CHAPTER 5

System Performance

Highway System Performance

The transportation system provides for the movement of people and goods and influences land use and the environment around it. Transportation agencies make decisions on where to expand an existing system and where to build a new one. Increasingly, when making these decisions, the various impacts are assessed to ensure that negative ramifications on the environment are minimized, while providing a service that serves the diverse needs of its users. Many of these issues are addressed during the project development phase as directed by Federal and/or State policy.

The transportation system is best able to operate at the peak of its performance when it can support economic competitiveness at the local, regional, and national levels by providing adequate capacity and reliability, while upholding sustainability goals. Therefore, transportation agencies are being held accountable for how well they address these issues in addition to providing a system that is safe and in a state of good repair, as discussed in Chapters 3 and 4. This chapter discusses the performance of the highway system, and how sustainable transportation systems, livability, and economic competitiveness contribute to this performance. It also includes a discussion of the effect of congestion on freight travel. The U.S. Department of Transportation (DOT) Strategic Plan FY 2012–FY 2016 included the goals of reliability, economic competitiveness, livable communities, and environmental sustainability. MAP-21 also recognized the importance of developing measures for congestion reduction, system reliability, freight movement, and economic activity.

Adopting these goals and tracking performance using the new metrics could influence the type of investments made. Different highways may be selected to serve different trip purposes, e.g., freight versus a commuter trip or a local trip versus an intrastate or interstate trip. Better understanding the types of trips served by a particular roadway or mode would help in determining where to invest resources. A congested metropolitan area may provide improved transit, pedestrian, or biking facilities to take some trips off a highway in order to better serve freight trips or reduce emissions. A trade-off between the goal areas will be necessary.

U.S. DOT Strategic Goals Covered in Chapter 5

Economic Competitiveness – Promote transportation policies and investments that bring lasting and equitable economic benefits to the Nation and its citizens.

Livable Communities – Foster livable communities through place-based policies and investments that increase the transportation choices and access to transportation services.

Environmental Sustainability – Advance environmentally sustainable policies and investments that reduce carbon and other harmful emissions from transportation sources.

Transportation Systems and Livable Communities

The U.S. DOT Strategic Plan FY 2012–FY 2016 includes a goal to "Foster livable communities through place-based policies and investments that increase transportation choices and access to transportation services." Livable communities are places where transportation, housing, and commercial development investments have been coordinated so that people have access to adequate, affordable, and environmentally sustainable travel options. Incorporating livability approaches into transportation, land use, and housing policies can help improve public health and safety, lower infrastructure costs, reduce combined household transportation and housing costs, reduce growth in vehicle miles traveled, and improve air and water quality, among many other benefits.

The U.S. DOT Strategic Plan FY 2012–FY 2016 includes a separate goal to "Advance environmentally sustainable policies and investments that reduce carbon and other harmful emissions from transportation sources." Transportation is crucial to our economy and our quality of life, but building, operating, and maintaining transportation systems clearly have environmental consequences. In order to meet today's set of challenges—reducing carbon and other harmful emissions, promoting energy independence, and addressing global climate change—it is critical to foster more sustainable approaches to transportation in order to allow future generations to enjoy even higher standards of living and mobility.

Fostering Livable Communities

Designing transportation systems to balance access and mobility needs of all users is an important aspect of promoting livable communities. This includes drivers, bicyclists, pedestrians, and transit riders, among others. This approach to improving transportation systems also recognizes that each community is different and should determine what its needs are.

Transportation systems provide the foundation for how communities are formed. Deciding to build houses, schools, grocery stores, employment centers, and transit stations close to one another—while providing a well-connected street network and facilities for walking or biking—provides more transportation choices and convenient access to daily activities. It also ensures that community resources and services are used efficiently. Transportation agencies are being called upon by their stakeholders to plan, build, and operate transportation systems that support a variety of environmental, economic, and social objectives such as protecting natural resources, improving public health and safety, expanding the economy, and providing mobility. These objectives lead to a desire for a more integrated and holistic approach to planning, building, and expanding the transportation system.

Communities benefit when decisions about transportation and land use are made simultaneously. Containing development to a more compact area, allowing for mixed-use zoning, and reutilizing existing spaces or redeveloping parcels of land can reduce infrastructure costs, lower household transportation costs, preserve rural lands, reduce air and water pollution, and protect natural resources. Coordinating land use and development decisions with transportation investments can produce clear results, such as increasing viable options for people to access opportunities, goods, services, and other resources to improve quality of life.

Millwork District Project

An example of a community that has benefited from coordinated transportation and land use is the Millwork District in Dubuque, Iowa. Dubuque was challenged to reinvigorate the Millwork District, which includes the waterfront area and the Washington neighborhood, while respecting and recognizing the area's historic character. The new concept was for the District to connect the Port of Dubuque to the downtown area in order to create a thriving livable community. The Historic Millwork District was redeveloped from old factories and mills into a new mixed-use development incorporating housing, workplaces, and entertainment. Multimodal transportation improvements were made as a keystone in the strategy to bolster the community. Expanding the District's transportation options attracted both businesses and residents of the area.

The project made use of cost-effective and sustainable practices, such as reusing brick pavers and installing energy-efficient street lights. It also created jobs and capitalized on local resources by using locally manufactured benches, bike racks, and trash receptacles. As a result of the Millwork District project, new streets are now accessible to all road users regardless of age or ability. The once-empty warehouses and idle mills have become popular shops, employment centers, and homes. The Millwork District is now a vibrant community, building on the past that has transformed into a more livable community. The U.S. DOT awarded a $5.6-million Transportation Investment Generating Economic Recovery (TIGER) Discretionary grant to Dubuque, Iowa, for revitalization of the Millwork District. Federal dollars are helping the city leverage millions more in additional investments for a total of $7.7 million.

Addressing livability issues in transportation ensures that transportation investments support both mobility and broader community goals. A well-designed transportation system can be the catalyst for achieving a range of community and regional goals including economic growth, job creation, goods movement, and access to education and health care. Transportation also contributes to increased quality of life for residents and helps maintain the Nation's role in a global economy. As will be discussed later in this chapter, freight movement is an essential part to moving goods and building stronger economies and, when carefully planned, it helps reduce congestion and fosters livable communities. Communities can be aesthetically pleasing, safe, and walkable, while still providing efficient access for large trucks, rail lines, and other modes of transportation.

There is a growing demand to design facilities for all users, while balancing the different access and mobility needs of motorists, truckers, bicyclists, pedestrians, and transit riders. The ability of transportation networks to connect and function, support regional economies, and protect environmental and public health is becoming increasingly relevant to long-term economic prosperity and community quality of life. Additional information on the characteristics of livability and the benefits of livable communities can be found in Chapter 13 of the 2010 C&P Report and at the U.S. DOT Livability website at www.dot.gov/livability.

Philadelphia Area Pedestrian Bicycle Network

In Philadelphia, PA, the area pedestrian and bicycle network spans 128 miles connecting six counties around Philadelphia and Southern NJ. U.S. DOT TIGER funds are being used to repair and improve 16 miles of the network on well-used commuter routes to downtown and in economically distressed neighborhoods in Philadelphia and Camden, NJ.

Measuring Livability

Measuring the impact of transportation investments on livability is an ongoing effort. The U.S. DOT Strategic Plan FY 2012–FY 2016 emphasizes the importance of adopting a comprehensive, coordinated, and performance-based approach to enhancing livability and evaluating transportation investments. As previously mentioned, in support of this coordinated outcome-driven approach, the U.S. DOT Strategic Plan establishes as one of five strategic goals "fostering livable communities through place-based policies and investment that increase transportation choices and access to transportation services." This Livable Communities strategic goal is supported by three outcome-based objectives, shared among the Federal Highway Administration (FHWA), the Federal Transit Administration (FTA), and the Federal Railroad Administration (FRA):

1. Increased access to convenient and affordable transportation choices
2. Improved networks that accommodate pedestrians and bicycles
3. Improved access to transportation for people with disabilities and older adults.

Livable Communities Outcomes and Performance Measures

FHWA focuses on two of the three outcomes, and is tracking them by State using performance measures:

- **Outcome:** Improved networks that accommodate pedestrians and bicycles.
  Performance Measure: Increase the number of States that have policies that improve transportation choices for walking, wheeling, and bicycling. In FY2011, the target was 22 States and the actual was 24; in FY2012, the target was 26, increasing to 27 by FY2013.
- **Outcome**: Improved access to transportation for people with disabilities and older adults.
  Performance Measure: Increase the number of States that have developed an Americans with Disabilities Act (ADA) transition plan that is current and includes public rights-of-way. In FY2011, the target was nine States and the actual was 13; in FY2012, the target was 13, increasing to 15 by FY2013.

The Interagency Partnership for Sustainable Communities, a joint initiative of the U.S. Department of Housing and Urban Development, U.S. DOT, and U.S. Environmental Protection Agency (EPA), is working to share information about how communities can track performance. In addition, FHWA is examining ways that communities can gauge whether their programs, policies, and projects are making a positive impact on quality of life. *Exhibit 5-1* lists examples of measures that communities could consider.

Exhibit 5-1 Potential Livability Performance Measures

Accessibility	Economic	Housing	Land Use	Public Health	Safety
Annual public transportation passenger miles per capita Annual public transportation trips per capita Availability of bicycle parking Average commute distances	Access to jobs and markets for disadvantaged populations compared to entire population Access to personal vehicle, by age, race, income, and location Average number of employment opportunities within a given number of miles of a transit stop	Acres of land consumed per residential unit Average commute distances Average energy efficiency rating of homes Average number of full-service super-markets within a given number of miles or minutes	Acreage of agricultural lands disturbed Acreage of habitat consumed/ habitat fragmentation index Acreage of high-quality wetlands Acreage of land consumed per lane mile Acreage of sensitive lands/important habitats impacted/ consumed	Air quality conformity status Ambient air quality Amount and percent change in greenery and open space Average commute distances	Barriers to pedestrians and cyclists Average speed of emergency vehicles on emergency calls Pedestrian crash fatality rate Number/ percent of people living in substandard residential units

The U.S. EPA has also identified 12 sustainable transportation performance measures in its Guide to Sustainable Transportation Performance Measures (http://www.epa.gov/dced/transpo_performance.htm). The guidebook describes the 12 measures that can readily be applied in transportation decision-making. It also presents possible metrics, summarizes the relevant analytical methods and data sources, and illustrates the use of each measure.

Sustainable Transportation Performance Measures

- Transit Accessibility
- Bicycle and Pedestrian Mode Share
- Vehicle Miles Travelled per Capita
- Carbon Intensity
- Mixed Land Use
- Transportation Affordability
- Benefits by Income Group
- Land Consumption
- Bicycle and Pedestrian Activity and Safety
- Bicycle and Pedestrian Level of Service
- Average Vehicle Occupancy
- Transit Productivity

Multimodal Transportation and Livability

One of the key efforts of the U.S. DOT livability initiative is to promote safe, affordable, and convenient transportation choices. Across the country, States and communities are focusing renewed attention on improving transportation facilities for walking and bicycling. This is evident in the use of Federal-aid funds for walking and bicycling projects. The highest level of Federal-aid investment on record for nonmotorized facilities was achieved in FYs 2009, 2010, and 2011 ($1.19 billion, $1.04 billion, and $790 million, respectively). SAFETEA-LU created two new programs that specifically focused on walking and bicycling: the Nonmotorized Transportation Pilot Program (NTPP) and the Safe Routes to School (SRTS) Program. The programs have explored how communities can improve safety and transportation choices with increased investment in walking and bicycling.

The NTPP provides a glimpse at what happens when communities increase their investment in walking and bicycling transportation facilities. SAFETEA-LU specified that four communities—Marin County, CA; Columbia, MO; Sheboygan County, WI; and Minneapolis, MN—would each receive $25 million to improve their walking and bicycling transportation networks. The FHWA was tasked with reporting on the outcomes of this investment in a Report to Congress (see http://www.fhwa.dot.gov/environment/bicycle_pedestrian/ntpp/2012_report/). This report documents the changes in transportation use and estimated changes in several key factors including safety and emissions as well. Among the key findings are that counts of walkers and bicyclists increased an average of 49 percent and 22 percent, respectively. An estimated 16 million miles were walked and bicycled in the communities in 2010 and it is estimated that the pilot communities saved 22 pounds of CO_2 in 2010 per person, or a total of 7,710 tons, due to replacing personal vehicle trips with walking and bicycling. Despite notable increases in walking and bicycling, fatal bicycle and pedestrian crashes remained steady, indicating that safety has not been adversely affected.

On the other hand, the SRTS Program has provided funds to each State by a formula based on each State's population of children in kindergarten through eighth grade. The SRTS Program, a $612-million program over 5 years, has supported infrastructure and noninfrastructure (e.g., safety education) activities and required that each State have an SRTS Coordinator. As of August 2011, over 10,400 schools in all 50 states and the District of Columbia, have been involved in the program (see http://www.saferoutesinfo.org/sites/default/files/resources/progress%20report_FINAL_web.pdf). So far the most common use of funds has been sidewalk improvements (19 percent), followed by traffic calming (14 percent) and education (14 percent). In sum, estimates are that over 4.8 million students may benefit from the transportation improvements near their schools.

Although the two SAFETEA-LU programs have taken different approaches (e.g., providing funding to specific communities versus distributing funds to all States), they both demonstrate the national interest in walking and bicycling transportation. Based on recent demographic changes, which indicate that adults under age 30 are driving less, it will be even more important to provide safe, convenient, and affordable transportation options for people of all ages and abilities (see http://www.fhwa.dot.gov/policy/otps/nextgen_htps_scan.htm).

Advancing 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 a number of other definitions for sustainability have emerged, a concept often used is the "triple bottom line," referring to environmental, social, and economic principles. In transportation, the triple bottom line relates to sustainable solutions for the natural environment, the economic efficiency of the system, and societal needs for those using the system (e.g., mobility, accessibility, and safety). Transportation agencies can address sustainability through a wide range of initiatives, such as Intelligent Transportation Systems, livability, smart growth, planning and environment linkages, and addressing requirements of the National Environmental Policy Act (NEPA).

From an environmental sustainability perspective, the heavy reliance of the transportation system on fossil fuels is a significant concern. Fossil fuels are non-renewable; generate air pollution; and contribute to the buildup of carbon dioxide (CO_2) and other greenhouse gases (GHGs), which trap heat in the Earth's atmosphere. Although some progress has been made in reducing emissions of air pollutants both nationally and from the transportation sector in particular, many Americans continue to live in regions that do not meet health-based air-quality standards. Through oversight of the Clean Air Act "conformity" requirements, FHWA helps to ensure that these regions continue to make progress toward their air-quality standards.

Projects funded through the Congestion Mitigation and Air Quality Improvement program (CMAQ) contribute to emissions reductions in these regions. FHWA also promotes potential strategies to reduce GHG emissions, through improving system efficiency, reducing VMT, and transitioning to fuel-efficient vehicles and alternative fuels. FHWA supports research related to these strategies, provides technical assistance to stakeholders, and coordinates its activities within U.S. DOT and with other Federal agencies.

Beyond strategies to reduce emissions, the transportation community is beginning to focus its efforts on anticipating future extreme weather events and changes in climate (e.g., higher sea levels, increased temperatures, altered precipitation patterns, greater storm intensity) and the potential impact of these changes on the transportation system (e.g., damaged or flooded facilities). For a transportation system to be sustainable, it must be able to adapt to future as well as present conditions. Research efforts regarding the potential impacts of climate change on transportation infrastructure are ongoing at the Federal, State, and local levels. The U.S. DOT released a report on projected changes in climate over the next 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. FHWA has developed a flexible framework to assist transportation agencies in adapting to the impacts of climate change that starts with inventorying critical infrastructure, understanding potential future climate change impacts, and assessing vulnerabilities and risks.

Adaptation Pilots

In autumn of 2010, FHWA funded five State areas' DOTs and Metropolitan Planning Organizations to pilot a draft framework for conducting vulnerability and risk assessments of transportation infrastructure given the projected impacts of climate change. Each area's approach was different and contributed significantly to its understanding of potential climate change impacts on its transportation assets, and to the body of knowledge of the transportation community as a whole. FHWA is currently using the experiences of these five pilots and other studies to update the draft framework and expand it with "in-practice" examples.

The **Washington** DOT (WSDOT) assessed the infrastructure it owns, including roads, rail, ferry facilities, and airports. In internal workshops around the State, they developed criticality and impact ratings for each asset, which they used to create vulnerability maps for each region.

An interagency group in **New Jersey**, led by the North Jersey Transportation Planning Authority, closely followed the three steps of FHWA's framework in its analysis of the New Jersey Turnpike/I-95 corridor and the New Jersey Coast. It worked closely with the State climatologist to downscale climate model projections to New Jersey, estimating future changes to the 100-year floodplain due to heavier rainfall resulting from climate change. In addition, the interagency group worked with the New Jersey Department of Environmental Protection to create estimates of relative sea level rise. To identify facilities vulnerable to the effects of sea level rise, storm surge, and inland flooding, it used geographic information systems to determine intersections between inundated areas and transportation assets.

The **Oahu** Metropolitan Planning Organization used an interagency, multidisciplinary, 2-day workshop to facilitate a climate change dialogue and identify five key groups of vulnerable transportation assets for further study. The five groups of assets, based on geographic areas, were then analyzed in more detail by transportation experts in three full-day work sessions, resulting in a detailed qualitative risk assessment for each asset.

The University of **Virginia**'s Center for Transportation developed a priority-setting tool to assess how consideration of climate change and other factors may affect project prioritization in a transportation plan. It used the Hampton Roads region as a case study and made the model available for use by other regions.

The Metropolitan Transportation Commission, in partnership with the **San Francisco Bay** Conservation and Development Commission and others, led a study of a portion of the San Francisco Bay stretching from the Oakland Bay Bridge to the San Mateo Bridge (Alameda County). This study was focused on sea level rise. The project team developed profiles of risk from the effects of sea level rise, including exposure, sensitivity, and adaptive capacity for a representative list of roads, transit, facility, and pedestrian and bicycle transportation assets within the study area.

Additional information on sustainability and climate change can be found in Chapters 11 and 12 of the 2010 C&P Report, and at FHWA's sustainable transport and climate change websites at http://www.fhwa.dot.gov/environment/climate_change and at http://www.sustainablehighways.dot.gov.

Measuring Sustainability

Using sustainability as a metric generally means an expansion of traditional measurement frameworks to take into account the triple bottom line of social, environmental, and economic performance. Many organizations are developing organization-specific or industry-specific measurement tools and best practices to help them achieve the appropriate balance among social, environmental, and economic principles.

At the Federal level, environmental sustainability has been adopted as a strategic goal in the U.S. DOT Strategic Plan FY 2012–FY 2016. At the State level, transportation agencies are developing metrics that address various aspects of sustainability and are 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.

FHWA's INVEST Sustainability Self-Evaluation Tool

The FHWA has launched an initiative to support transportation agencies in making highway projects and programs more sustainable. This new initiative features a voluntary web-based self-evaluation tool, the Infrastructure Voluntary Evaluation Sustainability Tool (INVEST). In addition to measuring the sustainability of a project or program, INVEST can enable transportation agencies to:

- **Evaluate Sustainability Trade-Offs.** INVEST can help users better evaluate sustainability tradeoffs. Every highway project involves tradeoffs, and decisions often become more difficult when two or more options are not directly comparable. INVEST can help with these decisions by assigning points to various criteria based on their sustainability impacts.
- **Find and Address Programmatic Barriers.** Measuring sustainability on a program, project, or group of projects can enhance an agency's ability to identify programmatic barriers that they encounter so they can be addressed and removed. These barriers might be the result of policies, design standards and specifications, or stakeholder agency policies.
- **Communicate Benefits and Goals.** Measuring sustainability and reporting results allows transportation organizations to communicate sustainability goals and benefits to stakeholders.

More information on INVEST can be found at www.sustainablehighways.org.

Economic Competitiveness

The U.S. DOT Strategic Plan FY 2012–FY 2016 includes a goal to "Promote transportation policies and investments that bring lasting and equitable economic benefits to the Nation and its citizens."

Maintaining economic competitiveness means increasing and maximizing the contribution of the transportation system to economic growth. At the same time, such investments help accomplish other strategic goals, because maximizing economic benefits requires consideration of the safety, asset management, livability, personal and freight mobility, and environmental sustainability of the entire transportation network. Economic competitiveness will also require implementation of new technologies that enable people and goods to move more efficiently and fully utilize existing capacity across all modes. This section presents information on various aspects of a highway transportation system that affect economic competitiveness.

System Reliability

Reliability is an important characteristic of any transportation system, one that industry in particular requires for efficient production. American manufacturers are increasingly shifting production to high-value, high-tech products whose manufacture integrates transportation into a just-in-time supply chain based on efficient performance and consistent reliability. Additional emphasis will be placed on the American freight network as more manufactured products will need to move across the country. Imported goods shipped to ports will also increase as the American economy continues to grow. Freight shippers, a substantial portion of the nation's economy, depend on a predictable and reliable system to move goods across regions. Although industry may budget for extra time for congestion, unexpected travel delays cannot be accounted for. If industry is unable to utilize a reliable system, they 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. Before travel time reliability, simple averages were mostly used to explain traffic congestion. However, most travelers experience and remember something much different than a simple average throughout a year of commutes. Their travel times vary greatly from day to day, and they remember those few bad days they suffered through unexpected delays. If unexpected delays are minimized in a given period, all users are able to adequately plan for the best use of their time while moving through the transportation network.

Many transportation reliability measures exist, with varying levels of utility. 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 the severity of delay on specific routes during the worst one or two travel days each month. Another method, 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. Generally, the Buffer Index goes up during peak periods—when congestion occurs—indicating a reliability problem.

FHWA Urban Congestion Report

The Urban Congestion Report (UCR) is produced quarterly and characterizes traffic congestion and reliability at the national and city levels. The reports utilize archived traffic operations data gathered from State DOTs and through a public-private partnership with a traffic information company and reflect data from 19 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 congestion information presented in these reports may not be representative of the entire roadway system in any particular city because the UCR includes only those roadways that are instrumented with traffic sensors for the purposes of real-time traffic management and/or traveler information. 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 of the current year to the same 3 months of the prior year.

Data from April through June 2012 concluded that the average duration of weekday congestion is 1 minute longer than in 2011 at 4 hours and 23 minutes per day (during the hours of 6 a.m. to 10 p.m.). Further information can be found at http://ops.fhwa.dot.gov/perf_measurement/ucr/.

System Congestion

Congestion results when traffic demand approaches or exceeds the available capacity of the system. "Recurring" congestion occurs in roughly the same place and time on the same days of the week, and occurs when the physical infrastructure is not adequate to accommodate demand during peak periods. Nonrecurring congestion is caused by temporary disruptions that take away part of the roadway from use. The three main causes of nonrecurring congestion are: incidents ranging from a flat tire to an overturned hazardous material truck (25 percent of total congestion), work zones (10 percent of total congestion), and weather (15 percent of total congestion). Nonrecurring congestion accounts for about half of the congestion on roadways.

Congestion leads to delays, and variability in congestion can lead to or exacerbate reliability problems. Therefore, measuring congestion is very much linked to measuring reliability. There is no universally accepted definition or measurement of exactly what constitutes a congestion "problem." 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.

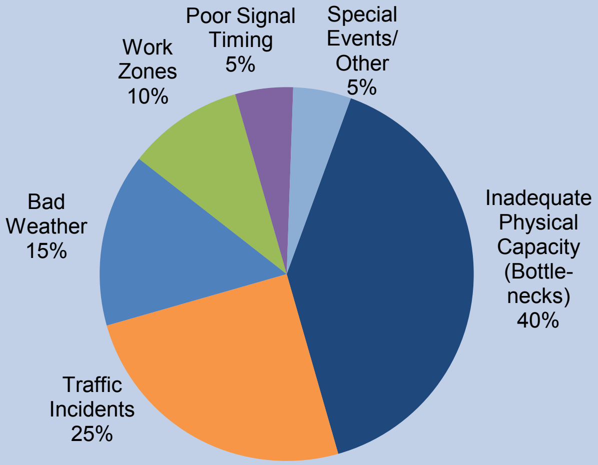
Three key aspects of congestion are severity, extent, and duration. The **severity** of congestion refers to the magnitude of the problem or the degree of congestion experienced by drivers. The **extent** of congestion is defined by the geographic area or number of people affected. The **duration** of congestion is the length of time that the roadway is congested.

Causes of Congestion

The process of congestion relief begins with an understanding of the problem. The various sources of congestion, detailed in *Exhibit 5-2*, frequently interact, meaning that mitigation strategies typically address more than one problem.

- Inadequate capacity: the roadway does not have adequate capacity to efficiently move the number of vehicles traveling on it.
- Bottlenecks: points where the roadway narrows or regular traffic demands cause traffic to backup.
- Traffic incidents: crashes, stalled vehicles, and debris on the road cause about one-fourth of congestion problems.
- Work zones: new road building, rehabilitation, preservation, and maintenance activities are necessary, but the amount of congestion caused by these actions can be reduced by a variety of strategies.
- Bad weather: cannot be controlled, but travelers can be notified of the potential for increased congestion.
- Poor traffic signal timing: the faulty operation of traffic signals where the time allocation for a signal does not match the traffic volume on that road is a source of congestion on some major and minor streets.
- Special events that cause spikes in traffic volume and changes in traffic patterns: irregularities cause delay on days, at times, or in locations where there usually is none, or add to regular congestion problems.

Exhibit 5-2 Sources of Congestion



Source: Federal Highway Administration http://www.fhwa.dot.gov/congestion/describing_problem.htm.

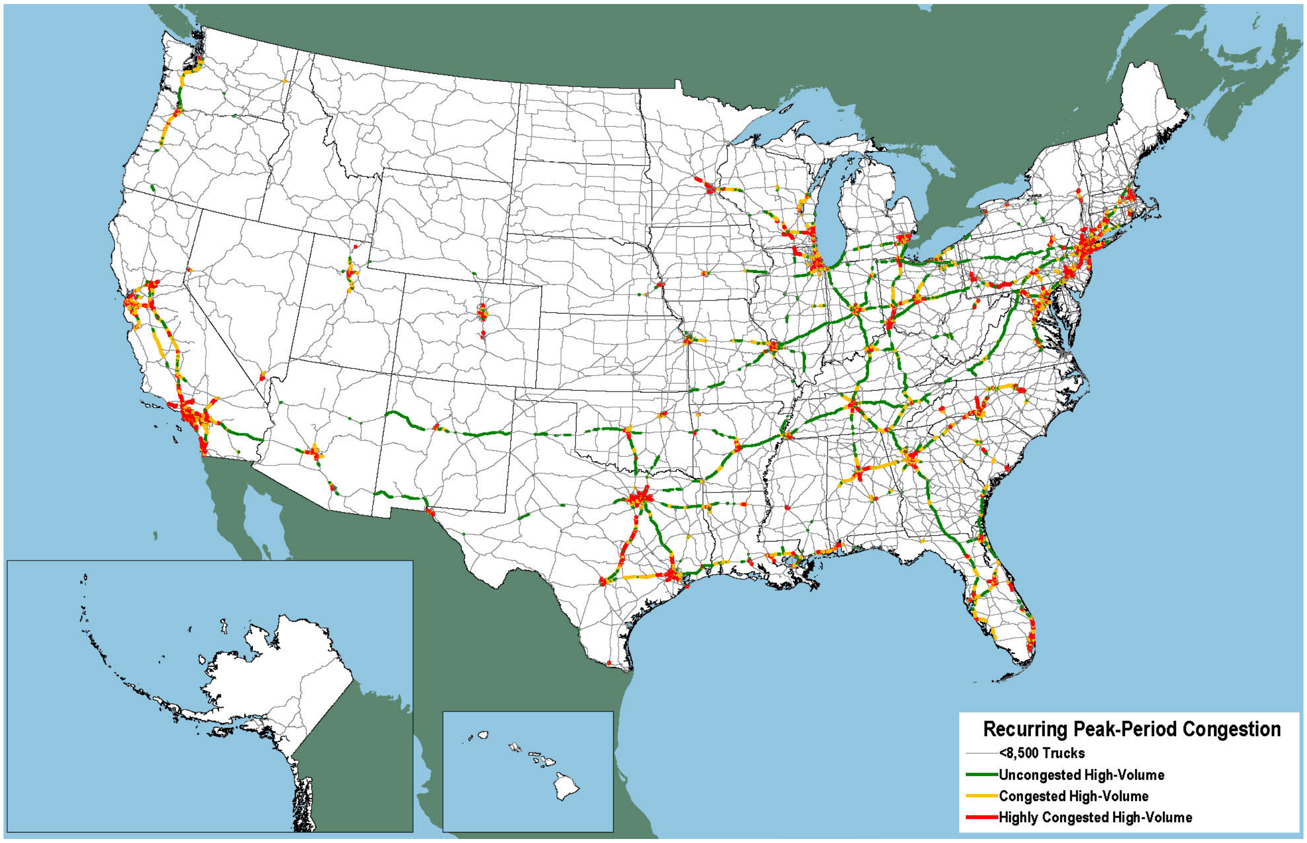
Effect of Congestion and Reliability on Freight Travel

FHWA has created and examined various freight performance measures (FPMs) to analyze the impacts of congestion and determine the operational capacity and efficiency of various Interstate highways and other important freight routes in the United States. Much of the current congestion negatively impacting truck carrier operations occurs on a recurring basis during peak periods of 6 a.m. to 9 a.m. and 4 p.m. to 7 p.m. local time, particularly in and near major metropolitan areas. *Exhibit 5-3* shows a map indicating where this peak period congestion on high-volume truck portions of the National Highway System (NHS) took place

Freight Performance Measurement

The 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 2012. 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 U.S. 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 that 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 5-3 **Peak-Period Congestion on High-Volume Truck Portions of the National Highway System, 2007**



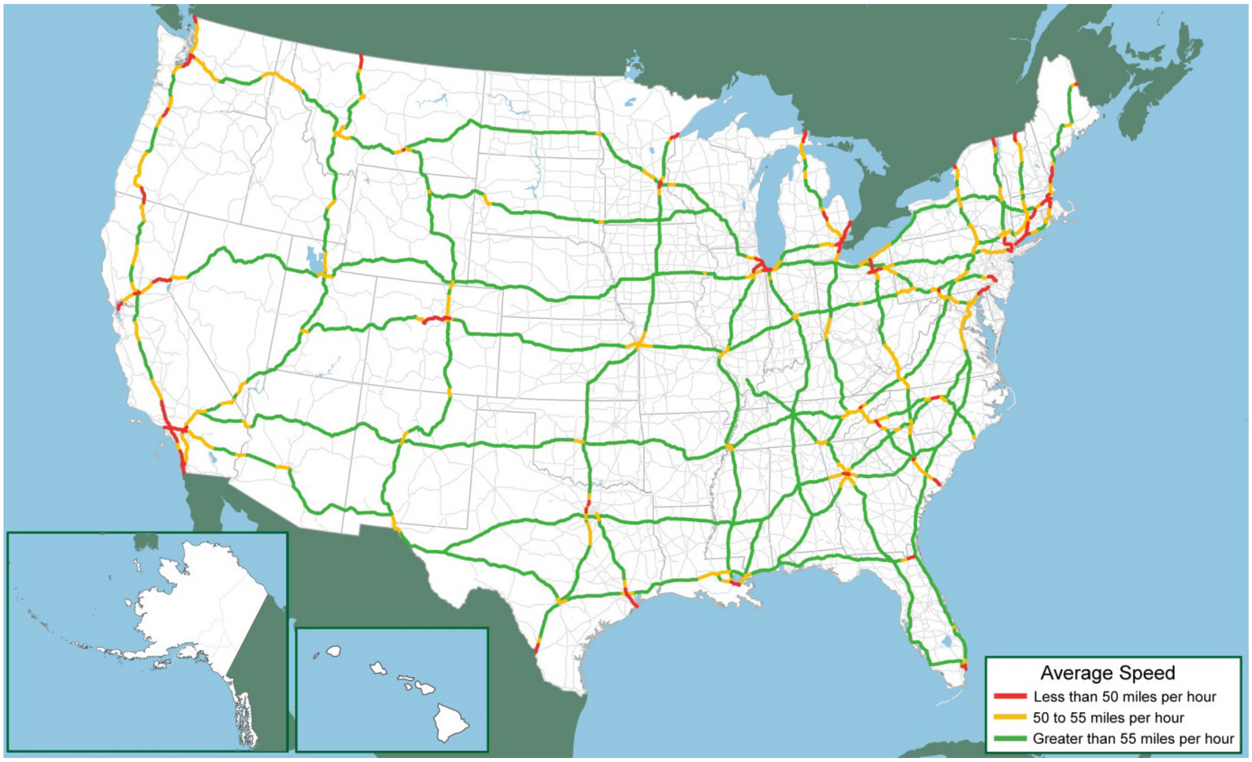
Note: High-volume truck portions of the National Highway System carry more than 8,500 trucks per day, including freight-hauling long-distance trucks, freight-hauling local trucks, and other trucks with six or more tires. Highly congested segments are stop-and-go conditions with volume/service flow ratios greater than 0.95. Congested segments have reduced traffic speeds with volume/service flow ratios between 0.75 and 0.95.

Sources: U.S. Department of Transportation, Federal Highway Administration, Office of Highway Policy Information, Highway Performance Monitoring System, and Office of Freight Management and Operations, Freight Analysis Framework, version 3.2, 2010.

in 2007. Overall, peak period congestion created stop-and-go conditions on 3,700 miles of the NHS and caused traffic to travel below posted speed limits on an additional 4,700 miles of the NHS.

In some locations, freight-hauling trucks are impacted not only during peak periods, but also at other times during the day. In cooperation with private industry, FHWA measures the speed and travel time reliability of more than 500,000 trucks along 25 Interstate corridors on an annual basis. *Exhibit 5-4* shows some of the results of this cooperative initiative, indicating the average truck travel speeds on selected Interstate

Exhibit 5-4 Average Truck Speeds on Selected Interstate Highways, 2010



Interstate Route	Average Operating Speed	Average Peak Period Speed*	Average Speed Nonpeak Period	Interstate Route	Average Operating Speed	Average Peak Period Speed*	Average Nonpeak Period Speed
5	53.0	52.1	53.2	**70**	57.1	56.8	57.2
10	57.8	57.6	58.1	**75**	57.3	56.7	57.9
15	56.7	56.5	56.8	**76**	55.4	55.3	55.4
20	59.2	59.0	59.1	**77**	55.3	54.9	55.3
24	57.5	56.7	57.5	**80**	58.0	57.8	58.1
25	59.3	59.3	59.2	**81**	56.8	56.8	56.8
26	54.2	53.8	54.3	**84**	54.1	52.7	54.5
35	56.9	56.1	57.2	**85**	57.6	56.7	57.7
40	59.0	58.8	59.1	**87**	54.5	54.1	54.7
45	55.4	54.3	55.8	**90**	57.2	57.0	57.3
55	57.8	57.6	57.8	**91**	53.6	52.8	54.1
65	58.0	57.5	58.1	**94**	58.4	58.1	58.5
				95	56.5	55.4	57.0

* 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.

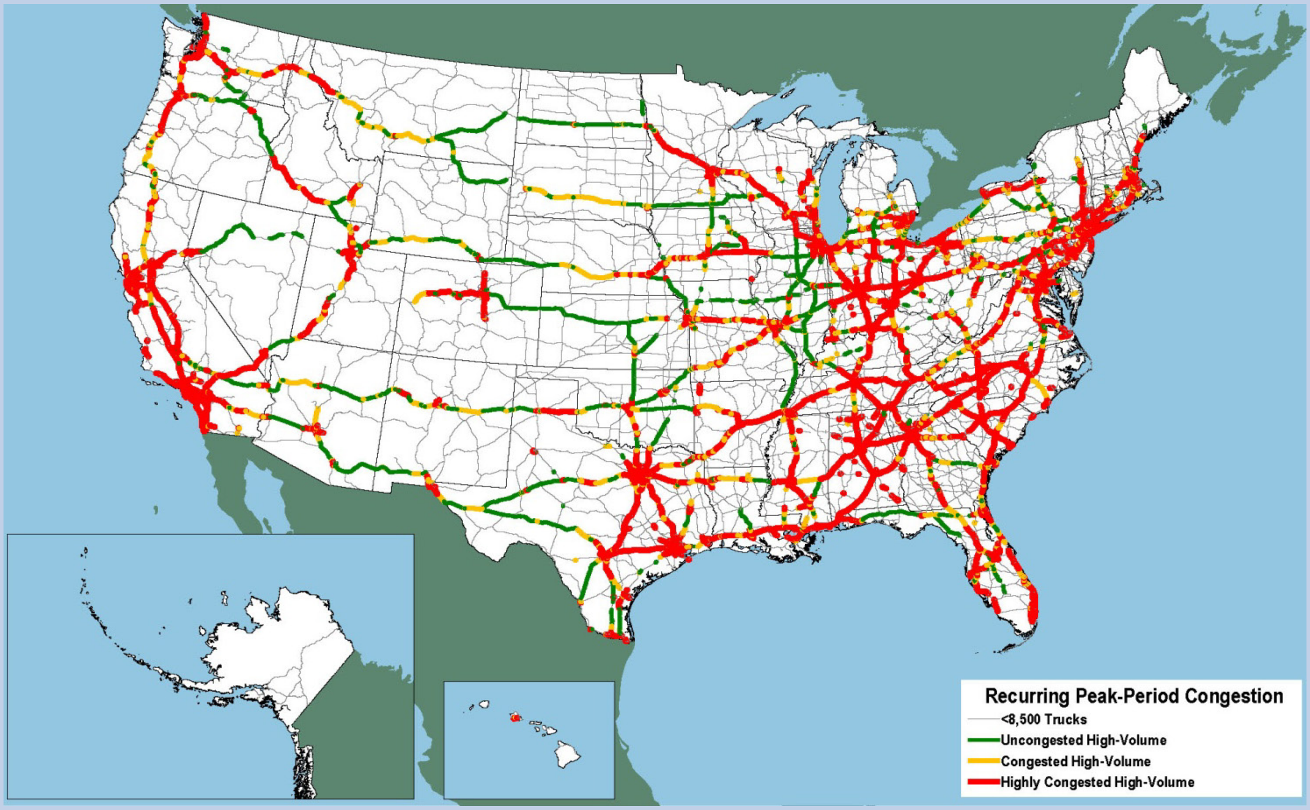
Sources: U.S. Department of Transportation, Federal Highway Administration, Office of Freight Management and Operations, Performance Measurement Program, 2011 (map), 2012 (table data).

highways. Reduced truck travel speeds most commonly occur in large metropolitan areas, but can also occur at international border crossings and gateways, in mountainous areas that require trucks to climb steep inclines, and in areas frequently prone to poor visibility driving conditions.

Projections of Future Congestion

Though in many cases congestion on many high-volume NHS truck routes in various large metropolitan areas is already severe, particularly during peak periods, the congestion could become much more severe in terms of its geographic scope and impact on major intercity corridors and metropolitan areas if network capacity remains unchanged. *Exhibit 5-5* shows a map indicating where this peak-period congestion on high-volume truck portions of the NHS could take place in 2040 . Peak-period congestion is projected to create stop-and-go conditions on 23,500 miles of the NHS (over six times as many miles as in 2007) and traffic slower than posted speed limits on an additional 7,200 miles of the NHS (nearly twice as many miles as in 2007).

Exhibit 5-5 **Peak-Period Congestion on High-Volume Truck Portions of the National Highway System, 2040**



Note: High-volume truck portions of the National Highway System carry more than 8,500 trucks per day, including freight-hauling long-distance trucks, freight-hauling local trucks, and other trucks with six or more tires. Highly congested segments are stop-and-go conditions with volume/service flow ratios greater than 0.95. Congested segments have reduced traffic speeds with volume/service flow ratios between 0.75 and 0.95. The volume/service flow ratio is estimated using the procedures outlined in the HPMS Field Manual, Appendix N.

Sources: U.S. Department of Transportation, Federal Highway Administration, Office of Highway Policy Information, Highway Performance Monitoring System, and Office of Freight Management and Operations, Freight Analysis Framework, version 3.2, 2010.

Congestion Mitigation and Reliability Improvement

Efforts to mitigate congestion and improve reliability can take place by improving service on existing roads, introducing pricing schemes, or enhancing information provided to drivers. Frequently, several of the strategies presented below are applied in tandem, mitigating a number of congestion sources in a holistic manner. More detail can be found at http://www.fhwa.dot.gov/congestion/toolbox/index.htm.

Improve Service on Existing Roads

- **Traffic Incident Management** is a planned and coordinated process shared by public and private sector partners to detect, respond to, and remove traffic incidents and restore traffic capacity as safely and quickly as possible.
- **Arterial Management** improves travel throughout entire communities by coordinating traffic signals through timing and access management. Arterial roadways are high-capacity roads to deliver traffic from collector roads to freeways, and between urban centers.
  - *Traffic Signal Timing* can produce benefit-cost ratios as high as 40 to 1. The costs for retiming traffic signals are generally very small, but provide substantial benefit.
  - *Access Management* is the proactive management of vehicular access points to land parcels adjacent to roadways. State and local governments can control access to facilities by increasing the distance between traffic signals; constructing fewer driveways spaced farther apart to allow for more orderly merging; constructing dedicated left- and right-turn lanes, indirect left-turn and U-turn lanes, and roundabouts to keep through-traffic flowing; constructing two-way left-turn lanes and non-traversable, raised medians; and managing right-of-way for future widening, good sight distance, access location, and other access-related issues.
- **Freeway Management and Traffic Operations** involves applying the appropriate policies, strategies, and actions to mitigate any potential impacts resulting from the intensity, timing, and location of travel and to reduce congestion. The Traffic Management Center (TMC) is often the hub of most freeway management systems.
- **Active Transportation and Demand Management** (ATDM) is the dynamic management, control, and influence of travel demand, traffic demand, and traffic flow of transportation facilities. Through the use of archived data and/or predictive methods, traffic flow is managed and traveler behavior is influenced in real time to achieve operational objectives, such as preventing or delaying breakdown conditions, improving safety, promoting sustainable travel modes, reducing emissions, or maximizing system efficiency.
- **Road Weather Management** allows weather events and their impacts on roads to be viewed as predictable, nonrecurring incidents that affect safety, congestion, and productivity. Advisory strategies provide information on prevailing and predicted conditions to both transportation managers and motorists, such as posting fog warnings on dynamic message signs or listing flooded routes on websites. Control strategies alter roadway devices (messages, timing of signals, etc.) to permit or restrict traffic flow and regulate roadway capacity, such as reducing speed limits with variable speed limit signs and modifying traffic signal timing. Treatment strategies supply resources to roads to minimize or eliminate weather impacts, the most common of which are application of sand, salt, and anti-icing chemicals to pavements to improve traction and prevent ice bonding.
- **Planned Special Events Traffic Management** allows agencies to develop and deploy the operational strategies, traffic control plans, protocols, procedures, and technologies needed to control traffic and share real-time information with other stakeholders on the day of an event. Planned special events cause congestion and unexpected delays to travelers by increasing traffic demand or reducing roadway capacity (e.g., street closures for parades).

Pricing

- **Congestion Pricing**, sometimes referred to as value pricing or peak-period pricing, involves charging relatively higher prices for travel during peak periods. It is identical to the technique used in many other sectors of the economy to respond to peak-use demands. Congestion pricing entails fees or tolls for road use that vary with the level of congestion. Introducing congestion pricing to highway facilities brings transportation supply and demand into balance and keeps the lanes congestion free. Fees are typically assessed electronically to eliminate delays associated with manual toll collection facilities.

Add Capacity

- **Easing Bottlenecks** is necessary when a road is at capacity and the flow of traffic is disrupted. The capacity of a road is determined by a number of factors, including the number and width of lanes and shoulders, merge areas at interchanges, and roadway alignment (grades and curves). Minimizing the impacts of or eliminating bottlenecks is one of the most effective ways to reduce congestion.

Better Work Zones

- **Work Zone Management** can have a positive impact on preventing or relieving congestion by aggressively anticipating and mitigating congestion caused by highway work zones. Solutions can come from fundamental changes in the way projects are planned, estimated, designed, bid, and constructed.

Travel Options

- **Travel Demand Management** involves strategies to provide travelers with effective travel choices such as work location, route, time, and mode. Managing both the growth of and periodic shifts in traffic demand are necessary elements of managing traffic congestion.
- **Transportation Choices** such as accessibility to transit, car-sharing or bicycle/pedestrian facilities helps alleviate congestion on the Nation's road network. By promoting the use of transit or bicycle/pedestrian facilities, the use of fewer cars during peak travel times also improves air quality in communities with close proximity to major highways.

Traveler Information

- The **511** telephone number was designated for traveler information services by the Federal Communications Commission in 2001 and assigned to public transportation agencies for implementing services throughout the United States. FHWA is working cooperatively with FTA, the American Association of State Highway and Transportation Officials, the American Public Transportation Association, the Intelligent Transportation Society of America, and the members of the 511 Coalition to establish more 511 travel information services throughout the United States.
- **Travel Time Message Signs** are dynamic signs located near roadways that give motorists the estimated time it will take them to get to the next one or two significant destinations.
- **National Traffic and Road Closure Information** is provided to travelers and freight shippers to broadcast current weather, road, and traffic conditions.
- **Real-Time System Management Information** is a real-time information system that provides the capability to monitor traffic and travel conditions on major highways. This information enables drivers to make informed decisions. FHWA is supporting the deployment of the Real-Time System Management Information Program so that all States are able to broadcast information to travelers.
- The **Cross-Town Improvement Project** (C-TIP) combines real-time travel time information and freight shipper congestion information to optimize the flow of freight within a metropolitan area. Cross-town truck traffic is coordinated using both public and private traffic and freight data to reduce empty truck bobtail (tractor without trailer) moves between railroad terminals and freight distribution facilities. The system uses four components that include an information exchange, wireless update capability, real-time traffic monitoring, and dynamic routing applications to deliver up-to-the-minute information regarding roadway conditions, travel speeds, and predicted travel times. This information is passed to the freight traveler to deliver enhanced traveler information and predictive travel times for freight pick-up and delivery routes in urban areas.

Transit System Performance

Basic goals shared by all transit operations include minimizing travel times, making efficient use of vehicle capacity, and providing reliable performance. The Federal Transit Administration (FTA) collects data on average speed, how full the vehicles are (utilization), and how often they break down (mean distance between failures) to characterize how well transit service meets these goals. These data are reported here; safety data are reported in Chapter 4.

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 do not support time series analysis.

New technology has allowed progressive transit agencies to report service metrics on their Web sites. Because this is a relatively new practice, measures that are standardized across the industry have not yet been developed. Industry associations are beginning to address this issue, but for now there is no generally recognized set of standards.

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.

FTA Livable Communities Outcomes and Performance Measures

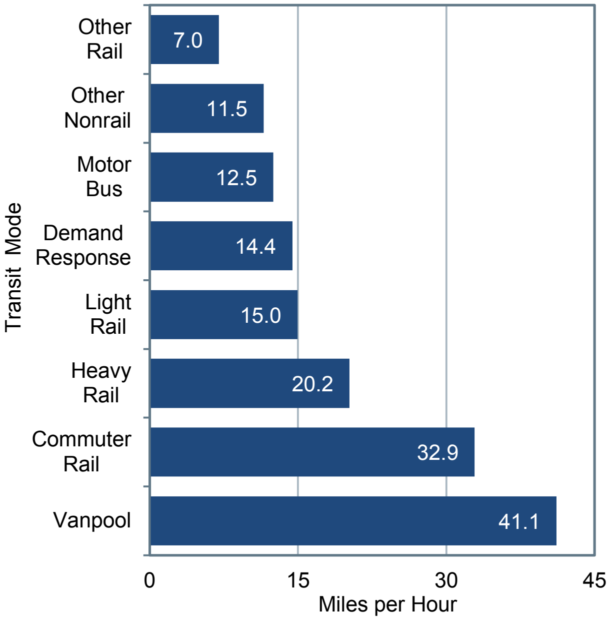
Modal Network	*Demand Response*
1. Increased access to convenient and affordable transportation choices	• Increase the number of transit boardings reported by urbanized area transit providers from 10.0 billion in 2011 to 10.5 billion in 2016. • Increase the number of transit boardings reported by rural area transit providers from 141 million in 2011 to 160 million in 2016. • Increase transit's market share among commuters to work in at least 10 of the top 50 urbanized areas by population, as compared to 2010 market share levels.
2. Improved access to transportation for people with disabilities and older adults	• Increase the number of key transit rail stations verified as accessible and fully compliant from 522 in 2010 to 560 in 2016.

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 mode, as reported to the National Transit Database (NTD). In cases where an agency contracts with a service provider and provides the service directly, the speeds for each of the services within a mode are calculated and weighted separately. The results of these average speed calculations are presented in *Exhibit 5-6*.

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. These average speeds have not changed significantly over the last decade.

Exhibit 5-6 **Average Speeds for Passenger-Carrying Transit Modes, 2010**



Notes: Other Nonrail includes Público, trolleybus, and demand taxi; Other Rail includes Alaska railroad, automated guideway, cable car, inclined plane, and monorail.

Source: National Transit Database.

Vehicle Use

Vehicle Occupancy

Exhibit 5-7 shows vehicle occupancy by mode for selected years from 2000 to 2010. Vehicle occupancy is calculated by dividing PMT by vehicle revenue miles (VRMs), resulting in the average number of people carried in a transit vehicle. There has been little change in vehicle occupancy between 2000 and 2010 indicating sustained ridership levels across all types of transit.

Taking into account that vehicle capacities differ by mode, *Exhibit 5-8* shows the 2010 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 2010: vanpool, 11; heavy rail, 59; light rail, 57; trolleybus, 45; ferryboat, 385; commuter rail, 96; motor bus, 33; demand response, 12). For example, the average full-size bus seats 33 people and, as shown in *Exhibit 5-7*, the average occupancy for a bus in 2010 was 10.7 riders. This occupancy, as a percentage of seating capacity, is 32.5 percent. Some modes also have substantial standing capacity that is not considered here, but which can allow the measure of the percentage of seats occupied to exceed 100 percent for a full vehicle.

Although, on average, it appears that there is excess capacity in all these modes, 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 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 (i.e., filled to maximum capacity) on part of the trip may still only achieve an average occupancy of around 35 percent (as shown by analysis of the Washington Metropolitan Area Transit Authority peak-period data).

Exhibit 5-7 Unadjusted Vehicle Occupancy: Passengers per Transit Vehicle, 2000–2010

Mode	2000	2002	2004	2006	2008	2010
Rail						
Heavy Rail	23.9	22.6	23.0	23.2	25.7	25.3
Commuter Rail	37.9	36.7	36.1	36.1	35.7	34.2
Light Rail	26.1	23.9	23.7	25.5	24.1	23.7
Other Rail[1]	8.4	8.4	10.4	8.4	9.3	10.7
Nonrail						
Motor Bus	10.7	10.5	10.0	10.8	10.8	10.7
Demand Response	1.3	1.2	1.3	1.3	1.2	1.2
Ferryboat	120.1	112.1	119.5	130.7	118.1	119.3
Trolleybus	13.8	14.1	13.3	13.9	14.3	13.6
Vanpool	6.6	6.4	5.9	6.3	6.3	6.0
Other Nonrail[2]	7.3	7.9	5.8	7.8	8.2	7.4

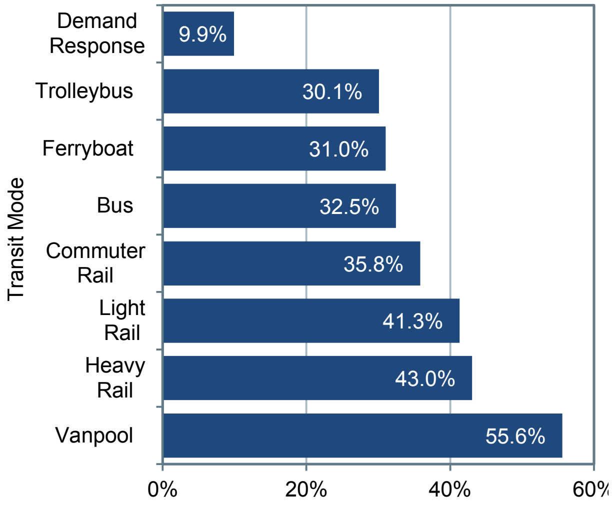
[1] *Alaska railroad, automated guideway, cable car, inclined plane, and monorail.*

[2] *Aerial tramway and Público.*

Source: National Transit Database.

Another issue that makes it hard to fully use vehicle capacity is called "bunching." If a stop has a particularly large number of passengers, the servicing vehicle takes longer to load increasing the spacing between it and the previous vehicle. This not only means the vehicle's next stop will have more riders due to the longer interval, but that there will be a shorter interval between it and the vehicle behind it. This compounds the problem by slowing the vehicle more and speeding up the vehicle behind it. Soon the vehicles become bunched up, causing longer wait times for some passengers and inconsistent in-vehicle volumes with some being overcrowded and others underutilized. This situation is common and difficult to mitigate.

Exhibit 5-8 Average Seat Occupancy Calculations for Passenger-Carrying Transit Modes, 2010



Note: Some modes also have substantial standing capacity that is not considered here, but which can allow the measure of the percentage of seats occupied to exceed 100 percent for a full vehicle.

Source: National Transit Database.

Revenue Miles per Active Vehicle (Service Use)

Vehicle service use, the average distance traveled per vehicle in service, can be measured by VRMs. *Exhibit 5-9* provides vehicle service use by mode for selected years from 2000 to 2010. Heavy rail, generally offering long hours of frequent service, had the highest vehicle use during this period. Vehicle service use for light rail, and to a lesser extent for vanpool and demand response, shows an increasing trend. Vehicle service use for other nonrail modes appears to be relatively stable over the past few years with no apparent trends in either direction.

Exhibit 5-9 **Vehicle Service Utilization: Vehicle Revenue Miles per Active Vehicle by Mode**

Mode	Thousands of Revenue Vehicle Miles 2000	2002	2004	2006	2008	2010	Average Annual Rate of Change 2010/2000
Rail							
Heavy Rail	55.6	55.1	57.0	57.2	57.7	56.6	0.2%
Commuter Rail	42.1	43.9	41.1	43.0	45.5	45.1	0.7%
Light Rail	32.5	41.1	39.9	39.9	44.1	42.5	2.7%
Nonrail							
Motor Bus	28.0	29.9	30.2	30.2	30.3	29.7	0.6%
Demand Response	17.9	21.1	20.1	21.7	21.3	20.0	1.1%
Ferryboat	24.1	24.4	24.9	24.8	21.9	24.9	0.3%
Vanpool	12.9	13.6	14.1	13.7	14.3	15.5	1.8%
Trolleybus	18.9	20.3	21.1	19.1	18.7	20.4	0.8%

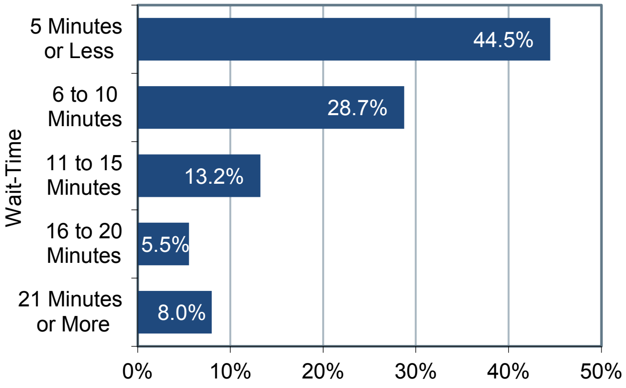
Source: National Transit Database.

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 it will attract fewer users. Further, when scheduled service is offered less frequently, reliability becomes more important to users.

Exhibit 5-10 shows findings on wait-times from the 2009 FHWA National Household Travel Survey (NHTS), 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 21 minutes or more. 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 21 minutes or more indicate that service is likely less frequent or less reliable.

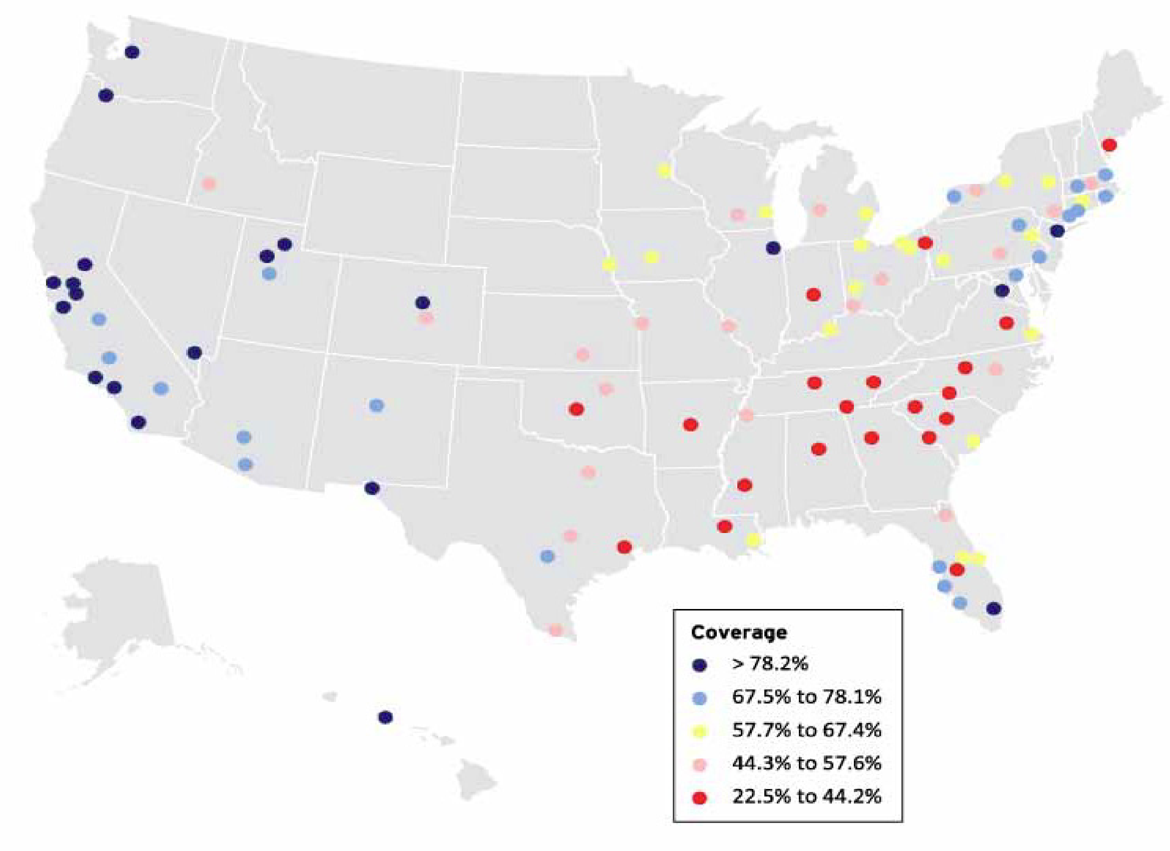
Exhibit 5-10 **Distribution of Passengers by Wait-Time**



Source: National Household Travel Survey, FHWA, 2009.

Access to transit service varies by location. *Exhibit 5-11* shows the share of working-age residents that have access to transit in 100 selected metro areas. The study evaluated census block groups and counted block groups with at least one transit stop within three-fourths of a mile of their population-weighted centroid as having access. Cities in the Western U.S. tend to enjoy higher rates of coverage while those in the southeast tend to have a lower percentage of residents with access to transit.

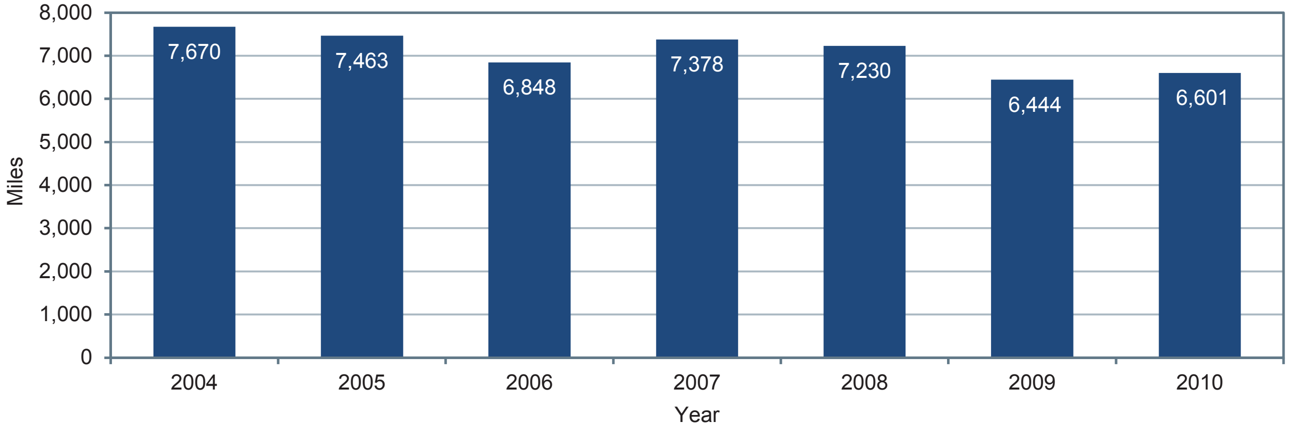
Exhibit 5-11 **Share of Working-Age Residents With Access to Transit, 100 Metropolitan Areas**



Source: Brookings Institution, Missed Opportunity: Transit and Jobs in Metropolitan America*, May 2011 report citing Brookings Institution analysis of transit agency data and Nielson Pop-Facts 2010 data.*

Mean distance between failures, as shown in *Exhibit 5-12*, has declined 14 percent since 2004 to 6,601 miles. The average distance between failures is calculated by adding all mechanical failures to all other failures and dividing VRMs by this total number of failures. The stability shown in the graph 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.

Exhibit 5-12 **Mean Distance Between Failures, 2004–2010**



Source: National Transit Database.

System Coverage: Urban Directional Route Miles

The extent of the Nation's transit system is measured in directional route miles, or simply "route miles." Route miles measure the distance covered by a transit route; 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 because these transit modes do not travel along specific predetermined routes. Route miles data are also not collected for jitney services because these transit modes often have highly variable route structures.

Exhibit 5-13 shows directional route miles by mode over the past 10 years. Growth in both rail (27.3 percent) and nonrail (20.7 percent) route miles is evident over this period. The average 6.0 percent rate of annual growth for light rail clearly outpaces the rate of growth for all other modes.

Exhibit 5-13 **Transit Urban Directional Route Miles, 2000–2010**

	Route Miles						Average Annual Rate of Change
Transit Mode	**2000**	**2002**	**2004**	**2006**	**2008**	**2010**	**2010/2000**
Rail	**9,222**	**9,484**	**9,782**	**10,865**	**11,270**	**11,735**	**+2.4%**
Commuter Rail [1]	6,802	6,923	6,968	7,930	8,219	8,590	+2.4%
Heavy Rail	1,558	1,572	1,597	1,623	1,623	1,617	+0.4%
Light Rail	834	960	1,187	1,280	1,397	1,497	+6.0%
Other Rail [2]	29	30	30	31	30	30	+0.5%
Nonrail[3]	**196,858**	**225,820**	**216,619**	**223,489**	**212,801**	**237,580**	**+1.9%**
Bus	195,884	224,838	215,571	222,445	211,664	236,434	+1.9%
Ferryboat	505	513	623	620	682	690	+3.2%
Trolleybus	469	468	425	424	456	456	-0.3%
Total	**206,080**	**235,304**	**226,401**	**234,354**	**224,071**	**249,314**	**+1.9%**
Percent Nonrail	95.5%	96.0%	95.7%	95.4%	95.0%	95.3%	

[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

Exhibit 5-14 provides reported VRMs for both rail and nonrail modes. These numbers are of interest because they show the actual number of miles traveled by each mode in revenue service. VRMs provided by both bus services and rail services show consistent growth, with light rail and vanpool miles growing somewhat faster than the other modes. Overall, the number of VRMs has increased by 22.5 percent since 2000.

Transit system capacity, particularly in cross-modal comparisons, is typically measured by capacity-equivalent VRMs. These 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.

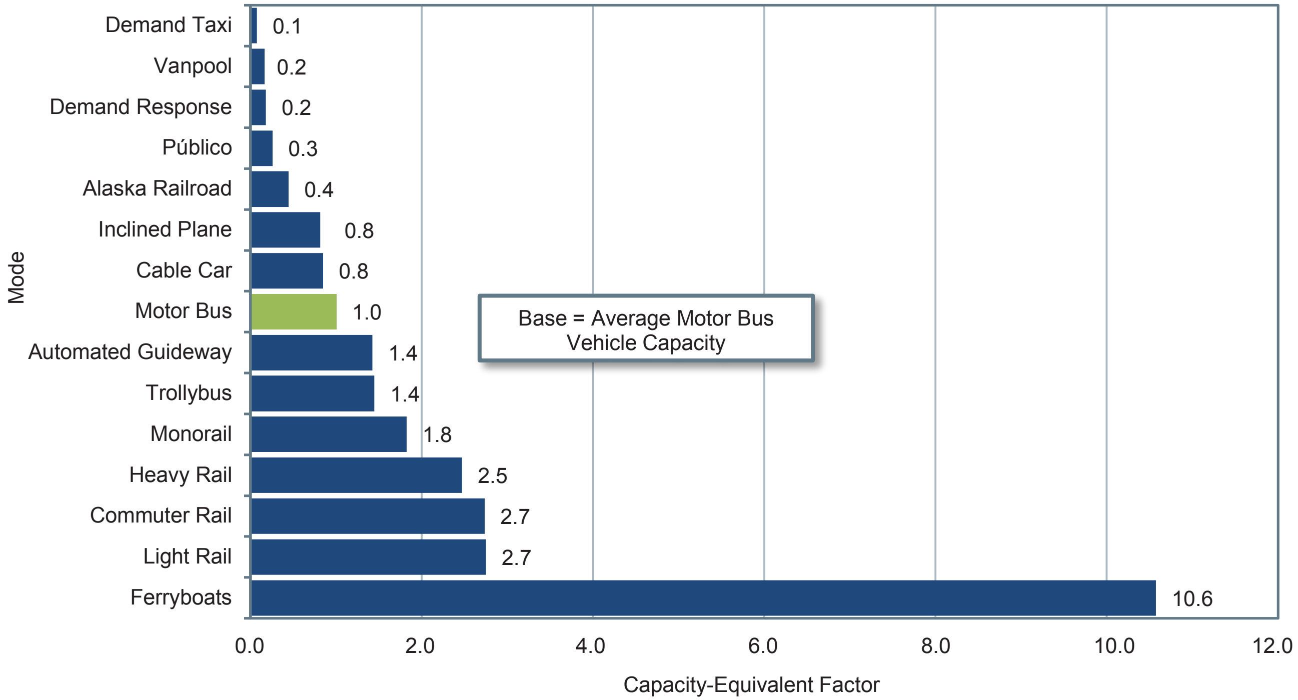
Exhibit 5-14 Rail and Nonrail Vehicle Revenue Miles, 2000–2010

	Miles (Millions)						Average Annual Rate of Change
Transit Mode	**2000**	**2002**	**2004**	**2006**	**2008**	**2010**	**2010/2000**
Rail	**879**	**925**	**963**	**997**	**1,054**	**1,056**	**1.9%**
Heavy Rail	578	603	625	634	655	647	1.1%
Commuter Rail	248	259	269	287	309	315	2.4%
Light Rail	51	60	67	73	86	92	6.0%
Other Rail	2	3	2	3	3	2	1.7%
Nonrail	**2,322**	**2,502**	**2,586**	**2,674**	**2,841**	**2,863**	**2.1%**
Motor Bus	1,764	1,864	1,885	1,910	1,956	1,917	0.8%
Demand Response	452	525	561	607	688	718	4.7%
Vanpool	62	71	78	110	157	181	11.3%
Ferryboat	2	3	3	3	3	3	5.0%
Trolleybus	14	13	13	12	11	12	-1.8%
Other Nonrail	28	26	46	32	25	32	1.5%
Total	**3,201**	**3,427**	**3,549**	**3,671**	**3,895**	**3,920**	**2.0%**

Source: National Transit Database.

The 2010 capacity-equivalent factors for each mode are shown in *Exhibit 5-15*. 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 2010 was 39 seated and 23 standing for a total of 62 riders.

Exhibit 5-15 Capacity-Equivalent Factors by Mode



Source: National Transit Database.

Total capacity-equivalent VRMs are shown in *Exhibit 5-16*. Showing the most rapid expansion in capacity-equivalent VRMs in the period from 2000 to 2010 was vanpools, followed by light rail, demand response, and then commuter rail. Total capacity-equivalent revenue miles increased from 3,954 million in 2000 to 4,845 million in 2010, an increase of 22.5 percent.

Exhibit 5-16 **Capacity-Equivalent Vehicle Revenue Miles, 2000–2010**

	Vehicle Miles (Millions)						Average Annual Rate of Change
Transit Mode	**2000**	**2002**	**2004**	**2006**	**2008**	**2010**	**2010/2000**
Rail	**2,046**	**2,274**	**2,413**	**2,681**	**2,799**	**2,714**	**2.9%**
Heavy Rail	1,321	1,469	1,546	1,648	1,621	1,599	1.9%
Commuter Rail	595	652	685	832	940	860	3.8%
Light Rail	127	150	179	197	235	252	7.1%
Other Rail	3	3	3	4	3	3	-1.1%
Nonrail	**1,908**	**2,037**	**2,064**	**2,118**	**2,152**	**2,131**	**1.1%**
Motor Bus	1,764	1,864	1,885	1,910	1,956	1,917	0.8%
Demand Response	76	100	101	121	115	124	5.1%
Vanpool	11	15	15	22	27	30	10.0%
Ferryboat	30	32	32	37	32	35	1.4%
Trolleybus	20	20	20	19	16	17	-1.6%
Other Nonrail	7	7	12	10	6	8	1.3%
Total	**3,954**	**4,311**	**4,478**	**4,800**	**4,951**	**4,845**	**2.1%**

Source: National Transit Database.

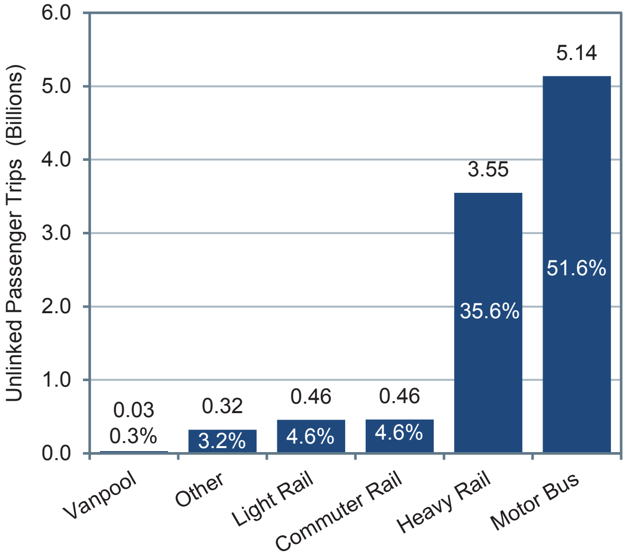
Ridership

There are two primary measures of transit ridership: unlinked passenger trips and PMT. An unlinked passenger trip, sometimes called a boarding, is defined as a journey on *one* transit vehicle. PMT is calculated on the basis of unlinked passenger trips and estimates of average trip length. Either measure provides an appropriate time series because 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 5-17 and *Exhibit 5-18* show the distribution of unlinked passenger trips and PMT by mode. In 2010, urban transit systems provided 9.9 billion unlinked trips and 52.6 billion PMT across all modes. 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 4.0 for bus, 4.6 for heavy rail, and 4.8 for light rail).

Exhibit 5-19 provides total PMT for selected years between 2000 and 2010, showing steady growth in all the major modes. Demand response, light rail, and vanpool modes grew at the fastest rates. Growth in demand response (up 4.0 percent per year) may be a response to demand from the growing number of

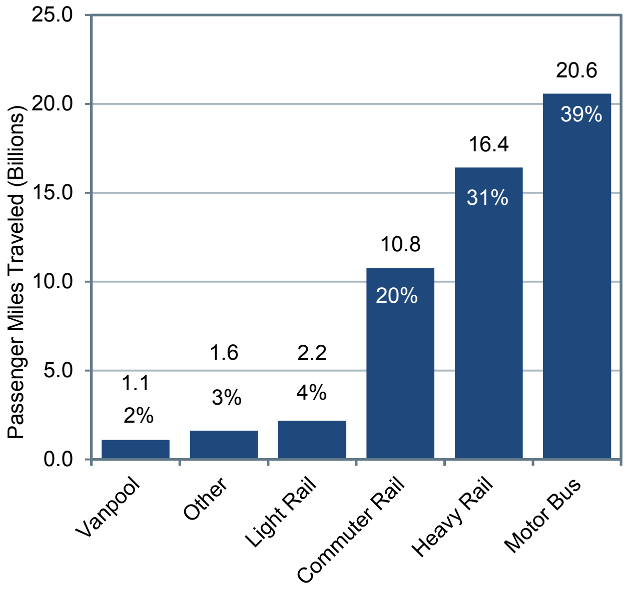
Exhibit 5-17 **Unlinked Passenger Trips (Total in Billions and Percent of Total) by Mode, 2010**



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

Source: National Transit Database.

Exhibit 5-18 **Passenger Miles Traveled (Total in Billions and Percent of Total) by Mode, 2010**



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

Source: National Transit Database.

elderly citizens. Light rail (up 5.0 percent per year) enjoyed increased capacity during this period due to expansions and addition of new systems. Vanpool's rapidly increasing popularity (up 10.3 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. FTA has also encouraged vanpool reporting during this period, successfully enrolling a large number of new vanpool systems to report to NTD.

Exhibit 5-20 shows the complex relationship among an index of rolling 12 months' transit ridership, gasoline prices, and employment rates.

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 they perceive that 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 very little to do with the characteristics of transit.

Exhibit 5-19 **Transit Urban Passenger Miles, 2000–2010**

	Passenger Miles (Millions)						Average Annual Rate of Change
Transit Mode	**2000**	**2002**	**2004**	**2006**	**2008**	**2010**	**2010/2000**
Rail	**24,604**	**24,617**	**25,667**	**26,972**	**29,989**	**29,380**	**1.8%**
Heavy Rail	13,844	13,663	14,354	14,721	16,850	16,407	1.7%
Commuter Rail	9,400	9,500	9,715	10,359	11,032	10,774	1.4%
Light Rail	1,340	1,432	1,576	1,866	2,081	2,173	5.0%
Other Rail[1]	20	22	22	25	26	26	2.8%
Nonrail	**20,497**	**21,328**	**20,879**	**22,533**	**23,723**	**23,247**	**1.3%**
Motor Bus	18,807	19,527	18,921	20,390	21,198	20,570	0.9%
Demand Response	588	651	704	753	844	874	4.0%
Vanpool	407	455	459	689	992	1,087	10.3%
Ferryboat	298	301	357	360	390	389	2.7%
Trolleybus	192	188	173	164	161	159	-1.9%
Other Nonrail[2]	205	206	265	176	138	169	-1.9%
Total	**45,101**	**45,945**	**46,546**	**49,504**	**53,712**	**52,627**	**1.6%**
Percent Rail	54.6%	53.6%	55.1%	54.5%	55.8%	55.8%	

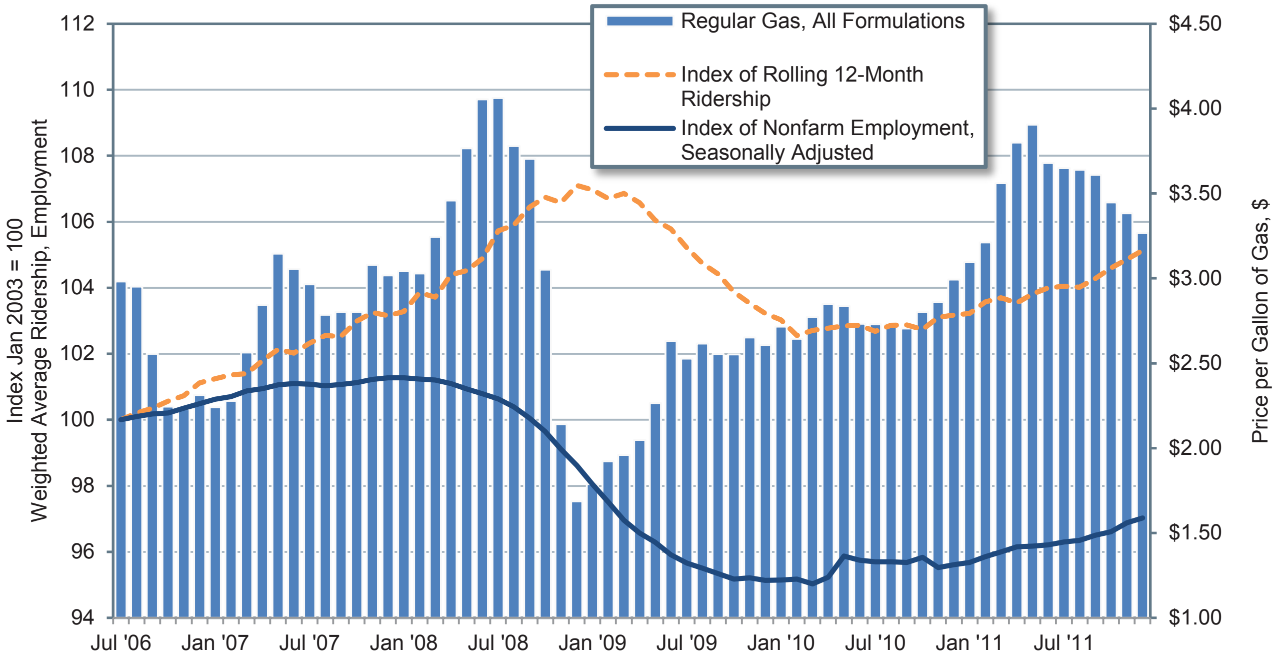
[1] *Alaska railroad, automated guideway, cable car, inclined plane, and monorail.*

[2] *Aerial tramway and Público.*

Source: National Transit Database.

The relationship between employment and transit is well established. According to the May 2007 APTA report *A Profile of Public Transportation Passenger Demographics and Travel Characteristics Reported in On-Board Surveys:* "Commuting to work is the most common reason a person rides public transportation, accounting for 59.2 percent of all transit trips reported in on-board surveys." It would follow from this that

Exhibit 5-20 Transit Ridership versus Employment, 2006–2011

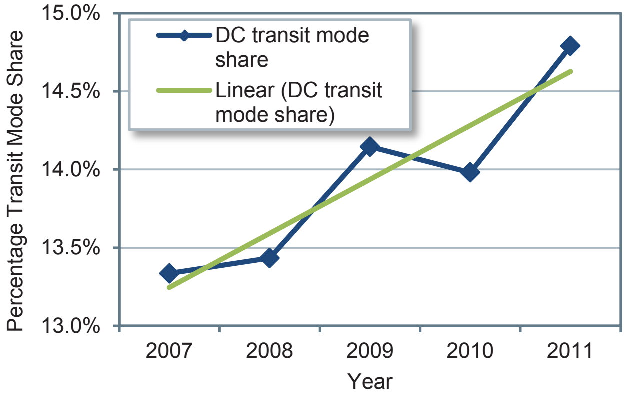


Source: National Transit Database, U.S. Energy Information Administration's Gas Pump Data History, and Bureau of Labor Statistics' Employment Data.

transit ridership should drop off in times of high unemployment and, in fact, until 2008 the correlation between transit ridership and employment levels was so strong that FTA corrected ridership to account for employment levels. From early 2007 through summer of 2008, however, transit ridership increased in the absence of employment growth. This anomaly may be due to dramatic increases in the price of gas during this period; gas prices increased from around $2.35 per gallon to over $4.00 per gallon. Since the start of 2009, gas prices have eased and then grown again in a similar but more gradual pattern, but without influencing transit ridership in the same way (perhaps due to a concurrent decline in employment). Since 2010, ridership has once again been tracking employment levels but has retained some of its 2007–2008 gains. In July of 2011, transit ridership was up 5 percent over its July 2006 level while employment was still down 3 percent from its July 2006 level.

If gas prices are the causal factor here, one would expect to see transit taking a greater market share of commuting rides to work. This would be a different effect than there being more riders due to an increase in the number of commuters overall, which would not imply a change in market share. To test this hypothesis, FTA examined American Community Survey (ACS) data for 2007 through 2011 for the Washington, DC, metropolitan area. ACS data for 2008–2011, presented in *Exhibit 5-21*, show a gain in transit mode share during this period, which supports the explanation that gas prices are having a major impact on transit ridership.

Exhibit 5-21 Washington, DC, Transit Mode Share, 2007–2011



Source: U.S. Census Bureau, American Community Survey.