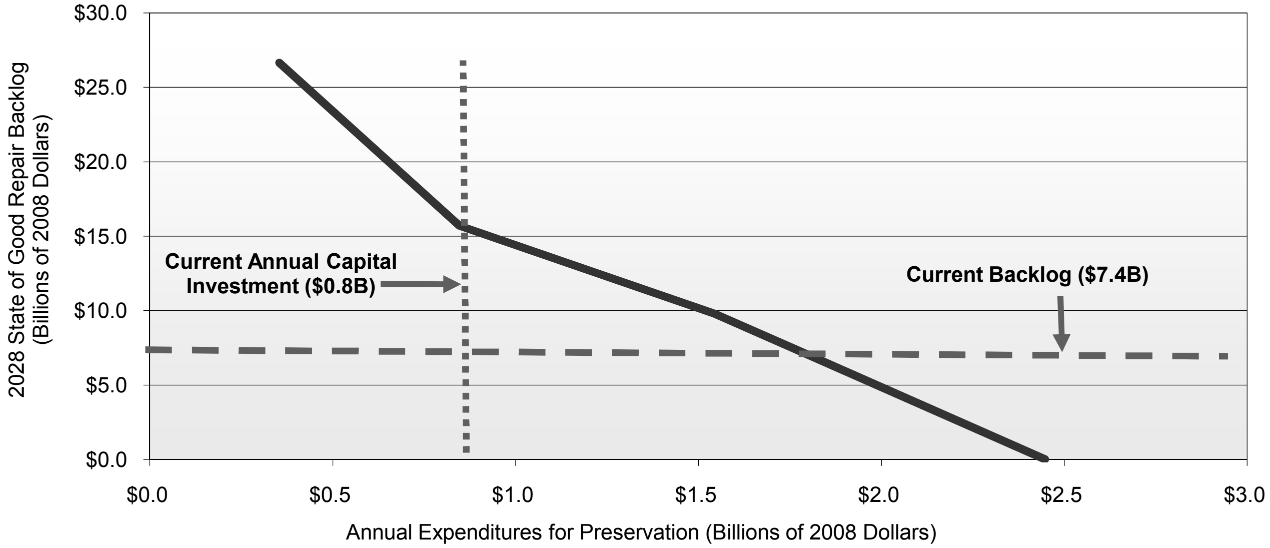
Average Annual Percent Change vs. 2008	Average Annual Investment (Billions of 2008 Dollars) Total Capital Outlay	Average Transit Conditions in 2028						Notes
		Asset Categories					All Transit Assets	
		Guideway	Facilities	Systems	Stations	Vehicles		
10.9%	$3.1	4.52	3.85	3.89	4.07	3.66	3.96	Unconstrained, Replace at 3.00
9.5%	$2.7	4.45	3.89	3.79	3.90	3.36	3.88	Unconstrained, Replace at 2.75
8.5%	$2.4	4.47	3.24	3.75	3.90	3.35	3.59	Unconstrained, Replace at 2.50
0.0%	$0.8	3.74	2.48	3.15	3.55	2.93	2.95	2008 Capital Expenditures
-5.4%	$0.3	3.70	2.43	3.07	3.45	1.94	2.65	

Source: Transit Economic Requirements Model.

As shown in *Exhibit 7-29,* the 2008 level of capital reinvestment of $0.8 billion for rural areas and smaller UZAs is insufficient to keep pace with ongoing rehabilitation and replacement needs. If maintained over the next 20 years, this rate of investment would result in a larger SGR backlog of roughly $15.7 billion by 2028, as compared with the current backlog of $7.4 billion for this group. In contrast, increasing the rate of reinvestment to an annual average of roughly $2.4 billion will completely eliminate the entire backlog by 2028. The annual level of reinvestment would need to be increased to roughly $1.8 billion annually to maintain the backlog at roughly its current size.

Exhibit 7-29

Impact of Preservation Investment on 2028 Transit SGR Backlog (Under 1 Million in Population)



Average Annual Percent Change vs. 2008	Average Annual Investment (Billions of 2008 Dollars)	Replacement Condition	Average Condition Rating in 2028	Backlog in 2028 (Billions of 2008 Dollars)	Funding Level Description
8.5%	$2.4	2.50	3.59	$0.0	SGR Scenario
6.3%	$1.8	2.50	3.19	$7.4	Current Backlog
5.5%	$1.5	2.50	3.06	$9.8	
0.0%	$0.8	2.50	2.95	$15.7	2008 Capital Expenditures
-5.1%	$0.4	2.50	2.65	$26.7	

Source: Transit Economic Requirements Model.

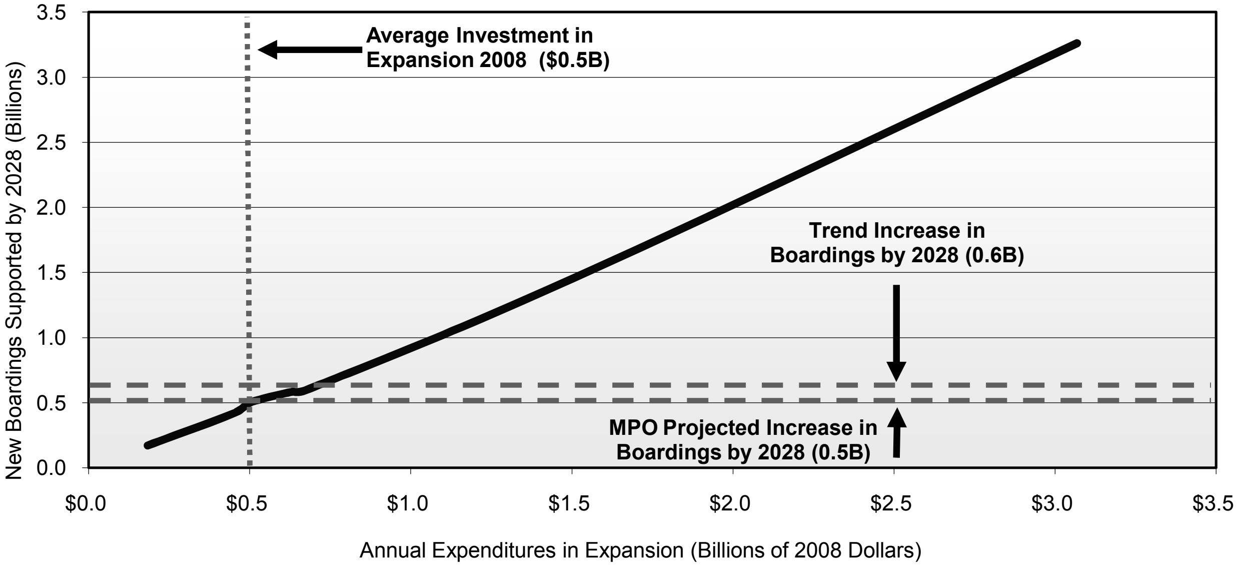
Expansion Investments

While the urbanized and rural areas in this group represent a smaller number of riders and a smaller existing transit asset base, these areas are also expected to have a higher projected rate of increase in transit ridership.

Exhibit 7-30 presents estimates of the level of expansion investment required to support varying levels of growth in transit demand while maintaining current performance levels (as measured by transit passenger miles per peak vehicle) for the smaller urbanized and all rural areas. Note that the 2008 level of investment for these areas ($0.5 billion) was the same as that required to support the rate of increase in transit demand as projected by the Nation's MPOs and slightly less than the trend rate of increase as experienced over the last several years. Such investments should yield both improvements in transit performance in these UZAs and also help promote transit-led urban development in UZAs subject to above average rates of population and transit growth.

Exhibit 7-30

New Ridership Supported in 2028 by Expansion Investments (Under 1 Million in Population)



Average Annual Percent Change vs. 2008	Average Annual Investment (Billions of 2008 Dollars)	Total New Boardings by 2028 New Riders Supported (Billions of Annual Boardings)	Total New Boardings by 2028 Average Annual Growth in Boardings*	Funding Level Description
	$3.1	3.26	4.5%	
	$1.5	1.45	4.1%	
	$0.7	0.59	2.1%	Trend Growth in PMT (1999 through 2008)
	$0.6	0.58	2.1%	
	$0.5	0.50	1.8%	MPO Projected Increase in PMT
0.0%	$0.5	0.42	1.5%	Capital Expenditure for 2008
	$0.2	0.17	0.7%	

* *As compared with total urban ridership in 2008; only includes increases covered by investments passing TERM's benefit-cost test.*

Source: Transit Economic Requirements Model.

Chapter 8

Selected Capital Investment Scenarios

Selected Highway Capital Investment Scenarios

This section presents a set of future investment scenarios that builds on the Chapter 7 analyses of alternative levels of future investment in highways and bridges. Each scenario includes projections for system conditions and performance based on simulations developed using the Highway Economic Requirements System (HERS) and National Bridge Investment Analysis System (NBIAS). In addition, each scenario considers types of capital investment beyond these models' current scopes.

After initially focusing on Federal-aid highways, this section examines scenarios for the entire highway system, the National Highway System (NHS), and the Interstate Highway System. A subsequent section of this chapter explores scenarios for future transit investments. All of these scenarios start with a 2008 base year and cover the 20-year period through 2028.

For proper interpretation of these scenarios, the background information presented in the Introduction to Part II is essential. In particular, the scenarios represent rough estimates of what **could** be achieved with a given level of investment assuming an economically driven approach to project selection, as opposed to what **would** be achieved given current decision making practices. It is also important to appreciate that the scenarios incorporate various technical assumptions, some of which are based on more limited information than others. Some of the simplifying assumptions made in the models necessarily limit their utility as predictive tools.

Chapter 10 includes a series of sensitivity analyses that explore the impact of altering certain assumptions about market trends and technical parameter values. Of particular importance are the sensitivity analyses concerning the trend rate at which vehicle miles traveled (VMT) would grow in the absence of any change in average user cost of travel (in constant dollars), as this can have a significant impact on the HERS analysis in particular. In addition, Chapter 9 includes some supplemental analyses based on alternative assumptions about future financing mechanisms or system management policies.

The future spending levels associated with investment scenarios presented in this chapter are all stated in constant 2008 dollars. Put another way, the levels are "real" values with a 2008 base year, rather than "nominal" (future dollar) values. As shown in Chapter 9, nominal values can be derived from these results through adjustments that account for actual or predicted inflation beyond 2008. Each scenario retains the assumption from Chapter 7 that changes in the level of investment occur gradually over time, and highlights the average annual level of investment over the entire analysis period. (Note that the average annual investment levels are determined by summing the amounts expended for each year from 2009 to 2028 under the scenario, and dividing by 20).

Scenario Components

For each set of highways considered—Federal-aid highways, all highways, NHS, and Interstate Highways—this section examines the four scenarios described below. **These scenarios are intended to be illustrative; none of them is endorsed as a target level of funding.** Other investment levels could be equally valid, depending on what system condition and performance outcomes are desired. Each of these scenarios is based on capital investment by all levels of government combined. **The question of what portion should be funded by the Federal government, State governments, local governments, or the private sector is beyond the scope of this report.**

In addition to the types of investments modeled by HERS and NBIAS, each scenario includes the non-modeled types of highway and bridge investment. The investments modeled by HERS are system expansion and pavement rehabilitation projects on highways eligible for Federal aid. The Highway Performance Monitoring System (HPMS) sample, on which HERS relies for data, excludes the three highway functional classes that are generally ineligible for Federal aid: rural minor collectors, rural local roads, or urban local roads. In addition to system expansion and pavement rehabilitation investments in these classes of highways, the non-modeled category in this chapter's scenarios includes investments classified as System Enhancements. As discussed in Chapters 6 and 7, System Enhancements include safety enhancements, operational improvements, and environmental projects. Chapter 7 discussed the distribution of 2008 highway and bridge investment among the HERS-modeled, NBIAS-modeled, and non-modeled categories.

In the absence of the data required to rigorously analyze the non-modeled improvement types, the scenarios simply assume that the non-modeled share of bridge and highway investment will remain the same as in the base year, 2008. While the_scenarios in this section include this allowance for residual (non-modeled) investment when measuring total spending, they do not include the benefits from such investments when projecting highway and bridge conditions and performance.

The scenarios presented differ in the annual percentage rates at which real investment grows over the 20-year analysis period, and these rates may also differ between the components of investment modeled by HERS and NBIAS. Within each modeled component, the scenarios impose no constraints on the allocation of funding. For example, the distribution of HERS-modeled investment spending among highway functional classes is the allocation HERS determines to be most cost-beneficial without regard to actual current or past allocation patterns. The allocation of NBIAS-modeled investment is likewise determined flexibly through application of benefit-cost principles. For additional discussion of the technical features of HERS and NBIAS, see Appendix A and Appendix B.

Scenario Definitions

The **Sustain Current Spending scenario** assumes for each of the three broad investment categories (HERS-modeled, NBIAS-modeled, and non-modeled) that real spending remains at the 2008 level over the following two decades. However, the allocation of the HERS-modeled component among resurfacing, reconstruction, and widening is determined by the model's combination of engineering and benefit-cost criteria, and thus will differ from the actual allocation in 2008. Likewise, the allocation of the NBIAS-modeled component among bridge repair, bridge rehabilitation, and bridge replacement will differ from the actual 2008 distribution. (Chapter 7 presents an alternative funding-constrained analysis that considers what would happen to conditions and performance if the investment modeled by HERS and NBIAS were to decrease by 1.0 percent per year.)

The **Maintain Conditions and Performance scenario** gears the annual rates of growth in real investment to the target of keeping two key performance indicators at the same level in 2028 as in 2008. These indicators are average speeds (as computed by HERS) and the economic backlog for bridge investment (as computed by NBIAS), and serve as summary measures of the overall conditions and performance of highways and bridges. Although this scenario would maintain these summary indicators at base year levels for the system as a whole, the conditions and performance of individual components of the system would vary. (Chapter 9 presents a supplemental scenario aimed at maintaining conditions and performance separately on individual functional systems. Chapter 7 identifies the investment levels associated with maintaining two other HERS performance indicators: average pavement roughness and average delay.)

How do the definitions of the selected scenarios presented in this report compare to those presented in the 2008 C&P Report?

The name and definition of the **Sustain Current Spending scenario** are unchanged. The **Maintain Conditions and Performance scenario** is similar to the "Sustain Conditions and Performance scenario" in the 2008 C&P Report except that the performance target has been modified from adjusted average users costs to average speeds. (The implications of this shift are discussed in Chapter 7.)

The definition of the **Improve Conditions and Performance scenario** is identical to that of the "MinBCR=1.0" scenario in the 2008 C&P Report. The HERS-derived component of the **Intermediate Improvement scenario** is defined in a manner consistent with the "MinBCR=1.5" scenario; the NBIAS-derived component has been redefined in a manner that reduces its costs and projected impacts (i.e., the bridge investment backlog would be reduced rather than eliminated).

The **State of Good Repair benchmark** is a new addition, while the "MinBCR=1.2" scenario from the 2008 C&P Report has been dropped. (The inputs to that scenario have been retained in Chapter 7.)

Chapter 9 includes comparisons of key scenario statistics from this report with comparable scenarios from the 2008 C&P Report and prior editions.

The **Improve Conditions and Performance scenario** assumes that real investments in HERS-modeled and NBIAS-modeled improvements increase over 20 years at an annual rate projected to be sufficient to fund all potentially cost-beneficial investments (i.e., those with a benefit-cost ratio [BCR] of 1.0 or higher) by 2028. This scenario can be thought of as an "investment ceiling" above which it would not be cost-beneficial to invest, even if available funding were unlimited. This level of funding would eliminate the economic backlog for bridge investment as computed by NBIAS, and would improve various measures of conditions and performance measured in HERS.

The **Intermediate Improvement scenario** is presented in this report to emphasize that any investment above the level of **Maintain Conditions and Performance scenario** would tend to result in an overall improvement to the system, and that it is not necessary to reach the level associated with the **Improve Conditions and Performance scenario** in order to have a significant impact on conditions and performance. The **Intermediate Improvement scenario** assumes that, between 2008 and 2028, real investment in HERS-modeled improvements increases annually at a rate sufficient to implement all improvements with a BCR greater than or equal to 1.5 (i.e., benefits exceed costs by 50 percent). Applying a minimum BCR cutoff higher than 1.0 tends to reduce the risk of investing in potential projects that might initially appear cost beneficial, but that might not ultimately meet this standard due to unexpected changes in future costs or travel demand. For NBIAS-modeled improvements, this scenario applies the same growth rate in real investments as used for the HERS-based improvements (to the extent that this would continue to pass the NBIAS benefit-cost test) because the benefit-cost procedures in NBIAS are not sufficiently robust to directly support this type of analysis. This approach results in a reduction in the economic investment backlog by 2028. (Chapter 7 also identifies the investment levels associated with a BCR cutoff of 1.2.)

The **State of Good Repair benchmark** represents the subset of the **Improve Conditions and Performance scenario** defined above that is directed towards the types of improvements defined as System Rehabilitation in Chapters 6 and 7. Chapter 3 includes a discussion of the state of good repair concept that lays out some key factors that should be considered in defining the term in the content of various types of transportation assets. While there is broad recognition that our Nation's transportation infrastructure falls short of a "State of Good Repair"; there is no national consensus as to exactly how the term should be applied in the context of various types of transportation assets. The **State of Good Repair benchmark** presented in this section includes investments that would address deficiencies in the physical conditions of pavements and bridges based on engineering criteria, but only those that pass a benefit-cost test. (This has the effect of screening out assets that may have outlived their original purpose, rather than automatically re-investing in all assets in perpetuity.)

Does the State of Good Repair benchmark apply the same criteria for all types of roadways modeled in HERS?

No. For principal arterials, the deficiency levels in HERS have been set so that the model will consider taking action on a pavement only when its international roughness index (IRI) value has risen above 95 (inches per mile), meaning it would no longer be considered to have "good" ride quality based on the criteria described in Chapter 3.

For roads functionally classified as collectors, the HERS deficiency levels have been set so that pavement actions will only be considered when IRI values have risen above 170, and the roads, thus, no longer meet the criteria for "acceptable" ride quality. The IRI threshold for minor arterials is set at 120.

Although the engineering thresholds identified above define when the model may consider a pavement improvement, any such improvement must pass a benefit-cost test in order to be implemented. Even when HERS is given an unlimited budget to work with, it does not recommend improving all principal arterials to the "good" ride quality level, or all collectors to the "acceptable" ride quality level. The specific IRI value at which a pavement improvement will pass a benefit-cost test depends on a number of factors, including the traffic volume and average speeds on that facility. As discussed in Chapter 3, pavement ride quality has a greater impact on highway user costs on higher speed roads.

While this definition is logical within the context of the other scenarios presented in this section, alternative state of good repair benchmarks with different objectives could be equally valid from a technical perspective. (Because this benchmark is a subset of a larger scenario, it is referenced only in selected locations within this section.)

Federal-Aid Highway Scenarios

Exhibit 8-1 summarizes the derivation of the scenarios constructed for Federal-aid highways, identifying their HERS-modeled, NBIAS-modeled, and non-modeled (other) components. These scenarios incorporate selected funding levels from the analysis in Chapter 7 (the footnotes in *Exhibit 8-1* identify the specific Chapter 7 exhibits to which the scenarios are linked). All levels of government spent a combined $70.6 billion on capital improvements to Federal-aid Highways in 2008; $54.7 billion of this total (77.4 percent) was used for types of capital improvements modeled in HERS, $9.4 billion (13.4 percent) was used for types of capital improvements modeled in NBIAS, and $6.5 billion (9.2 percent) was used for other types of capital improvements. By definition, these amounts match the average annual investment levels for the **Sustain Current Spending scenario** for Federal-aid highways.

Exhibit 8-1 also identifies the annual rates of spending growth associated with the HERS and NBIAS components of each scenario, and the BCR cutoff associated with the HERS component. In addition to providing information relevant to how these scenario components were constructed,

Why does this section begin by presenting scenarios for Federal-aid highways rather than all roads?

The investment analyses for Federal-aid highways are considered to be stronger than those for all roads because the available data are best suited to supporting this type of analysis.

As discussed in Chapter 2, the term "Federal-aid highways" includes roads that are generally eligible for Federal funding assistance under current law. This includes all public roads that are not functionally classified as rural minor collector, rural local, or urban local. Because the HPMS does not contain detailed sample information for these three functional classes, the scenarios based on all roads include a much larger non-modeled component and hence are more speculative.

The stratified sample structure within the HPMS is organized around individual functional classes. Consequently, the accuracy of the scenarios based on the Interstate Highway System should be considered to be comparable to those for Federal-aid Highways. The scenarios based on the National Highway System are not quite as robust because the HPMS does not target the NHS separately in its sample design.

These distinctions are not as significant for the portions of each scenario derived from NBIAS because the National Bridge Inventory includes comparably detailed information on all of the Nation's bridges.

Exhibit 8-1

Definitions of Selected Federal-Aid Highway Capital Investment Scenarios, and Average Annual Investment Levels for 2009 to 2028 Associated With Scenario Components

Scenario Name and Description	Scenario Component (Source of Estimate)[1]	Component Share of 2008 Capital Outlay	Annual Percent Change in Spending vs. 2008	Minimum BCR	Average Annual Capital Investment on Federal-Aid Highways	
					Billions of 2008 Dollars	**Percent of Total**
Sustain Current Spending scenario (Sustain spending at base year levels in constant dollar terms.)	HERS [2]	77.4%	0.00%	2.42	$54.7	77.4%
	NBIAS [3]	13.4%	0.00%		$9.4	13.4%
	Other	*9.2%*			*$6.5*	*9.2%*
	Total	100.0%			**$70.6**	100.0%
Maintain Conditions and Performance scenario (Maintain average speed and the economic bridge investment backlog at 2008 levels.)	HERS [2]	77.4%	1.31%	2.02	$62.9	78.5%
	NBIAS [3]	13.4%	0.40%		$9.8	12.3%
	Other	*9.2%*			*$7.4*	*9.2%*
	Total	100.0%			**$80.1**	100.0%
Intermediate Improvement scenario (Invest in projects with benefit-cost ratios as low as 1.5 and reduce the economic bridge investment backlog.)	HERS [2]	77.4%	3.51%	1.50	$80.1	77.4%
	NBIAS [3]	13.4%	3.51%		$13.8	13.4%
	Other	*9.2%*			*$9.5*	*9.2%*
	Total	100.0%			**$103.5**	100.0%
Improve Conditions and Performance scenario (Invest in all cost-beneficial projects and eliminate the economic bridge investment backlog.)	HERS [2]	77.4%	5.90%	1.00	$105.4	78.1%
	NBIAS [3]	13.4%	5.36%		$17.1	12.7%
	Other	*9.2%*			*$12.4*	*9.2%*
	Total	100.0%			**$134.9**	100.0%

[1] Each scenario consists of three separately estimated components. The components derived from HERS and NBIAS represent the combined investment by all levels of government associated with achieving the scenario goals identified. The third scenario component, identified as "Other," represents other types of capital spending beyond those modeled in HERS or NBIAS; each scenario assumes that the percentage of total spending on these nonmodeled items in the future will be the same as the actual percentage in 2008.

[2] The scenario components derived from HERS are directly linked to the analyses presented in Exhibits 7-3 through 7-10 in Chapter 7; these components can be cross-referenced to the exhibits using either the annual percent change in spending relative to 2008, or the minimum BCR identified in this table.

[3] The scenario components derived from NBIAS are directly linked to the analysis presented in Exhibit 7-18 in Chapter 7; these components can be cross-referenced to this exhibit using the annual percent change in spending relative to 2008 identified in this table.

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

these statistics also provide the means to directly link each scenario back a particular row in the more detailed investment/performance tables presented in Chapter 7. For the **Sustain Current Spending scenario**, the average annual growth rates in HERS and NBIAS spending are assumed to be zero by definition; this level of HERS investment is projected to be sufficient to fund potential capital improvements on Federal-aid highways with a benefit cost ratio of 2.42 or higher.

To meet the objectives of the **Maintain Conditions and Performance scenario** for Federal-aid highways (maintain average speed and the economic bridge investment backlog in 2028 at their 2008 levels), investment in the types of capital improvements modeled in HERS would need to increase 1.31 percent per year above the 2008 baseline level in constant dollar terms; this would translate into an average annual investment level of $62.9 billion over 20 years and would be sufficient to fund all potential capital improvements with a BCR of 2.02 or higher. Investment in the types of capital improvements modeled in NBIAS would need to increase 0.40 percent annually in real terms, which translates into an average annual

How strongly are the scenario investment levels presented in *Exhibit 8-1* affected by the underlying assumptions regarding future travel growth?

Travel growth forecasts are inherently speculative, and can have a significant impact on analyses of the potential future impacts of highway capital investment. The scenarios presented in this chapter rely on forecasts of future vehicle miles traveled (VMT) provided by the States for each individual sample highway section in the HPMS; the composite weighted average annual VMT growth rate based on these forecasts is 1.85 percent. The HERS model assumes that the forecast for each section represents the amount of travel that would occur if average highway user costs per VMT were to remain constant over time.

Chapter 10 includes an analysis of the potential impacts of alternative VMT forecasts on the HERS results. One key observation is that had the HPMS VMT growth forecasts averaged to 1.23 per year, the HERS component of the **Improve Conditions and Performance scenario** presented in *Exhibit 8-1* would have been smaller ($80.2 billion per year rather than $105.4 billion). Had the HPMS VMT growth forecasts averaged only 0.56 percent per year, the HERS component of this scenario would have been only $59.8 billion per year. Lower future VMT growth would reduce the potential benefits of widening projects and reduce annual wear and tear on pavements.

A separate analysis presented in Chapter 10 of the impact of alternative VMT forecasts on the NBIAS results shows that this model is much less sensitive to this variable. Therefore, substituting lower VMT forecasts into the scenarios presented in *Exhibit 8-1* would have a smaller percentage impact on the overall average annual investment level presented for each scenario than would be the case for the HERS component of that scenario.

investment level of $9.8 billion in constant 2008 dollars. All of Federal-aid highway scenarios assume that improvements of the types not modeled in HERS or NBIAS—the "other" component in *Exhibit 8-1*—account for 9.2 percent of the total investment in Federal-aid highways, the same as in 2008. Adjusting for these non-modeled types of capital spending brings the total average annual investment level associated with this scenario up to $80.1 billion.

As noted above, the **Intermediate Improvement scenario** is defined to include all potential capital improvements considered in HERS with a BCR of 1.50 or higher. This would require investment in these types of improvements on Federal-aid highways to increase at a real annual rate of 3.51 percent. Applying the same growth rate to the NBIAS-modeled and non-modeled capital improvement types brings the total average annual investment level for this scenario to $103.5 billion for Federal-aid highways.

Implementing all potentially cost-beneficial capital improvements (BCR≥ 1.0) over the 20 years would require HERS-modeled investments on Federal-aid highways to increase 5.90 percent annually and NBIAS-modeled investments to increase 5.36 percent annually. Adjusting for non-modeled investments (so that they represent 9.2 percent of the total cost of the scenario) brings the average annual investment level for Federal-aid highways under the **Improve Conditions and Performance scenario** to $134.9 billion.

Federal-Aid Highway Scenario Impacts and Comparison with 2008 Spending

For each Federal-aid highway scenario, *Exhibit 8-2* compares the associated capital investment levels with actual spending in 2008 and provides selected summary measures of future system conditions and performance.

In the **Maintain Conditions and Performance scenario,** annual spending averages $80.1 billion, which is $9.5 billion (13.4 percent) higher than the $70.6 billion of actual capital spending on Federal-aid highways in 2008. Attaining this average annual level of spending would require real capital spending to increase over the 20 years by 1.18 percent per year. (As one would expect, this growth rate falls between the growth rates for the HERS and NBIAS components of this scenario identified in *Exhibit 8-1*.)

Exhibit 8-2

Selected Federal-Aid Highway Capital Investment Scenarios for 2009 to 2028: Comparisons With 2008 Spending and Projected Federal-Aid Highway Performance Indicators

Comparison Parameter	Sustain Current Spending Scenario	Maintain Conditions & Performance Scenario	Intermediate Improvement Scenario	Improve Conditions & Performance Scenario
Comparison of Scenarios With 2008 Spending				
Average Annual Investment (Billions of 2008 Dollars)	$70.6	$80.1	$103.5	$134.9
Difference Relative to 2008 Spending (Billions of 2008 Dollars)	**$0.0**	$9.5	$32.8	$64.3
Percent Difference Relative to 2008 Spending	0.0%	13.4%	46.5%	91.0%
Annual Percent Increase to Support Scenario Investment [1]	0.00%	1.18%	3.51%	5.82%
Projected Impacts of Scenarios on Federal-Aid Highways				
Percent Change in Average Speed (2028 vs. 2008) [2]	-0.7%	**0.0%**	1.2%	2.6%
Percent of VMT on Roads With Good Ride Quality, 2028 [3]	55.0%	59.4%	66.6%	74.1%
Percent of VMT on Roads With Acceptable Ride Quality, 2028 [3]	82.4%	84.6%	88.0%	91.7%
Percent Change in Average IRI (2028 vs. 2008) [3]	2.8%	-3.8%	-13.7%	-24.3%
Percent Change in Average Delay per VMT (2028 vs. 2008) [4]	6.7%	3.8%	-1.7%	-7.7%
Percent Change in Economic Bridge Investment Backlog (2028 vs. 2008) [5]	6.5%	**0.0%**	-55.7%	**-100.0%**

[1] *This percentage represents the annual percent change relative to 2008 that would be required to achieve the average annual funding level specified for the scenario in constant dollar terms. Additional increases in nominal dollar terms would be needed to offset the impact of future inflation.*

[2] *Values shown correspond to amounts in Exhibit 7-6 in Chapter 7.*

[3] *Values shown correspond to amounts in Exhibit 7-5 in Chapter 7. Reductions in average pavement roughness (IRI) tranlate into improved ride quality.*

[4] *Values shown correspond to amounts in Exhibit 7-7 in Chapter 7.*

[5] *Values shown correspond to amounts in Exhibit 7-18 in Chapter 7.*

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

By definition, the **Maintain Conditions and Performance scenario** would achieve the targets of zero change between 2008 and 2028 in average speed and in the economic bridge investment backlog. For other (non-targeted) measures of conditions and performance on Federal-aid highways, the projections for this scenario indicate some change over the analysis period: average pavement roughness (as measured by the International Roughness Index [IRI] discussed in Chapter 3 and Chapter 7), would decrease by 3.8 percent, while average delay per vehicle-mile traveled would increase by roughly the same percentage. These statistics suggest a tradeoff between improved physical conditions and a worsening of operational performance under this scenario, driven by the mix of projects HERS identified as the most cost-beneficial at this level of investment.

In comparison, the **Sustain Current Spending scenario** features lower levels of real investment over the analysis period on Federal-aid highways and, thus, worse outcomes for 2028. Relative to values in the base year, 2008, the projections are for average speed to decrease 0.7 percent, reflecting an overall decline in system performance. Further, average pavement roughness is projected to increase by 2.8 percent, average delay is projected to increase by 6.7 percent, and the economic bridge investment backlog is projected to increase by 6.5 percent (in constant dollar terms) by 2028 relative to the 2008 baseline.

The **Improve Conditions and Performance scenario** features the highest level of investment among the four scenarios presented in *Exhibit 8-2* and shows the largest projected impacts on system conditions and performance. Under this scenario, the shares of vehicle miles traveled (VMT) on Federal-aid highway pavements with "good" ride quality and "acceptable" ride quality (as defined in Chapter 3) are expected to rise to 74.1 percent and 91.7 percent, respectively, by 2028. In contrast, the lower investment levels under the **Sustain Current Spending scenario** are projected to result in only 55.0 percent of Federal-aid highway VMT occurring on pavements with good ride quality and 82.4 percent on pavements with acceptable ride quality.

By definition, the **Improve Conditions and Performance scenario** would eliminate the economic bridge investment backlog on Federal-aid highways by 2028; this scenario is also projected to increase average speeds by 2.6 percent by 2028. Other measures of Federal-aid highway conditions and performance are also projected to improve; average pavement roughness could decline by as much as 24.3 percent and average delay per VMT could decline by 7.7 percent. The average annual investment level of $134.9 billion for this scenario exceeds actual spending on Federal-aid highways in 2008 by $64.3 billion, or 91.7 percent; spending would need to increase by 5.82 percent per year over 20 years to reach this average annual level.

The performance improvements projected in the **Intermediate Improvement scenario** are less marked than in the **Improve Conditions and Performance scenario** but still significant. For Federal-aid highway bridge projects, the economic investment backlog is projected to be reduced by roughly half from the 2008 level (by 55.7 percent) rather than eliminated. Average speed is projected to increase over the analysis period by 1.2 percent; average pavement roughness could decrease by 13.7 percent, and average delay per VMT could decrease by 1.7 percent.

Federal-Aid Highway Scenario Estimates by Improvement Type and Highway Functional Class

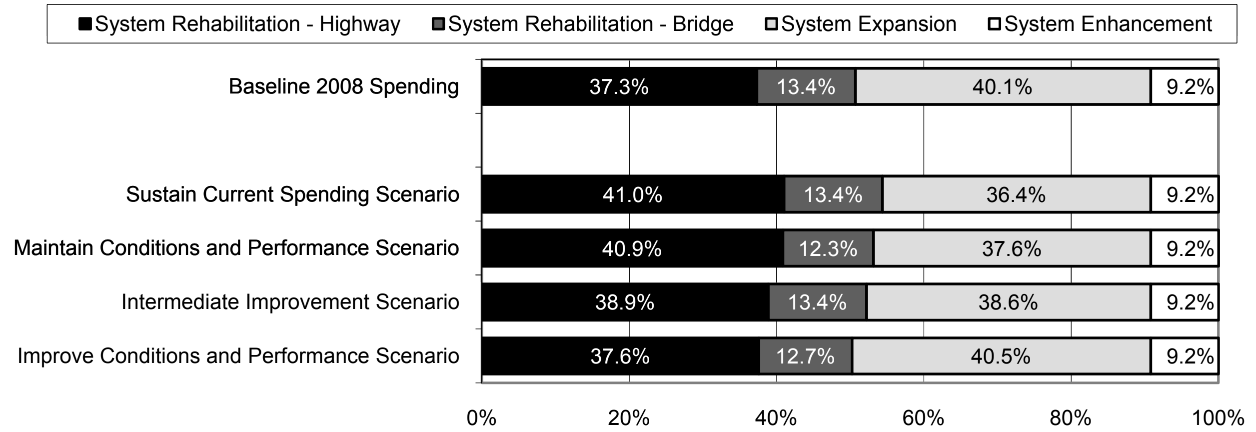
Exhibit 8-3 shows the distribution of spending by improvement type for each Federal-aid highway scenario and compares this distribution with actual spending in 2008. As noted above, capital spending on system enhancements amounts to 9.2 percent of each scenario's investment total, consistent with the percentage of total capital spending on Federal-aid highways by all levels of government directed to these types of improvements in 2008. By design, the **Sustain Current Spending scenario** and the **Intermediate Improvement scenario** each allocates 13.4 percent of spending to the types of bridge improvements modeled in NBIAS (repair, rehabilitation, and replacement), which is the share of actual 2008 spending on Federal-aid highways that was directed to such improvements. In the other scenarios, the level of NBIAS-modeled investment is determined independently. The types of improvements modeled in HERS are reflected in the "System Rehabilitation – Highway" and "System Expansion" categories; the distribution between these categories in each scenario is based on an evaluation of the relative benefits and costs of potential investments in each area.

In 2008, 40.1 percent of capital outlay by all levels of government on Federal-aid highways was directed to system expansion. The **Sustain Current Spending scenario** reduces this share to 36.4 percent, while other scenarios maintain or increase this share at higher levels of spending. For example, the **Improve Conditions and Performance scenario** directs 40.5 percent of its total investment towards system expansion.

The **Improve Conditions and Performance scenario** directs $67.8 billion, or 50.3 percent, of the $134.9 billion in average annual spending it programs for Federal-aid highways towards the types of system rehabilitation actions reflected in the **State of Good Repair benchmark**. Although this level of investment falls short of the $70.6 billion of total capital spending on Federal-aid highways in 2008, it substantially exceeds the portion of that spending, $35.8 billion, that was used for system rehabilitation improvements.

Exhibit 8-3

Distribution of Capital Improvement Types for Selected Federal-Aid Highway Capital Investment Scenarios for 2009 to 2028



	Average Annual Investment (Billions of 2008 Dollars)					
	System Rehabilitation			System Expansion [3]	System Enhance-ment	Total
Scenario Name	Highway [1]	Bridge [2]	Total			
Baseline 2008 Spending	$26.4	$9.4	$35.8	$28.3	$6.5	**$70.6**
Sustain Current Spending scenario	$29.0	$9.4	$38.4	$25.7	$6.5	**$70.6**
Maintain Conditions and Performance scenario	$32.7	$9.8	$42.6	$30.1	$7.4	**$80.1**
Intermediate Improvement scenario	$40.2	$13.8	$54.0	$39.9	$9.5	**$103.5**
Improve Conditions and Performance scenario	$50.7	$17.1	$67.8	$54.7	$12.4	**$134.9**
State of Good Repair benchmark [4]	$50.7	$17.1	**$67.8**			

[1] Values shown correspond to amounts in Exhibit 7-5 in Chapter 7.

[2] Values shown correspond to amounts in Exhibit 7-18 in Chapter 7.

[3] Values shown correspond to amounts in Exhibits 7-6 and 7-7 in Chapter 7.

[4] The State of Good Repair benchmark is a subset of the Improve Conditions and Performance scenario.

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

This suggests that the current backlog of cost-beneficial improvements to address pavement and bridge deficiencies is substantial, and that achieving a state of good repair on Federal-aid highways would require either a significant increase in overall highway and bridge investment, or a significant redistribution of investment from other types of improvements towards System Rehabilitation.

Sustain Current Spending Scenario

For the **Sustain Current Spending scenario** for Federal-aid highways, *Exhibit 8-4* compares the scenario distribution of capital investments by improvement type and functional class with the corresponding actual distribution in 2008 (from Chapter 6; see *Exhibit 6-10* and *Exhibit 6-12*). Due to the manner in which this scenario was constructed, the total percentage change identified for the "System Rehabilitation – Bridge," "System Enhancement" and the "Total" columns in the table are automatically all zero, as are the values for individual functional classes in the "System Enhancement" column.

Although the **Sustain Current Spending scenario** for Federal-aid highways fixes average annual capital spending on these highways at the actual 2008 level, the portion of this spending it allocates to the "System Rehabilitation – Highway" category is 9.8 percent higher than the corresponding 2008 amount. Conversely, the allocation to "System Expansion" is 9.2 percent lower than the actual 2008 values. When it comes to the distribution of investment by highway functional class, the differences between the scenario and actual 2008

Exhibit 8-4

Sustain Current Spending Scenario for Federal-Aid Highways: Distribution of Average Annual Investment for 2009 to 2028 Compared With Actual 2008 Spending, by Functional Class and Improvement Type

Average Annual National Investment on Federal-Aid Highways (Billions of 2008 Dollars)

	System Rehabilitation			System	System	
Functional Class	**Highway**	**Bridge**	**Total**	**Expansion**	**Enhancement**	**Total**
Rural Arterials and Major Collectors						
Interstate	$1.6	$0.6	$2.3	$1.5	$0.4	$4.2
Other Principal Arterial	$1.5	$0.5	$2.0	$0.7	$0.7	$3.4
Minor Arterial	$1.7	$0.5	$2.1	$0.4	$0.5	$3.0
Major Collector	$2.1	$0.8	$2.9	$0.2	$0.7	$3.7
Subtotal	**$6.9**	**$2.4**	**$9.3**	**$2.7**	**$2.3**	**$14.3**
Urban Arterials and Collectors						
Interstate	$6.0	$2.6	$8.6	$11.5	$1.0	$21.1
Other Freeway and Expressway	$2.8	$1.0	$3.8	$4.5	$0.6	$8.9
Other Principal Arterial	$4.9	$1.6	$6.5	$3.1	$1.2	$10.8
Minor Arterial	$6.1	$1.3	$7.4	$2.7	$0.9	$11.0
Collector	$2.3	$0.5	$2.8	$1.1	$0.5	$4.4
Subtotal	**$22.1**	**$7.0**	**$29.1**	**$23.0**	**$4.3**	**$56.3**
Total, Federal-Aid Highways *	**$29.0**	**$9.4**	**$38.4**	**$25.7**	**$6.5**	**$70.6**

Percent Above Actual 2008 Capital Spending on Federal-Aid Highways by All Levels of Government Combined

	System Rehabilitation			System	System	
Functional Class	**Highway**	**Bridge**	**Total**	**Expansion**	**Enhancement**	**Total**
Rural Arterials and Major Collectors						
Interstate	-50.3%	-3.6%	-42.4%	1.7%	0.0%	-28.1%
Other Principal Arterial	-63.5%	-32.8%	-58.5%	-85.1%	0.0%	-66.9%
Minor Arterial	-33.7%	-39.7%	-35.2%	-81.5%	0.0%	-47.8%
Major Collector	-16.7%	-30.1%	-20.8%	-82.4%	0.0%	-30.2%
Subtotal	**-44.6%**	**-27.8%**	**-41.0%**	**-70.1%**	**0.0%**	**-47.4%**
Urban Arterials and Collectors						
Interstate	40.6%	0.7%	25.3%	82.5%	0.0%	49.0%
Other Freeway and Expressway	90.3%	164.2%	105.5%	105.5%	0.0%	91.7%
Other Principal Arterial	23.3%	7.6%	19.0%	-52.2%	0.0%	-18.1%
Minor Arterial	131.1%	45.8%	109.9%	-3.7%	0.0%	52.2%
Collector	41.1%	-32.0%	19.8%	-11.4%	0.0%	7.7%
Subtotal	**58.1%**	**15.5%**	**45.2%**	**20.2%**	**0.0%**	**29.8%**
Total, Federal-Aid Highways *	**9.8%**	**0.0%**	**7.2%**	**-9.2%**	**0.0%**	**0.0%**

** 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.

allocations are more pronounced. Relative to the corresponding actual 2008 amounts, the $14.3 billion of average annual investment on rural arterials and major collectors included in this scenario would represent a 47.4 percent decrease, while the $56.3 billion of average annual investment on urban arterials and collectors would represent a 29.8 percent increase.

Overall, the **Sustain Current Spending scenario** for Federal-aid highways would reduce annual spending below the 2008 level for each rural functional class and for urban other principal arterials. Within the "System Rehabilitation – Highway" category, the same is true for each individual rural functional class, while the opposite holds for each urban functional class (i.e., the scenario spending would exceed the 2008 level). The results for the "System Rehabilitation – Bridges" category are similar, except that scenario spending would also be less than the 2008 level for bridges on urban collectors. For the "System Expansion" category, scenario spending would exceed the 2008 level significantly on the urban portion of the Interstate System and on other urban freeways and expressways, and slightly on the rural portion of the Interstate System; for all other functional systems, the scenario spending would be less than the 2008 level.

These differences between the scenario and actual allocations, while suggestive from a policy perspective, do not necessarily indicate misallocations of actual capital spending. Apart from the errors that may result from limitations of the HERS and NBIAS models and the associated databases, two other considerations argue for caution. First, the actual distribution of expenditures among improvement types and functional classes varies from year to year, and 2008 may be atypical in some respects. Second, even if annual highway and bridge investment were to continue on average at the 2008 level, changing circumstances would alter the economically optimal distribution of this spending. The actual distribution in 2008 could, therefore, make perfect economic sense and still differ significantly from the economically optimal distribution over the following 20 years.

Maintain Conditions and Performance Scenario

Exhibit 8-5 identifies the distribution of capital investments by improvement type and functional class for the **Maintain Conditions and Performance scenario** for Federal-aid highways. The $16.2 billion of

Exhibit 8-5

Maintain Conditions and Performance Scenario for Federal-Aid Highways: Distribution of Average Annual Investment for 2009 to 2028, by Functional Class and Improvement Type

Average Annual National Investment on Federal-Aid Highways (Billions of 2008 Dollars)

	System Rehabilitation			System	System	
Functional Class	**Highway**	**Bridge**	**Total**	**Expansion**	**Enhancement**	**Total**
Rural Arterials and Major Collectors						
Interstate	$1.8	$0.7	$2.4	$1.6	$0.5	$4.5
Other Principal Arterial	$1.8	$0.6	$2.4	$0.8	$0.8	$4.0
Minor Arterial	$1.9	$0.5	$2.4	$0.4	$0.5	$3.4
Major Collector	$2.6	$0.8	$3.4	$0.3	$0.8	$4.4
Subtotal	**$8.1**	**$2.5**	**$10.6**	**$3.1**	**$2.6**	**$16.2**
Urban Arterials and Collectors						
Interstate	$6.5	$2.7	$9.2	$13.1	$1.1	$23.5
Other Freeway and Expressway	$3.1	$1.0	$4.1	$5.3	$0.7	$10.1
Other Principal Arterial	$5.6	$1.7	$7.3	$4.0	$1.4	$12.7
Minor Arterial	$6.7	$1.4	$8.1	$3.3	$1.1	$12.4
Collector	$2.7	$0.5	$3.2	$1.4	$0.6	$5.1
Subtotal	**$24.7**	**$7.3**	**$32.0**	**$27.1**	**$4.8**	**$63.9**
Total, Federal-Aid Highways *	**$32.7**	**$9.8**	**$42.6**	**$30.1**	**$7.4**	**$80.1**

** 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.

capital investment on rural arterials and major collectors represents 20.2 percent of the $80.1 billion total average annual investment (by all levels of government combined) under this scenario. By design, the rural share of total system enhancement expenditures is 34.6 percent ($2.6 billion out of $7.4 billion), the same as the actual percentage in 2008. Rural roads receive in this scenario 10.2 percent of system expansion expenditures and 24.9 percent of system rehabilitation expenditures.

It is important to note that the goal of the **Maintain Conditions and Performance scenario** is to maintain average conditions and performance on a systemwide basis; the conditions and performance of individual functional classes may vary. Consequently, the dollar amount shown for each of the functional classes in *Exhibit 8-5* does not represent the cost of maintaining the condition or performance of that functional class in isolation. A supplemental scenario is presented in Chapter 9 that identifies the costs of maintaining the conditions and performance of individual system components.

Intermediate Improvement Scenario

Exhibit 8-6 identifies the distribution of capital investments on Federal-aid highways by improvement type and functional class for the **Intermediate Improvement scenario**. The $20.6 billion of capital investment on rural arterials and major collectors represents 19.9 percent of the $103.5 billion total average annual investment under this scenario. Rural roads receive in this scenario 8.9 percent of system expansion expenditures and 25.3 percent of system rehabilitation expenditures. The relatively modest size of these rural shares reflects partly that rural minor collectors (along with rural local and urban local roads) are not classified as Federal-aid highways. As discussed in Chapter 2, while Federal-aid highways carry over five-sixths of total VMT, they account for less than one-quarter of total mileage. The system rehabilitation needs on the remaining three-quarters of total mileage are significant.

Exhibit 8-6

Intermediate Improvement Scenario for Federal-Aid Highways: Distribution of Average Annual Investment for 2009 to 2028, by Functional Class and Improvement Type

Average Annual National Investment on Federal-Aid Highways (Billions of 2008 Dollars)

	System Rehabilitation			System	System	
Functional Class	**Highway**	**Bridge**	**Total**	**Expansion**	**Enhancement**	**Total**
Rural Arterials and Major Collectors						
Interstate	$2.1	$0.9	$3.0	$1.7	$0.6	$5.3
Other Principal Arterial	$2.4	$0.7	$3.0	$1.0	$1.0	$5.0
Minor Arterial	$2.5	$0.7	$3.1	$0.4	$0.7	$4.2
Major Collector	$3.5	$1.0	$4.6	$0.4	$1.0	$6.0
Subtotal	**$10.4**	**$3.3**	**$13.7**	**$3.6**	**$3.3**	**$20.6**
Urban Arterials and Collectors						
Interstate	$7.5	$3.6	$11.1	$17.0	$1.5	$29.6
Other Freeway and Expressway	$3.6	$1.4	$5.1	$7.3	$0.9	$13.3
Other Principal Arterial	$7.3	$2.5	$9.8	$5.6	$1.8	$17.1
Minor Arterial	$7.8	$2.2	$10.0	$4.4	$1.4	$15.7
Collector	$3.5	$0.8	$4.4	$2.1	$0.7	$7.2
Subtotal	**$29.8**	**$10.6**	**$40.3**	**$36.4**	**$6.2**	**$82.9**
Total, Federal-Aid Highways *	**$40.2**	**$13.8**	**$54.0**	**$39.9**	**$9.5**	**$103.5**

** 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.

Improve Conditions and Performance Scenario

In the **Improve Conditions and Performance scenario** for Federal-aid highways, total investment in these highways by all levels of government averages $134.9 billion per year, or nearly double the 2008 level of spending, but rural arterials and major collectors receive only $26.9 billion of this amount, or 1.3 percent less than in 2008. This stems mainly from a substantial reduction in funding for rural other principal arterials. As shown in *Exhibit 8-7*, this scenario would direct 15.2 percent more per year toward rural system rehabilitation than what was spent in 2008, but would direct 52.3 percent less toward rural system expansion.

Exhibit 8-7

Improve Conditions and Performance Scenario for Federal-Aid Highways: Distribution of Average Annual Investment for 2009 to 2028 Compared With Actual 2008 Spending, by Functional Class and Improvement Type

Average Annual National Investment on Federal-Aid Highways (Billions of 2008 Dollars)

	System Rehabilitation			System Expansion	System Enhancement	Total
Functional Class	**Highway**	**Bridge**	**Total**			
Rural Arterials and Major Collectors						
Interstate	$2.3	$1.1	$3.4	$2.0	$0.8	$6.2
Other Principal Arterial	$3.2	$0.8	$4.0	$1.3	$1.3	$6.6
Minor Arterial	$3.4	$0.8	$4.1	$0.5	$0.9	$5.6
Major Collector	$5.4	$1.2	$6.7	$0.6	$1.3	$8.5
Subtotal	**$14.3**	**$3.8**	**$18.2**	**$4.4**	**$4.3**	**$26.9**
Urban Arterials and Collectors						
Interstate	$8.6	$4.3	$12.8	$21.8	$1.9	$36.5
Other Freeway and Expressway	$4.4	$1.7	$6.1	$9.9	$1.2	$17.2
Other Principal Arterial	$9.6	$3.2	$12.8	$9.0	$2.3	$24.0
Minor Arterial	$9.1	$3.0	$12.1	$6.5	$1.8	$20.3
Collector	$4.7	$1.1	$5.8	$3.2	$1.0	$9.9
Subtotal	**$36.3**	**$13.2**	**$49.6**	**$50.3**	**$8.1**	**$108.0**
Total, Federal-Aid Highways *	**$50.7**	**$17.1**	**$67.8**	**$54.7**	**$12.4**	**$134.9**

Percent Above Actual 2008 Capital Spending on Federal-Aid Highways by All Levels of Government Combined

	System Rehabilitation			System Expansion	System Enhancement	Total
Functional Class	**Highway**	**Bridge**	**Total**			
Rural Arterials and Major Collectors						
Interstate	-28.6%	58.9%	-13.6%	34.0%	91.0%	6.0%
Other Principal Arterial	-21.9%	-4.8%	-19.1%	-72.7%	91.0%	-36.5%
Minor Arterial	34.2%	-3.4%	25.1%	-72.6%	91.0%	-2.2%
Major Collector	116.7%	11.3%	84.4%	-43.4%	91.0%	60.2%
Subtotal	**15.7%**	**13.4%**	**15.2%**	**-52.3%**	**91.0%**	**-1.3%**
Urban Arterials and Collectors						
Interstate	101.7%	63.0%	86.9%	244.4%	91.0%	157.3%
Other Freeway and Expressway	198.9%	348.0%	229.6%	351.0%	91.0%	268.7%
Other Principal Arterial	142.9%	112.5%	134.6%	36.5%	91.0%	81.9%
Minor Arterial	244.3%	238.6%	242.9%	133.2%	91.0%	181.2%
Collector	183.6%	64.8%	148.9%	151.6%	91.0%	142.6%
Subtotal	**160.3%**	**118.8%**	**147.7%**	**163.0%**	**91.0%**	**148.9%**
Total, Federal-Aid Highways *	**92.3%**	**81.0%**	**89.3%**	**93.1%**	**91.0%**	**91.0%**

* *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.

Among the urban functional classes, the scenario would more than triple the amount currently expended on other urban freeways and expressways; the scenario would more than double the amount currently expended on the urban portion of the Interstate System, urban minor arterials, and urban collectors.

Overall, the average annual investment level under the **Improve Conditions and Performance scenario** for Federal-aid highways is 91.0 percent higher than the actual amount spent in 2008; spending on system enhancements for each functional class was assumed to grow by this same percentage. System expansion expenditures under this scenario are 93.1 percent higher than in 2008, while system rehabilitation expenditures are 89.3 percent higher.

Systemwide Scenarios

As discussed in Chapter 7 (*Exhibit 7-1*), the functional classes not counted as Federal-aid highways— rural minor collectors, rural local roads, and urban local roads—received $17.2 billion out of the $91.1 billion invested systemwide in highways and bridges in 2008. Since these functional classes are not represented in the HPMS sample, they are not modeled in HERS. Adding this $17.2 billion to the $6.5 billion spent on system enhancements to Federal-aid highways means that $23.7 billion, or 26.0 percent, of systemwide capital spending was in the residual category not modeled by HERS or NBIAS.

Exhibit 8-8 summarizes the derivation of the systemwide scenarios. Each scenario links back to a specific funding level identified in the HERS and NBIAS analyses presented in Chapter 7. In computing the average annual investment levels over 20 years, the combined projections for the capital spending from the two models were adjusted upwards so that the non-modeled capital improvement types would remain at 26.0 percent of the total cost of each scenario, consistent with their share in 2008. The HERS-derived components of the systemwide scenarios are identical to those identified in *Exhibit 8-1* for the Federal-aid highway scenarios. However, the NBIAS-derived components of the systemwide scenarios are different, as sufficient data available are available through the National Bridge Inventory to develop separate estimates, applying the scenario criteria to all bridges rather than just the subset of bridges on Federal-aid highways.

In 2008, $3.4 billion of the $12.8 billion in total bridge rehabilitation spending by all levels of government was directed to bridges on non-Federal-Aid highways. For the systemwide **Sustain Current Spending scenario**, this additional funding is available for NBIAS to direct to bridges on or off Federal-aid highways, as determined by the optimization algorithms in NBIAS. (In fact, the model would direct 85.4 percent of the $12.8 billion to bridges on Federal-aid highways under this scenario, while only 73.7 percent of this amount was directed to such bridges in 2008.)

The average annual investment level for the systemwide **Maintain Conditions and Performance scenario** is $101.0 billion. For bridge rehabilitation, NBIAS projects that maintaining the systemwide economic backlog of investment at its 2008 level would require investing over 20 years at an average annual level of only $11.9 billion in 2008 dollars, which is below the $12.8 billion spent in 2008. In the scenario, this reduction in average annual spending would be attained with spending on real expenditures on bridge rehabilitation decreasing 0.70 percent per year. In contrast, *Exhibit 8-1* showed that maintaining the economic backlog for bridges on Federal-aid highways only would require rehabilitation spending on these bridges to increase. In combination, these findings suggest that the distribution of bridge spending in 2008 was somewhat better aligned with addressing long-term bridge needs off Federal-aid highways than on Federal-aid highways. (These findings are only suggestive because the modeling process entails many uncertainties and the 2008 spending data are partially estimated for some functional classes).

The average annual investment levels for the 20-year period through 2028 for the systemwide **Intermediate Improvement scenario** and the systemwide **Improve Conditions and Performance scenario** are

Exhibit 8-8

Definitions of Selected Systemwide Capital Investment Scenarios, and Average Annual Investment Levels for 2009 to 2028 Associated With Scenario Components

					Average Annual Capital Investment on All Roads	
Scenario Name and Description	**Scenario Component (Source of Estimate)[1]**	**Component Share of 2008 Capital Outlay**	**Annual Percent Change in Spending vs. 2008**	**Minimum BCR**	**Billions of 2008 Dollars**	**Percent of Total**
Sustain Current Spending scenario (Sustain spending at base year levels in constant dollar terms.)	HERS[2]	60.0%	0.00%	2.42	$54.7	60.0%
	NBIAS[3]	14.0%	0.00%		$12.8	14.0%
	Other	*26.0%*			*$23.7*	*26.0%*
	Total	100.0%			**$91.1**	100.0%
Maintain Conditions and Performance scenario (Maintain average speed and the economic bridge investment backlog at 2008 levels.)	HERS[2]	60.0%	1.31%	2.02	$62.9	62.3%
	NBIAS[3]	14.0%	-0.70%		$11.9	11.8%
	Other	*26.0%*			*$26.2*	*26.0%*
	Total	100.0%			**$101.0**	100.0%
Intermediate Improvement scenario (Invest in projects with benefit-cost ratios as low as 1.5 and reduce the economic bridge investment backlog.)	HERS[2]	60.0%	3.51%	1.50	$80.1	60.0%
	NBIAS[3]	14.0%	3.51%		$18.7	14.0%
	Other	*26.0%*			*$34.7*	*26.0%*
	Total	100.0%			**$133.5**	100.0%
Improve Conditions and Performance scenario (Invest in all cost-beneficial projects and eliminate the economic bridge investment backlog.)	HERS[2]	60.0%	5.90%	1.00	$105.4	62.0%
	NBIAS[3]	14.0%	4.31%		$20.5	12.1%
	Other	*26.0%*			*$44.2*	*26.0%*
	Total	100.0%			**$170.1**	100.0%

[1] Each scenario consists of three separately estimated components. The components derived from HERS and NBIAS represent the combined investment by all levels of government associated with achieving the scenario goals identified. The third scenario component, identified as "Other," represents other types of capital spending beyond those modeled in HERS or NBIAS; each scenario assumes that the percentage of total spending on these nonmodeled items in the future will be the same as the actual percentage in 2008.

[2] The scenario components derived from HERS are directly linked to the analyses presented in Exhibits 7-3 through 7-10 in Chapter 7; these components can be cross-referenced to the exhibits using either the annual percent change in spending relative to 2008, or the minimum BCR identified in this table.

[3] The scenario components derived from NBIAS are directly linked to the analysis presented in Exhibit 7-17 in Chapter 7; these components can be cross-referenced to this exhibit using the annual percent change in spending relative to 2008 identified in this table.

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

$133.5 billion and $170.1 billion, respectively. These figures are stated in constant 2008 dollars (as are all of the other scenario investment levels presented in this chapter, as stated earlier).

It is important to note that these scenarios are intended to be illustrative, and any number of alternative scenarios based on different BCR cutoff points, performance targets, or funding targets could be constructed that would be equally valid from a technical perspective.

Systemwide Scenario Impacts and Comparison with 2008 Spending

Exhibit 8-9 compares the systemwide scenarios with 2008 spending. The average annual investment level associated with the **Maintain Conditions and Performance scenario** is 10.8 percent higher than actual spending by all levels of government on capital improvements to highways and bridges in 2008; the comparable “gap” between the **Improve Conditions and Performance scenario** and 2008 spending is 86.6 percent.

Exhibit 8-9

Selected Systemwide Highway Capital Investment Scenarios for 2009 to 2028: Comparisons With 2008 Spending and Projected Systemwide Highway Performance Indicators

Comparison Parameter	Sustain Current Spending Scenario	Maintain Conditions & Performance Scenario	Intermediate Improvement Scenario	Improve Conditions & Performance Scenario
Comparison of Scenarios With 2008 Spending				
Average Annual Investment (Billions of 2008 Dollars)	$91.1	$101.0	$133.5	$170.1
Difference Relative to 2008 Spending (Billions of 2008 Dollars)	**$0.0**	$9.8	$42.4	$78.9
Percent Difference Relative to 2008 Spending	0.0%	10.8%	46.5%	86.6%
Annual Percent Increase to Support Scenario Investment [1]	0.00%	0.97%	3.51%	5.62%
Projected Impacts of Scenarios on All Roads [2]				
Percent Change in Economic Bridge Investment Backlog (2028 vs. 2008) [3]	-11.2%	**0.0%**	-79.1%	**-100.0%**

[1] This percentage represents the annual percent change relative to 2008 that would be required to achieve the average annual funding level specified for the scenario in constant dollar terms. Additional increases in nominal dollar terms would be needed to offset the impact of future inflation.

[2] Systemwide performance information for pavement condition and congestion is not available, as the HERS analysis is limited to Federal-aid highways for which HPMS sample data are collected by the FHWA. See Exhibit 8-2 for performance information on Federal-aid highways. Bridge performance information is available on a systemwide basis, as the NBI includes data for all bridges over 20 feet in length.

[3] Values shown correspond to amounts in Exhibit 7-17 in Chapter 7.

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

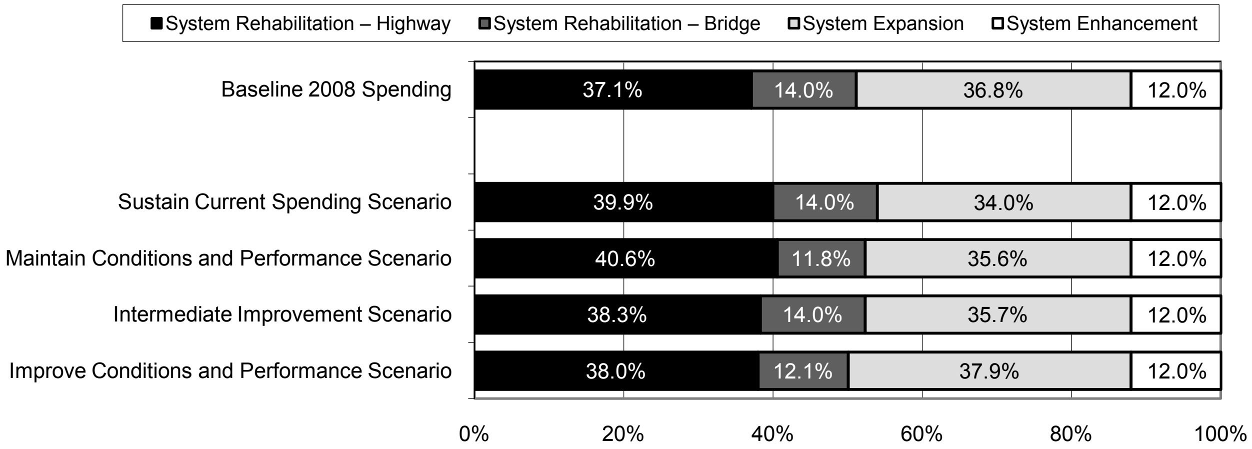
Exhibit 8-9 also shows the projected impacts on the economic backlog of bridge rehabilitation projects in 2028. For the other conditions and performance indicators, which relate to speed, delay, or pavement condition, the only projections available for this analysis come from the HERS simulations, which cover the Federal-Aid highways alone. Hence, these indicators are absent from *Exhibit 8-9*, where the focus is systemwide. The **Intermediate Improvement scenario** projects that the economic investment backlog in 2028 will be 79.1 percent lower than in 2008, while the **Sustain Current Spending scenario** (in which bridge spending is higher than in the **Maintain Conditions and Performance scenario**, as noted above) projects an 11.2 percent reduction. For the other two scenarios, the scenario assumptions ensure that the backlog disappears by 2028 (**Improve Conditions and Performance scenario**) or remains at its 2008 level (**Maintain Conditions and Performance scenario**).

Systemwide Scenario Estimates by Improvement Type

Exhibit 8-10 shows the distribution of highway capital spending by improvement type for each systemwide scenario, as well as the corresponding distribution of actual systemwide spending by all levels of government) in 2008. A comparison of this distribution with that shown in *Exhibit 8-3*reveals that the percentage allocations to system expansion are typically a few points lower, and those to system enhancements are typically a few points higher in the systemwide scenarios than in the comparable Federal-aid highway scenarios; these differences primarily reflect corresponding differences in the base year spending patterns. In 2008, the system expansion share of capital spending was 40.1 percent of on Federal-aid highways and 36.8 percent systemwide, while the system enhancement shares were 9.2 percent on Federal-aid highways versus 12.0 percent systemwide.

Exhibit 8-10

Distribution of Capital Improvement Types for Selected Systemwide Highway Capital Investment Scenarios for 2009 to 2028



	Average Annual Investment (Billions of 2008 Dollars)					
	System Rehabilitation			System	System Enhance-ment	
Scenario Name	**Highway [1]**	**Bridge [2]**	**Total**	**Expansion [1]**		**Total**
Baseline 2008 Spending	$33.8	$12.8	$46.6	$33.6	$11.0	**$91.1**
Sustain Current Spending scenario	$36.4	$12.8	$49.2	$31.0	$11.0	**$91.1**
Maintain Conditions and Performance scenario	$41.0	$11.9	$52.9	$36.0	$12.1	**$101.0**
Intermediate Improvement scenario	$51.1	$18.7	$69.9	$47.6	$16.1	**$133.5**
Improve Conditions and Performance scenario	$64.6	$20.5	$85.1	$64.5	$20.5	**$170.1**
State of Good Repair benchmark [3]	$64.6	$20.5	**$85.1**			

[1] Values shown include estimates for functional classes not modeled in HERS, and thus do not directly correspond to the exhibits presented in Chapter 7.

[2] Values shown correspond to amounts in Exhibit 7-17 in Chapter 7.

[3] The State of Good Repair benchmark is a subset of the Improve Conditions and Performance scenario.

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

Of the $170.1 billion average annual investment level for the systemwide **Improve Conditions and Performance scenario**, $85.1 billion (50.1 percent) would be directed towards the types of system rehabilitation actions reflected in the **State of Good Repair benchmark**. Although this level of investment is below the $91.1 billion spent for all highway capital improvements in 2008, it significantly exceeds the $46.6 billion spent in 2008 for system rehabilitation improvements.

National Highway System Scenarios

Exhibit 8-11 describes the derivation of the investment levels for each of four NHS capital investment scenarios, which each draw from the HERS and NBIAS analyses presented in Chapter 7. (The footnotes in *Exhibit 8-11* identify the specific Chapter 7 exhibits to which the scenarios are linked.) Each scenario covers the 20-year period from 2008 to 2028, and the investment levels shown are all “real,” stated in constant 2008 dollars.

Exhibit 8-11

Definitions of Selected NHS Capital Investment Scenarios, and Average Annual Investment Levels for 2009 to 2028 Associated With Scenario Components

Scenario Name and Description	Scenario Component (Source of Estimate)[1]	Component Share of 2008 Capital Outlay	Annual Percent Change in Spending vs. 2008	Minimum BCR	Average Annual Capital Investment on the NHS	
					Billions of 2008 Dollars	Percent of Total
Sustain Current Spending scenario (Sustain spending at base year levels in constant dollar terms.)	HERS[2]	79.3%	0.00%	2.26	$33.3	79.3%
	NBIAS[3]	12.9%	0.00%		$5.4	12.9%
	Other	*7.8%*			*$3.3*	*7.8%*
	Total	100.0%			**$42.0**	100.0%
Maintain Conditions and Performance scenario (Maintain average speed and the economic bridge investment backlog at 2008 levels.)	HERS[2]	79.3%	-0.87%	2.55	$30.4	78.4%
	NBIAS[3]	12.9%	-0.09%		$5.4	13.8%
	Other	*7.8%*			*$3.0*	*7.8%*
	Total	100.0%			**$38.9**	100.0%
Intermediate Improvement scenario (Invest in projects with benefit-cost ratios as low as 1.5 and reduce the economic bridge investment backlog.)	HERS[2]	79.3%	2.80%	1.50	$45.1	79.3%
	NBIAS[3]	12.9%	2.80%		$7.3	12.9%
	Other	*7.8%*			*$4.4*	*7.8%*
	Total	100.0%			**$56.9**	100.0%
Improve Conditions and Performance scenario (Invest in all cost-beneficial projects and eliminate the economic bridge investment backlog.)	HERS[2]	79.3%	4.91%	1.00	$57.3	79.8%
	NBIAS[3]	12.9%	4.48%		$8.9	12.4%
	Other	*7.8%*			*$5.6*	*7.8%*
	Total	100.0%			**$71.8**	100.0%

[1] Each scenario consists of three separately estimated components. The components derived from HERS and NBIAS represent the combined investment by all levels of government associated with achieving the scenario goals identified. The third scenario component, identified as "Other," represents other types of capital spending beyond those modeled in HERS or NBIAS; each scenario assumes that the percentage of total spending on these nonmodeled items in the future will be the same as the actual percentage in

[2] The scenario components derived from HERS are directly linked to the analyses presented in Exhibits 7-11 through 7-13 in Chapter 7; these components can be cross-referenced to the exhibits using either the annual percent change in spending relative to 2008, or the minimum BCR identified in this table.

[3] The scenario components derived from NBIAS are directly linked to the analysis presented in Exhibit 7-19 in Chapter 7; these components can be cross-referenced to this exhibit using the annual percent change in spending relative to 2008 identified in this table.

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

All levels of government spent a combined $42.0 billion on capital improvements to highways and bridges on the NHS in 2008; as shown in *Exhibit 8-11*, $33.3 billion of this total (79.3 percent) was used for the type of capital improvements modeled in HERS, $5.4 billion (12.9 percent) for types of improvements modeled in NBIAS, and $3.3 billion (7.8 percent) for other types of capital improvements. By definition, these amounts match the average annual investment levels for the NHS **Sustain Current Spending scenario**. Each of the other NHS scenarios assume that the share of average annual investment directed towards non-modeled capital improvements will remain at the 2008 level of 7.6 percent.

Exhibit 8-11 also identifies the annual rates of real spending growth associated with the HERS and NBIAS components of each scenario. For the NHS **Maintain Conditions and Performance scenario**, each of these growth rates is negative, indicating that 2008 spending levels are higher than the amount required over 20 years to meet the performance objectives of this scenario (maintain average speed at 2008 levels and prevent the economic bridge investment backlog from rising above its 2008 level in constant dollar terms).

The average annual investment level associated with the NHS **Maintain Conditions and Performance scenario** is $38.9 billion. The HERS-derived component of this scenario would address all potential capital improvements with a BCR of 2.55 or higher; the comparable value for the **Sustain Current Spending scenario** is 2.26 (because the model implements improvements in descending order of their BCRs, scenarios with higher investment levels will have lower minimum BCRs).

Addressing all potential improvements with BCRs of 1.50 or higher as computed by HERS would require annual increase in related spending of 2.80 percent per year over 20 years. Applying this same growth rate to all other types of capital spending generates the estimated average annual investment level of $56.9 billion for the NHS **Intermediate Improvement scenario**.

The goal of the **Improve Conditions and Performance scenario** is to address all potential highway and bridge improvements with a BCR of 1.0 or higher. As shown in *Exhibit 8-11*, HERS projects that meeting this goal would require capital spending on the NHS to increase annually by 4.91 percent and 4.48 percent for the types of NHS improvements modeled in HERS and NBIAS, respectively. Funding these cost-beneficial improvements, while keeping the share of non-modeled spending at its 2008 share of 7.8 percent of total spending, would require an average annual investment of $71.8 billion for capital improvements to NHS highways and bridges over 20 years, stated in constant 2008 dollars.

NHS Scenario Impacts and Comparison with 2008 Spending

Exhibit 8-12 compares the capital investment levels associated with each of the selected NHS scenarios with actual NHS capital spending in 2008 and presents the associated projections for summary measures of conditions and performance. By definition, the NHS **Maintain Conditions and Performance scenario** will result in zero change between 2008 and 2028 in average speed and in the economic bridge investment backlog. The other non-targeted measures include the average IRI, projected to decrease by 9.2 percent (consistent with an improvement in physical conditions), and average delay per VMT, projected to increase by 0.7 percent (consistent with a worsening of operational performance). The $38.9 billion average annual investment level for the NHS **Maintain Conditions and Performance scenario** is 7.6 percent below the $42.0 billion of actual capital spending on the NHS in 2008. The scenario assumes that this reduction in investment would be achieved with spending decreasing by 0.76 percent per year over 20 years. This result, combined with the finding presented in *Exhibit 8-1* that an increase in investment would be needed to achieve the objectives of this scenario for Federal-aid highways, suggests that the distribution spending in 2008 was somewhat better aligned with addressing long-term highway and bridge needs on the NHS than off of the NHS.

As the NHS **Sustain Current Spending scenario** has a higher average annual investment level than the NHS **Maintain Conditions and Performance scenario**, it is projected to result in improvements to NHS conditions and performance. As shown in *Exhibit 8-12*, relative to values in the 2008 base year, the projections are for average speeds to increase by 0.8 percent. Average delay and average IRI are also projected to decline, consistent with general improvements to operational performance and pavement conditions. The size of the economic bridge investment backlog is also projected to be reduced by approximately 1.8 percent over 20 years.

Under the NHS **Improve Conditions and Performance scenario**, the percent of NHS VMT on pavements with good ride quality is projected to rise to 89.6 percent, while the percent of VMT on pavements with acceptable ride quality reaches 97.4 percent. By definition, this scenario would eliminate the economic bridge investment backlog on the NHS by 2028; it is also projected to increase average speeds by 5.7 percent by that date relative to 2008. Average pavement roughness is projected to be reduced by 33.6 percent on the NHS, while average delay per VMT on the NHS would decrease by 26.3 percent by 2028. The potential

Exhibit 8-12

Selected NHS Capital Investment Scenarios for 2009 to 2028: Comparisons With 2008 Spending and Projected NHS Performance Indicators

Comparison Parameter	Sustain Current Spending Scenario	Maintain Conditions & Performance Scenario	Intermediate Improvement Scenario	Improve Conditions & Performance Scenario
Comparison of Scenarios With 2008 Spending				
Average Annual Investment (Billions of 2008 Dollars)	$42.0	$38.9	$56.9	$71.8
Difference Relative to 2008 Spending (Billions of 2008 Dollars)	**$0.0**	-$3.2	$14.9	$29.7
Percent Difference Relative to 2008 Spending	0.0%	-7.6%	35.3%	70.7%
Annual Percent Increase to Support Scenario Investment [1]	0.00%	-0.76%	2.80%	4.85%
Projected Impacts of Scenarios on the NHS				
Percent Change in Average Speed (2028 vs. 2008) [2]	0.8%	**0.0%**	3.6%	5.7%
Percent of VMT on Roads With Good Ride Quality, 2028 [3]	73.6%	70.8%	83.0%	89.6%
Percent of VMT on Roads With Acceptable Ride Quality, 2028 [3]	93.6%	92.8%	95.8%	97.4%
Percent Change in Average IRI (2028 vs. 2008) [3]	-13.4%	-9.2%	-25.2%	-33.6%
Percent Change in Average Delay per VMT (2028 vs. 2008) [2]	-2.9%	0.7%	-16.1%	-26.3%
Percent Change in Economic Bridge Investment Backlog (2028 vs. 2008) [4]	-1.8%	**0.0%**	-56.7%	**-100.0%**

[1] This percentage represents the annual percent change relative to 2008 that would be required to achieve the average annual funding level specified for the scenario in constant dollar terms. Additional increases in nominal dollar terms would be needed to offset the impact of future inflation.

[2] Values shown correspond to amounts in Exhibit 7-13 in Chapter 7.

[3] Values shown correspond to amounts in Exhibit 7-12 in Chapter 7. Reductions in average pavement roughness (IRI) tranlate into improved ride quality.

[4] Values shown correspond to amounts in Exhibit 7-19 in Chapter 7.

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

Q&A

Can highway capacity be expanded without either building new roads and bridges or adding new lanes to existing facilities?

Yes. The "System Expansion" investment levels identified in this chapter reflect a need for a certain amount of effective highway capacity, which could be met by traditional expansion or by other means. In some cases, effective highway capacity can be increased by improving the utilization of the existing infrastructure rather than by expanding it. The investment scenario estimates presented in this report consider the impact of some of the most significant operations strategies and deployments on highway system performance; these relationships are described in more detail in Appendix A. The potential implications of accelerating the deployment of operations strategies or implementing congestion pricing are explored in Chapter 9.

The methodology used to estimate the system expansion component of the investment scenarios also allows high-cost capacity improvements to be considered as an option for segments with high volumes of projected future travel, but have been coded by States as infeasible for conventional widening. Conceptually, such improvements might consist of new highways or bridges in the same corridor (or tunneling or double-decking on an existing alignment), but the capacity upgrades could also come through other transportation improvements, such as a parallel fixed-guideway transit line or mixed-use, high-occupancy vehicle/bus lanes.

for reductions to average delay per VMT is relatively large (relative to the values identified for Federal-aid highways in *Exhibit 8-3*) because strategic investments in NHS System Expansion, coupled with the continued deployment of Intelligent Transportation Systems on a growing share of the NHS, has the potential to significantly improve operating performance.

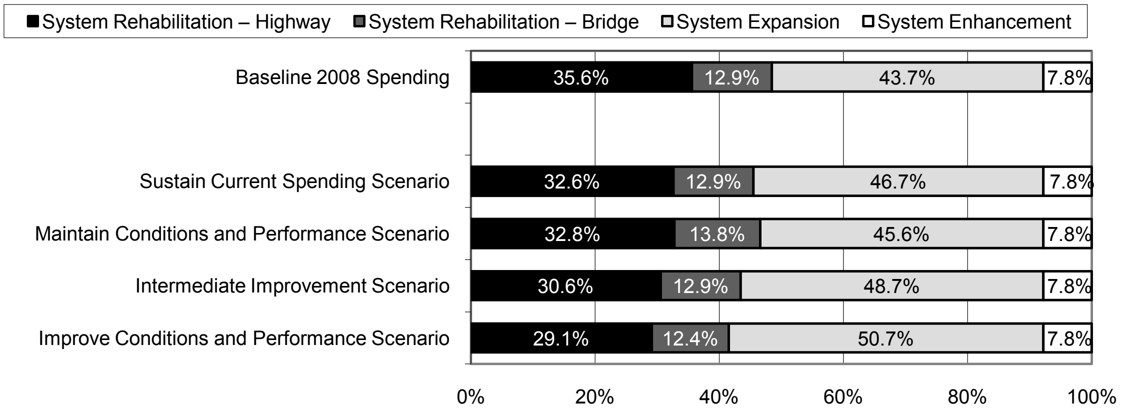
The average annual investment level for NHS **Improve Conditions and Performance scenario** of $71.8 billion is 70.7 percent higher than actual spending on the NHS in 2008. NHS spending would need to increase by 4.85 percent per year over 20 years to reach this average annual level. Achieving the less-ambitious objectives of the NHS **Intermediate Improvement scenario** would require an annual spending increase of 2.80 percent through 2028.

NHS Scenario Estimates by Improvement Type

Exhibit 8-13 compares the distribution of highway and bridge capital outlay among the 20-year NHS capital investment scenarios and with actual NHS spending in 2008. As noted above, each scenario was derived in such a manner that capital spending on non-modeled system enhancement would equal 7.8 percent of the average annual investment level for that scenario. The share of the **Sustain Current Spending scenario** and the **Intermediate Improvement scenario** capital spending directed to bridge system rehabilitation matches the 2008 percentage of 12.9 percent by design; for the other scenarios, the level of NBIAS-modeled investment is determined independently.

Exhibit 8-13

Distribution of Capital Improvement Types for Selected NHS Capital Investment Scenarios for 2009 to 2028



	Average Annual Investment (Billions of 2008 Dollars)					
	System Rehabilitation			System	System Enhance-ment	
Scenario Name	Highway [1]	Bridge [2]	Total	Expansion [3]		Total
Baseline 2008 Spending	$15.0	$5.4	$20.4	$18.4	$3.3	**$42.0**
Sustain Current Spending scenario	$13.7	$5.4	$19.1	$19.6	$3.3	**$42.0**
Maintain Conditions and Performance scenario	$12.7	$5.4	$18.1	$17.7	$3.0	**$38.9**
Intermediate Improvement scenario	$17.4	$7.3	$24.7	$27.7	$4.4	**$56.9**
Improve Conditions and Performance scenario	$20.9	$8.9	$29.8	$36.4	$5.6	**$71.8**
State of Good Repair benchmark [4]	$20.9	$8.9	**$29.8**			

[1] *Values shown correspond to amounts in Exhibit 7-12 in Chapter 7.*

[2] *Values shown correspond to amounts in Exhibit 7-19 in Chapter 7.*

[3] *Values shown correspond to amounts in Exhibit 7-13 in Chapter 7.*

[4] *The State of Good Repair benchmark is a subset of the Improve Conditions and Performance scenario.*

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

In each of the four scenarios, system expansion receives a higher share of future investment than the 43.7 percent actually received in 2008. The NHS **Sustain Current Spending scenario** increases this share to 46.7 percent, while the NHS **Improve Conditions and Performance scenario** would increase it further to 50.7 percent.

Of the $71.8 billion average annual investment level for the NHS **Improve Conditions and Performance scenario**, $29.8 billion (41.5 percent) would be directed towards the types of system rehabilitation actions reflected in the **State of Good Repair benchmark**. This benchmark level is 46.1 percent more than the $20.4 billion spent by all levels of government on capital improvements of this nature on the NHS in 2008. While achieving this objective would be ambitious, this funding gap is relatively smaller than many of the others presented in this chapter.

Interstate System Scenarios

The average annual investment levels shown for the Interstate System **Sustain Current Spending scenario** are identified in *Exhibit 8-14* and are consistent with the 2008 Interstate System spending figures identified in Chapter 7 (see *Exhibit 7-1*). This scenario assumes the continuation of the percentage splits in spending among HERS-modeled, NBIAS-modeled, and non-modeled improvement types. Of the $20.0 billion of capital investment on the Interstate System in 2008, approximately $15.3 billion (or 76.4 percent) was used for types of improvements modeled in HERS, including pavement resurfacing, pavement reconstruction, and capacity additions to the existing highway and bridge network. Approximately $3.3 billion (or 16.4 percent) was used for types of bridge repair, rehabilitation, and replacement improvements modeled in NBIAS. The remaining $1.4 billion (or 7.1 percent) went for types of capital improvements not currently addressed by either HERS or NBIAS, including various safety enhancements, environmental enhancements, and traffic operations improvements.

Each of the Interstate System scenarios presented in *Exhibit 8-14* assumes that the share of average annual investment directed towards non-modeled capital improvements will remain at the 2008 level of 7.1 percent. Consequently, the amounts identified as "other" capital spending in *Exhibit 8-14* are proportionally larger or smaller than the 2008 spending level of $1.2 billion based on the change in modeled spending relative to the 2008 baseline. The footnotes in *Exhibit 8-14* identify the exhibits in Chapter 7 to which the HERS-modeled and NBIAS-modeled components of each scenario are linked.

As shown in *Exhibit 8-14*, the average annual investment level for the Interstate System **Maintain Conditions and Performance scenario** for 2009 to 2028 is $24.3 billion, stated in constant 2008 dollars. The HERS-modeled component of this total is $19.3 billion; this level of investment could be achieved if spending on the types of capital improvements modeled in HERS were to increase by 2.17 percent annually in real terms during this 20-year period over the base year 2008 level of $15.3 billion. This finding, combined with the finding presented in *Exhibit 8-11* that the objectives of the NHS version of this scenario component could be achieved without increasing related NHS spending above its 2008 level, suggests that the distribution of spending in 2008 was somewhat better aligned with addressing long-term highway needs on the portion of the NHS that is off the Interstate System than is on the Interstate System. The average annual investment level associated with the NBIAS-modeled component of the Interstate System **Maintain Conditions and Performance scenario** of $3.2 billion is slightly below the amount actually spent for related types of capital improvements in 2008.

Exhibit 8-14

Definitions of Selected Interstate Highway System Capital Investment Scenarios, and Average Annual Investment Levels for 2009 to 2028 Associated With Scenario Components

Scenario Name and Description	Scenario Component (Source of Estimate) [1]	Component Share of 2008 Capital Outlay	Annual Percent Change in Spending vs. 2008	Minimum BCR	Average Annual Capital Investment on Interstate Highways	
					Billions of 2008 Dollars	Percent of Total
Sustain Current Spending scenario (Sustain spending at base year levels in constant dollar terms.)	HERS [2]	76.4%	0.00%	2.90	$15.3	76.4%
	NBIAS [3]	16.4%	0.00%		$3.3	16.4%
	Other	*7.1%*			*$1.4*	*7.1%*
	Total	100.0%			**$20.0**	100.0%
Maintain Conditions and Performance scenario (Maintain average speed and the economic bridge investment backlog at 2008 levels.)	HERS [2]	76.4%	2.17%	2.63	$19.3	79.5%
	NBIAS [3]	16.4%	-0.18%		$3.2	13.3%
	Other	*7.1%*			*$1.7*	*7.1%*
	Total	100.0%			**$24.3**	100.0%
Intermediate Improvement scenario (Invest in projects with benefit-cost ratios as low as 1.5 and reduce the economic bridge investment backlog.) [4]	HERS [2]	76.4%	5.54%	1.50	$28.3	78.1%
	NBIAS [3]	16.4%	4.39%		$5.3	14.7%
	Other	*7.1%*			*$2.6*	*7.1%*
	Total	100.0%			**$36.2**	100.0%
Improve Conditions and Performance scenario (Invest in all cost-beneficial projects and eliminate the economic bridge investment backlog.)	HERS [2]	76.4%	7.27%	1.00	$34.6	80.5%
	NBIAS [3]	16.4%	4.39%		$5.3	12.4%
	Other	*7.1%*			*$3.1*	*7.1%*
	Total	100.0%			**$43.0**	100.0%

[1] Each scenario consists of three separately estimated components. The components derived from HERS and NBIAS represent the combined investment by all levels of government associated with achieving the scenario goals identified. The third scenario component, identified as "Other," represents other types of capital spending beyond those modeled in HERS or NBIAS; each scenario assumes that the percentage of total spending on these nonmodeled items in the future will be the same as the actual percentage in 2008.

[2] The scenario components derived from HERS are directly linked to the analyses presented in Exhibits 7-14 through 7-16 in Chapter 7; these components can be cross-referenced to the exhibits using either the annual percent change in spending relative to 2008, or the minimum BCR identified in this table.

[3] The scenario components derived from NBIAS are directly linked to the analysis presented in Exhibit 7-20 in Chapter 7; these components can be cross-referenced to this exhibit using the annual percent change in spending relative to 2008 identified in this table.

[4] The NBIAS component of this scenario for the Interstate System would be sufficient to eliminate the bridge backlog, rather than simply reduce it. This was not the case in the Federal-aid highway, systemwide, or NHS versions of this scenario presented earlier in the chapter.

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

Compared to the analyses of Federal-aid highways and the NHS discussed earlier, the HERS model identifies a relatively larger pool of economically attractive potential capital improvements to the Interstate System. In order to address all such improvements with a BCR of 1.00 or higher (the objective of the Interstate System **Improve Conditions and Performance scenario**), spending on the types of Interstate System capital improvements modeled in HERS would need to increase by 7.27 percent per year over 20 years. Applying a more conservative minimum BCR of 1.50 (the objective of the HERS component of the Interstate System **Intermediate Improvement scenario**) would require an increase in related capital spending of 5.54 percent per year. In contrast, the NBIAS analyses of Interstate System bridges suggest that a smaller annual increase in NBIAS-related capital spending of 4.39 percent per year over 20-years would be adequate to implement all potentially cost-beneficial bridge improvements identified by the model; this level of spending growth would generate the $5.3 billion average annual investment level for the NBIAS component of both the Interstate System **Improve Conditions and Performance scenario** and the Interstate System **Intermediate Improvement scenario**. The combined average annual investment levels derived from the HERS-modeled, NBIAS-modeled, and non-modeled components of the two scenarios are $43.0 billion for the Interstate System **Improve Conditions and Performance scenario** and $36.2 billion for the Interstate System **Intermediate Improvement scenario**.

Interstate Scenario Impacts and Comparison with 2008 Spending

As shown in *Exhibit 8-15*, sustaining investment 2008 levels in constant dollar terms over 20 years (as assumed in the Interstate System **Sustain Current Spending scenario**) is projected to result in a 3.2-percent reduction in average speed in 2028 relative to 2008 and a 13.4 percent increase in average delay per VMT, symptomatic of a decline in overall operating performance. Interstate System physical conditions are projected to improve slightly, with a 0.4 percent reduction in average pavement roughness by 2028 relative to 2008 and a 3.6 percent reduction in the economic bridge investment backlog.

Exhibit 8-15

Selected Interstate Highway System Capital Investment Scenarios for 2009 to 2028: Comparisons With 2008 Spending and Projected Interstate Highway System Performance Indicators

Comparison Parameter	Sustain Current Spending Scenario	Maintain Conditions & Performance Scenario	Intermediate Improvement Scenario	Improve Conditions & Performance Scenario
Comparison of Scenarios With 2008 Spending				
Average Annual Investment (Billions of 2008 Dollars)	$20.0	$24.3	$36.2	$43.0
Difference Relative to 2008 Spending (Billions of 2008 Dollars)	**$0.0**	$4.2	$16.2	$23.0
Percent Difference Relative to 2008 Spending	0.0%	21.2%	80.8%	115.0%
Annual Percent Increase to Support Scenario Investment [1]	0.00%	1.80%	5.35%	6.83%
Projected Impacts of Scenarios on Interstate Highways				
Percent Change in Average Speed (2028 vs. 2008) [2]	-3.2%	**0.0%**	5.1%	8.0%
Percent of VMT on Roads With Good Ride Quality, 2028 [3]	72.4%	79.7%	89.8%	94.2%
Percent of VMT on Roads With Acceptable Ride Quality, 2028 [3]	93.9%	95.6%	98.3%	99.3%
Percent Change in Average IRI (2028 vs. 2008) [3]	-0.4%	-11.5%	-27.7%	-34.1%
Percent Change in Average Delay per VMT (2028 vs. 2008) [2]	13.4%	-2.9%	-27.8%	-41.5%
Percent Change in Economic Bridge Investment Backlog (2028 vs. 2008) [4]	-3.6%	**0.0%**	-100.0%	**-100.0%**

[1] *This percentage represents the annual percent change relative to 2008 that would be required to achieve the average annual funding level specified for the scenario in constant dollar terms. Additional increases in nominal dollar terms would be needed to offset the impact of future inflation.*

[2] *Values shown correspond to amounts in Exhibit 7-16 in Chapter 7.*

[3] *Values shown correspond to amounts in Exhibit 7-15 in Chapter 7. Reductions in average pavement roughness (IRI) tranlate into improved ride quality.*

[4] *Values shown correspond to amounts in Exhibit 7-20 in Chapter 7.*

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

Under the Interstate System **Improve Conditions and Performance scenario**, the percent of Interstate System VMT on pavements with good ride quality is projected to rise to 94.2 percent, while the percent of VMT on pavements with acceptable ride quality reaches 99.3 percent. (In a small number of cases, HERS does not find it cost-beneficial to address Interstate System pavement deficiencies until just after they have fallen below the acceptable ride quality threshold rather than just before). By definition this scenario would eliminate the economic bridge investment backlog on the Interstate System by 2028; it is also projected to increase average speeds by 8.0 percent relative to 2008. Average Interstate System pavement roughness is projected to be reduced by 34.1 percent, while average delay per Interstate System VMT would decrease by 41.5 percent by 2028.

The average annual investment level for the Interstate System **Improve Conditions and Performance scenario** of $43.0 billion is $23.0 billion (115.0 percent) higher than the actual spending by all levels of government combined on capital improvements to Interstate System highways and bridges. The comparable gap between the Interstate System **Intermediate Improvement scenario** and 2008 spending is 80.8 percent, while the average annual investment level for the Interstate System **Maintain Conditions and Performance scenario** is 21.2 percent higher than base year 2008 Interstate System spending.

Interstate Scenario Estimates by Improvement Type

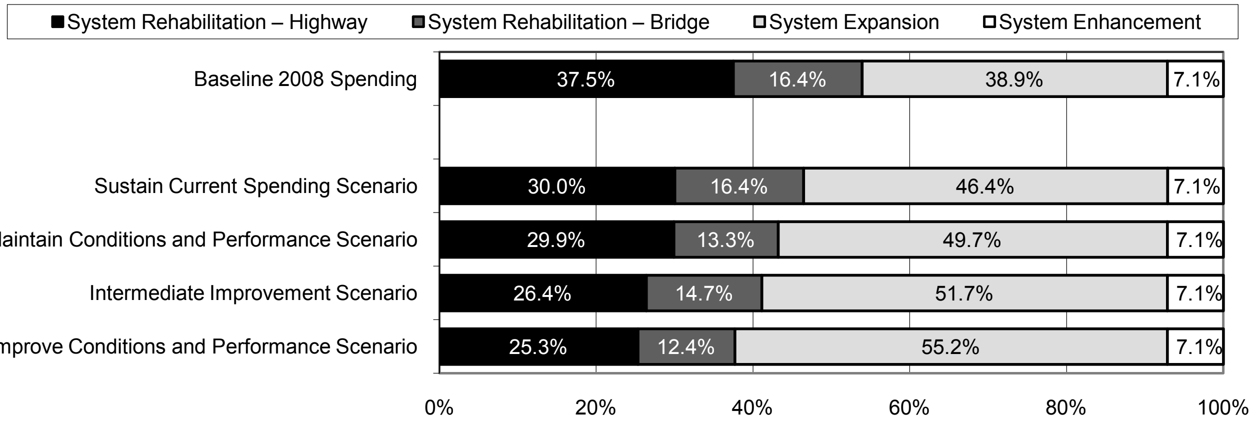
Exhibit 8-16 shows for each Interstate System capital investment scenario the distribution of highway and bridge capital outlay and compares this with the distribution of actual Interstate System capital spending in 2008. As noted above, capital spending on non-modeled system enhancements for each scenario was set at 7.1 percent of the total investment level for that scenario, consistent with the percentage of total Interstate System capital spending by all levels of government for these types of improvements in 2008. By design, the percentage of the **Sustain Current Spending scenario** investment directed to bridge system rehabilitation matches the share of Interstate System capital improvements used for this purpose in 2008. (This is not the case for the Interstate System version of the **Intermediate Improvement scenario**, because maintaining this share would have required investments in bridge improvements that were not determined to be cost-beneficial.)

The HERS model identifies significant opportunities for potentially cost-beneficial investments in capacity expansion on the Interstate System, driven by the higher traffic volumes carried on these facilities and the higher State projections for future VMT growth on the Interstate System relative to other functional classes. Although 38.9 percent of Interstate System capital spending was directed towards expansion in 2008, the Interstate System **Sustain Current Spending scenario** increases this percentage to 46.4 percent; the Interstate System **Improve Conditions and Performance scenario** directs 55.2 percent of its total investment to system expansion.

Of the $43.0 billion average annual investment level for the NHS **Improve Conditions and Performance scenario**, $16.2 billion (37.7 percent) would be directed towards the types of system rehabilitation actions reflected in the **State of Good Repair benchmark**. This benchmark level is 50.3 percent more than the $10.8 billion spent by all levels of government on system rehabilitation on the Interstate System in 2008.

Exhibit 8-16

Distribution of Capital Improvement Types for Selected Interstate Highway System Capital Investment Scenarios for 2009 to 2028



Scenario Name	Average Annual Investment (Billions of 2008 Dollars)					
	System Rehabilitation			System Expansion[3]	System Enhance-ment	Total
	Highway[1]	Bridge[2]	Total			
Baseline 2008 Spending	$7.5	$3.3	$10.8	$7.8	$1.4	**$20.0**
Sustain Current Spending scenario	$6.0	$3.3	$9.3	$9.3	$1.4	**$20.0**
Maintain Conditions and Performance scenario	$7.2	$3.2	$10.5	$12.0	$1.7	**$24.3**
Intermediate Improvement scenario	$9.6	$5.3	$14.9	$18.7	$2.6	**$36.2**
Improve Conditions and Performance scenario	$10.9	$5.3	$16.2	$23.7	$3.1	**$43.0**
State of Good Repair benchmark[4]	$10.9	$5.3	**$16.2**			

[1] Values shown correspond to amounts in Exhibit 7-15 in Chapter 7.

[2] Values shown correspond to amounts in Exhibit 7-20 in Chapter 7.

[3] Values shown correspond to amounts in Exhibit 7-16 in Chapter 7.

[4] The State of Good Repair benchmark is a subset of the Improve Conditions and Performance scenario.

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

Selected Transit Capital Investment Scenarios

While Chapter 7 considered the impacts of varying levels of capital investment on transit conditions and performance, this chapter provides in-depth analysis of four specific investment scenarios, as outlined below in *Exhibit 8-17*. The **Sustain Current Spending scenario** assesses the impact of sustaining current expenditure levels on asset conditions and system performance over the next 20-year period. Given that current expenditure rates are generally less than are required to maintain current condition and performance levels, this scenario generally reflects the magnitude of the expected declines in conditions and performance given maintenance of current capital investment rates. The **State of Good Repair (SGR) benchmark** considers the level of investment required to eliminate the existing capital investment backlog as well as the condition and performance impacts of doing so. In contrast to the other scenarios considered here, the **SGR benchmark** only considers the preservation needs of existing transit assets (with no consideration of expansion requirements). Moreover, this is the only scenario that does not require that investments pass the Transit Economic Requirements Model's (TERM's) benefit-cost test (hence, this scenario brings all assets to SGR regardless of TERM's assessment of whether reinvestment is warranted). Finally, the **Low Growth** and **High Growth scenarios** both assess the required levels of reinvestment to (1) preserve existing transit assets at a condition rating of 2.50 or higher and (2) expand transit service capacity to support differing levels of ridership growth while passing TERM's benefit-cost test.

Exhibit 8-17

2010 C&P Analysis Scenarios for Transit

Scenario Aspect	Sustain Current Spending	SGR	Low Growth (MPO Projected Growth)	High Growth (Historical Growth)
Description	Sustain preservation and expansion spending at current levels over next 20 years	Level of investment to attain and maintain SGR over next 20 years (no assessment of expansion needs)	Preserve existing assets and expand asset base to support MPO projected ridership growth (about 1.4%)	Preserve existing assets and expand asset base to support historical rate of ridership growth (2.8% between 1999 and 2008)
Objective	Assess impact of constrained funding on condition, SGR backlog and ridership capacity	Requirements to attain SGR (as defined by assets in condition 2.5 or better)	Assess unconstrained preservation and capacity expansion needs assuming low ridership growth	Assess unconstrained preservation and capacity expansion needs assuming high ridership growth
Apply Benefit-Cost Test?	Yes [1]	No	Yes	Yes
Preservation?	Yes [2]	Yes [2]	Yes [2]	Yes [2]
Expansion?	Yes	No	Yes	Yes

[1] To prioritize investments under constrained funding.

[2] Replace at condition 2.5.

Exhibit 8-18 summarizes the analysis results for each of these scenarios. It should be noted that each of the scenarios presented in *Exhibit 8-18* imposes the same asset condition replacement threshold (i.e., assets are replaced at condition 2.50 when there is sufficient budget to do so) when assessing transit reinvestment needs. Hence, the differences in the total preservation expenditure amounts across each of these scenarios primarily reflect the impact of either (1) an imposed budget constraint (**Sustain Current Spending scenario**) or (2) application of TERM's benefit-cost test (the **SGR benchmark** does not apply the benefit-cost test). A brief review of *Exhibit 8-18* reveals the following:

Exhibit 8-18

Annual Average Cost by Investment Scenario (2008–2028)

Mode, Purpose, and Asset Type	Investment Projection (Billions of 2008 Dollars) Sustain Current Spending	SGR	Low Growth	High Growth
Urbanized Areas Over 1 Million in Population [1]				
Nonrail [2]				
Preservation	$3.7	$4.9	$4.5	$4.6
Expansion	$1.0	$0.0	$1.1	$2.3
Subtotal Nonrail [3]	**$4.7**	**$4.9**	**$5.6**	**$6.9**
Rail				
Preservation	$6.5	$10.7	$10.0	$10.5
Expansion	$3.6	$0.0	$2.6	$4.4
Subtotal Rail [3]	**$10.1**	**$10.7**	**$12.7**	**$14.8**
Total, Over 1 Million in Population [3]	**$14.8**	**$15.6**	**$18.2**	**$21.7**
Urbanized Areas Under 1 Million in Population and Rural				
Nonrail [2]				
Preservation	$0.8	$2.1	$1.9	$1.9
Expansion	$0.5	$0.0	$0.5	$0.7
Subtotal Nonrail [3]	**$1.3**	**$2.1**	**$2.4**	**$2.6**
Rail				
Preservation	$0.0	$0.3	$0.2	$0.2
Expansion	$0.0	$0.0	$0.0	$0.0
Subtotal Rail [3]	**$0.0**	**$0.3**	**$0.2**	**$0.2**
Total, Under 1 Million and Rural [3]	**$1.3**	**$2.4**	**$2.5**	**$2.8**
Total [3]	**$16.1**	**$18.0**	**$20.8**	**$24.5**

[1] Includes 37 different UZAs.

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

[3] Note that totals may not sum due to rounding.

Source: Transit Economic Requirements Model.

- **Sustain Current Spending Scenario:** Total spending under this scenario is well below that of each of the other needs—based scenarios, indicating that a sustainment of recent spending levels is insufficient to attain the investment objectives of the **SGR, Low Growth, or High Growth scenarios** (suggesting future increases in the size of the SGR backlog and a likely increase in the number of transit riders per peak vehicle—including an increased incidence of crowding—in the absence of increased levels of expenditures).
- **SGR Benchmark:** The level of expenditures required to attain and maintain SGR over the upcoming 20-year period—which covers preservation needs but excludes any expenditures on expansion investments—is roughly 12 percent higher than that currently expended on asset preservation and expansion combined.
- **Low and High Growth Scenarios:** The level of investment to address expected preservation and expansion needs is estimated to be roughly 33 percent to 55 percent higher than currently expended by the Nation's transit operators. Preservation and expansion needs are highest for urbanized areas (UZAs) exceeding 1 million in population.

The following subsections present more detailed assessments of each scenario.

Sustain Current Spending Scenario

In 2008, as reported by transit agencies to the National Transit Database (NTD), transit operators spent a total of $16.1 billion on capital projects (see *Exhibit 7-21* and the corresponding discussion in Chapter 7). Of this amount, $11.0 billion was dedicated to the preservation of existing assets while the remaining $5.1 billion was dedicated to investment in asset expansion both to support ongoing ridership growth and to improve service performance. This **Sustain Current Spending scenario** considers the expected impact on the long-term physical conditions and service performance of the Nation's transit infrastructure if these 2008 expenditure levels are sustained in constant dollar terms through 2028. Similar to the discussion in Chapter 7, the analysis considers the impacts of asset preservation investments separately from those of asset expansion.

Capital Expenditures for 2008. It is important to note that the level of transit capital expenditures as reported to the NTD was higher in 2008 than at any other point in the 5-year period from 2004 through 2008 (see *Exhibit 8-19*). Even when adjusted for inflation, which was significant for capital assets over this period, total expenditures in 2008 were roughly $0.5 billion higher for preservation and $1.3 billion higher for expansion as compared with the average for the preceding 4-year period. Moreover, based on preliminary data for 2009, it is likely that this is a one-time, permanent increase in the reported level of transit capital expenditures (at least partially driven by changes in transit agency accounting practices).

Exhibit 8-19

Annual Transit Capital Expenditures, 2004 to 2008 (Billions of YOE Dollars)

Year	Preservation	Expansion	Total
2004	$9.40	$3.20	$12.60
2005	$9.00	$2.90	$11.80
2006	$9.30	$3.50	$12.80
2007	$9.60	$4.00	$13.60
2008	$11.00	$5.10	$16.10
Average	**$9.70**	**$3.70**	**$13.40**
Expenditures 2004 to 2007 in 2008 Dollars			
Average	**$10.50**	**$3.80**	**$14.70**

Source: NTD.

Given that financial data is typically reported under the accrual basis of accounting, expenditures may be reported during periods when costs are accrued, not when they are paid. If an operator changes accounting practices for employee expenses (e.g., salaries, wages, benefits, etc.), for example, financial trends may show an increase or decrease from one accounting period to another that would not otherwise have appeared.

In 2004, the Governmental Accounting Standard Board issued a statement (Statement No. 45) regarding the accounting for post-employment benefits. Examples of these benefits include healthcare and life insurance (the statement does not address accounting for pensions). This statement, which was phased in over three years starting with accounting periods after 2006, now requires the accrued costs of these benefits to be accounted for during the employee's period of employment as opposed to when they are paid. For state and local governmental employers that apply this accounting approach, their financial data and trends—including changes in total reported expenditures—may reflect changes that otherwise would not have been reported, all else being equal. This may account for the significant increases in expenses and funding reported to NTD as of 2008. Hence, it should be noted that the 2008 level of transit capital expenditures is expected to be representative of future years' levels.

TERM's Funding Allocation. The following analysis of the **Sustain Current Spending scenario** relies on TERM's allocation of 2008-level preservation and expansion expenditures to the Nation's existing transit operators, their modes, and their assets over the upcoming 20-year period as depicted in *Exhibit 8-20*. As with other TERM analyses involving the allocation of constrained transit funds, TERM allocates limited funds based on the results of the model's benefit-cost analysis, which ranks potential investments based on their assessed benefit-cost ratios (with the highest-ranked investments being funded first). Note that this TERM benefit-cost–based allocation of funding between assets and modes may differ from the allocation that local agencies might actually pursue assuming total spending is sustained at current levels over 20 years.

Preservation Investments

As noted above, transit operators spent an estimated $11.0 billion in 2008 on the rehabilitation and replacement of existing transit infrastructure. Based on current TERM analysis, this level of reinvestment is less than that required to address the anticipated reinvestment needs of the Nation's existing transit assets, and, if sustained over the forecasted 20-year period, would result in an overall decline in the condition of existing transit assets as well as an increase in the size of the investment backlog.

For example, *Exhibit 8-21* presents the projected increase in the proportion of existing assets that exceed their useful life, by asset category, over the period 2008 to 2028. Given the benefit-cost–based prioritization imposed by TERM for this scenario, the proportion of existing assets that exceed their useful life is projected to undergo a near-continuous increase across each of these asset categories. (This condition projection

Exhibit 8-20

Sustain Current Spending Scenario: Average Annual Investment by Asset Type, 2008–2028 (Billions of 2008 Dollars)

	Investment Category		
Asset Type	**Preservation**	**Expansion**	**Total**
Rail			
Guideway Elements	$1.4	$1.0	$2.4
Facilities	$0.6	$0.1	$0.6
Systems	$2.4	$0.2	$2.6
Stations	$1.0	$0.6	$1.6
Vehicles	$1.1	$0.8	$2.0
Other Project Costs		$0.9	$0.9
Subtotal Rail*	**$6.5**	**$3.6**	**$10.1**
Nonrail			
Guideway Elements	$0.4	$0.1	$0.5
Facilities	$0.8	$0.3	$1.0
Systems	$0.0	$0.0	$0.1
Stations	$0.0	$0.0	$0.1
Vehicles	$3.2	$1.1	$4.3
Other Project Costs		$0.0	$0.0
Subtotal Nonrail*	**$4.5**	**$1.5**	**$6.0**
Total*	**$11.0**	**$5.1**	**$16.1**

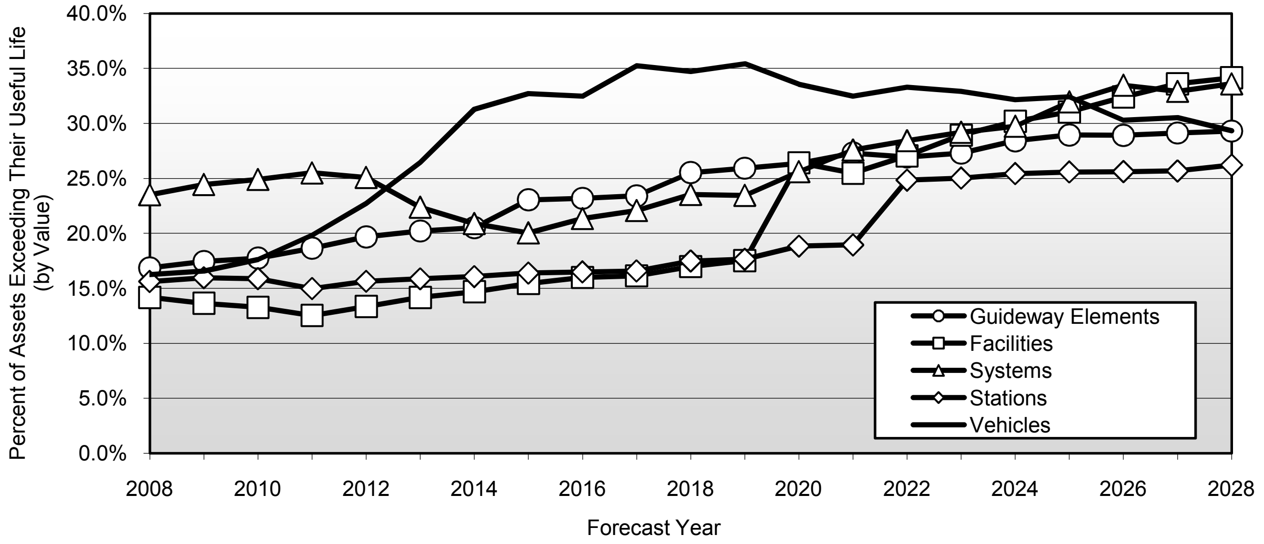
** Note that totals may not sum due to rounding.*

Source: Transit Economic Requirements Model and FTA staff estimates.

Exhibit 8-21

Sustain Current Spending Scenario: Over-Age Forecast by Asset Category, 2008–2028

(Existing Transit Assets; FTA Minimum Useful Life for Vehicles)



Note that the proportion of assets exceeding their useful life is measured based on asset replacement value, not asset quantities.

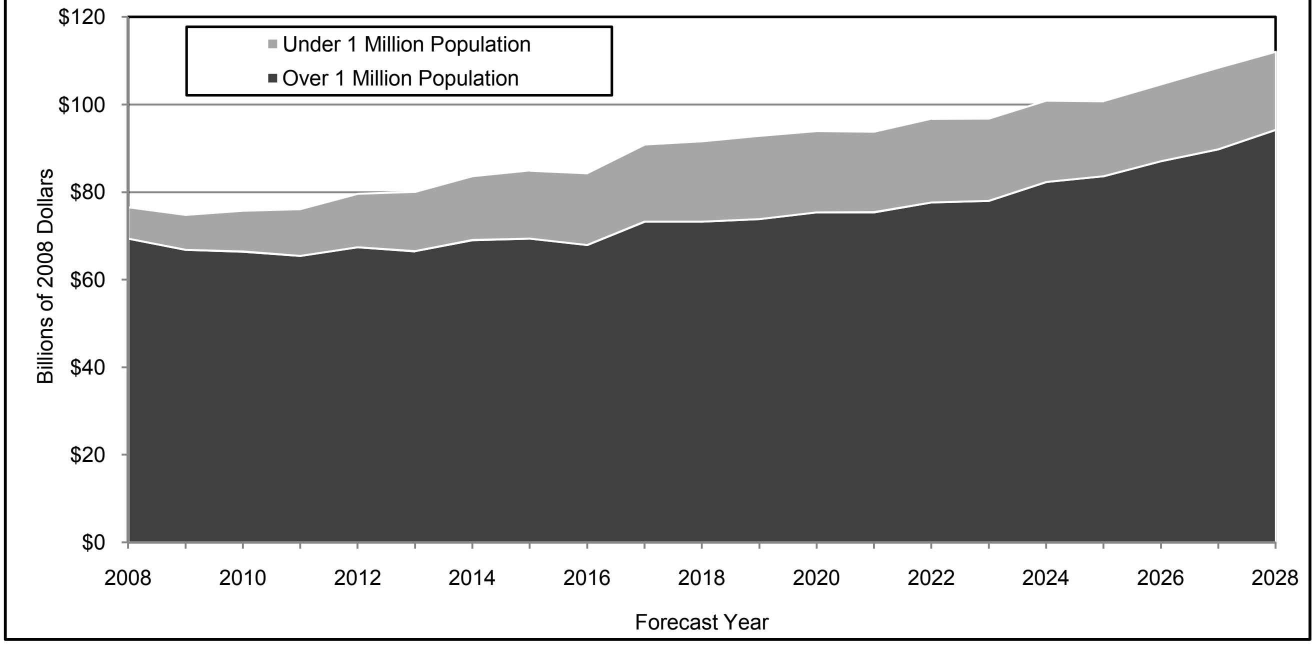
Source: Transit Economic Requirements Model.

uses TERM's benefit-cost test to prioritize rehabilitation and replacement investments in this scenario. Specifically, for each investment period in the forecast, TERM ranks all proposed investment activities based on their assessed benefit-cost ratios [highest to lowest]. TERM then invests in the highest-ranked projects for each period until the available funding for the period is exhausted. Investments not addressed in the current period as a result of the funding constraint are then deferred until the following period.) Also, given that the proportion of "over-age" assets is projected to increase for *all* asset categories under this prioritization, it is clear that any reprioritization to favor reinvestment in one asset category over another would only serve to accelerate the rate of increase of the remaining categories. Note that these over-age assets tend to deliver the lowest-quality transit service to system users (e.g., have the highest likelihood of in-service failures).

Finally, *Exhibit 8-22* presents the projected change in the size of the investment backlog if reinvestment levels are sustained at the 2008 level of $11.0 billion, in constant dollar terms. As described in Chapter 7, the investment backlog represents the level of investment required to replace all assets that exceed their useful life and also to address all rehabilitation activities that are currently past due. Given that the current rate of capital reinvestment is insufficient to address the replacement needs of the existing stock of transit assets, the size of that backlog is projected to increase from the currently estimated level of $78 billion to roughly $116 billion by 2028. This chart also divides the backlog amount according to transit service area size, with the lower portion showing the backlog for UZAs with populations greater than 1 million and the upper portion showing the backlog for all other UZAs and rural areas combined. This segmentation highlights the significantly higher existing backlog for those UZAs serving the largest number of transit riders. The initial reduction in the backlog for these largest-transit UZAs, as shown in *Exhibit 8-22*, results from TERM's higher prioritization of replacement needs for this urban area type and does not necessarily reflect the actual or expected allocation of expenditures between urban area types given maintenance of current spending levels in the future. Regardless of the actual allocation, it is clear that the 2008 expenditure level of $11.0 billion, if sustained, is not sufficient to prevent a further increase in the backlog needs of one or more of these UZA types.

Exhibit 8-22

Investment Backlog: Sustain Current Spending ($11.0 Billion Annually)



Source: Transit Economic Requirements Model.

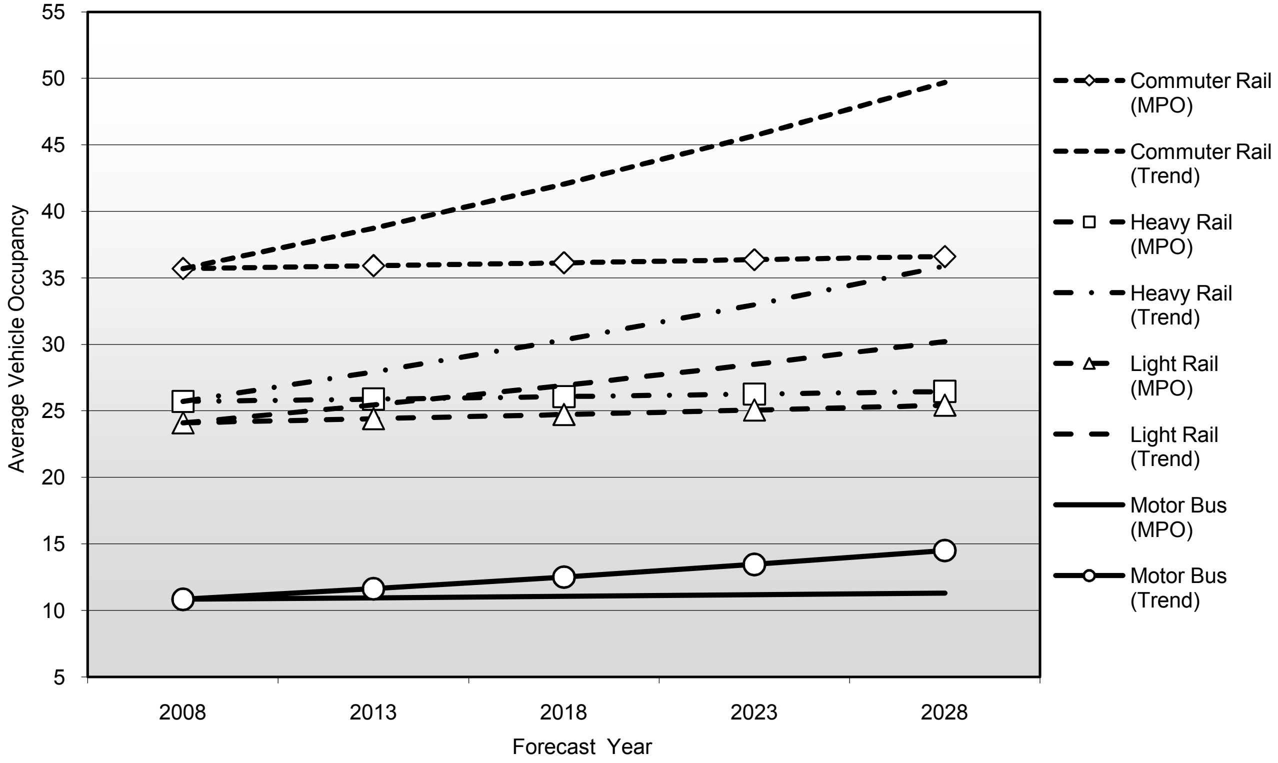
Expansion Investments

In addition to the $11.0 billion spent on transit asset preservation in 2008, transit agencies spent $5.1 billion on expansion investments to support ridership growth and to improve transit performance. This section considers the impact of sustaining the 2008 level of expansion investment on future ridership capacity and vehicle utilization rates under both lower and higher ridership growth rate assumptions. As noted above, it is important to consider here that the $5.1 billion spent on expansion investments in 2008 was significantly higher than that reported in prior years.

As already considered in Chapter 7 (see *Exhibit 7-27*), the 2008 rate of investment in transit expansion is not sufficient to expand transit capacity at a rate equal to the rate of growth in travel demand, as projected by the Nation's Metropolitan Planning Organizations (MPOs) or based on the historical trend rate of increase. Under these circumstances, it should be expected that transit capacity utilization (e.g., passengers per vehicle) will increase, with the level of increase determined by actual growth in demand. Although the impact of this change may be minimal for systems that currently have lower capacity utilization, service performance on some higher utilization systems would likely decline as riders experience increased vehicle crowding and potential for service delays. This impact is illustrated in *Exhibit 8-23*, which presents the projected change in vehicle occupancy rates by mode during the period from 2008 through 2028 (reflecting the impacts of spending from 2009 through 2028) under both lower (MPO) and higher (trend) rates of growth in transit scenarios, assuming that transit agencies continue to invest an average of $5.1 billion per year on transit expansion. Under both the MPO projected and the historical trend rates of increase, there is a steady rise in the average number of riders per transit vehicle across each of the four modes depicted here, with the impact being small under the MPO projected rate of growth but significant under the trend rate of growth scenario, which is higher. For perspective, note that MPO growth rate projections tend to be conservative because

Exhibit 8-23

Sustain Current Spending Scenario: Capacity Utilization by Mode Forecast, 2008–2028



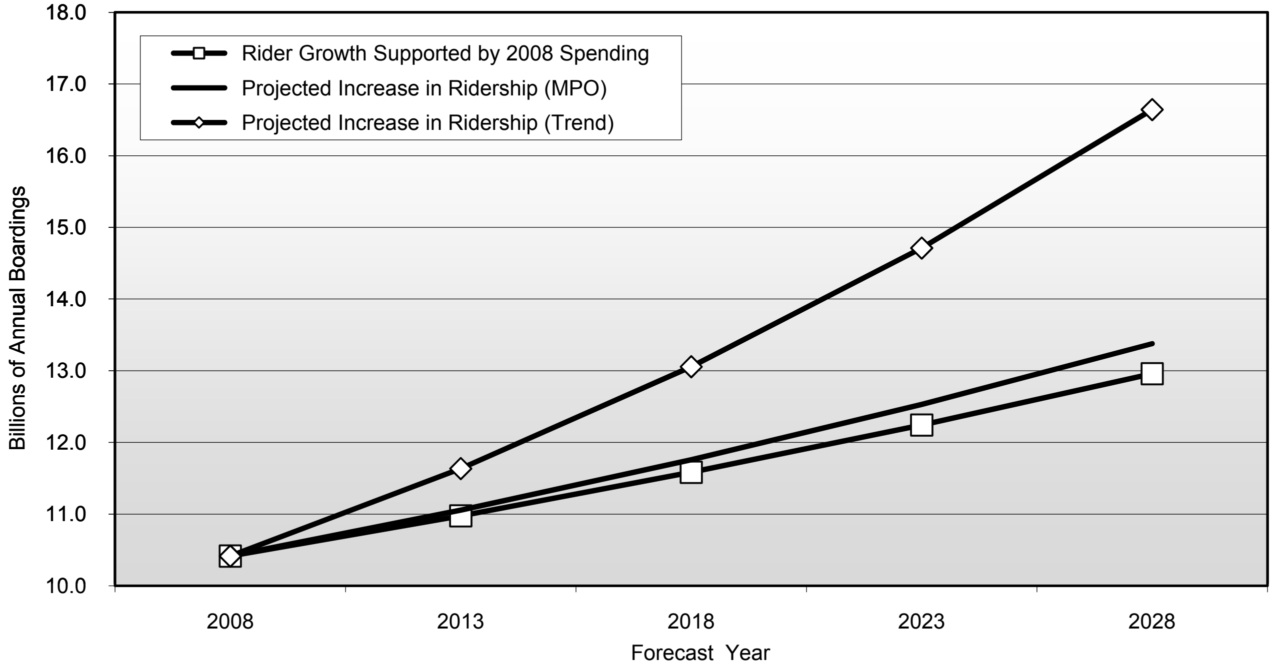
Source: Transit Economic Requirements Model.

they are developed based on financially constrained transportation plans. Moreover, the actual growth in travel demand has typically exceeded the MPO growth projections for much of the past decade.

Exhibit 8-24 presents the projected growth in transit riders that can be supported by the 2008 level of investment (keeping vehicle occupancy rates constant) as compared with the potential growth in total ridership under both the low- and higher-growth rate scenarios. Similar to prior analyses, the $5.1-billion level of investment can support ridership growth that is similar to the MPO projected ridership increases, but is short of that required to support continued ridership growth at recent historical rates (i.e., without impacting service performance).

Exhibit 8-24

Projected Versus Currently Supported Ridership Growth



Source: Transit Economic Requirements Model.

State of Good Repair Benchmark

What is the definition of a State of Good Repair for transit assets?

Q&A

The definition of "state of good repair" used for this scenario relies on TERM's assessment of transit asset conditions. Specifically, for this scenario, TERM considers assets to be in a state of good repair if they are rated at condition rating of 2.50 or higher and if all required rehabilitation activities have been addressed.

The preceding scenario considered the impacts of sustaining transit spending at current levels, which appear to be insufficient to address either deferred investment needs (which are projected to increase) or the projected increases in transit ridership (without a reduction in service performance). In contrast, this section focuses on the level of investment required both to eliminate the investment backlog over the next 20 years and to provide for sustainable rehabilitation and replacement needs once the backlog has been addressed. Specifically, the **SGR benchmark** estimates the level of annual investment required to replace assets that currently exceed their useful life, to address all deferred rehabilitation activities (yielding a state of good repair where the asset has a condition rating of 2.50 or higher), and then to address all future rehabilitation and replacement activities as they come due. The **SGR benchmark** considered here is the same as that described in the Federal Transit Administration's National State of Good Repair study, released July 2010.

Differences with Other Scenarios: In contrast to the other scenarios in this Chapter, the **SGR benchmark** (1) makes no assessment of expansion needs and (2) does not apply TERM's benefit-cost test to investments proposed by TERM. These benchmark characteristics are considered consistent with the concept of "state of good repair." First, analyses of expansion investments are ultimately focused on capacity improvements and not on the needs of deteriorated assets. Second, application of TERM's benefit-cost test would leave some reinvestment needs unaddressed. The intention of this benchmark is to assess the total magnitude of unaddressed reinvestment needs for all transit assets currently in service, regardless of whether it appears to be cost-beneficial for these assets to remain in service.

SGR Investment Needs

Annual reinvestment needs under the **SGR benchmark** are presented in *Exhibit 8-25*. Under this benchmark, an estimated $18.0 billion in annual expenditures is required over the next 20 years to bring the condition of all existing transit assets to an SGR. Of this amount, roughly $11.0 billion (60 percent) is required to address the SGR needs of rail assets. Note that a large proportion of rail reinvestment needs are associated with guideway elements (primarily aging elevated and tunnel structures) and rail systems (including train control, traction power, and communications systems) that are past their useful life and potentially technologically obsolete as well. Bus-related reinvestment needs are primarily associated with aging vehicle fleets.

Exhibit 8-25 also provides a breakout of capital reinvestment needs by type of UZA. This breakout emphasizes the fact that capital reinvestment needs are most heavily concentrated in the Nation's larger UZAs. Together, these urban areas account for close to 87 percent of total reinvestment needs (across all mode and asset types), with the rail reinvestment needs of these urban areas accounting for more than one-half of the total reinvestment required to bring all assets to an SGR. This high proportion of total needs reflects the high level of investment in older assets found in these urban areas.

Exhibit 8-25

SGR Benchmark: Average Annual Investment by Asset Type, 2008–2028 (Billions of 2008 Dollars)

Asset Type	Urban Area Type Over 1 Million Population	 Under 1 Million Population	Total
Rail			
Guideway Elements	$2.9	$0.1	$3.0
Facilities	$1.1	$0.1	$1.1
Systems	$3.2	$0.0	$3.2
Stations	$1.8	$0.0	$1.8
Vehicles	$1.8	$0.0	$1.8
Subtotal Rail*	**$10.7**	**$0.3**	**$11.0**
Nonrail			
Guideway Elements	$0.4	$0.1	$0.5
Facilities	$1.1	$0.7	$1.7
Systems	$0.1	$0.0	$0.2
Stations	$0.1	$0.0	$0.1
Vehicles	$3.2	$1.3	$4.6
Subtotal Nonrail*	**$4.9**	**$2.1**	**$7.0**
Total*	**$15.6**	**$2.4**	**$18.0**

** Note that totals may not sum due to rounding.*

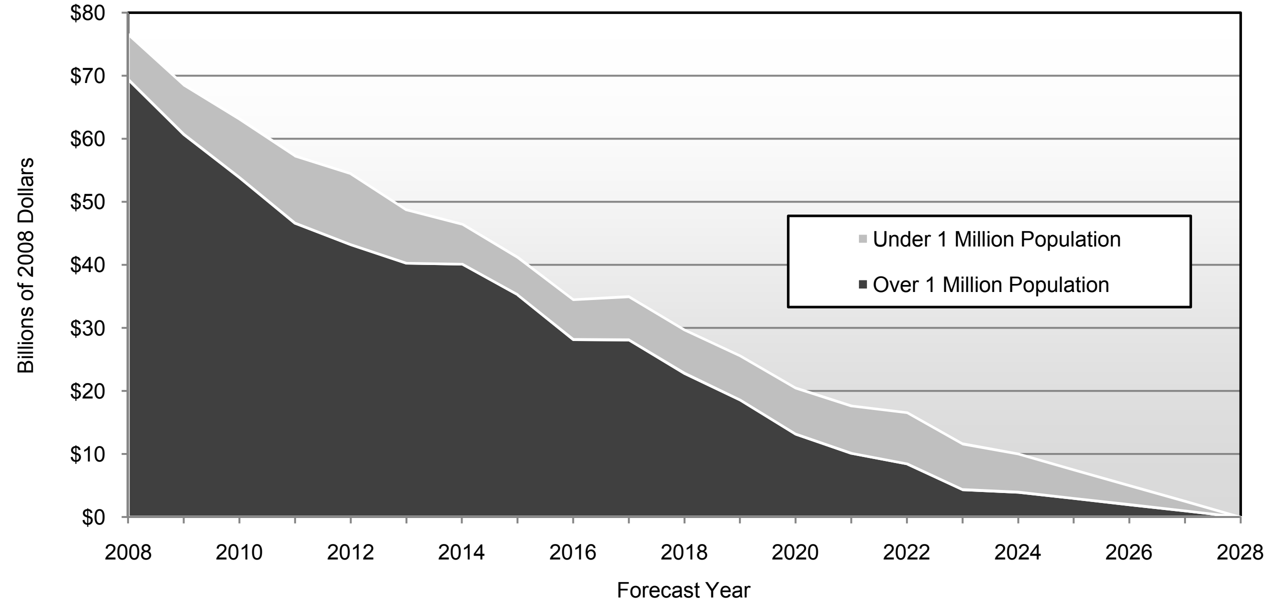
Source: Transit Economic Requirements Model.

Impact on the Investment Backlog

A key objective of the **SGR benchmark** is to determine the level of investment required to attain and then maintain an SGR across all transit assets over the next 20 years, including elimination of the existing investment backlog. *Exhibit 8-26* shows the estimated impact of the $18.0 billion in annual expenditures under the **SGR benchmark** on the existing investment backlog over the 20-year forecast period (compare these data with *Exhibit 8-22*). Given this level of expenditures, the backlog is projected to be eliminated by 2028, with the majority of this drawdown addressing the reinvestment needs of the UZAs with populations greater than 1 million.

Exhibit 8-26

Investment Backlog: SGR Benchmark ($18.0 Billion Annually)



Source: Transit Economic Requirements Model.

Impact on Conditions

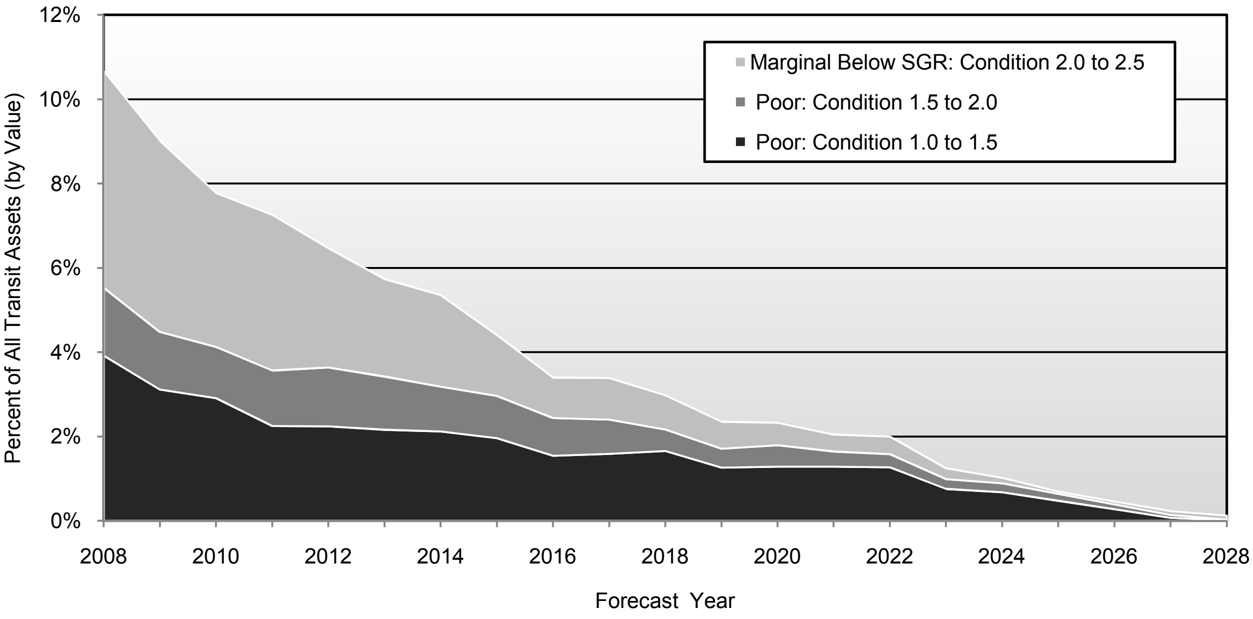
In drawing down the investment backlog, the annual capital expenditures of $18.0 billion under the **SGR benchmark** would also lead to the replacement of assets with an estimated condition rating of 2.5 or lower. Within TERM's condition rating system, this includes assets in marginal condition that have ratings of below 2.5 and all assets in poor condition. *Exhibit 8-27* shows the current distribution of asset conditions for assets estimated to be in a rating condition of 2.50 or lower (with assets in poor condition segmented into two sub-groups). Note that this graphic excludes both tunnel structures and subway stations in tunnel structures because these are considered assets that require ongoing capital rehabilitation expenditures but that are never actually replaced. As with the investment backlog, the proportion of assets at rating condition 2.50 or lower is projected to decrease under the **SGR benchmark** from roughly 10 percent of assets in 2008 to well below 1 percent by 2028. Once again, this replacement activity would remove from service those assets with higher occurrences of service failures, technological obsolescence, and lower overall service quality.

Impact on Vehicle Fleet Performance

While the preceding analysis has considered the impact of higher investment on reducing the investment backlog and potential replacement of assets past their useful life, this analysis may not provide a sense of the potential positive implications of these changes for daily transit service. To help better understand these effects, *Exhibit 8-28* shows the estimated percent reduction in fleet-wide revenue service disruptions (relative to 2008) for heavy rail and motor bus vehicles resulting from the retirement of over-age transit passenger vehicles under the **SGR benchmark**. Note that the large variation in the percent reduction for bus is a result of the timing of large bus fleet replacements. Also, while the reductions in service disruptions is significant for bus and heavy rail vehicles, some vehicle types (e.g., light and commuter rail) actually show a net increase in service disruptions under the **SGR benchmark**; this is because the current age distribution for these

Exhibit 8-27

Proportion of Transit Assets Not in SGR (Excluding Tunnel Structures)

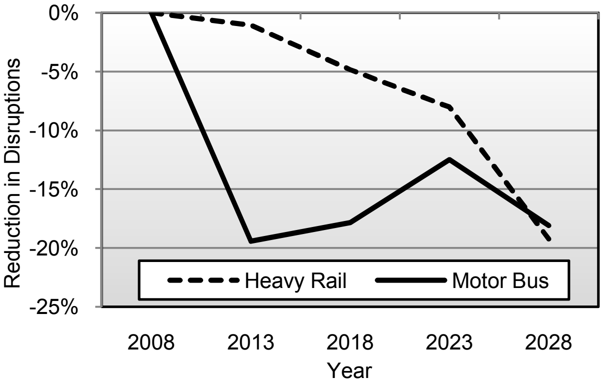


Source: Transit Economic Requirements Model.

fleets is skewed toward younger vehicle ages and is not sustainable in the longer term. This effect is the result of the recent development of new light rail and commuter rail systems.

Exhibit 8-28

Percent Reduction in Revenue Service Disruptions Relative to 2008 for SGR Benchmark



Source: Transit Economic Requirements Model.

Low and High Growth Scenarios

The preceding scenario considered the level of investment to bring existing transit assets to a SGR but in doing so did not consider either (1) the cost effectiveness of these investments (investments were not required to pass TERM's benefit-cost test) or (2) the level of expansion investment required to support projected ridership growth. The **Low Growth scenario** and **High Growth scenario** address both of these issues. Specifically, these scenarios use the same rules to assess when assets should be rehabilitated or replaced as were applied in the preceding **SGR benchmark** (e.g., with assets being replaced at condition 2.50), but also require that these preservation and expansion investments pass TERM's benefit-cost test. In general, some reinvestment activities do not pass this test (i.e., have a benefit-cost ratio of less than one), which can result from low ridership benefits, higher capital or operating costs, or a mix of these factors. Excluding investments that do not pass the benefit-cost test has the effect of reducing total estimated needs.

In addition, the **Low** and **High Growth scenarios** also assess transit expansion needs given ridership growth as projected by the Nation's MPOs (low growth) and based on the average annual compound rate as experienced over the last 10-year period (high growth). For the expansion component of this scenario, TERM assesses the level of investment required to maintain current vehicle occupancy rates (at the agency-mode level) subject to the rate of projected growth in transit demand in that UZA and also subject to the proposed expansion investment passing TERM's benefit-cost test.

Low Growth Assumption

The **Low Growth scenario** is intended to provide a lower bound on the level of investment required to maintain current service performance (as measured by transit vehicle capacity utilization) as determined by a relatively low rate of growth in travel demand. In particular, this **Low Growth scenario** relies on growth in travel demand as projected by a sample of the MPOs (representing the Nation's 30 largest UZAs and a sample of smaller UZAs). When aggregated across the Nation's UZAs (and corrected for differences in transit demand by UZA), this source yields a national average annual growth rate of 1.4 percent over the 20-year period from 2008 to 2028. (This represents the weighted average growth rate at the national level. In practice, the ridership growth rates applied by TERM vary by UZA based on the growth projections obtained from that UZA's MPO.)

The MPO projections are considered low (or at least conservative) for the following reasons. First, MPO transit demand projections are financially constrained (i.e., projected ridership growth is limited by the expected capacity to fund expansion projects) and, hence, these projections are lower than the potential for increased ridership demand if funding were unconstrained. Second, as discussed further in Chapter 9, the historical rate of increase in transit ridership and transit passenger miles have generally exceeded MPO growth projections for these same time periods, again tending to characterize the MPO growth projections as relatively low or conservative.

High Growth Assumption

Similarly, the **High Growth scenario** provides a higher bound on the level of investment required to maintain current service performance as determined by a relatively high rate of growth in travel demand. In particular, the **High Growth scenario** relies on the trend rate of growth in transit passenger miles over the period 1999 through 2008 as reported to the NTD. When calculated across all transit operators, this historical trend rate of growth converts to a national average compound annual growth rate of 2.78 percent during this time period. Similar to the MPO growth rates in the **Low Growth scenario**, the 10-year trend growth rates applied by TERM for the **High Growth scenario** also vary by UZA either based on the actual trend rates of growth experienced by each UZA (for UZAs close to or higher than 1 million in population) or based on the average for UZAs of comparable size in the same geographic region.

This rate is considered relatively high primarily due to the unusually high rate of growth in ridership experienced over the period from roughly 2006 to 2008, partly in response to high fuel prices. The growth rate for this **High Growth scenario** is very close to double that of the **Low Growth scenario**.

Low and High Growth Scenario Needs

TERM's projected annual average capital investment needs under the **Low** and **High Growth scenarios**—including those for both asset preservation and asset expansion—is presented in *Exhibit 8-29*.

Exhibit 8-29

Low and High Growth Scenarios: Average Annual Investment by Asset Type, 2008–2028 (Billions of 2008 Dollars)

	Lower Growth (MPO; 1.4%)			Higher Growth (10-Year Trend; 2.8%)		
Asset Type	**Preservation**	**Expansion**	**Total**	**Preservation**	**Expansion**	**Total**
Rail						
Guideway Elements	$2.7	$0.7	$3.4	$2.9	$0.8	$3.7
Facilities	$1.0	$0.1	$1.1	$1.0	$0.2	$1.2
Systems	$3.1	$0.2	$3.3	$3.2	$0.2	$3.4
Stations	$1.6	$0.4	$2.0	$1.8	$0.5	$2.3
Vehicles	$1.8	$0.7	$2.4	$1.8	$1.9	$3.7
Other Project Costs	$0.0	$0.7	$0.7	$0.0	$0.8	$0.8
Subtotal Rail*	**$10.2**	**$2.6**	**$12.8**	**$10.7**	**$4.4**	**$15.0**
Nonrail						
Guideway Elements	$0.4	$0.1	$0.5	$0.5	$0.1	$0.5
Facilities	$1.4	$0.3	$1.7	$1.5	$0.6	$2.0
Systems	$0.1	$0.0	$0.2	$0.1	$0.0	$0.2
Stations	$0.0	$0.0	$0.1	$0.0	$0.0	$0.1
Vehicles	$4.3	$1.2	$5.5	$4.4	$2.2	$6.6
Other Project Costs	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Subtotal Nonrail*	**$6.3**	**$1.6**	**$7.9**	**$6.5**	**$2.9**	**$9.4**
Total Investment*	**$16.6**	**$4.2**	**$20.8**	**$17.2**	**$7.3**	**$24.5**

**Note that totals may not sum due to rounding.*

Source: Transit Economic Requirements Model.

Lower Growth Needs

Assuming the relatively low ridership growth in the **Low Growth scenario**, total investment needs for both system preservation and expansion are estimated to average roughly $20.8 billion each year for the next two decades. Of this amount, roughly 80 percent are for preservation of existing assets and close to half is associated with preservation of existing rail infrastructure alone. Note that the $1.4 billion difference between the $18.0 billion in annual preservation needs under the **SGR benchmark** and the $16.6 billion in preservation needs under the **Low Growth scenario** is entirely due to the application of TERM's benefit-cost test under the **Low Growth scenario**. Finally, expansion needs in this scenario total $4.2 billion annually, with more than half of that amount associated with rail expansion costs.

Higher Growth Needs

In contrast, total investment needs under the **High Growth scenario** are estimated to be $24.5 billion annually. This includes $17.2 billion for system preservation and an additional $7.3 billion for system expansion. Note that system preservation costs are higher under the **High Growth scenario** because the higher growth rate leads to a larger expansion of the asset base as compared to the **Low Growth scenario**. Under this scenario, investment in rail assets is still larger than that for bus expansion but both rail and non-rail continue to have roughly equal shares of the expansion total (60 percent for rail and 40 percent for non-rail). However, at the asset category level, investment requirements for additional fleet capacity appear to be greater under the **High Growth scenario** (increasing from roughly 45 percent of expansion needs under the **Low Growth scenario** to just under 60 percent in the **High Growth scenario**). Overall, total expansion investment needs are roughly 70 percent higher for the **High Growth scenario** than for the **Low Growth scenario** (despite an approximate doubling in the overall growth rate).

Impact on Conditions and Performance

The impact of the Low and High Growth Rate preservation investments on transit conditions is essentially the same as that already presented for the **SGR benchmark** in *Exhibit 8-26* and *Exhibit 8-27.* As noted above, these scenarios use the same rules to assess when assets should be rehabilitated or replaced as were applied in the **SGR benchmark** (e.g., with assets being replaced at condition rating 2.50). In terms of asset conditions, the primary difference between the **SGR benchmark** and the **Low** and **High Growth scenarios** relates to: (1) TERM's benefit-cost test not applying to the **SGR benchmark** (leading to higher SGR preservation needs overall) and (2) the **Low** and **High Growth scenarios** having some additional needs for the replacement of expansion assets with short service lives. Together, these impacts tend to work in opposite directions with the result that the rate of drawdown in the investment backlog and the elimination of assets exceeding their useful life are roughly comparable for each of these three scenarios.

Similarly, the impact of the Low and High Growth rate expansion investments on transit performance was considered in *Exhibit 8-24.* That analysis demonstrated the significant difference in the level of ridership growth supported by the **High Growth scenario** as compared with either the current level of expenditures ($5.1 billion in 2008) or the rate of growth supported under the **Low Growth scenario**.

Scenario Benefits Comparison

Finally, this subsection summarizes and compares many of the investment benefits associated with each of the four analysis scenarios considered above. While much of this comparison is based on measures already introduced above, this discussion also considers a few additional investment impact measures. These comparisons are presented in *Exhibit 8-30.* Note that the first column of data in *Exhibit 8-30* presents the current values for each of these measures (as of 2008). The subsequent columns present the estimated future values in 2028 assuming the levels, allocations, and timing of expenditures associated with each of the four investment scenarios.

Exhibit 8-30 includes the following measures:

- **Average Annual Expenditures in billions of dollars:** This amount is broken down into preservation and expansion expenditures.
- **Condition of Existing Assets:** This analysis only considers 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 life). The backlog is presented here both as a total dollar amount and also as a percent of the total replacement value of all U.S. transit assets.

  Backlog Ratio: The ratio of the current investment backlog to the annual level of investment required to maintain normal annual capital needs once the backlog is eliminated.

Exhibit 8-30

Scenario Investment Benefits Scorecard

Measure	Baseline 2008 Actual Spending, Conditions and Performance	Scenarios for 2028			
		Sustain Current Spending	SGR	Low Growth	High Growth
Average Annual Expenditures (Billions of 2008 Dollars)					
Preservation	$11.0	$11.0	$18.0	$16.6	$17.2
Expansion	$5.1	$5.1	na	$4.2	$7.3
Total	**$16.1**	**$16.1**	**$18.0**	**$20.8**	**$24.5**
Conditions (Existing Assets)					
Average Physical Condition Rating	3.78	3.38	3.59	3.57	3.58
Investment Backlog (Billions of Dollars)	$77.7	$112.5	$0.0	$0.0	$0.0
Investment Backlog (% of Replacement Costs)	11.7%	17.0%	0.0%	0.0%	0.0%
Backlog Ratio[1]	5.4	7.8	0.0	0.0	0.0
Performance					
Ridership Impacts of Expansion Investments (2028)					
New Boardings Supported by Expansion (Billions)	na	2.5	na	2.6	6.2
CO_2 Emissions Avoided (Millions of Metric Tons)	na	1.6	na	1.7	4.0
Fleet Performance					
Revenue Service Disruptions per PMT	9.6	10.5	8.6	8.6	8.6
Fleet Maintenance Cost per Revenue Vehicle Mile	$1.70	$1.76	$1.59	$1.59	$1.59
Other Benefits					
Job Years Impact (Thousands)[2]					
Operating and Maintenance	1,201.7	1,554.5	1,201.7	1,590.8	1,945.1
Capital	257.6	257.6	288.0	332.8	392.0
Total Annual Job Years Supported	1,459.3	1,812.1	1,489.7	1,923.6	2,337.1
GDP Impact (Billions of Dollars)					
Operating and Maintenance	$71.1	$92.0	$71.1	$94.1	$115.1
Capital	$21.5	$21.5	$24.0	$27.7	$32.7
Total Annual Incremental Impact	$92.6	$113.4	$95.1	$121.8	$147.7

[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.*

[2] *Includes direct, indirect, and induced impacts.*

- **Performance Measures:** The impact of investments on U.S. transit ridership capacity and system reliability.

  New Boardings Supported by Expansion Investments: The number of additional riders that transit systems can carry without a loss in performance (given the projected ridership assumptions for each scenario).

  Carbon Dioxide (CO_2) Emissions Avoided (millions of metric tons): Potential reduction in CO_2 emissions from providing the additional transit rider carrying capacity (assumes that riders would otherwise use other modes of travel, including automobiles).

Revenue Service Disruptions per Passenger Mile Travelled: Number of disruptions to revenue service per million passenger miles.

Fleet Maintenance Cost per Revenue Vehicle Mile: Fleet maintenance costs tend to increase with fleet age (or reduced asset condition). This measure estimates the change in fleet maintenance costs expressed in a per-revenue-vehicle-mile basis.

- **Other Benefits:** Impacts other than those to transit conditions and performance. The jobs and Gross Domestic Product (GDP) impacts considered here were determined using an input-output analysis.

  Jobs Impacts: The number of job years associated with both transit mode operations and ongoing capital investment (both preservation and expansion), including direct, indirect and induced job years. Each $1 million invested in transit operation activities is estimated to support 33 job years while each $1 million invested in transit capital investments supports 16 job years.

  GDP Impacts: The impact on GDP associated with both transit mode operations and ongoing capital investment (both preservation and expansion), including direct, indirect and induced impacts. Each $1 invested in transit operation activities is estimated to generate $0.95 in additional GDP while each $1 invested in transit capital investments generates $0.33 in additional GDP.

Scorecard Comparisons

A review of the scorecard results for each of the four investment scenarios reveals the impacts discussed below.

Preservation Impacts

Continued reinvestment at the 2008 level is likely to yield a decline in overall asset conditions, an increase in the size of the investment backlog, and an increase in both service disruptions per million passenger miles and in maintenance costs per revenue vehicle mile. In contrast, with the exception of overall asset conditions, each of these measures is projected to improve under the **SGR, Low Growth, and High Growth scenarios**, each of which project roughly comparable levels of required capital reinvestment expenditures. Note that the overall condition rating measure of roughly 3.6 under these last three investment scenarios represents a sustainable, long-term condition level for the Nation's existing transit assets over the long term (in contrast to the current measure of roughly 3.8, which would be difficult to maintain in the long term without replacing many asset types prior to the conclusion of their expected useful lives).

Expansion Impacts

While continued expansion investment at the 2008 level appears sufficient to support a relatively low rate of increase in transit ridership, recent historical rates of growth suggest that a significantly higher rate of expansion investment is required to avoid a decline in overall transit performance (e.g., in the form of increased crowding on high utilization systems). Higher rates of transit expansion investment, as required to support higher transit ridership growth or through a shift from auto travel to transit, can also help yield reductions in CO_2 emissions. Finally, higher rates of expansion investment also tend to support higher direct, indirect and induced impacts on jobs and other economic activity related to transit operations, construction, and rehabilitation activities.

Chapter 9

Supplemental Scenario Analysis

Highway Supplemental Scenario Analysis

This section explores the implications of the investment scenarios considered in Chapter 8 and of scenarios with alternative assumptions about investment-related policies. Differences in the level and composition of investment between the Chapter 8 scenarios for the projection period (2009–2028) and patterns in the base year (2008) are compared for potential insights into the recent trends in highway conditions and performance reported in Chapters 3 and 4. The scenario projections for investment are also compared with those presented in previous editions and converted from real to nominal dollars, taking account of inflation. This section includes a comparison of the long-term projections from two previous editions, the 1989 C&P Report and the 1999 C&P Report, with actual changes to the condition and performance of the highway system over time.

This section also explores alternative assumptions concerning the timing of investment over the 20-year projection period and identifies the initial backlog of cost-beneficial highway and bridge investments as of the 2008 base year. In addition, this section examines the potential impact on future vehicle miles traveled (VMT), capital investment needs, and overall system performance of several variations to the policy assumptions underlying the scenarios in Chapter 8, including:

- Setting the target of the **Maintain Conditions and Performance scenario** on individual components of the highways system rather than the system as a whole.
- Financing the increase in scenario projections for spending relative to base year spending through increases in user charges, including flat rate surcharges assessed on a per-mile or per-gallon basis, and peak-period congestion charges.
- Accelerating the deployment of intelligent transportation systems (ITSs) and operations strategies
- Implementing alternative bridge management strategies.

Comparison of Scenarios With Previous Reports

The **Maintain Conditions and Performance scenario** presented in this report is generally comparable to the fixed-rate financing version of the **Sustain Conditions and Performance scenario** presented in the 2008 C&P Report. The two key differences are in the portion of the scenario derived from the Highway Economic Requirements System (HERS) model. First, the revised scenario targets average speed rather than adjusted average user costs. Second, the revised scenario makes no assumption about how the increased investment needed to support the scenario would be generated, whereas the scenario in the 2008 C&P Report assumed that this funding gap would be covered by a flat-rate surcharge per VMT. The **Improve Conditions and Performance scenario** presented in this edition of the C&P report is generally comparable to the MinBCR=1.0 scenario with fixed-rate user financing that was presented in the 2008 edition, except that the revised scenario in this edition makes no assumption about financing mechanisms. The potential impacts of alternative financing mechanisms are explored later in this chapter. It should also be noted that the values reported in the 2008 C&P Report were stated in constant 2006 dollars and that the scenarios covered the period from 2007 to 2026; in contrast, the scenarios presented in this report are stated in constant 2008 dollars and cover the period from 2009 to 2028.

As discussed in Chapter 6, highway construction costs as measured by the Federal Highway Administration's (FHWA's) new National Highway Construction Cost Index decreased by 3.4 percent between 2006 and 2008. Consequently, adjusting the 2008 C&P Report's scenario figures from 2006 dollars to 2008 dollars causes them to appear smaller. As shown in *Exhibit 9-1,* the 2008 C&P Report estimated the average annual investment level in the scenario comparable to the current **Maintain Conditions and Performance scenario** at $105.6 billion; adjusting for inflation (actually deflation) decreases this amount to $102.0 billion in 2008 dollars. The comparable amount for the **Maintain Conditions and Performance scenario** presented in Chapter 8 of this edition is $101.0 billion, approximately 1.0 percent lower.

Exhibit 9-1

Selected Highway Investment Scenario Projections Compared With Comparable Data From the 2008 C&P Report (Billions of Dollars)

	2007–2026 Projection (Based on 2006 Data)		**2009–2028 Projection (Based on 2008 Data) (Billions of 2008 Dollars)**
Highway and Bridge Scenarios—All Roads	**2008 C&P Report (Billions of 2006 Dollars)**	**Adjusted for Inflation [1] (Billions of 2008 Dollars)**	
Maintain Conditions and Performance scenario [2]	$105.6	$102.0	$101.0
Improve Conditions and Peformance scenario [3]	$174.6	$168.6	$170.1

[1] The investment levels for the highway and bridge scenarios were adjusted for inflation using the FHWA National Highway Construction Cost Index (NHCCI).

[2] The $105.6 billion figure from the 2008 C&P Report is from the "Sustain Conditions and Performance Scenario Assuming Fixed Rate User Financing." The HERS component of that scenario focused on maintaining adjusted average user costs, rather than maintaining average speed.

[3] The $174.6 billion figure from the 2008 C&P Report is from the "MinBCR=1.0 Scenario Assuming Fixed Rate User Financing."

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

Q&A

How did the change in the scenario target measure for the Maintain Conditions and Performance scenario affect its average annual investment level?

As referenced in Chapter 8, the **Maintain Conditions and Performance scenario** in this report targeted maintaining average speed in 2028 at base year 2008 levels. The comparable scenario from the 2008 C&P Report had instead targeted maintaining adjusted average user costs in 2026 at base year 2006 levels in constant dollar terms.

Based on information presented in Chapter 7 (see *Exhibit 7-10*) and the scenario computation methods described in Chapter 8 (see *Exhibit 8-8*), the average annual investment level for the **Maintain Conditions and Performance scenario** would have been approximately $1.0 billion lower ($100.0 billion rather than $101.0 billion, stated in constant 2008 dollars) if adjusted average user costs had been used as the target measure in this report rather than average speed. As shown in *Exhibit 9-1*, the comparable figure presented in the 2008 C&P Report was $105.8 billion (stated in constant 2006 dollars).

The average annual investment level in the 2008 C&P Report scenario comparable to the current **Improve Conditions and Performance scenario** was $174.6 billion; adjusting for inflation decreases this amount to $168.6 billion in 2008 dollars. The comparable amount for the current **Improve Conditions and Performance scenario** presented in Chapter 8 of this edition is $170.1 billion, approximately 0.8 percent higher.

The relatively small changes between the scenario findings in this report relative to the 2008 C&P Report are attributable both to changes in the underlying characteristics, conditions and performance of the highway system reported in Chapters 2, 3, and 4, and to changes in the methodology and models used to generate the estimates. The changes in the scenario definitions noted above had a small impact; the changes in the HERS and National Bridge Investment Analysis System (NBIAS) models were relatively minor for this edition compared with previous editions. Appendices A and B include additional information on these two models.

Comparisons of Implied Funding Gaps

Exhibit 9-2 compares the estimated percentage differences of current spending and the average annual investment scenario estimates for the **Maintain Conditions and Performance scenario** and the **Improve Conditions and Performance scenario** with the comparable estimated percentage differences identified in previous C&P reports. For each of the reports identified, actual spending in the base year for that report has been below the estimate of the average annual investment level required to maintain conditions and performance at base-year levels over 20 years. In the current report, the gap between these amounts, 10.8 percent, is smaller than in the 2008 C&P Report, which stems partly from the decrease in highway construction costs since 2006 discussed above, and from the increase in spending by all levels of government combined between 2006 and 2008 (as identified in Chapter 6). A 10.8 percent gap is more consistent with the corresponding estimate in the 2004 and 2006 editions of the C&P report. The same is true for the 86.6-percent gap between 2008 spending and the average annual investment level in the **Improve Conditions and Performance scenario** in the present edition.

Exhibit 9-2

Average Annual Highway and Bridge Investment Scenario Estimates Versus Current Spending, 1997 to 2010 C&P Reports

		Percent Above Current Spending	
Report Year	Relevant Comparison	Primary "Maintain" Scenario*	Primary "Improve" Scenario*
1997	Average annual investment scenario estimates for 1996–2015 compared with 1995 spending	21.0%	108.9%
1999	Average annual investment scenario estimates for 1998–2017 compared with 1997 spending	16.3%	92.9%
2002	Average annual investment scenario estimates for 2001–2020 compared with 2000 spending	17.5%	65.3%
2004	Average annual investment scenario estimates for 2003–2022 compared with 2002 spending	8.3%	74.3%
2006	Average annual investment scenario estimates for 2005–2024 compared with 2004 spending	12.2%	87.4%
2008	Average annual investment scenario estimates for 2007–2026 compared with 2006 spending	34.2%	121.9%
2010	Average annual investment scenario estimates for 2009–2028 compared with 2008 spending	10.8%	86.6%

** 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 between reports. The values shown for this report reflect the Maintain Conditions and Performance and the Improve Conditions and Performance scenarios.*

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

Changes in the actual capital spending by all levels of government combined can substantially alter these spending "gaps," as can sudden, large swings in construction costs such as the large increase experienced between 2004 and 2006. However, **the differences among C&P report editions in the implied gaps**

reported in *Exhibit 9-2* are not a consistent indicator of changes over time in how effectively highway investment needs are being addressed. The FHWA continues to enhance the methodology used to determine scenario estimates for each edition of the C&P report in order to provide a more comprehensive and accurate assessment. In some cases, these refinements have increased the level of investment in one or both of the scenarios (the "Maintain" or "Improve" scenarios, or their equivalents); other refinements have reduced this level.

Comparison of 1989 C&P Report Scenario Projections for 2005 With Actual Condition and Performance in 2005

The highway component of the C&P report is part of a series dating back to the 1968 *National Highway Needs* report to Congress. It is challenging to directly compare the results of different editions over time for many reasons, including differences in base year conditions and analysis periods, changes in analytical models, and changes in scenario definitions. However, comparing the long-term scenario projections from previous editions with what actually occurred in terms of system conditions and performance is a useful exercise that can be of assistance in putting the scenario findings from this edition into the proper perspective. The 1989 *Status of the Nation's Highways and Bridges: Condition and Performance and Highway Bridge Replacement and Rehabilitation Program* report to Congress (1989 C&P Report) is the most recent edition for which the period of the long-term capital investment scenarios has ended, and thus represents a useful document for comparative analysis.

Differences in 1989 C&P Report Scenario Design and Construction

In order to evaluate the 1989 C&P Report's scenarios, it is important to note certain critical differences from those presented in the current edition. The current edition relies primarily on 2008 data, includes 20-year capital investment scenarios covering investment for the period 2009 through 2028, and includes "Maintain" scenarios that estimate the costs of maintaining conditions and performance at base year 2008 levels through 2028. In contrast, although the 1989 C&P Report relied primarily on 1987 data, its "Maintain" scenarios focused on maintaining conditions and performance at 1985 levels through 2005. Further, the 1989 C&P Report's capital investment scenarios included spending for the period 1987 through 2005 (a 19-year period which included the 1987 base year, a year that had already passed).

Another key difference between the current edition and the 1987 C&P Report is in the coverage of the capital investment scenarios. The current edition includes rough estimates for functional classes for which data are not available in the Highway Performance Monitoring System (HPMS), so that the systemwide versions of the scenarios include needs associated with all roads and bridges. In contrast, the 1987 C&P Report's highway investment scenarios explicitly excluded roads functionally classified as rural local or urban local (though bridges on these functional systems were included).

The HERS model was first utilized in the 1995 C&P Report and the NBIAS model made its debut in the 2002 C&P Report; the scenarios presented in the 1989 C&P Report were based on older tools that placed more emphasis on engineering criteria and less on economic considerations.

1989 C&P Report Scenario Definitions

The 1989 C&P Report presented three primary scenarios (identified as "investment strategies" in the document) for highways and bridges.

The **Constrained Full Needs** scenario estimated the investment levels required to address all existing and projected future highway and bridge deficiencies through the year 2005. Deficiencies were identified by comparing simulated conditions and performance against an established set of minimum conditions standards. The 1989 C&P Report noted that these standards were set well below full design standards for new roads, so that the resulting system would not be in perfect condition. The word "constrained" in the scenario title related to the treatment of capacity improvements. If the data reported in the HPMS for a particular highway segment indicated that there was no room within the existing right of way for additional through lanes, no expansion options were considered, regardless of how congested the facility might become. The document specifically noted that overall operational performance was expected to get worse in urban areas under this scenario.

The **Maintain Overall 1985 Conditions scenario** estimated the cost to maintain the highway system at 1985 levels through 2005, based on a composite rating taking into account service, safety, and condition measures. In general, the scenario provided for some improvement in highway physical conditions while resulting in some deterioration in operational performance. Specifically, the document notes that operational performance would decline on both the rural and urban components of the Interstate System. (The bridge investment requirements included in this scenario were identical to those included in the **Constrained Full Needs scenario** because a new bridge model had just been adopted that was not yet considered sufficiently robust to support a separate "Maintain" analysis.)

The Maintain System Performance scenario focused on identifying the predominant purpose that individual functional systems serve and estimating the cost of sustaining effective delivery of that function through the year 2005. For instance, on the higher functional systems, maintaining service and safety was considered to be the priority; the level of service, a measure of peak-period congestion, was used to simulate the service characteristics on the higher-level systems. For other roads, the composite index of maintaining safety, condition, and performance was utilized. The document notes that, despite the increased emphasis on operational performance under this scenario, congestion was still projected to get worse, as no widening options were considered outside of the existing right of way. (The bridge investment requirements included in this scenario were identical to those included in the **Constrained Full Needs scenario**.) Although the **Maintain System Performance scenario** was presented as a theoretical refinement to the approach taken in the **Maintain Overall 1985 Conditions scenario** (which was more consistent with previous editions), the average annual investment levels associated with the two scenarios were very close because neither included potential higher-cost capacity expansion options such as building parallel routes, double-decking, tunneling, or investing in alternative transportation modes.

The composite average annual VMT growth rate derived from the HPMS forecasts of future VMT through 2005 was 2.34 percent per year. For the highway components of each scenario, two alternative versions were developed, one assuming an average annual VMT growth rate of 2.0 percent and one assuming 3.0 percent annual VMT growth. The actual VMT growth rate for the period 1987 through 2005 was 2.52 percent, which is conveniently near the midpoint of these two alternative scenario assumptions. For the bridge components of each scenario, the average annual growth rate of 2.34 percent taken from HPMS was utilized.

Comparison of 1989 C&P Report Scenarios With Actual Spending

Exhibit 9-3 shows the estimated average annual and cumulative 19-year highway and bridge needs associated with each of the scenarios presented in the 1989 C&P Report. The cumulative values are also adjusted for inflation to 2008 dollars using the FHWA Composite Bid Price Index (BPI) through the year 2006 and the new FHWA National Highway Construction Cost Index (NHCCI) for subsequent years.

Exhibit 9-3

Primary 1989 C&P Report Investment Scenario Estimates Versus Cumulative Spending, 1987 Through 2005

	1987–1995 Projection From 1989 C&P Report		Adjusted for Inflation
	Average Annual (Billions of 1987 Dollars)	Cumulative 19 Years (Billions of 1987 Dollars)	Cumulative 19 Years (Billions of 2008 Dollars)
Scenarios Assuming 3.0 Percent Annual VMT Growth			
Cost to Maintain 1985 Overall Conditions	$28.8	$546.8	**$1,169.3**
Cost to Maintain 1985 System Peformance	$28.7	$545.6	$1,166.7
Constrained Full Needs	$39.4	$748.5	**$1,600.6**
Scenarios Assuming 2.0 Percent Annual VMT Growth			
Cost to Maintain 1985 Overall Conditions	$25.1	$476.0	**$1,017.9**
Cost to Maintain 1985 System Peformance	$25.1	$476.0	$1,017.9
Constrained Full Needs	$34.7	$658.4	**$1,407.9**
Actual Highway Capital Outlay, Adjusted to 2008 Dollars [1]			
Cumulative Capital Outlay, 1987 through 2005 [2]			$1,562.8
Estimated Capital Outlay on Comparable Facilities [3]			**$1,257.2**

[1] VMT grew at an average annual rate of 2.52 percent between 1987 and 2005.

[2] Highway capital outlay by all levels of government combined totaled $1,210.5 billion in nominal dollar terms over the 19-year period from 1987 through 2005. This equates to $730.8 billion in constant 1987 dollars or $1,562.8 billion in constant 2008 dollars.

[3] An estimated 80.4 percent of highway capital spending from 1997 through 2005 was directed toward arterials and collectors covered by the 1989 C&P Report investment scenarios. This equates to $587.9 billlion in constant 1987 dollars or $1,257.2 billion in constant 2008 dollars.

Sources: 1989 Status of the Nation's Highways and Bridges: Conditions and Performance Report to Congress, page 112; Highway Statistics, various years, Tables HF-10A, HF-10, PT-1, and SF-12A; and unpublished FHWA data.

The average annual highway capital investment needs reported for the **Maintain 1985 Overall Conditions scenario** ranged from $25.1 billion to $28.8 billion in constant 1987 dollars, depending on whether future average annual VMT growth was assumed to be 2.0 percent or 3.0 percent. Cumulative 19-year needs for the period from 1987 through 2005 were identified as $476.0 billion to $546.8 billion in constant 1987 dollars; this equates to $1.0179 trillion to $1.1667 trillion in constant 2008 dollars. The investment needs associated with the **Maintain System Performance scenario** were very similar because the limitations on capacity expansion assumed in both scenarios tended to overwhelm the differences in their theoretical approaches.

The average annual highway capital investment needs reported for the **Constrained Full Needs scenario** ranged from $34.7 billion to $39.4 billion in constant 1987 dollars, depending on whether future average annual VMT growth was assumed to be 2.0 percent or 3.0 percent. Cumulative 19-year needs for the period from 1987 through 2005 were identified as $658.4 billion to $748.5 billion in constant 1987 dollars; this equates to $1.4079 trillion to $1.6006 trillion in constant 2008 dollars.

Actual highway capital spending by all levels of government from 1987 through 2005 totaled $1.2105 trillion in nominal dollar terms; this equates to $1.5628 trillion in constant 2008 dollars. Of this total, approximately 80.4 percent, or $1.2572 trillion in constant 2008 dollars was directed towards the types of facilities (arterials and collectors) reflected in the 1989 C&P Report scenarios; the remaining 19.6 percent was directed to roads functionally classified as rural local or urban local.

In constant dollar terms, actual highway capital spending for the 19-year period from 1987 through 2005 was 7.5 percent higher than the version of the **Maintain 1985 Overall Conditions scenario** assuming 3.0 percent annual VMT growth and 23.5 percent higher than the version assuming 2.0 percent annual VMT growth. In contrast, cumulative 19-year spending was 10.7 percent below the version of the **Constrained Full Needs scenario** assuming 2.0 percent annual VMT growth and 21.5 percent lower than the version assuming 3.0 percent annual VMT growth. To the extent that the 1989 C&P Report scenario projections were accurate, this would suggest that the outcomes in terms of system conditions and performance in 2005 should have been better than what was projected for the **Maintain 1985 Overall Conditions scenario**, but worse than what was projected for the **Constrained Full Needs scenario**.

Comparison of 1989 C&P Report Projections With Actual Outcomes

The pavement condition data shown in the 1989 C&P Report was based on the Present Serviceability Rating (PSR) data reported by the States. As discussed in Chapter 3, the PSR is a subjective measure of overall pavement quality. FHWA has subsequently adopted the International Roughness Index (IRI), a mechanically measured indicator of pavement ride quality, as its primary performance measure. States are still permitted to provide PSR data for some functional classes; in such cases, the PSR values are converted to IRI equivalents for reporting purposes in Chapter 3. The information presented in *Exhibit 9-4* was developed in a similar manner, with PSR values from 1985 converted to their IRI equivalents and reported using terminology consistent with Chapter 3.

Actual capital spending in constant dollars over the 19-year period from 1987 through 2005 was higher than the investment levels associated with the **Maintain 1985 Overall Conditions scenario**, which suggests that some improvements to pavement conditions should have been achieved. As shown in *Exhibit 9-4*, pavement conditions have generally improved over this period. The percentage of arterial and collector pavements with "acceptable" ride quality increased from 88.6 percent in 1985 to 94.0 percent in 2005, while the percentage of pavements with "good" ride quality increased from 39.7 percent to 43.2 percent. (It should be noted that this overall improvement was driven primarily to improvements in the quality of rural pavements because the percentage of urban pavements in both the "good" and "acceptable" categories declined from 1985 to 2005.)

Exhibit 9-4

Percent of Mileage With Good and Acceptable Ride Quality, by Functional System, for 1985 and 2005

	Percent Good	
Functional System	**1985**	**2005**
Rural Interstate	59.6%	75.1%
Rural Principal Arterial	49.1%	63.7%
Rural Minor Arterial	42.6%	52.5%
Rural Major Collector	30.3%	35.2%
Subtotal Rural	**39.7%**	**44.9%**
Urban Interstate	55.8%	57.8%
Urban Other Freeway & Expressway	51.0%	47.2%
Urban Other Principal Arterial	44.3%	25.2%
Urban Minor Arterial	39.5%	31.8%
Urban Collector	32.5%	30.9%
Subtotal Urban	**39.7%**	**32.1%**
Total Good *	**39.7%**	**43.2%**

	Percent Acceptable	
Functional System	**1985**	**2005**
Rural Interstate	93.0%	98.3%
Rural Principal Arterial	92.6%	99.1%
Rural Minor Arterial	90.9%	97.1%
Rural Major Collector	75.0%	93.5%
Subtotal Rural	**88.4%**	**95.2%**
Urban Interstate	93.4%	93.8%
Urban Other Freeway & Expressway	95.4%	96.2%
Urban Other Principal Arterial	91.9%	81.4%
Urban Minor Arterial	88.9%	87.6%
Urban Collector	85.1%	83.2%
Subtotal Urban	**89.4%**	**85.4%**
Total Acceptable *	**88.6%**	**94.0%**

** 1985 values primarily reflect PSR data; 2005 values reflect a mix of PSR and IRI data.*

Source: Highway Statistics 1985 and Highway Statistics 1995, Tables HM-63 and HM-64.

Exhibit 9-5

Systemwide Bridge Deficiencies, 1986 and 2006

	1986	2006
Structurally Deficient	22.9%	12.6%
Functionally Obsolete	19.5%	15.0%
Total Deficient	**42.3%**	**27.6%**

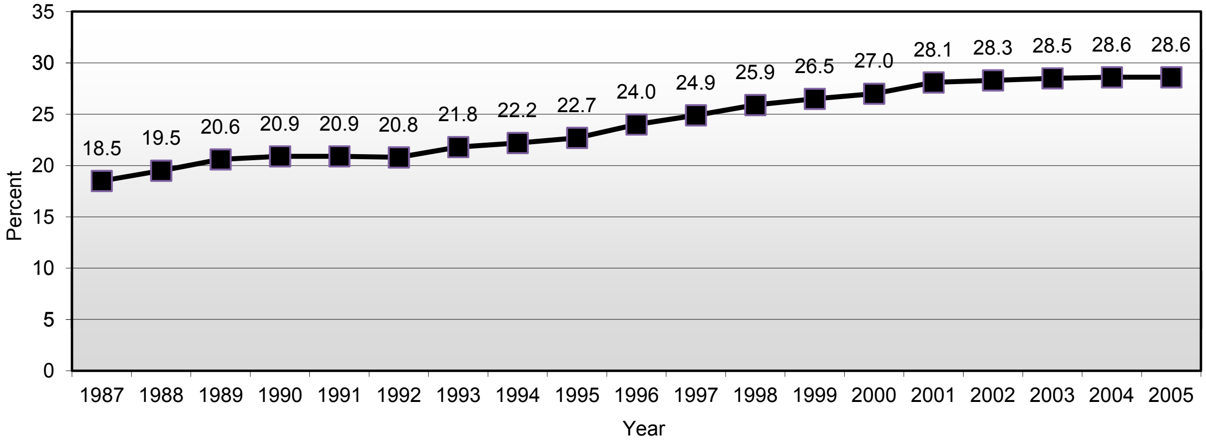
Source: National Bridge Inventory.

Due to the timing of data availability, the bridge data in the C&P report has typically run a year ahead of the pavement data. *Exhibit 9-5* compares the percent of deficient bridges in 1986 with that in 2006. During this period, the percentage of bridges classified as functionally deficient declined from 22.9 percent to 12.6 percent, and the percentage of bridges classified as functionally obsolete declined from 19.5 percent to 15.0 percent (Chapter 3 includes definitions of these terms). These reductions in bridge deficiencies represent a significant improvement to the state of the Nation's bridges; this is consistent with actual capital spending in constant dollars over the 19-year period from 1987 through 2005 having been higher than the investment levels associated with the **Maintain 1985 Overall Conditions scenario**.

The 1989 C&P Report discussed operational performance using measures such as volume/capacity ratios. Such measures are not directly consistent over time because the theoretical capacity of different roadway types has been updated periodically to reflect changes in driver behavior and other factors. Although the statistics presented in Chapter 4 based on analysis by the Texas Transportation Institute (TTI) had not yet been developed at that time, TTI has computed data on a consistent basis back to 1987 to facilitate comparisons over time. *Exhibit 9-6* shows that the percentage of travel occurring under congested conditions rose from 18.5 percent in 1987 to 28.6 percent in 2008. This increase is very significant and has resulted in a significant increase in the costs experienced by travelers in the form of wasted fuel and time. The 1989 C&P Report was very explicit about expected increases in highway congestion and delay even if investment had reached the level of the **Constrained Full Needs scenario**. Because actual capital spending in constant dollars over the 19-year period from 1987 through 2005 fell well below the level of this scenario, it is not surprising that congestion increased significantly over this period.

Exhibit 9-6

Average Daily Percentage of VMT Under Congested Conditions for All Urbanized Areas, 1987–2005



Source: Texas Transportation Institute.

Comparison of 1999 C&P Report Scenario Projections for 2017 With Actual Condition and Performance Through 2008

The scenario projections from the 1999 C&P Report extended from a base year of 1997 through the year 2017. While it is too early to make a definitive assessment of these 20-year forecasts, it is possible to draw some initial conclusions based on changes in conditions and performance that have occurred through 2008, the 11th year of this forecast period.

Unlike the 1989 C&P Report, the general approach for developing the investment scenarios for the 1999 C&P Report was similar to the approach in the current report. The 1999 C&P Report relied on 1997 base year data, and its 20-year scenarios projected the impact of investment for 1998 through 2017; the "Maintain" scenarios presented in the 1999 C&P Report focused on maintaining measures of conditions and performance at base year 1997 levels through 2017.

The coverage of the 1999 C&P investment scenarios also is similar to the current edition in that they include estimates for types of highway capital improvements that were not captured through the analytical models. Consequently, when comparing actual highway capital spending with the investment scenarios, it is not necessary to deduct a percentage of spending to align with the scope of the scenarios, as was the case in the discussion of the 1989 C&P Report presented earlier.

The investment requirements associated with the primary scenarios are broken down into three major categories—System Preservation, System Expansion, and System Enhancements—that roughly correspond to the categories presented in the current edition. The HERS model was used in the development of the highway components of the 1999 C&P Report, although the bridge analysis relied on an older model that did not incorporate the economic considerations built into the NBIAS model used in the current report.

1999 C&P Report Scenario Definitions

The 1999 C&P Report presented two main scenarios for highways and bridges, supplemented by two "benchmarks" defined around their highway components.

The **Cost to Improve Highways and Bridges** combined the investment levels associated with a **Maximum Economic Investment scenario** for highways with an **Eliminate Deficiencies scenario** for bridges. This costs associated with the highway component of this scenario were estimated to be sufficient to implement all potential highway improvements identified by HERS with a benefit-cost ratio (BCR) greater than or equal to 1.0. The costs associated with the bridge component of this scenario were estimated to be sufficient to fully address the existing backlog of bridge investments, and to correct other bridge deficiencies projected to develop over the next 20 years. (This scenario is very similar in definition to the **Improve Conditions and Performance scenario** in the current edition, except that the bridge analysis did not apply benefit-cost criteria in computing the backlog of bridge investments.) At this level of investment, key performance indicators such as pavement condition, travel time, and total highway user costs were all projected to improve.

The **Cost to Maintain Highways and Bridges** combined the investment levels associated with a **Maintain Conditions scenario** for highways with a **Maintain Backlog scenario** for bridges. The costs associated with the highway component of this scenario were estimated to be sufficient to implement all potential highway improvements identified by HERS with a BCR greater than or equal to 2.33, which were projected to result in average pavement conditions in 2017 that matched those in the 1997 base year. The costs associated with the bridge component of this scenario were estimated to be sufficient to keep the overall backlog of bridge investments in 2017 from growing larger than the amount computed for the 1997 base year. At this level of investment, travel time and total highway user costs were projected to rise, reflecting a deterioration in systemwide operational performance.

Similar to the **Maintain Condition scenario** for highways, the **Maintain User Cost benchmark** and **Maintain Travel Time benchmark** were developed by progressively increasing the minimum BCR cutoff point above 1.0 so that fewer potential highway investments would be undertaken until the point where the particular indicator targeted would be maintained at the 1997 level on average over the 20-year period through 2017. The costs associated with the **Maintain User Cost benchmark** were estimated to be sufficient to implement all potential highway improvements identified by HERS with a BCR greater than or equal to 2.15; at this level of investment, average user costs were projected to remain steady over 20 years while average pavement conditions improved and average operational performance declined. The costs associated with the **Maintain Travel Time benchmark** were estimated to be sufficient to implement all potential highway improvements identified by HERS with a BCR greater than or equal to 1.50; at this level of investment, average travel time costs were projected to remain steady over 20 years while average pavement conditions improved and average highway user costs were reduced. Although these two benchmarks did not formally include a bridge component, investment levels for bridges were interpolated between those computed for the two main scenarios in order to produce combined highway and bridge needs estimates that could be more readily compared to combined highway and bridge capital spending figures.

Comparison of 1999 C&P Report Scenarios With Actual Spending

Exhibit 9-7 shows the estimated average annual highway and bridge needs associated with the scenarios and benchmarks presented in the 1999 C&P Report for the 20-year period ending in 2017, stated in constant 1997 dollars; these average annual values are converted to cumulative 11-year values in 1997 dollars for the period ending in 2008. The cumulative 11-year values are also adjusted for inflation to 2008 dollars, using the FHWA BPI through the year 2006, and the new FHWA NHCCI for subsequent years.

The average annual **Cost to Maintain Highways and Bridges** was identified as $56.6 billion in constant 1997 dollars in the 1999 C&P Report; over 11 years, this equates to $623.0 billion in constant 1997 dollars or $1.0201 trillion in constant 2008 dollars. Actual highway capital spending by all levels of government

Exhibit 9-7

1999 C&P Report Investment Scenario Estimates Versus Cumulative Spending, 1998 Through 2008

	1998–2017 Projection From 1999 C&P Report		Adjusted for Inflation
	Average Annual Over 20 Years (Billions of 1997 Dollars)	Cumulative for First 11 Years Through 2008 (Billions of 1997 Dollars)	Cumulative for First 11 Years Through 2008 (Billions of 2008 Dollars)
Cost to Maintain Highways and Bridges	$56.6	$623.0	**$1,020.1**
Maintain User Costs Benchmark [1]	$60.1	$661.5	$1,083.2
Maintain Travel Time Benchmark [1]	$76.3	$838.9	$1,373.6
Cost to Improve Highways and Bridges	$94.0	$1,033.6	**$1,692.4**
Actual Highway Capital Outlay, Adjusted to 2008 Dollars [2]			**$1,029.2**

[1] The 1999 C&P Report defined these benchmarks in terms of highway performance only, but interpolated a separate bridge component to facilitate comparisons with combined highway and bridge spending.

[2] Highway capital outlay by all levels of government combined totaled $782.4 billion in nominal dollar terms over the 11-year period from 1998 through 2008. This equates to $628.5 billion in constant 1987 dollars or $1,029.2 billion in constant 2008 dollars.

Sources: 1999 Status of the Nation's Highways, Bridges and Transit: Conditions and Performance report to Congress, Exhibit 9-4, Highway Statistics, various years, Tables HF-10A, HF-10, PT-1, and SF-12A; and unpublished FHWA data.

combined from 1998 through 2008 totaled $782.4 billion in nominal dollar terms; this equates to $1.0292 trillion in constant 2008 dollars, which is 0.9 percent higher than the **Cost to Maintain Highways and Bridges** level.

The average annual cost associated with the **Maintain User Costs benchmark** (including an interpolated bridge figure) was identified as $60.1 billion in constant 1997 dollars in the 1999 C&P Report; over 11 years, this equates to $661.6 billion in constant 1997 dollars or $1.0832 trillion in constant 2008 dollars. Actual highway capital outlay from 1998 through 2008 ($1.0292 trillion in constant 2008 dollars) would have had to have been 5.0 percent higher in constant dollar terms in order to have reached the level for this benchmark.

The average annual cost associated with the **Maintain Travel Time benchmark** (including an interpolated bridge figure) was identified as $76.3 billion in constant 1997 dollars in the 1999 C&P Report; over 11 years, this equates to $838.9 billion in constant 1997 dollars or $1.3736 trillion in constant 2008 dollars. Actual highway capital outlay from 1998 through 2008 ($1.0292 trillion in constant 2008 dollars) would have had to have been 25.1 percent higher in constant dollar terms in order to have reached the level for this benchmark.

The average annual **Cost to Improve Highways and Bridges** was identified as $94.0 billion in constant 1997 dollars in the 1999 C&P Report; over 11 years, this equates to $1.0336 trillion in constant 1997 dollars or $1.6924 trillion in constant 2008 dollars. Actual highway capital outlay from 1998 through 2008 ($1.0292 trillion in constant 2008 dollars) would have had to have been 39.2 percent higher in constant dollar terms in order to have reached the **Cost to Improve Highways and Bridges** level.

Exhibit 9-8

Percent of VMT on Pavements With Good and Acceptable Ride Quality, by Functional System, 1997 and 2008

	Percent Good	
Functional System	**1997**	**2008**
Rural Interstate	56.5%	79.0%
Rural Principal Arterial	47.0%	68.4%
Rural Minor Arterial	43.8%	56.2%
Rural Major Collector	41.9%	39.0%
Subtotal Rural	**47.9%**	**62.5%**
Urban Interstate	36.3%	55.7%
Urban Other Freeway & Expressway	28.0%	44.4%
Urban Other Principal Arterial	27.1%	26.9%
Urban Minor Arterial	41.1%	32.5%
Urban Collector	39.3%	31.5%
Subtotal Urban	**34.1%**	**38.9%**
Total Good *	**39.4%**	**46.4%**

	Percent Acceptable	
Functional System	**1997**	**2008**
Rural Interstate	95.7%	97.3%
Rural Principal Arterial	93.8%	97.6%
Rural Minor Arterial	92.1%	94.5%
Rural Major Collector	87.3%	88.3%
Subtotal Rural	**92.5%**	**94.8%**
Urban Interstate	88.5%	91.9%
Urban Other Freeway & Expressway	87.2%	91.4%
Urban Other Principal Arterial	74.4%	72.4%
Urban Minor Arterial	83.4%	75.5%
Urban Collector	83.6%	72.0%
Subtotal Urban	**82.7%**	**81.0%**
Total Acceptable *	**86.4%**	**85.4%**

** Totals shown reflect Federal-aid highways only and exclude roads classified as rural minor collector, rural local, or urban local, for which pavement data are not reported in HPMS.*

Source: Highway Performance Monitoring System as of December 2009.

Comparison of 1999 C&P Report Projections With Actual Outcomes

Actual capital spending in constant dollars over the 11-year period from 1998 through 2008 was 0.9 percent higher than the investment levels associated with the **Cost to Maintain Highways and Bridges,** suggesting that some small improvements to pavement and bridge conditions should have been achieved. Actual constant dollar spending was significantly lower than the investment levels associated with the **Maintain Travel Time benchmark** over this period, suggesting that operational performance should have gotten worse.

Based on the HPMS sample sections evaluated by HERS, average IRI improved slightly from 1997 to 2008, from a value of 115.0 to 114.4 (the former value was not identified in the 1999 C&P Report itself, but was used in the computation of projected changes in average IRI that were reported). As illustrated in *Exhibit 9-8*, changes in pavement ride quality varied by functional class. Although the percentage of travel on pavements with good ride quality increased from 39.4 percent in 1997 to 46.4 percent in 2008, the portion of travel meeting this criteria declined for rural major collectors, urban other principal arterials, and urban collectors. In contrast, the percentage of travel on pavements with acceptable ride quality declined from 86.4 percent in 1997 to 85.4 percent in 2008; declines on urban other principal arterials, urban minor arterials, and urban collectors over this period outweighed improvements on other functional systems. Given how close actual spending from 1997 to 2008 was to the **Cost to Maintain Highways and Bridges** level in constant dollar terms, these types of mixed results are not surprising.

The bridge investment backlog figures presented in the 1999 C&P Report were computed differently than those in the current edition, and thus are not directly comparable. However, the definition of structurally deficient and functionally obsolete bridges has remained consistent. *Exhibit 9-9* compares the percentage of deficient bridges for 1998 presented in the 1999 C&P Report with those for 2009 presented in the current edition. The overall percentage of bridges classified as structurally deficient or functionally obsolete declined from 29.6 percent in 1998 to 26.5 percent in 2009. The percentage of bridges classified as structurally deficient declined over this period from 28.8 percent to 24.3 percent, and the percentage of bridges classified as functionally obsolete increased from 13.6 percent to 14.5 percent. The percentage of structurally deficient and functionally obsolete bridges declined in both rural and urban areas between 1998 and 2009. However, while the percentage of rural functionally obsolete bridges declined from 11.4 percent to 11.0 percent during this period, the percentage of urban functionally obsolete bridges rose from 21.5 percent to 24.5 percent. This finding has significant implications in terms of the bridge investment backlog because the cost of addressing functional obsolescence can be particularly expensive in urban areas due to potentially high construction costs and right of way limitations.

Exhibit 9-9

Bridge Deficiencies by Functional System, 1998 and 2009

	Structurally Deficient	
	1998	**2009**
Rural	17.4%	13.3%
Urban	11.0%	8.4%
Rural and Urban	**16.0%**	**12.0%**
	Functionally Obsolete	
	1998	**2009**
Rural	11.4%	11.0%
Urban	21.5%	24.5%
Rural and Urban	**13.6%**	**14.5%**
	Total Deficient	
	1998	**2009**
Rural	28.8%	24.3%
Urban	32.5%	32.9%
Rural and Urban	**29.6%**	**26.5%**

Source: National Bridge Inventory.

The operational performance metrics presented in the 1999 C&P Report are not fully comparable to those presented in the current edition. However, as shown in *Exhibit 9-10*, applying a consistent methodology over time the TTI has estimated that the average daily percentage of travel in urbanized areas occurring under congested conditions has risen from 24.9 percent in 1997 to 26.3 percent in 2008. Although operational performance declined over this period, the magnitude of that decline appears smaller than what might have been expected given the large gap between the **Maintain Travel Time benchmark** and actual spending from 1998 through 2008 in constant dollar terms. This apparent discrepancy can be explained in part by the 1999 C&P Report's estimates of future travel volumes. The 1999 C&P Report projected that, based on State travel forecasts provided via HPMS and assuming a spending increase to the level of

Exhibit 9-10

Average Daily Percentage of VMT Under Congested Conditions for All Urbanized Areas, 1997–2008

Year	Average	Year	Average
1997	24.9%	2003	28.5%
1998	25.9%	2004	28.6%
1999	26.5%	2005	28.6%
2000	27.0%	2006	28.4%
2001	28.1%	2007	27.8%
2002	28.3%	2008	26.3%

Source: Texas Transportation Institute.

the **Cost to Maintain Highways and Bridges**, total VMT would rise to 3.4 trillion by 2008. However, actual VMT in 2008 was only 3.0 trillion. Because VMT has grown more slowly than had been projected, congestion has also worsened more slowly. Chapter 2 includes a discussion of VMT growth rates over time and of the decline in VMT associated with the recent recession.

Linkage Between Recent Conditions and Performance Spending Trends and Selected Capital Investment Scenarios

The inferences that can be drawn from comparing this report's prospective capital investment scenarios with its retrospective analyses of conditions, performance, and system finance are limited. As a result of the aging of existing highway and bridge infrastructure and growth in travel volumes, an amount of funding that achieved a certain level of system performance in the past might be inadequate to sustain that same level of performance in the future. In addition, while this report's consideration of past levels of investment focuses on the base year of 2008, system conditions and performance in that and previous years will depend on the amounts invested over a long period. That said, while the real level of highway investment fluctuated substantially within 2000–2008—the historical period with which this section compares 2009–2028— it was fairly stable for this period as a whole, increasing at an average annual rate of only 0.1 percent according to the estimates in Chapter 6.

Recognizing these potential limitations, simple comparisons between the retrospective and prospective analyses can still yield suggestive findings that help draw out the implications of the capital investment scenarios. *Exhibit 9-11* compares selected observations based on the investment/performance relationships identified in Chapter 7 with retrospective performance observations drawn from Chapters 3 and 4; these observations are discussed in more detail below.

Pavement Conditions

As shown in Chapter 6, all levels of government spent a combined $15.0 billion on highway system (pavement) rehabilitation in 2008 (see *Exhibit 6-15*) on the NHS. This is well above the $10.8-billion figure estimated as the average annual investment level (in constant 2008 dollars) needed to sustain average IRI in 2028 at base year 2008 levels (see *Exhibit 7-12*). HERS projects that if this $15.0 billion spending level were sustained in constant dollar terms over 20 years, pavement conditions would increase significantly. This projection is generally consistent with recent trends identified in Chapter 3—the percentage of VMT on the National Highway System (NHS) on pavements with good ride quality increased from 48 percent in 2000 to 57 percent in 2008.

In contrast, for Federal-aid highways, HERS projects that maintaining average pavement condition would require annual spending on pavement rehabilitation to average more than the 2008 level. From 2009 through 2028, investment in pavement improvements on Federal-aid highways would need to average an estimated $29.0 billion per year to sustain average IRI at the 2008 level (see *Exhibit 7-5*), whereas actual investment in pavement improvements on Federal-aid highways in 2008 was only $26.4 billion. Alternatively, continuing to invest in pavement improvements on Federal-aid highways at a level of $26.4 billion annually (constant dollars) is projected to produce mixed pavement results by 2028. Relative to 2008, a higher percentage of VMT on the Federal-aid highways would occur on pavements with good ride quality and a lower percentage on pavements with acceptable ride quality.

Exhibit 9-11

Comparison of Capital Investment Scenarios With Recent System Performance for Selected Indicators

Future Investment Scenario Observation	Historic Performance Observation
System Rehabilitation—Pavements	
Base year 2008 levels of capital spending on NHS pavements are projected to be adequate to support improvements to pavement ride quality through 2028. [Exhibit 7-12]	From 2000 to 2008, the share of NHS VMT on pavements with good ride quality and acceptable ride quality both increased. [Exhibit 3-2]
Base year 2008 levels of capital spending on all Federal-aid highway pavements (including the NHS) are projected to be inadequate to support improvements to average pavement ride quality through 2028. [Exhibit 7-5]	From 2000 to 2008, the percent of VMT on pavements with good ride quality declined for rural major collectors, urban minor arterials, and urban collectors. The percent of total Federal-aid highway VMT on pavements with acceptable ride quality declined slightly over this period. [Exhibit 3-4]
System Rehabilitation—Bridges	
Base year 2008 levels of capital spending on NHS bridges are projected to be adequate to support a reduction to the existing backlog of potential cost-beneficial bridge improvements through 2028. [Exhibit 7-19]	From 2001 to 2009, the share of NHS briges classified as structurally deficient has been reduced. [Exhibit 3-14]
Base year 2008 levels of capital spending on all bridges (including NHS bridges) are projected to be adequate to support a reduction to the existing backlog of potential cost-beneficial bridge improvements through 2028. [Exhibit 7-17]	From 2001 to 2009, the share of all briges classified as structurally deficient has been reduced. [Exhibit 3-15]
System Expansion	
Base year 2008 levels of capital spending on capacity expansion for all Federal-aid highways are projected to be inadequate to support improvements to operational performance (in terms of average delay) through 2028. [Exhibit 7-7]	From 2000 to 2008, the average percentage of VMT under congested conditions rose in urbanized areas less than 1 million in population. For larger urbanized areas, this percentage rose from 2000 to 2006 before dropping off by 2008. (This improvement is primarily attributable to the decline in VMT between 2006 and 2008; VMT has subsequently begun to rise again.) [Exhibit 4-3]

Sources: Highway Performance Monitoring System, Highway Economic Requirements System, National Bridge Inventory, and National Bridge Investment Analysis System.

As indicated in Chapter 3, the percent of VMT on Federal-aid highway pavements with good ride quality rose from 42.8 percent in 2000 to 46.4 percent in 2008, while the comparable percentage in the category for acceptable quality decreased slightly (see *Exhibit 3-4*). Although this historic performance observation appears more positive than the HERS projection for the next 20 years, it should be noted that recent pavement performance results have been mixed. The percent of VMT on pavements with good ride quality fell between 2006 and 2008 for Federal-aid highways overall, and declined over the longer eight-year period from 2000 to 2008 for rural major collectors, urban minor arterials, and urban collectors.

Bridge Conditions

NBIAS projects that if NHS bridge replacement and rehabilitation investment were sustained in constant dollar terms at the 2008 level of $5.4 billion, this would be adequate to slightly reduce the economic bridge investment backlog below its 2008 level by 2028 (see *Exhibit 7-19*). This finding appears generally consistent with recent trends identified in Chapter 3, as the percent of deficient NHS bridges fell from 23.3 percent in 2001to 21.9 percent in 2009 (see *Exhibit 3-14*).

Looking more broadly at all bridges, NBIAS projects that sustaining the 2008 level of bridge rehabilitation and replacement investment of $12.8 billion in constant dollar terms over 20 years could reduce the economic bridge investment backlog by 11.2 percent by 2028 (see *Exhibit 7-17*), reflecting an overall improvement in bridge conditions. The percent of deficient bridges fell from 30.1 percent in 2001 to 26.5 percent in 2009 (see *Exhibit 3-15*), suggesting an improvement in bridge conditions.

It should be noted that the bridge statistics presented in Chapter 3 are affected by the addition of new bridges, as well as changes in the conditions of existing bridges; for some subsets of the Nation's bridge inventory, the deck area of deficient bridges actually rose from 2001 to 2009, but at a slower rate than the deck area of new bridges.

Operational Performance

As referenced in Chapter 6, all levels of government spent a combined $28.3 billion for system expansion on Federal-aid highways in 2008 (see *Exhibit 6-14*). This falls well below the $36.6 billion average annual level of system expansion spending identified in Chapter 7 as being needed to maintain average delay in 2028 at 2008 base-year levels (see *Exhibit 7-7*). The existence of a funding gap of this nature appeared consistent with the general worsening of congestion observed in previous editions of the C&P report, but congestion appears to have stabilized based on statistics computed using the methodology from the Texas Transportation Institute's 2009 Urban Mobility Study. As indicated in Chapter 4, the percent of VMT under congested conditions in 2008 was lower than in 2000 for urbanized areas overall. However, this decrease was driven by urbanized areas of more than 1,000,000 in population; smaller urbanized areas experienced an increase in congestion over this period.

Part of the recent improvement in certain measures of congestion is attributable to the decline in overall VMT that occurred between 2006 and 2008. However, VMT has subsequently started to grow and States are projecting larger annual increases for the 20-year period through 2028. In light of this presumed increase in future VMT, HERS projecting a worsening of congestion (unless annual investment in system expansion increases) does not constitute a direct contradiction of recent observed trends in congestion. If VMT were to grow more slowly than projected, this would reduce the level of investment needed to maintain average delay so that the current level of investment in system expansion could be adequate to avoid increases in congestion. Chapter 10 includes an analysis of alternative assumptions about future VMT growth on the investment requirement projections. An analysis of the potential impacts of congestion pricing on reducing peak-period VMT and future investment needs is presented later in this chapter.

Accounting for Inflation

The analysis of potential future investment/performance relationships in the C&P report traditionally stated future investment levels in constant dollars, with the base year set according to the year of the conditions and performance data supporting the analysis. Throughout Chapters 7 and 8, this edition of the C&P report has stated all investment levels in constant 2008 dollars. For some purposes, however, such as comparing investment spending in a particular scenario with nominal dollar revenue projections, one would want to adjust for inflation. Given an assumption about future inflation, one could either convert the C&P report's constant-dollar numbers to nominal dollars or convert the nominal projected revenues to constant 2008 dollars.

Exhibit 9-12 illustrates how the constant dollar figures associated with three of the four systemwide scenarios for highways and bridges presented in Chapter 8 could be converted to nominal dollars, based on two alternative inflation rates. The 3.5 percent inflation rate represents the average annual increase in highway construction costs over the last 20 years (from 1988 to 2008). The 2.0 percent inflation rate corresponds

Exhibit 9-12

Illustration of Potential Impact of Alternative Inflation Rates on Selected Systemwide Investment Scenarios

	Highway Capital Investment (Billions of Dollars)								
	Constant 2008 Dollars*			Nominal Dollars (Assuming 2.0 Percent Annual Inflation)			Nominal Dollars (Assuming 3.5 Percent Annual Inflation)		
Year	Sustain Current Spending Scenario	Maintain Conditions & Performance Scenario	Improve Conditions & Performance Scenario	Sustain Current Spending Scenario	Maintain Conditions & Performance Scenario	Improve Conditions & Performance Scenario	Sustain Current Spending Scenario	Maintain Conditions & Performance Scenario	Improve Conditions & Performance Scenario
2008	$91.1	$91.1	$91.1	$91.1	$91.1	$91.1	$91.1	$91.1	$91.1
2009	$91.1	$92.0	$96.3	$93.0	$93.9	$98.2	$94.3	$95.2	$99.6
2010	$91.1	$92.9	$101.7	$94.8	$96.7	$105.8	$97.6	$99.5	$108.9
2011	$91.1	$93.8	$107.4	$96.7	$99.6	$114.0	$101.1	$104.0	$119.1
2012	$91.1	$94.7	$113.4	$98.7	$102.5	$122.8	$104.6	$108.7	$130.2
2013	$91.1	$95.6	$119.8	$100.6	$105.6	$132.3	$108.3	$113.6	$142.3
2014	$91.1	$96.6	$126.6	$102.6	$108.7	$142.5	$112.0	$118.7	$155.6
2015	$91.1	$97.5	$133.7	$104.7	$112.0	$153.5	$116.0	$124.0	$170.1
2016	$91.1	$98.4	$141.2	$106.8	$115.3	$165.4	$120.0	$129.6	$185.9
2017	$91.1	$99.4	$149.1	$108.9	$118.8	$178.2	$124.2	$135.5	$203.2
2018	$91.1	$100.3	$157.5	$111.1	$122.3	$192.0	$128.6	$141.5	$222.2
2019	$91.1	$101.3	$166.4	$113.3	$126.0	$206.9	$133.1	$147.9	$242.9
2020	$91.1	$102.3	$175.7	$115.6	$129.7	$222.9	$137.7	$154.6	$265.5
2021	$91.1	$103.3	$185.6	$117.9	$133.6	$240.1	$142.5	$161.5	$290.3
2022	$91.1	$104.3	$196.0	$120.3	$137.6	$258.7	$147.5	$168.8	$317.3
2023	$91.1	$105.3	$207.1	$122.7	$141.7	$278.7	$152.7	$176.4	$346.9
2024	$91.1	$106.3	$218.7	$125.1	$145.9	$300.2	$158.0	$184.3	$379.2
2025	$91.1	$107.3	$231.0	$127.6	$150.3	$323.5	$163.6	$192.6	$414.6
2026	$91.1	$108.4	$244.0	$130.2	$154.8	$348.5	$169.3	$201.3	$453.2
2027	$91.1	$109.4	$257.7	$132.8	$159.4	$375.4	$175.2	$210.4	$495.4
2028	$91.1	$110.5	$272.2	$135.4	$164.2	$404.5	$181.4	$219.8	$541.6
Total	**$1,822.9**	**$2,019.7**	**$3,401.0**	**$2,258.9**	**$2,518.5**	**$4,363.9**	**$2,667.7**	**$2,988.0**	**$5,284.0**
	0.00%	**0.97%**	**5.62%**	**Constant Dollar Growth Rate**					
	$91.1	**$101.0**	**$170.1**	**Average Annual Investment Level in Constant 2008 Dollars**					

* *Based on average annual investment levels and annual constant dollar growth rates identified in Exhibit 8-8.*

Source: FHWA Staff Analysis.

to the average annual increase in highway construction costs from 1980 to 2000; this is the 20-year period with the lowest construction cost inflation since the creation of the Federal Highway Trust Fund in 1956. (Historic inflation rates were determined using the FHWA Composite Bid Price Index through 2006, and the new FHWA National Highway Construction Cost Index from 2006 to 2008; these indices are discussed in Chapter 6.)

The systemwide **Sustain Current Spending scenario** presented in Chapter 8 assumes that combined capital spending for highway and bridge improvements would be sustained at its 2008 level in constant dollar terms for 20 years. Hence, *Exhibit 9-12* shows $91.1 billion of spending in constant 2008 dollars for each year from 2009 through 2028, for a 20-year total of $1.8 trillion. Assuming annual inflation in construction costs of 2.0 percent, or alternatively 3.5 percent, would imply a 20-year total in nominal dollars of $2.3 trillion or $2.7 trillion for this scenario.

Q&A

Why are the investment analyses presented in this report expressed in constant base-year dollars?

The investment/performance models discussed in this report estimate the future benefits and costs of transportation investments in constant-dollar terms. This is standard practice for this type of economic analysis. To convert the model outputs from constant dollars to nominal dollars, it would be necessary to externally adjust them to account for projected future inflation.

Traditionally, this type of adjustment has not been made in the C&P report. Because inflation prediction is an inexact science, adjusting the constant-dollar figures to nominal dollars would tend to add to the uncertainty of the overall results and make the report more difficult to use if the inflation assumptions were later proved to be incorrect. Allowing readers to make their own inflation adjustments based on actual trends observed subsequent to the publication of the C&P report and/or the most recent projections from other sources is expected to yield a better overall result, particularly in light of the sharp swings in highway construction materials costs over the last several years.

The use of constant dollar figures is also intended to provide readers with a reasonable frame of reference in terms of an overall cost level that they have recently experienced. When inflation rates are compounded for 20 years, even relatively small growth rates can produce nominal dollar values that appear very large when viewed from the perspective of today's typical costs.

The primary drawback to using constant base-year dollar figures in the C&P report is that they are sometimes misapplied by readers and treated as if they were expressed in current-year dollars. However, because the C&P report is produced every 2 years, the base-year costs reflected in the most recent edition are generally close enough to current costs to provide a useful perspective.

Inflation is just one of two separate and distinct factors that account for why the value of a dollar, as seen from the present, diminishes over time. The second factor is the time value of resources, which reflects that there is a cost associated with diverting the resources needed for an investment from other productive uses. The investment/performance models described in this report take the time value of resources into account via a separate mechanism called the discount rate, which is discussed in Chapter 10.

Chapter 8 indicates that achieving the objectives of the systemwide **Maintain Conditions and Performance scenario** would require investment averaging $101.0 billion per year in constant 2008 dollars (see *Exhibit 8-8*), and, to attain this average, a 0.97-percent annual growth in constant-dollar spending (see *Exhibit 8-9*). *Exhibit 9-12* illustrates the application of this real growth rate, demonstrating how annual capital investment would increase from $91.1 billion in 2008 to $110.5 billion in 2028, resulting in a 20-year (2009 to 2028) total of $2.0 trillion in constant 2008 dollars. A 2.0-percent inflation rate applied to these constant-dollar estimates would produce a 20-year cost of $2.5 trillion, and a 3.5-percent inflation rate a 20-year cost of $3.0 trillion, both measured in nominal dollars.

The compounding impacts of inflation are even more evident in the figures for the systemwide **Improve Conditions and Performance scenario** presented in *Exhibit 9-12*. As described in Chapter 8, this scenario assumes 5.62 percent growth in constant dollar highway capital spending per year in order to address all potentially cost-beneficial highway and bridge improvements by 2028. The $170.1 billion average annual investment level associated with this scenario equates to a 20-year investment level of $3.4 billion in constant 2008 dollars. Adjusting this figure to account for inflation of 2.0 percent or 3.5 percent would translate into 20-year nominal dollar costs of $4.4 trillion or $5.3 trillion, respectively.

Costs of Maintaining Individual System Components Versus Maintaining the Overall System

The goal of the **Maintain Conditions and Performance scenario** presented in Chapter 8 is to invest at a level sufficient so that two measures of conditions and performance (average speed and the economic backlog of bridge investments) can be maintained through 2028 at their 2008 levels. The HERS and NBIAS analyses on which the scenario is based attempt to achieve this objective for the lowest cost possible. The conditions and performance of individual functional systems are allowed to vary under this scenario; they tend to improve for higher-ordered functional systems with high traffic volumes (as improvements in these systems tend to have higher BCRs), and deteriorate for lower-ordered systems.

What if one were to add to this scenario further requirements for maintaining certain measures of conditions and performance? Even before rerunning the simulations, one could predict with confidence that the estimate of the total investment requirement would increase. A general rule in mathematical optimization is that when seeking to find the lowest cost solution that meets a set of objectives, adding constraints to the system of equations increase the cost of the solution. For example, in the context of this scenario, adding a constraint that system performance must be maintained individually for each county in the Nation may involve selecting potential improvements with lower BCRs in some counties than in others; when these separate analyses are added together, their cost would tend to be higher than a nationwide approach that applies the same minimum BCR across all counties.

Exhibit 9-13 further illustrates this concept by presenting the level of investment needed to maintain average IRI (a targeted measure of pavement condition), average delay per VMT (a targeted measure of operational performance), and the economic bridge investment backlog (a targeted measure of bridge condition) for individual functional systems (to the extent that it would be cost-beneficial to do so). Logically, applying the constraint that indicators should be maintained for individual functional systems and applying more specific indicators (IRI and average delay rather than average speed) will tend to increase the cost of achieving the general objective of the scenario. As shown in *Exhibit 9-13*, the combined cost of maintaining these modified indicators on individual functional systems is estimated to be $88.8 billion per year over 20 years in constant 2008 dollars; this is 10.9 percent higher than the $80.1-billion average annual investment level identified for the **Maintain Conditions and Performance scenario** for Federal-aid highways, identified in Chapter 8 (see *Exhibit 8-5*).

The negative percentages identified in the comparison at the bottom of *Exhibit 9-13* reflect cases in which maintaining a particular performance indicator on a particular functional class would cost less than the amount in the comparable component of the **Maintain Conditions and Performance scenario** for Federal-aid highways (the implication is that performance actually improved for these system components under that scenario). The positive percentages indicate system components for which conditions or performance deteriorated under that scenario (so that additional resources would be needed to maintain these components at 2008 levels through 2028).

While broad national targets, such as those of the Chapter 8 **Maintain Conditions and Performance scenario**, are consistent with this report's focus on overall conditions and performance, targets specific to functional classes, such as those of the supplemental analysis presented in *Exhibit 9-13* would be more suitable for certain analytical objectives. For example, in projecting the costs associated with maintaining

Exhibit 9-13

Cost of Maintaining System Components Compared With the Cost to Maintain Scenario for Federal-Aid Highways for 2009 to 2028

Average Annual National Investment to Maintain Average IRI, Bridge Investment Backlog, and Average Delay on Individual Functional Classes (Billions of 2008 Dollars) [1]

	System Rehabilitation			System	System	
Functional Class	**Highway**	**Bridge**	**Total**	**Expansion**	**Enhancement**	**Total**
Rural Arterials and Major Collectors						
Interstate	$1.0	$0.7	$1.7	$2.0	$0.5	$4.2
Other Principal Arterial	$1.4	$0.6	$2.0	$1.3	$0.9	$4.2
Minor Arterial	$3.4	$0.5	$3.9	$0.5	$0.6	$5.0
Major Collector	$5.4	$0.9	$6.3	$0.6	$0.8	$7.7
Subtotal	**$11.3**	**$2.6**	**$13.9**	**$4.4**	**$2.8**	**$21.1**
Urban Arterials and Collectors						
Interstate	$4.9	$2.5	$7.4	$10.1	$1.3	$18.7
Other Freeway and Expressway	$2.2	$1.0	$3.2	$3.9	$0.8	$7.9
Other Principal Arterial	$4.7	$1.6	$6.3	$9.0	$1.5	$16.8
Minor Arterial	$6.3	$1.5	$7.8	$6.5	$1.2	$15.4
Collector	$4.3	$0.7	$5.0	$3.2	$0.6	$8.9
Subtotal	**$22.5**	**$7.2**	**$29.8**	**$32.5**	**$5.3**	**$67.7**
Total, Federal-Aid Highways [2]	**$33.8**	**$9.9**	**$43.7**	**$36.9**	**$8.2**	**$88.8**

Percent Above the Cost to Maintain Scenario for Federal-Aid Highways for 2009 to 2028

	System Rehabilitation			System	System	
Functional Class	**Highway**	**Bridge**	**Total**	**Expansion**	**Enhancement**	**Total**
Rural Arterials and Major Collectors						
Interstate	-41.8%	2.6%	-29.7%	24.6%	10.9%	-6.3%
Other Principal Arterial	-19.3%	0.2%	-14.7%	55.2%	10.9%	5.1%
Minor Arterial	74.0%	0.7%	59.0%	38.3%	10.9%	48.9%
Major Collector	111.4%	6.4%	86.3%	129.0%	10.9%	75.7%
Subtotal	**39.7%**	**2.9%**	**30.9%**	**43.4%**	**10.9%**	**30.1%**
Urban Arterials and Collectors						
Interstate	-24.1%	-8.8%	-19.6%	-23.5%	10.9%	-20.3%
Other Freeway and Expressway	-27.4%	-6.1%	-22.0%	-27.2%	10.9%	-22.5%
Other Principal Arterial	-16.2%	-7.0%	-14.1%	123.8%	10.9%	32.1%
Minor Arterial	-6.6%	12.9%	-3.3%	97.8%	10.9%	24.5%
Collector	62.1%	38.8%	58.5%	133.6%	10.9%	73.3%
Subtotal	**-8.5%**	**-0.8%**	**-6.8%**	**20.1%**	**10.9%**	**6.0%**
Total, Federal-Aid Highways [2]	**3.3%**	**0.2%**	**2.6%**	**22.5%**	**10.9%**	**10.9%**

[1] *Amounts shown reflect the cost of maintaining average ride quality (system rehabilitation—highway), the bridge investment backlog (system rehabilitation—bridge) and average delay (system expansion) at base year 2008 levels for individual functional classes. In those cases where maintaining an indicator at base year levels would not be cost-beneficial, the comparable value from the Cost to Improve Highways and Bridges scenario was utilized.*

[2] *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.

average pavement conditions specifically on urban arterials and collectors, the $22.5 billion identified in *Exhibit 9-13* constitutes a better estimate than the $24.7 billion highway system rehabilitation component of the **Maintain Conditions and Performance scenario** for Federal-aid highways presented in Chapter 8 (as urban pavement conditions actually improve somewhat under that scenario, offset by declines in condition and performance elsewhere on the system).

As noted above, the investment levels presented in *Exhibit 9-13* only seek to maintain individual measures of conditions and performance on individual functional classes where such investment is projected to be cost-beneficial. The average annual investment level for each system component was capped at the corresponding amount identified as part of the **Improve Conditions and Performance scenario** for Federal-aid highways.

Highway and Bridge Investment Backlog

The investment backlog represents all highway and bridge improvements that could be economically justified for immediate implementation, based solely on the current conditions and operational performance of the highway system (without regard to potential future increases in VMT or potential future physical deterioration of infrastructure assets). Conceptually, the backlog represents a subset of the investment levels reflected in the **Improve Conditions and Performance scenario** presented in Chapter 8; that scenario addresses the existing backlog as well as additional projected pavement, bridge, and capacity needs that may arise over the next 20 years.

Exhibit 9-14 presents an estimate of the backlog in 2008 for those types of capital improvements that are modeled in HERS and NBIAS. The shaded cells in the table represent types of improvements that are not currently modeled, including improvements to non-Federal-aid highways pavements and system enhancements; the data are presented in this manner to emphasize that the estimated backlog of $648.2 billion is incomplete. (In contrast, the scenarios presented in Chapter 8 include an adjustment factor for non-modeled capital improvement types.)

Exhibit 9-14

Estimated Highway and Bridge Investment Backlog as of 2008

System Component	(Billions of 2008 Dollars)						Percent of Total
	System Rehabilitation			System Expansion	System Enhancement*	Total	
	Highway	Bridge	Total				
Federal-Aid Highways—Rural	$58.2	$28.1	$86.3	$11.0		$97.3	15.0%
Federal-Aid Highways—Urban	$243.3	$74.0	$317.3	$214.5		$531.8	82.0%
Federal-Aid Highways—Total	$301.6	$102.1	$403.6	$225.5		$629.1	97.1%
Non-Federal-Aid Highways*		$19.1	$19.1			$19.1	2.9%
All Roads*	**$301.6**	**$121.2**	**$422.8**	**$225.5**		**$648.2**	**100.0%**
Interstate Highway System	$68.7	$38.1	$106.8	$102.7		$209.5	32.3%
National Highway System	$139.5	$60.4	$199.9	$157.1		$356.9	55.1%

** Estimated backlog includes only those system components and capital improvement types modeled in HERS or NBIAS. System enhancements are excluded, as well as pavement and expansion improvements to roads functionally classified as rural minor collector, rural local, or urban local, for which HPMS data are not available to support a HERS analysis.*

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

The portion of the backlog derived from NBIAS accounts for $121.2 billion of the total backlog presented in *Exhibit 9-14*; Chapters 7 and 8 also reference this figure since targets for the economic backlog of bridge investment are used as a performance metric in defining the **Maintain Conditions and Performance scenario** and the **Improve Conditions and Performance scenario**. The remaining $527.0 billion included in the total backlog is derived from the HERS model; this represents the pool of potentially cost-beneficial capital investment for system expansion or pavement improvements based solely on the conditions and performance of the system in 2008.

Of the $648.2 estimated backlog figure presented in *Exhibit 9-14*, approximately $209.5 billion (32.3 percent) is on the Interstate highway system and $356.9 billion (55.1 percent) is on the NHS (which includes the Interstate highway system). Approximately 65.2 percent ($422.8 billion) of the total backlog is attributable to system rehabilitation needs, while the remainder is associated with system expansion improvements to address existing capacity deficiencies. The share of the total backlog attributable to system rehabilitation is progressively lower for Federal-aid highways (64.2 percent), the NHS (56.0 percent), and the Interstate highway system (51.0 percent), but still represents a majority of the total backlog in each case.

The $648.2 billion estimated backlog is heavily weighted towards urban areas; approximately 82.0 percent of this total is attributable to Federal-aid highways in urban areas. As noted in Chapter 3, pavement ride quality in 2008 was better on average for rural Federal-aid highways than those in urban areas; urban areas also face relatively greater problems with congestion and functionally obsolete bridges than do rural areas.

Timing of Investment

The investment/performance analyses presented in this report focus mainly on how alternative average annual investment levels over 20 years might impact system performance at the end of this period. Within this period, system performance can be significantly influenced by the timing of investment. Consistent with the approach in the 2008 edition of the C&P report, and as discussed in Chapter 7, the analyses in the present edition assumed that any change from the 2008 level of combined investment per year by all levels of government would occur gradually, at a constant percent rate. However, some previous editions used different approaches. The HERS 2006 C&P Report assumed that combined investment would immediately jump to the average annual level being analyzed, then remain fixed at that level for 20 years. The HERS analyses presented in the 2004 C&P Report were tied directly to alternative BCR cutoffs rather than to particular levels of investment in any given year. At higher spending levels, this approach resulted in a significant front-loading of capital investment in the early years of the analysis as the existing backlog of potential cost-beneficial investments (discussed above) was addressed, followed by a sharp decline in later years.

The discussion below explores the impact of the choice among these three assumptions about the timing of future investment—ramped spending, flat spending, or BCR-driven spending—on system performance within the 20-year period analyzed. The average annual investment levels analyzed each correspond to the baseline HERS analyses for Federal-aid Highways, and the baseline NBIAS analyzes for all bridges presented in Chapter 7.

Alternative Timing of Investment in HERS

Exhibit 9-15 indicates how alternative assumptions regarding the timing of investment would impact the distribution of spending among the four 5-year funding periods considered in HERS, and how these spending patterns could potentially impact average speeds. The eight investment levels shown correspond to the baseline ("ramped") HERS analyses for Federal-aid highways presented in Chapter 7. For the baseline

Exhibit 9-15

Distribution of Spending Among 5-Year HERS Analysis Periods and Projected Impacts on Average Speeds, for Alternative Approaches to Investment Timing

Average Annual HERS-Modeled Capital Investment (Billions of 2008 Dollars) [1]	Percentage of HERS-Modeled Spending Occurring in Each 5-Year Period											
	Baseline				Alternatives							
	Ramped Spending				Flat Spending				BCR-Driven Spending [2]			
	2009 to 2013	2014 to 2018	2019 to 2023	2024 to 2028	2009 to 2013	2014 to 2018	2019 to 2023	2024 to 2028	2009 to 2013	2014 to 2018	2019 to 2023	2024 to 2028
$105.4	15.5%	20.6%	27.4%	36.5%	25.0%	25.0%	25.0%	25.0%	*37.9%*	*19.5%*	*19.9%*	*22.8%*
$93.4	16.9%	21.4%	27.2%	34.5%	25.0%	25.0%	25.0%	25.0%	37.0%	20.2%	20.6%	22.2%
$80.1	18.9%	22.5%	26.8%	31.8%	25.0%	25.0%	25.0%	25.0%	34.1%	22.8%	20.8%	22.3%
$74.7	20.0%	23.0%	26.5%	30.5%	25.0%	25.0%	25.0%	25.0%	32.6%	23.6%	21.6%	22.2%
$62.9	22.6%	24.1%	25.8%	27.5%	25.0%	25.0%	25.0%	25.0%	30.4%	25.9%	21.8%	21.9%
$58.0	24.0%	24.6%	25.3%	26.1%	25.0%	25.0%	25.0%	25.0%	29.2%	26.7%	22.5%	21.5%
$54.7	**25.0%**	**25.0%**	**25.0%**	**25.0%**	**25.0%**	**25.0%**	**25.0%**	**25.0%**	27.8%	27.7%	22.3%	22.3%
$49.3	26.9%	25.6%	24.3%	23.1%	25.0%	25.0%	25.0%	25.0%	26.3%	28.9%	23.0%	21.8%

Average Annual HERS-Modeled Capital Investment (Billions of 2008 Dollars) [1]	Change in Average Speeds Relative to 2008 on Roads Modeled In HERS [3]											
	Baseline				Alternatives							
	Ramped Spending, Percent Change as of:				Flat Spending, Percent Change as of:				BCR-Driven Spending [2] Percent Change as of:			
	2013	2018	2023	2028	2013	2018	2023	2028	2013	2018	2023	2028
$105.4	2.0%	1.8%	2.1%	2.6%	2.9%	2.9%	2.8%	2.5%	*3.7%*	*3.3%*	*2.8%*	*2.4%*
$93.4	1.9%	1.6%	1.7%	2.0%	2.6%	2.5%	2.3%	1.9%	3.5%	3.0%	2.5%	1.9%
$80.1	1.8%	1.3%	1.1%	1.2%	2.4%	2.0%	1.6%	1.2%	2.9%	2.4%	1.8%	1.2%
$74.7	1.8%	1.2%	0.9%	0.9%	2.2%	1.8%	1.3%	0.8%	2.7%	2.2%	1.5%	0.8%
$62.9	1.7%	0.9%	0.4%	**0.0%**	1.9%	1.2%	0.5%	0.0%	2.2%	1.6%	0.7%	-0.1%
$58.0	1.7%	0.7%	0.1%	-0.4%	1.7%	0.9%	0.2%	-0.4%	2.0%	1.3%	0.4%	-0.5%
$54.7	1.6%	0.6%	-0.1%	-0.7%	1.6%	0.6%	-0.1%	-0.7%	1.8%	1.0%	0.1%	-0.7%
$49.3	1.6%	0.4%	-0.5%	-1.3%	1.5%	0.2%	-0.6%	-1.3%	1.5%	0.6%	-0.4%	-1.3%

[1] *The eight alternative investment levels shown correspond to the levels identified in Chapter 7 (Exhibit 7-3) as being associated with the investment needed to achieve certain specific targets (expressed in terms of minimum BCR cutoffs, maintaining specific performance indicators, or growing at a specific rate in constant dollar terms). Of the $91.1 billion of total capital expenditures in 2008, $54.7 billion was used for the types of capital improvements modeled in HERS.*

[2] *Each percentage distribution shown corresponds to a HERS analysis assuming investment up to a minimum benefit-cost ratio cutoff point (not shown). For each row, this cutoff was set at a level such that total spending would be consistent with the average annual spending level shown. The italicized values identified for the row labeled $105.4 billion are actually based on a lower average annual investment level of $104.0 billion, as HERS projects this to be the highest level of investment that would be cost-beneficial (given a front-loaded, BCR-driven spending strategy).*

[3] *The performance impacts identified in this table are driven by spending modeled in HERS and do not reflect rural minor collectors, rural local, or urban local roads, because these functional systems are not included in the HPMS sample data.*

Source: Highway Economic Requirements System.

analyses, the distribution of spending among funding periods is driven by the annual constant dollar spending growth rate assumed; for higher growth rates, a smaller percentage of a total 20-year investment would occur in the first 5 years.

The "flat spending" alternative is linked directly to the average annual investment levels associated with each of the baseline analyses; as spending would remain the same in each of the 20 years, the distribution of spending within each 5-year period makes up exactly one-quarter of the total. When HERS-modeled capital investment spending is sustained at the base-year level of $54.7 billion, the results of the ramped spending and flat spending alternatives are identical. (Spending is flat when its growth rate is zero.)

The "BCR-driven" spending percentages identified in *Exhibit 9-15* represent the distribution of spending that would occur if a uniform minimum BCR were applied in HERS across all four 5-year funding periods. The benefit-cost cutoff points were selected to coordinate with the total 20-year spending for each of the baseline analyses. At higher spending levels, the existence of the backlog of cost-beneficial investments would cause a higher percentage of spending to occur in the first 5-year period through 2013. This effect is less pronounced at lower levels of investment, as some potential projects included in the estimated backlog would have a BCR below the cutoff point associated with that level of spending, and would thus be deferred for consideration in later funding periods. The portion of total BCR-driven spending occurring in the first 5 years ranged from 26.3 percent for the lowest spending level analyzed to 37.9 percent for the highest level analyzed. (As noted in *Exhibit 9-15,* applying a uniform minimum BCR of 1.0 across all 20 years would result in an average annual investment level of $104.0 billion, slightly below the $105.4 billion level identified for the baseline ramped spending approach.)

The analyses presented in Chapter 7 (see *Exhibit 7-2*) show that increasing HERS-modeled capital spending by 1.31 percent per year over 20 years above the baseline 2008 level of $54.7 billion would result in a 20-year spending figure of $1.257 trillion, translating into an average annual investment level of $62.9 billion. (This is the HERS-modeled component of the **Maintain Conditions and Performance scenario** presented in Chapter 8.) As shown in *Exhibit 9-15*, at this level of investment, the baseline ramped spending approach would direct that approximately 22.6 percent of the total 20-year amount be expended in the first five years, rising to 27.5 percent in the last five years. In contrast, given the same 20-year budget constraint under the BCR-driven alternative, approximately 30.4 percent of total spending would be expended in the first five years, falling to 21.9 percent in the last five years.

The projected average speeds for 2028 shown in *Exhibit 9-15* are similar among the three investment patterns. For example, at an average annual investment level of $62.9 billion, average speed in 2028 would match that in 2008 for both the ramped spending and flat spending alternatives, and would decrease by 0.1 percent under the BCR-driven spending approach. This suggests that the amount of cumulative 20-year constant-dollar investment is more critical to final-year system performance than the distribution of that investment within the 20-year period.

The potential benefits of front-loading capital spending toward the early part of the analysis period become more apparent when examining projected average speeds for the intermediate years of 2013, 2018, and 2023. At an average annual investment level of $62.9 billion, average speeds are projected to increase by 1.7 percent by 2013 for the baseline ramped spending approach, compared to a 1.9 percent increase for the flat spending approach and a 2.2 percent increase for the BCR-driven spending approach. These speed reductions in the early years, along with corresponding reductions in delay and pavement roughness and improvements in other system performance indicators, would translate into significant user cost savings during these years.

Alternative Timing of Investment in NBIAS

Exhibit 9-16 identifies the impacts of alternative investment timing on the backlog of potentially cost-beneficial bridge investments. As discussed in Chapter 7, changes in the economic bridge investment backlog can be viewed as a proxy for changes in overall bridge conditions.

Exhibit 9-16

Distribution of Spending Among 5-Year Periods in NBIAS and Projected Impacts on the Bridge Investment Backlog, for Alternative Approaches to Investment Timing

Average Annual NBIAS-Modeled Capital Investment (Billions of 2008 Dollars)[1]	Percentage of NBIAS-Modeled Spending Occurring in Each 5-Year Period											
	Baseline				Alternatives							
	Ramped Spending				Flat Spending				BCR-Driven Spending[2]			
	2009 to 2013	2014 to 2018	2019 to 2023	2024 to 2028	2009 to 2013	2014 to 2018	2019 to 2023	2024 to 2028	2009 to 2013	2014 to 2018	2019 to 2023	2024 to 2028
$20.5	17.7%	21.9%	27.0%	33.4%	25.0%	25.0%	25.0%	25.0%	35.5%	21.9%	20.7%	21.8%
$18.7	18.9%	22.5%	26.8%	31.8%	25.0%	25.0%	25.0%	25.0%	35.1%	21.5%	21.2%	22.2%
$17.5	20.0%	23.0%	26.5%	30.5%	25.0%	25.0%	25.0%	25.0%	34.6%	21.3%	21.4%	22.8%
$14.7	22.6%	24.1%	25.8%	27.5%	25.0%	25.0%	25.0%	25.0%	32.6%	20.3%	22.4%	24.7%
$13.6	24.0%	24.6%	25.3%	26.1%	25.0%	25.0%	25.0%	25.0%	31.7%	20.3%	22.4%	25.6%
$12.8	**25.0%**	**25.0%**	**25.0%**	**25.0%**	**25.0%**	**25.0%**	**25.0%**	**25.0%**	31.0%	20.5%	22.4%	26.2%
$11.9	26.3%	25.4%	24.5%	23.7%	25.0%	25.0%	25.0%	25.0%	29.8%	20.3%	23.1%	26.9%
$11.5	26.9%	25.6%	24.3%	23.1%	25.0%	25.0%	25.0%	25.0%	29.3%	19.8%	23.3%	27.5%

Average Annual NBIAS-Modeled Capital Investment (Billions of 2008 Dollars)[1]	Change in Bridge Investment Backlog Relative to 2008[3]											
	Baseline				Alternatives							
	Ramped Spending, Percent Change as of:				Flat Spending, Percent Change as of:				BCR-Driven Spending[2] Percent Change as of:			
	2013	2018	2023	2028	2013	2018	2023	2028	2013	2018	2023	2028
$20.5	-37.2%	-51.5%	-73.4%	**-100%**	-57.7%	-74.6%	-84.4%	-83.4%	-75.1%	-79.2%	-80.9%	-78.0%
$18.7	-36.0%	-46.5%	-62.9%	-79.1%	-51.7%	-65.3%	-73.0%	-71.4%	-68.4%	-69.9%	-72.4%	-69.5%
$17.5	-35.0%	-43.0%	-55.4%	-65.3%	-47.3%	-57.8%	-63.9%	-61.5%	-62.6%	-62.6%	-64.1%	-60.5%
$14.7	-32.6%	-33.7%	-37.3%	-34.7%	-37.6%	-40.8%	-41.8%	-35.1%	-48.8%	-43.5%	-42.1%	-35.9%
$13.6	-31.5%	-29.6%	-29.0%	-20.9%	-33.5%	-32.5%	-31.4%	-21.7%	-43.0%	-35.7%	-31.8%	-24.2%
$12.8	-30.7%	-26.8%	-22.9%	-11.2%	-30.7%	-26.8%	-22.9%	-11.2%	-38.7%	-29.6%	-24.0%	-15.1%
$11.9	-29.7%	-23.1%	-15.7%	**0.0%**	-27.4%	-20.0%	-13.0%	1.5%	-33.2%	-21.3%	-14.5%	-3.2%
$11.5	-29.3%	-21.8%	-12.9%	4.9%	-26.1%	-17.4%	-9.1%	6.7%	-31.2%	-17.2%	-9.6%	1.7%

[1] The eight alternative investment levels shown correspond to the levels analyzed in Chapter 7 (Exhibit 7-17) for all bridges; these levels were linked to annual rates of growth in spending relative to the baseline 2008 level. Of the $91.1 billion of total capital expenditures in 2008, $12.8 billion was used for the types of capital improvements modeled in NBIAS.

[2] Each percentage distribution shown corresponds to an NBIAS analysis assuming investment up to a minimum BCR cutoff point (not shown). For each row, this cutoff was set at a level such that total spending would be consistent with the average annual spending level shown.

[3] As discussed in Chapter 7, the economic investment backlog for bridges represents the total level of investment that would be required to address existing bridge deficiencies where it is cost-beneficial to do so. Reductions in this backlog would be consistent with an overall improvement in bridge conditions. The amounts shown do not reflect system expansion needs; the bridge component of such needs are addressed as part of the HERS model analysis.

Source: National Bridge Investment Analysis System.

The relative impacts of the alternative bridge investment approaches identified in *Exhibit 9-16* vary by funding level. At the three highest average annual NBIAS-modeled investment levels analyzed for the 2009 to 2028 period ($17.5 billion or higher), the ramped spending approach assumed in the baseline analyses from Chapter 7 would result in a lower economic backlog in 2028 than the flat-spending or BCR-driven spending alternatives. At the five lowest investment levels analyzed (average annual NBIAS-related spending of $14.7 billion or lower), the "BCR-driven" spending approach would result in a lower economic backlog in 2028 than the other two alternatives.

The poorer relative performance of the flat spending approach may be related to "lumpiness" in the future bridge investment needs identified by NBIAS. As discussed in Chapter 3, the rate of construction of new bridges has not been uniform over time, so that the age distribution of the bridge inventory includes some peaks. Consequently, the need for certain types of bridge repair and rehabilitation actions is clustered in time to some extent. Holding spending constant at the same level across all years is not consistent with this pattern.

The BCR-driven spending approach is intended to link annual spending to annual needs; as noted above, for the lowest five levels of investment analyzed, this approach results in a lower projected bridge investment backlog in 2028 than the baseline ramped spending approach. However, at the three highest levels of investment analyzed, the BCR-driven spending approach is even more front-loaded, concentrating a significant amount of spending into a relatively short period of time; although this approach has benefits in reducing ongoing maintenance costs, it also tends to exacerbate the concentration of future bridge needs by putting a larger number of bridges onto the same repair and rehabilitation cycle. The imposition of an annual spending constraint in the baseline ramped spending analyses tends to stretch out bridge work across a longer period, so that subsequent repair and rehabilitation cycles would be more spread out.

Road Pricing and Financing Mechanisms

As referenced in the Introduction to Part II, the HERS model can be run with a "balanced budget" constraint, which forces changes to highway capital spending from the base-year level to be budget-neutral. Neutrality is achieved through adjustments to highway user taxes—specifically, to flat rate user charges such as a systemwide VMT charge or fuel tax. By altering the demand for highway travel, these adjustments would also affect system operational performance and investment needs. An increase in the flat-rate charges would reduce the effective VMT growth rate, which would in turn improve system performance. For congestion pricing, which HERS can also simulate, the linkage to highway operational performance is stronger, since the charges vary by the time and location of travel according to level of congestion. Moreover, with operational performance improved, the amount of highway investment needed to achieve a given performance target is reduced. These concepts and related analytical procedures are discussed in more detail in Appendix A.

The primary investment scenarios presented in the 2006 C&P Report assumed that any increase in highway and bridge capital investment above 2004 baseline levels would be funded by a flat rate per-gallon surcharge; this had the effect of reducing the average annual investment levels for these scenarios by 2 to 4 percent and resulted in small improvements in projected performance.

The 2008 C&P Report presented two versions of each of the primary investment scenarios, one of which was similar to the approach used in the 2006 C&P Report, except that the flat rate surcharge was imposed on a per-VMT basis rather than a per-gallon basis and was computed relative to a baseline year of 2006 rather than 2004. The second set of scenarios presented in the 2008 C&P Report assumed the immediate imposition of peak-period congestion charges on all congested highway sections, with rates set for individual locations based on the estimated marginal cost that each user of a congested facility imposes on all other users of that facility. To the extent that these congestion charges did not cover the full additional capital investment costs associated with a particular scenario, an additional flat rate surcharge was imposed; to the extent that the congestion charges would more than cover these costs, a reduction in existing user charges was assumed. The results indicated that by reducing growth in VMT, the mechanisms for funding additional highway investment would improve future system performance and reduce future system investment needs, but these effects would be much greater with widespread congestion pricing in place (second set of scenarios) than with the flat rate surcharge as the only mechanism (first set of scenarios). The indications were that congestion pricing could substantially reduce the amount of investment that would be needed to achieve different system performance objectives.

The primary investment scenarios presented in Chapter 8 of this report make no assumptions about funding sources for future highway investment and assume congestion pricing to be absent. The discussion below compares the impacts of six alternative sets of assumptions regarding future revenue mechanisms and congestion pricing mechanisms:

- No future congestion pricing assumed; additional revenue needed to cover scenario funding levels not taken into consideration (baseline assumptions from Chapter 8)
- No future congestion pricing; additional revenue needed to cover scenario funding levels would come from a VMT-based surcharge (comparable to 2008 C&P Report "fixed-rate" scenarios)
- No future congestion pricing; additional revenue needed to cover scenario funding levels would come from a per-gallon surcharge (comparable to 2006 C&P Report baseline scenarios)
- Peak-period congestion charges imposed; additional revenue needed to cover scenario funding levels not taken into consideration
- Peak-period congestion charges imposed; additional revenue needed to cover scenario funding levels would come from a VMT-based surcharge (comparable to 2008 C&P Report "variable-rate" scenarios)
- Peak-period congestion charges imposed; additional revenue needed to cover scenario funding levels would come from a per-gallon surcharge.

Exhibit 9-17 shows how these alternative analytical assumptions affect the overall level of investment identified by HERS as cost-beneficial and the projected impacts of this investment on future VMT, average pavement roughness, and average delay per VMT. The baseline values shown correspond to the HERS-modeled portion of the **Improve Conditions and Performance scenario** presented in Chapter 8.

Exhibit 9-18 shows how these alternative analytical assumptions would affect projected future system performance given a fixed level of future investment. The particular level chosen corresponds to the HERS-modeled portion of the **Maintain Conditions and Performance scenario** presented in Chapter 8.

Impacts Assuming All Cost-Beneficial Improvements Implemented

Exhibit 9-17 shows how incorporation of the balanced budget constraint and/or congestion charges affects key results from HERS investment scenarios targeted at implementing all potentially cost-beneficial investments. Without a "balanced budget" constraint or congestion charge, the amount of such investment within the scope of HERS was estimated to average $105.4 billion per year over the 2009–2028 projection period.

If a balanced budget constraint were assumed so that any increase in spending above 2008 levels would be funded by a VMT-based or per-gallon surcharge, this would reduce the estimate of average annual cost-beneficial investment because the increased costs experienced by highway users would tend to reduce future VMT. It is important to note that while the investment amounts shown in *Exhibit 9-17* include only spending within the scope of HERS, the balanced budget constraint is applied to total highway capital spending. As described in Appendix A, the difference between the HERS-modeled capital investment presented in *Exhibit 9-17* and the $54.7 billion actually spent on the types of capital improvements modeled in HERS (representing 60.0 percent of total capital spending by all levels of government in 2008) is scaled upward to account for the types of capital improvements not modeled in HERS.

Exhibit 9-17

Impact of Alternative Revenue Mechanisms and Congestion Pricing Assumptions on the Level of Potentially Cost-Beneficial HERS-Modeled Investment and on Selected Performance Indicators

Analytical Assumptions		Assumptions Reflected in Highways Scenarios in Prior C&P Reports[3]	Average Annual HERS-Modeled Capital Investment (Billions of 2008 Dollars)[4]	Projected VMT on Federal-Aid Highways in 2028 (Trillions)	Percent Change, 2028 Compared With 2008		Minimum BCR Cutoff
Scenario Financing Mech-anism[1]	**Congestion Pricing[2]**				**Average Pavement Roughness (IRI)**	**Average Delay per VMT**	
None	None	**2010 C&P Baseline**	**$105.4**	3.724	-24.3%	-7.7%	1.00
Per VMT	None	2008 C&P Fixed Rate	$101.4	3.652	-23.8%	-8.3%	1.00
Per Gallon	None	2006 C&P Baseline	$103.2	3.684	-24.0%	-7.7%	1.00
None	Peak Period		$73.8	3.583	-20.0%	-10.8%	1.00
Per VMT	Peak Period	2008 C&P Variable Rate	$73.6	3.584	-20.2%	-10.1%	1.00
Per Gallon	Peak Period		$73.5	3.581	-20.1%	-10.1%	1.00

[1] The analyses presented in this table each assumes that either (1) there is no linkage between the investment scenario and funding mechanisms ("None") or (2) the difference between the scenario investment level and current 2008 capital outlay by all levels of government combined would be financed by a user fee imposed on either a gallonage ("Per Gallon") or a distance traveled ("Per VMT") basis. For those analyses which also include congestion pricing, the resulting revenues are assumed to be available to cover part of the cost of the scenario.

[2] The analyses presented in this table assume that congestion pricing, if implemented, would commence mid-2011.

[3] The baseline scenarios presented in Chapters 7 and 8 of this report assume no linkage between scenario investment levels and financing mechanisms, returning to the approach utilized in the 2004 C&P Report and prior editions. The 2008 C&P Report included two versions of each scenario: a fixed-rate user financing version assuming user charges imposed on a per VMT basis, and a variable-rate user financing version assuming both peak-only congestion pricing beginning in the base year and fixed-rate VMT-based user charges. The 2006 C&P Report baseline scenarios assumed fixed-rate user charges imposed on a per gallon basis.

[4] Of the $91.1 billion of total capital expenditures for highways and bridges in 2008, $54.7 billion was used for types of capital improvements modeled in HERS.

Source: Highway Economic Requirements System.

HERS projects that the average annual level of cost-beneficial investment assuming a VMT-based surcharge would be $101.4 billion; assuming a per-gallon surcharge, HERS projects an investment level of $103.2 billion. The magnitude of the reductions in travel demand reflect that the surcharges are relatively small, adding about 2.5 cents per mile to the user cost of travel compared to an average user cost of $1.07 per mile in the 2008 base year. The estimated impacts of adding a balanced funding constraint on average pavement roughness and average delay are likewise shown by *Exhibit 9-17* to be marginal.

In contrast, the impacts of imposing congestion pricing (with or without a balanced budget constraint) substantially reduce the estimate of potentially cost-beneficial investment. Assuming congestion pricing without a balanced budget constraint, the estimated amount of such investment averages $73.8 billion per year, or 30.0 percent less than the baseline estimate of $105.4 billion per year. The difference reflects that VMT is lower with congestion pricing in place—for example, 3.8 percent lower in the final year of the analysis period (2028)—and that the reduction is concentrated on the heavily congested sections of highway that generate much of the need for investments in system capacity.

Despite the amount of investment being lower, the summary measure of congestion—average delay per VMT—shows improvement with congestion pricing, reflecting the role of pricing in managing demand. From 2008 to 2028, average delay per VMT is projected to decline by 10.1 percent, compared to only 7.7 percent for the baseline assumptions of no pricing or balanced budget requirement. For average

How high are the congestion charges being imposed by HERS, and what would be the associated revenues?

Taking, as an example from *Exhibit 9-17,* the application of congestion pricing without a balanced budget constraint (but with all cost-beneficial improvements assumed implemented over the entire 20-year analysis period), the peak-period tolls average 33.8 cents per VMT across all sections where the tolls are assumed to apply.

These sections are projected to carry 4.4 percent of all VMT on Federal-aid highways during the final 5-year funding period modeled (2024–2028) and a slightly lower percentage during the earlier years of the analysis. (For technical reasons, the imposition of the congestion charges is assumed to kick in at the middle of the first 5-year funding period, in mid-2011, rather than immediately at the beginning of that period in 2009.)

Projected gross revenue from the congestion charge averages $37.6 billion per year over the entire analysis period (2009–2028), stated in constant 2008 dollars. The costs of implementing and operating the congestion pricing system—including, for example, the costs of billing systems and, assuming a Global Positioning System (GPS)-based system, on-board vehicle computers, and GPS transponders—have not been estimated for this report, and could make net revenue significantly lower than gross revenue.

At the lower level of capital spending presented in *Exhibit 9-18*, peak-period tolls would average 34.6 cents per VMT across all sections where the tolls are assumed to apply, and would generate an average of $39.6 billion per year over the 20-year period. If spending were sustained at 2008 base year levels, HERS estimates that peak-period tolls would average 35.2 cents per VMT and generate an average of $41.3 billion per year. The projected average rates and revenues are higher at lower levels of investment because the overall level of congestion would be higher (because less investment would be made in adding capacity to the system), and the rates for the congestion charge for each location are set based on the level of congestion on that facility.

pavement roughness, however, the pattern is reversed: the projected change over the analysis period is a decline of 20.1 percent with congestion pricing versus a somewhat greater decline of 24.3 percent under the baseline assumptions. This pattern is explained by differences in the projected level of investment. Relative to the baseline assumptions, the projections predicated on pricing indicate about 70 percent as much investment in pavement preservation and approximately half as much investment in system expansion. The lower level of investment in pavement preservation is one reason why the pavements are typically rougher with pricing in place. The other reason is that with investment in system expansion also lower, fewer miles of new, smooth lanes are added to the existing system, thereby reducing average ride quality.

Exhibit 9-17 also reveals that adding a balanced funding constraint to the congestion pricing analysis has only minor effects on the estimate of potentially cost-beneficial investment and the conditions and performance indicators.

Impacts Assuming Fixed Total Spending Level

Exhibit 9-18 shows key results from HERS simulations that assume 1.31 percent annual growth over the projection period in real highway capital spending, which corresponds to average annual spending of $62.9 billion in 2008 dollars. For the baseline assumptions without congestion pricing or a balanced budget constraint, HERS projects that average speed in 2028, the final year of the projection period, would be the same as in the base year, 2008.

Adding peak congestion pricing to the picture increases the average speed projected for 2028 by 2.3 percent, and turns the projected 2008–2028 change in average delay per VMT from a deterioration of 3.8 percent to an improvement of 8.7 percent. *Exhibit 9-18* also shows a projected 2008-2028 improvement in average pavement roughness of 14.6 percent assuming congestion pricing, compared to a 3.8 percent improvement for the baseline assumptions. Contributing to this favorable outcome for pavements is the effect of congestion pricing on the HERS allocation of capital spending between pavement preservation and system

Exhibit 9-18

Impact of Alternative Revenue Mechanisms and Congestion Pricing Assumptions on Selected Performance Indicators, Assuming a Uniform Level of Capital Spending

Analytical Assumptions		Assumptions Reflected in Highways Scenarios in Prior C&P Reports[3]	Average Annual HERS-Modeled Capital Investment (Billions of 2008 Dollars)[4]	Percent Change, 2028 Compared With 2008			Minimum BCR Cutoff
Scenario Financing Mech-anism[1]	Congestion Pricing[2]			Average Speed	Average Pavement Roughness (IRI)	Average Delay per VMT	
None	None	**2010 C&P Baseline**	$62.9	**0.0%**	-3.8%	3.8%	2.02
Per VMT	None	2008 C&P Fixed Rate	$62.9	**0.0%**	-3.9%	4.0%	2.01
Per Gallon	None	2006 C&P Baseline	$62.9	**0.0%**	-3.8%	4.1%	2.01
None	Peak Period		$62.9	2.3%	-14.6%	-8.7%	1.24
Per VMT	Peak Period	2008 C&P Variable Rate	$62.9	2.1%	-14.7%	-7.6%	1.24
Per Gallon	Peak Period		$62.9	2.1%	-14.8%	-7.9%	1.23

[1] The analyses presented in this table each assumes that either (1) there is no linkage between the investment scenario and funding mechanisms ("None") or (2) the difference between the scenario investment level and current 2008 capital outlay by all levels of government combined would be financed by a user fee imposed on either a gallonage ("Per Gallon") or a distance traveled ("Per VMT") basis. For those analyses which also include congestion pricing, the resulting revenues are assumed to be available to cover part of the cost of the scenario.

[2] The analyses presented in this table each assume congestion pricing, if implemented, would commence in mid-2011.

[3] The baseline scenarios presented in Chapters 7 and 8 of this report assume no linkage between scenario investment levels and financing mechanisms, returning to the approach utilized in the 2004 C&P Report and prior editions. The 2008 C&P Report included two versions of each scenario: a fixed-rate user financing version assuming user charges imposed on a per VMT basis, and a variable-rate user financing version assuming both peak-only congestion pricing beginning in the base year and fixed-rate VMT-based user charges. The 2006 C&P Report baseline scenarios assumed fixed-rate user charges imposed on a per gallon basis.

[4] Of the $91.1 billion of total capital expenditures for highways and bridges in 2008, $54.7 billion was used for types of capital improvements modeled in HERS. The $62.9 billion average annual investment level assumed for each analysis represents the HERS-derived portion of the baseline Cost to Maintain Highways and Bridges scenario presented in Chapter 8.

Source: Highway Economic Requirements System.

expansion. Although average annual capital spending is fixed at $62.9 billion, incorporating congestion pricing increases the portion that HERS allocates to pavement rehabilitation from $32.7 billion to $40.5 billion. This reallocation arises because the needs for system expansion are more sensitive to changes in traffic volume than are the needs for pavement preservation, which, especially with weather-related effects, stem partly from time- rather than traffic-related deterioration.

As in the results presented in *Exhibit 9-17*, the results shown in *Exhibit 9-18* are relatively insensitive to the inclusion or omission of a balanced funding constraint. Adding this constraint to the base case leaves the projections for the conditions and performance indicators essentially unchanged. Adding it to the congestion pricing regime also does little to the results; the largest impact is on the projected 2009–2028 change in average delay per VMT, which is a decline of 8.7 percent with only congestion pricing assumed versus 7.6 percent when pricing is combined with a balanced budget constraint. This difference occurs because the gross congestion pricing revenues would exceed the amount needed to support the level of funding assumed for this analysis; as a result, the balanced budget constraint would force a reduction to existing user charges, which would encourage additional VMT outside the peak period. This aspect of the balanced budget procedure is discussed in more detail in Appendix A.

Accelerating Operations/ITS Deployments

As described in Chapter 7, the HERS model considers the impacts on highway conditions and performance of various types of ITS and other operational enhancements to highways. Appendix A describes the types of strategies considered (including arterial management, freeway management, incident management, and traveler information systems) and three scenarios for future deployment. The baseline assumptions used in Chapters 7 and 8 of this report are consistent with the "Continuation of Existing Deployment Trends" scenario. One of the alternative sets of assumptions used in this section is consistent with the "Aggressive Deployment" scenario, which assumes an accelerated pace of deployment above existing trends along with more advanced forms of operations strategies than are considered in the baseline. The other set of alternative assumptions is consistent with the "Full Deployment" scenario, which differs from the "Aggressive Deployment" scenario in assuming that all deployments will occur immediately rather than being phased in over 20 years.

The analyses presented in Chapter 7 (see *Exhibit 7-2*) show that increasing HERS-modeled capital spending by 5.90 percent per year over 20 years above the baseline 2008 level of $54.7 billion would result in a 20-year spending figure of $2.108 trillion, translating into an average annual investment level of $105.4 billion. This level of investment was estimated to be sufficient to finance all potential capital improvements up to a BCR cutoff of 1.00. (This is the HERS-modeled component of the **Improve Conditions and Performance scenario** presented in Chapter 8.) As shown in the top half of *Exhibit 9-19*, under the Aggressive Deployment alternative, HERS identifies even more potentially cost-beneficial investments, which average $109.5 billion annually. This finding suggests that the types of operations strategies and ITS deployments considered as part of this scenario are complementary to widening options in some circumstances; in some cases, expanding a facility while simultaneously deploying advanced operations technology can yield more benefits than could be achieved by either action alone. At this level of investment, system performance measured by average speed, average pavement roughness, and average delay would be better in 2028 assuming aggressive deployment patterns than would be the case under the baseline assumption. Under the Full Immediate Deployment alternative, the average annual investment level associated with a BCR of 1.00 would be $115.1 billion; this alternative would result in even better performance than the Aggressive Deployments alternative.

While HERS does not perform benefit-cost analysis of spending on operational deployments versus lane additions in a particular location, it can help to elucidate the tradeoffs between these spending alternatives at a systemwide basis. The bottom of *Exhibit 9-19* shows the impacts on HERS projections of deploying operational improvements more aggressively without changing the total amount invested in highways. This analysis assumes that any extra spending on deployment of operational improvements will be funded by reducing the HERS-modeled investment in system expansion and rehabilitation. The initial amounts of this investment before any reduction is applied are, alternatively, the amount actually spent in 2008 ($54.7 billion from the **Sustain Current Spending scenario**) plus the amounts estimated to be sufficient to maintain current average speed ($62.9 billion) or fund all cost-beneficial improvements ($105.4 billion) under the baseline projections.

At each of these initial levels, funding the more aggressive operational improvement spending by curtailing system expansion and rehabilitation investment worsens projected average pavement roughness in 2028. This is to be expected because operational improvements have no direct impacts on pavement condition and could indirectly worsen pavement condition by inducing additional travel; thus, they produce no benefits in pavement condition to offset the deterioration associated with the curtailment of spending on system expansion and rehabilitation. At an initial level of $105.4 billion in HERS-modeled investment in system expansion and rehabilitation, average pavement roughness is projected to decrease over the analysis period

Exhibit 9-19

Impact of Alternative Operations Strategies Deployment Rate Assumptions on the Level of Potentially Cost-Beneficial HERS-Modeled Investment and on Selected Performance Indicators

Operations/ITS Deployments Assumption [1]	Average Annual HERS-Modeled Capital Investment (Billions of 2008 Dollars) [2]	Percent Change, 2028 Compared With 2008 [3]			Minimum BCR Cutoff [4]
		Average Speed	Average Pavement Roughness (IRI)	Average Delay per VMT	
Make All Cost-Beneficial Investments					
2010 C&P Baseline (existing trends)	**$105.4**	2.6%	-24.3%	-7.7%	**1.00**
Aggressive deployments alternative	$109.5	2.8%	-24.4%	-8.9%	1.00
Full immediate deployments alternative	$115.1	3.2%	-24.7%	-11.1%	1.00
Average Annual Spending $105.4 Billion					
2010 C&P Baseline (existing trends)	$105.4	2.6%	-24.3%	-7.7%	1.00
Aggressive deployments alternative	$105.4	2.6%	-22.9%	-8.2%	1.06
Full immediate deployments alternative	$105.4	2.7%	-20.9%	-9.0%	1.16
Average Annual Spending $62.9 Billion					
2010 C&P Baseline (existing trends)	$62.9	0.0%	-3.8%	3.8%	2.02
Aggressive deployments alternative	$62.9	-0.1%	-0.3%	3.9%	2.21
Full immediate deployments alternative	$62.9	-0.4%	4.5%	4.0%	2.48
Sustain Current Highway Spending	**$188.7**	**-0.5%**	**0.5%**	**11.6%**	**6.71**
2010 C&P Baseline (existing trends)	$54.7	-0.7%	2.8%	6.7%	2.42
Aggressive deployments alternative	$54.7	-1.0%	6.9%	7.1%	2.67
Full immediate deployments alternative	$54.7	-1.4%	12.3%	7.7%	2.99

[1] The analyses presented in this table assume one of the following: (1) existing trends in ITS deployments will continue for 20 years; (2) an aggressive pattern of deployment will occur over the next 20 years; or (3) all of the aggressive deployments would occur immediately, rather than being spread out over 20 years. The costs associated with the more aggressive deployments were deducted from the budget available in HERS for pavement and widening investments.

[2] Of the $91.1 billion of total capital expenditures for highways and bridges in 2008, $54.7 billion was used for types of capital improvements modeled in HERS.

[3] Increases in average speed reflect an improvement to system performance, as do decreases in average pavement roughness (IRI) and average delay per VMT.

[4] The minimum BCR represents the lowest benefit-cost ratio for any project implemented by HERS during the 20-year analysis period at the level of funding cutoff shown.

Source: Highway Economic Requirements System.

from 2008 to 2028 by 24.3 percent in the existing trends scenario for operational improvements versus 20.9 percent in the full immediate deployment scenario. In the aggressive deployment scenario, which is intermediate between the existing trends and full deployment scenarios, the corresponding estimate is a reduction of 22.9 percent. At lower initial levels of HERS-modeled investment in system expansion and rehabilitation, reallocating funding to operational improvements is projected to result in even more significant effects on pavement roughness. At the lowest level considered, sustaining spending at the $54.7 billion level of 2008, projections in all the operational improvement scenarios are for pavements to be rougher on average in 2028 than 2008; however, the deterioration goes from 2.8 percent in the baseline existing trend scenario to 12.3 percent in the most aggressive "full immediate deployments" scenario.

Reallocating funding to operational improvements produces a more marked sacrifice of pavement quality at lower levels of initial investment in HERS-modeled highway system expansion and rehabilitation, which is consistent with the prioritization of investments in HERS according to BCR. As discussed in relation to *Exhibit II-1* in the Introduction to Part II of this report, the marginal BCR rises as the level of HERS-modeled investment in system expansion and rehabilitation declines. The marginal BCR (in *Exhibit 9-19*, the "minimum BCR cutoff") represents the benefit foregone per marginal dollar of investment reduction below the initial level, and reduced pavement quality constitutes part of this loss. Thus, curtailing investment in system expansion and rehabilitation by a given amount will tend to produce larger reduction in pavement quality at lower levels of overall investment.

Unlike pavement quality, travel time directly benefits from the operational improvements represented in HERS so that increased spending on these improvements can potentially affect speed and delay favorably, even when the increase is funded by spending cutbacks on system expansion and rehabilitation. In *Exhibit 9-19*, when the initial level of investment in HERS-modeled system expansion and rehabilitation averages $105.4 billion per year, or about the maximum that HERS can justify on benefit-cost grounds, these overall beneficial impacts would be realized under both of the more aggressive operational deployment strategies considered. However, when this investment is at one of the lower levels shown, *Exhibit 9-19* indicates that pursuing the more aggressive operational deployment alternatives would have adverse overall impacts on both average speed and average delay. At these initial levels of investment, which average $62.9 billion and $54.7 billion annually, the beneficial impacts on these performance measures from the earlier and more widespread deployment of operational improvements are outweighed by the adverse impacts stemming from the offsetting cutbacks in spending on system expansion and rehabilitation. That the overall adverse impacts are more pronounced at lower initial spending levels is again reflective of the pattern of diminishing marginal returns depicted in *Exhibit II-1* (the marginal BCR declines as the level of investment increases). When annual investment is assumed to remain at the 2008 level of $54.7 billion, the average delay per VMT is projected to increase between 2008 and 2028 by 7.1 percent under the "aggressive deployment alternative," which compares with a 6.7 percent assuming continuation of existing deployment trends. When the full immediate deployment of operational improvements is assumed, this projected change in average delay becomes still larger at 7.7 percent.

Alternative Bridge Management Strategies

The NBIAS model includes a capability to analyze the impact of alternative strategies regarding bridge replacements; this section explores how such strategies would impact the backlog of investments needed to address bridge deficiencies. As noted in Chapter 7, the NBIAS model considers bridge deficiencies at the level of individual bridge elements based on engineering criteria and computes an initial value for the cost of a set of corrective actions that would address all such deficiencies. NBIAS tracks this backlog of potential bridge improvements over time, recomputing it to account for corrective actions taken and for the ongoing deterioration of bridge elements. A portion of this engineering-based backlog represents potential corrective actions that would not pass a benefit-cost test and hence would not be implemented by the model even if available funding were unlimited. The remaining portion of the backlog that would be cost-beneficial to address is identified as the economic bridge investment backlog.

The analyses presented in Chapter 7 focused on the economic bridge investment backlog, which NBIAS estimates to have been $121.2 billion in 2008. The analyses presented in Chapter 7 (see *Exhibit 7-2*) show that real growth in NBIAS-modeled spending over 20 years of 4.31 percent annually would make average annual spending $20.5 billion, which would just suffice to eliminate the economic backlog by 2028. From *Exhibit 9-20*, however, it would not suffice to eliminate the engineering backlog, of which $6.4 billion would remain, which is 5.0 percent of the engineering backlog estimated to have existed in 2008. This represents the portion of the engineering backlog that NBIAS did not find cost-beneficial to address. The analysis in this chapter focuses more on the engineering backlog, partly to facilitate comparisons among alternative bridge management strategies.

Exhibit 9-20

Impact of Alternative Bridge Management Strategies on the Projected System Rehabilitation Investment Backlog for All Bridges

Alternative Bridge Management Strategies [1]	Average Annual NBIAS-Modeled Capital Investment (Billions of 2008 Dollars) [2]	Bridge Investment Backlog for System Rehabilitation [3]			
		2008 Economic Backlog	2008 Engineering Backlog	2028 Engineering Backlog	Percent Change 2028 vs. 2008
Maximum (Ramped) Spending Level [4]					
2010 C&P Baseline	$20.5	$121.2	$127.6	$6.4	-95.0%
Replace Bridges over 50 years old	$33.3		$183.9	$289.3	57.3%
Replace Bridges over 75 years old	$22.5		$136.3	$51.0	-62.6%
Replace Bridges with Health Index <85	$42.6		$212.6	$115.4	-45.7%
Replace Bridges with Health Index <80	$36.5		$184.4	$37.2	-79.8%
Replace Bridges with Health Index <75	$30.2		$163.3	$20.9	-87.2%
Sustain Current Spending Level					
2010 C&P Baseline	$12.8	$121.2	$127.6	$114.0	-10.6%
Replace Bridges over 50 years old	$12.8		$183.9	$386.7	110.3%
Replace Bridges over 75 years old	$12.8		$136.3	$158.4	16.2%
Replace Bridges with Health Index <85	$12.8		$212.6	$565.1	165.7%
Replace Bridges with Health Index <80	$12.8		$184.4	$446.3	142.0%
Replace Bridges with Health Index <75	$12.8		$163.3	$331.0	102.7%

[1] The alternative bridge strategies presented would each apply an additional bridge replacement criteria on top of the decision making criteria implicit in the baseline analyses presented in Chapter 7. Applying these criteria would increase the 2008 engineering backlog and alter the mix of bridge investments over the 20-year period analyzed.

[2] Of the $91.1 billion of total capital expenditures for highways and bridges in 2008, $12.8 billion (14.0 percent) was used for types of capital improvements modeled in NBIAS.

[3] Reductions in the economic investment backlog for bridges would be consistent with an overall improvement in bridge conditions. The amounts shown do not reflect system expansion needs; the bridge component of such needs are addressed as part of the HERS model analysis.

[4] The investment levels identified for each alternative represent the average annual level of investment over 20 years consistent with the highest constant annual rate of spending growth above the 2008 baseline level for which NBIAS would spend the full amount of funds available in each of the 20 years.

Source: National Bridge Investment Analysis System.

Of the five alternative management strategies discussed in this section, two relate to the age of bridges and three relate to the average health index rating for bridges as described below. These strategies are intended to be illustrative. Other strategies based on different targets could be used and be equally valid from a technical perspective.

Age-Based Replacement Rules

The number of new bridges constructed per year has varied over time. Many existing bridges were built decades ago during the peak era of Interstate Highways construction. Based on estimates of a 50-year design life of a bridge structure, this has raised concerns that such bridges will soon reach their service life limit.

The assumption of a maximum design life of 50 years may be conservative when timely maintenance and rehabilitation has kept a structure in good repair, thus potentially extending its service life. Conversely, less than aggressive maintenance and factors such as loading a bridge in excess of its anticipated, as-built limit can make a structure deteriorate more quickly or require more extensive rehabilitation.

Exhibit 9-20 shows the impacts on NBIAS projections of mandating replacement of bridges older than 50 years or, alternatively, 75 years. In the model runs that include them, these rules are additional to the other NBIAS criteria for project selection. In one set of these runs, NBIAS implements over the 20-year analysis period all improvements meeting these criteria or required by the replacement rules without any funding constraints assumed. In the other set of runs, annual investment in constant dollars is fixed over the 20 years at the 2008 level of $12.8 billion.

Requiring the replacement of bridges older than 50 years would sharply increase the NBIAS estimate of the engineering backlog that existed in 2008, from the baseline estimate of $127.6 billion to $183.9 billion. This increase is attributable to bridges that are currently over 50 years old that NBIAS does not find to be in need of immediate replacement based on other criteria. In the model runs that maintain spending at $12.8 billion per year (in constant-dollar terms), the engineering backlog soars by 110.3 percent to $386.7 billion by 2028. In the runs where funding is unlimited, spending on the types of bridge improvements modeled in NBIAS increases by 8.42 percent annually over the 20 years, making for an average annual investment of $33.3 billion. Even so, the engineering backlog continues to grow (to $289.3 billion in 2028) as large numbers of bridges cross the 50-year threshold.

A less aggressive replacement rule applied to bridges older than 75 years would increase the estimated engineering backlog for bridges to $136.3 billion in 2008; this is lower than the estimated backlog referenced above for an age-50 replacement rule because there are far fewer bridges that are currently over age 75 than are currently over age 50. When the funding assumption is that annual spending on the types of bridge improvements modeled in NBIAS stays at the 2008 level of $12.8 billion, the engineering backlog is projected to rise by 16.2 percent by 2028. When no funding constraint is assumed, the investment that the model can justify over the 20 years averages $22.5 billion per year, and would be sufficient to cut the $136.3-billion backlog by 62.6 percent to $51.0 billion by 2028.

Health Index-Based Replacement Rules

The health index is a measure of the structural integrity of an element of the bridge. Each element is evaluated individually and these values are then compiled into a total bridge score. The health index ranges from a high of 100 to a low of 0; a lower the health index number indicates a higher priority for structure rehabilitation or maintenance. In *Exhibit 9-20,* the results of analyses based on three alternative replacement thresholds are presented, corresponding to health indices of 85, 80, and 75. With a higher threshold, more bridges would qualify for replacement. A threshold of 85 would be associated with a larger backlog and higher investment needs to address that backlog. As is the case for the age-based alternatives discussed above, these analyses assume that any bridge crossing the health index threshold will be replaced, in addition to other bridge actions selected based on the normal NBIAS criteria.

Among these three alternatives, the estimated engineering bridge backlog for 2008 ranges from $163.3 billion to $212.6 billion, which is considerably higher than the comparable figure of $127.6 billion computed using the baseline assumptions. Assuming investment is sustained at the 2008 level, this backlog projected for 2028 varies from $331.0 billion to $565.1 billion, depending on the health index threshold assumed. As noted at the beginning of this section, the particular health index threshold selected for analysis is intended to illustrate the implications of setting these types of criteria, rather than to suggest that any of these alternatives would form the basis for a comprehensive bridge management strategy.

Transit Supplemental Scenario Analysis

This section is intended to provide the reader with a deeper understanding of the assumptions behind the scenarios presented in Chapters 7 and 8 and also of the real world issues that impact transit operators' ability to address their outstanding capital needs. Specifically, this section includes discussion of the following topics:

- A comparison of the **State of Good Repair (SGR) benchmark** with the maintain conditions and improve conditions scenarios from prior years' C&P reports
- A comparison of recent historic passenger miles traveled (PMT) growth rates with the growth projections of the Nation's metropolitan planning organizations (MPOs) (used for the **Low** and **High Growth scenarios**)
- The gap between cost and revenue growth for transit operations
- The accuracy of TERM in predicting transit capital needs.

TERM Scenarios: SGR Versus Maintain or Improve Conditions

Prior editions of the C&P report included scenarios that considered the level of investment required either to (1) *maintain* the condition of the Nation's existing transit assets at current levels or to (2) *improve* the condition of those assets to an overall condition of "good" (i.e., 4.0 on the Transit Economics Requirements Model's [TERM's] asset condition rating scale). For this edition, these "maintain" and "improve" conditions scenarios have been replaced by the **SGR benchmark**, which estimates the level of investment required to *attain* and then *maintain* an overall state of good repair for the Nation's existing transit assets. This section considers the reasoning and implications of this change.

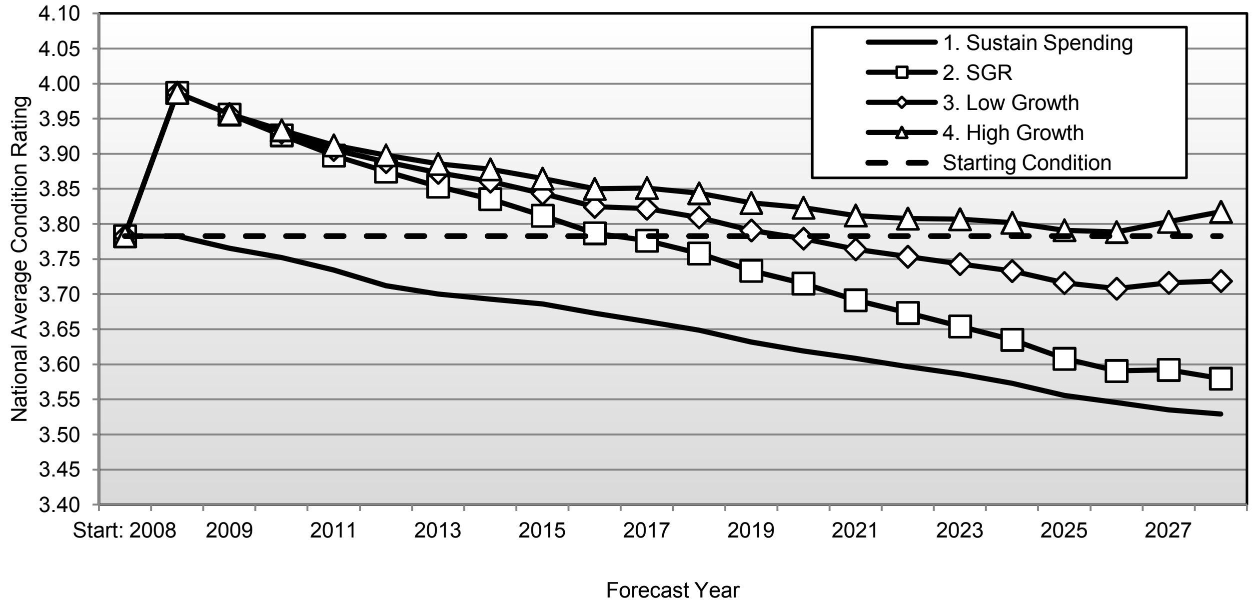
Challenges With the Maintain and Improve Conditions Scenarios

While easy to comprehend and explain conceptually, the maintain and improve conditions scenarios presented in prior editions also suffered from a number of key limitations. First, while each of these scenarios provides a helpful investment reference point, it is not clear that either the maintain or improve conditions outcome is desirable or even sensible. For example, are current asset conditions at an acceptable level or are they too low (or too high) for individual asset types? Is maintaining current conditions financially sensible in the long term and does this objective represent sound asset management practice? Similar questions may be asked of improving conditions to an overall condition of "good." Would this result in replacing assets before the end of their useful lives? Are average conditions truly significant, or is it more critical to improve those assets with the worst conditions?

To help answer these questions, consider *Exhibit 9-21*, which presents the condition projections for each of the four scenarios considered in this report. Note that these projections predict the condition of all transit assets in service at any one time, including transit assets that exist today and any investments in expansion

Exhibit 9-21

Asset Condition Forecast for All Transit Assets: Includes Both Existing and Expansion Assets



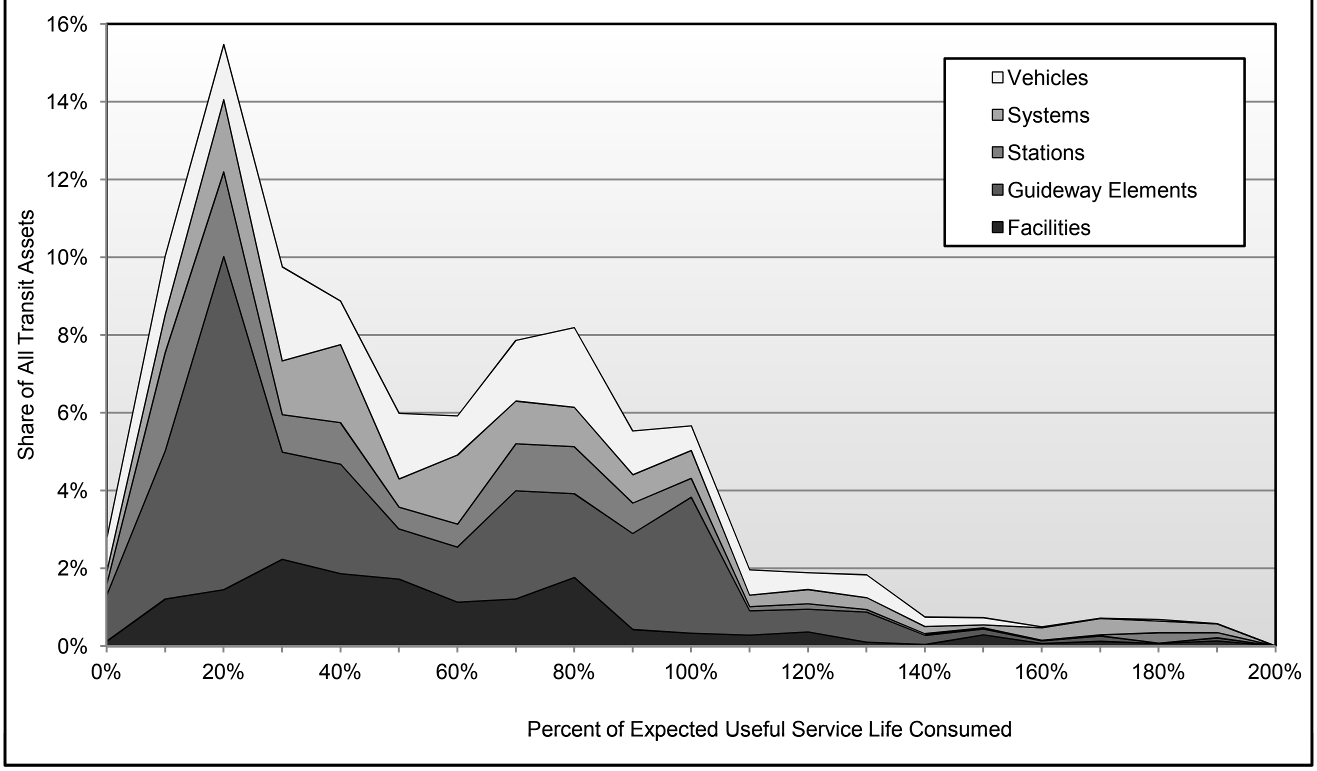
Source: Transit Economic Requirements Model.

assets by these scenarios (the **Sustain Current Spending**, **Low Growth**, and **High Growth scenarios** each have investment in expansion assets and the **SGR benchmark** only reinvests in existing assets). Note also that the estimated current average condition of the Nation's transit assets is 3.78. As discussed in Chapter 8, expenditures under the financially constrained **Sustain Current Spending scenario** are not sufficient to address replacement needs as they arise, leading to a predicted increase in the investment backlog. This increasing backlog is a key driver in the decline in average transit asset conditions as shown for this scenario in *Exhibit 9-21*.

In contrast, the **SGR benchmark** is financially unconstrained and considers the level of investment required both to eliminate the current investment backlog and to address all ongoing reinvestment needs as they arise such that all assets remain in a SGR (i.e., a condition of 2.50 or higher). In *Exhibit 9-21*, elimination of the investment backlog yields the sharp improvement in asset conditions as shown in the early years of the projection (e.g., as all over age assets are replaced). Nonetheless, despite adopting the objective of maintaining all assets in SGR throughout the forecast period, average conditions under the **SGR benchmark** also ultimately decline to levels well below the current average condition value of 3.78. While this result may appear counterintuitive it is explained by a high proportion of long-lived assets (e.g., guideway structures, facilities, and stations) that currently have fairly high average condition ratings and a significant amount of useful life remaining, as shown in *Exhibit 9-22*. The spike in *Exhibit 9-22* at the point where only 20 percent of useful life has been consumed is driven in part by ongoing expansion investments. Hence, while elimination of the current SGR backlog removes a significant number of over age assets from service (resulting in an initial jump in asset conditions), the ongoing aging of the longer-lived assets will ultimately draw the average asset conditions down to a long-term condition level that is consistent with the objective of SGR (and hence sustainable) but ultimately measurably below current average aggregate conditions.

Exhibit 9-22

Comparison of Expected Useful Service Life Consumed for All Transit Assets, by Component



Source: Transit Economic Requirements Model.

Now consider the implications of this finding for the maintain conditions scenario presented in prior reports. If the **SGR benchmark** represents a reasonable long-term investment strategy—namely replacing assets within a short time of attaining their expected useful life—that nonetheless yields a long-term decline in average conditions, then investing to maintain current conditions necessarily implies an investment strategy of replacing assets at earlier ages, in better conditions, and potentially before the end of their useful life. In short, under current asset conditions, the maintain conditions scenario does not align with a reasonable reinvestment policy and, for the same reasons, neither does the improve conditions scenario. In practice, the maintain conditions scenario and the improve conditions scenario from prior editions of the C&P report never did attain the stated maintain and improve conditions investment objectives precisely because these scenarios would have required that some assets be replaced at unreasonably early ages and TERM does not permit early asset replacement. In this context, the **SGR benchmark** provides results that are more realistic and that reflect a sounder reinvestment strategy.

Finally, to underscore these findings, note that the **Low Growth scenario** and the **High Growth scenario** include investments in both asset replacements and asset expansions. Hence, not only are older assets replaced as needed without financial constraint, but new expansion assets are also continually added to support ongoing growth in travel demand. While initially insufficient to fully arrest the decline in average conditions, the impact of these expansion investments ultimately would reverse the downward decline in average asset conditions in the final years of the 20-year projections. As should be expected, the **High Growth scenario** adds newer expansion assets at a higher rate than does the **Low Growth scenario**, ultimately yielding higher average condition values for that scenario (and average condition values that exceed the current average of 3.78 throughout the entire forecast period).

Historic Versus Projected Transit Travel Growth

The **Low** and **High Growth scenarios** presented in Chapter 8 assessed transit expansion investment needs assuming two differing rates of growth in transit PMT. Specifically, the **Low Growth scenario** assumed urbanized-area (UZA)–specific rates of PMT growth as projected by the Nation's MPOs, while the **High Growth scenario** assumed the UZA-specific average annual compound rates experienced over the most recent 10-year period. The objective of this discussion is to help place these two differing growth rates into better perspective.

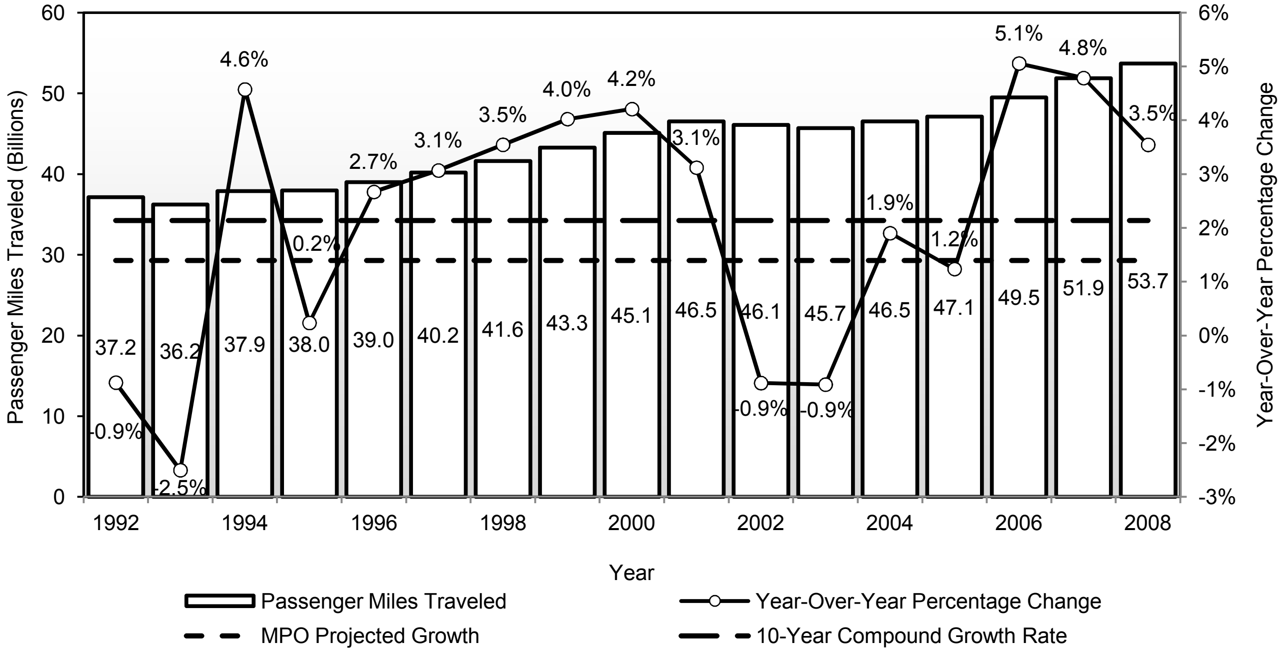
In general, the MPO projections are believed to provide a lower range for PMT growth because these projections are financially constrained (i.e., the assumed rate of transit and highway network expansion is constrained to what is feasible given expected future funding capacity and long-term expansion plans). Hence, while the **Low Growth scenario** is intended to represent unconstrained transit investment needs given a projected rate of increase in PMT, the MPO PMT growth rates underlying this scenario are financially constrained, thus imposing an implicit financial constraint on this scenario. The UZA PMT projections used for the **Low Growth scenario** were provided by a sample of MPOs; this sample was dominated by the Nation's largest UZAs but also included a mix of small- and medium-sized metropolitan areas from around the Nation. When weighted to account for differences in current annual PMT, this sample yields a weighted national average PMT growth rate of 1.3 percent.

MPO Versus Historical Growth for All Urbanized and Rural Areas

As shown in *Exhibit 9-23*, the historical rates of PMT growth experienced over the past 20 years have typically been in excess of the MPO-projected growth rates. During the period from 1992 through 2008 as presented here, the compound annual growth rate averaged roughly 2.1 percent as compared with the 1.3-percent growth rate projected by MPOs for the upcoming 20- to 30-year period (note that this analysis period differs from the 1999 to 2008 period used to assess average growth for the **High Growth scenario.**

Exhibit 9-23

Passenger Miles Traveled, All Urbanized and Rural Areas



Source: National Transit Database and metropolitan planning organization estimates.

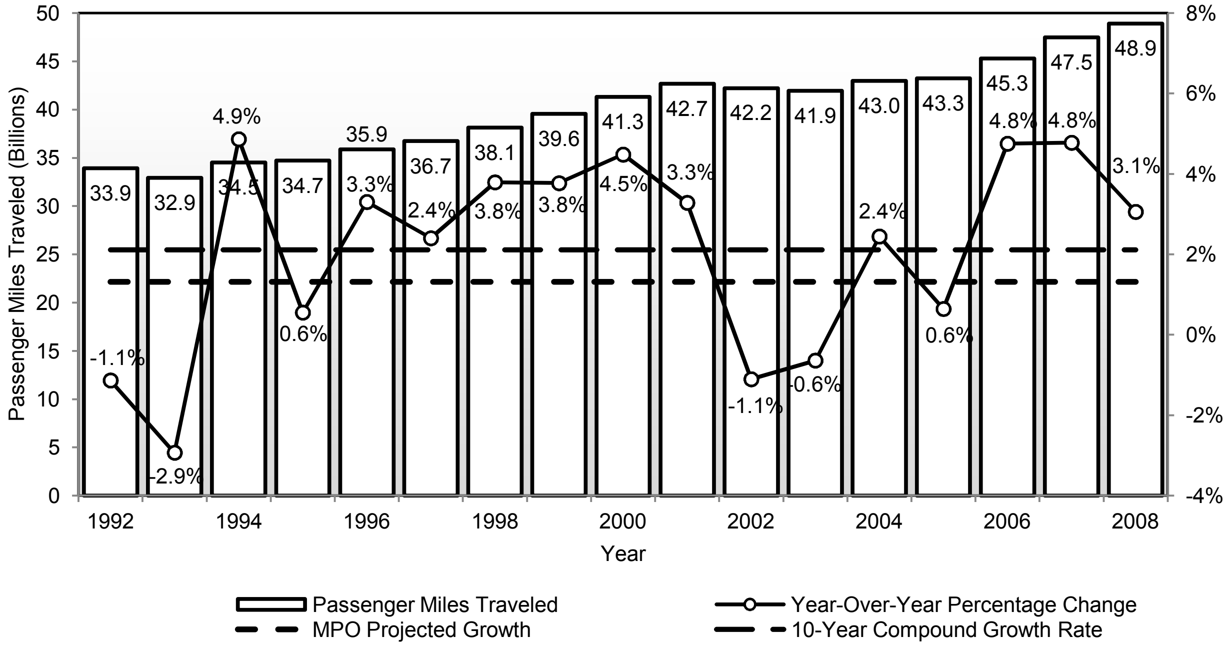
The objective here is to contrast MPO forecasts with long-term PMT growth trends. In contrast, the growth rate identified for the **High Growth scenario** was intended to be more representative of recent higher PMT growth). Given the significant difference in these two rates (and the relatively high rate of historic PMT growth as compared to other additional measures, such as urban area population growth), the historical rate of PMT was identified as a reasonable input value for the **High** (or higher) **Growth Scenario**.

UZAs Over 1 Million in Population

As shown in *Exhibit 9-24*, the difference between the MPO-projected growth rate and the recent historical PMT growth rate remains unchanged when limited to UZAs with populations greater than 1 million. For these larger UZAs, the compound average annual growth rate again averaged roughly 2.1 percent during the period from 1992 through 2008 as compared with the 1.3-percent growth rate projected by MPOs for the up-coming 20- to 30-year period. Note that the larger UZAs carry the vast majority of PMT each year.

Exhibit 9-24

Passenger Miles Traveled, UZAs Over 1 Million in Population



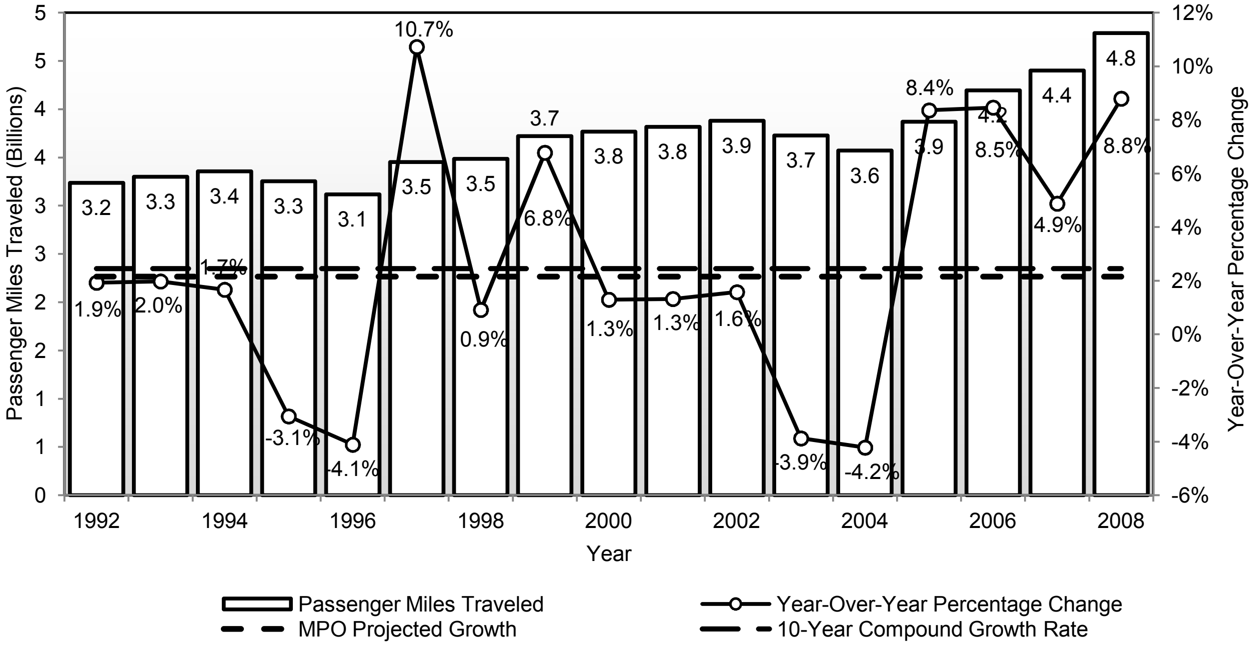
Source: National Transit Database and metropolitan planning organization estimates.

Other Urbanized and Rural Areas

Finally, as shown in *Exhibit 9-25* there is significantly less difference between the MPO-projected and recent annual average historical PMT growth rates when the analysis is limited to urbanized areas with populations less than 1 million and rural areas (i.e., when the larger UZAs are excluded). For this group, the compound average annual growth rate averaged roughly 2.4 percent over the period from 1992 through 2008, which is close to the 2.2-percent growth rate projected by MPOs for this group. There are two significant differences to note here with the findings for the larger UZAs. First, the MPO-projected rate of increase for these smaller UZAs is roughly 64 percent higher than for the largest UZAs. This difference is partly accounted for by (1) the higher rates of population growth in many of these smaller UZAs (particularly in the south and in the west) and (2) proposed light and commuter rail investments in some UZAs in this group. Second, the year-to-year variance in the actual growth rates for this group roughly double that experienced by the largest UZAs.

Exhibit 9-25

Passenger Miles Traveled, UZAs Under 1 Million in Population



Source: National Transit Database and metropolitan planning organization estimates.

Assessing the Accuracy of TERM

The Federal Transit Administration's (FTA's) TERM is an analysis tool designed to estimate transit capital investment needs. It has been used since 1995 to support preparation of the U.S. Department of Transportation's (U.S. DOT's) biennial C&P report. Since TERM has been predicting transit capital investment needs for many years, it is worth considering how accurate TERM has been in estimating how resource levels will impact outcomes.

This section compares TERM's 2004 C&P Report predictions (based on 2002 data) with 2009 data and draws the following conclusions:

- Actual reinvestment expenditures were somewhat lower than TERM's predictions of reinvestment need (less was spent on SGR than was needed to maintain conditions).
- Actual asset conditions in 2009 were lower than TERM predictions in the 2004 C&P Report, which should be expected since transit operators did not reinvest at a rate sufficient to maintain conditions (the objective of the TERM scenario used for comparison).
- Actual capital expansion expenditures for the 2003 to 2009 period were generally lower than TERM estimated would be required to maintain vehicle capacity utilization at 2002 levels. As would then be expected, vehicle capacity utilization increased over the 2003 to 2009 period.
- In general, TERM provided reasonable predictions of transit investment requirements (as determined by actual investment rates) while the differences between TERM's predictions of transit asset conditions and vehicle capacity utilization and the actual, realized values of these measures were consistent with expectations.

Assessment Approach

This section assesses the accuracy of TERM in predicting the following measures: (1) transit reinvestment and expansion needs, (2) future asset conditions, (3) asset expansion, and (4) actual ridership growth. Additional information about TERM is provided in Appendix C. This accuracy evaluation test is based on a comparison of 2004 C&P Report projections of conditions, ridership, and system capacity with actual measures from 2009 data. The 2004 C&P Report that used the 2002 version of TERM with 2002 National Transit Database (NTD) data was selected as the basis of comparison. The 2002 version of TERM was selected because the quality of the asset inventory data that year was much improved relative to submissions in earlier years used to support prior C&P reports. Note that inventory data for TERM must be requested from a sample of agencies. At present (1) there is no Federal asset inventory reporting requirement, and (2) there are no standards for maintaining and reporting such data—hence, there is a broad range of data quality and limited consistency in the asset data obtained for TERM analysis. This situation will change with the introduction of asset reporting through NTD within the next few years. The 2002 version of TERM, which uses 2002 NTD data as reflected in the 2004 C&P Report, also reflects the earliest time period for which reliable reporting of transit capital expenditures segmented between reinvestment and expansion is available.

Investment Needs—Reinvestment

Exhibit 9-26 compares the 2004 C&P Report capital reinvestment needs projections (maintain conditions) with the actual average annual amounts for the 2003 through 2009 period with all amounts expressed in 2008 dollars. Review of this exhibit shows that, over the period from 2003 through 2009, the Nation's transit operators expended an estimated $1.6 billion less on annual capital reinvestment than the amount required to maintain assets at the condition levels prevailing in 2002 (as estimated by TERM). This spending "deficit" was spread across all asset types with the exception of guideway and stations, where actual expenditures reported exceeded TERM's needs estimates.

The largest gap between needs and actual expenditures occurred for bus vehicles (where the gap was on the order of $2.4 billion). Note that, in TERM's estimates, bus life-cycle costs have been reduced since the 2004

Exhibit 9-26

Predicted Versus Actual Capital Reinvestment

Asset Category	TERM Predicted Needs: 2004 C&P—Maintain Conditions (Millions of 2008 Dollars)	Actual Expenditures: NTD Average for 2003 Through 2009 (Millions of 2008 Dollars)[1]	Predicted Minus Actual	Percent Difference
Guideway (track and structures)	$1,678	$2,283	-$605	-36%
Facilities (including admin buildings)	$1,721	$1,427	$295	17%
Systems (including fare collection)	$1,242	$997	$245	20%
Stations	$1,560	$1,800	-$240	-15%
Vehicles[2]	$5,917	$3,477	$2,440	41%
– Rail	$1,731	$1,594	$137	8%
– Bus/Other	$4,186	$1,810	$2,376	57%
Other	$0	$493	-$493	100%
Total	**$12,119**	**$10,477**	**$1,642**	**14%**

[1] *TERM, being unconstrained, replaces all assets on a shorter cycle than financially constrained local operators.*

[2] *Bus life-cycle costs have been reduced since the 2004 C&P Report to reflect the fact that only the Nation's largest bus operators perform capital budget funded mid-life overhauls.*

Source: National Transit Database and 2004 Conditions and Performance Report.

C&P Report to reduce the cost of mid-life rehabilitations. Specifically, while major bus operators invest heavily in mid-life bus rehabilitations, mid- to small-size bus operators do not. At the time the 2004 C&P Report was produced, TERM assumed that all bus operators performed extensive mid-life overhauls. Based on the revised needs calculations, the gap between estimated and actual bus reinvestment needs would be reduced by roughly $1.0 billion annually, thus reducing the overall investment gap to roughly $600 million.

Enhancement Versus Rehabilitation and Replacement Spending: It should also be noted that the annual capital expenditures reported to NTD for asset reinvestment include investments in asset "enhancements" (e.g., technology and materials upgrades and minor capacity improvements) to existing assets in addition to in-kind rehabilitation and replacement activities. Given that TERM is primarily focused on in-kind asset rehabilitation and replacement (i.e., does not estimate all enhancement needs), the actual gap between the level of investment in rehabilitation and replacement to maintain current conditions and actual rehabilitation and replacement spending for 2003 through 2009 is larger than that reported in *Exhibit 9-26*.

Asset Conditions

Given the shortfall between actual spending and that required to maintain conditions (roughly 15 percent annually), asset conditions should be expected to decline over the 2003 through 2009 period. Subject to an important caveat, this expectation is generally supported by the analysis in *Exhibit 9-27*. Specifically, *Exhibit 9-27* compares the 2004 C&P Report estimated asset conditions by asset category as of 2009 with the "actual" conditions based on the 2009 asset inventory data set (and estimated using TERM's decay curves). With the exception of passenger stations (where expenditures were higher than those required to maintain conditions), this comparison shows a decline in condition for all asset types. A significant outlier is guideway elements where asset conditions actually declined even though reported actual reinvestment expenditures were higher than the estimated amount required to maintain conditions (hence, the actual change in asset conditions is at odds with the expected change given the level of reinvestment). This is likely more the result of changes in consistency in reporting asset inventory data both between operations and from one period to the next than an actual change in condition.

Exhibit 9-27

Predicted Versus "Actual" Asset Conditions as of 2009

Asset Category	TERM Predicted Condition: 2004 C&P Report	2009 "Actual" Condition[1]	Predicted Minus Actual[2]
Guideway Elements (track and structures)	4.28	3.79	0.49
Maintain and Admin Facilities	3.52	3.35	0.17
Systems (including fare collection)	3.68	3.31	0.37
Stations	3.26	3.32	-0.06
Vehicles[3]	3.4	3.32	0.08
– Rail	3.47	3.4	0.07
– Bus/Other	3.24	3.16	0.08
All	**3.74**	**3.49**	**0.25**

[1] "Actual" 2009 conditions estimated based on 2008 data set and TERM decay curves. Agencies with significant New Starts investments over the 2003 to 2009 period have been removed from this analysis.

[2] Change in conditions between 2004 and 2005 partially driven by changes in data quality since 2002.

[3] Vehicle conditions for 2009 modified to exclude expansion vehicle purchases between 2003 and 2009.

Source: National Transit Database, TERM, and 2004 Conditions and Performance Report.

Finally, *Exhibit 9-28* summarizes the comparative results between *Exhibits 9-26* and *9-27*. Specifically, *Exhibit 9-28* shows whether TERM correctly "predicted" improvements or declines in asset conditions between 2002 (2004 C&P Report) and 2009 based on whether actual levels of reinvestment were above or below TERM's estimate of the amount required to maintain current conditions. Excluding guideway, *Exhibit 9-28* shows that TERM correctly predicted asset conditions.

Exhibit 9-28

Summary of TERM Prediction Tests: Capital Reinvestment

Asset Category	Actual Expenditures Above or Below Maintain Condition Level?	Expected Change in Condition	Actual Change in Condition	Change in Condition Predicted Correctly?
Guideway (track and structures)	⇧	⇧	⇩	No
Maintenance and Admin Facilities	⇩	⇩	⇩	Yes
Systems (including fare collection)	⇩	⇩	⇩	Yes
Stations	⇧	⇧	⇧	Yes
Vehicles	⇩	⇩	⇩	Yes
– Rail	⇩	⇩	⇩	Yes
– Bus/Other	⇩	⇩	⇩	Yes

Caveat on Changes in Asset Data Quality: While the improvement in station conditions might be expected (as spending was slightly higher than that predicted to maintain conditions—see *Exhibit 9-26*), by the same logic, some improvement in the condition of guideway elements (track and structures) also might be expected; but in fact, there is an estimated decline. Why? The answer lies in the quality of the asset data reported. Given that, as noted above, there is no Federal asset inventory reporting requirement and that there are currently no standards for maintaining and reporting such data, the TERM analysis is subject to inconsistency in data reporting both between operations and from one period to the next. Moreover, from 2003 through 2009, a number of the Nation's larger transit operators exerted considerable effort to improve the quality of the asset inventory data that they maintain for their own analysis purposes. While this improved data quality has greatly benefited the accuracy of TERM's needs and condition analysis, it has also resulted in significant changes to TERM's estimates of current asset conditions—most notably for rail track and structures. This issue of changes in the underlying data used to generate TERM's needs and condition analysis will be eliminated as required asset inventory reporting through NTD is implemented within the next few years. For the purposes of this analysis, it should be noted that the differences in 2009 asset condition estimates reported in *Exhibit 9-27* are the product of both (1) changes in condition resulting from reinvestment levels that are higher/lower than those required to maintain asset conditions and (2) changes in the quality of the reported data.

Investment Needs—Expansion

Exhibit 9-29 compares the 2004 C&P Report capital expansion investment needs projections ("maintain performance") with the actual average annual amounts of investments for the 2003 through 2009 period, with all amounts expressed in 2008 dollars. Note that expansion needs are presented both by asset category (top of exhibit) as well as for the four primary transit modes (commuter rail, heavy rail, light rail, and bus—bottom of exhibit). Note also that the maintain performance level of expansion investment is that level of

Exhibit 9-29

Predicted Versus Actual Capital Expansion Investment

Asset Category	TERM Predicted Needs: 2004 C&P—Maintain Performance (Millions of 2008 Dollars)	Actual Expenditures: NTD Average for 2003 Through 2009 (Millions of 2008 Dollars)	Predicted Minus Actual	Percent Difference
General Assets				
Guideway (track and structures)	$1,474	$2,638	-$1,164	-79%
Maintenance and Admin Facilities	$508	$251	$257	51%
Systems (includes fare collection)	$336	$121	$215	64%
Stations	$723	$427	$296	41%
Vehicles	$2,472	$497	$1,975	80%
– Rail	$1,084	$344	$740	68%
– Bus/Other	$1,388	$150	$1,238	89%
Other Projects	$1,165	$140	$1,025	88%
Total	**$6,678**	**$4,074**	**$2,604**	**39%**
For Primary Transit Modes				
Commuter Rail	$1,192	$526	$666	56%
Heavy Rail	$2,605	$586	$2,019	78%
Light Rail	$705	$2,451	-$1,746	-248%
All Rail	**$4,502**	**$3,563**	**$939**	**21%**
Bus	**$1,359**	**$422**	**$937**	**69%**

Source: National Transit Database, metropolitan planning organization estimates, and 2004 Conditions and Performance Report.

investment required to maintain current vehicle utilization rates (i.e., the number of riders per passenger vehicle) given the projected growth in transit ridership (based on a sample of the ridership projections of those MPOs representing the Nation's 30 largest UZAs as well as a sample of MPO projections representing the Nation's smaller UZAs). Similar to the reinvestment needs comparison (*Exhibit 9-26*), actual investment in asset expansion was less than that required to maintain current transit performance by roughly $2.6 billion annually. On an asset category basis, actual annual expenditures lagged the maintain performance levels for all asset categories except guideway elements.

On the basis of major transit mode, *Exhibit 9-29* suggests that, with the exceptions of light rail, expansion investments were insufficient to address the projected increase in transit ridership for this period. This hypothesis is tested below based on changes in vehicle capacity utilization and the actual expansion in the number of track miles, stations, and fleet vehicles in transit service over the 2003 to 2009 period. Before proceeding to that analysis, note that the large actual expansion investment in light rail relative to the maintain performance needs level should not come as a surprise given that the vast majority of expenditures funded by FTA New Starts over the 2003 to 2009 period was invested in light rail projects.

Changes in Vehicle Occupancy

Given that expenditures on bus and rail expansion were less than that required to maintain performance (*Exhibit 9-29*), it may be expected that vehicle occupancy levels increased for both bus and all rail modes in total. Within the rail modes, *Exhibit 9-29* suggests that vehicle utilization rates should have increased for commuter rail and heavy rail (where actual investment was less than the estimated amount to maintain the number of riders per passenger vehicle) and decreased for light rail. With one exception, *Exhibit 9-30*, which presents the change in actual vehicle utilization rates from 2002 to 2009 by mode, confirms all of these expectations. The exception is commuter rail where actual utilization rates declined despite levels of actual expansion investment that were well below those required to maintain the current utilization rate.

Exhibit 9-30

Vehicle Capacity Utilization Rates for Rail and Bus (From NTD)

Asset Category	2002	2009	Difference	Percent Difference
Commuter Rail	36.7	35.7	-1	-2.70%
Heavy Rail	22.6	25.7	3.1	13.70%
Light Rail	26.1	24.1	-2	-7.70%
Rail (weighted avg.)	**24.4**	**26.6**	**2.2**	**8.80%**
Bus	**10.5**	**10.8**	**0.3**	**2.90%**

Source: National Transit Database.

To better understand the rail expansion investment and vehicle capacity utilization results in *Exhibit 9-30*, it is helpful to review *Exhibit 9-31,* which compares TERM's 2002 (2004 C&P Report) estimates of the increase in the number of track miles, stations, and revenue vehicles by major mode (for the 2003 through 2009 period) with the actual increase in these asset counts as reported to NTD over this same time period. Note that the actual expansion in commuter rail and light rail assets was greater overall than the estimated amount required to maintain performance (particularly for vehicles), thus helping explain the reduction in vehicle occupancy rates as reported in *Exhibit 9-30* for these two modes. In contrast, the actual expansion in heavy rail and bus fleets was less than the estimated amount required to maintain performance, thus helping explain the increase in vehicle occupancy rates as reported in *Exhibit 9-30* for the heavy rail and bus modes.

Exhibit 9-31

Predicted Versus Actual Capital Expansion

Asset Category	TERM Predicted Needs: 2004 C&P—Maintain Performance (Millions of 2008 Dollars)	Actual Counts: Increase Reported to NTD 2003–2009	Predicted Minus Actual	Percent Difference
		Track Miles		
Commuter Rail	380	386.7	-7	-1.80%
Heavy Rail	67	93.1	-27	-40.00%
Light Rail	98	172.6	-75	-76.10%
Rail Total	**545**	**652**	**-107**	**-19.70%**
		Stations		
Commuter Rail	152	71	81	53.30%
Heavy Rail	67	47	20	29.30%
Light Rail	118	196	-78	-66.70%
Rail Total	**337**	**314**	**23**	**6.80%**
		Revenue Vehicles—Rail		
Commuter Rail	551	1,053	-502	-91.10%
Heavy Rail	910	464	446	49.00%
Light Rail	245	543	-298	-121.30%
Rail Total	**1,706**	**2,060**	**-354**	**-20.80%**
		Revenue Vehicles—Bus		
Bus	**9,121**	**5,249**	**3872**	**42.40%**

Source: National Transit Database, TERM estimates, and 2004 Conditions and Performance Report.

Exhibit 9-32 summarizes the comparison of TERM's ability to correctly predict actual changes in vehicle utilization rates by mode based on whether the rate of actual expansion investments for 2003 to 2009 was above or below the estimated amount to maintain current utilization rates. *Exhibit 9-32* shows that TERM correctly predicted the change in utilization for all vehicles except commuter rail.

Exhibit 9-32

Summary of TERM Prediction Tests: Expansion Investments

Asset Category	Actual Investment Above or Below Maintain Performance Level?	Expected Change in Utilization (Riders per Vehicle)	Actual Change in Utilization (Riders per Vehicle)	Change in Utilization Predicted Correctly?
Commuter Rail	⇩	⇧	⇩	No
Heavy Rail	⇩	⇧	⇧	Yes
Light Rail	⇧	⇩	⇩	Yes
All Rail	⇩	⇧	⇧	Yes
Bus	⇩	⇧	⇧	Yes
All Modes	⇩	⇧	⇧	Yes

Assessment Results

This section assessed the accuracy of TERM's projections prepared for the 2004 C&P Report in predicting (1) transit investment needs (as compared with actual expenditures); (2) future asset conditions; (3) asset expansion requirements; and (4) actual ridership growth for the 2003 through 2009 period. First, in the 2004 C&P Report, TERM's predictions of reinvestment needs were comparable to, but generally higher than, actual reinvestment expenditures for the 2003 through 2009 period. This result should be expected given that TERM is predicting reinvestment needs (to maintain asset conditions), not actual spending, and that TERM's needs estimates are financially unconstrained (in direct contrast to local agency investment levels). Second, in the 2004 C&P Report, TERM tended to overpredict actual asset conditions as of 2009, which again should be expected if transit operators are not reinvesting at a rate sufficient to maintain conditions (the objective of the TERM scenario used for comparison). Last, as with reinvestment expenditures, TERM's predictions of capital expansion needs in the 2004 C&P Report were generally higher than actual capital expansion expenditures for the 2003 to 2009 period. Again, this outcome is not unexpected given that TERM's needs estimates are financially unconstrained. Moreover, given that the actual expansion investments were less than what TERM estimated as required to maintain vehicle capacity utilization at 2002 levels, it should be expected that vehicle capacity utilization increased, which indeed was the case over the 2003 to 2009 period. In general, TERM provided reasonable predictions of transit investment requirements (as compared with actual, constrained investment rates) while the differences between TERM's predictions of transit asset conditions and vehicle capacity utilization and the actual, realized values of these measures were consistent with prior expectations (i.e., given the differences in predicted needs and actual expenditures).

This analysis raised a number of issues and questions to be addressed through further research and related improvements to future TERM and C&P analysis:

- Constructability Constraints: TERM's underestimation of rail expansion for light rail, commuter rail, and track miles is likely driven in part by constructability constraints designed to ensure that the model "builds" only a limited number of additional track miles in any given year (constrained on a UZA basis). These constraints may be set too low and hence should be reviewed and potentially revised (i.e., loosened).
- Differential Growth Rates by Mode: TERM is designed to establish the rate of ridership growth at the UZA level, and hence the ridership growth rate is fixed across all mode types within the same UZA. Revising the tool to allow for differential ridership growth by mode may help reduce the imbalance between individual rail modes (i.e., across commuter, heavy, and light rail) as well as between rail and bus.
- Revised Expansion Assumptions for Commuter Rail: TERM's per-mile costs for commuter rail expansion are likely too high (TERM may be investing in too many assets—including number of stations per mile—and the unit costs of those assets are also likely too high). These assumptions should be reviewed and modified based on actual per-mile costs for recent New Starts commuter rail projects.

Chapter 10

Sensitivity Analysis

Highway Sensitivity Analysis

The results produced by the Highway Economic Requirements System (HERS), the National Bridge Investment Analysis System (NBIAS), and the Transit Economic Requirements Model (TERM) reflected in the investment scenario estimates presented in this report are strongly affected by the values of certain key variables. In any modeling effort, it is critical to evaluate the validity of the underlying assumptions and determine the degree to which projected outcomes could be affected by changes to these assumptions. (Note that the analyses presented in this section relate primarily to technical assumptions; Chapter 9 includes similar analyses of some more policy-oriented assumptions, including the rate of deployment of operations strategies, the implementation of congestion pricing, and the adoption of alternative bridge management strategies.)

This section explores the sensitivity of the HERS and NBIAS projections from Chapter 7 to variation in some of the underlying assumptions. These sensitivity analyses pertain to the types of capital projects within the current scopes of the HERS and NBIAS models—pavement and system expansion projects on Federal-aid highways, and all bridge system rehabilitation projects, respectively. Excluded from analysis are pavement or system expansion improvements to other roads, or any system enhancements such as safety, traffic operational, or environmental enhancements; these types of highway capital improvements are not currently directly modeled in HERS or NBIAS. Sensitivity analyses are conducted separately for HERS and NBIAS; the results obtained from the two models were not combined.

It is important to note that the analyses for highways and bridges presented in this chapter relate to individual scenario components only, rather than to complete scenarios, so that the investment levels shown in the various exhibits are not directly comparable to those presented in Chapter 8. In order to fully reconstruct a Chapter 8 scenario using input from this section, one would need to combine a modified HERS-derived component with a modified NBIAS-derived component and to re-estimate the nonmodeled component of the scenario in the manner described in Chapter 8.

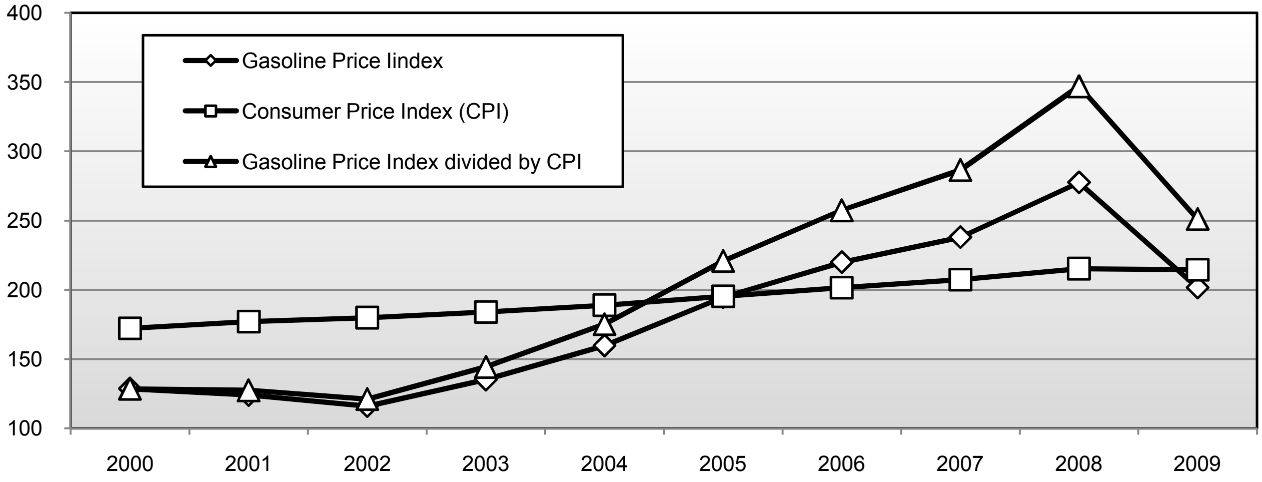
The first part of this section considers the uncertainty surrounding future trends in traffic volumes, fuel prices and vehicle fuel efficiency; and changes in construction costs. The second part includes additional sensitivity tests of the assumptions in the HERS and NBIAS simulations. These tests vary the assumptions about the value travelers attach to reductions in travel time and crash risk, the sensitivity of travel demand to changes in the cost of travel, and the discount rate used to convert future costs and benefits into present equivalents. An additional test drops the options normally included in HERS for adding capacity to a highway section through high-cost means (such as tunneling or double-decking) when the Highway Performance Monitoring System (HPMS) database indicates that conventional widening is infeasible. A subsequent section within this chapter explores information regarding the assumptions underlying the analyses developed using TERM.

Alternative Growth Rates in Prices and Travel Demand

Future traffic projections, central to evaluations of capital spending on transportation infrastructure, are speculative. Fuel prices are also difficult to forecast as indicated by the historical volatility depicted in *Exhibit 10-1* and by the alternate scenarios for fuel prices in the Energy Information Administration's *Annual Energy Outlook 2010*. Measurement of changes in highway construction costs has become problematic in recent years as these costs have become more volatile; the diversity among highway capital improvement types and changes in data availability have added to the uncertainty in this area.

Exhibit 10-1

Retail Gasoline and Consumer Price Indices (1982–1984 = 100)



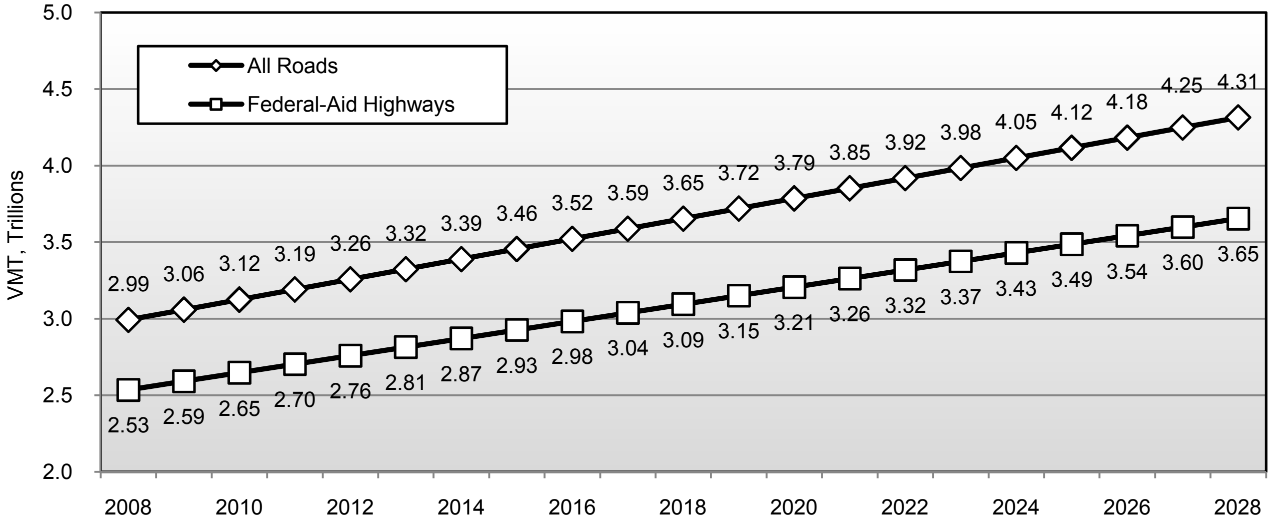
Source: Bureau of Labor Statistics, Consumer Price Index series.

Alternative Rates of Growth in Travel Demand—HERS

States provide forecasts of future vehicle miles traveled (VMT) for each individual HPMS sample highway section, based on available information concerning the particular section and the corridor of which it is a part. The composite weighted average annual VMT growth rate based on these forecasts is 1.85 percent. *Exhibit 10-2* shows projected year-by-year VMT for 2008 to 2028 for Federal-aid highways and all roads combined. Consistent with the approach used in the HERS and NBIAS analyses for this report, the values shown assume that VMT will grow in a linear fashion (so that 1/20th of the additional VMT is added each year), rather than geometrically (growing at a constant annual rate). Under this assumption, the annual percent rate of growth gradually declines over the forecast period. Projected VMT growth in rural areas averages 2.15 percent per year, somewhat higher than the average of 1.70 percent in urban areas. The forecasts for 2008 to 2028 are lower than the actual average annual VMT growth rate of 1.94 percent that occurred from 1988 to 2008.

Exhibit 10-2

Annual Projected Highway VMT Based on HPMS Forecasts



Source: Highway Performance Monitoring System.

HERS assumes that the forecast for each HPMS sample highway segment represents the amount of travel that would occur if the level of service on that segment remained at the base-year value. To measure level of service, HERS uses average highway user cost per VMT, including costs of travel time, vehicle operation, and crash risk. The average user cost will be forecast to remain at the base year value only under specific assumptions about the level and allocation of future investment. In all other cases, projected user costs will differ from the base year value, triggering an upward or downward adjustment in projected future VMT. Generally, higher levels of investment are associated with relatively higher levels of service for the overall system, higher VMT growth, and relatively lower highway user costs. Changes in average user cost that HERS forecasts affect the travel demand projections through the demand elasticity, which measures the sensitivity of travel volumes to changes in the effective price of driving.

The effective VMT growth rates predicted by the HERS model could thus be off-target because of inaccuracies in either the forecasts of the travel that would occur under a constant level of service or the predictions of demand responses to changes in average user cost. To address the former of these potential sources of error, this section includes a sensitivity analysis that varies the annual percentage rate at which VMT is assumed to grow under a constant level of service. As alternatives to the baseline assumption of 1.85 percent per annum growth derived from the HPMS, the sensitivity analysis uses the average rates of VMT growth over the 5- and 10-year periods ending in the base year. Potential errors in the elasticity-based predictions of demand responses are addressed in a separate sensitivity analysis later in this chapter.

What are some of the technical limitations associated with the analysis of alternative travel growth rates included in this section?

One of the strengths of the State-provided VMT forecasts used in the baseline analysis is their geographic specificity: Separate forecasts are provided for the more than 100,000 HPMS sample sections. In forming these forecasts, States can take account of specific local influences on travel growth and their own long-range planning assumptions about future travel patterns on particular routes or corridors. The inclusion of these section-level forecasts, as opposed to regional or statewide travel estimates, allows for more refined analyses of projected future investment/performance relationships.

The analyses of alternative travel growth rates presented in this section use the HPMS forecasts as a starting point, but adjust them up or down in uniform proportion on a national basis. In reality, if VMT were to grow faster or slower than State projections, these differences would not be uniform, and could be heavily concentrated in particular corridors, regions, or States. Moreover, these differences could significantly impact the level of investment that might be required to achieve particular systemwide performance targets. The assumption of uniformity thus limits the reliability of this section's analysis of alternative VMT growth rates.

During the period 1998–2008, VMT in the United States increased at an average annual rate of 1.23 percent, which is 0.62 percentage points lower than the baseline forecast. During the latter half of this period, 2003–2008, the average annual rate of increase was only 0.53 percent, reflecting the slow-down in VMT growth discussed in Chapter 2. *Exhibit 10-3* shows that replacing the baseline forecast of the VMT growth rate with the lower rates that occurred in recent years reduces the HERS-based estimates of the maximum cost-beneficial amount of highway investment. Projecting forward the 1998–2008 annual growth rate of 1.23 percent, the amount of highway investment that HERS can justify (i.e., all potential investments with a benefit-cost ratio BCR ≥ 1.00) averages $80.2 billion per year over the 20-year analysis period 2009–2028, which is less than under the baseline VMT growth assumption. Alternatively, assuming that VMT continues to grow at the average annual rate of the more recent 2003–2008 period would bring the estimate of economically justifiable funding down to $59.8 billion, or $45.6 billion below the baseline estimate. Since this report's analysis with the HERS model precludes consideration of spending in excess of what is economically justifiable, the cells in *Exhibit 10-3* where the results for such levels of spending would appear are left blank and shaded.

Exhibit 10-3

Impact of Alternative HERS Constant Price Travel Growth Forecasts on Selected Indicators, for Different Possible Funding Levels

HERS-Modeled Capital Investment		Projected 2028 VMT on Federal-Aid Highways (Trillions of VMT) for Three Constant Price VMT Growth Assumptions			Percent Change in Average Speed, 2028 Compared With 2008 for Three Constant Price VMT Growth Assumptions			Minimum BCR Cutoff[3] for Three Constant Price VMT Growth Assumptions		
Annual Percent Change in HERS Spending[1]	Average Annual Spending[2] (Billions of 2008 Dollars)	Baseline	Alternatives		Baseline	Alternatives		Baseline	Alternatives	
		State-Projected	Historic Rates		State-Projected	Historic Rates		State-Projected	Historic Rates	
			10-Year	5-Year		10-Year	5-Year		10-Year	5-Year
5.90%	$105.4	3.724			2.6%			**1.00**		
4.86%	$93.4	3.714			2.0%			1.20		
3.51%	$80.1	3.700	3.313		1.2%	3.6%		1.50	1.00	
2.88%	$74.7	3.694	3.308		0.9%	3.3%		1.64	1.11	
1.31%	$62.9	3.677	3.296		**0.0%**	2.7%		2.02	1.42	
0.56%	$58.0	3.670	3.290	2.913	-0.4%	2.4%	4.5%	2.24	1.58	1.05
0.00%	$54.7	3.664	3.286	2.910	-0.7%	2.1%	4.4%	2.42	1.70	1.15
-1.00%	$49.3	3.655	3.278	2.904	-1.3%	1.7%	4.1%	2.72	1.94	1.35
3.52%	$80.2		3.313			3.6%			**1.00**	
0.85%	$59.8			2.915			4.6%			**1.00**

[1] *The first eight rows correspond to annual percent changes in spending identified in Chapter 7 (Exhibit 7-3) as being associated with the investment needed to achieve certain specific targets (expressed in terms of minimum BCR cutoffs, maintaining specific performance indicators, or growing at a specific rate in constant dollar terms). The ninth and tenth rows correspond to the level of investment consistent with a minimum BCR cutoff of 1.00 for the two alternative assumptions; the comparable investment level for the baseline assumption appears in the top row in the table.*

[2] *The amounts shown represent the average annual investment over 20 years by all levels of government combined that would occur if such spending grows annually in constant dollar terms by the percentage shown in each row of the first column. Of the $91.1 billion of total capital expenditures for highways and bridges in 2008, $54.7 billion was used for the types of capital improvements modeled in HERS.*

[3] *The minimum BCR represents the lowest benefit-cost ratio for any project implemented by HERS during the 20-year analysis period at the level of funding shown.*

Source: Highway Economic Requirements System.

The variation in the minimum BCRs in *Exhibit 10-3* provides another indication of the effect of lower traffic growth rates on estimated investment needs. Lower traffic volumes tend to reduce the benefits from, and hence the need for, highway improvements. Additions to highway capacity become less urgent because more lightly traveled roads are less congested, while improvements to pavement quality will benefit a smaller volume of traffic. For a given amount of highway investment spending, the benefit-cost ratios estimated by HERS vary inversely with the level of traffic growth input to the model. For example, when funding over the 20-year analysis period grows at 0.56 percent per year (which translates to average annual funding of $58.0 billion), the minimum BCR is estimated at 2.24 assuming the baseline rate of traffic growth (State-supplied forecast). This compares to minimum BCRs of 1.58 and 1.05 assuming continuation of traffic growth rates from 1998–2008 and 2003–2008, respectively.

Exhibit 10-3 also shows how variation in the assumed rates of traffic growth affects the projections for average speed on Federal-aid highways in 2028. For example, if investment in HERS-modeled improvements were to average $62.9 billion over the 20 years, the average speed projected for 2028 is the same as the average speed in 2008 under the baseline assumptions on traffic growth, but would increase 2.7 percent under the assumption that traffic will grow at the lower rate that occurred between 2003 and 2008.

Alternative Rates of Growth in Travel Demand—NBIAS

As discussed in Chapter 7, the NBIAS model considers bridge deficiencies at the level of individual bridge elements based on engineering criteria and computes a value for the cost of a set of corrective actions that would address all such deficiencies. The portion of this engineering-based backlog that would pass a benefit-cost test is identified as an economic bridge investment backlog. The NBIAS analysis presented in Chapter 7, which serves as the baseline for sensitivity tests in this chapter, estimated that the economic backlog was $121.2 billion in 2008 and that its elimination by 2028 would require investment growing in constant dollars at 4.31 percent annually; this rate of growth translates to an average annual investment level of $20.5 billion in constant 2008 dollars.

For the NBIAS analysis, the baseline traffic projections are from the National Bridge Inventory database. Although these projections pertain specifically to bridge traffic, the implied average annual rate of growth differs little from the 1.85 percent implied by the HPMS projections that serve as the HERS baseline. For sensitivity testing, the alternative rates of growth considered in the HERS analysis were therefore reused for NBIAS. *Exhibit 10-4* shows the effect of reducing the rate of growth from the baseline value to 0.53 percent, which was the average annual VMT growth rate between 2003 and 2008. Even with this reduction, NBIAS estimates for 2008 a backlog of economically justifiable bridge investment amounting to $120.9 billion, which is only 0.2 percent less than the estimate of $121.2 billion assuming the baseline rate of traffic growth. Similarly, the reduction in assumed traffic growth rate has a slight effect on the estimated amount of bridge investment spending needed to eliminate this backlog by 2028. To provide this amount of funding, real investment in bridges would need to increase by an estimated 4.31 percent annually assuming the baseline rate of traffic growth, and by an estimated 4.30 percent in the sensitivity test (rounding to an average annual investment level of $20.5 billion in each case).

In general, the benefits associated with the types of bridge investments evaluated in NBIAS are more heavily weighted toward agency benefits (i.e., the reductions in maintenance costs that would be associated with a capital investment

Exhibit 10-4

Impact of Alternative NBIAS Travel Growth Forecasts on Projected Economic Bridge Investment Backlog in 2028, for Different Possible Funding Levels

NBIAS-Modeled Capital Investment		**2028 Economic Bridge Investment Backlog for System Rehabilitation (Billions of 2008 Dollars)[3] for Two VMT Growth Assumptions**	
Annual Percent Change in NBIAS Spending[1]	**Average Annual Spending[2] (Billions of 2008 Dollars)**	**Baseline State-Projected**	**Alternative Historic 5-Year**
4.31%	$20.5	**$0.0**	
3.51%	$18.7	$25.3	$24.9
2.88%	$17.5	$42.0	$41.9
1.31%	$14.7	$79.1	$78.9
0.56%	$13.6	$95.8	$95.7
0.00%	$12.8	$107.6	$107.6
-0.70%	$11.9	$121.6	$121.3
-1.00%	$11.5	$127.1	$127.0
4.30%	$20.5		**$0.0**
2008 Value:		**$121.2**	**$120.9**

[1] The first eight rows correspond to annual percent changes in spending reflected in the NBIAS analyses of all bridges presented in Chapter 7 (Exhibit 7-17). Each of these growth rates has significance in either the NBIAS or the HERS analyses and is associated with the investment needed to achieve certain performance targets. The ninth row represents the level of investment required to eliminate the economic bridge investment backlog under the alternative assumption for VMT growth; the comparable investment level for the baseline assumption for VMT growth appears in the top row in the table.

[2] The amounts shown represent the average annual invest-ment over 20 years by all levels of government combined that would occur if such spending grows annually in constant dollar terms by the percentage shown in each row of the first column. Of the $91.1 billion of total capital expenditures for highways and bridges in 2008, $12.8 billion was used for the types of capital improvements modeled in NBIAS.

[3] As discussed in Chapter 7, the economic investment backlog for bridges represents the total level of investment that would be required to address existing bridge deficiencies where it is cost-beneficial to do so. Reductions in this backlog would be consistent with an overall improvement in bridge conditions. The amounts shown do not reflect system expansion needs; the bridge component of such needs are addressed as part of the HERS model analysis.

Source: National Bridge Investment Analysis System.

to rehabilitate or replace bridge elements) rather than user benefits. The opposite is true for the types of investment analyzed in HERS, which partially explains the differences in the sensitivity of their results to VMT growth. Also, the performance of many types of bridge elements is primarily impacted by age and environmental conditions rather than the level of traffic carried by the bridge.

Alternative Forecasts of Fuel Prices and Vehicle Fuel Efficiency—HERS

The baseline assumptions in this report's simulations with the HERS model incorporated the Reference case projections' forecasts for fuel economy from the Energy Information Administration publication, *Annual Energy Outlook 2010* (AEO). The Reference case is a business-as-usual scenario in which laws and regulations affecting the energy sector remain unchanged during the projection period. As discussed in Chapter 7, these forecasts incorporate the effect of recent changes in Corporate Average Fuel Economy (CAFE) standards and the establishment in 2010 of Federal standards for vehicle emissions of greenhouse gases under the provisions of the Clean Air Act.

From the base year, 2008, to the end of the HERS analysis period, 2028, the projections show average fuel economy (mpg) increasing 28.2 percent among cars (all four-tire vehicles) and 13.7 percent among trucks. Although the AEO also provides projections for motor fuel prices relative to the Consumer Price Index (CPI), the baseline in the HERS analysis assumes that all price relativities remain at their 2008 levels. With this simplification, one can measure future dollar flows at 2008 prices (in "constant 2008 dollars") without h aving to select a particular price (or price index) to serve as a common denominator. For consistency and because they are difficult to forecast accurately, the relative prices of motor fuel were included under this assumption of constant price relativities.

For sensitivity testing, the HERS model was rerun with AEO projections replacing the baseline assumption that fuel prices remain at 2008 levels over time in constant dollar terms. Relative to the CPI, the AEO Reference case foresees the average price of gasoline rising sharply after 2010, by 2018 nearly returning to the unusually high level that prevailed during 2008. For the subsequent years through 2028, the final year in this report's HERS analysis period, the projections are for further increases in the relative gasoline price equivalent to 1.1 percent annual growth. The results obtained from rerunning the HERS simulation after factoring in these price projections are not presented in this report, because they differed from the baseline results presented in Chapter 7 only to a miniscule degree.

In comparison with the Reference case, the AEO High Oil Price case foresees world oil prices rebounding more rapidly with the return of world economic growth and escalating more rapidly long-term because of political and natural resource constraints. In this case, the projections are the price of gasoline relative to the CPI will nearly regain its 2008 level by 2012 and increase thereafter through 2028 at the equivalent of 3.4 percent annually. Because these projections for gasoline prices are higher than in the Reference case, those for motor fuel economy are slightly higher as well, reflecting consumer substitution toward more fuel-efficient vehicles.

Exhibit 10-5 compares selected results from the baseline simulation with those from an alternative simulation that incorporates the motor fuel price projections from the AEO High Oil Price case. Since higher fuel prices deter travel, the alternative simulation produces lower forecasts of traffic volumes. With traffic projected to be lighter, the amount of delay in 2028 is projected to be lower than in the baseline simulation at each level of investment analyzed. At the 2008 level of investment ($54.7 billion) maintained into the future in constant dollars, average delay per VMT is projected to increase over the analysis period (2008–2028) by 6.7 percent in the baseline simulation versus 3.1 percent in the alternative simulation.

Similarly, at each level of investment, the average IRI in 2028 is projected to be lower in the alternative simulation (assuming higher fuel prices) than in the baseline simulation, reflecting better overall pavement

Exhibit 10-5

Impact of Alternative HERS Fuel Price Assumptions on Selected Indicators, for Different Possible Funding Levels

HERS-Modeled Capital Investment		Baseline Assumption: No Change in Constant Dollar Prices				Alternative Assumption: EIA High Oil Price Scenario			
			Percent Change, 2028 Compared With 2008				Percent Change, 2028 Compared With 2008		
Annual Percent Change in HERS Spending[1]	Average Annual Spending[2] (Billions of 2008 Dollars)	Projected VMT on Federal-Aid Highways in 2028 (Trillions)	Average Pavement Roughness (IRI)	Average Delay per VMT	Minimum BCR Cutoff [3]	Projected VMT on Federal-Aid Highways in 2028 (Trillions)	Average Pavement Roughness (IRI)	Average Delay per VMT	Minimum BCR Cutoff [3]
5.90%	$105.4	3.724	-24.3%	-7.7%	**1.00**				
4.86%	$93.4	3.714	-19.8%	-5.0%	1.20	3.588	-21.4%	-7.8%	1.06
3.51%	$80.1	3.700	-13.7%	-1.7%	1.50	3.576	-15.2%	-4.8%	1.35
2.88%	$74.7	3.694	-11.1%	**0.0%**	1.64	3.570	-12.5%	-3.4%	1.47
1.31%	$62.9	3.677	-3.8%	3.8%	2.02	3.555	-5.2%	0.3%	1.86
0.56%	$58.0	3.670	**0.0%**	5.5%	2.24	3.548	-1.9%	2.1%	2.04
0.00%	$54.7	3.664	2.8%	6.7%	2.42	3.543	1.0%	3.1%	2.21
-1.00%	$49.3	3.655	7.4%	9.0%	2.74	3.534	5.7%	5.2%	2.53
5.18%	$96.9					3.591	-22.7%	-8.8%	**1.00**

[1] *The first eight rows correspond to annual percent changes in spending identified in Chapter 7 (Exhibit 7-3) as being associated with the investment needed to achieve certain specific targets (expressed in terms of minimum BCR cutoffs, maintaining specific performance indicators, or growing at a specific rate in constant dollar terms). The ninth row corresponds to the level of investment consistent with a minimum BCR cutoff of 1.00 for the alternative assumption presented; the comparable investment level for the baseline assumption appears in the top row in the table.*

[2] *The amounts shown represent the average annual investment over 20 years by all levels of government combined that would occur if such spending grows annually in constant dollar terms by the percentage shown in each row of the first column. Of the $91.1 billion of total capital expenditures for highways and bridges in 2008, $54.7 billion was used for the types of capital improvements modeled in HERS.*

[3] *The minimum BCR represents the lowest benefit-cost ratio for any project implemented by HERS during the 20-year analysis period at the level of funding shown.*

Source: Highway Economic Requirements System.

conditions. The difference between simulation results for average IRI stems directly and indirectly from the difference in traffic volume projections. Lower traffic volumes mean less wear and tear on the pavements (the direct effect); they also reduce the relative benefits of capacity expansion, causing HERS to allocate a larger portion of any given investment total to pavement rehabilitation (the indirect effect). In the case in which the 2008 level of investment is sustained in constant dollar terms in the future (0.00 percent annual increase in spending), the projected 2008–2028 change in the average IRI is an increase of 2.8 percent in the baseline simulation versus 1.0 percent in the alternative simulation with higher fuel prices.

In addition to shifting the composition of investment toward pavement rehabilitation, the traffic deterrent effect of higher fuel prices would also reduce the amount of investment needed to achieve a given target. When the target is implementing all cost-beneficial investments within the scope of HERS, the baseline simulation allocates over the analysis period an average of $105.4 billion per year, whereas the alternative simulation allocates $96.9 billion, or 8.1 percent less. The more modest target of maintaining average delay per VMT at the 2008 level would call for an estimated $74.7 billion per year under the baseline assumption versus a bit more than $62.9 billion under the alternative assumption with higher relative fuel prices. (The $62.9 billion would cause average delay per VMT to increase over the analysis period by an estimated 0.3 percent, so reducing the projected increase to zero would require a bit more than that amount.)

Construction Cost Indices—HERS

The costs per lane mile for the various types of capital improvements considered in HERS for this report were estimated in a Federal Highway Administration (FHWA) study with cost data for 2002. For recent editions of the C&P report, these estimates were adjusted to base year levels using the FHWA Bid Price Index (BPI), which was assembled quarterly from State-supplied data on bid prices for major work items on Federal-aid highway construction items. Following the release for fourth quarter 2006, however, the FHWA discontinued collecting these data and publishing the index (formerly published in *Price Trends for Federal-Aid Highway Construction*, http://www.fhwa.dot.gov/programadmin/pricetrends.htm).

In this report's baseline simulations with HERS, the 2006 estimates of construction costs used in the previous C&P report were updated to 2008 using the FHWA's replacement for the BPI, the National Highway Construction Cost Index (NHCCI), which is available for quarters starting with 2002. The new index is compiled quarterly from a proprietary database on highway construction contract bids that gradually increased in coverage from only a few States in the mid-1990s to all but Alaska and Hawaii by September 2009 (http://www.fhwa.dot.gov/ohim/nhcci/index.cfm). Given that this gradual increase in coverage occurred while States were dropping out of the BPI program, the NHCCI may have become a more reliable index sometime before the BPI terminated in 2006.

Thus, for sensitivity analysis of the HERS results, the 2002 estimates of construction costs were updated using the BPI through 2004 and the NHCCI from that year to 2008. The direct effect of this change was to reduce the estimated increase in highway improvement costs over 2002–2008 from 42.0 percent in the baseline to 23.7 percent. With base year construction costs thus lower, so are the future construction costs in constant dollars (assumed equal to base year costs). As a result, HERS projects that more will be accomplished out of any given budget for highway investment over the 20-year analysis period. As shown in *Exhibit 10-6,* assuming the budget averages $74.7 billion per year in 2008 constant dollars (37 percent more than the actual investment level in 2008), the projected change over this period in average delay per VMT increases from zero under the baseline procedure for updating construction costs to a decline of 3.0 percent under the alternative procedure. At the same level of investment, this sensitivity test changes the projected 2008–2028 reduction in average pavement roughness from 11.1 percent to 16.3 percent, signifying an improvement to pavement ride quality.

The other sensitivity test presented in *Exhibit 10-6* updates construction costs from 2002 to 2008 relying exclusively on the Producer Price Index (PPI) for highway and street construction prepared by the Bureau of Labor Statistics (BLS); this component of the PPI was discontinued by the BLS as of July 2010. While the BLS index has been used in some other studies' approach to updating highway construction costs, the BLS cautioned that its index did not include labor or capital costs, and hence should not be regarded as comprehensive measures of changes in construction costs. The BLS index only reflected movements in prices of material and supply inputs to highway and street construction produced by the mining or manufacturing sectors (e.g., refined petroleum products, ready-mix concrete, and asphalt paving mixtures). That said, each potential choice of index for updating highway construction costs has its limitations, and the 66.3 percent increase between 2002 and 2008 in the highway and street construction PPI substantially exceeded the 42.0 percent increase estimated with the baseline updating procedure. Since higher construction costs allow fewer improvements to be implemented out of a given budget, using the BLS index rather than the baseline procedure to update construction costs makes the HERS projections for 2028 less favorable. Again, assuming an average annual investment of $74.7 billion for illustration, this change in updating procedure increases the average delay per VMT projected for 2028 by 3.3 percent and reduces the projected improvement in pavement roughness to only 4.5 percent (versus 11.1 percent in the baseline).

Exhibit 10-6

Impact of Alternative HERS Construction Cost Index Assumptions on Selected Indicators, for Different Possible Funding Levels

HERS-Modeled Capital Investment		Percent Change in Average IRI, 2028 Compared With 2008 for Three Index Assumptions[4]			Percent Change in Average Delay per VMT, 2028 Compared With 2008 for Three Index Assumptions[4]			Minimum BCR Cutoff[3] For Three Index Assumptions[4]		
Annual Percent Change in HERS Spending[1]	Average Annual Spending[2] (Billions of 2008 Dollars)	Baseline	Alternative		Baseline	Alternative		Baseline	Alternative	
		NHCCI After 2006	NHCCI After 2004	PPI All Years	NHCCI After 2006	NHCCI After 2004	PPI All Years	NHCCI After 2006	NHCCI After 2004	PPI All Years
5.90%	$105.4	-24.3%		-18.7%	-7.7%		-4.3%	**1.00**		1.08
4.86%	$93.4	-19.8%	-24.8%	-14.0%	-5.0%	-8.0%	-1.8%	1.20	1.11	1.28
3.51%	$80.1	-13.7%	-19.1%	-7.6%	-1.7%	-4.6%	1.8%	1.50	1.41	1.56
2.88%	$74.7	-11.1%	-16.3%	-4.5%	**0.0%**	-3.0%	3.3%	1.64	1.56	1.70
1.31%	$62.9	-3.8%	-10.0%	3.7%	3.8%	0.9%	6.9%	2.02	1.97	2.11
0.56%	$58.0	**0.0%**	-6.6%	7.4%	5.5%	2.7%	8.7%	2.24	2.17	2.33
0.00%	$54.7	2.8%	-4.0%	10.0%	6.7%	4.1%	10.0%	2.42	2.32	2.48
-1.00%	$49.3	7.4%	0.7%	14.9%	9.0%	6.1%	12.5%	2.72	2.66	2.63
5.41%	$99.5		-27.0%			-9.3%			**1.00**	
6.37%	$111.3			-20.7%			-5.6%			**1.00**

[1] *The first eight rows correspond to annual percent changes in spending identified in Chapter 7 (Exhibit 7-3) as being associated with the investment needed to achieve certain specific targets (expressed in terms of minimum BCR cutoffs, maintaining specific performance indicators, or growing at a specific rate in constant dollar terms). The ninth and tenth rows correspond to the level of investment consistent with a minimum BCR cutoff of 1.00 for the two alternative assumptions; the comparable investment level for the baseline assumption appears in the top row in the table.*

[2] *The amounts shown represent the average annual investment over 20 years by all levels of government combined that would occur if such spending grows annually in constant dollar terms by the percentage shown in each row of the first column. Of the $91.1 billion of total capital expenditures for highways and bridges in 2008, $54.7 billion was used for the types of capital improvements modeled in HERS.*

[3] *The minimum BCR represents the lowest benefit-cost ratio for any project implemented by HERS during the 20-year analysis period at the level of funding shown.*

[4] *The cost data in HERS for different types of capital improvements are stated in 2002 dollars and inflated to 2008 dollars using an index. The baseline analyses applied the FHWA Composite Bid Price Index (BPI) through 2006 (when it was discontinued) and then transitioned to the new FHWA National Highway Construction Cost Index (NHCCI). The first set of alternative analyses transition over to the NHCCI in 2004 rather than 2006. The second set of alternative analyses apply the Bureau of Labor Statistics' Producer Price Index (PPI) Industry Data for Highway and Street Construction to inflate the 2002 costs to 2008 dollars.*

Source: Highway Economic Requirements System.

These sensitivity tests do not hugely alter the HERS indications of the average annual amount of potentially cost-beneficial investment. Between the two alternatives to the baseline procedure, the difference in the estimate of this amount is $11.8 billion (in *Exhibit 10-6*, the difference between the entries in the bottom two rows in the second column), which is 11.1 percent of the baseline estimate of $105.4 billion. That the difference is not larger reflects that fewer improvements pass the benefit-cost tests in HERS when construction costs rise. Between the two alternatives to the baseline procedure, the estimates of construction costs differ by 32.6 percent. If the cost of construction had no influence on the set of highway improvements that HERS selects as cost-beneficial, the estimated amount of potentially cost-beneficial investment would differ by this same percentage.

Alternative Economic Analysis Assumptions

Value of a Statistical Life

One of the more vexing issues in benefit-cost analysis is how to best determine the monetary cost to place on injuries of various severities. Few people would consider any amount of money to be adequate compensation for being seriously injured, much less killed. On the other hand, people can attach a value to changes in their *risk* of suffering an injury, and indeed such valuations are implicit in their everyday choices. For example, a traveler may face a choice between two travel options that are equivalent except that one carries a lower risk of fatal injury but costs more. If the additional cost is $1, 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.

Based on the results of various studies of individual choices involving money versus safety trade-offs, some government agencies estimate an average value of a statistical life for use in their regulatory and investment analyses. The U.S. Department of Transportation (DOT) issued new guidance in February 2008 recommending for immediate use a value of $5.8 million per statistical life and announced plans for periodic updates (the value was increased to $6.0 million in March 2009). For nonfatal injuries, the DOT retained from its 1993 guidance the practice of setting values per statistical injury as percentages of the value of a statistical life; these vary according to the level of severity, from 0.2 percent for a "minor" injury to 76.3 percent for a "critical" injury. (The injury levels are from the Maximum Abbreviated Injury Scale). In view of the uncertainty surrounding the average value of a statistical life, the Department also required that regulatory and investments analyses include sensitivity tests using alternative values of $3.2 million and $8.4 million.

Alternative HERS Values of a Statistical Life

The HERS model contains for each highway functional class equations to predict crash rates per VMT and parameters to determine the number of fatalities and nonfatal injuries per crash (see Appendix A for further discussion). The model assigns to crashes involving fatalities and other injuries an average cost consistent with the guidance in the DOT memorandum.

Exhibit 10-7 demonstrates that the results from the HERS simulations are nevertheless insensitive to the use of alternative values of a statistical life. This is consistent with the observations from Chapter 7 that crash costs: (1) form a small share of highway user cost (12 percent in 2008); and (2) are much less sensitive than travel time and vehicle operating costs to changes in the level of total investment within the scope of HERS, which excludes targeted safety-oriented investments due to data limitations. Replacing the baseline value of a statistical life with a figure of $8.4 million slightly raises the benefit-cost ratio for potential improvements and increases the estimate of the amount of potentially cost-beneficial investment by 0.6 percent from $105.4 billion to $106.0 billion. Using the higher value of a statistical life also shifts the HERS allocation of a given total investment level in ways that slightly increases average pavement roughness; the effect on the average amount of delay is also small but varies in both directions. Reducing the assumed value of a statistical life from the baseline value to the low value of $3.2 million results in slightly lower average pavement roughness.

Exhibit 10-7

Impact of Alternative HERS Value of a Statistical Life Assumptions on Selected Indicators, for Different Possible Funding Levels

HERS-Modeled Capital Investment		Percent Change in Average IRI, 2028 Compared With 2008 for Three Values of a Statistical Life Assumption [4]			Percent Change in Average Delay per VMT, 2028 Compared With 2008 for Three Values of a Statistical Life Assumption [4]			Minimum BCR Cutoff [3] for Three Values of a Statistical Life Assumption [4]		
Annual Percent Change in HERS Spending[1]	Average Annual Spending [2] (Billions of 2008 Dollars)		Alternative			Alternative			Alternative	
		Baseline	$3.2 Million	$8.4 Million	Baseline	$3.2 Million	$8.4 Million	Baseline	$3.2 Million	$8.4 Million
5.90%	$105.4	-24.3%		-24.1%	-7.7%		-7.8%	**1.00**		1.01
4.86%	$93.4	-19.8%	-19.9%	-19.5%	-5.0%	-5.3%	-5.1%	1.20	1.19	1.22
3.51%	$80.1	-13.7%	-13.8%	-13.5%	-1.7%	-1.9%	-1.6%	1.50	1.49	1.52
2.88%	$74.7	-11.1%	-11.2%	-10.8%	**0.0%**	-0.4%	0.0%	1.64	1.63	1.66
1.31%	$62.9	-3.8%	-3.8%	-3.5%	3.8%	3.6%	3.8%	2.02	2.01	2.04
0.56%	$58.0	**0.0%**	-0.1%	0.3%	5.5%	5.1%	5.5%	2.24	2.23	2.27
0.00%	$54.7	2.8%	2.8%	3.1%	6.7%	6.4%	6.8%	2.42	2.41	2.45
-1.00%	$49.3	7.4%	7.3%	7.7%	9.0%	8.7%	9.1%	2.72	2.70	2.74
5.86%	$104.9		-24.2%			-7.9%			**1.00**	
5.95%	$106.0			-24.4%			-7.9%			**1.00**

[1] *The first eight rows correspond to annual percent changes in spending identified in Chapter 7 (Exhibit 7-3) as being associated with the investment needed to achieve certain specific targets (expressed in terms of minimum BCR cutoffs, maintaining specific performance indicators, or growing at a specific rate in constant dollar terms). The ninth and tenth rows correspond to the level of investment consistent with a minimum BCR cutoff of 1.00 for the two alternative assumptions; the comparable investment level for the baseline assumption appears in the top row in the table.*

[2] *The amounts shown represent the average annual investment over 20 years by all levels of government combined that would occur if such spending grows annually in constant dollar terms by the percentage shown in each row of the first column. Of the $91.1 billion of total capital expenditures for highways and bridges in 2008, $54.7 billion was used for the types of capital improvements modeled in HERS.*

[3] *The minimum BCR represents the lowest benefit-cost ratio for any project implemented by HERS during the 20-year analysis period at the level of funding shown.*

[4] *The DOT has established a standard value of a statistical life (initially $5.8 million and subsequently adjusted to $6.0 million) for use in Departmental analyses. The guidance implementing this standard value also directs that alternative analyses be presented with values of life of $3.2 million and $8.4 million.*

Source: Highway Economic Requirements System.

Alternative NBIAS Values of a Statistical Life

Exhibit 10-8 shows that increasing the assumed value of a statistical life to $8.4 million raises the NBIAS estimate of the 2008 economic bridge investment backlog by 3.73 percent above the $121.2 billion baseline value to $125.9 billion. Similarly, it increases the model's estimate of the average annual investment in bridges that would be needed over the following 20 years to cut the economic backlog to zero by 2028, from $20.5 billion to $22.0 billion. Both these estimates well exceed the $12.8 billion invested in bridge rehabilitation and replacement in 2008. Conversely, when the value of a statistical life in NBIAS is reduced to $3.2 million, the model indicates lesser economic need for investment in bridges. The estimate of the investment backlog in 2008 falls to $115.5 billion, while the average annual investment needed to eliminate the backlog by 2028 is estimated at $18.9 billion.

Exhibit 10-8

Impact of Alternative NBIAS Value of a Statistical Life Assumptions on Projected Economic Bridge Investment Backlog in 2028, for Different Possible Funding Levels

NBIAS-Modeled Capital Investment		2028 Economic Bridge Investment Backlog for System Rehabilitation (Billions of 2008 Dollars)[3] for Three Values of a Statistical Life Assumption[4]		
			Alternative	
Annual Percent Change in NBIAS Spending[1]	Average Annual Spending[2] (Billions of 2008 Dollars)	Baseline	$3.2 Million	$8.4 Million
4.31%	$20.5	**$0.0**		$20.3
3.51%	$18.7	$25.3	$2.4	$43.6
2.88%	$17.5	$42.0	$21.4	$60.5
1.31%	$14.7	$79.1	$59.6	$97.1
0.56%	$13.6	$95.8	$76.4	$112.4
0.00%	$12.8	$107.6	$88.2	$124.0
-0.70%	$11.9	$121.6	$103.1	$138.0
-1.00%	$11.5	$127.1	$108.7	$143.7
3.57%	$18.9		**$0.0**	
4.91%	$22.0			**$0.0**
	2008 Value:	**$121.2**	**$115.5**	**$125.9**

[1] The first eight rows correspond to annual percent changes in spending reflected in the NBIAS analyses of all bridges presented in Chapter 7 (Exhibit 7-17). The ninth and tenth rows represent the level of investment required to eliminate the economic bridge investment backlog under the alternative assumptions presented; the comparable investment level for the baseline assumption appears in the top row in the table.

[2] The amounts shown represent the average annual investment over 20 years by all levels of government combined that would occur if such spending grows annually in constant dollar terms by the percentage shown in each row of the first column.

[3] Reductions in the economic investment backlog for bridges would be consistent with an overall improvement in bridge conditions. The amounts shown do not reflect system expansion needs; the bridge component of such needs are addressed as part of the HERS model analysis.

[4] The DOT has established a standard value of a statistical life (initially $5.8 million, and subsequently adjusted to $6.0 million) for use in Departmental analyses. The guidance implementing this standard value also directs that alternative analyses be presented with values of life of $3.2 million and $8.4 million.

Source: National Bridge Investment Analysis System.

Value of Ordinary Travel Time

Although less challenging than the costing of injuries, the valuation of travel time is another unsettled area of benefit-cost analysis. Increases in travel time impose costs on drivers; among these is the loss of time available for pursuits other than traveling, e.g., for reading a book instead of driving. The DOT issued guidance on valuing travel time savings per person-hour in April 1997; these procedures were revised in February 2003. Within the HERS and NBIAS models, the per person-hour estimates of travel time savings based on this guidance are converted to average values of time per *vehicle-hour* for different types of vehicle classes, drawing upon estimates of average vehicle occupancy, time-related vehicle depreciation cost, and for trucks, the inventory cost of freight in transit. For 2008, the average values per vehicle-hour ranged from $20.96 for small autos to $38.00 for five-axle combination trucks. (For the passenger vehicle classes, the averages are weighted means of a value for personal travel and a higher value for business travel).

Q&A

Why conduct a sensitivity analysis for the assumed value of travel time savings?

Arguments for conducting a sensitivity analysis that varies the average values of time include the following:

The Department based its guidance for valuing travel time on a review of the research literature, which reflects estimates that vary widely even after attempts to standardize them. Particularly for personal travel (including commuting), the evidence is hard to synthesize. Internationally, common practice among transportation government agencies is to assume that the average value of personal travel time bears a fixed ratio to a measure of economy-wide average wages (or some similar measure). The Department assumed a ratio of 50 percent, but other ratios would also be plausible. Indeed, the practice varies internationally, with some agencies known to have assumed ratios in the range between 40 percent and 60 percent (Luskin, 1999, *Facts and Furphies in Benefit-Cost Analysis: Transport*, Report 100, Bureau of Transport Economics, Canberra).

Changes in technology and other factors have made the Department's guidance less definitive now than when it was issued in 1997. For example, increased use of cell phones has presumably reduced the average value of travel time by making the travel experience of vehicle passengers more pleasant and productive. (This phenomenon has negative safety implications in terms of distracted driving, as discussed in Chapter 5.) Also relevant is the general worsening of congestion on U.S. roads between the mid-1990s and the present, with some evidence suggesting that increases in congestion tend to increase the average value of travel time.

The baseline assumption for the HERS simulations that relative prices will remain at their 2008 levels may be unrealistic for the values of travel time. The DOT guidelines assume that the average value per person-hour of travel is a fixed percentage of an average wage-related measure: 50 percent for personal travel as mentioned above, and 100 percent for business travel. Since the general trend in U.S. history has been for average wages to increase relative to the overall level of consumer prices, an implication of this assumption is that average values per person-hour of travel will likewise increase. Even from 1995 through 2008, when average real wages grew relatively slowly, average hourly labor compensation including benefits increased at an economy-wide rate of about 1.8 percent annually relative to consumer prices. Over the entire period, this amounted to an increase of about 26 percent.

Researchers are still grappling with how to treat unpredictable travel delay, which stems in large part from traffic incidents and which the evidence suggests imposes larger costs on travelers than predictable delays. As discussed later in this section, the HERS model deals with this by applying a higher value of travel time to incident delay.

Alternative HERS Values of Ordinary Travel Time

For sensitivity analysis, the baseline values of travel time in this report's HERS simulations were varied 25 percent in both directions. The choice of numbers is partly for comparability with the previous reports, which included the same sensitivity tests. In addition, increasing the 2008 values of travel time by 25 percent can be justified to some extent as a rough allowance for expected real growth in these values. If real wages were to increase over the 2009–2028 projection period at the 1.8 percent annual rate estimated for 1995–2008, the average real wage over the projection period would be about 22 percent higher than in 2008.

Increasing the value of time causes HERS to attribute more benefits, particularly to widening projects (which reduce travel time costs). *Exhibit 10-9* shows that the level of potentially cost-beneficial investments within the scope of HERS, expressed as an annual average over the analysis period (2009–2028) in 2008 dollars, increases from $105.4 billion in the baseline analysis to $114.0 billion after increasing the assumed values of time by 25 percent. The assumption of higher values of time also shifts the composition of investment spending toward system expansion, producing better outcomes for travel delay and worse outcomes for pavement roughness. When the annual level of investment is assumed to remain fixed at the 2008 level, average delay per VMT increases by 6.7 percent over the analysis period in the baseline simulation versus 4.6 percent in the alternative simulation with higher values of time. At the same 2008 level of investment, average IRI increases 2.8 percent in the baseline simulation and 4.8 percent in the alternative simulation.

In the other sensitivity test, reducing the assumed values of travel time 25 percent below the baseline levels reduces the amount of cost-beneficial investment within the scope of HERS to an annual average of $95.4 billion, or by 9.5 percent below the level under baseline assumptions. At the lower values of time, HERS would direct a greater share of investment to system rehabilitation, and thus projected average IRI for 2028 would be lower than in the baseline analysis and projected average delay per VMT would be higher.

Exhibit 10-9

Impact of Alternative HERS Value of Time Assumptions on Selected Indicators, for Different Possible Funding Levels

HERS-Modeled Capital Investment		Percent Change in Average IRI, 2028 Compared With 2008 for Three Values of Time Assumptions			Percent Change in Average Delay per VMT, 2028 Compared With 2008 for Three Values of Time Assumptions			Minimum BCR Cutoff:[3] for Three Values of Time Assumptions		
Annual Percent Change in HERS Spending[1]	Average Annual Spending[2] (Billions of 2008 Dollars)		Alternative			Alternative			Alternative	
		Baseline	Reduce by 25%	Increase by 25%	Baseline	Reduce by 25%	Increase by 25%	Baseline	Reduce by 25%	Increase by 25%
5.90%	$105.4	-24.3%		-23.0%	-7.7%		-9.3%	**1.00**		1.14
4.86%	$93.4	-19.8%	-21.2%	-18.3%	-5.0%	-2.7%	-6.7%	1.20	1.03	1.36
3.51%	$80.1	-13.7%	-15.6%	-11.9%	-1.7%	0.9%	-3.5%	1.50	1.30	1.69
2.88%	$74.7	-11.1%	-13.0%	-9.1%	**0.0%**	2.7%	-2.0%	1.64	1.43	1.85
1.31%	$62.9	-3.8%	-6.1%	-1.7%	3.8%	7.0%	1.8%	2.02	1.76	2.29
0.56%	$58.0	**0.0%**	-2.2%	2.1%	5.5%	8.7%	3.3%	2.24	1.95	2.54
0.00%	$54.7	2.8%	0.4%	4.8%	6.7%	10.2%	4.6%	2.42	2.10	2.74
-1.00%	$49.3	7.4%	5.2%	9.8%	9.0%	12.6%	6.6%	2.72	2.37	3.05
5.04%	$95.4		-22.0%			-3.1%			**1.00**	
6.57%	$114.0			-26.0%			-10.8%			**1.00**

[1] *The first eight rows correspond to annual percent changes in spending identified in Chapter 7 (Exhibit 7-3) as being associated with the investment needed to achieve certain specific targets (expressed in terms of minimum BCR cutoffs, maintaining specific performance indicators, or growing at a specific rate in constant dollar terms). The ninth and tenth rows correspond to the level of investment consistent with a minimum BCR cutoff of 1.00 for the two alternative assumptions; the comparable investment level for the baseline assumption appears in the top row in the table.*

[2] *The amounts shown represent the average annual investment over 20 years by all levels of government combined that would occur if such spending grows annually in constant dollar terms by the percentage shown in each row of the first column. Of the $91.1 billion of total capital expenditures for highways and bridges in 2008, $54.7 billion was used for the types of capital improvements modeled in HERS.*

[3] *The minimum BCR represents the lowest benefit-cost ratio for any project implemented by HERS during the 20-year analysis period at the level of funding shown.*

Source: Highway Economic Requirements System.

Alternative NBIAS Values of Ordinary Travel Time

As shown in *Exhibit 10-10,* if the value of time is 25 percent lower than the baseline, the estimated size of the initial economic bridge investment backlog would be $118.7 billion, or 2.1 percent lower than the $121.2 billion estimated in the baseline analysis. The average annual investment level associated with eliminating this reduced economic bridge backlog by 2028 is $20.3 billion, slightly lower than the $20.5 billion level identified in the baseline analysis.

Assuming a value of time of 25 percent higher than that in the baseline, the size of the initial economic bridge investment backlog would be $122.7 billion stated in constant 2008 dollars; the estimated average annual investment needed to eliminate the backlog by 2028 is $20.7 billion, slightly higher than in the baseline analysis.

Exhibit 10-10

Impact of Alternative NBIAS Value of Time Assumptions on Projected Economic Bridge Investment Backlog in 2028, for Different Possible Funding Levels

NBIAS-Modeled Capital Investment		2028 Economic Bridge Investment Backlog for System Rehabilitation (Billions of 2008 Dollars) [3] for Three Values of Time Assumptions		
Annual Percent Change in NBIAS Spending[1]	Average Annual Spending[2] (Billions of 2008 Dollars)	Baseline	Alternatives: Reduce by 25%	Alternatives: Increase by 25%
4.31%	$20.5	**$0.0**		$2.2
3.51%	$18.7	$25.3	$66.3	$26.5
2.88%	$17.5	$42.0	$39.3	$43.5
1.31%	$14.7	$79.1	$75.7	$81.0
0.56%	$13.6	$95.8	$91.3	$97.4
0.00%	$12.8	$107.6	$102.6	$109.6
-0.70%	$11.9	$121.6	$116.7	$123.4
-1.00%	$11.5	$127.1	$122.4	$129.6
4.22%	$20.3		**$0.0**	
4.37%	$20.7			**$0.0**
	2008 Value:	**$121.2**	**$118.7**	**$122.7**

[1] The first eight rows correspond to annual percent changes in spending reflected in the NBIAS analyses of all bridges presented in Chapter 7 (Exhibit 7-17). The ninth and tenth rows represent the level of investment required to eliminate the economic bridge investment backlog under the alternative assumptions about the value of travel time; the comparable investment level for the baseline assumption appears in the top row in the table.

[2] The amounts shown represent the average annual investment over 20 years by all levels of government combined that would occur if such spending grows annually in constant dollar terms by the percentage shown in each row of the first column.

[3] Reductions in the economic investment backlog for bridges would be consistent with an overall improvement in bridge conditions. The amounts shown do not reflect system expansion needs; the bridge component of such needs are addressed as part of the HERS model analysis.

Source: National Bridge Investment Analysis System.

Value of Incident Delay Reduction—HERS

Research has produced evidence suggesting that highway users perceive unpredictable delay associated with traffic incidents as more onerous (and thus more "costly" on a per hour basis) than the predictable, routine delay typically associated with peak traffic volumes. The HERS model therefore includes a reliability premium parameter, which is the ratio of the value of incident delay time to the value of ordinary travel time. Since the available research suggests that incident delay typically imposes about twice as much cost per hour as ordinary travel time, this parameter was set at 2.0 in the baseline simulations. For sensitivity testing, this section uses alternative values of 1.0, which effectively assumes that no premium exists and that the value of incident delay is equal to that of ordinary time, and 3.0.

Increasing the reliability premium would have qualitatively similar effects as increasing the assumed value of ordinary travel time. The level of potentially cost-beneficial investments within the scope of HERS would average $112.5 billion annually over the analysis period, which is 6.7 percent above the $105.4 billion level under baseline assumptions, as shown in *Exhibit 10-11*. In addition, at all levels of funding, the composition of investment would shift toward system expansion, producing a greater impact relative to the baseline analyses in improving average delay per VMT and a smaller relative impact on improving average IRI. When the annual level of funding is assumed unchanged from 2008, average delay per VMT increases by 6.7 percent over the analysis period in the baseline simulation versus 4.4 percent in the alternative simulation with the higher reliability premium. At the same 2008 level of funding, average IRI increases 2.8 percent in the baseline simulation and 5.3 percent in the alternative simulation.

The estimated effects are in the opposite directions when the reliability premium parameter is reduced to 1.0, meaning that incident delay imposes the same costs as ordinary delay. The amount of cost-beneficial investment within the scope of HERS declines to an annual average of $97.1 billion, or by 7.9 percent below the level in the baseline simulation. On the assumption of no premium for reliability, HERS would also direct more investment to system rehabilitation, and thus projected average IRI for 2028 would be lower than in the baseline analysis and projected average delay per VMT would be higher.

Exhibit 10-11

Impact of Alternative HERS Reliability Premium Assumptions on Selected Indicators, for Different Possible Funding Levels

HERS-Modeled Capital Investment		Percent Change in Average IRI, 2028 Compared With 2008 for Three Reliability Premium Assumptions[4]			Percent Change in Average Delay Per VMT, 2028 Compared With 2008 for Three Reliability Premium Assumptions[4]			Minimum BCR Cutoff[3] for Three Reliability Premium Assumptions[4]		
Annual Percent Change in HERS Spending[1]	Average Annual Spending[2] (Billions of 2008 Dollars)	Baseline	Alternative		Baseline	Alternative		Baseline	Alternative	
		2.0 Times	1.0 Times	3.0 Times	2.0 Times	1.0 Times	3.0 Times	2.0 Times	1.0 Times	3.0 Times
5.90%	$105.4	-24.3%		-23.1%	-7.7%		-9.2%	**1.00**		1.10
4.86%	$93.4	-19.8%	-21.6%	-18.2%	-5.0%	-2.7%	-6.7%	1.20	1.06	1.32
3.51%	$80.1	-13.7%	-15.9%	-12.1%	-1.7%	1.3%	-3.4%	1.50	1.32	1.64
2.88%	$74.7	-11.1%	-13.4%	-9.1%	**0.0%**	3.0%	-1.9%	1.64	1.45	1.80
1.31%	$62.9	-3.8%	-6.3%	-1.3%	3.8%	7.2%	1.6%	2.02	1.82	2.22
0.56%	$58.0	**0.0%**	-2.9%	2.4%	5.5%	9.1%	3.2%	2.24	2.01	2.47
0.00%	$54.7	2.8%	-0.3%	5.3%	6.7%	10.6%	4.4%	2.42	2.17	2.64
-1.00%	$49.3	7.4%	4.3%	10.4%	9.0%	13.1%	6.5%	2.72	2.45	2.98
5.20%	$97.1		-22.9%			-3.7%			**1.00**	
6.46%	$112.5			-25.4%			-10.5%			**1.00**

[1] The first eight rows correspond to annual percent changes in spending identified in Chapter 7 (Exhibit 7-3) as being associated with the investment needed to achieve certain specific targets (expressed in terms of minimum BCR cutoffs, maintaining specific performance indicators, or growing at a specific rate in constant dollar terms). The ninth and tenth rows correspond to the level of investment consistent with a minimum BCR cutoff of 1.00 for the two alternative assumptions; the comparable investment level for the baseline assumption appears in the top row in the table.

[2] The amounts shown represent the average annual investment over 20 years by all levels of government combined that would occur if such spending grows annually in constant dollar terms by the percentage shown in each row of the first column. Of the $91.1 billion of total capital expenditures for highways and bridges in 2008, $54.7 billion was used for the types of capital improvements modeled in HERS.

[3] The minimum BCR represents the lowest benefit-cost ratio for any project implemented by HERS during the 20-year analysis period at the level of funding shown.

[4] The reliability premium represents the value placed on reductions to delay due to incidents relative to reductions in recurring delay.

Source: Highway Economic Requirements System.

Elasticity Values—HERS

HERS applies both general and section-level elasticities to quantify the relationship between demand for highway travel and changes in the average cost per vehicle-mile of travel. Demand is measured by VMT, and average cost includes the costs of travel time, vehicle operation, and crash risk. A general elasticity describes a relationship at a system-level, and measures both VMT and average cost per VMT for an entire highway network. A section-specific elasticity, on the other hand, quantifies the responsiveness of demand for travel on a particular section of highway to the average cost per VMT on that same section. HERS varies the section-elasticity values according to section length and other characteristics, and derives them by making adjustments to the general elasticities, including the addition of an allowance for route diversion. A section on which average cost per VMT declines may draw traffic from sections along alternative routes; conversely, when average cost increases, these route diversions make the section-level reduction in traffic larger.

What are some examples of the types of behavior that the travel demand elasticity features in HERS represent?

If highway congestion worsens in an area, this increases travel time costs on the road network. In response, some highway users might shift their trips to mass transit or perhaps forgo some personal trips that they might ordinarily make. For example, they might be more likely to combine multiple errands into a single trip because the time spent in traffic discourages them from making a trip unless it is absolutely necessary. Increases in fuel prices also increase the cost of driving and would have a similar impact.

In the longer term, people might make additional adjustments to their lifestyles in response to changes in user costs that would impact their travel demand. For example, if travel time in an area is reduced substantially for an extended period of time, some people may make different choices about where to purchase a home. If congestion is reduced, purchasing a home far out in the suburbs might become more attractive because commuters would be able to travel farther in a shorter period of time.

For the general elasticity, HERS also distinguishes short- and long-run values in recognition that the demand responses to a change in travel cost develop over time. Some responses develop sooner than others— for example, someone may adjust to higher travel costs initially by shopping closer to home and eventually by moving to live closer to work. The short-run elasticity in HERS measures the total response of demand within the funding period when the change in average cost occurs. The long-run elasticity measures the total response one funding period later on the assumption that the various adjustments to a change in travel cost will be completed within 5 years (the length of a funding period).

The assumed values for the general elasticities in HERS have changed over successive editions of the C&P report as new evidence has come to light. The 2004 C&P Report assumed baseline values of -0.6 for the short-run elasticity—which means that demand for travel decreases by approximately 0.6 percent when average cost increases by 1 percent—and -1.2 percent for the long-run elasticity. These values were based on the results of a thorough literature review completed in 2000. However, in line with more recent evidence pointing to the possibility of lower values, the elasticity assumptions were changed to -0.4 for the short run and -0.8 for the long run beginning with the 2006 C&P Report. (Mechanically, HERS assumes that the short-run effects are immediate and that the portion of the long-run elasticity applicable within its standard 5-year analysis period is -0.65). Partly because a comprehensive literature review to update the 2000 effort has yet to be conducted, the present analysis includes a sensitivity test that instead assumes general elasticity values used in the 2004 C&P Report.

At levels of investment considered, the baseline simulations in this report projected that average cost per VMT would decline over the analysis period, in large part because of the projected improvements in fuel economy. As shown in *Exhibit 10-12*, applying the higher alternative general elasticity values from the 2004

C&P report to these declines in average cost per VMT would result in higher projected 2028 VMT than what was computed in the baseline simulation. These differences in VMT projections for 2028 are greater at relatively high levels of investment, but are nevertheless modest in magnitude across the range. At an assumed investment growth rate of 4.86 percent annually (which equates to an annual average investment of $93.4 billion versus $54.7 billion in 2008), the use of higher demand elasticities increases the VMT projected for 2028 by 1.2 percent.

Exhibit 10-12 shows that switching from the baseline to the alternative elasticity assumptions makes the projected changes in average IRI algebraically smaller (more negative or less positive), which indicates better outcomes. The switch in assumptions makes demand for travel (VMT) more sensitive to changes in the travel cost, which means that expanded facilities, on which cost falls as a result of the capacity expansion, would tend to fill up with traffic faster. Since this addition to traffic lessens the congestion relief that the expansion is aimed at achieving, the benefits from expanding capacity are reduced. Consequently, HERS directs a larger share of total spending toward system rehabilitation in the alternative analysis than in the baseline; this in turn causes projected average pavement ride quality to be better in the alternative analysis.

Exhibit 10-12

Impact of Alternative HERS Travel Demand Elasticity Values on Selected Indicators, for Different Possible Funding Levels

HERS-Modeled Capital Investment		Baseline Assumption				Alternative Assumption: Higher Elasticities From the 2004 C&P Report			
			Percent Change, 2028 Compared With 2008				Percent Change, 2028 Compared With 2008		
Annual Percent Change in HERS Spending[1]	Average Annual Spending[2] (Billions of 2008 Dollars)	Projected VMT on Federal-Aid Highways in 2028 (Trillions)	Average Pavement Roughness (IRI)	Average Delay per VMT	Minimum BCR Cutoff[3]	Projected VMT on Federal-Aid Highways in 2028 (Trillions)	Average Pavement Roughness (IRI)	Average Delay per VMT	Minimum BCR Cutoff[3]
5.90%	$105.4	3.724	-24.3%	-7.7%	**1.00**				
4.86%	$93.4	3.714	-19.8%	-5.0%	1.20	3.758	-21.3%	-4.9%	1.07
3.51%	$80.1	3.700	-13.7%	-1.7%	1.50	3.738	-16.0%	-1.6%	1.31
2.88%	$74.7	3.694	-11.1%	**0.0%**	1.64	3.729	-13.5%	-0.2%	1.42
1.31%	$62.9	3.677	-3.8%	3.8%	2.02	3.706	-6.7%	3.0%	1.77
0.56%	$58.0	3.670	**0.0%**	5.5%	2.24	3.695	-3.3%	4.6%	1.96
0.00%	$54.7	3.664	2.8%	6.7%	2.42	3.688	-1.0%	5.8%	2.10
-1.00%	$49.3	3.655	7.4%	9.0%	2.74	3.674	3.1%	7.7%	2.36
5.26%	$97.8					3.764	-22.7%	-5.9%	**1.00**

[1] *The first eight rows correspond to annual percent changes in spending identified in Chapter 7 (Exhibit 7-3) as being associated with the investment needed to achieve certain specific targets (expressed in terms of minimum BCR cutoffs, maintaining specific performance indicators, or growing at a specific rate in constant dollar terms). The ninth row corresponds to the level of investment consistent with a minimum BCR cutoff of 1.00 for the alternative assumption presented; the comparable investment level for the baseline assumption appears in the top row in the table.*

[2] *The amounts shown represent the average annual investment over 20 years by all levels of government combined that would occur if such spending grows annually in constant dollar terms by the percentage shown in each row of the first column. Of the $91.1 billion of total capital expenditures for highways and bridges in 2008, $54.7 billion was used for the types of capital improvements modeled in HERS.*

[3] *The minimum BCR represents the lowest benefit-cost ratio for any project implemented by HERS during the 20-year analysis period at the level of funding shown.*

Source: Highway Economic Requirements System.

The switch in assumptions toward higher elasticities also makes most of the projected changes in average delay more favorable. Except at the highest investment levels considered, where the switch in assumptions affects these projections negligibly, the projected change in average delay shown in *Exhibit 10-12* is algebraically smaller (better) in the alternative (high elasticity) simulation than in the baseline simulation. Although the projected growth in VMT is overall higher in the alternative simulation, which would lead one to expect the projected change in average delay to be less favorable than in the baseline simulation, the opposite pattern predominates in *Exhibit 10-12* because of the patterns in VMT growth comparing highway sections with differing levels of congestion. On unimproved congested sections where congestion is relatively severe, the average user cost of travel will be projected to increase over the analysis period notwithstanding the expected improvements to average fuel economy; at higher elasticities, the portion of travelers who will be deterred from traveling because of this cost increase will be larger. On the other hand, on newly expanded, less-congested sections, higher elasticities mean that travel would tend to grow more quickly; the share of total traffic that occurs on such sections would tend to increase as a result, thereby reducing average delay.

Discount Rate

Benefit-cost analyses use a discount rate that marks down benefits and costs arising farther in the future relative to those arising sooner. To this point, the real discount rate has been 7 percent in this report's applications of HERS, NBIAS, and TERM; this means that deferring a benefit or cost for a year reduces its real value by approximately 6.5 percent (≈1/1.07).

This choice of real discount rate conforms to the "default position" in the 1992 Office of Management and Budget (OMB) guidance on discount rates for benefit-cost analyses of public investment and regulatory programs (OMB Circular A-94, *Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs,* October 29, 1992. http://www.whitehouse.gov/sites/default/files/omb/assets/a94/a094.pdf). Subsequently, in 2003, OMB recommended that regulatory analyses use both 3 percent and 7 percent as alternative discount rates. (OMB Circular A-4, Regulatory Analysis, September 17, 2003, http://www.whitehouse.gov/sites/default/files/omb/assets/omb/circulars/a004/a-4.pdf). The justifications for these recommendations apply equally 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.

Q&A

Could the discount rate be higher than 7 percent?

The 2003 OMB guidance also calls for use of a discount rate higher than 7 percent as a further sensitivity test in some instances. In the context of public investment, this recommendation applies when there is a fair likelihood that: (1) much of the investment's opportunity cost will take the form of crowding out of private investment, and (2) the displaced investment would have generated an average real rate of return exceeding 7 percent annually. Although the first of these conditions could be valid for some public investments in highways and transit systems, the expectation that displaced private investments will average rates of return above 7 percent annually could be difficult to justify. In 2003, the OMB referred to its own recent estimate that the average real rate of return on private investment remained near the 7 percent that the OMB had estimated in 1992. While the OMB also noted that the average real rate of return on corporate capital in the United States was approximately 10 percent in the 1990s, it is by no means clear whether the current economic outlook could justify the expectation of a rate of return averaging above 7 percent over this report's analysis period.

Alternative Discount Rates—HERS

When the target is implementing all cost-beneficial improvements, changing the discount rate from 7 percent to 3 percent increases the amount of investment that HERS programs by 22 percent, with the annual average amount over 2009–2028 increasing from $105.4 billion to $129.0 billion. As shown in *Exhibit 10-13*, this increase in investment dollars shows up in more favorable projections for highway conditions and performance in 2028. The lowering of the discount rate reduces the projection for average

Exhibit 10-13

Impact of Alternative HERS Discount Rates on Selected Indicators, for Different Possible Funding Levels

HERS-Modeled Capital Investment		Baseline Assumption: 7 Percent Real Discount Rate				Alternative Assumption: 3 Percent Real Discount Rate			
		Percent Change, 2028 Compared With 2008[3]				Percent Change, 2028 Compared With 2008[3]			
Annual Percent Change in HERS Spending[1]	Average Annual Spending[2] (Billions of 2008 Dollars)	Average Speed	Average Pavement Roughness (IRI)	Average Delay per VMT	Minimum BCR Cutoff[4]	Average Speed	Average Pavement Roughness (IRI)	Average Delay per VMT	Minimum BCR Cutoff[4]
5.90%	$105.4	2.6%	-24.3%	-7.7%	**1.00**	2.4%	-24.0%	-7.4%	1.42
4.86%	$93.4	2.0%	-19.8%	-5.0%	1.20	1.9%	-19.5%	-4.8%	1.70
3.51%	$80.1	1.2%	-13.7%	-1.7%	1.50	1.1%	-13.7%	-1.3%	2.11
2.88%	$74.7	0.9%	-11.1%	**0.0%**	1.64	0.7%	-10.7%	0.2%	2.32
1.31%	$62.9	**0.0%**	-3.8%	3.8%	2.02	-0.2%	-2.7%	3.8%	2.87
0.56%	$58.0	-0.4%	**0.0%**	5.5%	2.24	-0.6%	1.0%	5.4%	3.20
0.00%	$54.7	-0.7%	2.8%	6.7%	2.42	-1.0%	3.8%	6.8%	3.45
-1.00%	$49.3	-1.3%	7.4%	9.0%	2.74	-1.6%	8.6%	9.4%	3.90
7.61%	$129.0					3.3%	-30.7%	-11.5%	**1.00**

[1] The first eight rows correspond to annual percent changes in spending identified in Chapter 7 (Exhibit 7-3) as being associated with the investment needed to achieve certain specific targets (expressed in terms of minimum BCR cutoffs, maintaining specific performance indicators, or growing at a specific rate in constant dollar terms). The ninth row corresponds to the level of investment consistent with a minimum BCR cutoff of 1.00 for the alternative assumption presented; the comparable investment level for the baseline assumption appears in the top row in the table.

[2] The amounts shown represent the average annual investment over 20 years by all levels of government combined that would occur if such spending grows annually in constant dollar terms by the percentage shown in each row of the first column. Of the $91.1 billion of total capital expenditures for highways and bridges in 2008, $54.7 billion was used for the types of capital improvements modeled in HERS.

[3] Increases in average speed reflect an improvement to system performance, as do decreases in average pavement roughness (IRI) and average delay per VMT.

[4] The minimum BCR represents the lowest benefit-cost ratio for any project implemented by HERS during the 20-year analysis period at the level of funding shown.

Source: Highway Economic Requirements System.

pavement roughness by 6.4 percentage points (from a 24.3 percent reduction to a 30.7 percent reduction) and for average delay per VMT by 3.8 percentage points (from a 7.7 percent reduction to an 11.5 percent reduction).

In addition to increasing the amount of investment that can be economically justified, the reduction in assumed discount rate shifts the HERS allocation of any given investment total, in particular toward improvements with relatively long lives. The reallocation of investment has minor effects on the aggregate performance indicators in *Exhibit 10-13*, generally slight changes for the worse. The changes are largest at the lowest levels of investment; assuming no growth in annual investment (in constant dollars) above the $54.7 billion spent in 2008, the predicted 2008–2028 changes in average pavement roughness indicate deterioration of 2.8 percent or 3.8 percent, depending on whether the assumed discount rate is 7 percent or 3 percent. As noted in the above discussion of alternative demand elasticities, reallocation of investment alters the composition of VMT through the impacts on costs of travel across different portions of the highway network. In the present sensitivity test, it could be that the reduction in the assumed discount rate causes HERS to reallocate a given investment total in ways that increase the share of VMT occurring on sections with below-average conditions and performance.

Alternative Discount Rates—NBIAS

Since many of the bridge improvements evaluated in NBIAS are relatively long-lived, the choice of discount rate can significantly affect the model's estimate of the backlog of economically warranted investment. Reducing the discount rate increases the portion of the engineering-based backlog computed by NBIAS that would pass a benefit-cost test. *Exhibit 10-14* shows that reducing the real discount rate in NBIAS from the baseline 7 percent to 3 percent increases the estimated backlog of cost-beneficial bridge investments as of 2008 from $121.2 billion to $151.2 billion. For 2028, the projected economic backlog depends on both the assumed discount rate and the assumed level of bridge investment over the preceding two decades. Given an average annual investment level of $20.5 billion, the projected backlog in 2028 is zero when the assumed discount rate is 7 percent, but remains at $52.0 billion when the assumed discount rate is 3 percent. NBIAS estimates that to eliminate the economic backlog when the assumed discount rate is 3 percent would require an average annual investment level of $24.8 billion, which would equate to an annual growth rate in investment of 5.96 percent.

Exhibit 10-14

Impact of Alternative NBIAS Discount Rates on Projected Economic Bridge Investment Backlog in 2028, for Different Possible Funding Levels

NBIAS-Modeled Capital Investment		2028 Economic Bridge Investment Backlog for System Rehabilitation (Billions of 2008 Dollars)[3] for Two Discount Rate Assumptions	
Annual Percent Change in NBIAS Spending[1]	Average Annual Spending[2] (Billions of 2008 Dollars)	Baseline 7.0 Percent	Alternative 3.0 Percent
4.31%	$20.5	**$0.0**	$52.0
3.51%	$18.7	$25.3	$75.4
2.88%	$17.5	$42.0	$91.6
1.31%	$14.7	$79.1	$130.6
0.56%	$13.6	$95.8	$147.8
0.00%	$12.8	$107.6	$160.0
-0.70%	$11.9	$121.6	$174.2
-1.00%	$11.5	$127.1	$179.7
5.96%	$24.8		**$0.0**
2008 Value:		**$121.2**	**$151.2**

[1] The first eight rows correspond to annual percent changes in spending reflected in the NBIAS analyses of all bridges presented in Chapter 7 (Exhibit 7-17). The ninth row represents the level of investment required to eliminate the economic bridge investment backlog under the alternative discount rate assumption (3.0%); the comparable investment level for the baseline discount rate assumption (7.0%) appears in the top row in the table.

[2] The amounts shown represent the average annual investment over 20 years by all levels of government combined that would occur if such spending grows annually in constant dollar terms by the percentage shown in each row of the first column.

[3] Reductions in the economic investment backlog for bridges would be consistent with an overall improvement in bridge conditions. The amounts shown do not reflect system expansion needs; the bridge component of such needs are addressed as part of the HERS model analysis.

Source: National Bridge Investment Analysis System.

High-Cost Transportation Capacity Investments

HERS includes options for adding capacity to a corridor through high-cost means (such as tunneling or double-decking) when the HPMS database indicates that widening a highway section through conventional means is infeasible. In some instances, however, adding capacity through these alternatives may be infeasible on environmental, economic, geological, or other grounds. Intuitively, eliminating the option to add high-cost capacity from the menu of investment possibilities should reduce the optimal amount of investment by making the menu less attractive. Consistent with this intuition, *Exhibit 10-15* indicates that directing HERS not to consider the option of high-cost widening reduces the estimate of the total amount of potentially cost-beneficial investment over the analysis period by 20.6 percent from an average annual investment level of $105.4 billion to $83.7 billion. Since this reduction in spending would be concentrated on projects entailing additions to capacity, the impacts would be much more significant for the speed-related measures than for pavement condition. Average speed would be projected to decline over the analysis period by 0.3 percent without the high-cost option, compared with an increase of 2.6 percent in the baseline simulation. For average delay per VMT, the effect on the 2028 projection is much larger, an increase of

Exhibit 10-15

Impact of Alternative HERS High-Cost Transportation Capacity Improvement Assumptions on Selected Indicators, for Different Possible Funding Levels

HERS-Modeled Capital Investment		Baseline: Consider High-Cost Alternatives				Alternative: Do not Consider High-Cost Alternatives			
		Percent Change, 2028 Compared With 2008[3]				Percent Change, 2028 Compared With 2008[3]			
Annual Percent Change in HERS Spending[1]	Average Annual Spending[2] (Billions of 2008 Dollars)	Average Speed	Average Pavement Roughness (IRI)	Average Delay per VMT	Minimum BCR Cutoff[4]	Average Speed	Average Pavement Roughness (IRI)	Average Delay per VMT	Minimum BCR Cutoff[4]
5.90%	$105.4	2.6%	-24.3%	-7.7%	**1.00**				
4.86%	$93.4	2.0%	-19.8%	-5.0%	1.20				
3.51%	$80.1	1.2%	-13.7%	-1.7%	1.50	-0.3%	-23.3%	7.3%	1.09
2.88%	$74.7	0.9%	-11.1%	**0.0%**	1.64	-0.6%	-20.5%	**8.5%**	1.26
1.31%	$62.9	**0.0%**	-3.8%	3.8%	2.02	**-1.1%**	-13.3%	11.0%	1.67
0.56%	$58.0	-0.4%	**0.0%**	5.5%	2.24	-1.4%	**-9.3%**	12.2%	1.91
0.00%	$54.7	-0.7%	2.8%	6.7%	2.42	-1.6%	-6.4%	13.1%	2.09
-1.00%	$49.3	-1.3%	7.4%	9.0%	2.74	-1.9%	-1.4%	14.6%	2.47
3.90%	$83.7					-0.3%	-25.1%	6.9%	**1.00**

[1] The first eight rows correspond to annual percent changes in spending identified in Chapter 7 (Exhibit 7-3) as being associated with the investment needed to achieve certain specific targets (expressed in terms of minimum BCR cutoffs, maintaining specific performance indicators, or growing at a specific rate in constant dollar terms). The ninth row corresponds to the level of investment consistent with a minimum BCR cutoff of 1.00 for the alternative assumption presented; the comparable investment level for the baseline assumption appears in the top row in the table.

[2] The amounts shown represent the average annual investment over 20 years by all levels of government combined that would occur if such spending grows annually in constant dollar terms by the percentage shown in each row of the first column. Of the $91.1 billion of total capital expenditures for highways and bridges in 2008, $54.7 billion was used for the types of capital improvements modeled in HERS.

[3] Increases in average speed reflect an improvement to system performance, as do decreases in average pavement roughness (IRI) and average delay per VMT.

[4] The minimum BCR represents the lowest benefit-cost ratio for any project implemented by HERS during the 20-year analysis period at the level of funding shown.

Source: Highway Economic Requirements System.

6.9 percent compared with a decrease of 7.7 percent. For average pavement roughness, on the other hand, the 2028 projection is only 0.8 percent higher without the high-cost option (projected 2008–2028 period decreases of 24.3 percent versus 25.1 percent).

Similarly, at any given level of investment in *Exhibit 10-15*, eliminating the high-cost widening option favors pavement outcomes over speed improvements. Without this option, HERS reallocates a portion of a fixed investment total from capacity-adding projects to improvements limited to pavement preservation. As a result, the pavement outcomes are projected to be better than in the baseline simulation, while the speed and delay outcomes are projected to be worse. For example, at an average annual investment of $62.9 billion (the baseline estimate of what would suffice to maintain average speed at the 2008 level), the 2028 projection for average delay per VMT would be 7.2 percentage points higher without the option for high-cost widening (11.0 percent increase versus 3.8 percent), while the 2028 projection for average pavement roughness would be 9.5 percentage points lower (-13.3 percent versus -3.8 percent).

As noted in Appendix A, while HERS models these high-cost transportation capacity investments as expansions to existing highway facilities, such investments could take other forms, such as the construction of new highway facilities or the construction or expansion of facilities for other modes of transportation.

Transit Sensitivity Analysis

This section examines the sensitivity of the Transit Economic Requirements Model's (TERM's) transit investment needs estimates to variations in the values of the following exogenously determined model inputs:

- Asset Replacement Timing (Condition Threshold)
- Capital Costs
- Value of Time
- Discount Rate

Specifically, these alternative projections assess how the estimates of baseline investment needs for the **State of Good Repair (SGR) benchmark** and the **Low** and **High Growth scenarios** discussed in Chapter 8 vary in response to changes in the assumed values of these key input variables. Note here that, by definition, funding under the **Sustain Current Spending scenario** is invariant to changes in any input variable and, for this reason, that scenario is not considered in this sensitivity analysis.

Changes in Asset Replacement Timing (Condition Threshold)

Each of the four investment scenarios examined in Chapter 8 assume that assets are replaced at condition rating 2.50 as determined by TERM's asset condition decay curves (in this context, 2.50 is referred to as the "replacement condition threshold"). Recall here that TERM's condition rating scale runs from 5.0 for assets in "excellent" condition through 1.0 for assets in "poor" condition. In practice, this assumption implies replacement of assets within a short term period (e.g., roughly 1 to 5 years depending on asset type) *after* they have attained their expected useful life. Replacement at condition 2.50 can therefore be thought of as providing a replacement schedule that is both realistic (in practice, few assets are replaced exactly at their expected useful life value due to a range of factors including the time to plan, fund, and procure an asset replacement) and potentially conservative (i.e., the needs estimates would be higher if all assets were assumed to be replaced at precisely the end of their expected useful life).

Based on this background, *Exhibit 10-16* shows the impact of varying the replacement condition threshold by increments of 0.25 on TERM's projected asset *preservation* needs for the **SGR benchmark** and the **Low Growth** and **High Growth scenarios**. It should be noted that selection of a higher replacement condition threshold results in assets being replaced at a higher condition (i.e., at an earlier age), which 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 will, of course, have the opposite effect. As shown in *Exhibit 10-16*, each of these three scenarios shows significant changes to total estimated preservation needs from quarter point changes in the replacement condition threshold. Relatively small changes in the replacement condition threshold frequently translate into significant changes in the expected useful life of some asset types and hence can also drive significant changes in replacement timing and replacement costs.

Exhibit 10-16

Impact of Alternative Replacement Condition Thresholds on Transit Preservation Investment Needs by Scenario (Excludes Expansion Impacts)

	SGR Benchmark		Low Growth Scenario		High Growth Scenario	
Replacement Condition Thresholds	Billions of 2008 Dollars	Percent Change From Baseline	Billions of 2008 Dollars	Percent Change From Baseline	Billions of 2008 Dollars	Percent Change From Baseline
Replace assets later (2.25)	$16.35	-9.2%	$15.11	-8.8%	$15.62	-9.1%
Baseline (2.50)	$18.00		$16.56		$17.18	
Replace assets earlier (2.75)	$21.49	19.4%	$19.73	19.1%	$20.36	18.5%
Very early asset replacement (3.00)	$25.94	44.1%	$23.56	42.3%	$24.22	41.0%

Source: Transit Economic Requirements Model.

Changes in Capital Costs

The asset costs used in TERM are based on actual prices paid by agencies for capital purchases as reported to Federal Transit Administration (FTA) in the Transit Electronic Award Management (TEAM) System and in special surveys. Asset prices in the current version of TERM have been converted from the dollar year replacement costs in which assets were reported to FTA by local agencies (which vary by agency and asset) to 2008 dollars using the RS Means 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 shown in *Exhibit 10-17,* TERM projects that a 25 percent increase in capital costs (i.e., beyond the 2008 level used for this report) would be fully reflected in the **SGR benchmark** but only partially realized under either the **Low Growth** or **High Growth scenarios**. This difference in sensitivity results is driven by the fact that investments are not subject to TERM's benefit-cost ratio in computing the **SGR benchmark** (hence there are no consequences to increasing costs) whereas the two scenarios do employ this test. Hence, for the **Low Growth** or **High Growth scenarios**, any increase in capital costs (without a similar increase in the value of transit benefits) results in lower benefit-cost ratios and the failure of some investments to pass this test. Therefore, for these latter two scenarios, a 25 percent increase in capital costs would yield a range of roughly 14 to 16 percent increase in needs that pass TERM's benefit-cost test.

Exhibit 10-17

Impact of an Increase in Capital Costs on Transit Investment Estimates by Scenario

	SGR Benchmark		Low Growth Scenario		High Growth Scenario	
Capital Cost Increases	Billions of 2008 Dollars	Percent Change From Baseline	Billions of 2008 Dollars	Percent Change From Baseline	Billions of 2008 Dollars	Percent Change From Baseline
Baseline (no change)	$18.00		$20.76		$24.47	
Increase Costs 25%	$22.50	25.0%	$23.64	13.9%	$28.27	15.5%

Source: Transit Economic Requirements Model.

Changes in the Value of Time

The most significant source of transit investment benefits as assessed by TERM's benefit-cost analysis is the net cost savings to users of transit services, a key component of which is the value of travel time savings. The per-hour value of travel time for transit riders is therefore a key model input and a key driver of total investment benefits for those scenarios that employ TERM's benefit-cost test. Readers interested in learning more about the measurement and use of the value of time for the benefit-cost analyses performed by TERM, HERS, and NBIAS should refer to the related discussion presented earlier in the highway section of this chapter.

For this C&P report, the **Low Growth** and **High Growth scenarios** are the only scenarios with investment needs estimates that are sensitive to changes in the benefit-cost ratio (note: the **Sustain Current Spending scenario** uses TERM's estimated benefit-cost ratios to allocate fixed levels of funding to preferred investments while the computation of the **SGR benchmark** does not employ TERM's benefit-cost test in any way).

Exhibit 10-18 shows the effect of varying the value of time on the needs estimates of the **Low Growth** and **High Growth scenarios**. The baseline value of time for transit users is currently $11.20 per hour, based on DOT guidance. Note that TERM applies this amount to all in-vehicle travel but then doubles this amount to $22.40 per hour when accounting for out-of vehicle travel time, including time spent waiting at transit stops and stations. For the purpose of sensitivity analysis, the following per-hour value of time rates is shown in *Exhibit 10-18*.

- Baseline: $11.20
- Value of time is half (reduce by 50 percent): $5.60
- Value of time is double (increase by 100 percent): $22.40
- Value of time is inflated to 2008 dollars: $13.49

Note that DOT guidance established the value of time in 2000 dollars. Hence, the fourth sensitivity test is intended to assess the impact of inflating the value to 2008 dollars (using the Consumer Price Index) consistent with all other analyses in the report.

As noted, related benefits to value of time are a key driver of total investment benefits as assessed by TERM; hence TERM's total needs estimates for the **Low Growth** and **High Growth scenarios** are accordingly responsive to significant changes of that value. This can be seen in *Exhibit 10-18* where the value of time

Exhibit 10-18

Impact of Alternative Value of Time Rates on Transit Investment Estimates by Scenario

	Low Growth Scenario		High Growth Scenario	
Changes in Value of Time	Billions of 2008 Dollars	Percent Change From Baseline	Billions of 2008 Dollars	Percent Change From Baseline
Reduce 50% ($5.60)	$17.91	-13.7%	$21.51	-12.1%
Baseline ($11.20)	$20.76		$24.47	
Increase 100% ($22.40)	$22.40	7.9%	$26.99	10.3%
Inflate to 2008 Dollars ($13.49)	$21.05	1.4%	$24.87	1.6%

Source: Transit Economic Requirements Model.

rate is doubled or halved, leading to increases or decreases in needs on the order of 10 percent. It should be noted, however, that the more modest increase in the value of time used to inflate it from 2000 dollars to 2008 dollars (an increase of roughly 20 percent) increased the total needs by only a range of 1.4 to 1.6 percent.

Changes to the Discount Rate

Finally, TERM's benefit-cost module utilizes a discount rate of 7 percent in accordance with OMB guidance. Readers interested in learning more about the selection and use of discount rates for the benefit-cost analyses performed by TERM, HERS, and NBIAS should refer to the related discussion presented earlier in the highway section of this chapter. For this sensitivity analysis and for consistency with the HERS and NBIAS discount rate sensitivity discussion above, TERM's needs estimates for the **Low Growth** and **High Growth scenarios** were re-estimated using a 3 percent discount rate. The results of this analysis are presented in *Exhibit 10-19*. These results show that this roughly 57 percent reduction in the discount rate yields an increase in total investment needs (or an increase in the proportion of needs passing TERM's benefit-cost test) of roughly 6 to 8 percent.

Exhibit 10-19

Impact of Alternative Discount Rates on Transit Investment Estimates by Scenario

	Low Growth Scenario		High Growth Scenario	
Discount Rates	**Billions of 2008 Dollars**	**Percent Change From Baseline**	**Billions of 2008 Dollars**	**Percent Change From Baseline**
7.00% (Baseline)	$20.76		$24.47	
3.00%	$22.02	6.1%	$26.42	7.9%

Source: Transit Economic Requirements Model.

PART III

Sustainable Transportation Systems

Introduction

The C&P report has traditionally focused on physical conditions—as measured by pavement ride quality, bridge deficiencies, and transit asset conditions, etc.—and on operational performance—as measured by levels of highway congestion, travel times, frequency of transit service, etc. However, given the impact of transportation on the human and natural environments, it is important to consider sustainability in order to evaluate overall system performance more comprehensively.

Social performance, or the performance of the system in enhancing the quality of life and the livability of communities, is also important, though an even more difficult area to measure. While performance metrics in transportation environmental and social arenas have not traditionally been tracked by transportation agencies, Part III of this report attempts to characterize the environmental and social performance of the system with regards to the "Environmental Sustainability" and "Livability Communities" goals identified in the *U.S. DOT Strategic Plan FY 2010–FY 2015*.

For environmental sustainability, the U.S. DOT goal is: "**Advance environmentally sustainable polices and investments that reduce carbon and other harmful emissions from transportation sources**." In addition, the following outcomes have been identified:

- Reduction in transportation-related carbon emissions, improved energy efficiency, and reduction in use of oil in the transportation sector
- Reduction in transportation-related air, water, and noise pollution and impacts on ecosystems
- Increasing use of environmentally sustainable practices and materials in the transportation sector.

For livable communities, the U.S. DOT goal is: "**Foster livable communities through place-based policies and investments that increase transportation choices and access to transportation services.**" In addition, the following outcomes have been identified:

- Increased access to convenient and affordable transportation choices
- Improved public transit experience
- Improved networks that accommodate pedestrians and bicycles
- Improved access to transportation for people with disabilities and older adults.

Defining Sustainability

There are numerous ways to define sustainability. One of the most commonly cited definitions was developed by the 1987 United Nations (UN) World Commission on Environment and Development, also known as the Brundtland Commission. The Commission defined sustainability as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

A March 2010 Report prepared for the U.S. Federal Highway Administration (FHWA), entitled "*Criteria and Tools for Sustainable Highways*," explores how organizations have "attempted to define sustainability and address it at strategic and programmatic levels." The report discusses two views of sustainability in the transportation sector, including one that focuses only on transportation and another that takes a holistic approach viewing transportation as an aspect of sustainable development, but not the focal point. The report recognized that there are many definitions for sustainable transportation. However, in an effort to create a more commonly understood definition, the report includes one of the more frequently used definitions, from the Centre for Sustainable Transport in Canada, which identifies the following as attributes of a sustainable transportation system:

- Allows the basic access needs of individuals and societies to be met safely and in a manner consistent with human and ecosystem health, and with equity within and between generations.
- Is affordable, operates efficiently, offers choices of transport mode, and supports a vibrant economy.
- Limits emissions and waste within the planet's ability to absorb them, minimizes consumption of nonrenewable resources, limits consumption of renewable resources to the sustainable yield level, reuses and recycles its components, and minimizes the use of land and the production of noise.

The American Public Transportation Association (APTA) has defined sustainability for the public transportation industry as:

- Employing practices in design and capital construction, such as using sustainable building materials, recycled materials, and solar or other renewable energy sources to make facilities as "green" as possible.
- Employing practices in operations and maintenance such as reducing hazardous waste, increasing fuel efficiency, creating more efficient lighting, and using energy-efficient propulsion systems.
- Employing community-based strategies to encourage land use and transit oriented development designed to increase public transit ridership.

One concept that adds context to sustainability is the triple bottom line. The triple bottom line includes three components—economic, environmental, and societal. In transportation, the triple bottom line relates to sustainable solutions in the areas of the natural environmental systems surrounding the transportation system, the economic efficiency of the system, and the societal needs (e.g., mobility, accessibility, safety, and equity). These three concepts are often used by the transportation industry—during transportation planning and design—to provide a basis for sustainability that is not a singular focus on building "green" roads and bridges, but a more comprehensive approach to transportation.

The triple bottom line themes—environmental, economic, and societal— will be prevalent throughout this discussion. The overarching term, "sustainable transportation systems," encompasses all three components—environmental, economic, and societal. Some organizations use the terms "livability" and "sustainability" interchangeably, but for U.S. DOT purposes, the term "sustainability" is generally used in conjunction with environmental sustainability, while livability discussions largely focus on the society (community).

The Triple Bottom Line

The triple bottom line concept adds context to the definition of sustainability through the use of three components—economic, environmental, and societal. The concept of the triple bottom line was created in 1998 by John Elkington for private sector use in developing more sustainable business practices. The concept has since been adopted by other industries, including the public sector. In transportation the triple bottom line related to sustainable solutions in the areas of the natural environmental systems surrounding the transportation system, the economic efficiency of the system, and the societal needs (e.g., mobility, accessibility, safety, and equity). These three concepts are often used by the transportation industry—during transportation planning and design—to provide a basis for sustainability that is not a singular focus on building "green" roads and bridges, but a more comprehensive approach to transportation. Additional information on the triple bottom line can be found at https://www.sustainablehighways.org/296/what-is-sustainability.html.

HUD/DOT/EPA Interagency Partnership for Sustainable Communities

In June 2009, the U.S. DOT, Department of Housing and Urban Development (HUD), and the U.S. Environmental Protection Agency (EPA) initiated an Interagency Partnership for Sustainable Communities (Partnership) to improve access to affordable housing, provide more transportation options, and lower transportation costs while protecting the environment in communities nationwide. Six livability principles were established to act as a foundation for interagency coordination as follows:

- Provide more transportation choices
- Promote equitable, affordable housing
- Enhance economic competitiveness
- Support existing communities
- Coordinate policies and leverage investment
- Value communities and neighborhoods.

Through the Partnership, the three Federal agencies coordinate existing and new programs. The U.S. DOT and HUD provide staff and resources to support EPA's Smart Growth Technical Assistance Program. The U.S. DOT also collaborates with EPA in the administration of HUD's Sustainable Communities Planning Grants, designed to fund coordinated regional planning. In addition, HUD and EPA provided technical assistance in the evaluation of U.S. DOT's Transportation Investment Generating Economic Recovery (TIGER) Discretionary Grant applications, for which livability and sustainability were two key criteria. Twenty-two of the 50 projects that were awarded focused on livability by giving Americans choices about how they travel and improving access to economic and housing opportunities in their communities.

The TIGER II Grant Program furthered the collaborative process, with U.S. DOT, HUD, and EPA working together to evaluate applications for $35 million in U.S. DOT"s TIGER II Planning Grants and $40 million in HUD's Sustainable Communities Challenge Grants. These grants encourage comprehensive planning activities that should ultimately lead to projects that integrate transportation, housing, and economic development.

In July 2010, U.S. DOT awarded nearly $300 million in Urban Circulator and Bus Livability grants. The urban circulator grants will fund streetcar, bus, and other urban transportation projects that connect destinations and foster walkable, mixed-use redevelopment. The bus livability grants support Partnership principles by improving bus service and facilities; encouraging development around public transit; and giving riders better access to jobs, health care, and education.

The Partnership will continue to identify barriers to and strategies for coordinating transportation, housing, and environmental programs and investments. Modifications will be proposed to address barriers that are based on Federal administrative rules or regulations. Efforts will be undertaken to work with Congress to address barriers that require legislative action, such as changes to U.S. DOT's, HUD's, or EPA's planning requirements.

Chapter 11 and Chapter 13 each provide more information on specific initiatives under the HUD/EPA/U.S. DOT Partnership.

Organization of Part III

Part III of this report is broken down into three chapters, each of which provides a broad overview of the concept that will be covered and citations for where additional information on related topics can be found. Where relevant data are not available at this time, this section includes a discussion on potential additional data collection and performance indices that could be utilized to measure progress in the future.

Chapter 11, **Environmental Sustainability**, provides an overview of the transportation system in terms of its environmental impacts. The chapter looks at goals for sustainable transportation and some potential indices to measure progress.

Chapter 12, **Climate Change Adaptation**, provides information on anticipated potential future changes due to a changing climate, such as higher sea levels and increased temperatures, and the resulting impact on transportation. The chapter looks at steps to assess adaptation needs. Examples of the FHWA and State DOT adaptation efforts are also provided.

Chapter 13, **Livability**, presents an overview of how transportation can improve livability in communities across the Nation with a focus on the characteristics, goals, and benefits of livability. It also includes a preliminary discussion on potential livability indices to measure progress. This chapter provides data and information to provide awareness of the benefits of livable communities and the U.S. DOT and transportation's role in this effort.

Chapter 11

Environmental Sustainability

Environmental Sustainability

Transportation is crucial to our economy and quality of life; but the process of building, operating, and maintaining transportation systems has environmental consequences. The U.S. Department of Transportation's (U.S. DOT's) goal is to foster more sustainable approaches to transportation in order to avoid negative impacts now and to ensure that future generations will be able to enjoy the same or better standards of living and mobility as the current one. A sustainable transportation system is holistic, "one in which (a) current social and economic transportation needs are met in an environmentally conscious manner and (b) the ability of future generations to meet their needs is not compromised."[1] Sustainable transportation focuses on environmental impacts such as improving energy efficiency, reducing dependence on oil, reducing greenhouse gas (GHG) emissions, and not harming the natural environment. A more extensive coverage of the definition of sustainability and sustainable transportation systems is provided in the Introduction to Part III, "Sustainable Transportation Systems."

Although the capital investment needs analyses presented in Part II of this report take increases in emissions (including GHG) into account as a societal cost (disbenefit) in their computation of the benefits and costs of infrastructure investment, they do not fully address the long-term societal benefits that could be obtained from more sustainable approaches to transportation services. The three chapters included in Part III of this report address the broader range of issues associated with moving toward more sustainable transportation systems. This chapter focuses on environmental sustainability issues, including GHG emissions attributable to the transportation sector. Chapter 12 examines issues pertaining to climate change adaptation, anticipating potential future changes in climate and the resulting impact on transportation infrastructure. Chapter 13 focuses on the livability of communities, addressing issues related to the human environment (in contrast with the focus on the natural environment in this chapter).

Given the impact of transportation on the natural environment and on society as a whole, it is important to measure the changing environmental, economic, and social impacts of the transportation system. This chapter provides a discussion of the goals and benefits of sustainability as it relates to transportation and looks at accomplishment made as well as the development of potential metrics for sustainable transportation trends. Given the range of issues related to environmental sustainability, this chapter does not attempt to explore all of them in depth.

Background

Chapter 2 describes the extent and use of the Nation's highway, bridge, and transit systems. In addition to these modes, travel by railroads, waterways, and air also play a key role in passenger and freight transportation, while pipelines move oil, gas, water, and other commodities. This transportation system has fostered new communities; connected cities, towns, and regions; and supported the growth of the national economy, but much of the movement on the system comes from the use of vehicles that rely on fossil fuels. From a sustainability perspective, the heavy reliance of the transportation system on such fuels is of significant concern, as they are non-renewable, generate air pollution, and contribute to the buildup of carbon dioxide (CO_2) and other pollutants that cause global warming. The transportation sector consumes 29 percent of the total energy used in the United States, and almost all of it is in the form of petroleum. Of all the fossil fuels, petroleum is the largest contributor to CO_2 emissions.[2]

The transportation sector was responsible for 29 percent of U.S. GHG emissions and 33 percent of U.S. CO_2 emissions in 2008.[3] CO_2 is the most prominent GHG and contributor to global climate change by far. About 60 percent of the transportation emissions are from passenger cars and light-duty trucks, 20 percent from medium and heavy-duty trucks, and the remaining 20 percent from other modes of transportation, such as commercial aircraft and other non-road vehicles (ships, boats, rail, and pipelines).

Over the past four decades, progress has been made in reducing emissions of air pollutants both nationally and from the transportation sector in particular. Since 1970, transportation-sector emissions of carbon monoxide have been reduced by 67 percent, emissions of volatile organic compounds have been reduced by 68 percent, and emissions of nitrogen dioxide have been reduced by 38 percent.[4] These reductions have been achieved, notwithstanding a 50 percent increase in the population, a tripling of real gross domestic product (GDP), and a 150 percent increase in passenger-miles traveled.[5] Nonetheless, as of 2007, some 158.5 million Americans lived in regions that exceeded health-based national ambient-air-quality standards for at least one regulated air pollutant. Significant challenges remain, particularly as national ambient-air-quality standards are revised to be more protective of public health.

Sustainability in transportation should be addressed with the mindset that transportation is one part of a larger economic system, and represents an integral part of sustainable development. To seek more sustainable options, transportation programs will need to focus on integrating transportation decision-making with environmental considerations, including planning multimodal transportation systems in conjunction with land use in order to maximize efficiencies, reducing the environmental impact of construction and maintenance, and improving the operating efficiency of the system. Transportation agencies at all levels of government and their partners are uniquely positioned to work collaboratively in support of the Nation's environmental sustainability efforts.

Establishing Sustainability Goals

The U.S. DOT is collaborating with other Federal agencies, including HUD and EPA, to develop performance metrics that support the advance of environmentally sustainable polices in the transportation community. One area of focus is the development of performance metrics that will assist in GHG reduction. Determining the necessary research and data needed to develop these metrics is required. In

What initial "Environmental Sustainability" performance measures have been identified by the FHWA and FTA?

The FHWA has established an initial target to increase the number of States with State Climate Action Plans that reduce greenhouse gas emissions from transportation from 35 in FY 2010 to between 38 and 40 in FY 2011.

Climate Action Plans can help States to determine the steps they can take to reduce greenhouse gas emissions and assess the vulnerability of various transportation assets to climate impacts. The FHWA provides technical and financial assistance to States in the form of workshops, webinars, and peer exchanges to assist in incorporating transportation elements into their Plans. The FHWA encourages its Division offices to review the transportation-related sections of the report as part of the assistance efforts. The FHWA is preparing a template that can be used to collect information on State climate activities, which will be useful in tracking progress.

The FTA has established three sustainability performance metrics:

1. Decreased fuel consumption per vehicle mile traveled and per passenger mile traveled.
2. Increased percent of transit vehicles using alternative fuels.
3. Increased transit market share for the top 50 urbanized areas.

These metrics are to support the outcomes of:

- Reduced carbon emissions and dependence on fossil fuels and improved energy efficiency
- Reduced transportation-related air, water, and noise pollution and impacts on ecosystems.

The FHWA and FTA continue to analyze and assess options for developing additional performance measures.

some cases, data are not available or difficult to capture; as a starting point, the U.S. DOT is implementing metrics where data and information are readily available as a quantifiable measure. For example, information is readily available for States that have Climate Change Action plans, and one way to assist in GHG reduction is to encourage more States to implement them and to provide assistance in improving them, as needed. Work will continue to identify additional measures over time.

A March 2010 report prepared for the FHWA entitled "*Criteria and Tools for Sustainable Highways*" explores additional performance measures for sustainability. One of the struggles in creating sustainability performance measures is the need for shifting from automobile-centric (and operations-focused) measures to more holistic indicators, even if they are more difficult to measure.[6] The report also notes the paradigm shift required to capture sustainability concerns, moving from measuring mobility to accessibility, and from assessing outputs to outcomes.[7]

At the Federal level, environmental sustainability has been adopted as a strategic planning goal in the U.S. DOT Strategic Plan FY 2010–2015. The goal is to: "Advance environmentally sustainable polices and investments that reduce carbon and other harmful emissions from transportation sources."

At the State level, transportation agencies are in various stages of developing performance metrics that address sustainability criteria and monitor progress toward the goal of more sustainable roadways. Many State transportation agencies have increasingly integrated the concept of sustainability into their activities. In the United States, over 40 percent of State transportation agencies have incorporated sustainability into their vision or mission statements.[8] Some are also developing specific sustainability goals and performance measures to assess their progress toward these goals. Sixty-eight public transportation agencies and private-sector transit industry members have signed the American Public Transportation Association Sustainability Commitment. Under this commitment, signatories commit to a core set of actions on sustainability, measure environmental impacts in key areas, and meet reduction targets.[9] By quantifying outcomes, a transportation sustainability performance metric can encourage more sustainable practices, allow informed decisions and trade-offs regarding roadway sustainability, enable transportation organizations to confer benefits on sustainable road projects and programs, and communicate roadway sustainability to stakeholders.

Assessing Sustainability of the Transportation System

Developing performance measures to evaluate sustainability is important in order to assess the progress of States, localities, and the Nation as a whole in meeting the goal. It involves looking through different lenses in order to ensure that all aspects of the concept are represented. In this section, some of the categories of measures that could be used to evaluate sustainability are explored. These categories include reducing GHG emissions, improving system efficiency and reducing the growth of VMT, transitioning to fuel-efficient vehicles and alternative fuels, and increasing the use of recycled materials in transportation. A list of some additional metrics for consideration is provided at the end of this section. Selected initiatives relating to the issues discussed in this section are presented in callout boxes, which include references to where more information is available.

Infrastructure Voluntary Evaluation Sustainability Tool (INVEST)

The FHWA has launched an initiative to support transportation agencies in making highway projects more sustainable. This new initiative provides a practical tool, called the Infrastructure Voluntary Evaluation Sustainability Tool (INVEST), for integrating sustainability best practices into transportation projects and programs. The tool is innovative in that it is a self-evaluation tool that allows users to assess for themselves how sustainable their programs or projects may be. Participation in the initiative and application of the tool are voluntary, allowing users to determine for themselves how best to achieve a desired level of sustainability in their programs and projects.

Reducing Greenhouse Gas Emissions

Metropolitan planning organizations (MPOs), State departments of transportation (DOTs), and transit agencies have recently begun to consider strategies available for immediate and future implementation, and some are implementing them. Ultimately, mitigation of GHG emissions reduces the extent of climate change experienced by current and future generations; but, given the large increases in concentrations of GHG over the last two centuries, some level of climate change is inevitable and is in fact already occurring.[10] GHGs, such as CO_2, trap heat in the Earth's atmosphere. According to the Intergovernmental Panel on Climate Change (IPCC), GHG emissions from human activities, principally the burning of fossil fuels, are the primary cause of global warming with projected impacts including sea level rise, more intense storms and droughts, biodiversity loss, reduced agricultural yields, and stress on the water supply. An IPCC report finds that GHG emissions must be reduced by 50 to 85 percent by 2050 in order to limit global warming to 4 degrees Fahrenheit, avoiding many of the worst impacts of climate change.[11] While widespread climate impacts are occurring now and are expected to increase, the extent of climate change and its impacts depend on choices made today to mitigate human-caused emissions of GHGs.[12] CO_2 makes up 96 percent of all transportation GHG emissions. Other human-induced GHG emissions created by transportation and other sectors are methane (CH_4), nitrous oxide (N_2O), chlorofluorocarbons (CFCs), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6).

California Senate Bill 375

The State of California has enacted "The Sustainable Communities and Climate Protection Act of 2008" (SB 375), which is an example of how State governments are beginning to adopt strategies to promote more sustainable communities. A requirement of this act is to establish GHG emission reduction targets for passenger vehicles by 2020 and 2035, for each of the State's 18 MPOs. Each MPO will prepare a Sustainable Communities Strategy (SCS) that will demonstrate how the region will meet GHG reduction targets through integrated land use, housing, and transportation planning. SCSs will then be incorporated into each MPO's Regional Transportation Plan (RTP). More information on SB 375 can be found at http://www.arb.ca.gov/cc/sb375/sb375.htm.

Initial measures of environmental performance of the Nation's transportation system, specifically related to climate change outcomes, use metrics of total GHG emissions from transportation, GHG emissions per capita from transportation, and GHG emissions per passenger mile or ton mile.

Total GHG From Transportation

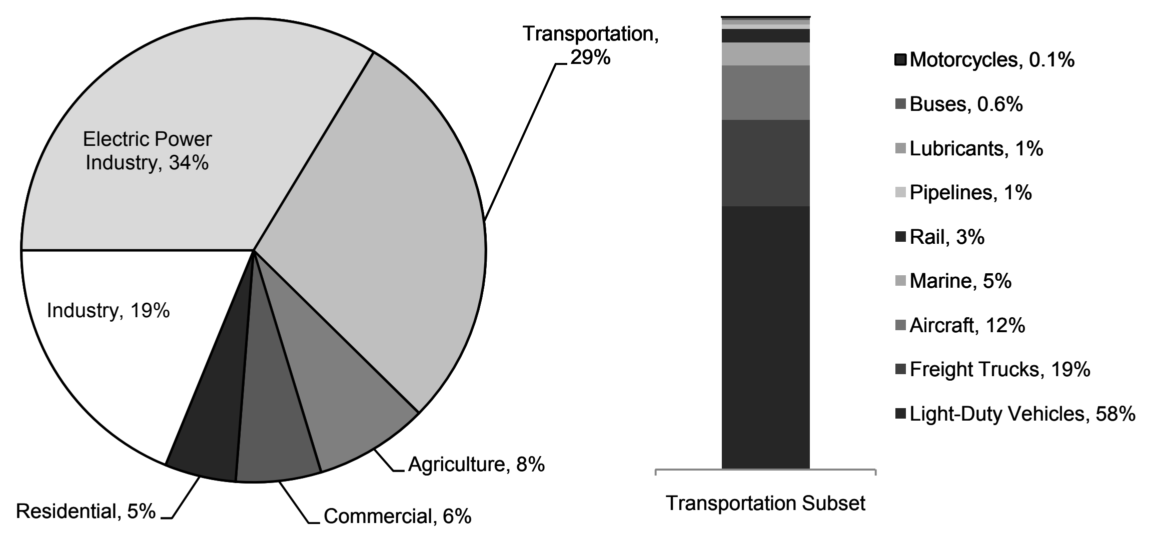
As shown in *Exhibit 11-1*, the transportation sector is a major contributor to GHG emissions. Burning fuel to power U.S. vehicles results in 2.1 billion metric tons of CO_2 equivalent (CO_2e), or 29 percent of all U.S. GHG emissions and 5 percent of global emissions (on-road vehicles comprise the largest share). The inclusion of life-cycle emissions—such as the production and distribution of fuel, the manufacture of vehicles, and the construction and maintenance of transportation infrastructure—increase transportation GHG emissions by around 50 percent.[13] GHGs from the transportation sector grew 27 percent from 1990 to 2006. Freight-truck GHGs have grown faster than those of any other transportation mode, growing 77 percent between 1990 and 2006. Emissions from light-duty vehicles grew 24 percent over the same time period, due to increases in VMT of over twice the population growth and a stagnation of vehicle fuel economy. Although airline passenger miles increased 69 percent over the period, commercial aircraft emissions increased only 4 percent, due primarily to increased passenger loads.[14]

Green Building

The FTA developed an action plan that promotes green building practices in transit facilities. Several transit agencies, including Santa Clara Transit and the Chicago Transit Authority, have obtained Leadership in Energy and Environmental Design (LEED) Gold certification from the Green Building Council. Additional information on the FTA Green Building Action Plan can be found at http://www.fta.dot.gov/12907_10318.html.

Exhibit 11-1

GHG Emissions



Note: Figures include international bunker fuels purchased in the United States.

Source: U.S. EPA Inventory of U.S. Greenhouse Gas Emissions and Sinks, 1990–2006, 2008.

The Energy Information Administration's (EIA's) Annual Energy Outlook (AEO) 2010 projects little growth in transportation GHG emissions through 2030. In the light-duty-vehicle sector, the AEO projects that increased Federal fuel-economy standards and the renewable-fuels standard will offset VMT growth and lead to a net 12 percent decline in light-duty-vehicle emissions. Freight trucks, on the other hand, show a 20 percent increase in emissions, while domestic aviation climbs 27 percent. AEO takes into account existing government legislation and regulations.[15]

GHG Emissions per Passenger Mile or Ton Mile

The fuel economy of light-duty vehicles increased with Corporate Average Fuel Economy (CAFE) standards in the 1970s and 1980s and had remained roughly stagnant until recently.[16] The number of passengers per vehicle had declined since the 1970s to an average of 1.68 per trip and 1.10 for work trips.[17] This has led to increased GHG per passenger mile traveled (PMT), with passenger cars at 261 grams CO_2equivalent per PMT and light-duty trucks at 301 grams CO_2e per PMT in 2006.[18] These estimates include vehicle operating emissions and not additional life-cycle components. With new fuel-economy standards promulgated by the U.S. DOT in 2010, fuel economy of new light-duty vehicles will average 35.5 mpg in 2016.

Freight-trucking GHG emissions per ton-mile carried increased almost 13 percent between 1990 and 2005, reflecting the stagnant fuel economy and decreased loads per truck resulting from structural changes in the economy that produced higher-value, lower-weight, time-sensitive shipments. The National Academy of Sciences completed a study in March 2010 of medium- and heavy-duty-vehicles' efficiency and found significant opportunities for cost-effective engine and aerodynamic improvements. In May 2010, it was announced that EPA and NHTSA would establish joint GHG and fuel-economy regulations for medium- and heavy-duty vehicles under existing statutory authority. This will improve the fuel efficiency of work trucks, delivery trucks, tractor trailers, buses, and other medium- and heavy-duty vehicles.

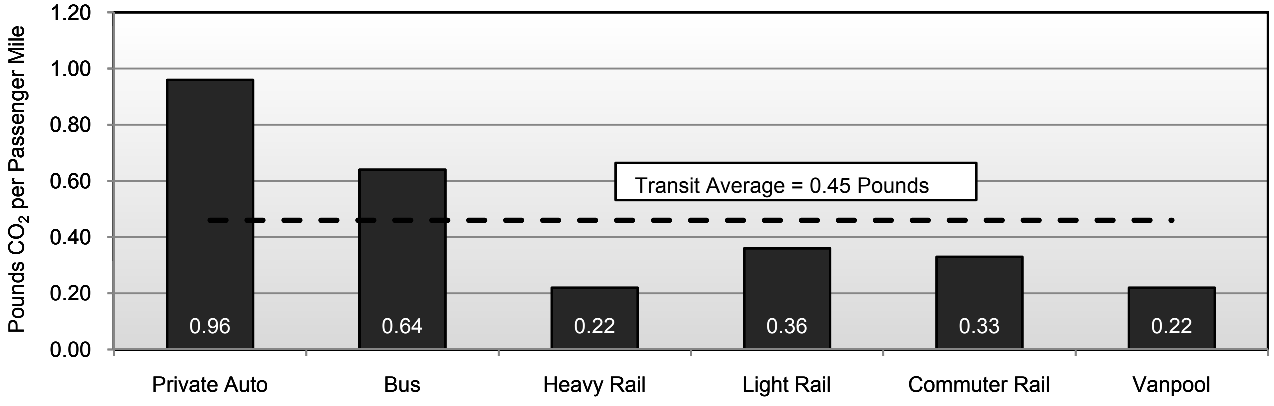
As shown in *Exhibit 11-2*, CO_2 operating emissions for transit per passenger mile can be lower than that of automobiles with a single occupant, when ridership levels result in more people moving in fewer vehicles. *Exhibit 11-3* shows that GHG efficiency for heavy rail systems varies greatly by region. One factor in this variation is typical vehicle occupancy for different transit systems; a full train has half as much emission per passenger mile as a half-full train. Differences in electricity sources in different regions also play a role; to the extent that electricity is produced by nuclear or hydroelectric plants versus coal-fired plants can have a significant impact on public transportation GHG efficiency. Differences in equipment, such as the weight and energy efficiencies of different types of trains, also play a role.

TIGGER Program

Through the Transit Investment for Greenhouse Gas and Energy Reduction (TIGGER) Program, the FTA works directly with public transit agencies to implement new strategies for reducing GHG emissions and energy use in their operations. Examples of projects supported by the program include on-board vehicle energy management, electrification of accessories, bus design, rail transit energy management, and locomotive design. Additional information on this program can be found at http://www.fta.dot.gov/assistance/research_11424.html.

Exhibit 11-2

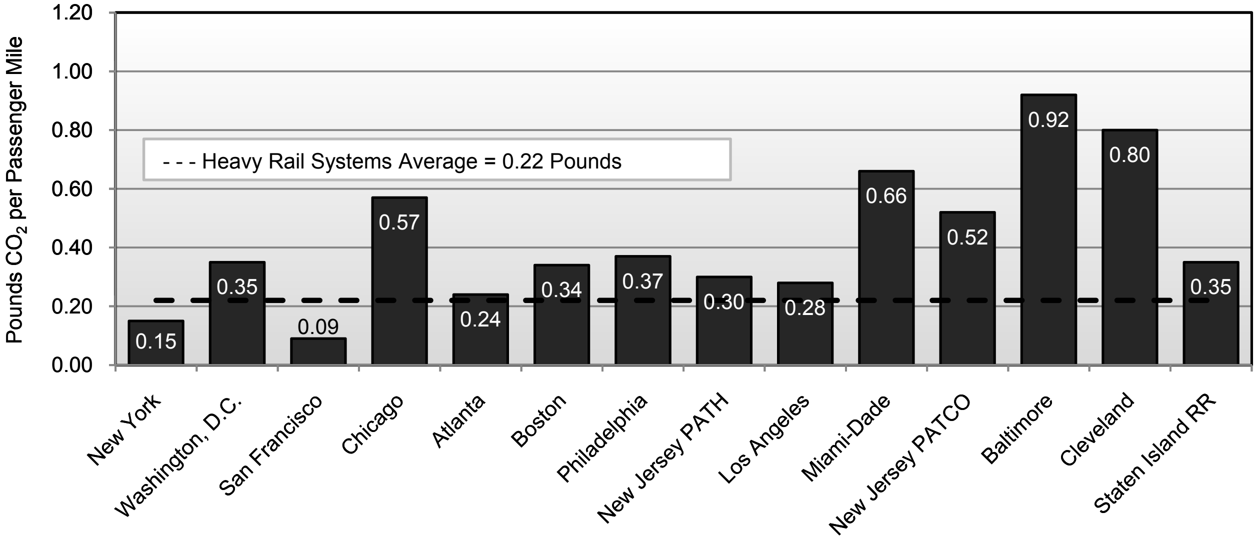
CO_2 Emissions per Passenger Mile Traveled



Source: Federal Transit Administration (FTA), Public Transportation's Role in Reducing Greenhouse Gas Emissions, 2010.

Exhibit 11-3

CO_2 Emissions per Passenger Mile Traveled for Selected U.S. Heavy Rail Systems



Source: FTA, Public Transportation's Role in Reducing Greenhouse Gas Emissions, 2010.

Improving System Efficiency and Reducing VMT Growth

One of the primary indicators of system inefficiency is congestion. Congestion occurs when the demand for travel is greater than supply in the transportation system. As discussed in Chapter 4, the Texas Transportation Institute estimates drivers in large metropolitan areas experienced 4.2 billion hours of delay due to congestion in 2007, resulting in 2.8 billion gallons of wasted fuel and congestion costs of $87 billion. Traffic volume is expected to grow, with freight movement expected to double by 2020.

Chapter 4 presents a number of potential congestion reduction strategies. While the strategic addition of road capacity can play a role, the traditional approach of building new routes or adding lanes to existing routes is not sustainable due to the effects of induced demand. The implementation of system management and operations strategies, including the deployment of intelligent transportation systems, provides opportunities to make more productive use of existing infrastructure assets. The use of congestion pricing can help create an efficient transportation market by addressing one of congestion's root causes, namely that most travelers do not pay the full cost of transportation services. Finally, building livable communities that consider the impacts of development on transportation demand can begin to reduce travel demands by providing more transportation choices and considering the impact of development and the transportation network.

Chapter 1 provides information on how households in America make trips. According to the 2009 NHTS, 94 percent of trips over 2 miles are made by vehicle and 60 percent of those trips shorter than one-half of a mile are walking trips. Most survey respondents reported that the greatest barriers to walking are the perception of too much traffic, not enough street lighting, or wide road crossings. People were also concerned about crime, had no nearby paths or sidewalks, and were too busy to walk more often. Improving access to pedestrian and biking infrastructure can encourage an increase in walking or riding a bike. To the extent travelers substitute car travel for travel by foot and bicycle, those travelers would experience improved health and lower travel costs. If total VMT by car falls as a consequence, then emissions and congestion will also fall. When biking or walking are not viable options, increased transit use and ride sharing are other means of reducing VMT.

Integrated Land-Use Planning

Coordinating land use with transportation planning and development helps to preserve and enhance natural and cultural resources and facilitates sustainable communities by fostering a balance of mixed-use space for housing,

Nonmotorized Transportation Pilot Program (NTPP)

The NTPP encourages bicycling and walking by promoting and building a network of nonmotorized transportation infrastructure facilities—including sidewalks, bicycle lanes, and trails—that connect directly with transit stations, schools, residences, businesses, and recreation areas. Pilot programs have been started in four communities: Columbia, Missouri; Marin County, California; Minneapolis, Minnesota; and Sheboygan County, Wisconsin. For more information on the program, see www.fhwa.dot.gov/environment/bikeped/ntpp.htm.

New Starts Program

New Starts provides Federal financial resources to locally planned, implemented, and operated transit "guideway" capital investment projects. The goal of the program is to improve mobility, reduce congestion, improve air quality, and foster livable communities. For more information on the program, see www.fta.dot.gov/planning/planning_environment_5221.html.

Transit-Oriented Development (TOD)

FTA promotes mixed-use development near transit facilities and access to transportation and housing for people of all ages and incomes. TOD activities that are eligible for Federal funding include walkways, open spaces, intermodal transfer facilities, and bicycle improvements. Through planning and land use, TOD activities can help decrease traffic congestion, improve air quality, and improve public health through increased walking. For more information on TOD, see http://www.fta.dot.gov/about_FTA_6932.html.

educational, employment, recreational, and service opportunities. The U.S. DOT encourages local and State governments to coordinate land use and development in their planning process through activities such as Transit Oriented Development and Brownfield Redevelopment. These options focus on increased infill development, smart growth, and a concentration of development around established activity centers—with increased multimodal access to transit, accessible roads, walkways, and bike paths. Additional information on integrated land-use planning can be found at www.fhwa.dot.gov/planning/landuse/index.htm.

Brownfield Redevelopment

Brownfields are abandoned or underused properties available for redevelopment but that may contain residual hazardous materials from the land's previous use. According to a study of the Brownfield Program, brownfield revitalization efforts have resulted in a 33- to 57-percent reduction in VMT due to compact development and transit expansion, and a 47- to 62-percent reduction in stormwater runoff in redeveloped project sites that were evaluated.[i] U.S. DOT encourages State and local transportation agencies to incorporate redevelopment sites into transportation improvement projects.[ii] For more information on this program see www.epa.gov/brownfields.

[i] EPA, "The EPA Brownfields Program Produces Widespread Environmental and Economic Benefits," April 2010, http://www.epa.gov/ brownfields/overview/Brownfields-Benefits-postcard.pdf.

[ii] FHWA, "FHWA and FTA Policy and Information on the Brownfields Economic Redevelopment Initiative," http://www.fhwa.dot.gov/environment/bf_disc.htm.

Transitioning to Fuel-Efficient Vehicles and Alternative Fuels

The types of fuels commonly used today (primarily gasoline and diesel) together with vehicles with low fuel efficiency both negatively impact the environment. According to the EIA, as of 2007, there were 249 million vehicles (including cars, buses, and trucks) in the United States. Personal vehicles, such as cars and light trucks, comprised 60 percent of the total energy consumed in the transportation sector. Gasoline and diesel made up 84 percent of the total energy used in transportation.[19] This has occurred while GHG emissions related to transportation grew 27 percent from 1990 to 2006. Emissions can be reduced by transitioning to more fuel-efficient vehicles and alternative fuels that decrease the use of high-emission fuels such as gasoline and diesel. As mentioned earlier, new U.S. DOT fuel economy standards for light-duty vehicles and heavy and medium-duty trucks will improve the fuel efficiency of the fleet.

Clean Fuels Grant Program

This FTA program assists nonattainment and maintenance areas achieve or maintain the National Ambient Air Quality Standards for ozone and carbon monoxide. Funding is available to transit agencies for clean fuel buses, clean fuel bus facilities, and electrical recharging facilities, and to support other projects related to clean fuel, biodiesel, hybrid electric, or zero-emissions technology buses. For more information, see http://www.fta.dot.gov/funding/grants/grants_financing_3560.html.

Over the past 30 years, numerous programs and projects have been established to decrease the transportation sector's energy consumption through the development of more fuel-efficient vehicles and the use of renewable energy to decrease fossil-fuel consumption. As of 2008, there were 1.5 million personal alternative-fuel vehicles and 2,565 alternative-fuel buses (transit, intercity, and school). Alternative fuels included types such as biodiesel, compressed natural gas, propane/liquefied petroleum, hydrogen, and liquefied natural gas. Obstacles to increasing the number of vehicles that use alternative fuels include the scarcity of fueling stations and other infrastructure necessities. Although the number of alternative-fuel stations in the United States has increased from 3,691 to 6,411 since 1992, these stations are not spread evenly across the country.

There are even fewer electric charging stations nationwide where users can charge a plug-in hybrid or electric vehicle. Most States do not have any of these stations or have fewer than 10. In 2008, only two States had more than 10 charging stations—Oregon had 34 and California had 420.[20]

Q&A

Has the number of alternative fuel and electric charging stations increased since 2008?

Yes. The Department of Energy Alternative Fuels and Advanced Vehicle Data Center provides the most current information on alternative fuel stations and electric charging stations on the website: http://www.afdc.energy.gov/afdc/fuels/stations.html.

By 2010, the number of alternative fuel stations increased nationwide from 6,411 in 2008 to around 9,000. Electric charging stations numbered around 2,400 by 2010 with over 500 in California; over 100 each in Texas and Washington; and over 50 each in Oregon and Florida. Approximately half of all States still have 10 or fewer stations.

Recycling in Transportation

Developing roads, bridges, transit systems, and other infrastructure by using materials and methods that reduce the negative impact on the environment is essential to sustainable transportation. This section describes where recycled materials are being used to reduce the adverse impact of transportation construction on the environment.

Recycled Materials

Aggregate is crushed rock or gravel used to produce concrete. The process of mining and transporting aggregate material creates environmental impacts in the form of GHG emissions, making the reprocessing or recycling of aggregate materials a more sustainable option. Currently, many State departments of transportation (DOTs) are using reclaimed asphalt pavement (RAP) and Warm Mix Asphalt (WMA) in highway construction to reduce energy consumption and GHG emissions and to preserve nonrenewable resources. In addition, recycled materials are expected to provide significant cost savings on transportation projects. Transit organizations also participate in recycling efforts.

Every Day Counts

In 2009, FHWA launched the *Every Day Counts* (EDC) initiative, designed to identify and deploy technologies that shorten project delivery time, enhance the safety of roadways, and protect the environment through the use of cost-effective techniques that help to reduce energy use and to increase recycling and greener transportation options. For more information on EDC, see http://www.fhwa.dot.gov/everydaycounts/.

Recycling in Transit

There are numerous recycling initiatives in public transportation. Many transit agencies reuse and recycle oil, oil filters, paint and other chemicals, scrap metal, bus and train batteries, and bus and train wash water either on-site or off-site in order to reduce operation costs. Some agencies, such as in Los Angeles, have agreements in place with tire companies to send all used tires back to the company for recycling into crumb rubber, which can be used for mats or in asphalt. TriMet in Portland, Oregon, reuses plastic billboards in the paved portions of its train tracks and also uses recycled tires in its sound walls along tracks.

Reclaimed Asphalt Pavement

RAP is made using a recycling process that mixes removed or reprocessed pavement materials, including asphalt and aggregates, with virgin aggregate.[i] On average, State DOTs use 12 percent RAP in hot-mix asphalt (HMA) mixtures. Currently, 44 State DOTs allow 25 percent RAP in at least one layer of HMA, with 23 allowing it in all layers. Twenty-seven States have increased their use of RAP since 2007.[ii]

[i] Audrey Copeland, Cecil Jones, and John Bukowski, "Reclaiming Roads," *Public Roads*, March/April 2010, Vol. 73, No.5; available at http://www.fhwa.dot.gov/publications/publicroads/10mar/06.cfm.

[ii] *Ibid*.

Warm Mix Asphalt (WMA)

WMA is made using a process that allows pavement materials to be produced at lower temperatures than other mixes and that reduces energy consumption and emissions in the production process. It is estimated that increased use of WMA will reduce CO_2 and sulfur dioxide emissions by 45 percent, nitrogen oxide by 60 percent, and use of organic material by 41 percent.[i]

For more information on WMA go to www.fhwa.dot.gov/pavemenet/asphalt/wma.cfm.

[i] FHWA, "Warm Mix Asphalt Technologies and Research," October 2008, http://www.fhwa.dot.gov/pavement/asphalt/wma.cfm.

Cost savings and environmental benefits can also occur through reuse and rehabilitation of existing facilities where practical, especially non-renewable historic resources. The greenest bridge may be one that is already built, saving not only the energy that would be required to produce new materials, but also the energy that is embodied in the existing structure. This is consistent with practical design and minimizing the use of non-renewable resources.

Other Environmental Issues

The U.S. DOT focuses on many issues concerning environmental protection and enhancement. As discussed earlier in this chapter, GHG emissions have gained much attention as a measure of the impacts of transportation. In addition to GHG, there are other environmental concerns surrounding air quality, water quality (including storm water and waste management), and wetlands preservation. The transportation planning and project development process must take these types of considerations into account.

Transportation agencies must follow the requirements of the National Environmental Policy Act (NEPA), which provides guidelines for protection of the environment as part of the process for project planning and design. Through the use of NEPA, the U.S. DOT provides a balanced and streamlined approach to transportation decision-making that takes into account the impacts of human and natural resources and the public's need for safe and efficient transportation improvements. NEPA has not only served as the framework for the environmental process, but as a precursor for current sustainable transportation system efforts as well. Additional information about NEPA can be found at http://www.environment.fhwa.dot.gov/projdev/index.asp.

Limiting Wastewater

Wastewater runoff associated with transportation projects can contain numerous pollutants that can be released into stormwater systems. Vehicle washing and steam cleaning can generate wastewater that contains oil, grease, and other detergents, which can wash into the sewer system. FTA is working with transit agencies on methods that limit wastewater runoff. New transit project proposals are now required to include methods of reducing runoff and preventing stormwater pollutants in their environmental documents. Existing transit facilities are encouraged to control the use of chemicals and detergents to prevent runoff. For more information on this issue, see http://www.fta.dot.gov/12347_2230.html.

Green Streets

"Green Streets" is an approach that encourages the use of natural systems for stormwater management that mimic natural hydrology, such as using swells and protected boxes that contain trees, bushes, shrubs, and grasses to allow stormwater to funnel through. The approach protects ecologically sensitive areas, reduces or minimizes heat islands, improves air quality, reduces stormwater pollutants, and is aesthetically attractive.

Stormwater Management

Surfaces such as roads and sidewalks can collect a variety of pollutants from usage, maintenance, and natural conditions. These pollutants become a potential threat when they are washed away in stormwater runoff. Best practices for stormwater management include implementing rain gardens, landscapes that filter rainwater, and the use of permeable paving that absorbs rainwater into underground reservoirs.[i]

[i] EPA, "EPA Headquarters Low Impact Development Program," April 2010, http://www.epa.gov/greeningepa/stormwater/hq_lid.htm;and "Low Impact Development (LID)," August 2009, http://cfpub.epa.gov/npdes/greeninfrastructure/information.cfm#glossary.

Wetlands Protection

Wetlands protection is another environmental concern because wetland habitats shelter endangered plant and animal species.[i] Using a wetland-banking "credits" system, Federally funded transportation projects must "bank" 1.5 acres of healthy wetland for every 1.0 acre of wetlands impacted by projects. As of 2006, Federal-aid highway projects banked, on average, 2.6 acres of wetlands for every acre impacted.[ii]

[i] FHWA, "Wetlands and Highways: A Natural Approach," 1995, http://www.environment.fhwa.dot.gov/ecosystems/wet_wetlands.asp.

[ii] FHWA, "Federal Highway Administration Wetland Mitigation Performance Measures for Federal-Aid Highway Projects Fiscal Year (FY) 2004," http://www. dot.gov/perfacc2006/environstew.htm.

Other Sustainability Strategies

Because of the limitations in discussing all potential metrics and strategies fully, *Exhibit 11-4* summarizes other sustainability strategies in transportation and briefly describes each.[21]

Transportation organizations are increasingly focusing on projects and programs that support the creation of a sustainable transportation system. Much has been accomplished, and much more is planned. Marking progress made in these endeavors is also in the works, although these efforts are still in the early phases for many transportation organizations. Efforts to collect information and data on best practices, select measures, and evaluate progress are in various phases of development among Federal, State, and local governments.

Exhibit 11-4

Summary of Other Sustainability Strategies

Strategy	Description
Improving System Efficiency	
Transit Signal Priority	Uses sensors to detect approaching transit vehicles and alter signal timings.
Speed Limit Reductions	Reduces speed limits to 55 mph nationally.
Truck Idling Reduction	Equips sleeper cabs with on-board auxiliary power units for heating and cooling, truck stop electrification, and anti-idling ordinances.
Lane Control	Controls signs, supported by surveillance and detection technologies, allowing temporary lane closures to avoid incidents on freeways.
Reducing Growth in VMT	
Ridesharing	Promotes carpools, vanpools, and other ridesharing techniques.
Combining Trips	Promotes and makes it easier to link multiple trips into one or two.
Transitioning to Fuel-Efficient Vehicles and Alternative Fuels	
CAFE Standards	Increases CAFE standards to increase the number of highly fuel efficient vehicles.
National Fuel Cell Bus Program	Develops new fuel cell technologies that improve fuel efficiency of transit.
Alternative Fuel Infrastructure	Improves and increases alternative-fuel infrastructure through tax credits, grant programs, and/or mandates.
Ecosystem Protection	
Protection and Preservation of Native Species	Uses native plants that have adapted to natural surroundings; protects endangered species.
Habitat Restoration	Restores or preserves natural habitats during/after transportation construction projects.
Reducing Construction Environmental Impacts	
Sustainable Paving Processes	Includes roller-compacted concrete and two-lift construction.
Local Materials	Promotes use of local aggregate in highway construction projects.

Have performance measures been developed at the national level?

Currently, a number of sustainable transportation system performance indicators show progress at the national level. A good example of this is the information collected to date on GHG emissions, although comprehensive data are not readily available in other areas at this point.

However, before more data and information are collected, there must be agreement on what should be measured. With the wide range of possible areas of emphasis and impact, the product of this agreement will likely be a collection of sustainability metrics. Discussion is underway as the U.S. DOT and partner agencies work toward gaining consensus on which metrics will be the focus.

Sustainability in the Transportation Planning Process

The transportation planning process plays a fundamental role in identifying and implementing the vision and strategic goals of a State, region, or community for its future. The long-range planning process is an opportunity for transportation stakeholders to consider the long-term costs and benefits involved in developing transportation projects—including sustainability—in their community. One recent study indicates that even though most transportation agencies have not explicitly mentioned sustainability in their long-range planning, a majority of them are incorporating sustainable transportation system concerns—such as environment, future needs, and social equity—into their transportation planning process.[22]

Q&A

What are some examples of States incorporating sustainability into their transportation planning process?

State transportation agencies are increasingly incorporating sustainable practices into their transportation programs for planning, design, operations, maintenance, and performance measurement. For example, Oregon DOT has adopted Solar Highways, using renewal energy for highway lighting. New York is using the GreenLITES (Green Leadership in Transportation Environmental Sustainability) rating system to recognize transportation projects that incorporate a high level of environmental sustainability. For more information on these, as well as other state initiatives, see http://environment.transportation.org/environmental_issues/sustainability/case_studies.aspx.

State DOTs also have project-level planning and design requirements. The NEPA process provides a framework in which planners and stakeholders can consider many factors, including sustainability, prior to construction of a proposed project. At present, Federal planning and NEPA-related legislation do not specifically reference sustainability per se. However, many of the factors that are commonly requirements for consideration during project-level planning and NEPA review are directly related to the types of sustainability-related issues identified in this chapter.

One example of efforts to respond to the challenge of creating a sustainable transportation system is the increased use of context sensitive solutions (CSS). A CSS approach requires that transportation planning consider the interactions between transportation systems and tailor them to the local area human, cultural, and natural environment.

Context Sensitive Solutions

The U.S. DOT is already using CSS to actively engage stakeholders in a collaborative, interdisciplinary, decision-making approach. CSS is a collaborative problem-solving model where transportation agencies consider and build on ideas generated by stakeholders. CSS projects consider communities' characteristics and visions, new and emerging technologies, bicycle and pedestrian facilities, transit and multimodal connections, stormwater management, and use of recycled materials and structures. The approach also preserves and enhances scenic, aesthetic, and historic community and environmental resources while improving or maintaining safety, mobility, and infrastructure conditions.[23]

CSS can be applied to all aspects of project development from planning and design to construction, operation, and maintenance. CSS has been utilized most frequently for difficult and complex projects with major impact. Increasingly, however, State DOTs are seeking to use CSS from the onset of project planning and in more routine projects. CSS does not represent a philosophy to be selectively applied to certain categories of projects, but an approach to transportation planning, design, construction, and maintenance that is scalable to use on every transportation project.

The application of CSS principles within the transportation planning process assists regions and communities in reaching their transportation goals by encouraging the integration of land use, transportation, and infrastructure. When transportation planning reflects community input and takes into consideration the impacts on both natural and human environments, it also promotes partnerships that lead to more balanced decisionmaking. Use of the CSS philosophy and approaches during project development can improve project decisionmaking; expedite project delivery; and enhance mobility, safety, livability, and environmental sustainability.

Endnotes

[1] W.R. Black, "Sustainable Transport: Definitions and Responses," *Integrating Sustainability into the Transportation Planning Process,* Conference Proceedings 37, Committee for the Conference on Introducing Sustainability into Surface Transportation Planning, July 11–13, 2004, Baltimore, Transportation Research Board, Washington DC, 2005, pages 35–43.

[2] See http://www.eia.gov/oiaf/1605/ggrpt/carbon.html.

[3] See http://www.eia.gov/environment/emissions/ghg_report/pdf/tbl3.pdf.

[4] EPA National Air Pollutant Emission Trends Report, 2008, http://www.epa.gov/ttn/chief/trends/.

[5] "Transportation Air Quality Selected Facts and Figures, 2006," http://www.fhwa.dot.gov/environment/air_quality/publications/fact_book/page06.cfm.

[6] Tara Ramani, "Criteria and Tools for Sustainable Highways," March 31, 2010, page 8.

[7] *Ibid,* page 8.

[8] Christy Mihyeon Jeon, *Dissertation: Incorporating Sustainability into Transportation Planning and Decisionmaking,* Georgia Institute of Technology, December 2007.

[9] American Public Transportation Association, *Sustainability Commitment*, 2010, http://www.apta.com/resources/hottopics/sustainability/Documents/APTA-Sustainability-Commitment.pdf.

[10] See U.S. Global Change Research Program, *Global Climate Change Impacts in the United States*, June 2009, http://www.globalchange.gov/what-we-do/assessment/previous-assessments/global-climate-change-impacts-in-the-us-2009.

[11] Intergovernmental Panel on Climate Change (IPCC), Fourth Assessment Report, 2007, http://www.ipcc.ch/publications_and_data/publications_and_data_reports.shtml#1.

[12] U.S. Global Change Research Program, *Global Climate Change Impacts in the United States*, June 2009.

[13] U.S. DOT, *Transportation's Role in Reducing U.S. Greenhouse Gas Emissions*, April 2010.

[14] U.S. EPA, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2006*, 2008.

[15] EIA, *Annual Energy Outlook 2010*, May 2010, http://www.eia.gov/forecasts/archive/aeo10/index.html.

[16] U.S. EPA, *Light Duty Automotive Technology and Fuel Economy Trends: 1975 through 2007*, Document #EPA420-S-07-001, September 2007.

[17] 2001 National Household Transportation Survey.

Endnotes continued

[18] U.S. DOT, *Transportation's Role in Reducing U.S. Greenhouse Gas Emissions*, April 2010, Vol. 1, pages 2–19.

[19] EIA, "Use of Energy in the United States: Energy Use for Transportation," 2010, http://www.eia.doe.gov/energyexplained/index.cfm?page=us_energy_transportation#tab1.

[20] EIA, Alternative Fuels & Advanced Vehicles Data Center, "Alternative Fueling Station Locator," http://www.afdc.energy.gov/afdc/locator/stations/state.

[21] FHWA, *Performance Evaluation of Various Rehabilitation and Preservation Treatments*, January 2010, page 31.

[22] C. Jeon and A. Amekudzi, "Addressing Sustainability in Transportation Systems: Definitions, Indicators, and Metrics," *Journal of Infrastructure Systems,* Vol. 11, March 2005, pages 31–50.

[23] "What is Context Sensitive Solutions?," FHWA and Center for Transportation and the Environment at North Carolina State University, National Dialog for Context Sensitive Solutions, http://cssnationaldialog.org/index.asp.

Chapter 12

Climate Change Adaptation

Climate Change Adaptation

Climate change has received increasing attention over the last decade. Policy-makers, scientists, and the public have been increasingly concerned about the impact that climate change will have on people and the planet. For the transportation community, climate change and policies to address climate change can be divided into two categories.

- *Mitigation* (discussed in Chapter 11) focuses on measures to reduce greenhouse gas (GHG) emissions that risk exacerbating climate change from transportation sources including vehicles, construction and maintenance activities, and materials.
- *Adaptation* (discussed in this chapter) focuses on consideration of what potential future changes in a community may be associated with climate change, and what might be the resulting impact of climate change on transportation assets. These considerations can be incorporated into policy and measure development so that transportation planners are adequately prepared to consider impacts of climate change as they become evident.

Impacts of Climate Change Adaptation on Transportation Infrastructure

Research on climate change's potential impacts to transportation infrastructure continues. Two studies published in 2008, the Transportation Research Board's *Special Report 290* and the U.S. Department of Transportation's (U.S. DOT's) *Gulf Coast Study, Phase I* outline the wide range of forecasted impacts to transportation infrastructure. The *Gulf Coast Study, Phase I* includes a comprehensive review of the literature related to the numerous potential impacts of climate change.

In 2002, the U.S. DOT Center for Climate Change and Environmental Forecasting convened a workshop focusing on the issue of climate change impacts to the transportation system, which brought together top transportation and climate change experts to discuss the issue. The U.S. DOT has used geographic information systems to map areas and transportation infrastructure along the Atlantic coast that is potentially vulnerable to rises in sea level. Climate change impacts have the potential to be geographically widespread and modally diverse, and would stress transportation systems in ways beyond which they were designed.

Highway and transit infrastructure is already planned, designed, and maintained in the context of weather-related effects. For example, engineers typically consider the likelihood of an extreme weather event, such as a 100-year storm (which has about a 1 percent chance of occurring in any given year), and incorporate the expected effects of such an event into project designs. However, should climate change proceed as some scientists predict, past weather patterns or environmental conditions would no longer be a good guide to the future. Further, the vulnerability of transportation infrastructure to climate change impacts varies based on location and the environmental context in which they occur. An understanding of how an area may be affected in the future should be informed both by potential changes in climate and by ongoing environmental processes, such as land subsidence/uplift or erosion.

The Gulf Coast Study

The Gulf Coast study, Phase 1 examined the potential impacts of climate change on the central portion of the low-lying Gulf of Mexico coastal zone from Houston-Galveston to Mobile, AL. The study focused on the potential impacts due to changes in temperature and precipitation, relative sea level rise, and storm surge. The impacts of climate change can vary by location in part because each region may have unique environmental characteristics (like land subsidence in the Gulf Coast region) and face varying levels of climate change. The study found that a four-foot increase in relative sea levels could affect 2,400 miles of major highways (arterials and interstates) in the 48-county Gulf Coast study region as well as some of the light rail and bus routes in New Orleans, LA, and Galveston, TX. *Exhibit 12-1* indicates the portion of facilities in the study region vulnerable to the two relative sea level rise scenarios.

Exhibit 12-1

Portion of Gulf Coast Region Highways That Are Vulnerable to Relative Sea Level Rise

Highway Functional Type	Relative Sea Level Rise 2 Feet	Relative Sea Level Rise 4 Feet
Arterial	20%	28%
Interstate	19%	24%
Intermodal Connector	23%	43%

Source: Impacts of Climate Variability and Change on Transportation Systems and Infrastructure – Gulf Coast Study, Phase 1 (2008).

Sea-level rise, coastal erosion, tropical storms/hurricanes, and storm surges are major concerns in coastal areas. Impacts on coastal infrastructure include increased risk of bridge scour and bridge failure during storms, periodic or permanent inundation of coastal roads, increased frequency of infrastructure repair after events, and more frequent and/or intense emergency evacuations using a more-fragile and less-resilient network. The *Gulf Coast Study, Phase I* analyzed sea-level rise scenarios on the Gulf Coast region, finding that a rise of 2 feet could affect 64 percent of the region's port facilities, while a 4- foot rise would impact nearly three-quarters of facilities; similarly, approximately "a quarter of" the region's arterials and Interstate System miles, "nearly half of the region's intermodal connector miles, and 10 percent of its rail lines would be affected by a four foot rise in sea level." A University of South Alabama study estimated that there are roughly 60,000 road miles in the United States that are occasionally exposed to coastal waves and surges today. After Hurricane Katrina, the Federal Highway Administration (FHWA) conducted an assessment of coastal bridges potentially vulnerable to failure from coastal storm events. Using very broad criteria, the assessment estimated that there are more than 36,000 bridges within 15 nautical miles of coasts. Of these, more than 1,000 bridges may be vulnerable to the same failures as those associated with recent coastal storms.

Increased variability in temperature extremes; more severe precipitation events; changes in the melting rate of snow pack and permafrost; and increased mudslides, fires, and avalanches—are not confined to coastal or near-lake areas and might be experienced more broadly across the Nation, which could affect transportation infrastructure and services throughout. Compounded effects, such as storm surges *and* sea level rise or temperature increase *and* more severe precipitation, could lead to severe and damaging impacts. These include increased pavement deterioration; an inability to implement or maintain environmental mitigation commitments, such as wetlands or forests; short-term flooding and/or compromised safety.

Our understanding of climate change is steadily improving. While science cannot tell us precisely how much change to expect, it can give us some information now, particularly on the range of future changes in temperature and sea levels. The science of projecting future changes, including precipitation patterns, is expected to improve substantially in coming years. In the meantime, it is prudent to prepare transportation planners to develop appropriate adaptation strategies as the science of projecting future changes improves and likely impacts can be identified.

Steps for Assessing Adaptation Needs

While transportation agencies across the Nation have been addressing climate change mitigation issues on various levels, the issue of adapting transportation infrastructure to climate change impacts has received less widespread attention, beyond the coastal states. The FHWA has developed a framework for analyzing climate and weather-related impacts on highway infrastructure and incorporating risk management approaches into all aspects of highway management. Specific adaptation activities that are currently underway within the U.S. DOT and among the States are discussed later in this chapter.

Adapting to the impacts of climate change starts with inventorying the likely impacts of potential changes in climate. Then, after assessing potential vulnerabilities and risks, adaptation options can be evaluated and prioritized alongside other investments.

Inventory Critical Infrastructure

It is generally good practice for transportation agencies to screen and rank transportation assets based on the relative importance of each asset in meeting local, regional and/or national priorities. Potential metrics include the level of use (e.g., VMT or ridership), freight tonnage or value moved over a facility, road classification (e.g., local verses arterial), a road's importance in linking regions or facilitating national trade flows, the existence of redundant routes, or its role in emergencies for evacuating people or facilitating assistance to a region. Then, agencies can use this information to assemble a list of infrastructure most critical to the region and assess risks posed to that infrastructure.

Understand Potential Future Climate Change Impacts

Assessments of impacts on transportation assets, and any resulting adaptation strategies, should be based on an assessment of climate change effects. Agencies should work with counterparts in the scientific community to collect information on projected changes in regional climate. Relevant information would include projected changes in temperatures, precipitation patterns and frequency, and in coastal areas sea level rise and coastal storm effects. Both the likelihood and potential magnitude of climate changes should be considered. These types of projections are an active area of research, and the ability to make projections with greater levels of certainty and at smaller scales should improve in coming years. Historic information can also inform understanding of the potential impacts of future changes in climate.

Assess Vulnerability and Risk

Assessing vulnerability and risk involves examining how transportation assets have been affected by storms and other weather events in the past, what is the probability that future weather patterns could change, and how assets may fare in the future given likely changes in weather. To start, areas should examine records of weather events—for example, heat waves, intense precipitation and flood events—and related repair and maintenance records to better understand how existing assets can withstand different kinds of climate stressors. Then, by referring to information developed on projected changes in climate, agencies can better understand whether those stressors will become stronger, remain the same, or perhaps lessen. These activities can help agencies assess the vulnerability of individual facilities and the system. Calculating risk involves an additional step of considering both the likelihood of a given impact on a facility, and the consequence of that impact. Such consequences could include costs associated with repairing or replacing a facility, impacts on traffic patterns, or health, safety and environmental consequences. In all cases, the cost of migration must be weighed against the costs of inaction on a present value basis and adjusting for probability.

Adaptation Options

Maintain, Manage, and Operate

With the maintenance adaptation strategy, no changes to the base transportation facility are made. In order to restore operational service, transportation agencies respond to interruptions without necessarily addressing the underlying factors contributing to the damage. Examples of repair and maintenance activities include closures and rerouting; simple damage repairs, such as resurfacing; water and debris clearance; cleaning of storm-drain basins; snow or sand removal; and establishing weight limitations to manage asphalt deficiencies caused by increased temperatures.

Protect and Strengthen

An adaptation strategy that focuses on reconstruction/strengthening is one that entails the application of higher design standards to effectively protect or reinforce a structure. It is a suitable strategy particularly when a facility has reached the end of its service life, is structurally deficient, or has been destroyed. At these times, there can be opportunities to build structures in ways that help them withstand current and potential future global climate change effects, possibly resulting in longer infrastructure life spans.

In areas where problems are occurring or could occur in the future, reconstruction/strengthening can also occur proactively; in these cases, the infrastructure is adapted as a preventative measure. In other cases, reaction to a problem, such as a structural deficiency, might be an impetus to reinforce the facility. Costs for each approach can be high and must weigh the benefits of incurring added cost adjusting for risk and time value. Some reconstruction/strengthening activities include building bridges to greater heights; increasing the size of culverts; considering higher design-events (e.g., using 100-year storm events instead of 50-year storm events) and changing the associated design assumptions; and constructing revetments, embankments, jetties, or other structural fortifications.

One example of reconstruction/strengthening is the application of the FHWA floodplain regulations to coastal bridge design (such as the US-90 and I-10 bridges, which were destroyed during Hurricanes Ivan and Katrina). Although most State DOT design standards are based on the "50-year event," the FHWA's regulations (23 CFR 650 Subpart A) allow engineers to consider the "greatest flood" event. In practice, reconstructed bridges with taller pile caps could be better protected from high stillwater elevations and wave action. Although Hurricanes Ivan and Katrina produced storm surges in excess of a 100-year event, the FHWA has been able to investigate the nature of these "greatest flood" events, develop probabilistic analyses of historic storms, and generate baselines for storm impacts. Using these baselines, the FHWA created the interim guidance "Coastal Bridges and Design Storm Frequency," which contains information about the range of engineering practices that could be applied in anticipation of major storm events.

Relocate and Avoid

Relocation is characterized by the moving of a facility from its existing location to avoid imminent threats. Accomplishing this strategy, the results of which likely have long-term implications, might require environmental review, right-of-way acquisition, new construction, or other related activities. Relocation may be expensive and require years to implement. However, relocation may sometimes be the most effective adaptation strategy because it avoids repeated repair, maintenance, or strengthening actions. Again, planners must weigh the high costs against the likely benefits.

An example of relocation is the proposed realignment of 2.8 miles of Highway 1 near Piedras Blancas Lighthouse, California. In September 2008, the California Department of Transportation released the Draft Environmental Impact Statement for the project, which proposes to relocate a portion of the highway that is subject to bluff erosion caused by high winds and ocean surf. The goal of the project is to protect the highway from bluff erosion for the next 100 years.

Abandon and Disinvest

The abandonment/disinvestment adaptation strategy is a decision to discontinue service on a piece of transportation infrastructure or to make it ineligible for funding based on its condition or location. This decision is based on whether it makes financial sense to continue investing in a facility given likely future threats and its level of use. Although lower in infrastructure costs than other options, this is not a costless decision. Beyond its direct economic costs, abandonment could lead to isolation of communities, political or public opposition, or loss of access. The state of Texas elected to abandon Texas Highway 87 because frequent storm events and erosion led to closure of the highway.

Promote Redundancy

Promoting infrastructure redundancy along key travel corridors is an approach that can reduce service disruption that may result should any one asset run into unanticipated problems.

Barriers to Action

There is a lack of adequate locality-specific information on how the climate will change. Without this type of information, assessment of risk to the infrastructure and development of appropriate adaptation strategies is not possible. For example, without knowing how much sea level will rise in the next 50 years, it is difficult to know whether a transportation facility located near the shoreline will be vulnerable to flooding or inundation. Obtaining this information depends on climate models that are not yet capable of consistently producing reliable results at small scales. The results from the climate models are also highly dependent on assumptions, many of which are in flux and could change significantly based on whether or not effective strategies are taken to reduce GHG emissions. However, climate models are advancing rapidly, and climate scientists hope the next 5 or 10 years will see substantial improvements in the ability of models to predict more localized impacts with a higher degree of certainty.

In some cases, even if adequate information were available, transportation design procedures may not yet be flexible enough to allow areas to consider new information as it becomes available, and instead may be based on historic weather patterns. Ultimately, design procedures, maintenance and replacement schedules, will need to become flexible enough to adequately account for changes in inputs and parameters to reflect assumptions of future temperatures, sea level rise rates, precipitation patterns, etc., once they can be validated. For new infrastructure and/or retrofits to existing transportation facilities, project designs and the choice of materials should reflect our understanding of future climate change impacts as it evolves in coming years.

Adaptation Activities

Interagency Activities

Climate Change Adaptation Task Force. On October 14, 2010, the Climate Change Adaptation Task Force, co-chaired by the White House Council on Environmental Quality (CEQ), the Office of Science and Technology Policy (OSTP), and the National Oceanic and Atmospheric Administration (NOAA), released its interagency report outlining recommendations to the President for how Federal agency policies and programs can better prepare the United States to respond to the impacts of climate change. The report recommends that the Federal government implement actions to expand and strengthen the Nation's capacity to better understand, prepare for, and respond to climate change. These recommended actions include the following:

- **Make adaptation a standard part of agency planning** to ensure that resources are invested wisely and services and operations remain effective in a changing climate.
- **Ensure scientific information about the impacts of climate change is easily accessible** so public and private sector decision-makers can build adaptive capacity into their plans and activities.
- **Align Federal efforts to respond to climate impacts that cut across jurisdictions and missions,** such as those that threaten water resources, public health, oceans and coasts, and communities.
- **Develop a U.S. strategy to support international adaptation** that leverages resources across the Federal government to help developing countries reduce their vulnerability to climate change through programs that are consistent with the core principles and objectives of the President's new Global Development Policy.
- **Build strong partnerships to support local, State, and tribal decision-makers** in improving management of places and infrastructure most likely to be affected by climate change.

On March 4, 2011, the Task Force released Implementing Instructions and the related Support Document for Federal Agencies to follow. Actions include:

- Establishing an agency climate change adaptation policy and mandate;
- Increasing agency understanding of how the climate is changing;
- Applying understanding of climate change to agency mission and operations;
- Developing, prioritizing, and implementing actions; and
- Evaluating and learning.

The U.S. DOT has been an active member of the Climate Change Adaptation Task Force since its inception and is moving ahead with adaptation efforts.

U.S. DOT Adaptation Activities

This section lists activities in which the U.S. DOT is engaged to better understand the potential impacts of climate change and adaptation best practices.

Conceptual Model for Vulnerability and Risk Assessment. The FHWA has developed a model for conducting vulnerability and risk assessments to help States and local governments identify which assets could be at risk of impacts because of global climate change and to assess the extent of that risk/vulnerability. The model focuses on impacts to both individual assets and the transportation system as a whole. Five agencies have been selected to pilot the model: the Metropolitan Transportation Commission (San Francisco Bay); the New Jersey DOT/North Jersey Transportation Planning Authority (Coastal and Central New Jersey); Virginia DOT (Hampton Roads); Washington State DOT (State of Washington); and Oahu Metropolitan Planning Organization (MPO) (Island of Oahu).

This pilot will (1) help State DOTs and MPOs to more quickly advance existing adaptation assessment activities and (2) assist the FHWA in "test-driving" the model. Based on the feedback received through the pilots, the FHWA will revise and finalize the model for national application. The FHWA's pilots will also be used to test the comprehensive Federal approach to adaptation that is being developed by the interagency Climate Change Adaptation Task Force. The pilots are scheduled to be completed by September 2011.

Adapting Transit to Climate Change Impacts. The Federal Transit Administration (FTA) is undertaking a study and series of workshops on adapting U.S. public transportation assets and services to projected climate change impacts. Climate change has particular impacts on public transportation. Extreme heat can cause deformities in rail tracks, at minimum resulting in speed restrictions and, at worst, causing derailments. Subway tunnels, busways, rails, and roads are vulnerable to an increase in flooding from sea-level rise, storm surge, and more intense rain storms. Public transportation is also called upon to provide evacuation services during the type of extreme weather emergencies that are projected to become more common with climate change. Transit-dependent populations are particularly vulnerable. Knowledge of how best to respond to climate change impacts is critical to attaining a state of good repair, protecting the safety of travelers, and ensuring mobility. The study will provide information and analysis, while the workshops will engage transit agency and the FTA staff in adaptation assessment and planning for public transportation, provide key information and tools to participants, and gather ideas for future action in this area.

Regional Climate Change Effects Report. The FHWA recently released a study on the regional impacts of climate change which focused on information that would be useful to transportation agencies. The goal of the study, which did not involve any new research, was to assemble the most up-to-date science on the regional impacts of climate change. The final report summarizes regional results from hundreds of studies, and includes projected increases in seasonal temperature ranges across nine regions of the country. It also provides a regional summary of background information. The report focuses on climate change at the regional level, but also discusses global, national, and local scales where information exists. More information on this report can be found at: http://www.fhwa.dot.gov/hep/climate/climate_effects/effects00.cfm.

The report reflects substantial uncertainty and will be updated in the coming years as models improve. However, this is a first step in assembling the data needed to make informed decisions regarding climate change, and a good starting point for considering climate change adaptation in transportation plans and project designs.

Gulf Coast Study Phase II. As referenced above, the FHWA and the U.S. DOT completed *Phase I of the Impacts of Climate Change and Variability on Transportation Systems and Infrastructure: Gulf Coast Study* in 2008. This first phase provided an assessment of impacts of climate change on transportation across the region from Houston to Mobile. The U.S. DOT is now proceeding with the second phase of this research study, which will focus on a much narrower piece of the Gulf Coast region—Mobile, Alabama. As part of this study, the U.S. DOT will conduct an in-depth analysis to assess the critical transportation infrastructure; project climate change impacts; evaluate vulnerability; conduct detailed engineering assessments for selected assets; and develop risk management tools to help identify risks and develop adaptation options. From this, the U.S. DOT and the FHWA will derive lessons learned and a process that other MPOs can replicate. This phase of the study is expected to be completed in 3 years.

Selected State and Local Adaptation Efforts

Alaska. The Alaska Department of Transportation and Public Facilities (DOT&PF) is a multimodal agency with ownership of public assets such as roads, bridges, rural airports, and harbors. In 2007, the State established the Alaska Climate Change Sub-Cabinet to focus on adaptation, mitigation, and research needs. In addition, the Governor appointed an Adaptation Advisory Group. The final report was delivered to the Sub-Cabinet in January 2010. Additionally, the Immediate Action Workgroup was established in 2007 to address known threats to communities caused by coastal erosion, thawing permafrost, flooding, and fires.

Documented climate change impacts in Alaska include melting permafrost, increased storm frequency and intensity, coastal erosion due to lack of sea ice, river erosion, sea-level rise, increasing temperatures, and loss of the subsistence way of life for native populations. There has been increased erosion on the coast line and along rivers due to higher amounts of precipitation, the infrastructure in many of Alaska's regions is underlain by ice-rich permafrost, an active layer that is permanently frozen; and, increasingly, the soil layers are experiencing melting cycles causing severe structural damage to infrastructure. The DOT&PF spends about $10 million per year to mitigate melting permafrost, yet this is only a fraction of the need and costs are expected to increase as warming trends continue. Storms are causing avalanches, floods, erosion, and debris flows, which all significantly increase maintenance and operations costs. The loss of shore-fast sea ice is also causing coastal erosion that poses serious threats to infrastructure and is causing entire communities to be displaced.

Alaska is adapting to these extreme impacts with shoreline protection programs, planned evacuation routes, the relocation of infrastructure and communities at risk, improving drainage, and protecting permafrost. There is a need to collect more data on stream flow, precipitation, and hydraulic data, and to investigate alternative design, construction, and maintenance techniques to address the changing environment. The Alaska DOT&PF will also need to continue to collaborate with others to address future impacts of climate change.

California. Executive Order S-13-08 was signed on November 14, 2008, directing state agencies to plan for sea-level rise and climate impacts. This included developing a statewide adaptation strategy for agency responses to climate change impacts. Another key component of S-13-08 directed business, transportation, and housing agencies to develop a report, which was released February 2009, assessing the vulnerability of transportation systems to sea-level rise. Additionally, the State government established the Climate Action Team (CAT) under Executive Order S-3-05 in June 2005. CAT is required to release a biennial science assessment report on climate change impacts and adaptation options for California. The current report was released in March 2009.

Florida. The Florida Energy and Climate Commission created by Florida Legislature in the 2008 Legislative session, is the primary organization for State energy and climate change programs and policies. Executive Order 07-128 created a Governor's Action Team on Energy and Climate Change in July 2007. The action team was tasked with creating a comprehensive Energy and Climate Change Action Plan for the State. One of the six Action Teams focused on Adaptation was tasked with developing "adaptation strategies to combat adverse impacts to society, public health, the economy, and natural communities in Florida."

Maryland. Executive Order 01.01.2007.07 was signed on April 20, 2007, establishing the Maryland Climate Change Commission (MCCC) and charging them with developing a state climate action plan that addresses both mitigation and adaptation. The State released a final Climate Action Plan in August 2008.

Maine. In April 2009, the State legislature passed a resolution charging the Department of Environmental Protection to initiate a stakeholder-based process evaluating options and actions available to state businesses and people to prepare for "the most likely" impacts of climate change.

New Hampshire. Executive Order 2007-3 was issued in November 2007, creating the Climate Change Policy Task Force. The Task Force comprises six working groups, with one dedicated to Adaptation, and was tasked with creating a New Hampshire Climate Action Plan. The final plan was released in March 2009.

New York. The Office of Climate Change was created within the Department of Environmental Conservation, and is tasked with leading the development of programs and policies to address both adaptation and GHG mitigation. Executive Order 24 was signed in August 2009, creating the New York Climate Action Council. The Council is charged with creating a draft Climate Action Plan by September 2010. The Plan is to cover both mitigation and adaptation for all economic sectors in the state.

New York Metropolitan Transportation Authority (MTA). New York MTA operates the Nation's largest public transportation system, serving the New York City metropolitan area. In conjunction with MTA's Blue Ribbon Panel on Sustainability Commission in 2008, the agency developed an initial assessment of key vulnerabilities of MTA assets and operations. MTA also identified temporary fixes, mid- to longer-term solutions, and more radical long-term solutions to these vulnerabilities. Finally, the agency outlined a plan for a more comprehensive vulnerability/risk assessment and identification of adaptation priorities.

Virginia. In March 2009, the State finalized a Climate Change Action Plan which was created by the Governor's Commission on Climate Change, Adaptation and Sequestration workgroup. The workgroup developed recommendations spanning public and human health, coastal and shoreline management, local planning, infrastructure protection and planning, floodplain management and insurance industry participation, emergency planning response and recovery, multi-State natural resource plans, and water resource management. The plan also calls for a separate Sea Level Rise Adaptation Strategy to be developed by 2011.

Washington. In 2007, Preparation Adaptation Working Groups were formed as part of the State's overall Climate Advisory Team (CAT). Vulnerabilities and recommendations for adaptive actions and research were released in the February 2008 CAT report for agriculture, forestry resources, human health, water resources, and quality sectors. Legislation E2SSB 5560 was signed on May 15, 2009, requiring an "integrated climate change response strategy" to better enable State and local governments, businesses, nongovernmental organizations and individuals to better prepare for, address, and adapt to climate change impacts. A draft Strategy is scheduled for Spring 2011, with the final report to the Legislature by December 2011.

Chapter 13

Livability

Livability

Fostering livable communities—places where transportation, housing, and commercial development investments have been coordinated so that everyone has access to adequate, affordable, and environmentally sustainable travel options—is a U.S. DOT goal. This chapter presents an overview of how transportation can improve livability in communities across the Nation with a focus on the characteristics, measures, and goals of livability. This chapter provides data and information that help to provide awareness of the benefits of livable communities and the U.S. DOT and transportation's role in this effort.

Integrating transportation, land use, and housing planning can help improve livability by encouraging mixed-use development (residential, commercial, education, recreation, etc.) that co-locates housing and other key amenities with multimodal transportation options in order to reduce both trip distance and time. Implementing strategies that incorporate the principles of livability in urban and rural areas will result in improved quality of life for all Americans and create more efficient and more accessible transportation networks to meet the needs of individual communities.

Characteristics of Livability

A livable community is one that provides safe and convenient transportation choices to all citizens, whether it's by walking, bicycling, transit, driving, or combinations of these modes. How a community is designed—including the layout of its roads, bridges, transit systems, walkways, and shared-use paths—has an impact on its residents. As the U.S. population increases and the characteristics of the population change, it is essential to identify new strategies to move people and goods within communities and throughout the Nation. Integrating transportation planning with community development and expanding transportation options will not only improve connectivity and influence how people choose to travel, but also enable communities to jointly consider the design of transportation and land use. There are many benefits of well designed mixed use neighborhoods with inter-connected streets, transit access, and bike and pedestrian connections. These include shorter trip lengths; reduced vehicle-miles traveled; safer streets for all users including bus riders, pedestrians, and bicyclists; lower per-capita greenhouse gas emissions; reduced dependence on fossil fuels; increased trip-chaining; and independence for those who prefer not to drive or are unable to drive.

It is important to understand that livability is important in all communities, urban and rural. A livable rural area is one in which people are able to obtain essential services, including employment, emergency services, health care, and educational opportunities; in such areas, transportation systems meet the access and mobility needs of all interests at a cost they can afford. In rural areas, paratransit for people who can no longer drive is a critical livability element. Transportation is also vitally important to support rural economies and provide access to economic generators. Creating livable communities is also important in tribal areas, where there is great need for reliable and affordable transit. Livability issues for tribal communities include the need for school routes that are accessible year-round and transportation to hospitals and emergency medical services.

The U.S. DOT is committed to focusing on the transportation needs of people and communities wherever they live and work, their mobility needs, and their quality of life; preserving and enhancing unique community characteristics are primary goals rather than an afterthought.

Benefits of Livable Communities

While not an exhaustive list, the following section provides examples of why the U.S. DOT is making investments in livability.

Provides More Transportation Options and Integrates Land Use Planning

A key objective for the U.S. DOT is to increase transportation options for all citizens. Building a multimodal system that integrates walking, bicycling, and transit use with use of personal automobiles will provide more choices for where to live, work, and play. Integrating transportation investments with land use planning has the potential to improve the health and safety of citizens, save money, and increase travel independence for community members—including persons with disabilities, the elderly, and low-income populations.

Transportation options integrated with land use planning also tend to foster a balance of mixed uses (including housing, educational, employment, recreational, retail, and service opportunities) which recognize the importance of geographic proximity, layout, and design of those uses. Considering the long-term impacts of land use decisions on the environment and transportation demand is critical to creating livable communities and long-term economic growth. Chapter 11 provides a more detailed discussion of environmental sustainability and the transportation system.

Promotes Healthy Living

For decades, Americans have understood the link between moderate physical activity and health; however, many communities have not made the connection that robust transportation and land use planning can play an important role in promoting healthy living. The Surgeon General's *Report on Physical Activity and Health* in 1996 stated, "Physical activity reduces the risk of premature mortality…coronary heart disease, hypertension, colon cancer, and diabetes."[1] The Surgeon General went on to recommend moderate physical activity at least five days a week, although nearly three in four Americans report that they do not get enough exercise to meet the recommended minimum.[2] While it is well documented that Americans do not obtain the recommended daily amount of exercise, many communities have not facilitated increasing walking and biking by providing sidewalks and bike lanes. It is estimated that the majority of trips that an individual takes are within walking or cycling distance.

Communities that develop without proper pedestrian amenities make it difficult or undesirable for individuals to walk more in their daily lives. Studies suggest that those who report living in walkable neighborhoods take approximately two times more walking trips per week than residents living in neighborhoods with poor pedestrian walkways. This translates to nearly 30 minutes of additional walking per week.[3] A 2003 study on the health effects of sprawl found that people living in more compact, walkable counties are likely to walk more and weigh less, and are less likely to suffer from hypertension than people living in more sprawling counties.[4] In 2004 a study published in the *Journal of Public Health* was the first to examine the relationship between sprawl and a wider spectrum of chronic illnesses.[5]

Another study looked at how walking or bicycling to work impacted the weight of middle-aged men and found that it was associated with a lower weight regardless of additional exercise.[6] The U.S. Centers for Disease Control and Prevention note that 42 percent of children walked or biked to school in 1969; that percentage dropped to 16 percent by 2001. Of children who lived within a mile of school in 2001, only 25 percent walked or biked to school, down from nearly 90 percent of those who lived that close to school in 1969. This may have serious implications for the rising trend in childhood obesity.[7] Research has also

U.S. DOT's Livability Initiative

The U.S. DOT's Livability Initiative enables communities across the Nation to grow in ways that ensure a better quality of life while enhancing their economic and social wellbeing. Under U.S. DOT's Livability Initiative, the intent is to enable communities to:

- Better integrate transportation and land use planning to inform decision making about public investments
- Foster multimodal transportation systems and effective multimodal connections
- Provide more safe transportation options to improve access to housing, jobs, healthcare, businesses, recreation, public services, and social activities
- Increase public participation in designing communities and coordinating transportation and housing
- Improve public health by reducing noise and air pollution
- Enhance planning for the unique transportation needs of individual communities
- Better accommodate the needs of our ever-increasing older population as they stop driving.

To achieve the Livable Communities agenda, U.S. DOT plans to:

- Establish an office within the Office of the Secretary to promote coordination of livability and sustainability in Federal infrastructure policy
- Give communities the tools and technical assistance they need to assess their transportation systems, plan for needed improvements, and integrate transportation and other community needs
- Work through the HUD/U.S. DOT/EPA Interagency Partnership for Sustainable Communities to develop broad, universal performance measures that can be used to track livability across the Nation, as well as performance measures that capture local circumstances
- Advocate for more robust State and local planning efforts, create incentives for investments that demonstrate the greatest enhancement of community livability based on performance measures, and focus transportation spending in a way that supports and capitalizes on other infrastructure investment, both public and private.

shown that increased access to public transit may help promote and maintain active lifestyles. A study published in the *American Journal of Preventive Medicine* analyzed transit trips from the National Household Travel Survey (NHTS) and found that the average transit user walks for 24.3 minutes in conjunction with their transit trip. Those who use transit walked, on average, 30 percent more and were four times more likely to walk 10,000 steps in a day—the recommended daily amount for a healthy lifestyle—than car commuters. Researchers also found that nearly one-third of transit riders achieved 30 minutes of physical activity a day solely by walking to and from transit. With both minorities and low-income populations reporting some of the highest levels of obesity, the benefits of walking to transit can assist in attaining recommended daily physical activity levels.[8]

While more research needs to be completed and it is difficult to demonstrate the causes of increased activity, there is a growing consensus that multimodal transportation could promote increased physical activity.[9] The aforementioned studies corroborate that the attributes of where a person lives are correlated with activity levels and that a person's activity level has an impact on health.

Improves Pedestrian Safety

Increased transportation options coupled with more effective land use planning also has important implications for the safety of residents in a community. According to the 2009 National Household Travel Survey, about 12 percent of all trips are made by walking and bicycling[10], a noted increase from the recent past. Pedestrian and cyclist fatality rates reflect this, accounting for about 13 percent of roadway fatalities.[11]

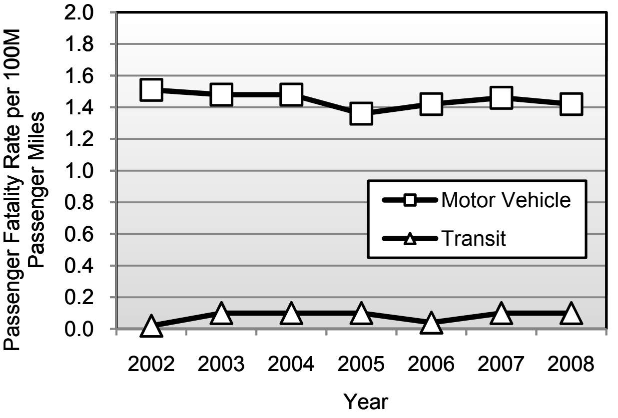
In a 2003 report, *Promoting Safe Walking and Cycling to Improve Public Health: Lessons from the Netherlands and Germany*, researchers examined the public health consequences of poorly planned and inconvenient walking and bicycling conditions in the United States and provided policy recommendations. Their results suggest a correlation between a lack of comprehensive planning on the one hand and fatalities or injuries of pedestrians and cyclists on the other. Per kilometer and per trip walked, American pedestrians are 3 times more likely to be killed than German pedestrians and 6 times more likely to be killed than Dutch pedestrians. Similarly, American bicyclists are twice as likely to be fatally injured as German cyclists and over 3 times as likely as Dutch cyclists.[12]

Fortunately, there is something that can be done to improve conditions for pedestrians and decrease the particularly high fatality and injury rates seen in the United States. Part of the answer comes from policies such as Complete Streets, a program that provides facilities for all potential road users. Fatalities and injuries decline as bike and pedestrian use becomes an integrated part of the community. This is supported by the "National Biking and Walking Study: a 15-year Status Report," a recent report that found that, from 1990 to 2009, reported walking trips increased from 18 billion to 42.5 billion and reported biking trips rose from 1.7 billion to 4 billion; however, as overall reported trips increased, the number of pedestrians killed decreased by 22.3 percent and the number of bicyclists killed decreased by 12 percent.[13] Since the reported number of trips taken on foot or on bike has more than doubled in the same period, the decreased fatality rates would suggest that efforts to improve pedestrian safety over this period have been effective.

Increasing the mode share of public transit trips also provides citizens with a very safe alternative. *Exhibits 13-1 and 13-2* highlight the differences in fatality and injury rates for individuals in personal automobiles and for those who take public transit. *Exhibit 13-1* presents passenger fatality rates per 100 million passenger miles and *Exhibit 13-2* describes the difference in injury rates between the two modes per 100 million passenger miles traveled. One can see that, on both accounts, public transit experiences far fewer fatality and injury rates per 100 million passenger miles traveled.[14]

Exhibit 13-1

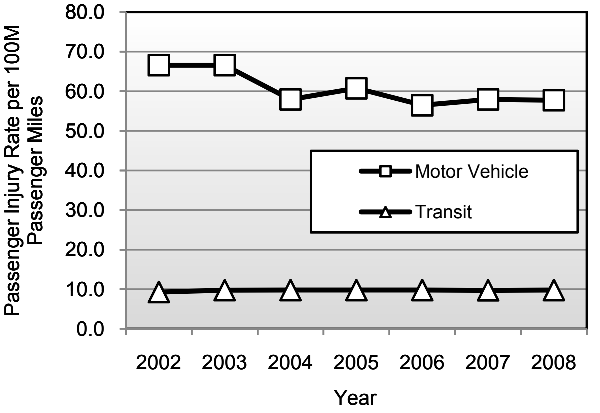
Passenger Fatality Rate per 100 Million Passenger Miles, 2002–2008



Source: Research and Innovative Technology Administration, Bureau of Transportation Statistics, National Transportation Statistics, http://www.bts.gov/publications/national_transportation_statistics/.

Exhibit 13-2

Passenger Injury Rate per 100 Million Passenger Miles, 2002–2008



Source: Research and Innovative Technology Administration, Bureau of Transportation Statistics, National Transportation Statistics, http://www.bts.gov/publications/national_transportation_statistics/.

Incentivizes Local Business Investment

There is a growing amount of literature that suggests public transit can play a key role in incentivizing developers to invest in properties to make a more livable community. Many developers are increasingly viewing transit as a desirable amenity that can improve the marketability of new residential units, office space, and other property types.[15] The introduction of transit can also make new sites available for development. A paper written by the Center for Transit Oriented Development states, "In some cases, the improved access provided by transit can make it possible to develop or redevelop sites where expected traffic impacts previously precluded development of more intensive uses."[16] Transit can also help communities improve the financial feasibility of a development because developers can command higher sales prices for projects they build.

Recent examples of this type of increased development can be seen on the Hiawatha Line in the Twin Cities region of Minnesota, the Southeast Corridor in the Denver region of Colorado, and the Blue Line in the Charlotte region of North Carolina. All three transit lines experienced a remarkable amount of new development. Each of the corridors attained more than 7.5 million square feet of new development, with Charlotte achieving approximately 10.4 million square feet. Development was often mixed among residential, commercial, and employment centers, providing a community with a multitude of options.[17] It should be noted that there are many different reasons why these developments have been successful. In fact, planners suggest that one of the reasons Charlotte was so successful was because it was centered on a walkable street grid.

Brownfield reuse can play a key role in incentivizing business investment. As discussed in Chapter 11, brownfields are abandoned industrial properties. Based on the previous use, potential contaminants could remain and must be removed before reuse of the property is possible. The EPA Brownfields program encourages redevelopment and reuse of land for the benefit of the community. The program has been expanded recently, with the EPA/U.S. DOT/HUD Interagency Partnership for Sustainable Communities (see the Introduction to Part III). The agencies have selected five brownfields where there is a convergence of public transit accessibility and the need for affordable housing. Cleaning and reusing this land and providing new housing choices will create jobs and new economic opportunities. The five sites are the Fairmount Line in Boston; the Smart Growth Redevelopment District in Indianapolis; the La Alma/South Lincoln Park neighborhood in Denver; the Riverfront Crossings District in Iowa City, Iowa; and the Westside Affordable Housing Transit-Oriented Development in National City, California.

Lowers Household Transportation Costs

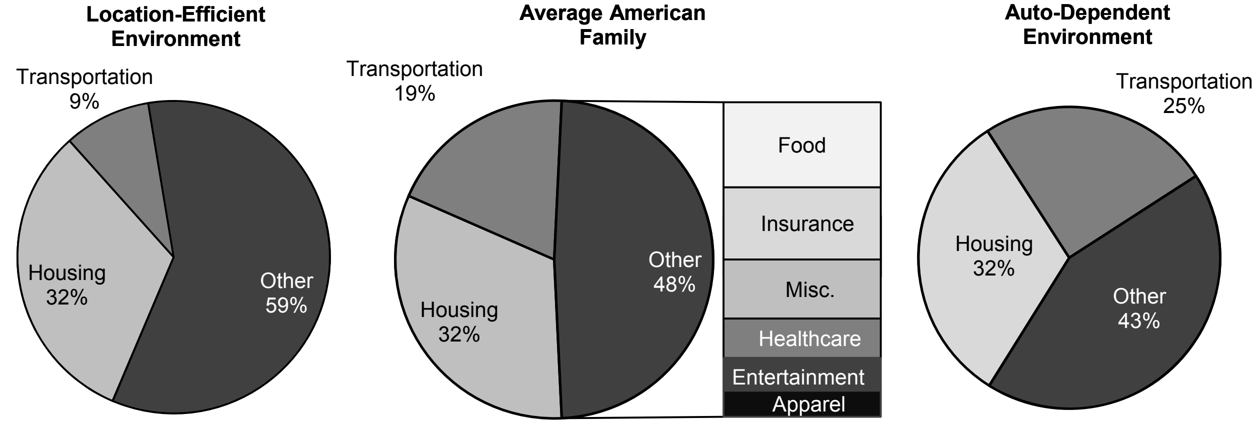
As mentioned previously, the average American household spends $8,758 per year to buy, maintain, and operate personal automobiles.[18] Providing more transportation options can potentially save the average American family thousands of dollars a year.[19]

A vital component of this discussion is location. *Exhibit 13-3* shows that an average household with access to transit spends just 9 percent of its household budget on transportation costs. Location efficiency, or living in a community with a multitude of options, is particularly relevant for very-low-income households; household transportation costs can sometimes consume 55 percent of the budget in very-low-income communities without access to transit.[20]

The Center for Neighborhood Technology (CNT) "Housing and Transportation Affordability Index" scores 337 U.S. metropolitan regions and illustrates how the growth of urban regions has increased the average costs of living for the average family. A comparison of index values across regions suggests that a

Exhibit 13-3

Distribution of Expenditures in Location-Efficient and Auto-Dependent Environments



Source: Center for Transit Oriented Development, 2007.

community's location and design are more effective predictors of overall affordability than household size and income. CNT reports, "Compact, walkable, mixed-use communities may initially appear expensive because of higher housing costs but these places can often be more affordable than less dense suburban communities because households can own few cars…"[21] In fact, household savings from residing in compact neighborhoods rather than less-dense communities can range from $1,580 per year in Little Rock to $3,850 in Boston.[22] Though more research needs to be done, there is a growing consensus that cost mitigation can be achieved by promoting the development of communities that make it possible to get to jobs, schools, and shopping on foot or by bike, bus, or train.

As economies develop in rural areas, focusing development in town and commercial centers can increase access to necessities and enable one-stop shopping for many residents, thus reducing fuel costs and time on the road and enhancing a sense of community.

Saves Community Infrastructure Costs

Finally, the economic benefits of livable communities can be realized by the community as it saves in infrastructure costs. Depending on the community, savings can be realized from land conservation and the reduced need for such services as: water and sewage infrastructure, local road infrastructure, local public service costs, and real estate development costs.

CNT has projected regional cost savings in specific communities around the country if 50 percent of the region's new households through 2030 were built in more compact, rather than dispersed, neighborhood designs. In smaller regions like Charlotte, which is expected to nearly double in population—cost savings are estimated at $239.8 million a year. San Francisco could realize savings of $1.1 billion and Phoenix, $2.1 billion, just by changing the way the communities grow. Similarly, Salt Lake City's Quality Growth Strategy focuses on compact, mixed-use development and is predicted to save the region $4.5 billion in infrastructure costs, preserve hundreds of miles of undeveloped land, double the transit trips taken, and increase residency near rail transit by over 20 percent. *Exhibit 13-4* illustrates the economic benefits of location efficiency for selected communities.

Exhibit 13-4

Economic Benefits of Location Efficiency

MPO Region	Sample Dispersed Neighborhood[1]	Sample Compact Neighborhood[1]	Difference in Annual Household Transportation Costs[2]	Difference in Annual Regional Transportation Costs (Millions)[3]
Austin, TX	Round Rock	Old West Austin	$2,310	$716.0
Boston, MA	Braintree	Somerville	$3,850	$613.5
Charlotte, NC	Sterling	Dilworth	$1,700	$239.8
Chicago. IL	Schaumburg	Oak Park	$3,110	$1,110.2
Cincinnati, OH	Milford	CUF Neighborhood	$3,050	$236.3
Denver, CO	Arvada	Washington Park	$2,240	$661.3
Little Rock, AR	Sherwood	Pulaski Heights	$1,580	$79.9
Minneapolis, MN	Orono	Seward	$1,830	$345.1
Newark, NJ	Butler	Montclair	$2,300	$550.8
Phoenix, AZ	Gilbert	Encanto	$3,610	$2,144.3
Portland, OR	Troutdale	Roseway	$2,230	$492.2
San Francisco, CA	Antioch	Rockridge	$2,780	$1,126.8

[1] Representative compact and dispersed neighborhoods used to cost out the savings associated with greater effciency.
[2] Household savings of the representative compact community over the representative dispersed community.
[3] Regional savings if 50% of projected household growth through 2030 as listed on the MPO website had the H+T savings of the compact over the dispersed community.

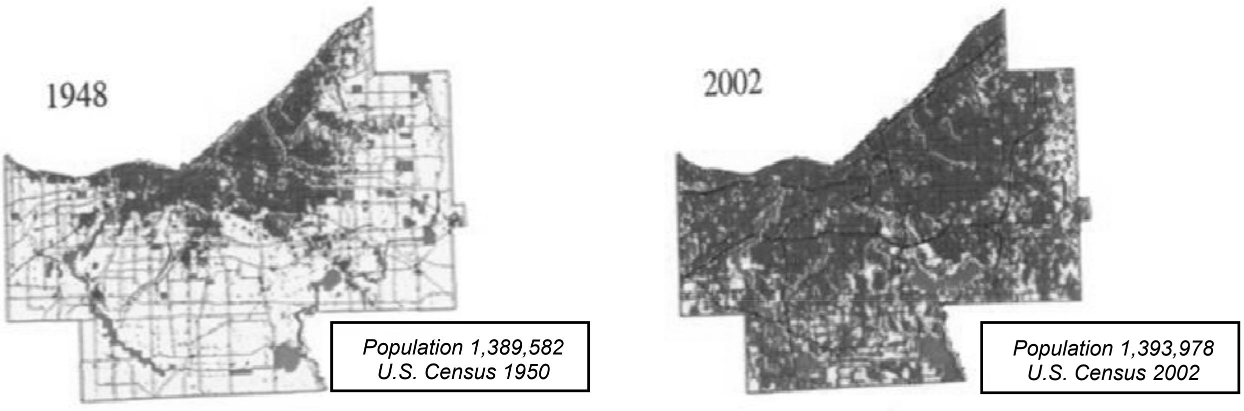
Source: CNT H+T Index and MPO websites.

During the period of 2000 to 2025, significant savings in community costs could be achieved if Smart Growth and livability principles are applied. It is estimated that local governments will expend more than $190 billion to provide water and sewer infrastructure under traditional development practices. Employing livability principles, up to 150 million gallons of water and sewer demand could be saved, which would add up to $12.6 billion over the 25-year period. Similarly, $110 billion in road infrastructure costs and $4 billion in public service costs could be saved.[23] Other research shows that Smart Growth can provide direct savings to the public in the form of reduced infrastructure costs of anywhere from $270 to $4,000 per dwelling unit. Taking into account incremental operations, maintenance, and service costs, estimates of public savings range from $500 to almost $10,000 annually per unit.[24]

Exhibit 13-5 illustrates these concepts. Cuyahoga County has experienced very minimal changes in its population over the past 50 years, yet the land use map shows the clear impact of modern day policies. The

Exhibit 13-5

Change in Patterns of Land Use in Cuyahoga County, Ohio, 1948 and 2002



Source: Cuyahoga County land use maps, Cuyahoga County, Ohio, Planning Commission.

Minneapolis Pedestrian and Bicycle Case Study

The Minneapolis–St. Paul seven-county area has annually invested in pedestrian and bicycle facilities and programs using Federal funds. These investments help implement projects consistent with local comprehensive plans and regional system plans and policies. From 1991 to 2004, the area invested more than $76 million in freestanding pedestrian and/or bicycle infrastructure.[1]

In 2005, Minneapolis and adjacent communities became one of four pilot sites for a Nonmotorized Transportation Pilot Program (NTPP), established by Congress, to demonstrate the extent to which bicycling and walking could carry a significant part of the transportation load.[2] Implementation of the Minneapolis pilot NTPP projects began in 2007, covering three categories: planning, operations, and infrastructure. These projects included 18 on-street operations projects, three planning projects, and six infrastructure projects such as bicycle parking in Minneapolis, a travel connection between high-traffic destinations, a bicycle boulevard as an alternative to heavy arterials, and a bicycle and pedestrian plan for the city of Minneapolis.[3/4] By the end of 2010, 37 projects are anticipated to be completed, including 75 miles of on- and off-street facilities, a bike station, and a bike library and sharing program.[5]

Bicycle magazine and census data suggest that the Minneapolis area's investment in walkway and bikeway facilities has helped produce one of the Nation's leading bicycle commuting populations. In spring 2010, Bicycle magazine named Minneapolis the number one bike-friendly U.S. city, highlighting the existing bicycle culture and new funding from the NTPP program.[6] The American Community Survey reports the number of people using bikes to commute to work in Minneapolis increased from 4,835 in 2006, to 8,164 in 2008 (a 68 percent increase), or an increase in mode share from 2.5 percent in 2006 to 4.3 percent in 2008.[7] Monthly bicycling and walking monitoring indicates seasonal resilience, with 68 percent of walkers continuing to walk and 20 percent of bikers continuing to bike on the worst winter day.[8]

[1] Metropolitan Council, [Minnesota's] 2030 Transportation Policy Plan, Publication no. 35-04-055, 2004.

[2] DOT – FHWA, *Interim Report to the U.S. Congress on the Nonmotorized Transportation Pilot Program SAFETEA-LU Section 1807*, 2007, http://www.fhwa.dot.gov/environment/bikeped/ntpp/index.htm, accessed July 20, 2010.

[3] *Ibid*.

[4] DOT – FHWA, *Nonmotorized Transportation Pilot Program Midterm Report*, 2009, http://www.fhwa.dot.gov/environment/bikeped/ntpp/midtermrpt09.htm, accessed July 28, 2010.

[5] Bike Walk Twin Cities, http://www.bikewalktwincities.org, accessed July 27, 2010.

[6] *Ibid*.

[7] U.S. Census Bureau, American Community Survey, http://factfinder2.census.gov/, 2010, accessed July 20, 2010.

[8] Bike Walk Twin Cities, http://www.bikewalktwincities.org, accessed July 27, 2010.

rate of land conversion to urban uses is due more to modern settlement patterns than population growth. According to the U.S. Department of Agriculture's National Resources Inventory, developed land in the contiguous United States increased 34 percent between 1982 and 1997. During the same 15-year period, population grew by about 15 percent; meaning land consumption occurred at more than twice the rate of population growth.[25]

While this is by no means an exhaustive list of all the benefits that can be seen from investing in livable communities, this brief discussion highlights some of the reasons that the U.S. DOT is making livability a priority.

Performance Indices

Measuring the impact of transportation investments on improving community livability is a multidisciplinary effort influenced by the interaction between transportation, land use, economic, social, and environmental systems. The HUD/DOT/EPA Interagency Partnership for Sustainable Communities is working to develop recommended performance measures, as discussed in more detail in the Introduction to Part III of this report.

Livability Performance Measures

Communities across the United States have begun tracking the implementation process and accessibility outcomes of livability investments that expand transportation options. *Exhibit 13-6* provides a list of potential performance measures related to livability that focus on the specific outcomes and strategies seen in the Partnership for Sustainable Communities guiding principles. The measures discussed in this section are ideas for how to measure livability and have not been adopted by the U.S. DOT as official performance measures. As the livability initiative matures, the performance measures will evolve and be refined.

Exhibit 13-6

Potential Livability Performance Measures
Increased Transportation Options
Change in vehicle miles traveled per capita
Increase in transit, walk, bike share of trips[1]
Equitable Affordable Housing
Decrease in household transportation costs
Percent of low income households within a 30-minute commute of major employment centers
Increase in affordable homes and rental units within or near *key activity centers* (which include fixed guideway transit stations or "well served transit stops")
Economic Competitiveness
Reduced average per capita public cost for infrastructure
Percent of employment within walking distance of transit, and/or key destinations
Value Communities
Decrease in transportation related emissions per capita[2]
Decline in non-occupant injury/fatality rate
Increase in the number of homes with walkable access to retail, services, parks, and transit

[1] ***Key Activity Center** definition tied to the region type:*

- ***Urban Region** – Fixed guideway transit station or "well served transit stop" = Small Starts operational requirements of at least 10-minute headways during peak hours and 15-minute headways during off peak hours, with operations for at least 14 hours daily.*
- ***Rural County** – Town center (area within the boundary of an existing Census Designated Place or other area specifically designated as a town center)*

Two key thresholds defining convenient access:

- ***Within** = walking distance (one-quarter to half mile)*
- ***Near** = short driving distance (one to two miles)*

[2] CO_2, *PM* NO_x *VOC emissions.*

Some of the measures directly capture broad outcomes such as reduced air pollution and lower household transportation costs, while others are indicators indirectly measuring progress toward such outcomes. Additionally, given the central importance of improved connections between development and transportation, several measures track implementation of strategies such as increased development near transit or more walkable neighborhoods. This includes improved connection to equitable affordable housing in proximity to transit.

U.S. DOT Performance Measurement

Fostering livable communities is one of the U.S. DOT's strategic planning goals. As work continues to develop comprehensive measures of livability and obtain the data required to track these measures, the U.S. DOT has identified some initial livability measures based on currently available data. Some of the livability performance measures included in the President's FY 2012 Budget were:

1) Increase in the number of States with policies that improve transportation choices for walking and bicycling, from 21 in 2010 to 23 in 2012.
2) Increase access to convenient and affordable transportation choices as reflected by the average percentage change in transit boarding per transit market (150 largest transportation agencies). The target is to increase transit boardings by 1.9 percent in 2009 and by 2.0 percent per year from 2010 through 2012.
3) Improve access to transportation for special needs populations and individuals with disabilities as reflected by the percentage of bus fleets that are compliant with the Americans with Disabilities Act (ADA). The target is to increase this percentage from 97 percent in 2007 to 98 percent in 2012.
4) Improve access to transportation for special needs populations and individuals with disabilities as reflected by the percentage of key rail stations that are compliant with the ADA. The target is to increase the percentage from 93 percent in 2007 to 95 percent in 2012.

While some of the measures in *Exhibit 13-6* can apply to rural areas, others have more of an urban focus. This is because livability may be different across the range of urban, rural, suburban, and tribal communities across the country. No two areas are alike, and each may choose different kinds of transportation investments that best fit its needs. However, these measures provide a useful framework for tracking progress at a high level and can be generalized to address many diverse contexts.

Interim Measures

One of the major challenges in measuring progress in improving livability is the current lack of consistent national-level data. For example, it would be useful to track the number of miles of bicycle trails, urban bicycle lanes, and sidewalks over time. However, while these types of data are collected by some jurisdictions, there are currently no reliable national-level statistics available.

As work continues in establishing a consensus around recommended performance measures, and data systems are developed to track these measures, it is necessary in some cases to rely on indirect measures of livability. For example, current data limitations preclude directly tracking changes in the number of miles of accessible sidewalks. However, an alternative approach would be to track the number of States that developed an Americans with Disabilities Act (ADA) transition plan that is current and provides a schedule and time period for achieving compliance for pedestrian accessibility in the public rights-of-way. While this indirect measure would not fully capture national progress, it would represent a more feasible interim method for starting to track performance in this area.

Walking and Bicycling Performance Measures

It is difficult to set national performance measures for nonmotorized transportation issues. In the 1994 *National Bicycling and Walking Study*, the U.S. Department of Transportation established two national goals related to walking and bicycling—to double the percentage of total trips made by bicycling and walking in the United States from 7.9 percent to 15.8 percent of all travel trips and to simultaneously reduce by 10 percent the number of bicyclists and pedestrians killed or injured in traffic crashes. Since 1994, the FHWA has provided 5-year updates on progress toward achieving these goals. (The 5-, 10-, and 15-year status reports can be accessed at http://www.fhwa.dot.gov/environment/bikeped/publications.htm).

Walking and bicycling trips are reported in the periodic National Household Travel Survey (conducted every 5 to 8 years), while the Fatality Analysis Reporting System from the National Traffic Safety Administration reports crash data annually.

There are currently few alternatives to these two national performance measures. There are no national estimates of walking and bicycling infrastructure (e.g., miles of sidewalks or miles of shared use paths or bicycle lanes). In fact, many communities lack these data at the local level as well. Federal, State, and local transportation agencies are recognizing the importance of identifying ways to monitor multimodal transportation networks and usage. Several FHWA and National Cooperative Highway Research Program (NCHRP) projects will help develop improved measures related to nonmotorized transportation. Examples of NCHRP projects can be found at

- NCHRP 08-78, Estimating Bicycling and Walking for Planning and Project Development (http://144.171.11.40/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=2707)
- NCHRP 07-17, Pedestrian and Bicycle Transportation along Existing Roads (http://144.171.11.40/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=2955)

In the future, it should be easier to report new performance measures related to walking and bicycling, but for the moment trip rates and crash data, which will both remain important measures, are the state of the art.

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PART IV

Appendices

Introduction

Appendices A, B, and C describe the modeling techniques used to generate the investment/performance analyses and selected capital investment scenario estimates highlighted in Chapters 7 through 10. Appendix D discusses crosscutting analytical issues.

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 describes the **National Bridge Investment Analysis System** (NBIAS), which is used for analyzing potential future bridge rehabilitation and replacement investments.

Appendix C presents technical information on the **Transit Economic Requirements Model** (TERM), which is used to analyze potential future transit investments in urbanized areas. TERM includes modules which estimate the funding that will be required to replace and rehabilitate transit vehicles and other assets and to invest in new assets to accommodate future transit ridership growth.

Appendix D describes ongoing research activities and identifies potential areas for improvement in the data and analytical tools used to produce the highway, bridge, and transit analyses contained in this report.

Appendix A

Highway Investment Analysis Methodology

Highway Investment Analysis Methodology

Investments in highway resurfacing and reconstruction and in highway and bridge capacity expansion are modeled by the Highway Economic Requirements System (HERS), which has been used since the 1995 C&P Report. This appendix describes the basic HERS methodology and approach in slightly more detail than is presented in Part II, including the treatment of intelligent transportation system (ITS) deployment and operations strategies, the allocation of investment across improvement types, the calculation of the highway backlog, and procedures that link investment levels to revenues and simulate the effect of universal congestion pricing. Also described are some of the changes that have been made to the model since the 2008 C&P Report. These include the refinement of the equations for predicting crash rates, updates to the capital improvement cost matrix and, the addition of a new procedure to quantify greenhouse gas (GHG) emissions and their associated costs.

Highway Economic Requirements System

The HERS model begins the investment analysis process by evaluating the current state of the highway system using information on pavements, geometry, traffic volumes, vehicle mix, and other characteristics from the Highway Performance Monitoring System (HPMS) sample dataset. Using section-specific traffic growth projections, HERS forecasts future conditions and performance across several funding periods. As used in this report, the future analysis covers four consecutive 5-year periods. At the end of each period, the model checks for deficiencies in eight highway section characteristics: pavement condition, surface type, volume/service flow (V/SF) ratio (a measure of congestion), lane width, right shoulder width, shoulder type, horizontal alignment (curves), and vertical alignment (grades).

Once HERS determines that a section's pavement or capacity is deficient, it identifies potential improvements to correct some or all of the section's deficient characteristics. The HERS model evaluates seven kinds of improvements: resurfacing, resurfacing with shoulder improvements, resurfacing with widened lanes (i.e., minor widening), resurfacing with added lanes (i.e., major widening), reconstruction, reconstruction with widened lanes, and reconstruction with added lanes. For reconstruction projects, the model allows for upgrades of low-grade surface types when warranted by sufficient traffic volumes. For improvements that add travel lanes, HERS further distinguishes between those that can be made at "normal cost" and those on sections with limited widening feasibility that could only be made at "high cost." HERS may also evaluate alignment improvements to improve curves, grades, or both.

Q&A

Where can I find more detailed technical information concerning the HERS model?

The Federal Highway Administration has previously developed a Technical Report for HERS. The most recent printed edition, dated December 2000, is based on HERS version 3.26, which was used in the development of the 1999 edition of the C&P report. An update to this document is currently underway, and should be completed in 2011.

The FHWA also has developed a modified version of HERS for use by States. This model, HERS-ST, builds on the primary HERS analytical engine with a number of customized features to facilitate analysis on a section-by-section basis. HERS-ST version 4.4 is largely based on HERS version 4.097, which was utilized in developing the 2004 edition of the C&P report. "The Highway Economic Requirements System – State Version: Technical Report" is available on request from the FHWA; see http://www.fhwa.dot.gov/infrastructure/asstmgmt/hersdoc.htm.

When evaluating which potential improvement, if any, should be implemented on a particular highway section, HERS employs incremental benefit-cost analysis. Such an analysis compares the benefits and costs of a candidate improvement relative to a less-aggressive alternative—for example, reconstructing and adding lanes to a section may be compared with reconstruction alone. The HERS model defines benefits as reductions in direct highway user costs, agency costs, and societal costs. Highway user benefits include reductions in travel time costs, crash costs, and vehicle operation costs (e.g., fuel, oil, and maintenance costs); agency benefits include reduced routine maintenance costs (plus the residual value of projects with longer expected service lives than the alternative); and societal benefits include reduced vehicle emissions. Increases in any of these costs resulting from a highway improvement (such as higher emissions rates at high speeds or the increased delay associated with a work zone) would be factored into the analysis as a negative benefit or "disbenefit."

Dividing these improvement benefits by the capital costs associated with implementing the improvement results in a benefit-cost ratio (BCR) that is used to rank potential projects on different highway sections. The HERS model implements improvements with the highest BCR 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, until the point where the marginal BCR falls below 1.0 (i.e., costs exceed benefits), total net benefits will continue to increase as additional projects are implemented. Investment beyond this point would not be economically justified because it would result in a decline in total net benefits.

Because the HERS model analyzes each highway section independently rather than the entire transportation system, it cannot fully evaluate the network effects of individual highway improvements. While efforts have been made to indirectly account for some network effects, HERS is fundamentally rooted to its primary data source, the national sample of independent highway sections contained in the HPMS. To fully recognize all network effects, it would be necessary to develop significant new data sources and analytical techniques.

Highway Investment Backlog

To determine which action items to include in the highway investment backlog, HERS evaluates the current state of each highway section before projecting the effects of future travel growth on congestion and pavement deterioration. Any potential improvement that would correct an existing pavement or capacity deficiency and that has a BCR greater than or equal to 1.0 is considered part of the current highway investment backlog.

As noted in Chapter 9, the backlog estimate produced by HERS does not include either rural minor collectors or rural and urban local roads and streets (since HPMS does not contain sample section data for these functional systems), nor does it contain any estimate for system enhancements. The backlog for the bridge portion of system rehabilitation is modeled separately through the National Bridge Investment Analysis System (NBIAS), which is discussed in Appendix B.

HERS Crash Rate Equations

The HERS model contains equations that predict for each highway section the vehicle crash rate per 100 million vehicle miles traveled (VMT) as a function of section characteristics (e.g. median width, shoulder width, number of intersections). The model also contains parameters for the average number of fatal, and nonfatal, injuries per crash by highway functional class. In preparation for this report, these parameters as well as the crash equations have been re-calibrated for consistency with data reported for 2007; previously, these parameters and equations had been benchmarked to data for 1995. The recalibration had the effect of reducing the overall estimate of crash costs by about 30 percent, which is partly attributable to the actual improvement in road safety that occurred between the original and updated calibration years. An indication of this improvement is the large decrease in the crash fatality rate in recent years identified in Chapter 5. Another reason why recalibration reduced the HERS estimated crash costs is that the 2007 data on crash incidence included only reported crashes. HERS used to include a factor to allow for unreported crashes, but omitting this factor made it easier to compare HERS estimates of crash incidence with other published estimates. For the recalibration, data on crash incidence was obtained from the Highway Safety Information System to which several States supply data from their crash records.

Greenhouse Gas Emissions

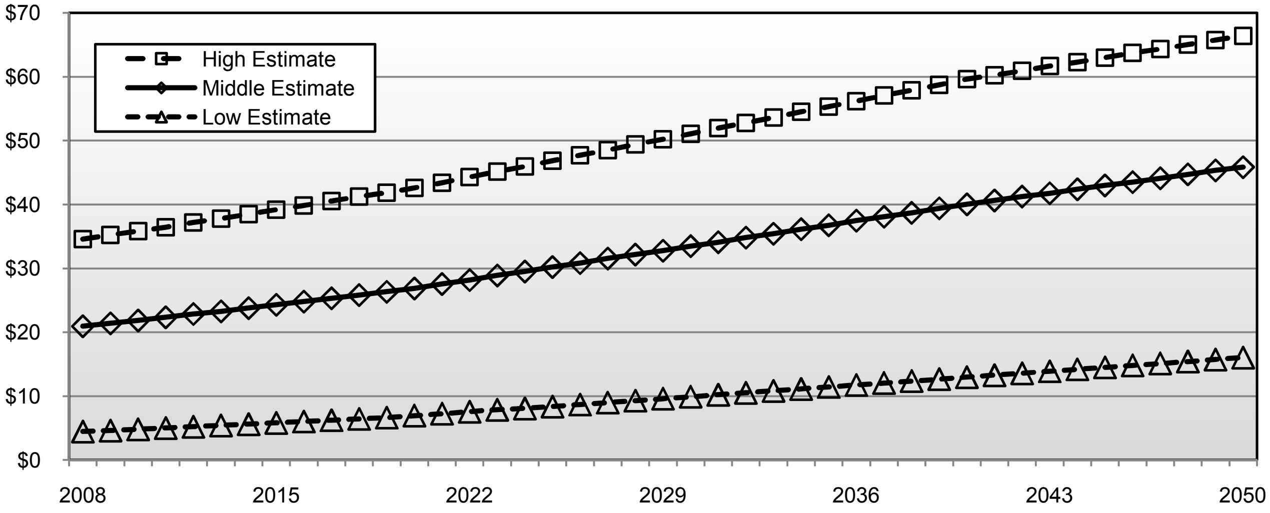
Road traffic generates an appreciable share of anthropogenic emissions of GHG. In the United States, passenger vehicles alone account for roughly 20 percent of emissions of carbon dioxide,[1] which account for about 95 percent of the global warming potential from passenger vehicle operation. In line with carbon dioxide emissions being the dominant concern, a capability for quantifying and costing these emissions has been added to the HERS model for the preparation of this report.

The quantification of CO_2 emissions from motor vehicle traffic is based on the amounts of gasoline and diesel fuel consumed (alternative fuels have yet to be incorporated into the model). Emissions directly from vehicles amount to 8,852 grams of CO_2 per gallon of gasoline consumed, and 10,239 grams per gallon of diesel fuel. These emissions may be termed "tailpipe emissions' since they result mainly from the combustion process, but they also result to some extent from evaporative release of vehicle fuel. In addition to these direct emissions, the production of fuel and the distribution processes for delivering fuel to vehicles produce emissions as well. HERS allows users of the model the option of adding these upstream emissions, about which there is greater quantitative uncertainty, to the direct emissions. The estimates of upstream emissions are 2,072 grams of CO_2 per gallon of gasoline consumed, and 2,105 grams CO_2 per gallon of diesel.

A recent study by a Federal interagency working group (Interagency Working Group on Social Cost of Carbon 2010) estimated the costs to society from incremental CO_2 emissions. The group's estimates of this social cost of carbon were intended to include, at a minimum, the monetized impacts of emissions-induced climate change on net agricultural productivity, on human health, on property damages from increased flood risk, and on the value of ecosystem services. Low, medium, and high estimates of the social cost per metric ton of carbon were formed for each year from 2010 through 2050 using alternative discount rates. For 2010, the medium estimate was about \$21, meaning that an incremental ton of CO_2 released into the atmosphere in that year would have present and future discounted costs totaling \$21. For the same year, the low and high estimates were \$4.55 and \$34.61. The estimates increase over the analysis period as shown in *Exhibit A-1*. All estimates were in 2007 dollars. For the baseline analyses presented in this report, the medium estimates were extrapolated back to 2008, re-expressed in 2008 dollars, and then averaged across the 5 years in each funding period.

Exhibit A-1

Social Marginal Cost per Metric Ton of CO_2 Emission Estimates, in Constant 2008 Dollars



Source: Interagency Working Group on Social Cost of Carbon, United States Government 2010, Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866.

Highway Operational Strategies

One of the key modifications to HERS featured in previous reports was the ability to consider the impact of highway management and operational strategies, including ITS, on highway system performance. This feature is continued in this report with only minor modifications. Current and future investments in operations are modeled outside of HERS, but the impacts of these deployments were allowed to affect the model's internal calculations and, thus, to also affect the capital improvements considered and implemented in HERS.

Among the many operational strategies available to highway agencies, HERS considers only certain types based on the availability of suitable data and empirical impact relationships. Grouped by category— arterial management, freeway management, incident management, and travel information —these are:

- Arterial Management
  - Signal Control
  - Electronic Roadway Monitoring (considered to be a supporting deployment necessary to other operations strategies)
  - Variable Message Signs

- Freeway Management
  - Ramp Metering (preset and traffic-actuated)
  - Electronic Roadway Monitoring (considered to be a supporting deployment necessary to other operations strategies)
  - Variable Message Signs
  - Integrated Corridor Management (ICM), with and without comprehensive deployment of Vehicle Infrastructure Integration (VII) technologies
  - Active Traffic Management, which includes lane controls, queue warning systems, and Variable Speed Limits (VSL), also known as "speed harmonization".
- Incident Management (freeways only)
  - Incident Detection (free cell phone call number and detection algorithms)
  - Incident Verification (surveillance cameras)
  - Incident Response (on-call service patrols)
- Traveler Information
  - 511 systems
  - Advanced in-vehicle navigation systems with real-time traveler information (enabled by Vehicle-Infrastructure Integration deployment)
  - Incident response (on-call service patrols).

Creating the operations improvements input files for use in HERS involved four steps: determining current operations deployment, determining future operations deployments, determining the cost of future operations investments, and determining the impacts of operations deployments. Different levels and types of deployments can be selected for an individual scenario.

Current Operations Deployments

To determine current operations deployments on the HPMS sample sections, data were used from three sources: HPMS universe data, HPMS sample data, and data from the ITS Deployment Tracking System. These section-level determinations took into account that operational deployments occur over corridors (or even over entire urban areas, as with traffic management centers).

Future Operations Deployments

For future ITS and operational deployments, three scenarios were developed. For the "Continuation of Existing Deployment Trends" scenario, existing deployments in urban areas were correlated with the congestion level and area population in order to predict on the basis of these factors where future deployments will occur. This scenario is reflected in the analyses presented in Chapters 7 and 8.

The other two scenarios were developed for the supplemental analysis presented in Chapter 9. The "Aggressive Deployment" scenario assumes that deployment accelerates above existing trends and expands to more advanced strategies. The "Full Immediate Deployment" scenario differs from the "Aggressive Deployment" scenario in assuming that all deployments will occur immediately rather than being phased in over 20 years. The "Full Immediate Deployment" scenario is intended to illustrate the maximum potential impact of the strategies and technologies modeled in HERS on highway operational performance. *Exhibit A-2* identifies the strategies employed in each scenario.

Exhibit A-2

Types of Operations Strategies Included in Each Scenario

Operations Strategy	Scenario Continue Existing Trends	 Aggressive and Full Immediate Deployment
Arterial Management		
Signal Control	●	●
Emergency Vehicle Signal Preemption	●	●
Variable Message Signs		●
Advanced Traveler Information		●
Freeway Management		
Ramp Metering	●	●
Variable Message Signs	●	●
511 Traveler Information	●	
Advanced Traveler Information		●
Integrated Corridor Mgmt.		●
Active Traffic Mgmt.		●
Incident Management (Freeways Only)		
Detection	●	●
Verification	●	●
Response	●	●

Source: Highway Economic Requirements System.

Operations Investment Costs

The unit costs for each deployment item were taken from the U.S. Department of Transportation's (U.S. DOT's) *ITS Benefits Database* and *Unit Costs Database* and supplemented with costs based on the ITS Deployment Analysis System (IDAS) model. Costs were broken down into initial capital costs and annual operating and maintenance costs. Also, costs were determined for building the basic infrastructure to support the equipment, as well as for the incremental costs per piece of equipment that is deployed. A major addition to operations deployment costs in this report is the inclusion of traffic signal replacement costs, which were not previously considered in the estimated capital costs.

Impacts of Operations Deployments

Exhibit A-3 shows the estimated impacts of the different operations strategies considered in HERS. These effects include the following:

- Incident Management: Incident duration and the number of crash fatalities are reduced. Incident duration is used as a predictor variable in estimating incident delay in the HERS model.
- Signal Control: The effects of the different levels of signal control are directly considered in the HERS delay equations.
- Ramp Meters, Variable Message Signs, Variable Speed Limits (VSL), Integrated Corridor Management, and Traveler Information: Delay adjustments are applied to the basic delay equations in HERS. VSL is assumed to have a small impact on fatalities as well.

Based on the current and future deployments and the impact relationships, an operations improvements input file was created for each of the two deployment scenarios. The file contains section identifiers, plus current and future values (for each of the four funding periods in the HERS analysis) for the following five fields:

- Incident Duration Factor
- Delay Reduction Factor
- Fatality Reduction Factor
- Signal Type Override
- Ramp Metering.

Exhibit A-3

Impacts of Operations Strategies in HERS (Highway Economic Requirements System)

Operations Strategy	Impact Category	Impact
Arterial Management		
Signal Control	Congestion/Delay	Signal Density Factor = n(nx+2)/(n+2), where n = # of signals per mile x = 1 for fixed time control 2/3 for traffic actuated control 1/3 for closed loop control 0 for real-time adaptive control/SCOOT/SCATS Signal Density Factor is used to compute zero-volume delay due to traffic signals
Electronic Roadway Monitoring	Congestion/Delay	Supporting deployment for corridor signal control (2 highest levels) and traveler information
Emergency Vehicle Signal Preemption		
Variable Message Signs	Congestion/Delay	-0.5% incident delay
Freeway Management		
Ramp Metering		
Preset	Congestion/Delay	New delay = ((1 - 0.13)(original delay)) + 0.16 hrs per 1000 VMT
Traffic Actuated	Congestion/Delay	New delay = ((1 - 0.13)(original delay)) + 0.16 hrs per 1000 VMT
	Safety	-3% number of injuries and PDO accidents
Electronic Roadway Monitoring	Congestion/Delay	Supporting deployment for ramp metering and traveler information
Variable Message Signs	Congestion/Delay	-0.5% incident delay
Integrated Corridor Management	Congestion/Delay	-7.5% total delay without VII, 12.5% total delay with VII
Active Traffic Management	Congestion/Delay	-7.5% total delay
	Safety	-5% fatalities
Incident Management (Freeways Only)		
Detection Algorithm/ Free Cell	Incident Characteristics	-4.5% incident duration
	Safety	-5% fatalities
Surveillance Cameras	Incident Characteristics	-4.5% incident duration
	Safety	-5% fatalities
On-Call Service Patrols		
Typical	Incident Characteristics	-25% incident duration
	Safety	-10% fatalities
Aggressive	Incident Characteristics	-35% incident duration
	Safety	-10% fatalities
All Combined	Incident Characteristics	Multiplicative reduction
	Safety	-10% fatalities
Traveler Information		
511 Only	Congestion/Delay	-1.5% total delay, rural only
Advanced Traveler Information (VII-enabled)	Congestion/Delay	-3% total delay, all highways

HERS Improvement Costs

For the 2004 C&P Report, significant changes were made to the structure of the HERS improvement cost matrix, the assumed unit costs in that matrix, and the manner in which those values were applied. The improvement cost updates reflected in the 2004 C&P Report were based on highway project data from six States (see Appendix A of that report for more information). Though adequate in most respects, that dataset was relatively thin in certain key areas. The 2004 update disaggregated the improvement cost values in urban areas by functional class and by urbanized area size. Three population groupings were used: small urban (populations of 5,000 to 49,999), small urbanized (populations of 50,000 to 200,000), and large urbanized (populations of more than 200,000). However, the data used to create values for the large urbanized areas did not include a significant number of projects in very large urbanized areas, and concerns were raised about the degree of construction cost comparability within this category.

For the 2006 C&P Report, additional project cost data were collected for large urbanized areas, rural mountainous regions, and high-cost capacity improvements. These data were used to update the HERS improvement cost matrix, which was also modified to include a new category for major urbanized areas with populations of more than 1 million. The HERS improvement cost matrix was adjusted further for the 2008 C&P Report based on some additional analysis of the data previously collected. For this report, no changes were made to the cost matrix except to adjust it for the change in the National Highway Construction Cost Index between 2006 and 2008.

Exhibit A-4 identifies the costs per lane mile assumed by HERS for different types of capital improvements. For rural areas, separate cost values are applied by terrain type and functional class, while costs are broken down for urban areas by population area size and type of highway. These costs are intended to reflect the typical values for these types of projects in 2006, and thus do not reflect the large variation in cost among projects of the same type even in a given year. Such variation is evident in the project-level data on which these typical values are based, and are attributable to a number of location-specific factors. For example, the costs assumed for highway widening projects will be predicated on each section having a number of bridges typical for its length, but in reality some sections will have more bridges than other sections of equal length, which adds to costs. Among other factors that could make costs unusually high are complicated interchanges, major environmental issues, and/or other extreme engineering issues.

The values shown for adding a lane at "Normal Cost" reflect costs for projects where sufficient right-of-way is available or could be readily obtained to accommodate additional lanes. The values for adding lane equivalents at "High Cost" are intended to reflect situations in which conventional widening is not feasible and alternative approaches would be required in order to add capacity to a given corridor. Such alternatives would include the construction of parallel facilities, double-decking, tunneling, or the purchase of extremely expensive right-of-way. While HERS models these lane equivalents as though they are part of existing highways, some of this capacity could come in the form of new highways or investment in other modes of transportation.

Allocating HERS Results Among Improvement Types

Highway capital expenditures can be divided among three types of improvements: system rehabilitation, system expansion, and system enhancements (see Chapters 6 and 7 for definitions and discussion). All improvements selected by HERS that do not add lanes to a facility were classified as part of system rehabilitation. Highway projects that add lanes to a facility normally include resurfacing or reconstructing the existing lanes. HERS therefore splits the costs of such projects between system rehabilitation and system expansion.

Exhibit A-4

Typical Costs per Lane Mile Assumed in HERS, by Type of Improvements

(Thousands of 2008 Dollars per Lane Mile)

Category	Reconstruct and Widen Lane	Reconstruct Existing Lane	Resurface and Widen Lane	Resurface Existing Lane	Improve Shoulder	Add Lane Normal Cost	Add Lane Equivalent High Cost	New Alignment Normal	New Alignment High
Rural									
Interstate									
Flat	$1,730	$1,130	$979	$401	$75	$2,224	$3,083	$3,083	$3,083
Rolling	$1,940	$1,159	$1,127	$427	$123	$2,411	$3,902	$3,902	$3,902
Mountainous	$3,678	$2,539	$1,868	$632	$258	$7,507	$8,788	$8,788	$8,788
Other Principal Arterial									
Flat	$1,351	$905	$817	$322	$50	$1,782	$2,550	$2,550	$2,550
Rolling	$1,525	$930	$928	$359	$83	$1,908	$3,079	$3,079	$3,079
Mountainous	$2,963	$2,094	$1,799	$507	$110	$6,734	$7,755	$7,755	$7,755
Minor Arterial									
Flat	$1,236	$795	$761	$285	$47	$1,619	$2,274	$2,274	$2,274
Rolling	$1,492	$880	$947	$307	$86	$1,856	$2,928	$2,928	$2,928
Mountainous	$2,479	$1,625	$1,799	$422	$195	$5,685	$6,822	$6,822	$6,822
Major Collector									
Flat	$1,301	$842	$786	$291	$60	$1,682	$2,272	$2,272	$2,272
Rolling	$1,424	$855	$884	$309	$81	$1,719	$2,796	$2,796	$2,796
Mountainous	$2,159	$1,338	$1,287	$422	$124	$3,640	$4,754	$4,754	$4,754
Urban									
Freeway/Expressway/Interstate									
Small Urban	$2,822	$1,954	$2,224	$474	$87	$3,540	$11,589	$4,771	$16,287
Small Urbanized	$3,033	$1,971	$2,300	$561	$115	$3,894	$12,709	$6,431	$21,955
Large Urbanized	$4,838	$3,226	$3,563	$753	$435	$6,474	$21,713	$9,433	$32,203
Major Urbanized	$9,676	$6,452	$6,914	$1,247	$869	$12,948	$53,991	$18,866	$72,173
Other Principal Arterial									
Small Urban	$2,459	$1,660	$2,035	$398	$88	$3,009	$9,829	$3,762	$12,838
Small Urbanized	$2,631	$1,680	$2,127	$470	$118	$3,260	$10,690	$4,641	$15,840
Large Urbanized	$3,759	$2,462	$3,113	$591	$379	$4,771	$15,941	$6,370	$21,744
Major Urbanized	$7,517	$4,925	$6,225	$954	$758	$9,542	$36,990	$12,740	$55,150
Minor Arterial/Collector									
Small Urban	$1,812	$1,254	$1,539	$291	$64	$2,222	$7,198	$2,714	$9,264
Small Urbanized	$1,899	$1,268	$1,553	$331	$78	$2,342	$7,608	$3,330	$11,367
Large Urbanized	$2,556	$1,695	$2,124	$406	$213	$3,246	$10,778	$4,334	$14,792
Major Urbanized	$5,112	$3,391	$3,213	$676	$426	$6,492	$36,990	$8,668	$45,774

Source: Highway Economic Requirements System.

Growth in Value of Travel Time

Among the sensitivity tests in Chapter 10 was varying the value of travel time by 25 percent from the value standard in HERS. As that chapter explained, the standard values are based on wage and income levels prevailing in the base year for the analysis and are assumed to remain constant over the 20-year analysis period. More realistically, the value of travel time will increase over time due to growth in real wages and incomes. According to the U.S. National Income and Product Accounts (NIPA), average hourly labor compensation of employees increased by 68 percent from 1995 through 2008, while the price index for personal consumption expenditure increased by 33 percent. Real wages, which measure wage growth after adjusting for purchasing power being eroded by inflation, grew at an average annual rate of about 1.8 percent based on these statistics. If real wages were to grow at the same rate over the 20-year period analyzed in this report, 2009–2028, the average real wage at the end of the period would be 22 percent higher than in the base year. To increase the value of time by 25 percent above the base year value would be a reasonable allowance in HERS for future economic growth.

One could come up with possibly lower estimates of real wage growth over the 1995–2008 period using alternative measures of wage growth and consumer price inflation. For real wage growth from 1975 to 2005, Fitzgerald[2] found that some combinations of measures produced by the Bureau of Labor Statistics (BLS) yielded a picture of stagnation or even slight decline. The study also found, however, that the measures from NIPA—also used in the calculations above—are more adequate. In particular, the BLS measure of average hourly earnings excludes supplements to wages, which have become an increasingly important part of compensation over time (due in no small part to the growth of employer costs for employee health benefits).

HERS Revenue and Pricing Analysis

The 2006 edition introduced into the C&P report the modeling of (1)congestion pricing and (2) budgetary linkages between highway spending and highway user taxes. The baseline analyses presented in Chapters 7 and 8 of this edition use neither procedure, but a supplemental analysis in Chapter 9 applies them both separately and in conjunction.

HERS Congestion Pricing Analysis

The congestion pricing procedures in HERS simulate the impacts of imposing peak-period charges on all relatively congested (V/SF>0.80) sections of Federal-aid highways. The procedures are designed to accommodate the model's current lack of a capability to predict the impacts of such charges on the distribution of traffic between the peak and off-peak periods. The limitations of the HPMS database, exacerbated by the sparseness of related evidence from the research literature, would make adding this capability a major challenge. The current congestion pricing procedures utilize the existing equations in HERS in combination with auxiliary assumptions.

The existing equations are used to simulate the impacts of an all-day charge per VMT on each relatively congested section. The charge varies among sections, generally being higher where congestion is more severe; but being uniform across the day, it may also be thought of as a VMT tax imposed on congested sections. The HERS model estimates for each section the optimal charge based on the cost of delay created by an extra mile of peak-period travel (as discussed in the Introduction to Part II) and the impact of the charge on daily VMT. To derive from these results predictions for peak-period congestion charges, the model assumes in essence that (1) the optimal peak-period charge would be the same as the estimated all-day charge and (2) the impact of peak-period charges on daily VMT would equal the impact of all-day charges on VMT multiplied the peak-period share of VMT (before pricing). These auxiliary assumptions both have a strong influence on the computations, with potential to introduce significant error. Using a model that can realistically simulate peak-period charges including their impacts on travel time-of-day decisions would clearly be preferable. For future editions of the C&P report, the FHWA will be exploring possibilities for more realistically modeling peak-period within HERS and for obtaining supplementary evidence from other modeling frameworks, such as urban transportation planning models.

HERS Revenue Analysis

The HERS revenue analysis procedures provide the option of imposing a "balanced budget" constraint with the aim of funding any modeled change in highway investment from the base-year level through an assumed surcharge on highway users. The surcharge may be applied on a per-mile or per-gallon basis, and will be negative when HERS considers spending levels below the base-year level. A negative surcharge, or rebate, represents the equivalent of reductions in existing user charges such as tolls or fuel taxes.

The first step in the procedure is to determine the amount of revenue that must be raised to reach a target funding level. This calculation is based on the difference between the average annual funding level projected in the HERS model run and and the actual level of HERS-related expenditures in the base year (2008 in this edition of the C&P report). This difference is then multiplied by the ratio of the base-year ratio of total highway capital spending to HERS-related expenditures on the assumption that this ratio will be maintained in the future. Highway capital spending that is not HERS-related includes spending on bridge rehabilitation and replacement, on system enhancement, and on the functional systems not modeled in HERS (rural minor collector, rural local, and urban local). Of the change in total highway capital spending, the percentage that will be funded with highway user tax revenue is model user-determined.

The next step in the procedure is to solve iteratively for the surcharge rate that will generate the required change in highway user tax revenue. The solution process is iterative to allow that the level of surcharge would affect the size of the associated tax base (VMT or fuel consumption). The iterations start with calculation of the tax rate by dividing the required revenue change by the HERS projection for total VMT or fuel consumption. After re-running the computations to take account of the influence of the tax on VMT or fuel consumption, the surcharge rate is recalculated followed by another simulation to adjust for this revision to the surcharge, and so forth until an equilibrium is reached. (At the equilibrium surcharge, the total VMT that enters the calculation of the surcharge is the same as the amount of VMT that the model projects would result from this surcharge.)

The revenue and surcharge calculations are repeated sequentially for each funding period. However, in evaluating the potential implementation of a highway improvement in a given funding period, HERS assumes that the surcharge tax rate in that period is carried forward into future periods during which benefits from the improvement continue to accrue. Another limitation of the procedure is the omission of surcharge impacts on the bases of existing fuel taxes. HERS incorporates the influence of these taxes on the demand for highway travel (VMT), but does not calculate changes in total revenue from these taxes resulting from changes in VMT or future fuel economy. In this, as in previous editions of the C&P report, the analysis does not directly address the issue of the sustainability of current highway financing structures and does not attempt to identify changes in revenue mechanisms or tax rates that might be required to sustain highway capital spending at the base-year levels in constant dollar terms.

Linking Congestion Pricing With Revenue Analysis Procedures

For HERS analyses in which both the congestion pricing and the revenue analysis procedures are enabled, the model takes into account the total revenue that is required to achieve the target funding level specified as well as the revenue that would be generated from the variable congestion pricing charges. In cases where the congestion pricing revenue exceeds the amount of total revenue required, a negative fixed rate all day surcharge is imposed, which has the effect of shifting some costs from off-peak highway users to peak-period highway users.

Because the all-day surcharge and the peak-period congestion charge both impact travel volumes through the travel demand elasticity procedures described above, the process of developing a new equilibrium volume and price is significantly more complex for analyses that incorporate both the congestion pricing and the revenue analysis procedures.

(Endnotes)

[1] B. Yacobucci and R. Bamberger, *Automobile and Light Truck Fuel Economy: The CAFE Standards*, Congressional Research Service Report for Congress, Order Code RL33413, 2008.

[2] T.J. Fitzgerald, "Has Middle America Stagnated? A Closer Look at Hourly Wages," *The Region*, Federal Reserve Bank of Minneapolis, 2007.

Appendix B

Bridge Investment Analysis Methodology

Bridge Investment Analysis Methodology

The National Bridge Investment Analysis System (NBIAS) was developed over the past 15 years as a tool for assessing national bridge investment needs and the trade-off between funding and performance. NBIAS, first introduced in the 1999 edition of the C&P report, is used to model investments in bridge repair, rehabilitation, and functional improvements. Over time, the system has been used increasingly as an essential decision support tool for analyzing policy and for satisfying the information needs of the U.S. Congress.

The NBIAS is based on an analytical framework similar to that used in the Pontis bridge program first developed by the Federal Highway Administration (FHWA) in 1992 and subsequently taken over by the American Association of State Highway and Transportation Officials (AASHTO). It incorporates economic forecasting analysis tools to project the multiyear funding needs required to meet user-selected performance metrics over the length of a user-specified performance period. The NBIAS is modified to work with bridge condition as reported by the States for the National Bridge Inspection System as well as the element/condition State inspection regime used in Pontis. The NBIAS combines statistical models with engineering judgment and heuristic rules to synthesize representative condition units so that they can be defined and manipulated using the same structure of condition states, actions, deterioration, costs, and effectiveness probabilities used in Pontis, making them compatible with Pontis' predictive models and analytical routines.

This appendix contains a technical description of the methods used in NBIAS to predict future nationwide bridge conditions and analyze bridge investment, including information on the system overview and determination of functional needs and of repair and rehabilitation needs.

NBIAS Overview

The NBIAS is an analysis tool used to analyze the investment needs associated with bridge repair, rehabilitation, and functional improvements. The system can be used to examine the backlog of needs, in dollars and number of bridges; distribution of work done, in dollars and number of bridges; agency and user benefits; benefit-cost ratios for work performed; and physical measures of bridge conditions. Outcomes can be presented by type of work, functional classification, whether the bridges are part of the National Highway System, and/or whether the bridges are part of the Strategic Highway Network.

Using the linear programming optimization of elements in the network, NBIAS generates a set of prototype maintenance policies for defined subsets of the Nation's bridge inventory. Models of element deterioration, feasible actions, and the cost and effectiveness of those actions are incorporated as major inputs for each subset of the inventory.

For functional deficiencies and improvements, NBIAS uses a model similar to the bridge level of service standards and user cost models of Pontis augmented by a bridge improvement model developed by Florida Department of Transportation (DOT).

Methodology

With a set of synthesized projects developed from the maintenance and functional improvement models, NBIAS calculates a trade-off structure showing the effect of hypothetical funding levels on each of more than 200 performance measures. For this analysis, it utilizes an adaptation of an incremental benefit-cost model with a graphical output showing the trade-off between funding and performance. To estimate functional improvement needs, NBIAS applies a set of improvement standards and costs, which can be modified by the user, to each bridge in the National Bridge Inventory (NBI). The system uses the available NBI data to predict detailed structural element data for each bridge. The system measures repair and rehabilitation needs at the bridge element level using the Markov decision model and then applies the obtained maintenance strategy, along with the improvement model, to each individual bridge.

Determining Improvement Costs

The replacement costs for structures are determined based on State-reported values provided by the FHWA. Improvement costs are based on default costs from Pontis adjusted to account for inflation. In evaluating functional improvement needs and repair and rehabilitation needs, the system uses a set of unit costs of different improvement and preservation actions.

Determining Functional Improvement Needs

The standards for functional improvement include standards for lane widths, shoulder width, load ratings, and clearances (vertical and horizontal). The NBIAS includes a set of standards by functional class and additional standards derived from Sufficiency Rating calculations, as well as those prescribed by the models developed at Florida DOT.

The standards used in NBIAS initially were set to be the same as those specified by default in Pontis, which were established as an early effort to define level of service standards for AASHTO. The standards used in the previous editions of the C&P report were reviewed and compared with design standards in the AASHTO Green Book, and adjustments were made where warranted. A revised set of standards has subsequently been added that triggers consideration of a functional improvement whenever there is a deduction in Sufficiency Rating as a result of a lane width, load rating, or clearances. The adoption of the Florida improvement model allowed further fine tuning of the analysis logic of functional needs.

The NBIAS determines needs for the following types of bridge functional improvements: widening existing bridge lanes, raising bridges to increase vertical clearances, and strengthening bridges to increase load-carrying capacity. Functional improvement needs are determined by applying user-specified standards to the existing bridge inventory, subject to benefit-cost considerations. For instance, a need to raise a bridge will be identified if the vertical clearance under the bridge fails to meet the specified standard and if the increased cost of diverting commercial vehicles around the bridge exceeds the cost of improving the bridge.

Because the benefit predicted for a functional improvement increases proportionately with the amount of traffic, the determination of whether a functional improvement is justified and the amount of benefit from the improvement is heavily dependent upon predicted traffic. In the current version of NBIAS, traffic predictions are made for each year in an analysis period based on NBI data. The NBIAS allows the user to apply either linear or exponential traffic growth projections. Linear growth was selected for this edition of the C&P report, consistent with the assumption used in the Highway Economic Requirements System (HERS).

When NBIAS selects a structure for replacement, the cost of the replacement is based on the number of lanes on the existing bridge. The cost of adding lanes to satisfy increased capacity needs is not included in the cost to construct the replacement structure. Additional costs for expanding bridges to meet increased capacity demands are included in the cost to construct a lane-mile of highway used in the HERS model.

Determining Repair and Rehabilitation Needs

To determine repair and rehabilitation needs, NBIAS predicts the elements that exist on each bridge in the U.S. bridge inventory and applies a set of deterioration and cost models to the existing bridge inventory. This allows NBIAS to determine the optimal preservation actions for maintaining the bridge inventory in a state of good repair while minimizing user and agency costs.

Predicting Bridge Element Composition

The NBIAS analytical approach relies on structural element data not available in the NBI. To develop this data, NBIAS uses a set of Synthesis, Quantity, and Condition (SQC) models to predict the elements that exist on each bridge in the NBI and the condition of those elements.

The current version of NBIAS has the capability to accept the direct import of structural element data where these data are available, but this capability was not used for the development of this report. While most of the States now routinely collect such data on State-owned bridges as part of the bridge inspection process, these data are not currently part of the NBI data set. It is expected that, in the future, structural element data may be provided by some or all States. It should be noted, however, that locally owned bridges may not have structural element data available. Once a mechanism is established for sharing these data, they could be incorporated in future NBIAS analyses to improve the prediction of bridge element composition.

Calculating Deterioration Rates

The NBIAS takes a probabilistic approach to modeling bridge deterioration based on techniques first developed for Pontis. In the system, deterioration rates are specified for each bridge element through a set of transition probabilities that specify the likelihood of progression from one condition state to another over time. For each element, deterioration probability rates vary across nine climate zones.

Applying the Preservation Policy

Using transition probability data, together with information on preservation action costs and user costs for operating on deteriorated bridge decks, NBIAS applies the Markov decision model to determine the optimal set of repair and rehabilitation actions to take for each bridge element based on the element's condition. During the simulation process, the preservation policy is applied to each bridge in the NBI to determine bridge preservation work needed to minimize user and agency costs over time.

Because the current version of the system models maintenance, repair, and rehabilitation needs for each bridge, the cost of performing preservation work can be compared with the cost of completely replacing a bridge. The NBIAS may determine that replacement of a bridge is needed if replacement is the most cost-effective means to satisfy the existing needs. Alternatively, if the physical condition of the bridge has deteriorated to a point where the bridge is considered unsafe (where the threshold for such a determination is specified by the system user), the system may consider bridge replacement to be the only feasible alternative for the bridge.

Expert Peer Review Panel

Peer reviews by panels of outside experts are an effective way to ensure that the methodologies and analytical tools used in the C&P report continue to meet acceptable standards of technical merit. Under the Office of Management and Budget's *Final Information Quality Bulletin for Peer Review,* such reviews are also required for any "highly influential scientific disseminations," a category that includes the C&P tools used for analyzing highway and bridge investments, HERS and NBIAS.

Both HERS and NBIAS have been subject to ongoing updates since their initial development. To ensure that significant conceptual changes in the models are scientifically sound, the FHWA periodically subjects the models to technical reviews by panels of outside experts. This vetting process is beneficial, providing feedback and helping to point the way for future research, as well as establishing the credibility of the models within the transportation community. A technical review focusing on the construction cost inputs applied in both models was conducted in 2009.

The review panel included a mix of State practitioners, university researchers, and consultants, with different areas of relevant expertise including highway and bridge engineering and construction, economics, and asset management. The panelists were asked to consider their recommendations and suggestions within the context of four focus areas:

- Review of Cost Data Currently Being Used in HERS and NBIAS
- Recommendations for Determining Cost Factors in the Future
- Consideration and Input on Adjusting the Cost Factors in the 2010 and 2012 C&P Reports
- Long-Term Approaches for Developing Cost Data for the C&P Report.

Some of the key recommendations of the panel regarding NBIAS were as follows:

- Unit cost inputs should be updated more frequently to account for changes in relative costs.
- The costs of risk mitigation activities should be included.
- The potential to measure costs on a bridge component level should be explored.
- A study should be conducted to gather construction cost data from States to estimate unit costs.
- The NBIAS software should be adapted to analyze culverts.

The final report of the panel will be made available at http://www.fhwa.dot.gov/policy/otps/index.htm.

Appendix C

Transit Investment Analysis Methodology

Transit Investment Analysis Methodology

The Transit Economics Requirements Model (TERM), an analytical tool developed by the Federal Transit Administration (FTA), forecasts transit capital investment needs over a 20-year horizon. Using a broad array of transit-related data and research including data on transit capital assets, current service levels and performance, projections of future travel demand, and a set of transit asset specific condition decay relationships, the model generates the forecasts that appear in the biennial C&P report.

This appendix provides a brief technical overview of TERM and describes the various methodologies used to generate the estimates for the 2008 C&P Report.

Transit Economics Requirements Model

TERM forecasts the level of annual capital expenditures required to attain specific physical condition and performance targets within a 20-year period. These annual expenditure estimates cover the following types of investment needs: (1) asset preservation (rehabilitations and replacements); and (2) asset expansion to support projected ridership growth.

TERM Database

The capital needs forecasted by TERM rely on a broad range of input data and user-defined parameters. Gathered from local transit agencies and the National Transit Database (NTD), the input data are the foundation of the model's investment needs analysis, and include information on the quantity and value of the Nation's transit capital stock. The input data in TERM are used to draw an overall picture of the Nation's transit landscape; the most salient data tables that form the backbone of the TERM database are described below.

Asset Inventory Data Table

The asset inventory data table documents the asset holdings of the Nation's transit operators. Specifically, these records contain information on each asset's type, transit mode, age, and expected replacement cost. As the FTA does not directly measure the condition of transit assets, asset condition data are not maintained in this table. Instead, TERM uses asset decay relationships to estimate the current and future physical condition as required for each model run. These condition forecasts are then used to determine when each type of asset identified in the asset inventory table is due for either rehabilitation or replacement. The decay relationships are statistical equations that relate asset condition to asset age, maintenance, and utilization. The decay relations and how TERM estimates asset conditions are further explained later in this appendix.

The asset inventory data are derived from a variety of sources including the NTD, responses by local transit agencies to the 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. Note that the FTA does not currently require agencies to report on all asset types (with the exception of data for revenue vehicles, these data are provided only when requested). Furthermore, the transit industry has no standards for collecting or recording such data. Because of this, TERM analyses must rely on asset inventory data in the format and level of detail as provided by those agencies that respond to the FTA's asset data requests. Hence the accuracy and consistency of TERM's estimates of asset needs would benefit from the availability of consistent and ongoing reporting of local agency asset holdings, including those assets types, ages, modes and replacement values.

Urban Area Demographics Data Table

This data table stores demographic information on close to 500 large-, medium-, and small-sized urbanized areas as well as for 10 regional groupings of rural operators. Fundamental demographic 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 data on each of the individual modes operated by approximately 700 urbanized transit agencies and more than 1,000 rural operators. Specifically, the agency-mode data on annual ridership, passenger miles, operating and maintenance costs, mode speed, and average fare data are used by TERM to help assess current transit performance, future expansion needs, and the expected benefits from future capital investments in each agency-mode (both for preservation and expansion). All the data in this portion of the TERM database come from the most recently published NTD reporting year. Where reported separately, directly operated and contracted services are both merged into a single agency-mode within this table.

Asset Types Data Table

The asset types data table identifies approximately 500 different asset types utilized by the Nation's public transit systems in support of transit service delivery (either directly or indirectly). Each record in this table documents each asset's type, unit replacement costs, and the expected timing and cost of all life-cycle rehabilitation events. Some of the asset decay relationships used to estimate asset conditions are also included in this data table. The decay relationships—statistically estimated equations relating asset condition to asset age, maintenance, and utilization—are discussed more in the next section of this appendix.

Benefit-Cost Parameters Data Table

The benefit-cost parameters data table contains values used to evaluate the merit of different types of transit investments forecasted by TERM. Measures in the data table include transit rider values (e.g., value of time and links per trip), auto costs per VMT (e.g., congestion delay, emissions costs, and roadway wear), and auto user costs (e.g., automobile depreciation, insurance, fuel, maintenance, and daily parking costs).

Mode Types Data Table

The mode types data table provides generic data on all of the mode types used to support U.S. transit operations— including their average speed, average headway, and average fare—and estimates of transit riders' responsiveness to changes in fare levels. Similar data are included for non-transit modes, such as private automobile and taxi costs. The data in this table are used to support TERM's benefit-cost analysis.

The input tables described above form the foundation of TERM, but are not the sole source of information used when modeling investment forecasts. In combination with the input data, which are static—meaning that the model user does not manipulate them from one model run to the next—TERM contains user-defined parameters to facilitate its capital expenditure forecasts.

Investment Policy Parameters

As part of its investment needs analysis, TERM predicts the current and expected future physical condition of U.S. transit assets over a 20-year horizon. These condition forecasts are then used to determine when each of the individual assets identified in the asset inventory table are due for either rehabilitation or replacement. The investment policy parameters data table allows the model user to set the physical condition ratings at which rehabilitation or replacement investments are scheduled to take place (though the actual timing of rehab 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 2010 C&P Report, all of TERM's replacement condition thresholds have been set to trigger asset replacement at condition 2.50 (under the **Sustain Current Spending scenario**, many of these replacements would be deferred due to insufficient funding capacity).

In addition to varying the replacement condition, users can also 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 shut down. Users can also assume assets are replaced either by agency (force-account) or by contracted labor. Each of these affects the cost of asset replacement for rail assets.

Financial Parameters

TERM also includes two key financial parameters. First, the model allows the user to establish the rate of inflation used to escalate the cost of asset replacements for TERM's needs forecasts. Note that this feature is not used for the C&P report, which reports all needs in current dollars. Second, users can adjust the discount rate used for TERM's benefit-cost analysis.

Investment Categories

The data tables described above allow TERM to estimate different types of capital investments, including rehabilitation and replacement expenditures, expansion investments, and capital projects aimed at performance improvements. These three different investment categories are described below.

Asset Rehabilitation and Replacement Investments

TERM's asset rehabilitation and replacement forecasts are designed to estimate annual funding needs for the ongoing rehabilitation and replacement of the Nation's existing transit assets. Specifically, these needs include the normal replacement of assets reaching the end of their useful life, mid-life rehabilitations, and annual "capital expenditures" to cover the cost of smaller capital reinvestment amounts not included as part of asset replacement or rehabilitation activities.

To estimate continuing replacement and rehabilitation investments, TERM estimates the current and expected future physical condition of each transit asset identified in TERM's asset inventory for each year of the 20-year forecast. These projected condition values are then used to determine when individual assets will require rehabilitation or replacement. TERM also maintains an output record of this condition forecast to assess the impacts of alternate levels of capital reinvestment on asset conditions (both for individual assets and in aggregate). In TERM, the physical conditions of all assets are measured using a numeric scale of 5 through 1; see *Exhibit C-1* for a description of the scale.

Exhibit C-1

Definitions of Transit Asset Conditions

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

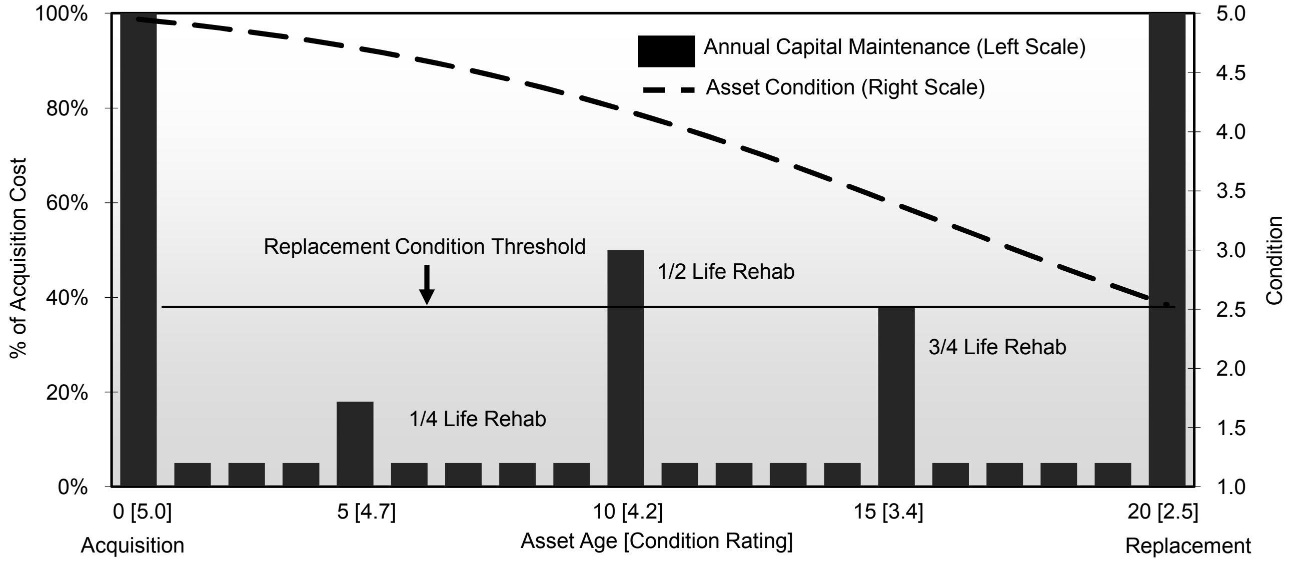
Source: Transit Economic Requirements Model.

TERM 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 re-investment event as a model output and adds it to the tally of national investment needs (provided they pass a benefit-cost test, if applied).

TERM's process of estimating rehabilitation and replacement needs is represented conceptually for a generic asset in *Exhibit C-2*. In this theoretical example, asset age is shown on the horizontal axis, the cost of life-cycle capital investments is shown on the left-vertical axis (as a percent 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 lifecycle 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

Template for Assignment of Asset Condition



Asset Expansion Investments

In addition to devoting capital to the preservation of existing assets, most transit agencies invest in expansion assets to support ongoing growth in transit ridership. To simulate these expansion needs, TERM continually invests in new transit fleet capacity as required to maintain at current levels the ratio of peak vehicles to transit passenger miles. The rate of expansion is projected individually for each of the Nation's roughly 500 urbanized areas (e.g., based on the urbanized area's specific growth rate projections or historic rates of transit passenger mile growth) while the expansion needs are determined at the individual agency-mode level. TERM will not invest in expansion assets for agency-modes with current ridership per peak vehicle levels that are well below the national average (these agency modes can become eligible for expansion during a 20-year model run if there is sufficient projected growth in ridership for them to rise above the expansion investment threshold).

In addition to forecasting fleet expansion requirements to support the projected ridership increases, the model also forecasts expansion investments in other assets needed to support that fleet expansion. This includes investment in maintenance facilities and, in the case of rail systems, additional guideway miles including guideway structure, trackwork, stations, train control, and traction power systems. Like other investments forecast by the model, TERM can subject all asset expansion investments to a benefit-cost analysis. Finally, as TERM adds the cost of newly acquired vehicles and supporting infrastructure to its tally of investment needs, it also ensures that the cost of rehabilitating and replacing the new assets is accounted for during the 20-year period of analysis.

The rate of growth in transit passenger miles underlying these asset expansion investments have typically been based on growth rate projections obtained from a sample from the Nation's 20 to 30 largest Metropolitan Planning Organizations. For this edition of the C&P report, urbanized-area–specific historic growth rates have also been used. Note that if the *actual* growth rate that materializes in the future is less than the current *projected* rate of increase, then the level of expansion will be higher than that required to maintain current service and service quality will improve.

Benefit-Cost Calculations

Before being added to the final tally of the Nation's public transit needs, investments forecasted by TERM may be required to pass a benefit-cost test. This benefit-cost test was applied across all investment scenarios for previous editions of the C&P report but was not utilized for the State of Good Repair benchmark of the current report.

When the benefit-cost test is applied, each investment must generate a stream of investment benefits that equals or exceeds the sum of discounted capital and operating costs (during the 20 years of the model run) to be included in the model's tally of national transit needs. Conversely, investments with a benefit-cost ratio of less than 1.0 are not included in TERM's tally of investment needs.

Benefit calculations utilized by TERM are limited to those that are readily quantifiable using publicly available data, such as those available in NTD. Benefits generally fall into two different categories: (1) benefits to transit riders and (2) benefits to society.

Most of the benefits from investment in public transit accrue to new and existing transit riders. Benefits for riders may include travel time savings, reduced costs associated with operating a motor vehicle, improved mobility, and improved quality of service. To quantify these benefits, TERM compares the sum of user costs for a trip when transit investments have been made with the sum of these costs for a trip when no transit investments have been made. In most instances, this means comparing riders' costs on the selected transit mode with the riders' costs on the mode that is the next-best alternative (TERM considers a range of potential alternatives).

Although consumers tend to be the primary beneficiaries of new transit investments, society as a whole often benefits as well, principally in the form of cost reductions. Cost savings to society include reductions in highway congestion, air and noise pollution, greenhouse gases, energy consumption, and automobile accidents; these benefits result from a portion of potential highway users selecting transit as their preferred alternative. These types of cost reductions are calculated on a per-automobile-VMT basis using publicly available data.

Although TERM calculates the value of these types of benefits across investment types, the model uses somewhat different methodologies to evaluate the costs and benefits of different kinds of investments.

Benefit-Cost Calculations for Preservation and Expansion Investments

For this edition of the C&P report, all of TERM's benefit-cost tests are performed in a multi-step sequence. In each step, the test is performed at the agency-mode level. First, the test evaluates the total discounted benefits and costs associated with continued reinvestment and expansion (both capital and operating) of each individual agency mode. This means that the effectiveness of all capital investments required to maintain that agency-mode's ongoing operations, holding asset conditions and performance levels constant, are evaluated jointly rather than as individual investments. If the benefits exceed the capital expenditures (i.e., the benefit-cost ratio is greater than 1.0), then TERM includes all of the agency-mode's preservation and expansion needs in the tally of national capital investment needs.

If, in contrast, the agency-mode fails this first step of TERM's benefit-cost test, then TERM conducts a supplemental analysis to determine whether the agency-mode combination will pass the benefit-cost test if TERM's proposed expansion investments are excluded from the analysis. If the agency-mode passes this lower-level test, then that agency-mode's preservation needs (but not expansion needs) are included in the tally of 20-year national transit needs.

Finally, if an agency mode fails this second test, it is re-evaluated a third and final time using the "partial" benefit cost test. The partial test operates under the assumption that there are diminishing returns to transit investment such that (1) if less productive (i.e., lower benefit generating) assets are removed from benefit-cost consideration, then the overall benefit-cost ratio for the agency mode will improve; and (2) if a sufficient number of the lowest benefit-producing assets are removed, the overall benefit-cost ratio for the remaining assets will attain a passing value of 1.0. Within TERM, the proportion of assets allowed to pass the partial benefit-cost test is determined based on the benefit-cost ratio as determined in the prior step of the benefit-cost test. Specifically, most of the assets of agency-modes with a "total" benefit-cost ratio close to (but not over) 1.0 will be allowed to pass the partial benefit-cost test. In contrast, only a small proportion of agency-mode assets will pass the partial benefit-cost test if that agency-mode has a very low "total" benefit cost ratio (e.g., under 0.2).

Appendix D

Crosscutting Investment Analysis Issues

Crosscutting Investment Analysis Issues

Introduction

The 2008 C&P Report included an Afterword (Part IV) that comprehensively discussed limitations of the modeling and databases used for the report's analysis as well as possible remedies. This Appendix updates that Afterword by discussing recent progress and plans. It further explores select issues that recent developments have made more relevant. The economic slow-down from which the Nation is now emerging has stimulated interest in the impacts of transportation investments on aggregate employment and on U.S. economic competitiveness—impacts which have always been difficult to measure. The increased policy emphasis at the U.S. DOT on livability, sustainability, and maintenance of transportation assets in a state of good repair has likewise moved certain modeling challenges to the fore. The structure of the discussion in this appendix largely follows that of the 2008 C&P Report Afterword so that readers can more easily refer back to that section for discussion of the many issues that have not been revisited.

Conditions and Performance

Pavement Condition

In recent years, the Federal Highway Administration (FHWA) has collected and used data based on the International Roughness Index as its primary indicator for pavement condition. The advantages of this metric include objectivity and a focus on a condition that, by influencing ride quality, directly affects road users. Disadvantages include failure to adequately reflect pavement structural problems that do not manifest themselves simply through roughness. A related concern, particularly in light of ongoing efforts to improve the life of pavement improvements, has been that the pavement performance models in the Highway Economic Requirements System (HERS) do not reflect modern pavement design. As part of the recent Highway Performance Monitoring System (HPMS) reassessment, the range of pavement data to be collected was expanded to include information on other pavement distresses (fatigue cracking, rutting depth, faulting depth, and transverse cracking) as well as additional information regarding the structure of existing pavements. This new information will be used in the improved pavement deterioration models which, when incorporated into the HERS model, will provide increased accuracy in the determination of pavement service lives.

The initial phase of implementing the enhanced pavement equations was to test them outside the overall HERS model. That phase has been successfully completed; and the second phase, incorporation of the equations into the HERS model, has started. Upon completion of the second phase, testing of the HERS model will be conducted. The goal is to have the improved HERS model with the new pavement deterioration equations available in time to be reflected in the analyses presented in the 2012 C&P Report.

Prior to the incorporation of the new pavement deterioration equations into HERS, only two types of pavement improvements were considered: resurfacing and reconstruction. The addition of new pavement data items and performance modeling procedures will allow for additional pavement improvements to be considered, including different degrees of reconstruction, different levels of resurfacing, and less aggressive pavement preservation techniques. As discussed in Chapter 7, the investment scenarios estimated in this report are for capital expenditures only and do not include ongoing routine maintenance. However, both the FHWA and State departments of transportation are paying increasing attention to preventive maintenance strategies as a means of extending the useful life of pavement improvements. To the extent that such strategies are successful, they can reduce the need for capital improvements to address pavement condition deficiencies, an effect that the investment models should account for where possible. Future improvements to the HERS model based on these new data and equations should facilitate the evaluation of tradeoffs between more aggressive preventive maintenance strategies and capital improvements.

Transit Asset Reporting

The Transit Economic Requirements Model's (TERM's) assessment of transit capital needs for both asset preservation and service expansion are heavily reliant on data that document the asset holdings of the Nation's urban and rural transit operators. However, with the exception of agency passenger vehicle fleets, local transit operators receiving Federal transit funding are not required to report asset inventory data documenting the types, quantities, ages, conditions, or replacement values of assets they use in support of transit service. Therefore, to obtain asset inventory data for use in TERM, the Federal Transit Administration (FTA) must periodically submit asset inventory data requests to the Nation's largest bus and rail operators and a sample of smaller operators. Given the absence of any standards for asset inventory recording or reporting, the response to these requests provides inventory data in a variety of formats and at varying levels of detail and quality. Moreover, the asset holdings of those agencies that either do not receive or do not effectively respond to these requests must be estimated (based on the asset composition and age distribution of agencies of comparable size).

TERM's estimates of national capital investment needs would clearly improve with a system that requires transit operators receiving Federal transit funding to report their asset holdings on a consistent and regular basis. The data would be comparable to the vehicle data the operators already provide and to the reported highway segment and bridge data used by HERS and the National Bridge Investment Analysis System (NBIAS). Moreover, given the FTA's objective of better understanding, assessing and tracking the state-of-good-repair of the Nation's transit assets, the agency would benefit from the availability of data documenting the rehabilitation history of at least a sample of asset types (such as passenger stations and maintenance facilities). The FTA has made initial efforts in this direction with consideration of expanding the items local transit agencies report to the National Transit Database (NTD) to include the age and quantity of major asset holdings. In addition to the potential for significantly improving the accuracy of TERM analysis results, developing this type of transit asset reporting system would ensure greater comparability of results between editions of the C&P report.

Therefore, the FTA is in the process of developing a reporting requirement for the complete asset inventories from all transit rail agencies. This new reporting requirement will supplement passenger vehicles data already reported by the Nations' transit operators with comparable data for other asset types, including facilities, stations, track and structures, and control systems. However, this new reporting requirement is not expected to include data on asset conditions as this information is expensive to collect and difficult for the FTA to verify. Though this data collection effort is anticipated to start with the 2013 NTD reporting year, actual implementation will depend on transit agencies' response to the Federal Register Notice of Proposed Rulemaking and on the Office of Management and Budget's response to the Paperwork Reduction Act request.

Vehicle Speed

The FHWA continuously considers ways to improve the metrics used in the HERS model to summarize highway operational performance. For example, the 2008 C&P report introduced a new metric, adjusted average user cost, to avoid confounding the influence on user costs of projected fuel economy improvements with the influence of highway infrastructure. For future editions of the C&P report, another innovation could be an alternative measure of average highway speed. The measure currently used in HERS is a vehicle miles traveled (VMT)-weighted average of predicted speeds across the individual highway sections. Although some readers of the report wanting to calculate total vehicle-hours of delay may divide total VMT by this measure of average speed, this would not yield the correct result. For the calculation to be correct, one would need to calculate average speed simply as the ratio of total VMT to total vehicle-hours of travel (VHT). For future reports, the presentation of HERS results could include this alternative measure of average speed, which, in technical terms is the VHT-weighted geometric mean, and which would be lower than the VMT-weighted averages currently used.

Vehicle Operating Costs

Growing concerns about energy independence and the environment costs of vehicle emissions have stimulated interest in the impacts of highway investments and policies on fuel consumption. Unfortunately, the modeling of the impacts on road fuel economy and, more generally, on vehicle operating costs is an area in which highway performance evaluation models have lagged. HERS, along with various other models (e.g., the FHWA's project evaluation tool, BCA.net), has relied primarily on decades-old evidence (from as far back as the 1960s), including foreign evidence that is not easily generalized to U.S. scenarios. For the impacts of pavement condition on vehicle operating costs, a principal source of evidence remains the results of tests conducted in Brazil in the 1970s on pavements typically rougher than those on U.S. roads. For the impacts of vehicle speed on vehicle operating costs, HERS relies on evidence that is dated and sheds only limited light on the effects of congestion delay. These effects are sometimes conceptualized as stemming partly from a reduction in average speed and partly from an increase in speed variability due to stop-and-go driving conditions. Reflecting the limitations of the evidence on which it draws, the HERS model allows for the speed variability effect only on signalized roadways. A more complete account of this effect would also extend to stop-and-go conditions on unsignalized facilities and in work zones.

To chart a course for improving the HERS treatment of vehicle operating costs, the FHWA will be convening an expert panel during FY 2011. The research literature to be reviewed by the panel will include the forthcoming report on National Cooperative Highway Research Program Project 01-45, *Models for Estimating the Effects of Pavement Condition on Vehicle Operating Costs*. The panel will also investigate the potential use of the Motor Vehicle Emission Simulator (MOVES) model, the EPA's state-of-the-art tool for estimating emissions from motor vehicles. Among the improvements over the MOBILE6 modeling software it replaced (from which the current emissions equations in HERS were derived), MOVES can predict the emissions of greenhouse gases (GHG) and energy consumption. Although these predictions do not factor in changes in pavement conditions, they are based on detailed modeling of the influence of vehicle operating speeds. This modeling takes account of the entire distribution of VMT by speed cycle, where a cycle describes the variation in speed over a short span of time. One of the questions for the review panel will be the feasibility of developing fuel consumption equations in HERS, which predicts only an all-day average speed, from this detailed modeling involving micro speed cycles. In common with MOBILE6, MOVES allow users to generate predictions when the only available indicator of the speed distribution is an all-day average, but the expert panel will need to evaluate this capability and its potential incorporation into HERS.

The review panel will also consider the possibilities for collecting additional field data for developing new vehicle operating cost equations. With the possibilities created by on-board vehicle computers, geographic information system (GIS)/global positioning system technologies, and other recent advances, the costs of collecting speed and fuel consumption data have declined dramatically, at the same time that data can be collected continuously, virtually second-by-second. Matching field data collected from the vehicles with the data on roadway characteristics would be more challenging, but is worth exploring.

Bridge Performance Issues

Future enhancements to NBIAS may provide the capability to take advantage of the GIS information in HPMS to permit integrated applications of the model and HERS. In costing the widening of a highway section, HERS already allows for the cost of widening the typical number of structures located on a facility of that type, but this allowance is relatively crude. By enabling NBIAS to identify the bridges on a particular HPMS section, such a linkage would also enable this replacement of this estimation procedure by a more accurate estimate derived from NBIAS. Also importantly, when HERS selects a particular highway section for widening, the link will enable NBIAS to update its database to reflect the associated improvements to the bridge. Since the models currently are run independently, NBIAS can select a bridge for replacement or rehabilitation to address deficiencies that have already been remedied as part of a widening project selected by HERS. Linking the two models could also enable improved identification of functional deficiencies on bridges, for example due to curvature characteristics on adjacent sections of highway, on which the HPMS includes data.

NBIAS rehabilitation and replacement investment analyses are based on major bridge component data from the National Bridge Inventory (NBI) on major bridge components; in many cases the data are aggregated from more detailed element-level data. Because the structural deterioration models used in NBIAS are employed at the element level, element conditions must be inferred from the aggregated component data. The need for such inferences would be avoided if the NBI reported the data at the element level.

Even without such detail being added, planned enhancements to NBIAS will more fully exploit available information:

1. **Preventive maintenance, repair, and rehabilitation (MR&R).** For most structural elements, NBIAS currently selects only bridges that have reached the worst or next-to-worst state of repair for MR&R actions. Consequently, the model allows bridges to deteriorate to a "structurally deficient" condition without prescribing any work. Thus, the planned enhancements to NBIAS include the development of a more aggressive model, starting with validation of the new model's usability followed by the changes needed for calibration.
2. **Measurement of bridge user costs.** Originally designed just to minimize agency costs, the NBIAS model was modified to minimize user costs only for deck elements. Additional modifications being planned will determine the time cost to bridge users that result from a broader set of deficiencies, structural (e.g., deck, superstructure and substructure) as well as functional. The time cost, formally measured by a "mean time to service interruption" (MTSI) will, in concept, allow for disruptions resulting from a deficiency before being remedied (e.g., heavy trucks having to divert around a load-posted bridge) as well as from the remedial bridge work. The MTSI for each bridge can be adjusted to reflect traffic (level and composition), environmental, and other factors such as detour length and crash rates. For structural deficiencies, NBIAS currently differentiates user costs only as a function of bridge size, without considering traffic volumes or other factors.
3. **Allowance for aging effects.** The deterioration probability matrix in NBIAS currently takes no account of bridge age. The probability that a bridge element will deteriorate from one state to another depends only on the element's current condition. Current plans for revising NBIAS include the incorporation of element age into the new MR&R model to be developed. Such an enhanced model would present deterioration probabilities as two-parametric Weibull functions of time (instead of constants, as they are now) and to develop an iterative procedure that will deliver a solution to the Markov decision model with accelerating deterioration probabilities. A separate effort would calibrate the Weibull curves so that the time-average deterioration pattern remains in line with the existing constant-rate deterioration pattern.

For the consequence of service interruption, a set of characteristics could be identified to determine the importance of the bridge to the overall highway network. These characteristics likely would include ADT, percentage of trucks, detour distance, etc. A range would be established for each characteristic and, after consideration of all characteristics, a given bridge can be placed within a spectrum of low to high consequence. The consequence rating can then be combined with the estimated probability of a bridge experiencing a service disruption, to establish the rating of each bridge on a risk criticality scale. Ratings would be calculated using the latest NBI data and available tools, and stored for use during NBI simulations. Later, the criticality models could be built into the main NBIAS system.

Since criticality is expressed in relative terms without monetary value, it cannot be factored into a benefit-cost ratio (BCR). One way to incorporate risk into NBIAS is to allow criticality to take precedence over an incremental BCR. This means that funds will be distributed first among the most critical bridges (in decreasing order of project incremental BCR), then among the next most critical, etc. An option could allow the user to select whether or not to use the enhanced risk model during a simulation.

Vehicle Emissions

The version of HERS used for this report added to the model's outputs the predicted emissions of greenhouse gases from consumption of gasoline and diesel fuel. As discussed in Appendix A, the measurement is limited to CO_2, which accounts for 95 percent of the global warming potential of vehicle emissions. Since CO_2 emissions are a function of the amount of fuel consumed, the potential improvements to the HERS equations for fuel consumption (discussed above) would also enhance the modeling of GHG emissions. As detailed in the 2005 Technical Report on the HERS-ST model, the HERS methodology for estimating vehicle emissions of other types (e.g., carbon monoxide, sulfur oxides, nitrogen oxides, and fine particulate matter) relies on the MOBILE6 model. For the 2012 C&P Report, FHWA plans to update this methodology to be consistent with the emission equations in the EPA MOVES model, which has replaced MOBILE6.

Transit Conditions, Reliability, and Safety

TERM's condition decay curves have provided an effective means of assessing current asset conditions and expected future conditions under alternative investment scenarios, but the FTA and the transit industry in general would benefit from an improved understanding of the relationship between asset conditions and key outcome measures such as service reliability, safety, and transit ridership. It is helpful to note in this context that the intended outcome of the FTA's heightened focus on state-of-good-repair is not to have assets in good condition per se, it is rather to ensure good quality, safe, reliable, and cost-effective transit service. Research and understanding on the relationships between condition and other outcome measures would also improve understanding of the merits of investment scenarios considered in future editions of this report.

Transit Vehicle Crowding by Agency-Mode

Given the nature and granularity of transit operating data as currently reported to the National Transit Database, most TERM analysis on transit operating performance is limited to the agency-mode level of detail (e.g., Houston metro bus is considered as a single agency-mode). Given this limitation, TERM is not capable of determining whether some or any portions of an agency-mode's existing service (e.g., specific rail lines or bus corridors) are in need of transit capacity improvements. Rather, TERM must assess expansion and performance improvement needs for the agency-mode as a whole, without consideration of the performance of individual service corridors (this is in contrast to the highway segment HPMS data used by HERS). In this regard, TERM would benefit from the availability of corridor-level operational data (e.g., level of service supplied and service consumed), if only for a sample of the Nation's transit operators, with which to better assess transit operator expansion needs at the subagency-mode level of detail).

Transportation Supply and Demand

Transportation Costs

The modeling supporting the C&P report has normally measured all costs and benefits in constant base-year dollars. The underlying assumption is not that inflation will be absent, but that ratios among prices and unit costs will remain at their base-year levels. For example, this would imply that the cost per hour of travel time will remain in constant ratio to the cost of depreciation per vehicle-mile. By incorporating the U.S. Energy Information Administration (EIA) projections that motor fuel prices will increase sharply relative to overall level of consumer prices (as measured by the Consumer Price Index), the 2008 edition of the C&P report is the first to make an exception to the constant-dollar assumption. Technically, this means that the HERS analysis in this report measures all benefits and costs in constant 2008 *consumer* dollars. For example, an average user of travel projected at $1.103 per mile in 2028 (from *Exhibit 7-8*, 0.00% change in spending) means more precisely that the average cost will equal $1.103 of foregone consumer expenditure at 2008 consumer prices. Among other possible exceptions to the constant dollar assumption, the projections for values of time and construction costs would warrant particular consideration in future modeling.

Cost of Travel Time

Although changes in relative prices are hard to predict—for example, the Malthusian fears widely held in the 1960s and 1970s that relative prices of food commodities would skyrocket have not been realized thus far—one trend that has characterized the broad sweep of modern economic history has been rises in real per capita incomes and wages. In the United States, some statistics have pointed to average real wages growth being stagnant over the past few decades, but a 2007 analysis from the Minneapolis Federal Reserve Bank showed a different picture after more careful selection of a consumer price index and factoring in supplements to wages. The supplements, which include employer contributions to employee pension and insurance funds and employer contributions to government social insurance (but excluding benefits such as paid leave that are included in the U.S. Bureau of Labor Statistics' estimates of average hourly earnings), have generally been increasing as a share of employee compensation and reached an estimated 30 percent in 2005. This upward trend has resulted in no small measure from the rapid increase in the relative cost of health insurance, a common employee fringe benefit. Based on the measurement approach taken in the Minneapolis Federal Reserve Bank paper, it has been estimated for this report that average employee compensation per hour increased between 1995 and 2008 at a real rate of 1.8 percent. In Chapter 10, this estimate provided a rationale for the sensitivity test that increased the average value of travel time by 25 percent above the estimate for 2008. However, this test adopted the same higher value of time for each year in the 2009–2028 analysis period. A more realistic sensitivity test would allow for annual growth in the average value of travel time.

Construction Costs

Allowing construction costs to change relative to consumer prices is another potential refinement for future C&P report modeling. Chapter 7 considered a wide range of potential growth rates in real spending on highways, including at the high end annual increases of 5.90 percent, which would mean a boost of 49.6 percent after only five years. In the Chapter 9 supplemental analysis where the timing of investment is BCR-driven, spending can ramp up even more dramatically toward the start of the analysis period. At the highest overall level of investment considered, an average of $105.4 billion per year, 37.4 percent of the 20-year investment total would occur within the first funding period, 2009–2013. That means that annual spending during those first five years would average $159.8 billion, nearly three times as much as the $54.7 billion actually spent in the 2008 base year.

In reality, a spending increase of this scale and speed would likely drive up prices for highway construction work relative to consumer prices. Even when unemployment rates are high, as at present, such increases in demand for highway construction could run up against short-run constraints on the supply of skilled labor and other specialized resources. At present, the looming wave of baby boomer retirements and the demand for American engineering expertise being generated by the infrastructure boom in developing countries are among the factors that could create shortages in the supply of skilled labor for U.S. highway construction projects, should demand for such labor increase substantially. To the extent that some of the spending levels considered in this report's modeling would run up against supply-side constraints, they would lead to higher costs for highway construction projects, contrary to the modeling assumption that these costs remain constant. In this respect, the projections for highway conditions and performance at relatively high levels of spending are overly optimistic.

Even without major demand-side pressures, future rates of inflation could differ significantly between industries engaged in transportation infrastructure construction industries and the economy generally. A forecasting exercise would need to consider the input cost structure of these industries, the expected rates of input cost inflation, and the likely rate of industry productivity growth. A profile of the highway, street, and bridge construction reports that labor accounts for 42.9 percent of the industry's costs, and materials 32.6 percent, with the rest attributed to miscellaneous expenses, such as equipment, services and supplies, rentals, and overhead (*Highway and Street Construction (Excluding Elevated Highways) Industry Report*; available at http://business.highbeam.com). The industry has also been characterized as relatively energy-intensive; together with the EIA projections for sharp increases in energy prices, this could suggest future upward pressures on the industry's output inflation rate relative to general inflation.

The industry's future productivity growth relative to the rest of the economy is also an important determinant of its relative inflation rate. An example of such growth is the significant advances in recent years in the development of long-life asphalt and concrete pavements. Common practice in forecasting industry growth combines reliance on expert assessments of future technology prospects with extrapolations from estimates of past rates of productivity growth. For the construction sector, however, the measurement of productivity growth is often made challenging by the lack of adequate price indices for the sector's output. For highway construction prices, the changeover from using the FHWA Bid Price Index to using its successor, the National Highway Construction Cost Index, has created some uncertainty about the rate at which prices increased in the recent past, as was discussed in Chapter 10. Moreover, neither of these indices adequately reflects the decreases in quality-adjusted prices that result from technological advances such as the above-mentioned development of new construction techniques that make pavements longer-lived. For transit investment, matters are still worse: the transit industry does not even have a price index suitable for inflating historical costs to current or future levels. TERM's needs estimates and those of the transit industry in general would clearly benefit from the availability of a transit-specific capital cost index.

Such problems with the price indices hinder the measurement of past real growth in industry output, and hence of past productivity trends. Nevertheless, the prospects for future productivity growth in transportation infrastructure construction warrants consideration in the preparation of future C&P reports as part of an analysis of how construction prices are likely to change relative to consumer prices.

Crash and Emissions Costs

As was seen in Chapter 10, the HERS model with its current scope excluding targeted safety-focused investments produces projections that are not particularly sensitive to the assumed value of a statistical life. Directly modeling national investment needs for these types of improvements would require an entirely new approach, including the collection of additional or supplemental data and the development of new safety capital investment tools. The FHWA will be examining the possibilities for implementing these enhancements as part of its ongoing HERS model development program. Broadening the model's capabilities in these areas would strengthen the case for rethinking the current HERS assumption that the value of a statistical life relative to consumer prices remains unchanged over the 20-year analysis period. Since releasing its new guidance on the value of a statistical life in 2008, the U.S. DOT has updated the recommended value on the assumption of an elasticity of 0.55 with respect to the average economy-wide real wage. Incorporating a similar procedure into HERS and assuming future growth in real wages would produce projected values of statistical life that increase over the analysis period relative to consumer prices. In addition to this possibility, it would also be worth considering making similar changes to the HERS constant-dollar treatment of the cost per additional unit of vehicle emissions. EPA regulatory impact analyses project that these marginal costs will change over time relative to consumer prices as a result of growth in population and per capita incomes and changes in atmospheric concentrations.

Travel Demand

For highways as well as transit systems, the model-based projections presented in Part II of this report are sensitive to variations in assumptions about future travel demand. These assumptions are embodied in the forecast rates of growth in travel demand that are input to the models, as well as the elasticities that adjust these forecasts for projected changes in the travel cost or service quality that users experience. Areas of potential refinements to the treatment of travel demand include the modeling of congestion pricing and of demand management strategies not modeled in this report, such as changes to land use policies. As well, the elasticities are in need of updating to be consistent with the most recent evidence and, possibly, restructuring to better allow for network effects.

Demand Management Impacts on VMT

For highways, the HERS model inputs the section-level forecasts of VMT from the HPMS, and interprets them as the outcomes that would occur if the average user cost of travel were to remain at its base-year level. According to the results in Chapter 10, if VMT were to grow over 2009–2028 at its recent historical rates rather than the overall percent rate implied by the HPMS projections, highway conditions and performance would be significantly improved at any given level of investment and the amount of potentially cost-beneficial investment over the 20 years would be significantly reduced. Although these sensitivity tests might be viewed as a rough proxy for the effects of future demand management policies other than congestion pricing (which is modeled in Chapter 10), it would be preferable for HERS modeling to directly incorporate meaningful estimates of these effects. A starting point could be the 2009 Transportation Research Board (TRB) Special Report, *Driving and the Built Environment: The Effects of Compact Development on Motorized Travel, Energy Use, and* CO_2 *Emissions*. The report found that more compact development has potential to substantially reduce VMT, with the literature suggesting that:

> *"…doubling residential density across a metropolitan area might lower household VMT by about 5 to 12 percent, and perhaps by as much as 25 percent, if coupled with higher employment concentrations, significant public transit improvements, mixed uses, and other supportive demand management measures."*

The TRB report also found that:

> *"Promoting more compact, mixed-use development on a large scale will require overcoming numerous obstacles. These obstacles include the traditional reluctance of many local governments to zone for such development and the lack of either regional governments with effective powers to regulate land use in most metropolitan areas or a strong state role in land use planning."*

As TRB further noted, the transportation planning models used by the MPOs and other agencies mostly have limited ability to predict the impacts of changes in land use policies. Future editions of the C&P report may be able to draw on evidence from the growing number of exceptions, such as the model developed at the Sacramento Area Council of Governments and the California statewide integrated land use/ transportation model under development at Caltrans.

Price Sensitivity of Highway Travel Demand

As was discussed in Chapter 10, the HERS model contains elasticity parameters that quantify the sensitivity of travel demand (as measured by VMT) to changes in travel cost. A general elasticity describes a relationship at a system-level and measures both VMT and average cost per VMT for an entire highway network. HERS considers such general elasticities only as an input to the estimation of a section-level elasticity, which measures the change in the travel cost and associated VMT response for a particular highway section. The HERS procedure for deriving section-level elasticities distinguishes a VMT response that occurs through route diversion and a scale effect that captures the VMT response that would occur even without route diversion, simply as a result of the change in travel cost. To quantify the scale effect, the procedure takes the ratio of the section length to the average length of a highway trip—estimated to be 10 miles—and multiplies by the estimated general elasticity. (To illustrate, the modeling in this report assumed the general elasticity to have a long-run value of -0.8, so that for a section one mile in length the scale effect would equal -0.08 percent, meaning that a 10 percent reduction in travel cost on that section would generate approximately 0.8 percent additional VMT on that section in the long run.) This procedure is just one of various approaches that could be taken to quantify the scale effect. Among the alternatives that could be incorporated into the versions of HERS used for future C&P reports are approaches that would apply a general elasticity to model-predicted changes in average user cost at a metropolitan area or regional level rather the section level.

For the route diversion response as well, alternatives to the current section-level approach in HERS are worth exploring. Currently, for a change in travel cost on any one section, the model predicts the change in VMT on that section alone. Impacts on VMT on other sections are implied by the allowance for route diversion but not incorporated in the model's analysis of other sections' conditions, performance, and investment needs. In addition, while the implied impacts are such that a reduction in travel cost on one section will attract traffic away from other sections, this presumes that the others sections form part of an alternative route; when other sections form part of the same route as the section where travel costs declines, VMT can be expected to increase on all these sections. Unfortunately, because HERS relies on data from only a sample of highway sections (from the HPMS), no amount of tinkering with the model can produce an altogether satisfactory allowance for network effects, but it may nevertheless be possible to improve on the current allowance.

Transit Ridership Growth Forecasts

For prior editions of this report, TERM's estimates of the investment expansion needs for transit were founded solely on the rate of growth in transit demand (passenger miles traveled [PMT]) as projected by the Nation's Metropolitan Planning Organizations (MPOs). In the past, some observers have expressed concern regarding this use of the MPO forecasts to generate unconstrained expansion needs estimates as these PMT growth projections are themselves generated based on financially constrained travel demand models (i.e., MPO PMT growth projections make assumptions regarding the level of potential future funding for transit capital improvements, including how those funds will be distributed between various modes and projects, with subsequent impacts on the rate of growth in transit ridership within each urbanized area). Hence, when used by TERM, the MPO growth forecasts effectively represent constrained PMT growth projections that are used to project unconstrained transit capital expansion needs.

This report edition has addressed this issue by labeling expansion needs based on MPO projections as a "Low Growth" scenario and by also introducing a "High Growth" scenario based for each urbanized area on its historical average rate of growth in PMT since 1999 (overall, high rates of PMT growth are roughly 60 percent higher than the low, MPO-projected rates). Future editions of the C&P report might consider other approaches to projecting PMT growth for assessing future transit capital expansion needs.

Congestion Pricing

In 2010, the FHWA convened an expert panel to evaluate the HERS-based modeling congestion pricing in the 2008 C&P Report and to recommend enhancements to this modeling for future applications. The panel found the foremost limitation of the modeling to be the current lack of capability in HERS to predict the impact of peak-period charges on the distribution of traffic across the day. HERS relies on the HPMS database, which reports only the all-day traffic volume. For the purpose of estimating recurrent traffic delay, the model distributes each section's daily traffic volume between the peak and off-peak periods, and then distributes the peak-period volume between the dominant and non-dominant directions of traffic (termed "peak" and "counter-peak"). The equations for estimating these distributions take account of the section's volume-to-capacity ratio, to allow for the well-known phenomenon of "peak spreading" and the "directional factor" reported in the HPMS database. To model peak-period congestion charges, however, would require elaborating this framework to include the influence of the cost of traveling in different periods on time-of-day travel decisions.

In addition to the inclusion of pricing effects on travel time-of-day decisions, the expert review panel recommended various potential improvements to the modeling of congestion pricing undertaken for the C&P reports. Some of these recommendations relate to fundamental limitations of the HERS model. As discussed above, HERS analyzes sample sections quasi-independently of each other, rather than conducting an integrated analysis of all sections on a highway network. This limitation made it difficult for panelists to interpret the section-level price elasticities and to evaluate the allowance these elasticities make for network effects (the inclusion of a route diversion response). Related recommendations were to (1) reconsider the estimation of the section-level elasticities to ensure consistency with the general elasticities, (2) get elasticity estimates based on route characteristics to capture network effects, and (3) update the HERS values for the general elasticities on the most recent evidence. The recommendation to update the general elasticities derives from the datedness of the evidence on which the current values are based (pre-2000) and will be implemented in time for the 2012 C&P Report. Progress on the other two recommendations concerning the elasticities is also possible, but will inevitably be limited by the non-network nature of the HERS model.

For future C&P reports, an addition to HERS-based modeling of congestion pricing could be case studies of potential pricing schemes in particular metropolitan regions, using transportation planning models that represent the region's entire network. Case studies of this sort have already been conducted for several areas, including the Washington DC and Puget Sound regions, with the modeled forms of pricing varying among and within studies from the more limited such as time-of-day varying tolls on managed lanes to more comprehensive forms similar to what has been considered in the C&P reports. Another potential advantage of this approach for addressing congestion pricing in future C&P reports concerns the treatment of traffic dynamics. HERS, in common with many traditional transportation planning models, produces measures of performance only over a lengthy period, such as average speed over a 3-hour afternoon peak. An incipient trend, however, is toward transportation planning models that represent conditions on a network dynamically, in successive time intervals of only a few minutes or less. The inclusion of such dynamics has the potential to substantially improve modeling to predict the impacts of congestion pricing. Indeed, evidence from the research literature suggests that, for maximum effectiveness, congestion charges may need to vary finely over a peak period, and that such charges may affect VMT quite differently from charges that are uniform over the peak (but otherwise set optimally).

That said, case studies of congestion pricing in metropolitan areas have thus far shed relatively little light on what is a key focus of this report's analysis, the impacts of pricing on highway investment needs, and the suitability of the available transportation planning models for estimating these impacts would need to be investigated. On the plus side, the multimodal coverage of many MPO models holds promise for investigating the impacts of congestion pricing on both highways and transit investment needs. In addition, while most of the models lack an in-built benefit-cost analysis capability, they can be used with benefit-cost postprocessors to evaluate investment needs. On the minus side, in contrast with HERS, many of the transportation planning models suitable for analyzing congestion pricing may not be designed for evaluating investment needs for pavement rehabilitation; with their typical origins as travel demand models, they are more suited for evaluating investments in highway capacity, which influence travel demand much more than pavement condition.

Another recommendation of the expert panel was to include the impacts of congestion pricing on vehicle operating costs. The HERS-based modeling undertaken for the C&P reports predicted impacts only on the travel time component of highway user cost, which can be attributed to the datedness and other limitations of the model's current equations for vehicle operating cost. As was discussed above, the FHWA is about to initiate the exploratory first stage of research to develop new equations with greater predictive power for use in HERS. These improvements, some of which may be implemented in time for the 2012 C&P Report, may also help advance the treatment of vehicle operating costs in models other than HERS. Lastly, the panel also called for consideration of the impacts of congestion pricing on non-recurrent congestion delay, which results mainly from traffic incidents. The HERS treatment of congestion pricing currently considers only the impacts on recurrent congestion delay, which results from the normal interaction of heavy traffic volumes and limited roadway capacity.

The expert panel's final report will be made available at http://www.fhwa.dot.gov/policy/otps/index.htm. Among the various other recommendations included is consideration of the impacts of congestion pricing on the rate of incident delay. The current congestion pricing procedure in HERS takes account only of what the model terms "congestion delay"—recurring delay that results from the routine presence of heavy traffic volumes. In the HERS equations, reductions in the ratio of traffic to roadway capacity—which congestion would produce—reduce the rate of incident delay (hours per thousand VMT), but the current congestion pricing procedures do not incorporate this component of the model.

Analytical Issues

Life-Cycle Cost Analysis

In addition to estimating the economically optimal level of future investment, an ideal investment analysis tool should be able to address the optimal timing of that investment by comparing the life-cycle costs of alternative temporal improvement strategies. It should also be able to quantify the tradeoffs between early, less aggressive improvements and deferred, more extensive improvements. While the input costs and modeled or assumed improvement lives used in the current investment models are intended to reflect the full life-cycle costs of improvements, this area remains a significant limitation on the methodology in use.

Each tool currently used by the FHWA and the FTA models system investments on a year-by-year (or period-by-period) basis. Although the improvements made in one period affect the condition of the system and improvement options available in subsequent periods, and the benefits of these improvements are evaluated over multiple periods that an improvement is in use, potential improvements in different time periods are not compared with one another. For example, while a particular improvement on a highway section may be justified on economic grounds, it could be more advantageous to postpone the improvement until a later time. The models do not currently consider this option, nor do they consider the potential effects of advancing certain actions. For the HERS model, however, the FHWA convened an expert panel in 2009 to consider potential modifications that would overcome these limitations. The initial steps that the panel decided on are in the process of implementation, though a new version of HERS that more fully optimizes the timing of improvements may not be ready in time for the 2012 C&P Report.

The HERS model is also limited by the way that it evaluates pavement improvements. The decision on whether a resurfacing improvement or full-depth pavement reconstruction is warranted is currently a mechanical one, based solely on whether the pavement condition is above or below a threshold reconstruction level. Ideally, such a decision would be made based on a tradeoff analysis between the less aggressive resurfacing option and the more expensive (but longer-lasting) reconstruction.

New Technologies and Techniques

Vehicles powered by alternative fuel technologies are expected to substantially increase their share of the U.S. vehicle fleet over the coming years. For the light-duty vehicle (LDV) fleet, EIA projections for 2030 put this share at 23.1 percent in the Reference Case scenario and 27.3 percent in the High Oil Price scenario, up from 1.8 percent in 2008. In each scenario, two technologies account for more than 89 percent of the alternative fuel LDVs: ethanol flex engines, which can run on gasoline or a blend of up to 85 percent ethanol and are currently common in Brazil; and electric-gasoline hybrid engines, which are currently found in a variety of models sold in the United States. Although electric vehicles are now making their debut on the U.S. market (e.g. Nissan Leaf and Chevy Volt), they and natural gas-powered vehicles face significant challenges in penetrating the LDV market; hence, neither of these technologies figure significantly in the EIA projections.

Incorporating alternative fuel technologies into HERS would require major revisions and supporting research efforts. The applications of HERS in this report indirectly make a crude allowance for their effect on vehicle fuel costs through the use of projections for the EIA "fuel efficiency indicator." This indicator corresponds to the average miles per gallon (MPG) measure for conventionally powered vehicles, except that the denominator is expressed in fuel gallon *equivalents*—that is, the gasoline usage that would consume an amount of energy (British thermal units or BTUs) identical to the energy actually consumed by all vehicles, including those powered by alternative fuels. To incorporate the EIA projections into the HERS model, this report's analysis has treated the efficiency indicators as though they measured average MPG for vehicles powered by the conventional fuels (gasoline and diesel fuel), since they are the only fuels the model recognizes. For using HERS model to predict the fuel component of vehicle operating cost, this simplification entails a certain loss of realism: an alternative fuel that consumes X percent more energy per unit than a gallon of gasoline will not necessarily cost X percent more per unit.

The omission of alternative-fueled vehicles from HERS also raises questions about the way the model allows for the influence on vehicle operating costs of highway conditions and performance. Traffic congestion, for example, could affect the energy consumption differently for conventional and alternative-fueled vehicles. As part of the planned research to update the model's vehicle operating cost equations, the FHWA will be considering the possibilities for incorporating such differences into HERS. The newness of the alternative technologies viewed against the extreme datedness of the current equations for predicting vehicle operating costs for conventional technologies might seem to suggest that such an effort would take many years to complete. However, the major advances that have occurred in vehicle data collection technologies could considerably shorten the time required. For some technologies such as electric plug-ins, development of vehicle operating cost equations should probably be deferred until such time as they establish a significant market presence. For others, such as electric-gasoline hybrid engines, the market presence and prospects may already be sufficient to start now.

As with highways and bridges, the introduction of new transit technologies can impact the timing and cost of asset life-cycle events, including the cost of rehabilitation and replacement activities and an asset's expected useful life. These changes will in turn impact the level of reinvestment dollars required to preserve existing transit assets or to acquire and maintain expansion assets. A key example here is alternative-fuel bus vehicles (e.g., biodiesel, hybrid buses), which make up an increasing proportion of the Nation's overall bus fleet. Acquisition and replacement costs for these vehicles can be on the order of 50 percent higher than for conventional diesel buses, and the useful lives of some of these technologies have yet to be ascertained. New designs, materials, and internal diagnostic systems are similarly impacting bus vehicle replacement costs and may be impacting vehicle service longevity as well. TERM has been able to track the impact of new technologies on the costs of vehicles and some other transit technologies by tracking changes in average procurement costs over time, but investment needs assessment accuracy may benefit from a better understanding of the impact of these new technologies on asset useful life. Ongoing updates and revisions to TERM's asset decay relationships (based on on-site engineering condition assessments) is one approach to tracking changes in transit asset expected useful life.

Benefit-Cost Analysis Procedures

For some transportation infrastructure investments, the determination as to whether or not they are cost-beneficial may hinge on the relative benefits of the implementation of supporting measures such as changes in land use policies. In such situations, which would seem to be particularly relevant to transit investments, the benefit-cost analysis should in principle evaluate the transportation investments and supporting policies as a package. This requires a framework capable of realistically modeling the interaction between land use and transportation; of representing the influences of specific land use policies such as changes to zoning; and of meaningfully measuring net benefits to society taking into account the impacts on travel cost and accessibility, housing prices, employment opportunities, etc. Developing such a framework for a given region is no small order, but progress has been made with various models, including the above-mentioned statewide model under development by Caltrans. The U.S. DOT will continuously be reviewing work in this field for its implications for C&P report issues and modeling frameworks.

Productivity and Economic Development

Since the preparation of the 2008 C&P Report, economic challenges facing the United States have to some extent shifted interest in the economic impacts of transportation investments from the regional to the national level. Among the many indications of this shift is the emphasis on U.S. economic competiveness and export growth in the Administration's recent report, *An Economic Analysis of Infrastructure Investment* (prepared by the Department of Treasury with the Council of Economic Advisers [CEA], released October 2010). The report refers in this regard to the call in the President's National Export Initiative for the Departments of Transportation and Commerce to "work together and with stakeholders to develop and implement a comprehensive, competitiveness-focused national freight policy."

In contrast, while past C&P reports have provided a rich picture of the impacts of investment on highway and transit conditions and performance, they have not delved much into the national economic impacts of these investments. Chapter 8 in this edition takes an initial step in this direction by using input-output analysis to measure the short-run economic stimulus effect of transit investments. Yet nowhere does this report attempt to quantify the full range of national economic impacts of transportation investments.

In the past, the FHWA commissioned econometric research on the productivity impacts of highway investments using industry-level data on the national economy, similar to a number of other econometric studies cited in the Treasury-CEA report. However, the FHWA's recent experience with this line of research has been that it does not yield estimates of productivity gains that are stable with respect to reasonable changes in model specification or sample period. One possible interpretation of this problem is that the marginal returns from additional investment have declined over the years as the highway network has expanded, to the point where they have become difficult to econometrically decipher and pin down. (The possibility of this network maturation effect on marginal returns to highway investment was also noted in the Treasury-CEA report).

Whatever the cause of this problem with the econometric research, the FHWA is now looking into the alternative of conducting simulations with national economic models drawing on evidence from benefit-cost analyses. Among the potential candidates for the national economic model to be used is the USAGE-ITC model developed by the U.S. International Trade Commission and several proprietary models. A possible application of this approach for a future C&P report would be to enter selected results from the HERS simulations into a national economic model to estimate the long-term impacts of alternative levels of investment. Macroeconomic indicators used to measure these impacts could include, for example, export volumes and prices, real GDP, real investment levels, and the balance of trade. Of the results from the HERS model, the estimated impacts on the costs of truck travel would be particularly useful for such an exercise. For travel in passenger vehicles, the portion of cost savings that accrue on business travel would also be valuable input; however, since HERS does not estimate the cost savings by travel purpose, this would have to be approximated.

Although estimates of such macroeconomic impacts are of independent interest, they should not divert attention to the bottom-line questions of benefit-cost analysis. Among the issues the FHWA will be investigating is whether national economic modeling of transportation investment, in addition to providing estimates of such impacts, also has a role in benefit-cost analysis. In theory, such modeling should be capable of capturing some effects relevant to benefit-cost analysis that are missing from conventional analyses. For one thing, most benefit-cost analyses concern themselves only with the total benefits and costs without considering their distribution according to country of residence. The Office of Management and Budget guidance on benefit-cost analysis explicitly calls for a focus on U.S. residents, which is the population to which models of the U.S. economy relate. For another, national economic models have the potential to capture some of the market "imperfections" in the economy related to taxes and the inadequate competition. On the other hand, using the national economic models to perform benefit-cost analysis requires that they contain suitable measures to summarize net benefits, and devising such measures may not be straightforward. Moreover, the use of unsuitable measures, such as changes in real GDP, represents a risk in the use of these models.

Economic impact analysis tools other than national economic models may also have the potential for factoring some market imperfections into benefit-cost analysis of transportation investments. A classic argument is that by lessening the "tyranny of distance," transportation improvements promote competition. The benefits from the enhanced competition will generally not be picked up in conventional benefit-cost analysis frameworks, but in theory could be captured using broader frameworks such as regional economic models. A variant of this classic argument that has attracted much attention in recent years, and has found its way into benefit-cost analysis practice for transportation investments in the United Kingdom, concerns “agglomeration economies” that result from transportation improvements that cause competitors to geographically cluster. The U.S. DOT will be following the research on this topic, which may have particular relevance to transit investments, to gain a clearer sense of the contribution of agglomeration economies to the benefits from transportation investments, and the feasibility of reliably quantifying this contribution for benefit-cost analysis.