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Transportation Statistics Annual Report 2017

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Quality Assurance Statement

The Bureau of Transportation Statistics (BTS) provides high quality information to serve government, industry, and the public in a manner that promotes public understanding. Standards and policies are used to ensure and maximize the quality, objectivity, utility, and integrity of its information. BTS reviews quality issues on a regular basis and adjusts its programs and processes to ensure continuous quality improvement.

Data Sources

The data used throughout this document reflect the latest numbers available at the time of publication. Data and statistics compiled in this report were obtained from a wide range of U.S. Department of Transportation operating administrations and other statistical agencies throughout the Federal Government.

Notice

Introduction

The *Transportation Statistics Annual Report* describes the Nation's transportation system, the system's performance, its contributions to the economy, and its effects on people and the environment. This 22nd edition of the report is based on information collected or compiled by the Bureau of Transportation Statistics (BTS)—the principle Federal statistical agency at the U.S. Department of Transportation.

Nearly 4.2 million miles of roads, more than 19,000 public and private use airports, more than 600,000 highway bridges, about 138,000 miles of freight and passenger railroads, 25,000 miles of navigable waterways, and nearly 2.7 million miles of oil and gas pipelines connect the Nation's people and businesses across the continent and with the rest of the world.

The estimated value of U.S. transportation assets in 2016 was approximately $7.7 trillion. The public owns 54.7 percent of the total transportation asset value, mostly highways and streets, but also publicly held transit facilities, airports, and numerous seaports, inland ports and terminals, and other facilities related to water transportation. Private companies own 25.1 percent of transportation assets, including railroads, pipelines, trucks, planes, and ships. Personal motor vehicles account for the remaining 20.2 percent.

The transportation sector accounted for:

- About $1.478 trillion in purchases and investments in transportation goods and services—or 9.0 percent of U.S. gross domestic product in 2015,
- $133.2 billion in public and private expenditures on transportation construction in 2016,
- 13.0 million jobs in transportation-related industries—or 9.0 percent of the U.S. labor force in 2016,
- $1,176 billion in transportation expenditures by U.S. residents—or 9.2 percent of all personal consumption expenditures in 2016,
- 39,625 lives lost in 2016 and roughly 2.48 million nonfatal injuries in 2015,
- 70.9 percent of total petroleum consumption in the United States in 2016, and

- about 27 percent of total U.S. greenhouse gas emissions in 2015.

BTS compiled these and other statistics under Section 52011: *Moving Ahead for Progress in the 21st Century Act* (Public Law No. 112-141), which requires information on:

- transportation safety across all modes and intermodally—Chapter 6;
- the state of good repair of U.S. transportation infrastructure—Chapters 1 and 4;
- the extent, connectivity, and condition of the transportation system, building on the BTS national transportation atlas database—Chapters 1, 2, and 3;
- economic efficiency across the entire transportation sector—Chapters 3, 4, and 5;
- the effects of the transportation system on global and domestic economic competitiveness—Chapters 3, 4, and 5;
- demographic, economic, and other variables influencing travel behavior, including choice of transportation mode and goods movement—Chapters 2 and 3;
- transportation-related variables that influence the domestic economy and global competitiveness—Chapters 3, 4, and 5;
- economic costs and impacts for passenger travel and freight movement—Chapters 2, 3, 4, and 5;
- intermodal and multimodal passenger movement—Chapters 1 and 2;
- intermodal and multimodal freight movement—Chapters 1 and 3; and
- consequences of transportation for the human and natural environment—Chapter 7.

This report of the BTS Director to the President and the Congress summarizes the Bureau's findings through 2017.

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CHAPTER 1

Extent and Physical Condition of the U.S. Transportation System

Highlights

- The Nation's transportation assets were valued at about $7.7 trillion in 2016, a 20.6 percent increase over 2010 estimates. Publicly owned infrastructure and equipment continued to account for over one-half of transportation capital stock.
- Highway travel as measured by person-miles traveled (PMT) and vehicle-miles traveled (VMT) increased by 5.4 and 4.3 percent, respectively, from 2010 to 2015.
- The condition of the U.S. transportation infrastructure is improving, but additional work is needed. The percentage of structurally deficient bridges declined from 12.0 percent in 2010 to 9.1 percent in 2016.
- One impact of bridge deterioration is reduced load limits. In 2016, 11.3 percent of all bridges had reduced load limits, which can cause commercial vehicle operators to carry smaller loads or take circuitous routes, increasing costs.
- The average age of the highway light-duty vehicle fleet increased by 29 percent over the 2000 to 2015 period and stood at about 11.5 years in 2015. The average age of commercial trucks was 14.8 years in 2015, up from 12.5 years in 2007.
- Buses accounted for about half of the 136,000 U.S. transit vehicles in 2015 and among transit vehicles had the lowest average age (7.4 years).
- The average age of inland waterway navigation locks, adjusted for the date of the most recent rehabilitation, is more than 50 years.
- Most airport runways (commercial service, reliever, and select general aviation) are in good condition; only 2 percent are considered poor.
- Class I freight railroad capital expenditures totaled $17.4 billion in 2015, almost triple the spending in 2000. Rail track defects have been trending downward since 2013.
- There is a general lack of data on the condition of vehicle and traffic control systems, regardless of mode; parking infrastructure; the physical condition of most types of vehicles and privately owned infrastructure (e.g., railroad track); and most aspects of intermodal connections.

In 2016 the U.S. transportation system served more than 323 million Americans—including those who may not own a vehicle or rarely travel. Transportation allows us to commute to work, obtain goods and services, call on family and friends, and visit distant places. It also drives our economy, connecting 7.6 million businesses with customers, suppliers, and workers [USDOC CENSUS QF 2017]. The transportation system allows over 75 million foreign visitors to travel to our country (see chapter two of this publication), resulting in a sizable contribution to the U.S. economy.

This chapter examines both the extent and condition of the principal transportation modes, including associated infrastructure, vehicles and control systems, and the estimated cost of keeping or bringing the system into a state of good repair. Interconnections that link one mode with one or more other modes are also important system elements, but a lack of public data on these connections prevents meaningful analysis of their condition.

Capital Stock and Investments

Transportation capital stock is the value of transportation infrastructure (e.g., roadways, bridges, and stations) and equipment (e.g., automobiles, aircraft, and ships) in existence as of a specific date. The net value of U.S. transportation capital stock was estimated at $7.7 trillion in 2016 (figure 1-1).

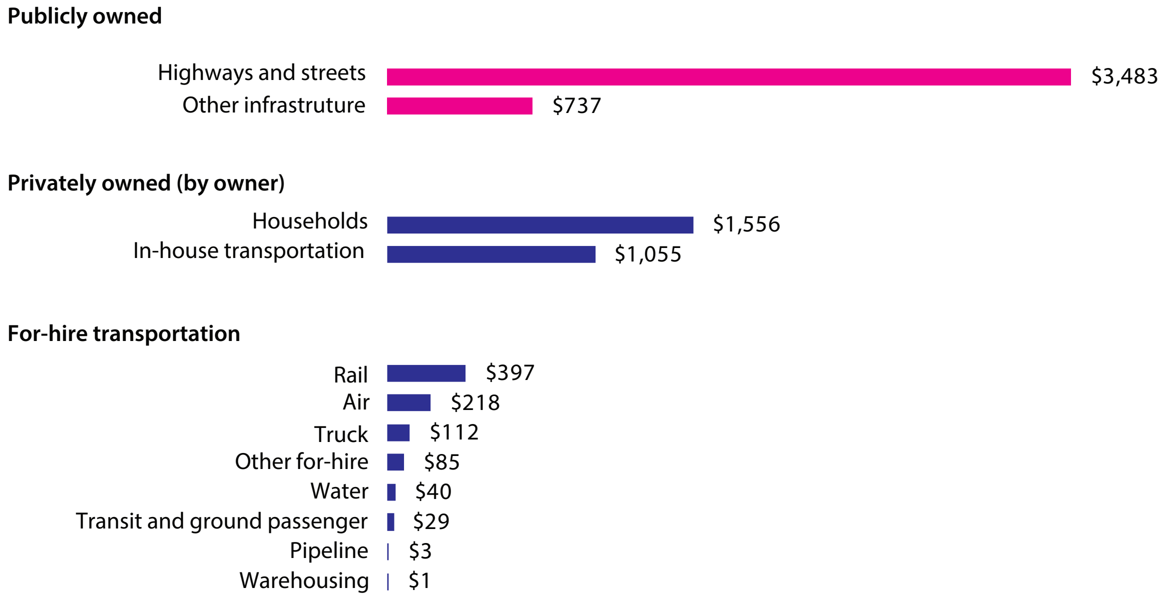
Transportation capital stock is owned by both the public and private sectors. Freight railroad facilities and equipment are almost entirely owned by the private sector, while state and local governments own highways and bridges, airports, seaports, and transit structures.

In 2016 the public sector owned $4.2 trillion (54.7 percent of transportation capital stock), while the private sector owned $3.5 trillion (45.3 percent) (figure 1-1). Public highways and streets accounted for the largest share of publicly owned transportation capital stock ($3.5 trillion of $4.2 trillion), while other publicly owned transportation, such as airports, seaports, and transit structures, accounted for the remaining share ($737 billion).

In 2016 personal motor vehicles and parts owned by households, some of which are used for business purposes, accounted for the largest amount of privately owned transportation capital stock ($1.6 trillion of $3.5 trillion) (figure 1-1). In-house transportation accounted for the second largest amount ($1.1 trillion) of private transportation capital stock, most of which was highway related, such as truck fleets owned by grocery chains. For-hire rail owned the next largest amount, accounting for $397 billion of transportation capital stock, followed by for-hire air at $218 billion.

In 2016 private and public spending on transportation construction totaled $133.2 billion. The public sector is the major funding source for transportation infrastructure construction, especially for streets and highways. In 2016 the value of government-funded (public) construction accounted for 90.8 percent ($120.9 billion) of total spending on transportation construction, while private transportation construction accounted for 9.2 percent ($12.2 billion). Approximately three-quarters of government-funded investment was for highways ($90.5 billion); the remainder supported the construction of air, land, and water transportation facilities ($30.4 billion).

FIGURE 1-1 Net Value of Transportation Capital Stock: 2016 (billions of dollars)



NOTES: Data include only privately owned capital stock except for those otherwise noted. Capital stock data are reported after deducting depreciation. *Other publicly owned transportation* includes publicly owned airway, waterway, and transit structures but does not include associated equipment. *Locks and dams* may be included under *Other publicly owned transportation*. *Household* includes personal vehicles, which are considered consumer durable goods. *In-house transportation* is capital stock owned by non-transportation companies. For example, grocery companies often use their own truck fleets to move goods from their warehouses to their retail outlets. *In-house transportation* and *for-hire transportation* figures cover the current cost net capital stock for fixed assets (transportation-related equipment including light trucks; other trucks, buses and truck trailers; autos; aircraft; ships and boats; and railroad equipment as well as transportation-related structures including air, rail, transit, and other transportation structures and track replacement) owned by a firm. *Other privately owned transportation* includes sightseeing, couriers and messengers, and transportation support activities, such as freight transportation brokers. Details may not add to totals due to rounding. Data may differ from those published in the 2016 TSAR due to revisions in the source data. Please see cited source for additional information.

SOURCE: U.S. Department of Commerce, Bureau of Economic Analysis, *Fixed Asset Tables*, tables 3.1ESI, 7.1B, 8.1; and *Nonresidential Detailed Estimates*, net stocks, current cost table. Available at http://www.bea.gov/ as of March 2017.

Chapter 5 details public and private transportation construction, transportation infrastructure spending, and the revenues generated by each transportation mode.

Roads, Bridges, Vehicles, Parking, and Traffic Control Systems

Roads

The total mileage of public roads and lane-miles increased by 2.2 and 1.8 percent, respectively, from 2010 to 2015 but decreased by 0.5 and 0.3 percent, respectively, between 2014 and 2015. Vehicle-miles traveled (VMT) increased by more than 4 percent over that period (table 1-1). Local roads are by far the most extensive, amounting to 2.9 million miles (69.2 percent of total system-miles). However, interstate highways, which accounted for 48,000 miles (1.2 percent of total system-miles), handled the highest volumes of traffic as measured by VMT—25.1 percent in 2015 [USDOT FHWA 2016]. Expansive Western and Midwestern states, such as Texas, California, Illinois, Kansas, and Minnesota,

TABLE 1-1 Public Roads and Streets, Lane-Miles, and VMT: 2000, 2010, 2014, and 2015

	2000	2010	2014	2015
TOTAL, Public Road and Street Mileage by Functional Type mileage (miles)	**3,936,222**	**4,067,077**	**4,177,073**	**4,154,727**
Interstate	46,427	46,900	47,662	48,053
Other freeways and expressways	9,140	14,619	17,250	17,986
Other principal arterial	152,233	157,194	157,034	156,473
Minor arterial	227,364	242,815	244,961	246,608
Collectors	793,124	799,226	808,363	811,231
Local	2,707,934	2,806,322	2,901,804	2,874,376
TOTAL lane-miles	**8,224,245**	**8,582,261**	**8,766,049**	**8,736,587**
TOTAL vehicle-miles of travel (VMT)	**2,746,925**	**2,967,266**	**3,025,656**	**3,095,373**

NOTE: Lane-miles are the centerline length in miles multipled by the number of lanes.

SOURCE: U.S. Department of Transportation (USDOT), Federal Highway Administration (FHWA), *Highway Statistics* (multiple years), as cited in the USDOT. Bureau of Transportation Statistics (BTS). *National Transportation Statistics* (NTS). Tables 1-5, 1-6, 1-28. Available at http://www.bts.gov/ as of March 2017.

have the most public road mileage.[1] The District of Columbia, followed by Hawaii, Rhode Island, Delaware, and Vermont, had the lowest public road and street mileage [USDOT FHWA 2016]. Figure 1-2 shows the National Highway System, which includes interstate highways as well as other roads important to the Nation's economy, defense, and mobility.

The U.S. Department of Transportation's (USDOT's) Federal Highway Administration (FHWA) reports the International Roughness Index (IRI), which measures the smoothness of pavement and is a key indicator of the condition of highways and bridges.[2]

Table 1-2 provides summary data on the percentage of rough surface mileage for different functional classes of highways. The physical deterioration of roads and bridges typically does not produce abrupt failures; rather, continued rough riding produces repetitive and gradual increases in vehicle maintenance and other highway user costs. For both urban and rural roads as the functional class decreases, from interstates down to collectors, the percentage of rough roads increases, and this is true for both years shown. This is likely the result of road maintenance and rehabilitation programs and budgets that favor the higher throughput classes of roadway.

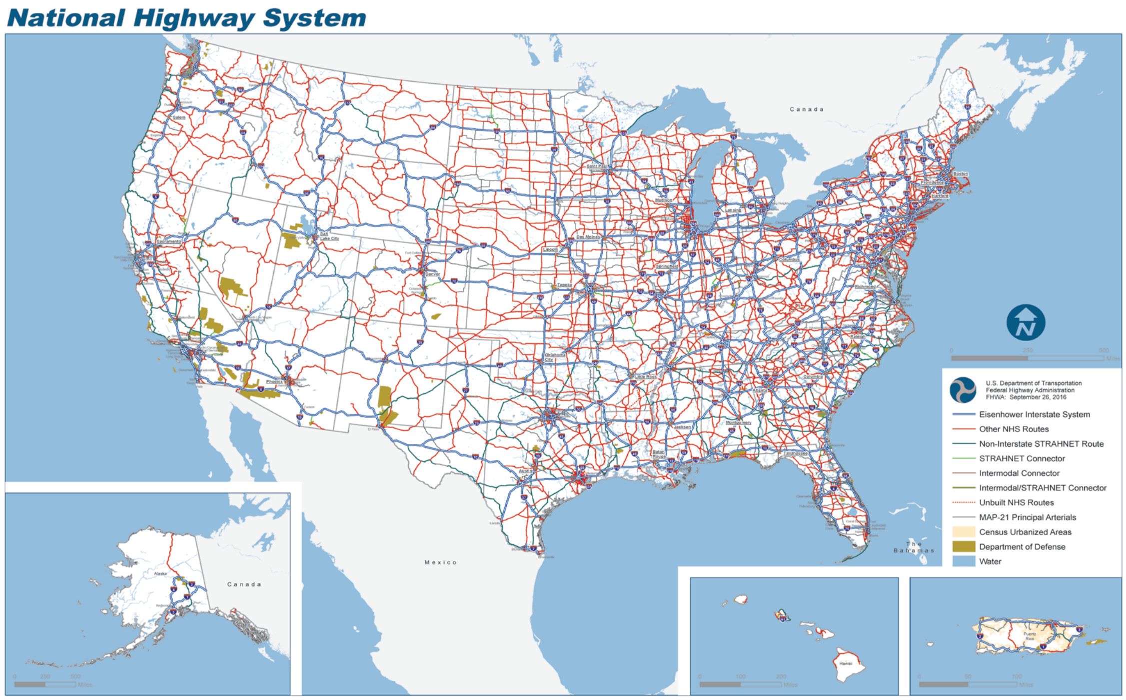
Bridges

A total of 614,386 highway bridges were in use in 2016, ranging in size from rural one-lane bridges crossing creeks to urban multilane and multilevel interstate bridges and major

[1] Alaska, the largest state by land area, has relatively few miles of roads, which reflects the lightly populated and relatively undeveloped character of the large landmass that lies outside of the Anchorage to Fairbanks corridor.

[2] A highway that has a roughness rating greater than 170 inches per mile is considered in poor condition.

FIGURE 1-2 National Highway System: 2016



SOURCE: U.S. Department of Transportation, Federal Highway Administration, National Highway System (September 2016).

TABLE 1-2 Condition of U.S. Highways: 2014 and 2015 National Highway System

Highway surface condition	2014	2015
Percent of mileage with International Roughness Index[a] over 170 (poor condition)		
Rural routes		
Interstates	2.2	1.8
Other principal arterials	3.8	4.4
Minor arterials	7.2	7.9
Collectors	20.3	21.5
Urban routes		
Interstates	5.4	5.0
Other freeways and expressways	8.5	8.2
Other principal arterials	26.3	27.7
Minor arterials	36.1	38.3
Collectors	49.8	52.2

[a] International Roughness Index (IRI) values are based on objective measurements of pavement roughness. A low IRI represents a smooth riding roadway.

KEY: IRI = International Roughness Index

SOURCE: U.S. Department of Transportation (USDOT), Federal Highway Administration, as reported in USDOT, Bureau of Transportation Statistics, *National Transportation Statistics*, table 1-27 (Highway surface condition). Available at www.bts.gov as of March 2017.

river crossings. Rural bridges, including rural interstate, accounted for about three-quarters of the total bridge network in 2016. But when the number of rural and urban interstate bridges are extracted from the total, they represent about 9.1 percent of all bridges while carrying the highest volumes of motor vehicle traffic. Texas had the most bridges, accounting for 8.7 percent of the entire U.S. bridge network, followed by Ohio (4.6 percent) and Illinois (4.3 percent) [USDOT FHWA 2017].

There has been slow but steady improvement in the condition of highway bridges, as shown in table 1-3. Bridge deficiency is characterized as either structurally deficient or functionally obsolete.

Structurally deficient bridges have reduced load bearing capacity due to the deterioration of one or more bridge elements. Such bridges are not necessarily unsafe, but they do require maintenance and repair to remain in service and will eventually require rehabilitation or replacement. Functionally obsolete bridges, while structurally sound, often carry traffic volumes that exceed their design limits and may need to be widened or replaced.

In 2016 almost one-quarter of the Nation's bridges were structurally deficient or functionally obsolete. The percentages of both structurally deficient and functionally obsolete bridges declined from 2000 to 2016, with the largest declines recorded for rural bridges (table 1-3). Despite the overall improvement, 23.1 percent of urban bridges were functionally obsolete in 2016, versus 10.0 percent of rural bridges. By comparison, 5.9 percent of urban bridges were structurally deficient.

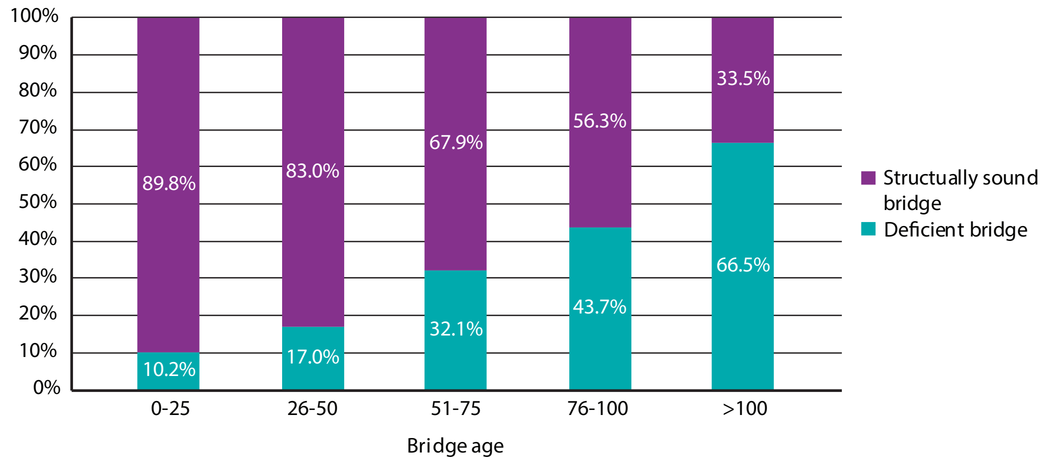
Age alone is not an automatic indicator of structural integrity. For example, the 134-year-old Brooklyn Bridge, due to consistent maintenance and several major rehabilitations, is still deemed safe for daily use, while the I-95

TABLE 1-3 Condition of U.S. Highway Bridges 2000, 2010, and 2014–2016

	2000	2010	2014	2015	2016
TOTAL number of bridges	**587,135**	**604,460**	**610,749**	**611,845**	**614,386**
Urban	131,778	157,571	166,292	168,753	170,776
Rural	455,357	446,889	444,457	443,092	443,610
All structurally deficient bridges (percent)	**15.2**	**12.0**	**10.0**	**9.6**	**9.1**
Urban structurally deficient (percent)	10.2	8.3	6.7	6.3	5.9
Rural structurally deficient (percent)	16.7	13.3	11.3	10.9	10.3
All functionally obsolete (percent)	**15.5**	**14.2**	**13.8**	**13.7**	**13.6**
Urban functionally obsolete (percent)	25.2	24.2	23.6	23.4	23.1
Rural functionally obsolete (percent)	12.7	10.7	10.2	10.1	10.0

SOURCES: **2000–2014**: U.S. Department of Transportation, Federal Highway Administration, as reported in U.S. Department of Transportation, Bureau of Transportation Statistics, *National Transportation Statistics*, table 1-28 (Bridges). Available at www.bts.gov as of May 2016. **2015–2016:** U.S. Department of Transportation, Federal Highway Administration, *National Bridge Inventory.* Available at https://www.fhwa.dot.gov/bridge/nbi.cfm as of March 2017.

FIGURE 1-3 Percent of Bridges by Deficiency and Age: 2016



NOTES: U.S. totals include the 50 states, the District of Columbia, and Puerto Rico. Table includes: Rural–Interstate, principal arterial, minor arterial, major collector, minor collector and local roads; Urban–Interstate, other freeways or expressways, other principal arterial, minor arterial, collector, and local roads.

SOURCE: U.S. Department of Transportation, Federal Highway Administration, *National Bridge Inventory.* Available at https://www.fhwa.dot.gov/bridge/nbi.cfm as of April 2017.

Mianus River Bridge in Connecticut collapsed in 1983 after only 25 years of service. The trend, however, is clear—the likelihood that a bridge will be found deficient increases with the age of the bridge (figure 1-3). About 62 percent of deficient bridges are more than 50 years old, and nearly 30 percent of bridges older than 75 years are rated as deficient.

A prevalent negative impact of bridge deterioration is the imposition of reduced load limits. In 2016, 69,207 out of the 614,386 total bridges in the National Bridge Inventory had some type of load restriction, comprising 11.3 percent of all bridges listed [USDOT FHWA 2017]. These load restrictions can cause commercial vehicle operators to either use trucks with smaller payloads or take circuitous routes, both of which can increase delivery costs.

Vehicles

Government, businesses, private individuals, and nongovernmental organizations owned and operated about 264 million motor vehicles in 2015, up by 5.4 percent since 2010, an increase that occurred as the country slowly recovered from the recession that began in December 2007 (table 1-4) [NBER 2012].

Motor vehicle registrations have grown at a faster rate than licensed drivers and the population since 1985 (figure 1-4). This growth produced an increase in the average number of motor vehicles owned by households. However, compared to rapidly industrializing countries, U.S. vehicle registrations have changed relatively little since 2005. For example, vehicle registrations in China grew from 13.4 million to nearly

TABLE 1-4 Motor Vehicles and Travel: 2000, 2010, 2014, and 2015

Motor Vehicle Registrations by Type

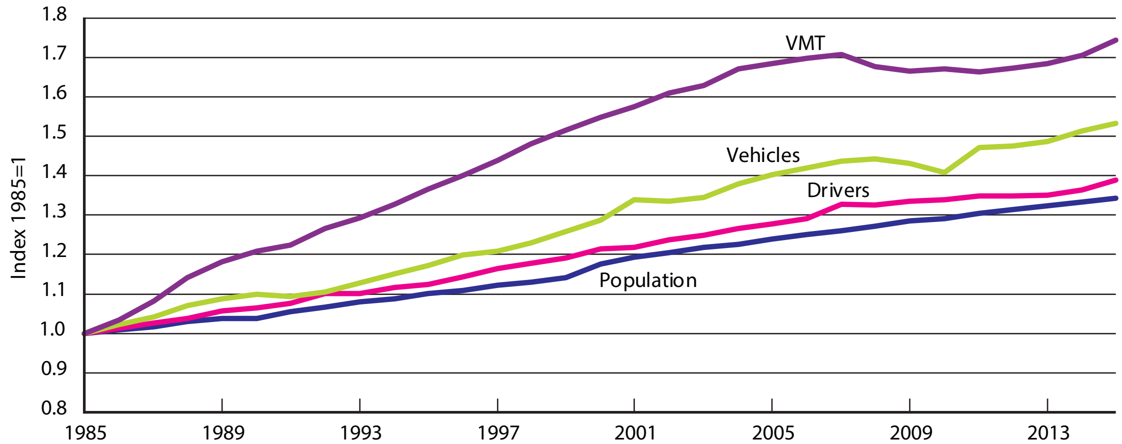
	2000	2010	2014	2015
TOTAL, registered vehicles	**225,821,241**	**250,070,048**	**260,350,938**	**263,610,219**
Light-duty vehicle, short wheelbase	U	190,202,782	187,554,928	189,619,308
Passenger Car	133,621,420	U	U	U
Motorcycle	4,346,068	8,009,503	8,417,718	8,600,936
Light-duty vehicle, long wheelbase	U	40,241,658	52,600,309	53,298,884
Other 2-axle 4-tire vehicles	79,084,979	U	U	U
Truck, single-unit 2-axle 6-tire or more	5,926,030	8,217,189	8,328,759	8,456,302
Truck, combination	2,096,619	2,552,865	2,577,197	2,746,882
Bus	746,125	846,051	872,027	888,907
TOTAL, average age of all light-duty vehicles (years)	**8.9**	**10.6**	**11.4**	**11.5**
Passenger cars	9.1	10.8	11.4	11.5
Light trucks	8.4	10.5	11.4	11.5
TOTAL, highway person-miles traveled (PMT) (millions)	**4,550,574**	**4,244,833**	**4,371,706**	**4,473,336**
Light-duty vehicle, short wheelbase	U	2,814,540	2,878,905	2,984,178
Passenger cars	3,107,729	U	U	U
Motorcycle	15,463	19,941	21,510	21,118
Light-duty vehicle, long wheelbase	U	831,912	852,983	844,123
Other 2-axle 4-tire vehicles	851,762	U	U	U
Truck, single-unit 2-axle 6-tire or more	100,486	110,738	109,301	109,597
Truck, combination	161,238	175,789	169,830	170,246
Bus	313,897	291,914	339,177	344,073
TOTAL, highway vehicle-miles traveled (VMT) (millions)	**2,746,925**	**2,967,266**	**3,025,656**	**3,095,373**
Light-duty vehicle, short wheelbase	U	2,025,745	2,072,021	2,147,840
Passenger cars	1,600,287	U	U	U
Motorcycle	10,469	18,513	19,970	19,606
Light-duty vehicle, long wheelbase	U	622,712	638,484	631,852
Other 2-axle 4-tire vehicles	923,059	U	U	U
Truck, single-unit 2-axle 6-tire or more	70,500	110,738	109,301	109,597
Truck, combination	135,020	175,789	169,830	170,246
Bus	7,590	13,770	15,999	16,230

KEY: U = Data are unavailable.

NOTE: PMT and VMT for 2000 are not comparable to data for later years. Motor bus and demand response figures are also included in the bus figure for highway.

SOURCES: **Vehicle registrations, age, PMT, VMT:** U.S. Department of Transportation (USDOT), Federal Highway Administration, Highway Statistics (multiple years), as cited in the USDOT, Bureau of Transportation Statistics, *National Transportation Statistics*. Tables 1-11, 1-26, 1-35, 1-40. Available at http://www.bts.gov/ as of March 2017.

FIGURE 1-4 Trends of Population, Drivers, Vehicles, and VMT: Indexed 1985–2015



KEY: VMT = vehicle-miles of travel

SOURCE: Vehicles and Drivers: U.S. Department of Transportation, Federal Highway Administration, Highway Statistics 2015. Tables DL-1C and MV-1. Available at http://www.fhwa.dot.gov/ as of April 2017. **Population**: U.S. Census Bureau, Quickfacts, available online at www.census.gov/quickfacts/ as of April 2017. VMT: USDOT, Bureau of Transportation Statistics, *National Transportation Statistics*, Table 1-35, available at bts.gov as of November 2017.

143 million over the 2000 to 2014 period and accounted for about 11.8 percent of the world total, up from 1.8 percent in 2000 [USDOE ORNL 2016]. On a per-capita basis, the United States has about 800 vehicles per 1,000 people, versus about 100 vehicles per 1,000 people in China. Increases in vehicle registrations from 2010 to 2015 varied widely by vehicle type (table 1-4). For example, while overall registrations grew 5.4 percent, registrations for light-duty short-wheelbase vehicles[3] remained virtually unchanged, while those for large cars, vans, pickup trucks, and SUVs[4] increased by 32 percent. Motorcycle registrations rose 7 percent, continuing a long-term upward trend. The numbers of single-unit and combination truck registrations increased 2.9 and 7.6 percent, respectively. Bus registrations grew by 5.1 percent from 2010 to 2015. Buses owned by schools, churches, and other groups accounted for 71 percent of bus registrations in 2015 [USDOT FHWA 2016]. Lastly, VMT has increased at a pace that exceeded growth in the resident population, number of drivers, and vehicle registrations (as show in figure 1-4).

From 2010 to 2015, person-miles traveled (PMT) increased by 5.4 percent, the same rate as vehicle registrations, and VMT increased by 4.3 percent over that period. Although commercial vehicles (trucks and buses) comprised about 4.6 percent of registered vehicles, they accounted for about 10 percent of VMT. Both PMT and VMT are discussed in more detail in chapter 2.

[3] Light-duty short-wheelbase vehicles includes passenger cars, light trucks, vans, and sport utility vehicles with a wheelbase equal to or less than 121 inches (e.g., Ford Explorer).

[4] Light-duty long-wheelbase vehicles includes large passenger cars, vans, pickup trucks, and sport/utility vehicles with wheelbases larger than 121 inches (e.g., Dodge Ram pickup).

There is no organized database on the operating condition of vehicles traveling on the Nation's highways. Table 1-4 shows that the average age of the light-duty vehicle fleet increased by 29 percent over the 2000 to 2015 period and stood at about 11.5 years in 2015. The commercial truck fleet is even older. The average age of a commercial truck was 14.8 years in 2015, up from 12.5 years in 2007 [IHS 2015].[5] However, age is not necessarily an indicator of vehicle condition.

Parking

The parking infrastructure in the United States is both vast and largely unmeasured at the national level. Parking spaces range from a single driveway or curbside spot adjacent to a private residence up to thousands of spaces in large parking structures at high-density developments, such as urban centers, airports, and universities. While there is no official estimate of the number of parking spaces in the United States, a recent research paper employs several scenarios to reach a mid-range estimate on the order of 800 to 850 million spaces [CHESTER 2010].

One reason that national estimates are lacking is that parking is inherently a local, mostly private-sector enterprise that is within the purview of land developers, businesses, and individual drivers. There are, however, some national or state level transportation issues that require data on parking supply. For example, adequate truck parking along major freight corridors to help commercial vehicle operators obtain adequate rest while adhering to Federal hours of service regulations is a major highway safety concern. In a recent FHWA parking survey, more than 75 percent of truck drivers reported having difficulty finding safe and legal parking during mandatory rest periods, and that number increased to 90 percent at night as drivers wait for their destination to open and accept deliveries [USDOT FHWA 2015]. This topic is discussed in chapter 6.

Traffic Control Systems

Traffic control features, such as traffic signs, signals, and pavement markings, are an important element of the highway system, but there is no national database on traffic control systems and their condition. An estimated 311,000 traffic signals have been installed in the United States, with an aggregate public capital investment of $83 billion [NTOC 2012]. There are no comparable estimates of the numbers of other types of traffic control devices.

Future Highway Infrastructure and Vehicles

Box 1-A describes new developments in automated highways that will transform highway infrastructure and vehicles. As autonomous vehicle (AV) on-the-road testing has become more widespread, many states have considered enacting regulations to address the potential impacts of these vehicles on their roads, particularly when AVs or connected vehicles (CVs) are operating in traffic mixed with non-equipped vehicles. Since 2012 at least 41 states and the District of Columbia (DC) have considered such legislation. As of September 2017, 21 states

[5] IHS Automotive acquired R.L. Polk & Co. in 2013 and continues the former Polk automotive registrations proprietary data series.

Box 1-A Automated Highways

Autonomous Vehicles

Autonomous vehicles (AVs), also known as automated, self-driving, driverless, or robotic vehicles, are those in which some aspect of vehicle control is automated by the car. Innovations in AV may fundamentally transform how the current transportation system works. These vehicles have the potential to increase safety, improve mobility, and reduce environmental impacts.

Many vehicles on the market today already include some level of automation. Several high-end vehicle models now have new AV technologies already built into them, including adaptive cruise control, lane tracking radars and steering, collision avoidance systems, global positioning system (GPS) location, and even some limited self-driving capabilities.

Several companies have made advancements in AV technology. Since 2009, Google's Self-Driving Car project has made substantial progress in AV technology and testing in real world scenarios. To date, the 23 vehicles in its self-driving car testing have traveled over 1 million miles on roads in Texas and California. BMW, Toyota, Audi, Volkswagen, and Tesla are a few of the car manufacturers that are also making substantial progress in AV technologies.

In recognition of these developing technologies, USDOT's National Highway Traffic Safety Administration (NHTSA) recently adopted the Society of Automotive Engineers' levels for automated driving systems, which range from complete driver control (Level 0) to full autonomy (Level 5). The project sought to study transfers of control between the driver and automated vehicles at conditional, or Level 3, automation. At this level drivers can shift both the physical and mental aspects of driving to the automated driving system but can still intervene if necessary [ITS JPO 2015].

Connected Vehicles

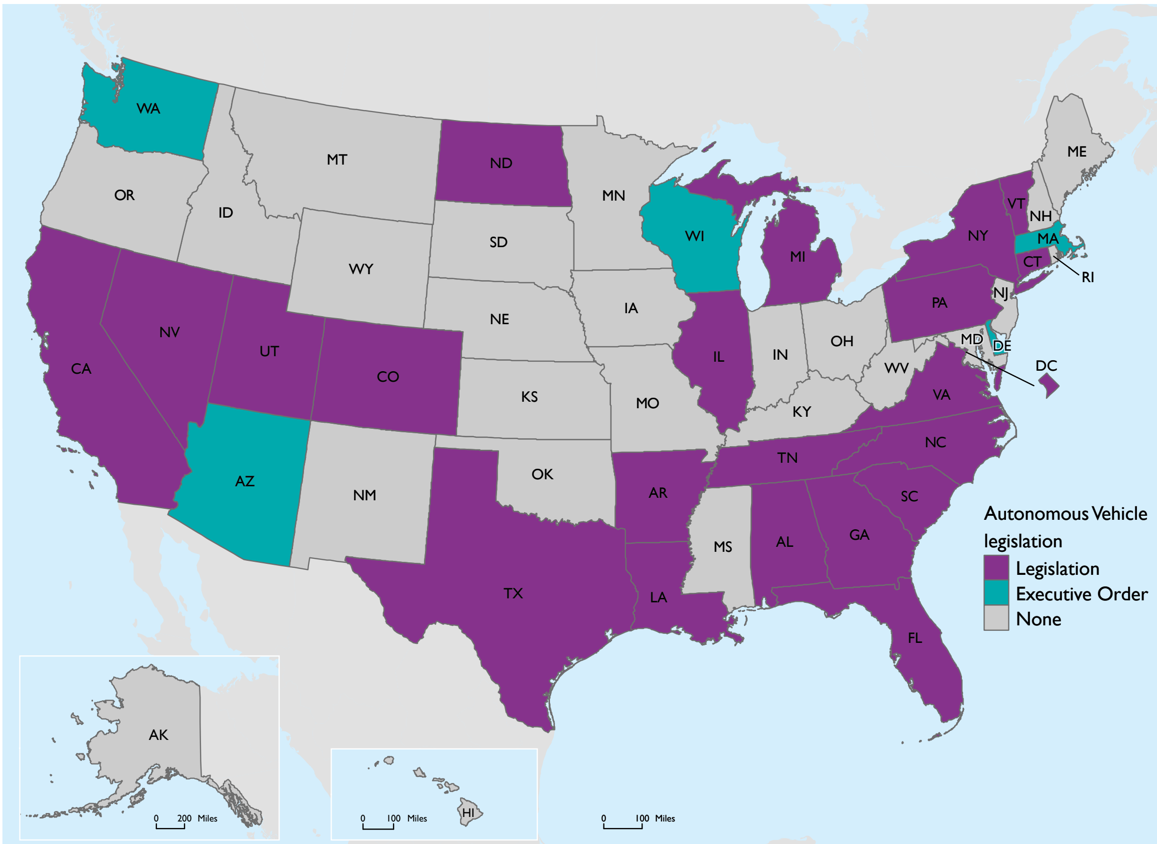
Connected vehicles (CVs) are those that can communicate with:

- each other, using vehicle-to-vehicle (V2V) communications;
- roadside devices such as traffic signals, using vehicle-to-infrastructure (V2I) communications; and
- non-motorized entities such as smart phones, using vehicle-to-anything (V2X) communications.

This is in contrast with the AVs discussed above, which use an array of sensors to detect vehicles and obstacles, and do not rely on communication with other vehicles.

A system of connected autonomous vehicles (CAVs) will help make strides in safety and mobility. In such a system of connected automation, AVs take advantage of CV technology to obtain greater situational awareness. The National Highway Traffic Safety Administration (NHTSA) is already working on a regulatory proposal to require CV technology devices in light vehicles, with plans to follow up with a similar ruling for heavy vehicles [SMITH 2016].

FIGURE 1-5 Autonomous Vehicle Legislation by State: 2017



SOURCE: National Conference of State Legislators, *Autonomous Vehicles Legislative Database*, available at http://www.ncsl.org/research/transportation/autonomous-vehicles-self-driving-vehicles-enacted-legislation.aspx as of July 2017.

and the District of Columbia have enacted such laws, and the governors of 5 states have issued executive orders related to AVs (figure 1-5). Box 1-B highlights various tests and pilots of autonomous vehicle and connected vehicle technology deployments.

Public Transit

Public transit provided 10.6 billion unlinked trips in 2015, up by 1.85 billion (21.2 percent) over the 2000 total. About 900 urban transit agencies and more than 1,400 rural and tribal government transit agencies offer a range of travel options, including commuter rail, subway, and light-rail; transit and trolley bus; and ferryboat. Buses accounted for nearly half (about 47.3 percent) of the 136,000 transit vehicles in 2015 (table 1-5). In 2015 these transit agencies operated over 5,200 stations, 80 percent of which comply with the *Americans with Disabilities Act* (Pub.L. 101-336), and 2,400 maintenance facilities. Transit agencies vary widely in size, ranging from 1 to 12,800 vehicles (e.g., the New York City Metropolitan Transportation Authority) [USDOT FTA 2016].

Box 1-B On-the-Road Connected Vehicle Test Programs

Test deployments of connected vehicle (CV) technology have been underway since 2012 in Michigan, New York, Wyoming, and Florida, as summarized below.

Ann Arbor, MI

A safety pilot model deployment program to test various vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) technologies was conducted in Ann Arbor, Michigan in 2012. The test involved 73 miles of instrumented roadway with 27 roadside units and over 2,800 vehicles equipped with a variety of devices. Data were collected for one year to support National Highway Traffic Safety Administration's decision-making, and the project has since transitioned to public roads for additional testing.

USDOT Connected Vehicle Pilot Deployment Program

In September 2015, USDOT awarded competitive grants to three consortia led by public agencies to conduct three very different CV deployment tests.

New York City

- The New York City DOT (NYCDOT) project area encompasses three distinct areas in the boroughs of Manhattan and Brooklyn. Approximately 5,800 cabs, 1,250 Metropolitan Transportation Authority buses, 400 commercial fleet delivery trucks, and 500 City vehicles that frequent these areas will be fit with the CV technology. Using Dedicated Short Range Communication (DSRC), the deployment will include approximately 310 signalized intersections for V2I technology. In addition, NYCDOT will deploy approximately 44 roadside units (RSUs) at strategic locations throughout the City to support system management functions. As a city bustling with pedestrians, the pilot will also focus on reducing vehicle-pedestrian conflicts through in-vehicle pedestrian warnings, and approximately 100 pedestrians will be equipped with personal devices to assist them in safely crossing the street.

Wyoming

- Wyoming DOT (WYDOT) will test V2V and V2I systems to aid freight movement on the 402 miles of I-80 in southern Wyoming, through a range of advisories including adverse weather and other roadside alerts, parking notifications and dynamic travel guidance. Approximately 75 RSUs that can receive and broadcast message using DSRC will be deployed along various sections of I-80. WYDOT will equip around 400 vehicles, a combination of fleet vehicles and commercial trucks with on-board units (OBUs). At least 150 of these vehicles will be heavy trucks that are expected to be regular users of I-80. In addition, 100 WYDOT fleet vehicles, snowplows and highway patrol vehicles, will be equipped with OBUs and mobile weather sensors.

Florida

- In Florida, the Tampa-Hillsborough Expressway Authority (THEA) will deploy a variety of V2V and V2I applications on the Selmon Reversible Express Lanes (REL) to relieve congestion, reduce collisions, and prevent wrong way entry at the REL exit. THEA also plans to use CV technology to enhance pedestrian safety, speed bus operations and reduce conflicts between street cars, pedestrians and passenger cars. The THEA CV Pilot will employ DSRC to enable transmissions among approximately 1,600 cars, 10 buses, 10 trolleys, 500 pedestrians with smartphone applications, and approximately 40 RSUs along city streets.

Overall, including locations not mentioned above, there are currently 20 communities moving forward with almost $350 million in advanced technology investments by USDOT [ITS JPO 2017].

TABLE 1-5 Transit Vehicles and Ridership: Revenue Years 2000, 2010, 2014, and 2015

	2000	2010	2014	2015
TOTAL, transit vehicles	**106,136**	**135,808**	**131,974**	**135,641**
TOTAL, rail transit vehicles	**17,114**	**20,374**	**20,172**	**20,366**
Heavy rail cars	10,311	11,510	10,551	10,737
Commuter rail cars and locomotives	5,497	6,768	7,177	7,151
Light rail cars	1,306	2,096	2,444	2,478
TOTAL, non-rail transit vehicles	**89,022**	**115,434**	**111,802**	**115,275**
Motor bus	59,230	63,679	62,449	64,184
Demand response	22,087	33,555	31,359	32,490
Ferry boat	98	134	144	145
Other	7,607	18,066	17,850	18,456
Average age of vehicles				
Heavy-rail passenger cars	22.9	18.7	20.4	22.2
Commuter-rail passenger coaches	16.9	18.9	18.8	19.5
Light-rail vehicles	16.1	16.8	16.7	17.3
Full-size transit buses	8.1	7.9	7.2	7.4
Transit vans	3.1	3.4	3.5	3.4
Ferry boats	25.6	20.5	23.8	22.8
TOTAL, transit person-miles traveled (PMT) (millions)	**45,100**	**52,670**	**57,013**	**56,109**
TOTAL, rail transit PMT	**24,583**	**29,353**	**32,614**	**32,804**
Heavy rail	13,844	16,407	18,339	18,400
Commuter rail	9,400	10,774	11,600	11,759
Light rail	1,339	2,173	2,675	2,645
TOTAL, non-rail transit PMT	**20,517**	**23,317**	**24,399**	**23,305**
Motor bus	18,999	20,739	21,587	20,390
Demand response	588	874	864	929
Ferry boat	298	389	414	492
Other	632	1,315	1,534	1,493
TOTAL, Transit Unlinked Passenger Trips (UPT) (billions)	**8.72**	**9.96**	**10.51**	**10.57**
TOTAL, rail transit UPT	**3.36**	**4.47**	**4.9**	**4.92**
Heavy rail	2.63	3.55	3.93	3.89
Commuter rail	0.41	0.46	0.49	0.49
Light rail	0.32	0.46	0.48	0.54
TOTAL, non-rail transit UPT	**5.36**	**5.49**	**5.61**	**5.65**
Motor bus	5.16	5.24	5.04	5.31
Demand response	0.07	0.1	0.1	0.17
Ferry boat	0.05	0.06	0.06	0.07
Other	0.08	0.1	0.4	0.1

NOTES: **Motor bus** includes Bus (MB), Commuter Bus (CB), Bus Rapid Transit (RB), and Trolley Bus (TB). **Light Rail** includes Light Rail (LR), Streetcar Rail (SR), and Hybrid Rail (YR). **Demand response** includes Demand Response (DR) and Demand Response Taxi (DT). **Other** includes Alaska railroad, automated guideway transit, cable car, inclined plane, monorail, and vanpool. **Unlinked passenger trips** is the number of passengers who board public transportation vehicles. Passengers are counted each time they board vehicles no matter how many vehicles they use to travel from their origin to their destination.

SOURCES: **Transit vehicles**: U.S. Department of Transportation (USDOT). Federal Transit Administration (FTA). National Transit Database (NTD) as cited in USDOT. Bureau of Transportation Statistics (BTS). *National Transportation Statistics* (NTS). Tables 1-11 and 1-29. Available at http://www.bts.gov/ as of March 2017. **Person-miles traveled**: USDOT/FTA/NTD as cited in USDOT/BTS/NTS. Table 1-40. Available at http://www.bts.gov/ as of March 2017. **Unlinked passenger trips**: USDOT/FTA/NTD, Table 19. Available at http://www.ntdprogram.gov/ as of March 2017.

The average age of transit vehicles from 2000 to 2015 is shown in table 1-5. Commuter rail passenger coaches had the greatest increase in average age of all rail vehicles over that period and are among the oldest of all transit equipment. The heavy-rail car fleet age decreased by 0.7 years between 2000 and 2015, but was still 22.2 years old on average. Light-rail vehicles had an average age of 16 to 17 years and transit buses 7 to 8 years over the reporting period, indicating that many transit agencies retired and replaced older vehicles on a regular basis or added new vehicles to the fleet. The transit bus fleet remained considerably newer than the rail fleet, which has locomotives and cars that typically last for decades. The average age of ferry boats dropped by 2.8 years, but they remained the oldest part of the transit vehicle population.

In 2015 transit riders made 10.6 billion trips and traveled 56.1 billion miles, an increase of 6.5 and 8.2 percent, respectively, since 2010 (table 1-5). Rail transit (heavy, commuter, and light rail) comprised only 15 percent of the transit vehicles, but accounted for 46.5 percent of transit trips and 58.5 percent of person-miles traveled. Buses recorded the highest share of transit trips, 50.2 percent, and 36.3 percent of the person-miles. Because bus passengers take shorter trips and buses operate at lower speeds compared to other modes, they carry less than two-fifths of all person-miles traveled. Conversely, rail vehicles provide only 15 percent of vehicle revenue hours of service. Due to longer trips and higher speeds, rail carries 55 percent of all person-miles traveled on transit [APTA Fact Book 2015]. The nature of demand-response systems, which are largely social service agency trip providers, is clearly shown in the table. These systems operated 24.0 percent of transit vehicles in 2015, but provided 1.6 percent of trips and 1.7 percent of person-miles.

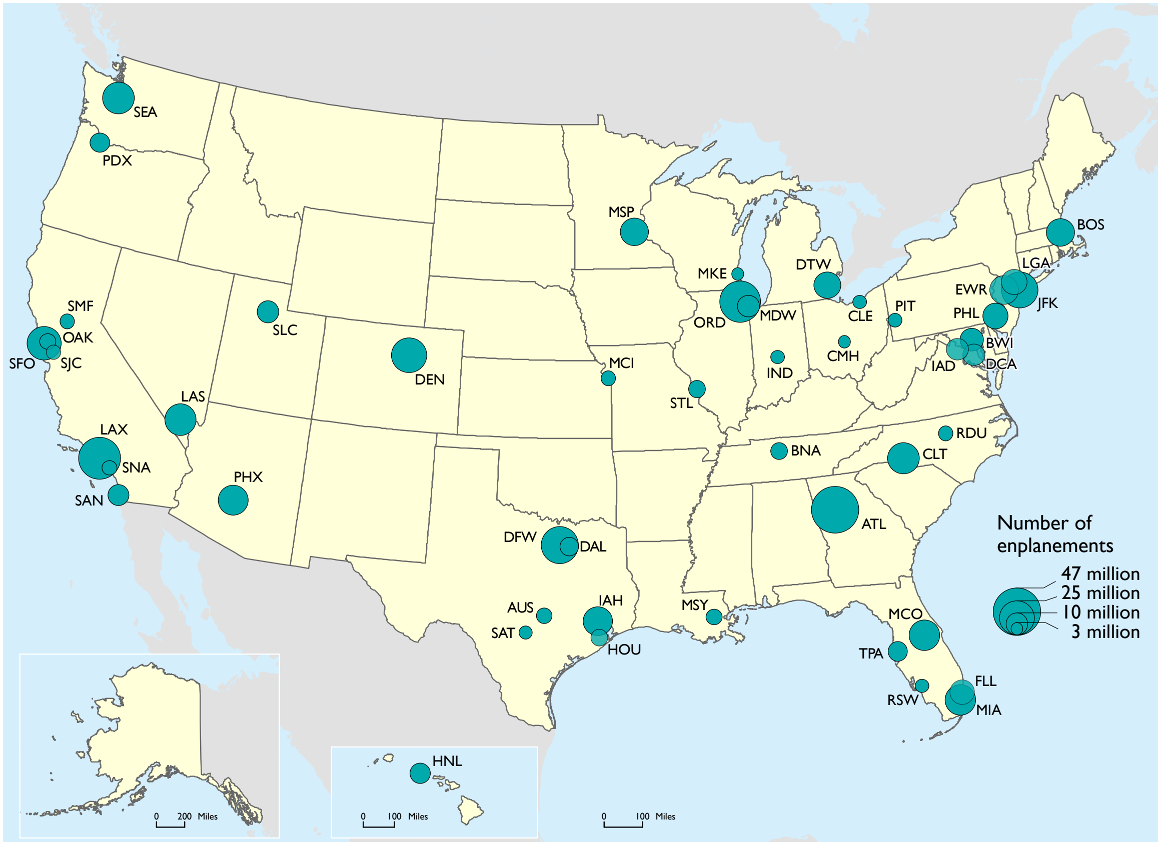
According to USDOT's Biennial Conditions and Performance report, the current total investment across all transit systems is about $16.9 billion annually. Bringing all systems to a state of good repair would require an increase to $17.0 billion per year, with all spending going to system preservation and none to service expansion (which is currently $7.1 billion per year). However, increasing system capacity to accommodate higher transit ridership would require an estimated $22.8 billion to support a 1.4 percent annual ridership growth rate, versus an estimated $26.4 billion to support a 2.2 percent annual ridership growth rate [USDOT FHWA and FTA 2015]. In both of these growth scenarios, annual spending on system preservation would be more than $16 billion.

Aviation

The main elements of the aviation system include airport runways and terminals, aircraft, and air traffic control systems. Table 1-6 shows that in 2016 the United States had about 19,500 airports, ranging from rural grass landing strips, to urban rooftop heliports, to large paved multiple-runway airports. Most of the 5,136 public-use facilities are general aviation airports, serving a wide range of users. In addition, there are more than 14,100 private airports, which are relatively small.

U.S. airports handled about 5.6 million commercial airline flights in 2016, down about 3.6 percent from the prior 2 years. Figure 1-6 shows passenger boardings at the top 50 U.S.

FIGURE 1-6 Passengers Enplaned on U.S. Flights at the Top 50 US Airports: 2016



NOTES: Includes passengers enplaned on U.S. carrier scheduled domestic service.

SOURCE: U.S. Department of Transportation, Bureau of Transportation Statistics, Office of Airline Information, *T-100 Market Data*, available at www.transtats.bts.gov as of May 2017.

airports in 2016. These airports accounted for 84.9 percent (about 652 million) of the U.S. passenger enplanements in 2016. The number of U.S. airports with nonstop international service increased from 72 in 1993 to 123 in 2016, offering more locations throughout the country with commercial air service to the world. Several carriers stopped or started nonstop international service, thus the total number of airports with nonstop international service is down slightly from 128 in 2015. For example, Atlantic City, NJ, Charleston, SC, and Bangor, ME, discontinued that service in 2016 [USDOT BTS 2016a].

The Federal Aviation Administration (FAA) compiles data on runway pavement conditions. Most airport pavements (commercial service, reliever, and select general aviation) were in good condition between 2000 and 2016, with only 2 percent rated as poor (table 1-6). There are no similar data for other elements of aviation infrastructure.

TABLE 1-6: U.S. Air Transportation System: 2000, 2010, 2013, and 2016

	2000	2010	2013	2016
TOTAL, U.S. airports	**19,281**	**19,802**	**19,453**	**19,536**
Public use	5,317	5,175	5,155	5,136
Private use	13,964	14,353	14,009	14,112
Military	U	274	289	288
TOTAL, U.S. aircraft (2015)	**225,359**	**230,555**	**206,660**	**216,906**
General aviation aircraft	217,533	223,370	199,927	210,030
Commercial aircraft	7,826	7,185	6,733	6,876
TOTAL pilots, general aviation and commerical (2015)	**625,581**	**627,588**	**599,086**	**590,039**
TOTAL, load factor (percent)	**U**	**81.9**	**82.8**	**82.4**
Domestic flights	U	82.2	83.5	84.6
International flights	U	81.6	82.1	80.5
TOTAL, U.S. passenger enplanements on U.S. and foreign carriers (thousands)	**U**	**755,222**	**785,015**	**877,087**
Domestic flights	U	629,500	645,700	719,000
International flights of U.S. carriers	U	91,000	97,500	104,000
International flights on foreign carriers, originated from the U.S.	U	34,722	41,815	54,087
TOTAL, air revenue pasenger-miles (RPM) on U.S. carriers (millions)	**U**	**798,000**	**840,400**	**933,500**
Domestic, RPM	U	552,900	577,900	660,000
International on U.S. carriers, RPM	U	245,200	262,500	273,500
TOTAL, enplaned revenue ton-miles on U.S. carriers (millions)	**56,400**	**65,000**	**61,900**	**63,600**
Domestic, enplaned revenue ton-miles	15,200	12,500	12,400	12,300
International on U.S. carriers, enplaned revenue ton-miles	41,200	52,500	49,500	51,000
Runway condition and aircraft age				
All NPIAS airports (percent)				
Good condition	73	79	81	80
Fair condition	22	18	17	18
Poor condition	5	3	2	2
Commercial service airports (percent)				
Good condition	79	82	83	84
Fair condition	19	16	15	15
Poor condition	2	2	2	1
Average aircraft age				
Major[a] airline aircraft	U	14.1	13.3	13.3
National[a] airline aircraft	U	9.1	11.6	10.3
Regional airline aircraft	U	28.2	26.9	25.7

[a] Major carriers have annual operating revenue exceeding $1 billion. National carriers have annual operating revenues between $100 million and $1 billion.

KEY: NPIAS = National Plan of Integrated Airport Systems. U = data are unavailable.

NOTES: General aviation includes air taxis.

SOURCES: **Airports and aircraft:** U.S. Department of Transportation (USDOT). Federal Aviation Administration (FAA) as cited in USDOT, Bureau of Transportation Statistics, *National Transportation Statistics*. Tables 1-3, 1-11, and 1-25. Available at http://www.bts.gov/ as of July 2017. **Pilots**: USDOT/FAA. FAA Aerospace Forecast, Fiscal Years (multiple issues). Available at www.faa.gov as of July 2017. **Passenger enplanements**: USDOT, Bureau of Transportation Statistics (BTS), Office of Airline Information (OAI), *T-100 market data*. Available at http://www.transtats.bts.gov/ as of May 2017. **RPM and Enplaned revenue ton-miles**: USDOT, BTS, OAI, T-100 Segment data. Available at http://www.transtats.bts.gov/ as of July 2017. **Aircraft age**: USDOT, BTS, Office of Airline Information, TranStats Database, Form 41, Schedule B-43, special tabulation, July 2017.

Table 1-6 shows average ages of U.S. commercial airline aircraft for selected years between 2000 and 2016. The aircraft flown by major and national airlines are roughly half the age of smaller planes used by regional airlines. Overall, the aircraft fleet became a bit younger between 2013 and 2016. There are no public data to indicate the physical condition of the aircraft fleet.

The FAA is amid a major effort to upgrade the U.S. air traffic control system to increase its capacity. Current efforts are focused on developing the Next Generation Air Transportation System (NextGen), which will utilize global positioning system satellite technology and related communications and information technology improvements.

New approach procedures using the Wide Area Augmentation System (WAAS) will increase access to general aviation airports, especially during low visibility. The FAA has published 3,767 WAAS-enabled approach procedures at 1,832 airports as of February 2017 [USDOT FAA 2017].

Railroads

The United States had about 138,000 railroad route-miles in 2015 [AAR 2016], including roughly 93,600 miles owned and operated by the seven Class I railroads.[6] Amtrak, local, and regional railroads operated the remaining 44,000 miles. Class I railroads provided freight transportation using over 26,000 locomotives and 1.56 million railcars (table 1-6). This is largely due to the increased number of hopper and tank cars entering service. Average freight car capacity was about 93 tons in 2000, and reached 103 tons during 2013–2015 due to construction of larger cars and a mix of different car types.

[6] Includes BNSF Railway, CSX Transportation, Grand Trunk Corp. (Canadian National operations in the United States), Kansas City Southern, Norfolk Southern, Soo Line (Canadian Pacific operations in the United States), and Union Pacific.

Over the past 50 years, Class I railroads and connecting facilities have developed increasingly efficient ways to carry and transfer cargo (e.g., larger cars as noted above, double-stack container railcars, and on-dock rail), allowing more cargo to be carried with fewer railcars. Figure 1-7 shows that the system mileage of Class I railroads in 2015 was less than one-half the mileage in 1960. However, freight rail ton-miles tripled to 1.8 trillion during the same period (despite a decline during the last recession).

Intercity Passenger Rail

The National Rail Passenger Corp. (Amtrak) is the primary operator of intercity passenger rail service in the United States. Amtrak operated 21,300 route-miles in 2016 and more than 500 stations that served 46 states and Washington, DC. Figure 1-8a shows the top 25 stations by ridership across the country, and figure 1-8b shows the stations by ridership in the Northeast Corridor (NEC). Ridership was also high around Chicago as well as at several locations in California and the Pacific Northwest.

Amtrak owns a small fraction of its route-miles, primarily 363 of the 457-mile NEC between Boston, MA, and Washington, DC, plus three other shorter segments totaling 261 miles [Amtrak 2016]. The clear majority of passenger train services outside the NEC are

TABLE 1-7 Rail Transportation System: Fiscal Years 2000, 2010, and 2013–2015

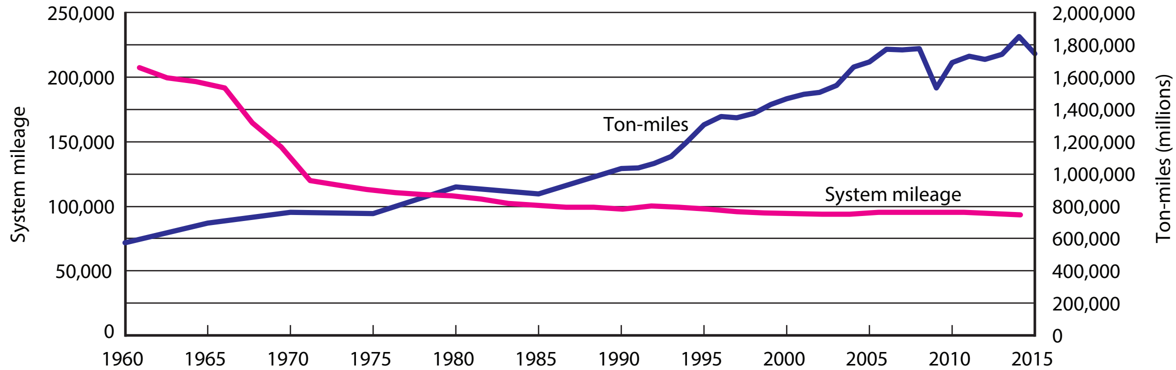
	2000	2010	2013	2014	2015
Equipment and Mileage Operated by Amtrak					
Locomotives	378	282	418	428	423
Passenger cars	1,894	1,274	1,447	1,419	1,428
System mileage	23,000	21,178	21,356	21,356	21,358
Stations	515	519	516	518	518
Passengers (millions)	20.9	28.7	30.9	31.0	30.7
Passenger-miles traveled (millions)	5,498	6,420	6,810	6,675	6,536
Equipment and Mileage Operated by Class I					
Locomotives	20,028	23,893	25,033	25,916	26,574
Freight cars (million)[a]	1.56	1.57	1.50	1.52	1.56
Average freight car capacity (tons)	92.7	101.7	103.4	103.3	103.2
System mileage	99,250	95,700	95,235	94,372	93,628
Ton-miles (trillion)	1.47	1.69	1.74	1.85	1.74
New rail and crossties laid					
Rail, thousand tons	690	564	620	673	691
Crossties, million	11.5	15.6	16.2	15.4	15.5
Capital expenditures, $ billion					
Roadway and structures	$4.55	$7.86	$9.32	$10.01	$11.44
Equipment	$1.51	$1.91	$3.77	$5.07	$5.97
Total	**$6.06**	**$9.77**	**$13.09**	**$15.08**	**$17.41**

[a] Includes totals for Canada and Mexico.

NOTE: Fiscal year ending in September.

SOURCES: **Amtrak-Locomotives, Railcars, System mileage, Stations and Passenger-miles travelled**: Amtrak as cited in U.S. Department of Transportation (USDOT). Bureau of Transportation Statistics (BTS). *National Transportation Statistics* (NTS). Tables 1-1,1-7, 1-11, 1-40. Available at http://www.bts.gov/ as of April 2017. **Passengers**: USDOT, Federal Railroad Administration, Office of Safety Analysis, as cited in USDOT, BTS, Multimodal Transportation Indicators. Available at www.bts.gov as of April 2017. **Class I railroads-Locomotives, Freight cars, and System Mileage**: Association of American Railroads, Railroad Facts (Annual issues) as cited in USDOT/BTS/NTS. Tables 1-1, 1-11, 1-49. Available at http://www.bts.gov/ as of April 2017. **Ton-miles, rail, crossties, and capital expenditures**: Association of American Railroads, Railroad Facts (Annual issues), as of April 2017.

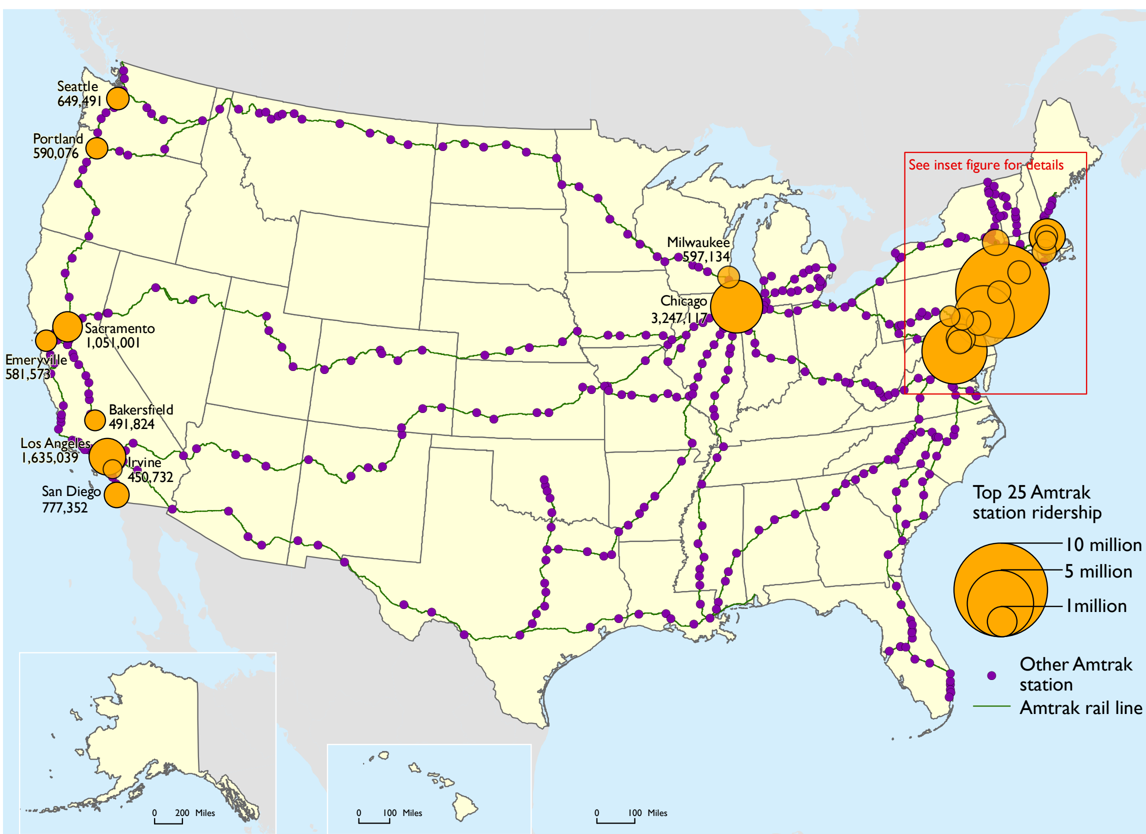
FIGURE 1-7 Class I Railroad System Mileage and Ton-miles of Freight: 1960, 1965, 1970–2015



NOTES: Report was every 5 years until 1970.

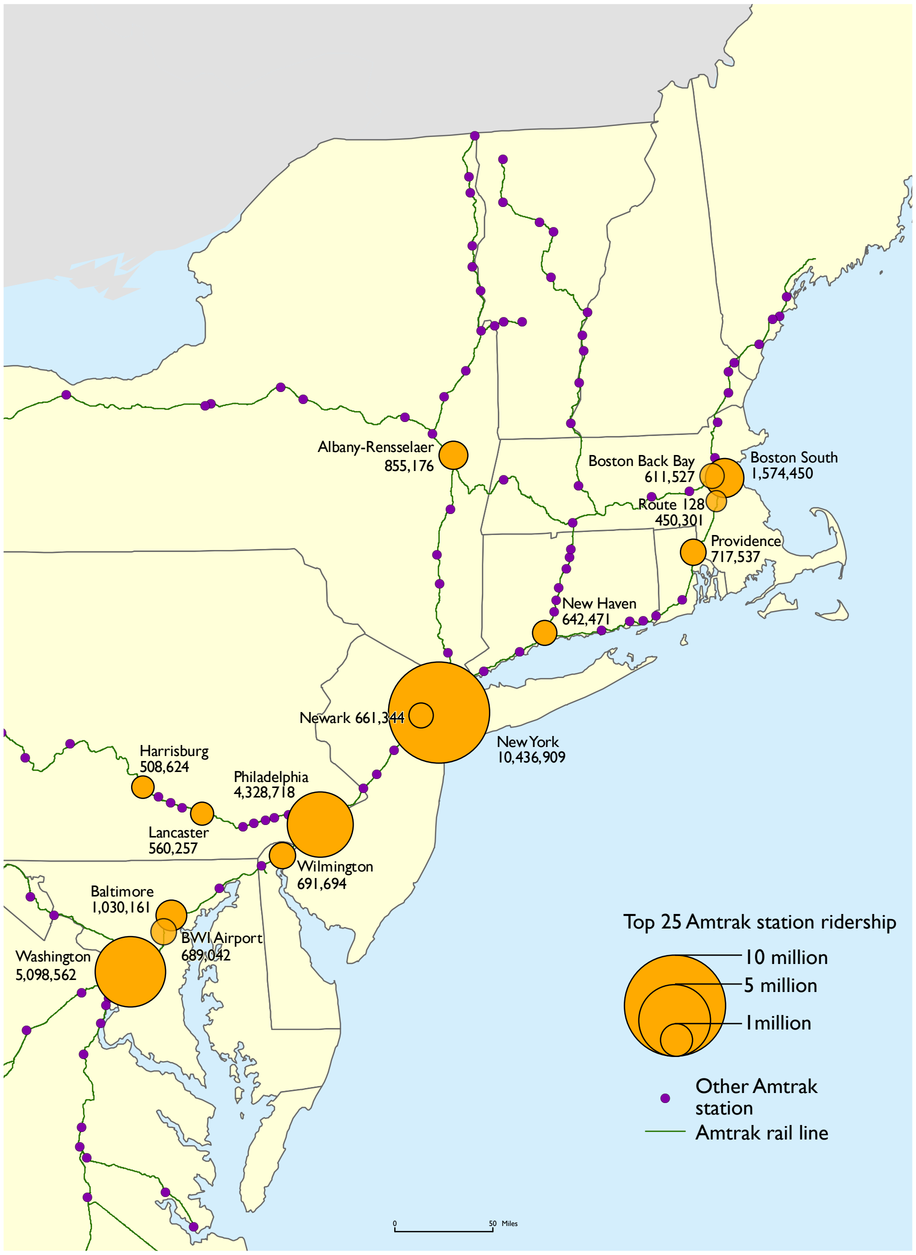
SOURCE: Association of American Railroads, *Railroad Facts*, Statistical Highlights (Washington, DC: Annual Issues).

FIGURE 1-8a Top 25 Busiest Amtrak Stations: Fiscal Year 2016



SOURCE: Amtrak, *State Fact Sheets*, available at www.amtrak.com as of February 2017.

FIGURE 1-8b Amtrak Stations Along the Northeast Corridor: Fiscal Year 2016



SOURCE: Amtrak, *State Fact Sheets*, available at www.amtrak.com as of February 2017.

provided over tracks owned by and shared with the Class I freight railroads. Hence, the condition of the infrastructure Amtrak uses is largely dependent on the condition of the host railroads, except for the NEC.

Freight Rail

The U.S. freight rail system is privately owned and operated, and rail carriers are under no obligation to report freight track conditions to public sector agencies. Thus, universal track condition reports are unavailable. Railroads regularly inspect their track and perform necessary repairs to ensure track safety. Federal Railroad Administration (FRA) regulations require railroads to maintain track inspection records and make them available to FRA or State inspectors on request. The FRA's rail safety audits focus on regulatory compliance, and prevention and correction of track defects. FRA publishes an annual enforcement report, summarizing the civil penalty claims for violations. In FY 2016 more than 4,200 recommended track violations were cited by FRA inspectors or other railroad regulators [USDOT FRA 2016].

In addition, FRA's Automated Track Inspection Program (ATIP) utilizes a small fleet of highly instrumented track geometry inspection cars to survey tens of thousands of miles of high-traffic density and other high-priority routes each year. Table 1-8 provides a summary of track inspection results for the years 2007 to 2017. The FRA upgraded the inspection

TABLE 1-8 Automated Track Inspection Program (ATIP) Exceptions[a] per 100 Miles: 2007–2017

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Profile	3.2	2.4	1.9	2.1	2.4	1.4	17.4	9.9	1.5	1.1	0.6
Alignment	1.7	1.4	1.8	2.0	2.0	1.5	18.4	10.6	1.8	2.9	0.6
Gage	5.1	12.2	7.2	3.1	2.1	4.4	5.9	2.1	5.5	1.8	1.1
Crosslevel	2.0	2.0	2.2	1.2	1.3	1.1	6.9	4.0	1.3	0.6	0.6
Warp	4.7	3.7	4.0	2.8	1.8	1.7	10.9	4.6	1.3	0.7	0.9
Runoff	0.4	0.6	0.7	0.6	0.8	0.4	10.0	8.4	0.7	0.5	0.6
Twist	1.8	1.7	1.5	1.3	1.0	0.8	5.6	3.0	U	U	U
Limited Speed	9.9	9.7	8.7	11.8	3.1	2.6	2.5	1.4	2.2	0.9	0.8
Total Per 100 Miles	**28.7**	**33.7**	**27.9**	**24.8**	**14.5**	**14.1**	**77.6**	**44.0**	**14.3**	**7.6**	**4.5**
Miles Inspected	59,165	52,997	74,715	83,013	74,541	70,049	62,882	74,202	61,753	86,997	70,848

KEY: ATIP = Automated Track Inspection Program. U = data are unavailable.

[a] Exceptions mean track did not meet normal operation standards

NOTES: The ATIP program does not provide a comprehensive evaluation of the national rail network on an annual basis due to the limited number of surveying cars. Inspection locations vary by year and are prioritized by factors such as safety risk analysis and operation types. The FRA implemented upgrades to the inspection and collection technology in the ATIP fleet in 2013 which allowed for increased sensitivity of exception detection. Multiple cars surveying except for 2005. Defects are briefly defined as variations from design values for the following track geometry properties:

Profile - rail surface elevations
Alignment - track direction (tangent or curvature)
Gage - distance between rails
Cross-level - elevation difference between the rails
Warp - maximum change in cross-level over a specified distance
Runoff - elevation (ramp) difference of a line along the top of the rail is used for the projection
Twist - rate of introduction and removal of cross-level on transitions from straight to curved track alignment
Limited Speed - reduced operating speed due to track geometry constraints

Detailed definitions and standards may be found in U.S. Department of Transportation, Federal Railroad Administration, Track and Rail and Infrastructure Integrity Compliance Manual, July 2012.

SOURCE: U.S. Department of Transportation, Federal Railroad Administration, Office of Safety, *ATIP Statistics*, special tabulation, October 2017.

and collection technology in the ATIP fleet in 2013, which allowed for increased sensitivity of exception detection, so earlier results may not be comparable to those for the most recent years. Since 2013 the incidences of all eight track inspection exceptions have generally tended to decrease over time. The number of locations and miles inspected vary by year due to the limited number of surveying cars and are prioritized by factors such as safety risk analysis and operation types.

The installation of new rail and crossties is one indicator of how track conditions are maintained and improved. The Association of American Railroads (AAR) reported that Class I railroads replaced or installed 691 thousand tons of rail and 15.5 million crossties in 2015, which is more than the annual average of 546 thousand tons of rail and 13.4 million crossties from 2001 to 2005 (table 1-8) [AAR 2016].

The AAR also provides data on the age of the seven Class I railroad locomotive fleets [AAR 2016]. The fleet has become newer overall since 2000. The percentage of locomotives that were less than 10 years old was 30 percent in 2015, versus about 33 percent in 2000, and the median age decreased from 17 to about 16 years. No comparable compilation of the age distribution of railcars is available.

Table 1-7 shows railroad capital expenditures, which totaled $17.4 billion in 2015, almost tripled the spending in 2000. In contrast, revenue ton-miles increased 18 percent over that period. Freight rail is a profit-making enterprise that self-funds its investments, and carriers have a strong incentive to maintain, rehabilitate, and upgrade their systems as needed to remain competitive in the market place and earn returns for their investors.

Ports and Waterways

There were more than 8,200 U.S. water transportation facilities, including cargo handling docks, in 2015. Of these facilities, 2,000 handled both foreign and domestic cargo, less than 80 handled foreign cargo only, and nearly 6,100 handled domestic cargo only. About 69 percent of cargo-handling facilities are located on the coasts—Gulf coast facilities accounted for 26.2 percent of the total, followed by the Atlantic coast (21.9 percent), and the Pacific coast (20.6 percent). The remaining 31.3 percent of cargo-handling facilities are situated along the Great Lakes or inland waterways. These facilities are served by a fleet of 40,500 domestic vessels—31,500 barges and 9,000 self-propelled vessels, including more than 3,000 towboats used to move the barges [USACE IWR NDC 2016].

Dams and navigation locks are two of the principal infrastructure features of the U.S. domestic waterway transportation system. They enable shallow draft operations on most rivers. The principal exceptions are the Lower Mississippi River and the Missouri River, which are free-flowing but still require some type of hydrologic structures, such as large rock and concrete groins and revetments, to manage the flow of the river and preserve navigation. The U.S. Army Corps of Engineers (USACE) owns and operates 239 lock chambers at 193 sites, which account for most of the U.S. inland navigation locks. The average age of all locks is over 64 years (table 1-9). A Transportation Research Board report [TRB 2015] shows that, when adjusted

TABLE 1-9 Water Transportation System: 2000, 2010, 2013, and 2014

	2000	2010	2013	2014
U.S.-Flag privately owned merchant fleet (1,000 GT or over)	282	221	187	179
Recreational boats, millions	12.8	12.4	12.0	11.8
Lock chambers	276	239	239	239
Lock sites	230	193	193	193
Waterway facilities (including cargo handling docks)	9,309	8,060	8,231	8,229
Ports (handling over 250,000 tons)	197	178	182	183
Miles of navigable waterways	25,000	25,000	25,000	25,000
Average age of locks, years	50.2	59.5	62.5	63.5
TOTAL, U.S.-flag Vessels	**41,354**	**40,512**	**39,999**	**40,082**
Barge/non-self-propelled vessels	33,152	31,412	31,081	31,043
Self-propelled vessels	8,202	9,078	8,918	9,039
Age of U.S.-flag vessels, percent				
< 6 years old	19.6	18.5	19.3	17.7
6 to 10 years old	9.2	11.5	12.1	14.1
11 to 15 years old	5.1	17.0	14.3	12.4
16 to 20 years old	19.6	8.7	13.6	15.1
21 to 25 years old	18.3	4.2	7.7	8.3
> 25 years old	27.7	39.3	32.6	31.9

KEY: GT = gross tons.

NOTE: *U.S.-Flag privately owned merchant fleet* includes only oceangoing self-propelled, cargo-carrying vessels of 1,000 GT and above. Total, Vessels includes unclassified vessels. CFR 33 Part 329 defines the mileage of navigable waterways of the U.S.

SOURCES: **Fleet**: U.S. Army Corps of Engineers. Waterborne Commerce Statistics Center. Navigation Data Center. *Waterborne Transportation Lines of the United States* (Annual issues). Available at http://www.navigationdatacenter.us/ as of May 2016. **Recreational boats**: U.S. Department of Homeland Security. Coast Guard. Recreational Boating Statistics as cited in USDOT. BTS. National Transportation Statistics. Table 1-11. Available at http://www.bts.gov/ as of May 2016. **Waterways and Vessels**: U.S. Army Corps of Engineers. Institute for Water Resources. Navigation Data Center. **The U.S. Waterway System**: Transportation Facts and Information (Annual issues). as cited in USDOT. BTS. *National Transportation Statistics*. Tables 1-1 and 1-11. Available at http://www.bts.gov/ as of May 2016. **Locks, Facilities, and Seaports**: U.S. Army Corps of Engineers. Institute for Water Resources. Navigation Data Center. General Characteristics of Locks, and The U.S. Waterway System: Transportation Facts and Information (Annual issues). Available at http://www.navigationdatacenter.us/ as of May 2016.

for the dates of major rehabilitation projects, the effective average age of locks is about 10 years less, but that still puts the average age at over 50 years. The USACE maintains comprehensive data on lock traffic, lockage time and delay, and lock outages for waterway performance analysis.

Table 1-10 provides data on representative main lock chambers throughout the inland waterway system. These data show some of the relationships between lock age and performance factors, such as tow delay and main lock chamber downtime. For example, the Emsworth Lock on the Ohio River, close to the head of navigation near Pittsburgh, is one of the oldest structures in the system and is considered functionally obsolete in that it handles tows longer than its 600-foot design limit. It has lock chambers designed for vessels of an earlier era and has lengthy out-of-service delays. The newer locks on the Ohio River, such as John T. Myers near Uniontown, KY, are 1,200-feet long

TABLE 1-10 Selected Inland Waterway Lock Characteristics: 2016

River	River mile[a]	Lock Name	Main lock chamber only: Length, feet	Width, feet	Age, years	Tons in 2016, millions[b]	Outages in 2016[b]: Number	Hours	Avg. hr. per outage	Avg. delay per tow, hr [b]
Ohio	6.2	Emsworth Lock & Dam Aux.	360	56	96					
Ohio	6.2	Emsworth Lock & Dam	600	110	96	11.0	37	1,147	31.00	2.04
Ohio	846	John T. Myers Lock & Dam Aux.	600	110	42					
Ohio	846	John T. Myers Lock & Dam	1,200	110	42	47.8	75	326	4.35	0.70
Ohio	938.9	Lock & Dam 52 Aux.	600	110	89					
Ohio	938.9	Lock & Dam 52	1,200	110	48	70.7	22	60	2.73	3.71
Mississippi	200.8	Melvin Price Lock & Dam Aux.	600	110	23					
Mississippi	200.8	Melvin Price Lock & Dam	1,200	110	27	63.7	12	47	3.92	2.18
Mississippi	185.5	Chain of Rocks L/D 27 Aux.	600	110	64					
Mississippi	185.5	Chain of Rocks L/D 27	1,200	110	64	68.2	4	2	0.50	2.47
GIWW East	7	Inner Harbor Navigation Canal Lock	640	75	94	9.9	227	4,440	19.56	16.59
Columbia	292	McNary Lock & Dam[c]	675	86	64	5.4	2	3	1.33	0.23

[a] Miles from the 0.0 milepoint reference location, usually at the mouth of the river, except on the Ohio River where mile 0.0 is at the source of the river at Pittsburgh, PA.

[b] Includes all lock chambers at sites with more than one chamber. [c] McNary Lock outage data are for 2015, since 2016 data are unavailable.

KEY: Aux = Auxiliary; GIWW = Gulf Intracoastal Waterway; L/D = Lock & Dam; N/A = Not Applicable.

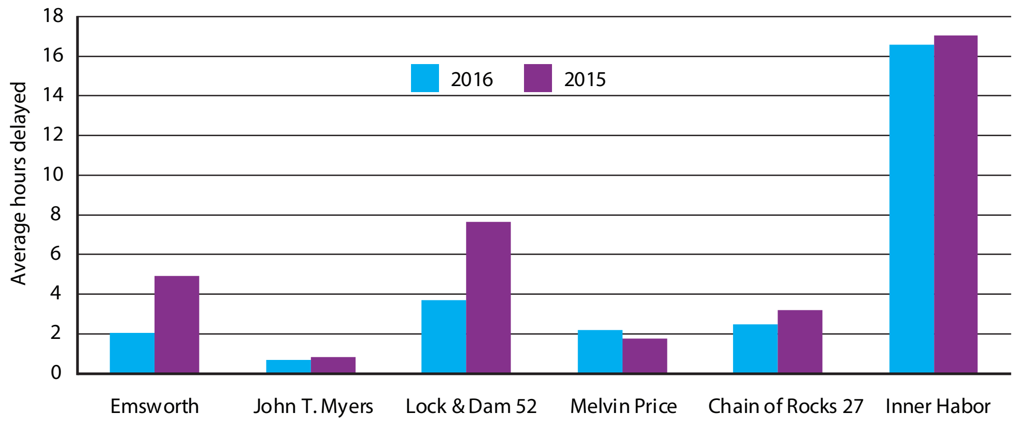
SOURCES: U.S. Army Corps of Engineers, Institute for Water Resources, Navigation Data Center, *Locks by Waterway, Tons Locked by Commodity Group, CY 1993 - 2016*. Available at http://www.navigationdatacenter.us/lpms/cy2013comweb.htm as of May 2017. U.S. Army Corps of Engineers, Institute for Water Resources, Navigation Data Center, *Locks by Waterway, Lock Usage, CY 1993 - 2016*. Available at http://www.navigationdatacenter.us/lpms/lock2013web.htm as of May 2017. U.S. Army Corps of Engineers, Institute for Water Resources, Navigation Data Center. *Locks by Waterway, Lock Unavailability, CY 1993 - 2016*. Available at http://www.navigationdatacenter.us/lpms/data/lock2013webunavail-021914.htm as of May 2017. U.S. Army Corps of Engineers, Institute for Water Resources, Navigation Data Center, *Lock Characteristics General Report*. Available at http://www.navigationdatacenter.us/lpms/pdf/lkgenrl.pdf as of May 2017.

and have relatively low average tow delays and only short-duration service outages. Lock 52 on the Ohio River, located 23 miles upstream from the confluence of the Ohio and Mississippi Rivers at Cairo, IL, is the busiest and also one of the oldest, with chambers that are 47 and 88 years old, respectively.[7] It had one of the higher average tow delays in the entire inland waterway system in 2016, at 3.7 hours per tow (as shown in figure 1-9), which is about half the delay per tow in 2015.

On the Upper Mississippi River, the Melvin Price Lock, which is 17 miles north of St. Louis, MO, has the two newest lock chambers listed in table 1-10. It passes over 60 million tons of freight per year with moderate delay and downtime. Just 15 miles downstream, Chain of Rocks Lock 27, with two identical size but much older chambers (64 years), has an average tow delay of nearly 2 ½ hours. The Inner Harbor Navigation Lock, in New Orleans, is one of the principal bottlenecks in the Gulf Intracoastal Waterway. The small chamber size of the 94-year-old lock results in an average tow delay of more than 16 hours (as shown in table 1-10) even though the number of outages has decreased, the hours of downtime increased in 2016.

[7] Ohio River Locks 52 and 53 will be replaced by the new Olmsted Lock, which is presently under construction.

FIGURE 1-9 Average Hours Delayed per Tow for Selected Inland Waterway Locks: 2015 and 2016



NOTE: The average delay time, expressed in hours, calculated only for tows that experienced a wait in passing through the lock chamber.

SOURCE: U.S. Army Corps of Engineers, Institute for Water Resources, Navigation Data Center, Usage Reports, CY 1993 - 2016. Available at http://www.navigationdatacenter.us/lpms/ as of November 2017.

Shallow and deep-draft ports and channels are other important infrastructure elements of the waterway system. There are several thousand inland river ports and terminals. The clear majority of which are privately owned and serve specific cargo-handling needs (e.g., coal loading or petrochemical transfers). Deep draft ports are large and capital-intensive facilities, typically with extensive docks, wharves, cranes, warehouses, and other cargo transfer equipment, and intermodal connections that integrate ocean transport with inland conveyance.

Private terminal operators do not routinely release data publicly on the condition of their facilities. The USACE maintains an extensive database of marine terminals, both shallow draft and deep draft, but it is largely static and does not include condition or performance data and summary tabulations [USDOT BTS 2016b].

To address the limitations on port performance data, BTS was directed to develop a port performance freight statistics program. As noted in the first annual port performance report,[8] [USDOT BTS 2016b] defining a "port" is highly context specific. In some cases, a single cargo terminal may be a port, or at the other extreme a port may comprise all the cargo terminals along many miles of waterfront. The 50 ports listed in table 1-11 are among the top 25 U.S. ports for 1 or more of 3 measures: total tonnage, container TEU (20-foot equivalent units), and dry bulk tonnage. About a third of the ports listed rank in the top 25 by more than one of these measures.

[8] The *Fixing America's Surface Transportation* (FAST) Act (Pub. L. 114-94; Dec. 4, 2015; 129 Stat. 1312) directs the USDOT Bureau of Transportation Statistics (BTS) to establish a port performance statistics program, and submit an annual report to Congress that includes statistics on capacity and throughput for at least the top 25 ports, as measured by total cargo tonnage, dry bulk tonnage, and twenty-foot equivalent units (TEU) of containers handled.

TABLE 1-11 Top 25 Ports by Tonnage, TEU, and Dry Bulk (2015)

Port	Total tonnage	TEU	Dry bulk tonnage
Anchorage, AK		•	
Baltimore, MD	•	•	•
Baton Rouge, LA	•		•
Beaumont, TX	•		
Boston, MA		•	
Camden-Gloucester, NJ		•	
Charleston, SC		•	
Chicago, IL			•
Cleveland, OH			•
Corpus Christi, TX	•		•
Detroit, MI			•
Duluth-Superior, MN and WI	•		•
Honolulu, HI		•	
Houston, TX	•	•	•
Huntington – Tristate, KY, OH, and WV	•		•
Indiana Harbor, IN			•
Jacksonville, FL		•	
Juneau, AK		•	
Kalama, WA			•
Lake Charles, LA	•		
Long Beach, CA	•	•	
Longview, WA			•
Los Angeles, CA	•	•	
Miami, FL		•	
Mobile, AL	•	•	•
New Orleans, LA	•	•	•
New York and New Jersey, NY and NJ	•	•	•
Oakland, CA		•	
Pascagoula, MS	•		
Philadelphia, PA		•	
Pittsburgh, PA			•
Port Arthur, TX	•		
Port Everglades, FL		•	
Port of Plaquemines, LA	•		•
Port of South Louisiana, LA	•		•
Port of Virginia, VA	•	•	•
Portland, OR			•
Ports of Cincinnati and Northern KY, OH and KY	•		•
Richmond, CA	•		
San Juan, PR		•	
Savannah, GA	•	•	
Seattle, WA		•	•
St. Louis, MO and IL	•		•
Tacoma, WA		•	
Tampa, FL	•		•
Texas City, TX	•		
Two Harbors, MN			•
Valdez, AK	•		
Wilmington, DE		•	
Wilmington, NC		•	

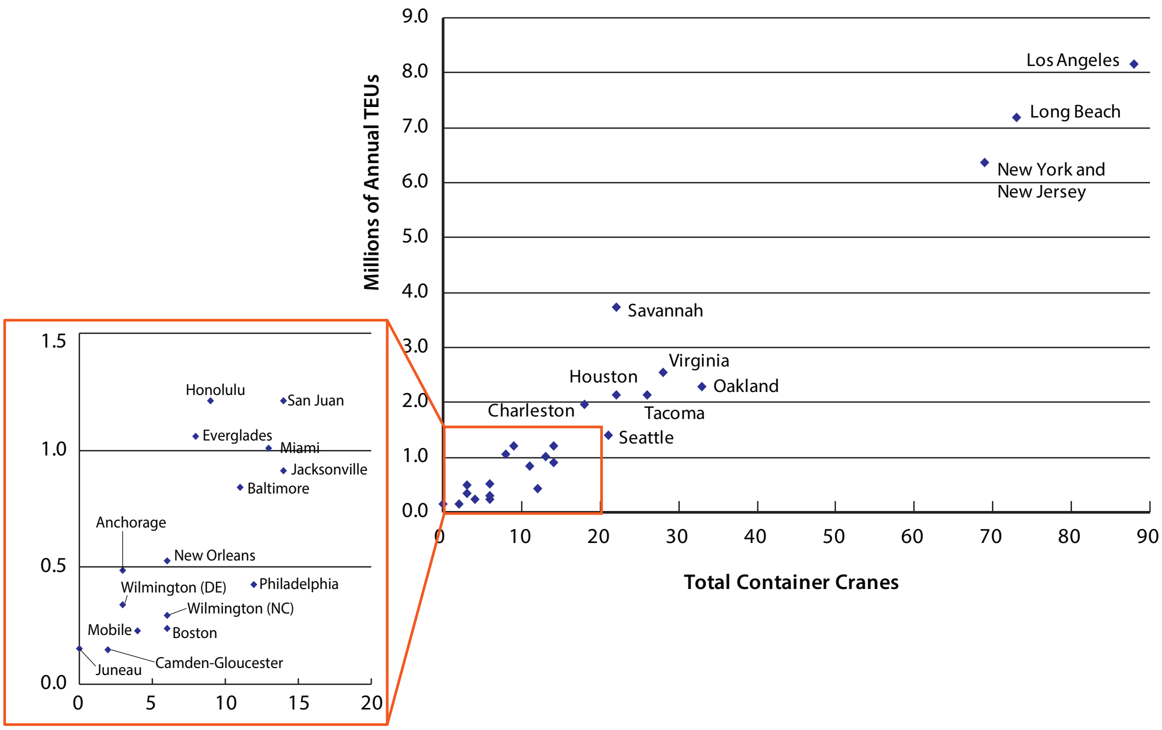
KEY: TEU = twenty-foot equivalent unit.
NOTE: Ports are listed in alphabetical order.
SOURCE: U.S. Department of Transportation (USDOT). Bureau of Transportation Statistics (BTS). *2016. Port Performance Freight Statistics Program: Annual Report to Congress 2016*. Table 4. Available at https://www.bts.gov/sites/bts.dot.gov/files/docs/PPFS_Annual_Report.pdf as of May 2017.

Many of the coastal seaports are served by post-Panamax vessels[9] that continue to increase in size. Containerships calling at U.S. ports had an average capacity of 4,666 TEU in 2015, an increase of 32 percent from 3,542 TEU in 2013 [USDOT MARAD 2015]. Serving these vessels efficiently calls for the port to have the requisite complement of large container cranes. Figure 1-10 shows the number of container cranes at the top 25 container ports by TEU in the United States in 2015. This shows the correlation between the number of container cranes and TEU handled. Los Angeles, Long Beach, and New York-New Jersey have the most cranes and handle the most containers. Today's largest containerships can carry upwards of 18,000 TEU. Larger vessels afford greater economies of scale and cost savings. However, they require investments in U.S. ports, such as increasing bridge clearances, channel depths, landside access, and port and terminal infrastructure [USACE IWR 2012].

The key characteristic of navigation channels that relates to condition is whether the authorized channel depth is available. Nearly all channels need periodic dredging to maintain

[9] Vessels exceeding the length and width of the lock chambers in the Panama Canal. The Canal expansion project was completed in 2016, so vessels that exceed its new larger lock chamber size are referred to as "new Panamax."

FIGURE 1-10 Number of Container Cranes at the Top 25 Container Ports by TEU: 2015



NOTES: The Port of Juneau uses roll on/roll off operations instead of cranes to move some of the containers.

SOURCE: Multiple sources as published in U.S. Department of Transportation, Bureau of Transportation Statistics, *Port Performance Freight Transportation Statistics Program: Annual Report to Congress 2016*. Figure 13. Available at www.bts.gov as of July 2016.

the authorized depth. Most channel dredging occurs under the auspices of the USACE. In 2015 USACE dredges removed 186 million cubic yards of material, which matched the 2014 total, but was down from 197 million cubic yards dredged in 2013. Maintenance dredging accounted for 89 percent of the removed material; the average cost per cubic yard increased 4.7 percent to $5.58, a 40.5 percent increase over the 2013 cost [USACE IWR NDC 2016]. The year 2015 marked the third consecutive year that the total amount of material dredged fell below the 238 million cubic yards dredged in 2012, representing a drop of 22 percent over the 3-year period. As noted above, many coastal seaports are serving post-Panamax vessels, which require dredging of navigation channels to maintain safe operations. The USACE maintains detailed dredging data, but it does not produce summary tabulations that differentiate the work by deep or shallow draft channels.

U.S. flag vessels operate on both shallow and deep draft waterways, and numerous foreign flag vessels call at deep draft ports. Table 1-9 provides age distributions of U.S. flag vessels for the 2000 to 2015 period. The fleet got a bit younger over that period. The percent of vessels younger than 16 years increased from 34 to 44 percent. Inland waterway towboats and barges account for the largest share (85 percent) of U.S. vessels. Towboats are the oldest vessels in this assemblage; 66 percent are older than 25 years [USACE IWR NDC 2016]. In contrast, barges are among the youngest vessels due to a combination of retirement and replacement of older dry cargo barges and acquisition of new tank barges. This is largely in response to the *Oil Pollution Act of 1990* (Pub. L. 101-380) that decreed tank barges and vessels must have double hulls by January 1, 2015.

In 2015 U.S. ferries carried an estimated 118.9 million passengers and over 25 million vehicles [USDOT BTS 2017]. There were 163 ferry operators working in 37 states, 6 in U.S. territories and 2 between U.S. and non-U.S. locations (e.g., Canada).[10] The U.S. ferry fleet comprised 652 vessels, 609 of which were in active service. New York and California had the most ferry vessels with 56 and 55, respectively. Nearly all the vessels carried passengers (93.3 percent), while less than half (42.8 percent) carried vehicles, and less than a quarter carried freight (19.9 percent). Operators participating in the 2016 National Census of Ferry Operators reported that there were 560 terminals in the U.S. ferry system in calendar year 2015. More than two-thirds (69.4 percent) had parking onsite or nearby, and nearly one-third (29.5 percent) were accessible by local bus service.

Pipelines

Natural gas was transported via about 320,000 miles of natural gas transmission and gathering pipelines and over 2.1 million miles of natural gas distribution main and service pipelines in 2015 (table 1-12). These pipelines connect to 67 million households and 5 million commercial businesses as well as the 1,900 electrical generating units that supply approximately 25 percent of U.S. electricity [AGA 2016]. There were over 212,000 miles of crude/refined oil and hazardous liquid

[10] The total number of operators in 2015 was larger than stated here. This number represents those who responded to the census.

TABLE 1-12 Pipeline System: 2000, 2010, and 2013–2015

Gas distribution systems mileage	2000	2010	2013	(R) 2014	2015
Distribution, main mileage	1,050,802	1,229,538	1,255,340	1,266,359	1,276,844
Distribution, estimated service mileage	737,298	872,384	894,356	902,896	913,097
TOTAL, gas distribution	**1,788,100**	**2,101,921**	**2,149,697**	**2,169,254**	**2,189,941**
Natural gas transmission & gathering systems mileage	2000	2010	2013	(R) 2014	2015
Onshore transmission	293,716	299,343	298,336	297,880	297,343
Offshore transmission	5,241	5,432	4,490	3,925	3,833
TOTAL, transmission	**298,957**	**304,775**	**302,827**	**301,804**	**301,177**
Onshore gathering	21,879	12,940	11,288	11,420	11,586
Offshore gathering	5,682	6,699	6,080	6,089	6,193
TOTAL, gathering	**27,561**	**19,640**	**17,369**	**17,509**	**17,748**
TOTAL, gas transmission & gathering	**326,518**	**324,415**	**320,196**	**319,313**	**318,925**
Hazardous liquid or carbon dioxide systems mileage	2000	2010	2013	(R) 2014	2015
Crude oil	U	54,631	61,087	66,813	73,204
Petroleum / refined products	U	64,800	63,351	61,767	62,588
Highly volatile liquids	U	57,980	62,768	65,787	66,813
CO_2 or other	U	4,560	5,195	5,276	5,233
Fuel grade ethanol	U	16	16	16	15
TOTAL, hazardous liquid or CO_2 systems	**U**	**181,986**	**192,417**	**199,659**	**208,616**

KEY: U = Data are unavailable; R = revised.

SOURCE: U.S. Department of Transportation, Pipeline Hazardous Material Safety Administration. *Annual Report Mileage Summary Statistics*. Available at http://www.phmsa.dot.gov/ as of April 2017.

pipelines in 2016 [USDOT PHMSA 2017a], and this system carried 2.9 billion barrels across the United States, an increase of 5.9 percent over 2015 [USDOE EIA 2017a].

In 2016 U.S. natural gas production reached 26.7 trillion cubic feet (tcf). Pipelines deliver about 37.4 percent of natural gas production to power plants to produce electricity, 29.0 percent to the industrial sector, 11.6 percent to the commercial sector, and 16.3 percent to homes for heating [USDOE EIA 2017b].

Natural gas can be converted to a liquid by cooling it to a temperature of -260 degrees Fahrenheit. Liquefied natural gas (LNG) is 1/600th of its gaseous volume, making it easier to transport by vessel over long distances. LNG vessels are double-hulled and specifically designed to handle LNG's low temperature, prevent damage or leaks, and limit LNG evaporation. Short LNG pipelines are used to move the product from the vessel to special LNG terminals. Alaska has been the principal

U.S. LNG exporter, primarily to Pacific Rim countries, but the volume has been small. The Energy Information Administration reported that the first LNG export shipment produced in the lower 48 states was shipped on February 24, 2016, from the Sabine Pass LNG terminal in Louisiana. LNG can also be transported by cryogenic tanker trucks and railway tanker cars [USDOE EIA 2016]. LNG storage facilities increase from 122 in 2010 to 155 in 2016, increasing U.S. storage capacity by 17.5 percent [PHMSA 2017b]

The Pipeline and Hazardous Materials Safety Administration (PHMSA) collects annual report data from pipeline operators, covering their system mileage, commodities transported, and inspection activities, but there is no publicly available database that tracks pipeline condition. A serious failure, such as the Santa Barbara, CA, crude petroleum pipeline spill in May 2014, serves as a reminder that this part of the transportation system has the same problems with aging infrastructure as other modes profiled in this chapter. The number of serious pipeline incidents, which are those involving fatalities or injuries, have trended downward since 2000, when there were 62 such incidents, and have averaged about 30 incidents per year over the past 5 years [USDOT PHMSA 2017c].

Challenges

The U.S. faces a continuing challenge of maintaining system conditions in sufficiently good shape to meet the increasing mobility requirements of the American economy and society. As indicated earlier, the condition of transportation infrastructure is improving, but additional improvements are needed. That said, little is known about the condition of privately owned infrastructure (e.g., railroads and pipelines). The average age of all inland waterway navigation locks is more than 50 years, and 9.1 percent of highway bridges are considered structurally deficient. If these and other condition issues are not addressed, they continue to affect system performance and safety in the coming years. An emerging challenge will be to retrofit the highway system with (largely) electronic and communications technology to transition to automated highways and connected autonomous vehicles.

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CHAPTER 2

Moving People

Highlights

- In 2015 Americans traveled more than in 2014. Cars and other personal vehicles remain the dominant choice for most trips.
- All-time highs for air travel were reached in 2016, following record-setting years in 2014 and 2015. Total enplanements in 2016 were 928 million, compared to 835 million in 2007 and 768 million in the recession year of 2009.
- International air travel passenger-miles surpassed domestic air travel passenger-miles for the fourth consecutive year in 2016.
- 2016 was the first year that foreign carriers transported more passengers to and from the United States than did U.S. carriers.
- There were 75.6 million international visitors to the United States in 2016, down from 77.5 million in 2015—the first annual decline since 2009. Foreign visitors spent an estimated $244.7 billion in their 2016 visits, down about 2 percent from 2015.
- Children walking and biking to school fell from nearly half of children in 1969 to just 13 percent in 2009 and has remained a small proportion despite modest recent growth.
- Bike-share systems operate in more than 150 cities nationwide, with riders taking 28 million trips on the larger systems during 2016.
- App-enhanced ride-hailing companies are capturing a growing share of the for-hire passenger transportation in many metropolitan markets. In the largest market, New York City, these services provided 80 million trips and carried 133 million passengers in 2016.
- Transit use grew between 2000 and 2015, with total ridership growing 1.2 billion and transit's share of commuters growing from 4.7 to 5.2 percent.
- Rural residents have greater reliance than urban residents on automobiles with more than 95 percent having access to a vehicle.

The Nation's transportation system accommodates extensive local and long-distance travel demanded by nearly 325 million U.S. residents and about 76 million foreign visitors [USDOC CENSUS 2017a, USDOC NTTO]. In 2015 person-miles of travel (PMT) in the United States was roughly 5.6 trillion. People used cars or other personal vehicles for 3.8 trillion of these travel-miles, or nearly 70 percent. Domestic and international air travel to and from this country accounted for 1.3 trillion of the 5.6 trillion PMT (23 percent)—of which 631.1 billion (11 percent of total PMT) was domestic and 661.1 billion (12 percent of total PMT) was international. Transit, intercity rail, and bus services accounted for the remaining PMT (table 2-1). Walking and biking also tallied a large number of local trips and travel-miles, with nearly 5 million people getting to work under their own power daily [USDOC CENSUS 2017c].

The number of commercial air passengers and airline revenue passenger-miles reached a record high in 2016, as discussed in the long-distance travel section, rebounding fully from declines during and after the 2007 to 2009 economic recession. After falling from 2007 through 2009, domestic air PMT rose above the pre-recession level in 2015 and reached a record high of 631.1 trillion in 2016. International air PMT to and from the

TABLE 2-1 Person-Miles of Travel in Selected Travel Modes
(million miles)

	TOTAL	Light-duty highway vehicles	Air carrier, domestic	U.S. and foreign air carrier, international	Bus	Motorcycle	Transit	Intercity/ Amtrak
2005	5,704,012	4,319,993	583,771	451,386	278,864	17,492	47,125	5,381
2006	5,769,816	4,332,465	588,471	472,005	297,631	24,329	49,504	5,410
2007	5,838,220	4,341,984	607,564	496,088	307,753	27,173	51,873	5,784
2008	5,735,729	4,248,783	583,292	503,056	314,278	26,430	53,712	6,179
2009	5,045,642	3,625,598	551,741	481,049	305,014	22,428	53,898	5,914
2010	5,082,855	3,646,451	554,618	510,884	291,914	19,941	52,627	6,420
2011	5,124,375	3,650,223	564,685	535,928	292,716	19,927	54,328	6,568
2012	5,195,569	3,669,278	569,931	(R) 558,046	313,357	23,034	55,169	6,752
2013	5,262,358	3,688,161	578,723	(R) 588,249	321,539	21,937	56,467	7,283
2014	5,372,132	3,731,888	595,970	(R) 621,915	339,177	21,510	54,998	6,675
2015	5,552,941	3,828,301	631,100	666,115	344,073	21,118	55,698	6,536
2016	U	U	660,473	711,759	U	U	U	6,520

KEY: R = revised; U = unavailable.

NOTES: *U.S. and foreign air carrier, international* includes only scheduled flight segments to and from the United States. *Light-duty highway vehicle* includes both short and long wheel base passenger cars, pickup trucks, vans, and sport utility vehicles (SUVs). Bus and demand response are included in both *Bus* and *Transit*, which results in some double counting. *Amtrak* does not include contract commuter passenger miles. The data in table above may not be consistent with other sources, particularly data that are revised on an irregular or frequent basis. Different vehicle occupancy rates were used to estimate passenger miles for *Light-duty highway vehicles* and *Bus* beginning with 2009. Nationwide travel data for walking and biking are not collected on an annual basis. Highway PMT data for 2016 had yet to be released when this report was finalized.

SOURCES: **U.S. foreign air carrier, international**: U.S. Department of Transportation, Bureau of Transportation Statistics, Scheduled Passenger Data Tool, available at http://www.transtats.bts.gov as of March 2017. **All other categories**: Various sources as cited in U.S. Department of Transportation, Bureau of Transportation Statistics, *National Transportation Statistics*, table 1-40, available at http://www.bts.gov/publications/national_transportation_statistics/ as of March 2017.

United States experienced a smaller decline during the recession and rose steadily from 2009 to reach an all-time high of 666.1 trillion in 2016. Highway PMT by cars and other personal vehicles in 2015 was still below the peak set in 2007 prior to the recession (table 2-1). Highway PMT data for 2016 had yet to be released when this report was finalized. However, monthly vehicle miles of travel (VMT) data, seasonally adjusted by the Bureau of Transportation Statistics (BTS), shows continuing VMT growth beyond 2007 levels throughout 2016 and in the first half of 2017 [USDOT BTS SA].[1] Transit and intercity passenger rail services grew in number of passengers and passenger-miles during the recession and in most years thereafter (table 2-1).

[1] PMT estimation requires information on the number of vehicle occupants that is not available in the monthly vehicle-miles traveled data. Additionally, the monthly VMT data does not distinguish between passenger and freight vehicle-miles traveled.

Local Travel

Local travel often involves repetitive daily trips (e.g., the daily commute to and from work or school). Social/recreational activities, family/ personal errands, and shopping accounted for nearly 60 percent of household travel and 70 percent of household trips in 2009 (figure 2-1). That year U.S. households averaged about 9.6 trips per day, with the average trip slightly under 10 miles in length (table 2-2). Total travel per household was about 33,000 miles, or 13,200 miles per capita that year. These 2009 benchmarks are the most recent data available from the National Household Transportation Survey (NHTS) [USDOT FHWA 2011]. Data collection for the 2017 NHTS was completed in April 2017, with a data release date of early 2018.[2] Work commutes and work-related trips are typically longer than other types of local travel, making

[2] Prior national surveys have been conducted every 8 to 10 years going back to 1969.

TABLE 2-2 Person Trips, Trip Length, and PMT by Trip Purpose: 2009 NHTS

Purpose	Total household trips in year	Trip length (miles)	Person-miles traveled per household (miles)	Percent of household PMT by trip purpose (percent)
Work	541	11.8	6,256	19.0
Work-related	106	20.0	2,078	6.3
Shopping	725	6.5	4,620	14.0
Family/personal errands	748	7.0	5,134	15.6
School/church	333	6.3	2,049	6.2
Social and recreational	952	10.7	9,989	30.3
Other	61	51.5	2,878	8.7
TOTAL	**3,466**	**9.7**	**33,004**	**100.0**

KEY: PMT = Person-Miles of Travel; NHTS = National Household Travel Survey.

NOTES: *Family/personal errands* includes personal business, shopping, and medical/dental appointments; other includes trips not falling in any of the other trip purpose categories.

SOURCE: U.S. Department of Transportation, Federal Highway Administration, 2009 National Household Travel Survey, *Summary of Travel Trends*. Table 5. Available at http://nhts.ornl.gov/ as of April 2016.

up about one-fourth of total mileage traveled but less than one-fifth of total trips. The shorter trips were typically for shopping, personal business, and social/recreation—each with large shares of the number of trips (table 2-2).

People use automobiles or other personal motor vehicles for the overwhelming majority of their travel, whether local or long distance. In 2015 about 91 percent of U.S. households had at least one vehicle available, with 57 percent of households having two or more [USDOC CENSUS 2017c].

Supporting the high percentage of travel by personal vehicle, the share of households without a vehicle declined from 11.5 percent in 1990 to 8.9 percent in 2015. Roughly 10.5 million households did not have access to a vehicle in 2015 [USDOC CENSUS 2017b]. The number of households without vehicles has stayed about the same, at 10 to 11 million for several decades, despite a growing number of households [AASHTO 2013]. People who rent their living place and people in low-income households are less likely to have access to a vehicle [USDOC CENSUS 2017b].

The 2009 NHTS survey found that about one-fifth of trips involve trip-chaining in which people sandwich in daily errands and activities, such as dropping off and picking up children at school/day care or stopping at a fitness center, while on the way to and from work [USDOT FHWA NHTS 2011].

The number of trips varies throughout the week. Friday accounted for the most trips in 2009, because of more social/recreational and family/personal/errand trips, and Sunday for the least. Reduced numbers of work trips and errands on Saturday and Sunday are partially offset by shopping and social/recreational trips, as well as travel to religious services [USDOT FHWA NHTS 2011].

As shown in figure 2-1, the overwhelming majority of person trips are taken in cars or other personal vehicles. Walking is used for a substantial number of errands and social/recreational trips. Family/personal errands and social/recreational activities accounted for more than two-thirds of trips, followed by trips to and from work, which accounted for 15.6 percent.

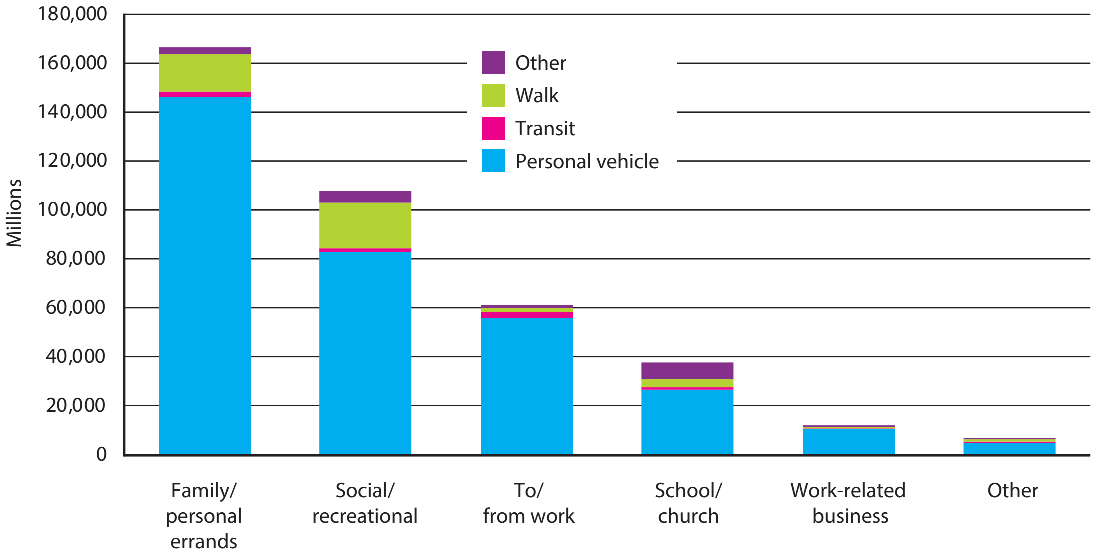
Journey to Work

Personal vehicles were used for about 86 to 88 percent of journeys-to-work in the 2000 to 2015 period. However, driving alone continued to rise in share and numbers, while carpooling declined. Roughly 16.5 million more people said they usually drove alone to work in 2015 than in 2000, while the number of carpoolers fell by nearly 2.3 million as shown in figure 2-2. Transit's share of commuters rose to 5.2 percent, up from 4.7 percent in 2000. About 752,000 more people walked or biked to work in 2015 than in 2000, accounting for about 5 million commuters or about 3.4 percent of all workers in 2015 [USDOC CENSUS 2017c, CENSUS 2004].

The geography and characteristics of commuting have changed:

- More people are working at home. The availability of computers and other advanced information technologies has increased the ability of people to work at home while performing their job responsibilities.

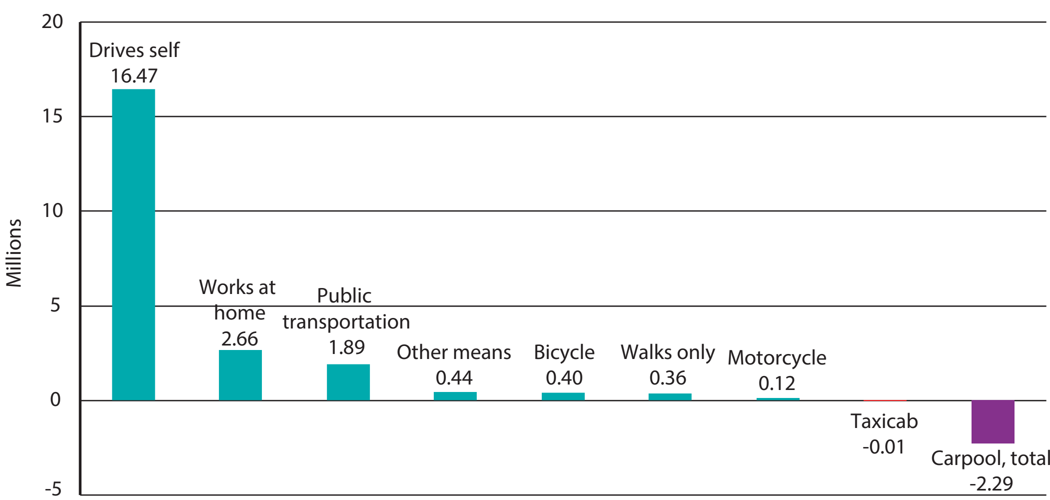
FIGURE 2-1 Annual Number of Person Trips by Mode and Purpose: 2009 NHTS



NOTES: Person trip is a trip by one person in any mode of transportation. *Family/Personal Errands* includes personal business, shopping, and medical/dental appointments. Other includes trips not falling in any of the other trip purpose categories. 2009 is the most recent year available.

SOURCE: U.S. Department of Transportation, Federal Highway Administration, 2009 National Household Travel Survey, *Summary of Travel Trends*. Table 11. Available at http://nhts.ornl.gov/ as of April 2016.

FIGURE 2-2 Net Change in Number of Commuters by Transportation Mode: Journey to Work 2000 and 2015



NOTES: Data are for journey to work only. *Drives self* includes people who usually drove alone to work as well as people who were driven to work by someone who then drove back home or to a non-work destination. *Public transportation* refers to bus, streetcar, subway, railroad, and elevated trains for 2000. *Other* means includes ferryboats, surface trains, and van service and other means not classified for years 2000.

SOURCE: 2000: U.S. Department of Commerce (USDOC), Census Bureau (CB), Decennial Census. About Commuting (Journey-to-Work). Available at http://www.census.gov/ as of June 2015. **2015**: USDOC/CB as cited in U.S. Department of Transportation, Bureau of Transportation Statistics, *National Transportation Statistics*, Table 1-41. Available at http://www.bts.gov as of February 2017.

- For workers who commute to work, the average distance from their home to their places of work has increased in recent years. A recent study of 96 major metropolitan areas found an overall decline of 7 percent in the number of jobs within a typical commuting distance[3] between 2000 and 2012. While the number of jobs in 29 metro areas increased within the typical commuting distance, 67 metro areas showed a decrease [BROOKINGS 2015].
- Workers leaving their home county to work in another in-state county or in a different state increased from 23.5 million to 40.9 million between 1990 and 2015; their percentage share of the workforce grew from 20.4 to 27.6 percent [USDOC CENSUS 1990, 2017c].

According to the Bureau of Labor Statistics, 22.3 percent of workers did some or all of their work at home in 2016, averaging about 3.1 hours per workday. This compares with 19 percent of workers averaging 2.6 hours of their workday at home in 2003 [USDOL BLS 2017a]. Another Census survey found that Monday and Friday were the most likely days to telework and Thursday was least likely [USDOC CENSUS 2013].[4] Consistent with the increase in telecommuting, average commute is down from 0.78 hours in 2010 to 0.76 hours per day in 2016 [USDOL BLS 2017a].

About 14.8 percent of workers with no available vehicle walked to work, roughly four times the percentage for workers with one available vehicle. Similarly, 2.8 percent of those without a vehicle biked to their workplace, compared with 0.8 percent for workers with one available vehicle. Only 4.5 percent of households with workers had no vehicle in 2014, but this percentage represents 6.3 million workers [MCKENZIE 2015].

About 11.6 percent of households have more workers than vehicles. The other 88.4 percent are about evenly split (about 44 percent each) between households with more vehicles than workers and households where the number of vehicles equals the number of workers [AASHTO 2013].

While the average commute to work is 24.6 minutes long, about 9 percent of commuters spend an hour or longer getting to work [USDOC CENSUS 2017c]. For so called megacommuters (workers who commute for more than 90 minutes and travel at least 50 miles one-way to and from work), the journey-to-work is more or less a form of long-distance travel. In the 10 counties attracting the most megacommuters, the mean distance to work among them ranged from just under 60 to over 90 miles, and their mean travel time ranged from 1 hour 44 minutes to just over 2 hours [RAPINO AND FIELDS 2013].

National trends do not portray travel in individual metropolitan areas. For example, transit serves a higher share of work trips

[3] The "typical commute distance" was calculated separately for each area based on median commute distances between Census tracts. Thus, in the Atlanta area, the typical commute distance was calculated to be 12.8 miles while in Stockton, CA, it was 4.7 miles.

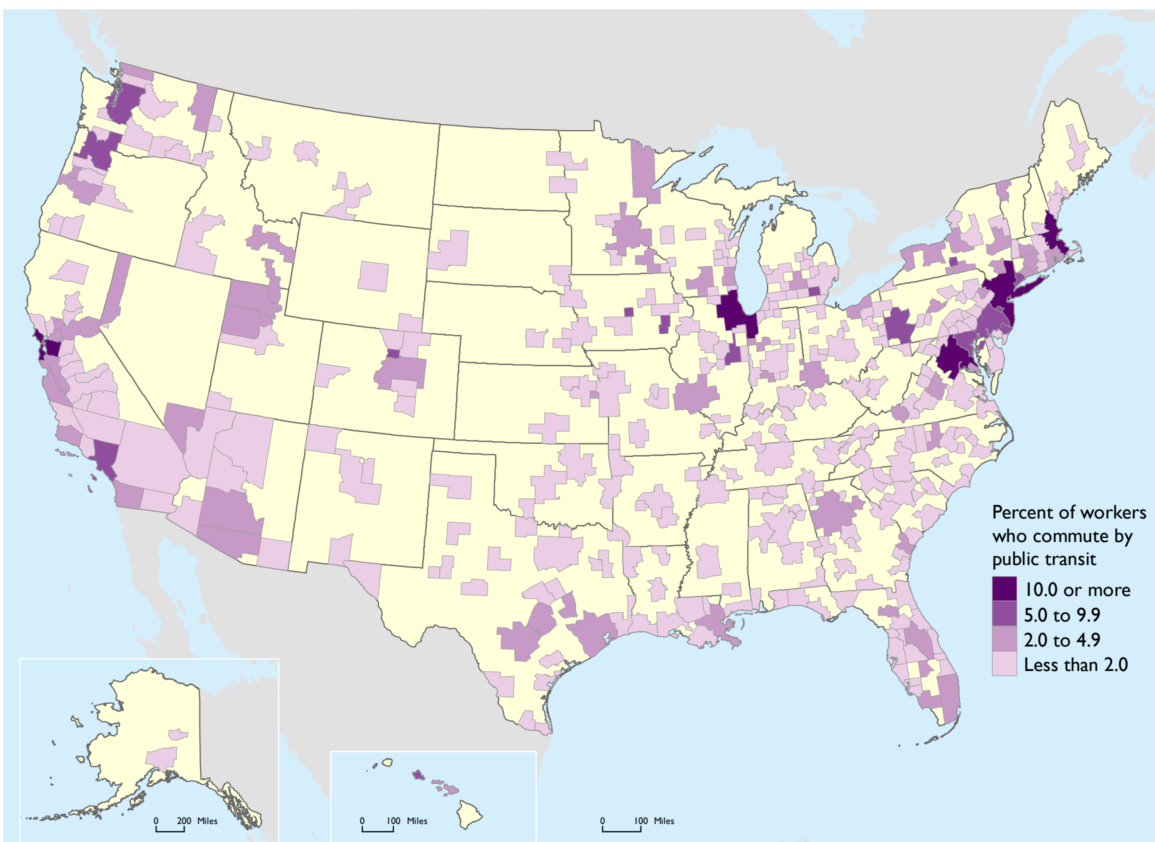
[4] The findings of the two Census Bureau surveys are not comparable because among other details, they use different definitions. The 2015 estimate is from the American Community Survey while the other estimate is from the Survey of Income and Program Participation.

in larger metropolitan areas: 11.0 percent in areas with a population over 5 million, 4.0 percent in areas between 2.5 and 5 million, and 2.2 percent in areas between 1 and 2.5 million. Transit ridership is highest in the New York-Newark-Jersey City, NY-NJ-PA; San Francisco-Oakland-Fremont, CA; Washington-Arlington-Alexandria, DC-VA-MD-WV; Boston-Cambridge-Quincy, MA-NH; and Chicago-Naperville-Elgin, IL-IN-WI metropolitan areas (figure 2-3).

Overall transit ridership has been on an upward trajectory since reaching a low in 1995, increasing by about 30 percent in 20 years. Most of the growth has been in the various transit rail modes; bus, the largest transit mode, has shown little growth in ridership over the period [APTA 2017]. Transit ridership stood at about 10.7 billion unlinked passenger trips in 2014, before declining slightly in 2015 and 2016, when ridership was 10.2 billion. The decline continued in the first half of 2017 [USDOT BTS 2017c].

Since 2010, transportation networked companies (TNC), app-based ride-hailing services in which drivers use their own cars to transport passengers for a fee, have emerged

FIGURE 2-3 Percent of Workers Who Commute by Public Transit: 2016



SOURCE: U.S. Department of Commerce, Census Bureau, *2015 American Communities Survey 5-year Estimates*, available at http://www.census.gov as of August 2017.

in many metropolitan areas around the world. TNCs, the largest of which are Uber and Lyft in the United States, are challenging the traditional taxi business in many large cities. They have become a new feature of urban transportation. As is discussed in box 2-A, public data are limited, but in the biggest market, New York City, TNCs provided 80 million trips in 2016, carrying 133 million passengers, compared to virtually no riders in 2012. Some of the TNC trips replaced traditional taxi and livery service trips [SCHALLER 2017]. The cell phone app has also revived interest in a variety of other mobility options, such as short-term car and

Box 2-A Ridesourcing: The Emergence of the Transportation Networking Company (TNC)

Tens of thousands of people now drive their own personal vehicle on a for-hire basis for others on their own schedule. They can do this on a full- or part-time basis because there are few requirements aside from owning a suitable motor vehicle, adequate car insurance, a driver's license indicating a good driving record, and a smartphone app from a TNC. Uber, Lyft, and other TNCs organize ridesourcing (also called app-enhanced ride services, transportation network services, and, somewhat misleadingly, ridesharing). The TNCs serve as intermediaries between drivers and people seeking rides, providing both with the requisite mobile phone app, handling the generally cashless credit-card based transaction, vetting drivers and vehicles, and providing a feedback mechanism for both the passenger and the driver. While most TNC drivers own their vehicles, a variety of leasing arrangements are available that allow people who do not own a car to drive for a TNC [USA TODAY 2017].

In less than a decade, these ridesourcing companies have come to greatly affect urban transportation in cities around the world where these services are permitted. Intense competition now exists between TNCs and traditional taxi services in many large metropolitan areas. Most data on ridership are closely held by the TNCs. However, NYC now collects TNC ridership data, allowing comparison with traditional taxi services, based on 2015 and 2016 data. A 2017 report [SCHALLER 2017] details the rapid growth of TNC services in NYC:

- From virtually no service available in 2012, TNCs carried 15 million passengers a month in 43,000 vehicles by the fall of 2016. This was nearly as many trips as carried by the city's yellow cab industry, the largest single component of NYC's traditional taxi industry.
- TNC ridership outpaced growth in NYC transit (subway and bus) ridership during 2014–2016. This contrasts with 2012–2013, when TNC service first began in the city and transit ridership accounted for two-thirds of the increase in non-auto trip making.

TNC services and other ridesourcing companies now operate in some 500 cities or communities in the United States. Uber and other such services (but not yet Lyft as of May 2017) are also available in dozens of foreign countries, making it possible for a U.S. resident traveling overseas to use the same cell phone app to hail a ride in a foreign country. While Uber is a major presence in many large cities around the world, it no longer operates in China, where its Chinese operations were acquired by DiDi Chuxing in August 2016. Didi is considered the largest ridesourcing company in the world.

bike rentals, car sharing, and van pooling as discussed in more detail in the *Passenger Access and Connectivity* section of this chapter.

Walking and Biking to Work and to School

Nationally, only a small percentage of people walk or bike to work. However, these nonmotorized modes of commuting are important in many cities of all sizes, as shown by the 2008–2012 American Community Survey. In the 50 largest U.S. cities, 5.0 percent of workers walked to work and another 1.0 percent biked. Over 15 percent of workers in Boston, MA, walked to work, as did more than 10 percent of commuters in Washington, DC, Pittsburgh, PA, and New York City. Portland, OR (6.1 percent) and Minneapolis, MN (4.1 percent) had the highest percentage of bicycle commuters. These cities have also invested in infrastructure to facilitate biking (e.g., building dedicated bike lanes). Some small cities have higher rates of walking and biking, especially where colleges and universities are located. For example, about 42 percent of workers in Ithaca, NY, walk to work and nearly 19 percent in Davis, CA, commute by bike [MCKENZIE 2014].

Among regions, the Northeast has the highest rate of walking to work, while the West had the highest rate of biking. The South had the lowest rate of walking and bicycling to work for most city-size categories.

People walking or biking to work spend less time on their commute than those using other modes—walkers average 11.5 minutes and bikers 19.3 minutes, compared to 25.9 minutes for other modes. Women were slightly less likely to walk to work than men, but less than half as likely to commute by bike. People who walk or bike to work also tend to be younger than the average commuter. Many people walk or bike to work, in part, for the exercise it provides in contrast to less active means of commuting [MCKENZIE 2014].

Some people combine biking and transit to make their commutes and other trips. Many transit vehicles can accommodate bicycles onboard. Another option, increasingly available at cities with bike-share systems, is to combine a transit trip with a short-term bicycle rental. Bike-share systems now exist in 124 U.S. cities, according to a BTS database. The National Association of City Transportation Officials estimates that ridership was 28 million in 2016 on bike-share systems with at least 100 bicycles and 10 docking stations, up from just 320,000 in 2010 [NACTO]. Bike-share systems and their proximity to transit and other transportation modes are discussed in more detail in the *Passenger Access and Connectivity* section of this chapter.

Walking and biking to school has declined dramatically from roughly half of students in 1969 to roughly 15 percent today, with nearly as many students driven to school in family cars as those who walk or take the bus. The decline is apparent even among children who live a short distance—a mile or less from school. Among Kindergarten through eighth grade (K-8) students residing within one mile of school, nearly 90 percent usually walked or biked in 1969, but this percentage fell to 35 percent in 2009 [NCSRTS 2011]. More recent data (albeit based on a different sampling approach) show increases in biking and walking to school, up to 15 percent in the morning and 18 percent in the afternoon in 2014 [NCSRTS 2016]. See box 2-B for more details.

Time Spent Traveling

On weekdays in 2016, the average person spent 83.6 minutes per day traveling for a variety of activities—up from 82.0 minutes in 2015, according to the American Time Use Survey (ATUS), an annual survey conducted by the Bureau of Labor Statistics. Among the 46.0 percent of people who engaged in travel for work, the average person in this group spent 45.5 minutes per day on work travel, the most travel time for all activities in 2016 [USDOL BLS 2017a].

People averaged 3.3 more minutes in weekend and holiday travel activities than on weekdays

Box 2-B How Children Travel To and From School: A Changing Picture

In the four decades between 1969 and 2009, the last year for which NHTS national survey data are available, walking/biking to school and going to school in a family vehicle roughly switched positions as the modal choice of parents for getting their children to and from school:

- In 1969, 48 percent of elementary and middle school children walked or biked to school; in 2009, just 12.7 percent did so.
- In 2009, 45 percent of children were taken to school in a family vehicle, compared to just 12 percent in 1969,
- In both years, children riding the school bus accounted for roughly the same percentages, 38 percent in 1969 and 39.4 percent in 2009.

Even when students live one mile or closer to school, they are less likely to walk or bike, and more likely to be dropped off by parents:

- In 1969, 88.6 percent of students living a mile or less from school usually walked or biked; in 2009 only 35.2 percent did so.[1]
- Children dropped off at a nearby school in a family vehicle increased from 6.9 percent in 1969 to 42.8 percent in 2009.
- Students living near their school also are more likely to take the school bus, rising from 3.8 to 20.4 percent over 40 years [NCSRTS 2011].

[1] The numbers for 1969 and 2009 do not sum to 100 percent because a small percentage of children also took transit or other means to get to school.

It is possible that the decline in walking and biking to school may have tapered off or even reversed since 2009. The National Center for Safe Routes to School (NCSRTS) estimates that walking to school increased from 11.9 to 15.2 percent between 2007/2008 and 2014. Walking home from school increased from 15.2 to 18.4 percent. Biking to and from school declined to under 2 percent between 2007/2008 and 2011, but then stabilized at about 2 percent between 2012 through 2014.

NCSRTS also found fewer children taking the school bus as walking increased in the 2007/2008 to 2014 period. The likelihood of getting to school on a school bus decreased from 36.8 to 29.8 percent over the period, and the likelihood of taking a bus home fell from 42.5 to 34.6 percent in the afternoon. However, the percentage of students taken to school by car increased from 49.1 to 51.5 percent, while those picked up after school rose from 40 to 45.9 percent [NCSRS 2016].

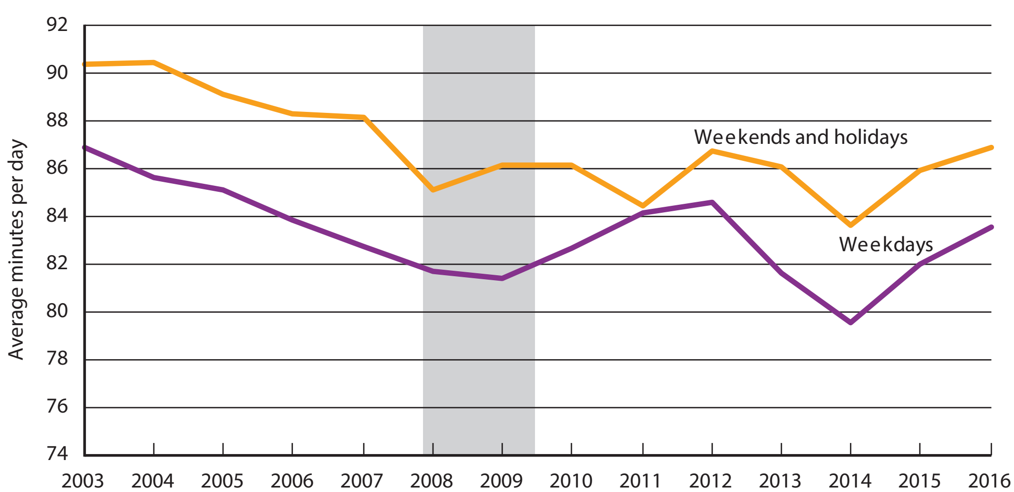
in 2016—an average of 86.9 minutes per day. The average person spent the most weekend and holiday travel time (43.7 minutes) for activities related to consumer purchases, about 8.8 minutes per day more than on weekdays. Travel related to eating and drinking on weekends and holidays accounted for 31.3 minutes—about 6 minutes more than on weekdays.

People spent less time traveling in 2016 than in 2003, according to the ATUS. On weekdays in 2016, people spent 3.3 fewer minutes traveling per day, a decrease of 3.8 percent from 2003. On weekends and holidays, people spent 3.5 fewer minutes traveling per day, a 3.9 percent decrease (figure 2-4).

Long-Distance and International Travel

Americans primarily use airlines and personal vehicles for their long-distance travel. There is no longer a comprehensive national data source for long-distance travel (usually considered as trips to places at least 50 miles away). Although totals could be estimated from a variety of sources, the end result is incomplete—in terms of system usage for long-distance trips, trip purpose and length, and traveler characteristics. The missing pieces include trips by car or other personal motor vehicle (used by most people for their long-distance trips), general aviation, and cruise ships. VMT on rural interstate highways are occasionally used as a surrogate for long-distance highway travel, but there is no methodology for separating local from long-distance travel within rural areas. Takeoffs and landings of general aviation aircraft are not a good proxy for long-distance travel because many flights take off and land at the same airport rather than transport plane occupants

FIGURE 2-4 Total Time Spent Traveling on Weekdays and Weekends: 2003–2016



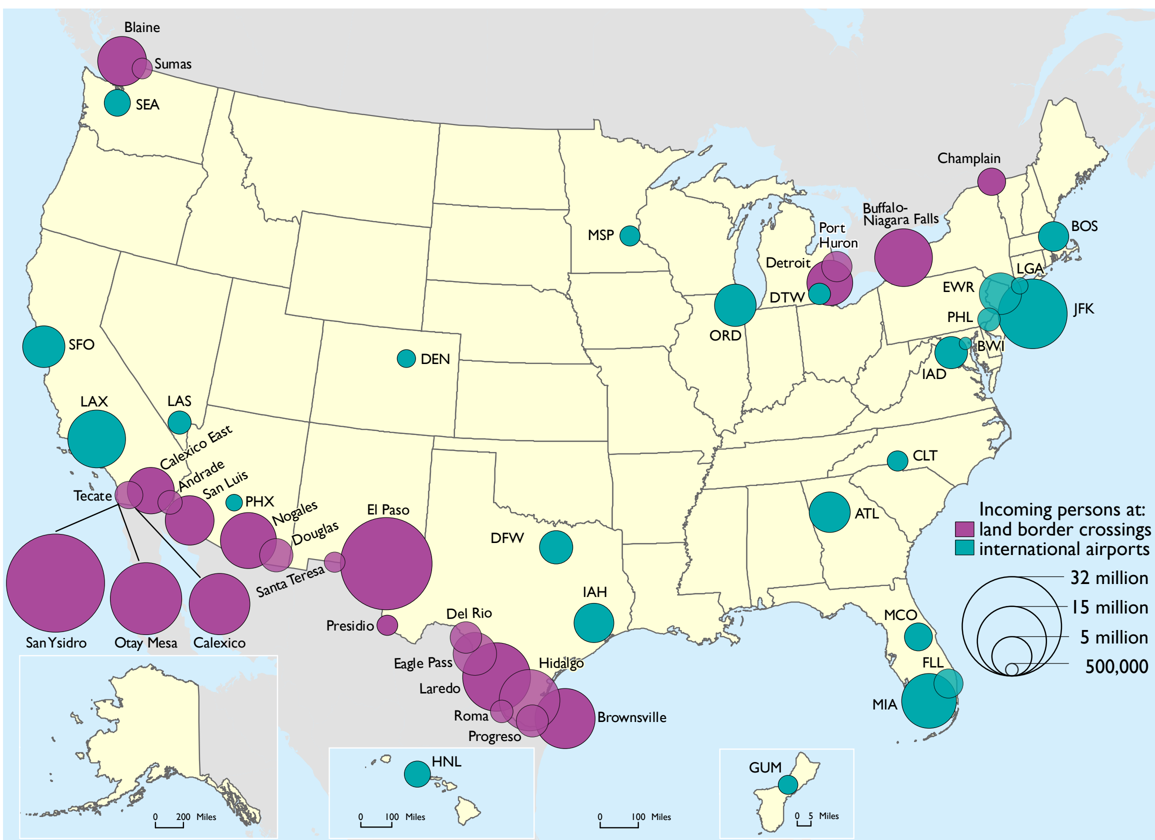
NOTE: Shaded area indicates economic recession. Activities are based on *American Time Use Survey Activity Lexicon* 2016 definitions. Weekdays exclude holidays. Weekends and holidays includes the following: New Year's Day, Easter, Memorial Day, the Fourth of July, Labor Day, Thanksgiving, and Christmas.

SOURCE: U.S. Department of Labor, Bureau of Labor Statistics, *American Time Use Survey 2016*, available at www.bls.gov as of July 2017.

to distant destinations. Numbers of passengers boarding and debarking from cruise ships in each port are counted, but detailed statistics on cruises, cruise passengers, departure ports, and destinations have not been compiled since June 2012.

Long-distance travelers include international visitors who enter the United States at official land border crossing checkpoints, airports, and to a far lesser extent, seaports as well as returning U.S. citizens and day workers (figure 2-5). The land crossing checkpoints along the border with Mexico process more than 3 million people entering the United States in an average week. In 2015, 182.1 million passed into the United States along the U.S.-Mexico border. The border crossing stations with Canada are more numerous, but process far fewer people—52.4 million in 2016 [USDOT BTS NTS].

FIGURE 2-5 Persons Entering the United States at Land Border Crossings and International Airports: 2016



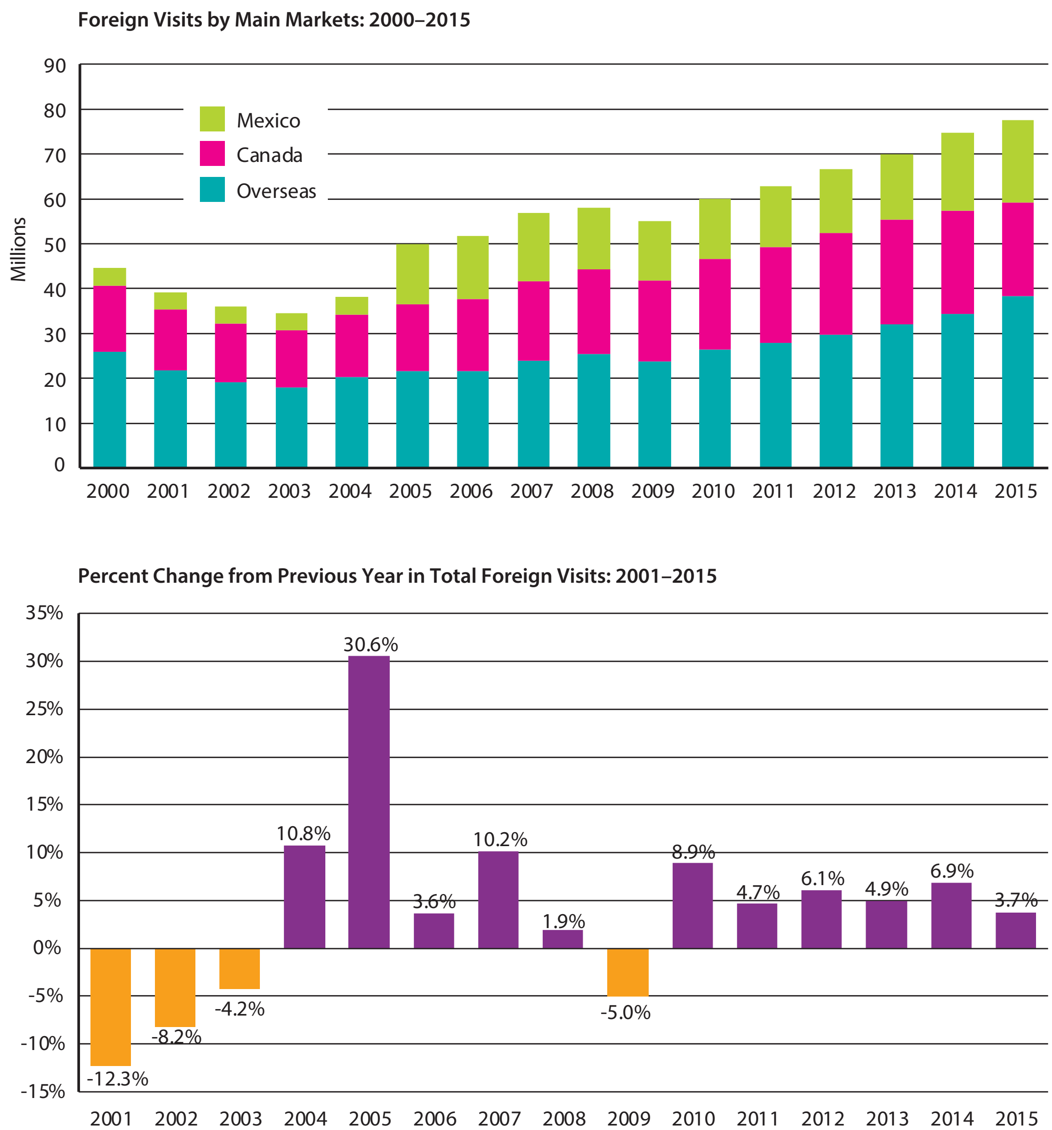
NOTE: Truck crossings are not included because they are primarily freight related.

SOURCE: Person Crossings: U.S. Department of Transportation, Bureau of Transportation Statistics, Border Crossing/Entry Database, available at transborder.bts.gov as of October 2017. **Air Passengers**: U.S. Department of Transportation, Bureau of Transportation Statistics, T-100 Data, available at www.transtats.bts.gov as of October 2017.

While the largest international airports are located at major cities along the East and West Coast, as well as Chicago and Atlanta, the number of smaller airports offering international services has grown. Since 1993 the number of U.S. airports with non-stop international flights has grown from 72 to 122.

In 2016 approximately 75.6 million foreign visitors stayed for at least overnight in the United States, a decline of 1.9 million from a peak in 2015 following 6 years of year-to-year growth (figure 2-6). The number of foreign visitors declined the consecutive years following the September 2001 terrorist

FIGURE 2-6 Foreign Visits by Main Markets: 2000–2015



NOTE: These statistics count visitors staying in the United States for at least one overnight.

SOURCE: U.S. Department of Commerce, Office of Travel and Tourism Industries, *U.S. Monthly Arrivals Trend Line: Overseas, Canada, Mexico & International*, available at travel.trade.gov as of March 2017.

attacks and in 2009 during the global economic recession [USDOC NTTO]. Many more people passed through land border crossing checkpoints from Mexico and Canada on day trips compared to overnight/multiday trips [USDOC NTTO].

Canada and Mexico together account for more than half of foreign visitors to the United States. Visitors from China have grown most dramatically—up nearly 1,000 percent since 2000 when only 249,000 Chinese visited the U.S., ranking it low as a source of U.S. tourism. Visitors from the United Kingdom and Japan have declined since 2000 while Italy and Venezuela no longer appear in the top 10 countries. Table 2-3 shows the change in the top 10 countries since 2000, with China growing from 24th to 10th place in the period. Australia also joined the top 10 list, with the number of its visitors more than double.

U.S. and foreign airlines carried 927.8 million passengers on domestic flights and international flights to and from the United States in 2016—an all-time high (table 2-4). Passenger enplanements were up by about 31 million from 2015, the previous peak year. Domestic enplanements in 2016 accounted for 77.4 percent of passengers, while international enplanements on U.S. and foreign airlines accounted for 22.6 percent. U.S. airlines carried less than half (49.5 percent) of passengers traveling between the United States and international points in 2016, making this the first time foreign carriers transported more passengers to and from the United States than did U.S. carriers [USDOT BTS 2017a].

TABLE 2-3 Countries Sending the Most Travelers to the United States: 2000 and 2016

	Thousands of travelers					
Country	**2000**	**Rank**	**Rank**	**2016**	**Country**	**Percent change, 2000 to 2016**
Canada	14,594	1	1	19,302	Canada	32.3
Mexico	10,322	2	2	18,730	Mexico	81.5
Japan	5,061	3	3	4,574	United Kingdom	-2.7
United Kingdom	4,703	4	4	3,577	Japan	-29.3
Germany	1,786	5	5	2,972	China[a]	1,093.6
France	1,087	6	6	2,035	Germany	13.9
Brazil	737	7	7	1,693	Brazil	129.7
South Korea	662	8	8	1,974	South Korea	198.2
Australia	540	12	9	1,628	France	49.8
China[a]	249	24	10	1,346	Australia	149.3

[a]Arrivals for 2016 excludes Hong Kong.

NOTES: Beginning in 2014, overseas data include one-night stay travelers.

SOURCE: U.S. Department of Commerce, International Trade Administration, Office of Travel & Tourism Industries, *International Visitation in the United States*, available at travel.trade.gov/outreachpages as of April 2017.

TABLE 2-4 Enplanements on Domestic Flights and Flight Segments To and From the United States (U.S. and Foreign Carriers): 2005–2016

Scheduled flights only

	Enplanements (millions)			Load factor (percent)		
	Domestic	International	Domestic and international	Domestic	International	Domestic and international
2005	657.3	143.6	800.8	77.2	78.7	77.8
2006	658.4	149.7	808.1	79.1	78.6	78.9
2007	679.2	156.3	835.4	79.9	79.1	79.5
2008	651.7	157.7	809.4	79.7	77.6	78.7
2009	618.1	149.7	767.8	81.1	78.3	79.7
2010	629.5	157.9	787.5	82.2	81.6	81.9
2011	638.2	163.9	802.1	82.9	80.3	81.6
2012	642.3	170.8	813.1	83.4	81.7	82.5
2013	645.7	179.3	825.0	83.5	82.1	82.8
2014	662.8	(R) 188.8	(R) 851.6	84.5	81.1	82.7
2015	(R) 696.0	(R) 200.6	(R) 896.6	85.0	(R) 80.6	82.7
2016	719.0	208.8	927.8	84.6	80.5	82.4

NOTE: *International enplanements* include U.S. and foreign carriers. *Load factor* is calculated by dividing demand, as measured by revenue passenger-miles (RPMs), by capacity, as measured in available seat-miles (ASMs). *Flight segment* in this context refers to a non-stop flight stage from taking off in the United States to the first destination in a foreign country or a non-stop flight stage from taking off in a foreign country to its first destination in the United States.

SOURCE: U.S. Department of Transportation, Bureau of Transportation Statistics, Office of Airline Information, *Airline Data and Statistics*, Passengers. Available at http://www.bts.gov/programs/airline_information/ as of March 2017.

Total (domestic and international flights in the United States) revenue passenger-miles also set all-time records in 2016, totaling 1.361 trillion, 4.7 percent more than in 2015, the previous record year. International flights accounted for 51 percent of passenger-miles, the fourth year in a row that passenger-miles on these flights exceeded those on domestic flights.

The number of domestic and international flights rose to 9.7 million in 2016, compared to 9.5 million in both 2014 and 2015. Despite the recent increase, the number of flights remains well below the 2005 peak of over 11.3 million flights. However, flights are carrying more passengers and have higher load factors than a decade ago.

Table 2-4 shows that planes have also become more crowded since 2005 as measured by load factors. Domestic flights were, in general, more crowded than international flights. Available seat miles, another measure of plane carrying capacity, increased about 10 percent from 2005 to 2016 on U.S. carriers [USDOT BTS SA]. It can be thought of as the supply of seats.

Flights between domestic airports in 2016 accounted for roughly 84 percent of total U.S. flights, while international flights of U.S. and foreign carriers accounted for about 16 percent. The percent of passengers who flew on international flights rose from 18 percent in 2005 to about 23 percent in 2016.

Long-distance railroad travel in the United States is primarily on Amtrak (also known as the National Rail Passenger Corp.). Amtrak ridership grew for 15 consecutive years between 1997 and 2012, rising from 19.7 million annual person-trips in fiscal year 1997, to 31.2 million in 2012. Subsequently, ridership fell for 3 years (declining to 30.8 million in 2015), but then rebounded in 2016 to 31.3 million, a new record. Ridership on Northeast Corridor trains reached a record of 11.9 million in 2016, surpassing the previous peak set in 2015 [AMTRAK 2017, 2015]. On the smaller Alaska Railroad, annual ridership peaked in 2007 at more than one-half million trips, and had not regained this level as of 2015. Customers traveling aboard railcars owned by cruise lines and pulled by the Alaska Railroad accounted for just under half of the 2015 Alaska Railroad passengers [ARRC 2016].

Compared to 2012, long-distance travel by motorcoach, including charter as well as scheduled service buses, declined somewhat in 2013 and 2014, the last year for which data are available (table 2-5). There were about 604 million person trips in the United States and Canada in 2014, roughly 33 million fewer trips than in 2012 but slightly more than in 2010, when there were more carriers and coaches but fewer passenger trips per coach. Just under half of all bus passengers in 2014 were either students or senior citizens [ABA 2016]. Charter service accounted for about 47.5 percent of motorcoach mileage, and scheduled service accounted for another 32.3 percent. The remaining miles were for commuting (4.6 percent); packaged tours (6.6 percent); transport to and from airports (3.7 percent); sightseeing (3.5 percent); and special operations, such as regular-route service to fairs, sports, and other events, and employee transport to work sites (1.8 percent).

Forces of Change in Travel

Many factors affect local, long-distance, and international travel trends. Among the most important are population, employment, car ownership, household income, and economic conditions. A subset of these include:

TABLE 2-5 Motorcoach Carriers, Coaches, Trips, and Passenger-Miles: 2010–2014

	2010	2011	2012	2013	2014	Percent change, 2010–2014
Carriers	4,011	3,984	3,954	3,801	3,628	-9.55
Coaches	40,709	40,141	39,607	36,903	36,520	-10.29
Passenger trips (millions)	601	627	637	605	604	0.44
Passenger trips per coach	14,800	15,600	16,100	16,400	16,500	11.49
Passenger miles (billions)	69	76	76	63	62	-10.87
Passenger miles per coach	1,703,200	1,897,400	1,912,500	1,710,000	1,700,000	-0.19

NOTE: The *Motorcoach Census* measures the size and activity of the motorcoach industry in the U.S. and Canada. The 2014 data year is the last year for which data are available.

SOURCE: American Bus Association, *Motorcoach Census*, available at www.buses.org as of March 2016.

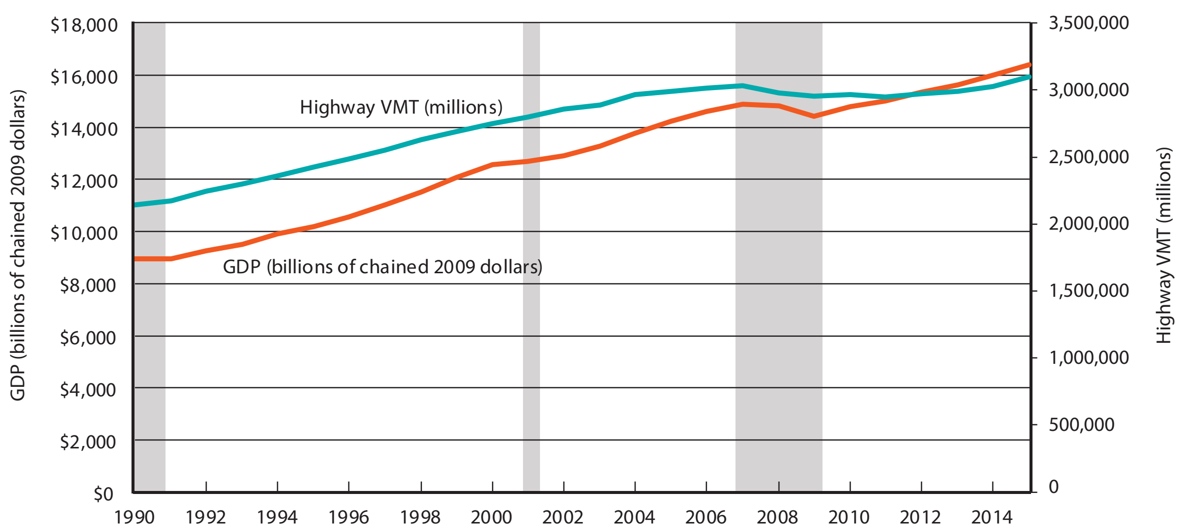
- how travel preferences may change and differ from each other among the aging baby boom generation (people born between mid-1946 and mid-1964), the equally numerous millennial generation (generally described as people born between the early 1980s and the early 2000s) and the subsequent generation (the first entire generation brought up with the ubiquitous presence of the cell phone);
- the emergence and popularity of app-enabled transportation options;
- uncertainties about future levels of immigration both into and within the United States; and
- the diminishing but possibly lingering effects of the economic recession spanning December 2007 to June 2009 on travel patterns.

Economics and Recession

U.S. gross domestic product (GDP) grew at about 3 percent per year between 2000 and 2007, but declined 0.3 percent in 2008 and 2.8 percent in 2009, before again growing each year from 2010 through the end of 2016 at a rate of about 2 percent annually [USDOC BEA].

Figure 2-7 charts GDP and highway VMT during the past quarter of a century, during which three recessions occurred. Highway VMT remained stable or grew in the first two recessions, which were of relatively short duration and relatively mild. VMT shows a different pattern during the longer and more severe 2007–2009 recession. As the figure illustrates, highway VMT peaked in 2007, just as the recession began, then dropped in 2008 and 2009. Again VMT dropped in 2011 before rebounding slowly, only again exceeding

FIGURE 2-7 U.S. GDP and Highway VMT: 1990–2015



KEY: GDP = gross domestic product. VMT = vehicle-miles traveled.

NOTE: Shaded areas indicate economic recessions.

SOURCE: GDP: U.S. Department of Commerce, Bureau of Economic Analysis as cited U.S. Department of Transportation (DOT), Bureau of Transportation Statistics (BTS), *National Transportation Statistics*, Tables 3-10, available: www.bts.gov as of March 2017. **VMT**: DOT, Federal Highway Administration as cited in DOT, BTS. *National Transportation Statistics*, Table 1-35. Available: www.bts.gov as of March 2017.

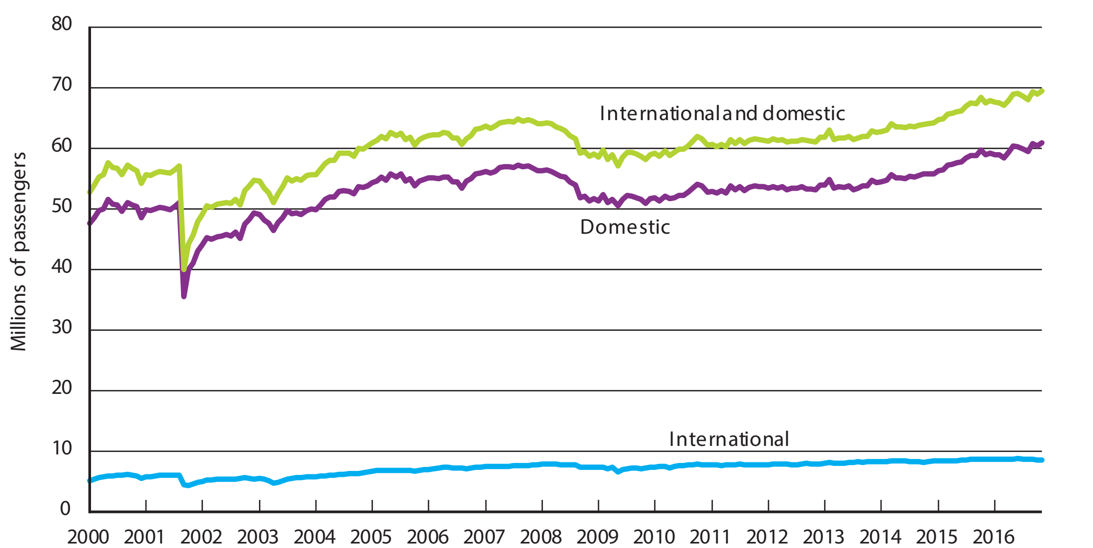
prerecession levels in 2015. GDP has grown more quickly than VMT since the end of the recession, rising 13.7 percent (in chained 2009 dollars) between 2009 and 2015, whereas VMT rose only 4.7 percent [USDOT FHWA 2017].

Airline travel—especially domestic traffic—was also adversely affected by the 2007–2009 recession. While the number of passengers on international flights to and from the United States returned to prerecession levels beginning in 2010, it was not until 2015 that enplanements on domestic flights finally exceeded their 2007 levels (figure 2-8).

Transit ridership reached a high point in 2008 at the height of the recession, then dropped 2.8 percent by 2010. This was followed by several years of growth, with 2008 levels exceeded in 2014 when there were 10.75 billion unlinked transit trips. Transit ridership was stimulated in part by rising gas prices in the 2002 to 2008 period, when many people chose to take transit rather than drive.[5] After a decline in 2009, gas prices bounced up to an all-time high in 2012 [USDOE EIA 2016]. The subsequent and rapid decline in gas prices—a nationwide average decline of $1.19 per gallon between 2012 and 2015, with $0.91 of the decline occurring in 2015—raises the question of whether people who switched to transit when gas prices were high will go back to driving if gas prices remain low [NOWAK AND SAVAGE]. Transit ridership declined from the 2014 high point in

[5] A 2014 report, *Net Effects of Gasoline Price Changes on U.S. Urban Areas*, examines the impact of gasoline price increases on transit ridership in 10 U.S. urban areas [ISEKI; ALI 2014]. The report is discussed in chapter 2 of the *Transportation Statistics Annual Report 2015*.

FIGURE 2-8 U.S. Air Carrier Monthly Passenger Enplanements: January 2000–November 2016



NOTE: Includes enplanements on scheduled services. International enplanements include only U.S. carriers.

SOURCE: U.S. Department of Transportation, Bureau of Transportation Statistics, Office of Airline Information, *T-100 Market Data*. Available at www.transtats.bts.gov as of April 2016.

2015, and the decline continued in 2016 and the first half of 2017 [USDOT BTS 2017c].

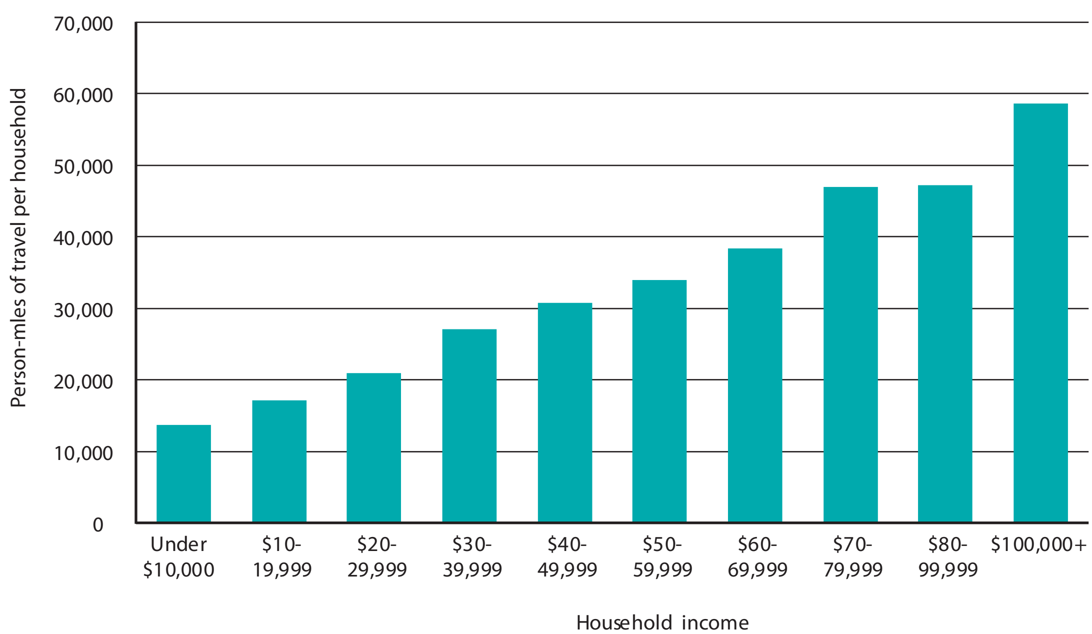
As shown in figure 2-9, PMT increased with household income. With the last National Household Travel Survey (NHTS) completed in 2009 at the end of the recession, it remains to be seen what data from the Federal Highway Administration's 2017 NHTS, not yet available when this report was finished, will reveal about how the trip-making propensities of the public may have changed.

Demographic and Geographic Shifts

Demographic factors and related economic forces affect travel demand, traffic patterns, and associated infrastructure needs. Between 2000 and 2016, the U.S. population grew from 282.2 million to 324.1 million people, placing additional travel demands on the transportation system [USDOC CENSUS 2017a]. All census regions added population, but the South and West accounted for more than 85 percent of the population gain, continuing a decades-long trend [USDOC CENSUS 2017d]. About 60 percent of the Nation's 3,143 counties, including nearly 80 percent of metropolitan counties, gained population from 2000 to 2015, with a total gain of about 42 million people. This contrasts with population losses of 2.7 million residents in the other 40 percent of counties [USDOC CENSUS 2016a, b].

As shown in figure 2-10, counties that lost population, while apparent in all regions, were especially prevalent in the middle of the

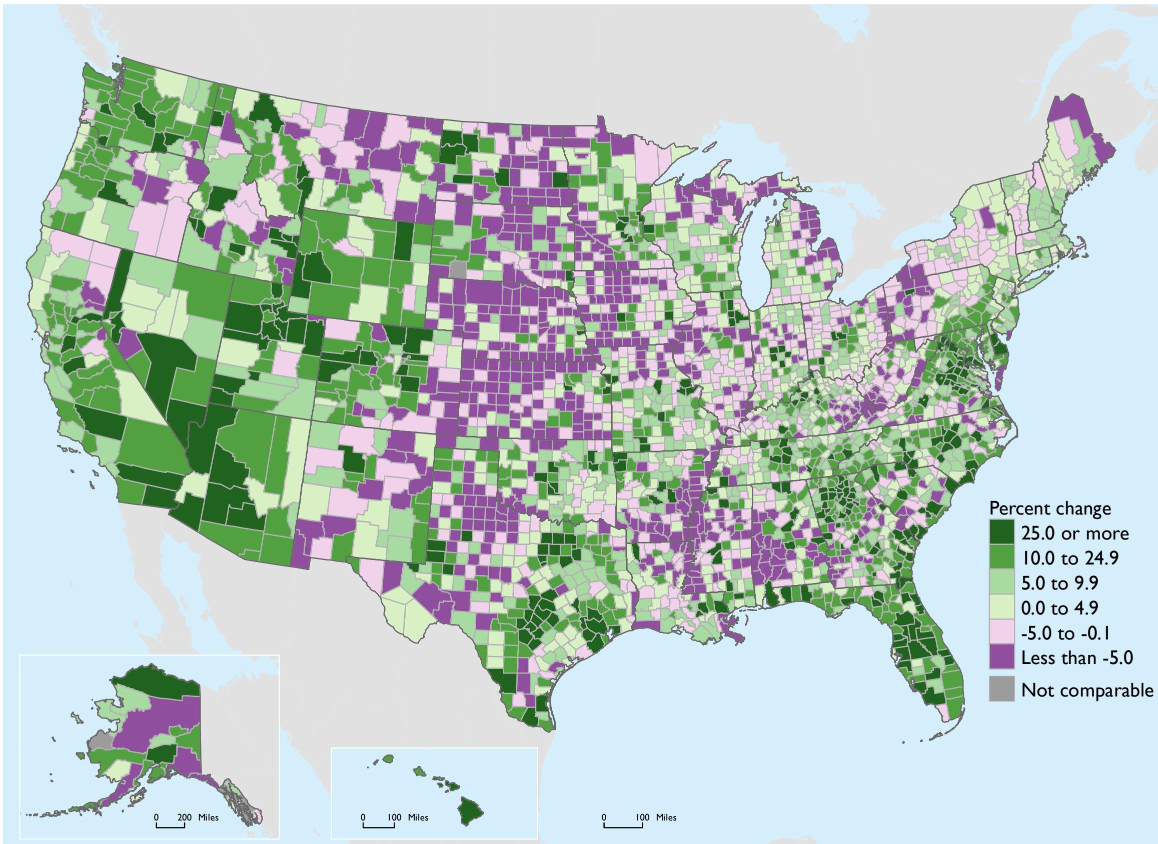
FIGURE 2-9 PMT per Household by Income Level: 2009 NHTS



NOTE: 2009 is the most recent year available.

SOURCE: U.S. Department of Transportation, Federal Highway Administration, *2009 National Household Travel Survey*, Online Analysis Tool. Available at http://nhts.ornl.gov/ as of April 2016.

FIGURE 2-10 Percent Change in Population by County: 2000–2015



SOURCE: U.S. Department of Commerce, Census Bureau, Population, County Population, Available at http://www.census.gov as of September 2017.

country, while counties gaining population were especially evident in the Western states and in Texas and Florida. Gains and losses in regional and metropolitan population affect transportation infrastructure needs and travel patterns.

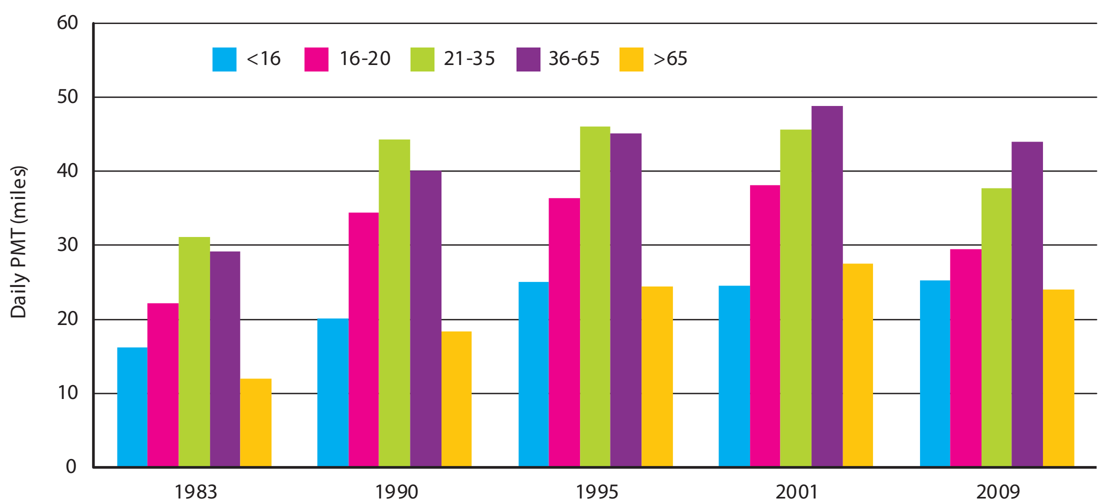
Travel demand is also affected by changes in the labor force and subsequent changes in journeys-to-work. Some of the income generated by the labor force is spent not only on essential travel but also on discretionary trips. The number of people in the workforce increased by nearly 33 million, growing from about 126 million in 2000 to about 159 million in 2016 [USDOL BLS 2017b]. While a greater share of the labor force works at home or walks and bikes to their jobs than in 2000, three-fourths or more continue to commute alone in their cars.

Age is another factor that affects travel demand. Age is closely associated with the progression of the household life cycle (e.g., single person, married couple, households with small children and/or school age children, empty nesters, and retired individuals). Both the youngest (under 16 years of age) and the oldest (over 65 years of age) traveled the least compared to other age groups (figure 2-11). The in-between age groups, particularly those between 36 and 65 years of age, accounted for the majority of PMT. This is a harbinger of future trends as older members of the labor force move toward the 65-year-age threshold where many people move into retirement.

The baby boom generation, people born between mid-1946 and mid-1964, has generated much of the travel activity at the local and intercity level for many decades. Today, even as the trailing edge of the baby boom generation, now in their early 50s, approaches early retirement age, boomers are still affecting travel patterns. They are the first generation in which both women and men have been close to reaching saturation points for driver licenses and vehicle availability.[6] Thus retired baby boomers could be expected to be more mobile in their retirement years than previous generations [AASHTO 2013]. In fact, the share of people with drivers licenses increased among people aged 55 and above between 1983 and 2014, with the greatest increase occurring among people 70 or more years of age [UMTRI]. By contrast, between 1983 and 2014, the share of people with driver's licenses fell for all age groups between 16 and 44, with the greatest decline occurring

[6] According to FHWA, more than 89 percent of people 16 and older had a driver's license in 2009. This included 107 million males and 104 million females. People have their licenses until older ages than in the past. About 84 percent of people 70 and above had a driver's license in 2009, compared to just 66 percent of the same age cohort in 1990. About 91 percent of U.S. households have access to a motor vehicle.

FIGURE 2-11 Daily Person-Miles of Travel (PMT) by Age Group: 1983, 1990, and 1995 NPTS, and 2001 and 2009 NHTS



NOTES: 1990 person trips were adjusted to account for survey collection method changes. Please see Appendix 2 of *2001 Summary of Travel Trends* for specifics. 2009 is the most recent year available.

SOURCE: U.S. Department of Transportation, Federal Highway Administration, National Household Travel Survey (multiple years), *2009 Summary of Travel Trends*. Table 14. Available at http://nhts.ornl.gov/ as of June 2015.

among the younger age groups [UMTRI]. As for new vehicle purchases, people 55 and above increased their share of new vehicle purchases in the United States, growing from 21.2 percent in 2000 to 36.4 percent in 2015. Conversely, the share of vehicle purchases among all age groups below the age of 55 declined between 2007, just before the start of the recession, and 2015, with little significant differences once income and employment were taken into account. [KURZ, LI AND VINE].

Challenges for Travel

An important component of the transportation system is offering widespread access to options, in particular for those groups in society who have the most difficulty traveling or those who have limited access to transportation services. This section begins with a discussion of the degree of connectivity between public transportation modes, using data from the BTS Intermodal Passenger Connectivity Database (IPCD). Other challenges discussed include access to transportation for people without a personal vehicle and transportation options for the elderly and the disabled.

Passenger Access and Connectivity

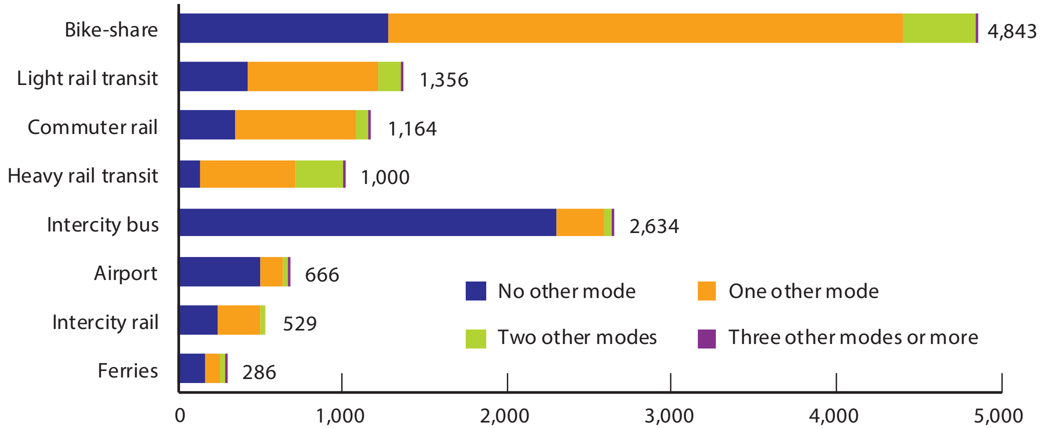
People using public transportation (e.g., Amtrak, intercity bus, or commercial aviation) often need to connect to another mode of transportation to reach their destinations. Proximity to transportation modes (e.g., transit, intercity bus, or train station access at airports) gives travelers more mobility options.

The BTS IPCD inventories the proximity of intercity passenger facilities (e.g., airports, long-distance bus and ferry, and intercity rail service), certain transit facilities (e.g., local ferry and heavy, light, and commuter rail), and bike-share locations to each other. As of August 2017, there are over 10,000 unique passenger travel facilities in the IPCD (see figure 2-12), of which 40.8 percent did not offer nearby connections to other transportation modes, 50.4 percent connected to one other mode, 8.7 percent connected to two other modes of transportation, and 0.1 percent connected to three or more other modes of transportation.

Specifically, 86.0 percent of the heavy rail-stations (high-speed transit rail on an exclusive right-of-way) offered connections to other modes and are the most connected of all travel options, followed by bike-share (with 73.8 percent), commuter rail (with 70.3 percent), light-rail transit (with 68.5 percent), and Amtrak/intercity rail (with 54.1 percent). About a quarter (23.7 percent) of airports with scheduled passenger service connect with other public transportation modes. Only 12.5 percent of intercity bus facilities have connections to other modes.

Bike-share systems that connect with other transportation modes extend the transportation network and increase modal options. For example, a bus passenger who disembarks near a bike- share facility and grabs a bike can ride to more area grocery stores or other commercial services than by walking for the same amount of time. A total of 93 bike-share systems operate 4,911 stations in over 150 U.S. cities as of August 2017 (figure 2-13). Most bike-share docking stations (74.1 percent) can be found near local public transportation stops

FIGURE 2-12 Intermodal Passenger Facilities by Mode: August 2017



NOTES: Intercity bus connection includes: intercity, code share, and supplemental bus service. Transit rail connection includes: light rail, heavy rail, and commuter rail. Ferries includes both transit ferry and intercity ferry.

SOURCE: U.S. Department of Transportation, Bureau of Transportation Statistics, Intermodal Passenger Connectivity Database (as of 08/01/2017). Available at www.bts.gov as of August 2017.

(transit bus, commuter rail, heavy rail, light rail, and/or transit ferry). Transit bus is the most typical connection, with 72.4 percent of bike-share stations located a block or less from a transit bus stop [USDOT BTS 2017b].

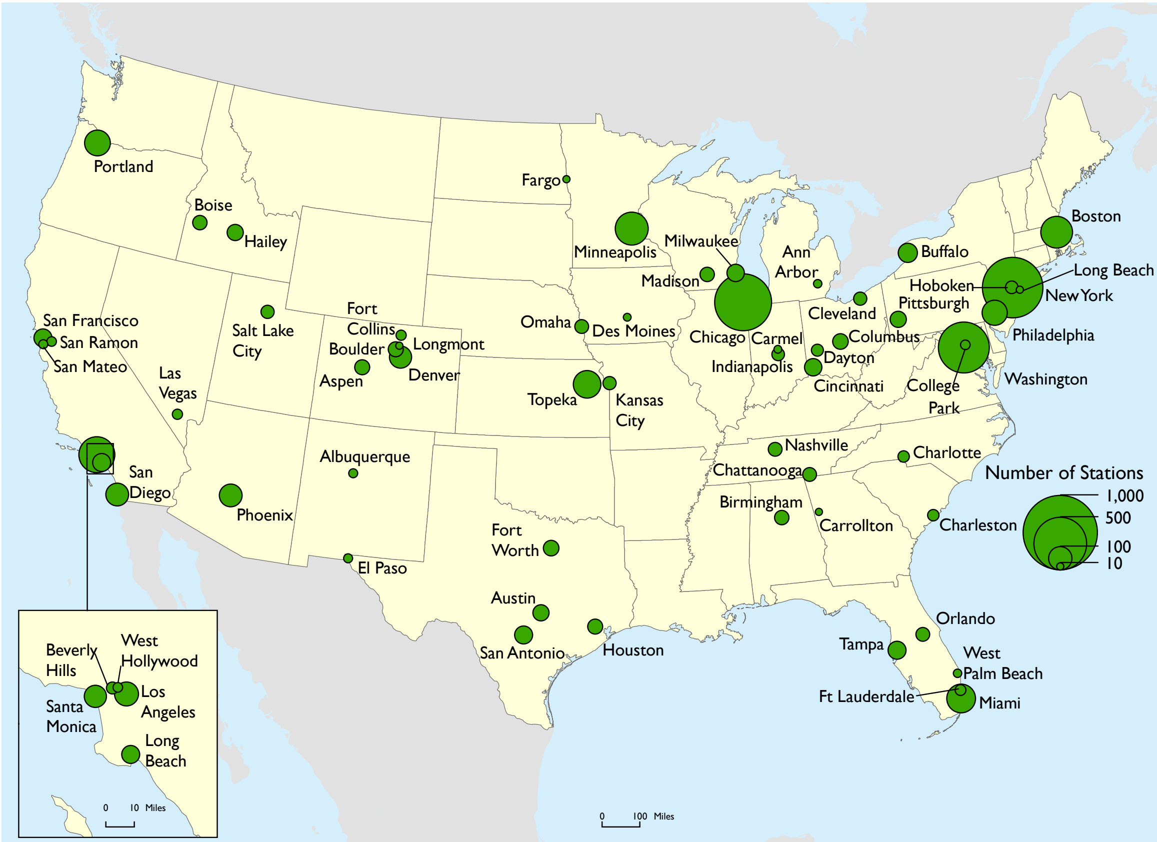
Several U.S. cities are testing or have adopted dockless bike-share (e.g. Washington, DC; Dallas, TX; Seattle, WA; and Revere, MA, among others), where users locate and unlock an available bike using a mobile app and then leave the bike almost anywhere when finished (versus returning the bike to a fixed docking station). Because the location of the bikes changes, it is difficult to measure how these systems extend the transportation system.

People using public transportation often need more information about exactly where and when to get to their next connection. Transit providers are now offering smartphone apps that "push forward" information about nearby connections, and provide GPS walking instructions about how to get to their connection from their current location. These apps can also be used for trip planning, mapping, routing, scheduling, identification of real-time status, and in some cases, cashless fare payment. Some cities also link these apps to bike-share, car-sharing, and ridesourcing services, allowing users to grab a bike at a bike-docking station, hail a TNC vehicle, or locate a car-share vehicle to rent. As new ways to connect transportation users to available services are developed, various niche roles and markets for service providers have proliferated that could enhance access and connectivity, as shown in box 2-C.

Transportation Options for People without Access to a Vehicle

Many people without access to a personal vehicle, especially low-income groups, have difficulty reaching stores, services,

FIGURE 2-13 U.S. Cities with More than 10 Bike-Share Stations: 2017



SOURCE: U.S. Department of Transportation, Bureau of Transportation Statistics, *Intermodal Passenger Connectivity Database*, available at http://www.bts.gov as of August 2017.

Box 2-C App-Enhanced Transportation Options

The app-enhanced[1] transportation options that have emerged in the last decade are revamping traditional ways of ride-sharing, such as sharing a taxi, a commuter bus, or taking a vanpool. Various smartphone apps are also making it easier for people to identify and make local transportation choices in real-time, showing what services are available at their specific location. Services include:

- Ridesharing: match customers going the same direction and determine how to split the fare.
- Bus pooling: match commuters going the same direction, allow people to reserve seats in advance, and charge a fixed fare.
- Neighborhood shuttles: follow a fixed route, with some in neighborhoods typically underserved by other transportation services.
- Car-sharing fleets: app-based services allow subscribers to reserve and rent a car for short periods of time.
- Car-sharing by individual owners: services allow car owners to rent their vehicles when unneeded to strangers.
- Bike-share: short-term bike rentals
- Mobile phone app for local trip planning: App displays real-time transit arrivals/ departures, and in some metro areas app can be used to pay fares electronically. Some apps link to bike-sharing, car-sharing, and ridesourcing options discussed above, allowing travelers to determine which option is most convenient for them.

[1] App is short for application, a software program downloaded to a mobile phone or other computing device that can be used to carry out a specific function.

and workplaces outside of their immediate neighborhoods. As previously discussed, about 8.9 percent of U.S. households do not have access to a personal vehicle. This share of vehicle-less households in urban areas is 10.1 percent, but in the most densely populated parts of cities (10,000 plus people per square mile), 28.4 percent of households had no vehicle in 2009 [USDOT FHWA NHTS 2011]. Vehicle availability is higher in rural areas than urban areas, with only 4.2 percent of rural households lacking access to a vehicle [NDSU].

People living below the poverty level are less likely to own or have access to a personal vehicle to get to work than the population as a whole. In 2015, 43.1 million people, 13.5 percent, of the U.S. population were living in poverty[7] [USDOC CENSUS 2016c]. BTS analysis of the 2009 NHTS found that households with annual incomes less than $25,000 were eight times more likely, on average, to be zero-vehicle households than households with annual incomes above that level [USDOT FHWA NHTS 2011]. Of workers below the poverty level, 64.3 percent drive to work compared to 76.8 percent of workers overall in 2014. Compared to commuters as a whole, people below the

[7] As defined by the U.S. Census Bureau, poverty thresholds in 2015 varied from $12,228 for a single person under the age of 65 to $49,721 for a family of nine. Lower thresholds pertain for people over the age of 65.

poverty level are more likely to carpool, take public transportation, walk, or use other transportation modes (figure 2-14).

While the app-enhanced transportation options, shown in box 2-C, hold promise for increasing availability of transportation in underserved neighborhoods, expense and other barriers could impede their use. For example, many app-enhanced services can only be accessed by users who have a smartphone linked to a credit/debit card account, or who are enrolled in a subscription service (e.g., bike-share programs or car-share services). Many low-income people have a hard time getting or affording such services.

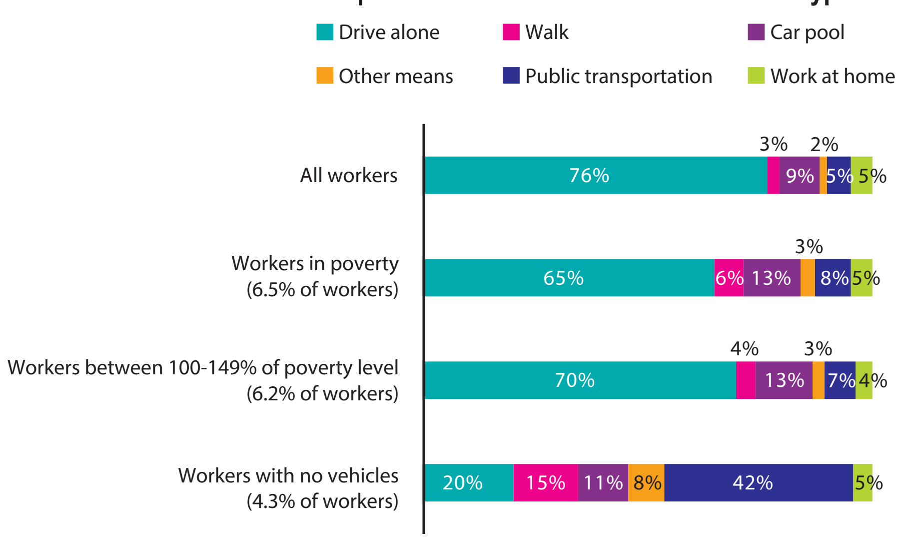
Bike-share stations are often located in central or high volume locations that are hard for people to reach without first using another transportation mode. However, some bike-share systems now offer so called "smart" bikes that contain all the functions of the stationary bike dock. This frees up riders to drop off their rental bike anywhere in the system area, not just a designated docking area. Although many of the newer systems rely exclusively on these smart-bikes, smart bikes only accounted for 13 percent of all bike-share bikes in 2016 [NACTO 2017].

About 24 percent of bike-share systems now offer subsidies for their low-income users, such as a reduced fixed-rate monthly or yearly subscription that can be paid by using an Electronic Benefit Transfer Card or cash.

Transportation Access for Elderly and Disabled Passengers

Access to transportation options is also a challenge for the elderly and for people with

FIGURE 2-14 Means of Transportation to Work for Selected Worker Types: 2016



NOTE: Workers 16 years and over; for workers with no vehicles, the data is calculated for workers 16 years and over in living in households; for workers with poverty status, the data is calculated on workers for whom poverty status is determined.

SOURCE: U.S. Census Bureau, American Community Survey, 2016 1 year estimates. Available at www.census.gov as of November 2017.

physical or cognitive impairments. Between 2000 and 2015, the elderly population (those age 65 or older) in the United States grew by 36.6 percent, increasing from about 35 million people to nearly 48 million in 15 years.

The transportation needs of the older population will change over time; some will continue to rely on their personal vehicle or other transportation options they used when younger. Others may make greater use of transit, paratransit services, and perhaps some of the app-enhanced transportation network services shown in box 2-C. Still others may depend on family members or friends for their transportation.

Some transit agencies are contracting with TNCs and traditional taxis to provide "last mile" rides to and from transit stations at subsidized rates. The American Association of Retired Persons Public Policy Institute estimated that 12 percent of all trips and 10 percent of all miles traveled in the United States in 2009 were taken by persons age 65 and older [AARP 2011]. Transit use by people age 65 and older as a share of all the trips they took increased by 40 percent between 2001 and 2009, which represented more than 1 billion trips on public transportation in 2009 (a 55 percent increase from what was reported in 2001).

People with disabilities often reduce their need to travel, or rely on other options, such as asking relatives or friends for a ride (figure 2-15). Since the 1990 enactment of the *Americans with Disabilities Act* (ADA), the Nation's transportation agencies have been charged with making it easier for people with disabilities to use public transportation through such accommodations as installing lifts and ramps on vehicles for wheelchairs and modifying station platforms, parking facilities, and restrooms. Progress varies among various service providers. All but about 3 percent of transit bus stations (51 out of 1,475) are said to be ADA compliant, as are 98.2 percent of transit buses (at least among those services that report to the Federal Transit Administration). All cars in the heavy rail transit fleet are now reported to be ADA compliant, but only about half (50.6 percent) of heavy rail stations (such as subway stations) are compliant. Similarly, in the case of commuter rail, 87 percent of train cars are compliant, but only 31.5 percent of the commuter rail stations meet ADA requirements. In the case of demand-response transit vehicles that can be assigned based on a passenger's individual needs, about 87 percent of the fleet is reported to be accessible [APTA no date].

As for long-distance passenger rail, Amtrak has had difficulties in meeting its schedule for upgrading its passenger train stations to ADA standards. This was supposed to occur by September 30, 2015, 25 years after passage of the ADA. In 2011 the Amtrak Inspector General found that only 10 percent (48 of 482) of Amtrak stations were compliant [AMTRAK OIG]. Under an understanding with the Department of Justice, Amtrak is developing a strategy to prioritize ADA actions [USDOJ]. As of March 2017, Amtrak information indicated that construction was complete on 57 stations, but noted that platform work could be needed at some stations to make platforms ADA compliant [GREAT AMERICAN STATIONS].

An examination of recent indicators of U.S. travel shows the following:

- Air travel rebounded quickly after the 2007–2009 recession and set new records in 2016.
- Highway travel has lagged recovery rates of prior recessions, with VMT only returning to prerecession levels in 2015 and 2015 PMT still below 2007 levels.
- Cars and other personal vehicles remain the predominant modal choice for most trips, including in urban areas. However, with transit ridership on an upward trajectory, walking and biking trips rebounding, and growing popularity of app-enhanced transport options, modal choices have expanded in many urban centers.

In order to understand possible changes in travel dynamics, good data about local, long-distance, and international travel will need to be collected on a regular basis. The central question for data development will be to distinguish what changes are cyclical phenomena, and therefore transient, from those that are structural and a fundamental part of a new era of travel behavior.

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CHAPTER 3

Moving Goods

Highlights

- In 2015 freight tonnage and value rose by 6.4 and 8.2 percent, respectively, over 2012 levels, fully rebounding from declines during the December 2007–June 2009 economic recession.
- The U.S. freight transportation system moved nearly 18.0 billion tons of goods valued at more than $19.1 trillion in 2015. Expressed in per-capita terms, this means that about 56 tons of freight moved for every man, woman, and child in the United States—a 4 percent increase since 2012.
- Trucks carry 60.0 percent of the weight and 60.7 percent of the value of all goods shipped in the United States, and is the predominate mode for shipments under 750 miles. Rail leads in tons and ton-miles for shipments of 750 to 2,000 miles, while modal combinations account for the largest share of the value of shipments moved 2,000 miles or more.
- The value of total U.S.-international merchandise trade increased from more than $2.4 trillion in 2000 to approximately $3.3 trillion in 2016 (in 2009 dollars)—a 37.6 percent inflation-adjusted increase. U.S. trade with Canada and Mexico accounted for 29.3 percent (nearly $1.07 trillion) of the value of U.S.-international merchandise trade in 2016.
- Trucks carried 26.8 percent of the tonnage and 65.5 percent of the value of U.S. merchandise trade with Canada and Mexico, while rail carried 18.2 percent of the tonnage and 15.5 percent of the value in 2016.
- Nearly 500 freight transportation gateways, including airports, border crossings, and seaports, handle international cargo; while the latest available data show that in 2015 the top 25 gateways handled 64.8 percent of the value of total U.S.-international merchandise trade—$2.4 trillion in current dollars.
- Alaska, North Dakota, and Wyoming are major producers of energy commodities—oil in Alaska and North Dakota and coal in Wyoming. Alaska and North Dakota had the highest ratios of domestic export to domestic import shipments by value, while Alaska and Wyoming accounted for the highest ratios by tonnage.

The U.S. freight transportation system moved nearly 18.0 billion tons of goods valued at more than $19.1 trillion in 2015, according to Freight Analysis Framework (FAF)[1] estimates (table 3-1). This means the freight transportation system carried, on average, about 49.3 million tons of goods worth more than $52.5 billion each day, or about 56 tons of freight annually per capita in the United States in 2015, a 4.0 percent increase from 2012. See box 3-A for information about the FAF and its foundation, the Commodity Flow Survey (CFS).

[1] Input sources for the FAF4 base year of 2012 are final, but each updated version of FAF incorporates continuous improvements to data quality. As a result, the latest data available online may not precisely match the data in this chapter or previous editions of this report.

TABLE 3-1 Weight and Value of Shipments by Transportation Mode: 2012, 2015, and 2045

Weight

	2012				2015				2045			
Millions of tons	Total	Domestic	Exports[1]	Imports[1]	Total	Domestic	Exports[1]	Imports[1]	Total	Domestic	Exports[1]	Imports[1]
Total	**16,896**	**14,901**	**864**	**1,130**	**17,978**	**15,983**	**920**	**1,075**	**25,346**	**20,940**	**2,202**	**2,204**
Truck	10,092	9,899	105	89	10,776	10,568	108	100	14,829	14,235	290	305
Rail	1,616	1,481	53	82	1,602	1,459	55	89	1,918	1,588	109	221
Water	884	502	68	313	884	544	95	246	1,100	609	190	301
Air, air & truck	10	2	4	4	10	2	4	5	37	4	16	18
Multiple modes & mail	1,311	309	596	406	1,346	324	615	407	2,962	431	1,521	1,010
Pipeline	2,942	2,672	37	233	3,326	3,056	43	226	4,468	4,058	73	338
Other & unknown	41	37	1	3	33	29	1	3	31	16	4	11

Value

	2012				2015				2045			
Billions of 2012 dollars	Total	Domestic	Exports[1]	Imports[1]	Total	Domestic	Exports[1]	Imports[1]	Total	Domestic	Exports[1]	Imports[1]
Total	**17,701**	**13,965**	**1,532**	**2,204**	**19,146**	**14,978**	**1,704**	**2,465**	**37,026**	**22,474**	**6,482**	**8,071**
Truck	10,929	10,253	365	311	11,626	10,903	381	342	18,691	16,227	1,246	1,218
Rail	578	411	61	107	623	445	63	115	1,077	646	155	276
Water	588	270	72	246	596	297	99	200	973	340	273	360
Air, air & truck	1,038	132	434	472	1,187	145	466	576	5,120	317	2,449	2,354
Multiple modes & mail	3,257	1,748	572	936	3,581	1,870	658	1,053	9,120	3,396	2,262	3,461
Pipeline	1,271	1,150	10	111	1,450	1,317	15	118	1,721	1,546	21	154
Other & unknown	40	1	17	22	83	1	21	61	325	0	76	248

[1] Data do not include imports and exports that pass through the United States from a foreign origin to a foreign destination by any mode.

NOTES: Numbers may not add to totals due to rounding. The 2015 data are provisional estimates that are based on selected modal and economic trend data. Data in this version is not comparable to similar data in previous years because of updates to the Freight Analysis Framework. All truck, rail, water, and pipeline movements that involve more than one mode, including exports and imports that change mode at international gateways, are included in multiple modes & mail to avoid double counting. As a consequence, rail and water totals in this table are less than other published sources.

SOURCE: U.S. Department of Transportation, Bureau of Transportation Statistics and Federal Highway Administration, Freight Analysis Framework, version 4.3.1, 2017.

Population growth and economic activity continue to be the primary factors that determine freight demand. As population increases or economic activity expands, more goods are needed and produced, resulting in additional freight movement. Between 2010 and 2016, the U.S. population increased by 4.5 percent [USDOC CENSUS American Fact Finder], and U.S. gross domestic product (GDP) grew by 12.7 percent in terms of chained 2009 dollars [USDOC BEA 2017]. Although freight moves throughout the United States, the demand for freight transportation is driven primarily by the geographic distribution of population and economic activity. Both population and GDP have grown faster in the South and West than in the Northeast and Midwest, but the Northeast has the highest GDP per capita (table 3-2).

TABLE 3-2 Population and Gross Domestic Product (GDP) by Region: 2010 and 2014–2016

	2010	2014	2015	2016	Percent change, 2010 to 2016
Resident Population (thousands)	**309,348**	**318,563**	**320,897**	**323,128**	**4.5**
Northeast	55,318	56,117	56,185	56,210	1.6
Midwest	66,930	67,726	67,838	67,941	1.5
South	114,563	119,696	121,039	122,320	6.8
West	71,947	75,024	75,834	76,657	6.5
GDP (millions of chained 2009 $)[1]	**14,783,800**	**15,982,300**	**16,397,200**	**16,662,100**	**12.7**
Northeast	3,553,225	3,700,258	3,772,627	3,816,577	7.4
Midwest	3,000,447	3,215,098	3,257,438	3,294,998	9.8
South	4,862,984	5,268,516	5,422,600	5,490,134	12.9
West	3,211,646	3,501,251	3,636,790	3,735,446	16.3
GDP per capita (chained 2009 $)[1]	**47,790**	**50,170**	**51,098**	**51,565**	**7.9**
Northeast	64,232	65,939	67,147	67,899	5.7
Midwest	44,830	47,472	48,018	48,498	8.2
South	42,448	44,016	44,800	44,884	5.7
West	44,639	46,668	47,957	48,729	9.2

KEY: R = revised.

[1]As of October 26, 2006, the Bureau of Economic Analysis renamed the gross state product (GSP) series to gross domestic product (GDP) by state.

NOTES: Chained dollars are not additive, especially for periods farther away from the base year of 2009. GDP for all regions is not equal to total GDP. Numbers may not add to totals due to rounding.

SOURCES: **Population**: U.S. Department of Commerce, Census Bureau, Population and Housing Unit Estimates Datasets, National Population Totals Datasets, available at https://www.census.gov/programs-surveys/popest/data.html as of June 2017. **Gross Domestic Product**: U.S. Department of Commerce, Bureau of Economic Analysis, Regional Economic Accounts, available at www.bea.gov/regional/ as of June 2017.

Economic recovery following the Great Recession through the end of 2016 was slow but steady. That same pattern was evident in transportation services where freight activities rose above the long-term growth trend. Freight activities began to rise quickly beginning in May 2009 (one month ahead of the economic acceleration following the recession) but has since slowed. Gross domestic product grew as rapidly before and after the Great Recession, suggesting that freight transportation has recovered more slowly than the economy as a whole. In addition, changes in the composition of goods demanded and shifts in population and economic centers had an effect on what goods were moved, what modes were used to transport them, and to where they were shipped. Freight carried by the for-hire transportation industry rose as the economy rebounded from the past recession [USDOT BTS 2017c].

Box 3-A The Commodity Flow Survey and the Freight Analysis Framework

The Commodity Flow Survey (CFS) is conducted every 5 years by the Bureau of Transportation Statistics (BTS) in partnership with the U.S. Census Bureau as part of the Economic Census. The CFS provides data for most of the U.S. economy on commodities shipped, their value and weight, mode of transport, and origin and destination within and between all U.S. regions. The survey covers about 75 percent of the tonnage shipped from a domestic origin to a domestic destination.

The CFS is the foundation for the Freight Analysis Framework (FAF), a freight database produced through a partnership between BTS and the Federal Highway Administration (FHWA). The FAF incorporates domestic shipments collected in the CFS (covering mining, manufacturing, wholesale, and other selected industries), and augments the CFS data with foreign trade statistics from the U.S. Census Bureau, agricultural data from the Department of Agriculture, energy commodity data from the Department of Energy, and other sources.

The fourth generation of FAF (FAF4) is based on the 2012 CFS, which includes improvements to data collection, data editing, and an expanded number of geographic areas. Improvements were also made to the non-CFS components of FAF.

FAF provides tonnage and value estimates by commodity type, mode, origin, and destination for years the CFS is conducted, provides annual estimates for years in between the CFS, and long-range (30 year) forecasts in 5-year increments. It also includes an assignment of truck flows to the highway network for the CFS year and a 30-year forecast to provide a picture of freight truck volumes.

FAF forecasts are based on long-term U.S. economic projections, including real gross domestic product growth, nonfarm business productivity, real oil prices, and the Federal budget deficit. Detailed information on CFS data and methodologies are available at www.bts.gov/publications/commodity_flow_survey. Information on FAF data and methodologies are available at www.bts.dot.gov/archive/subject_areas/freight_transportation/faf. While the FAF is more complete in coverage of freight flows, the CFS provides greater commodity detail and additional shipment characteristics, such as hazardous materials class.

It is important to note that the input sources for the FAF4 base year of 2012 are final, but each updated version of FAF incorporates continuous improvements to data quality. As a result, the latest data available online may not precisely match the data in this chapter or previous editions of this report.

U.S. exports and imports accounted for 5.1 and 6.1 percent of the weight and 8.8 and 12.9 percent of the value of freight transported in 2015, respectively. FAF forecasts that U.S. exports and imports will account for an even greater share of freight movements in 2045, reaching 17.5 percent of the weight and 39.3 percent of the value of goods shipped throughout the country [USDOT BTS and FHWA FAF 2017].

Domestic Freight Movement

The freight transportation industry moves goods over a network of truck routes, railroads, waterways, airports, and pipelines. The distance a shipment must travel and the cost to ship play a major part in determining what mode or mix of modes are used during any particular leg of a multimodal journey.

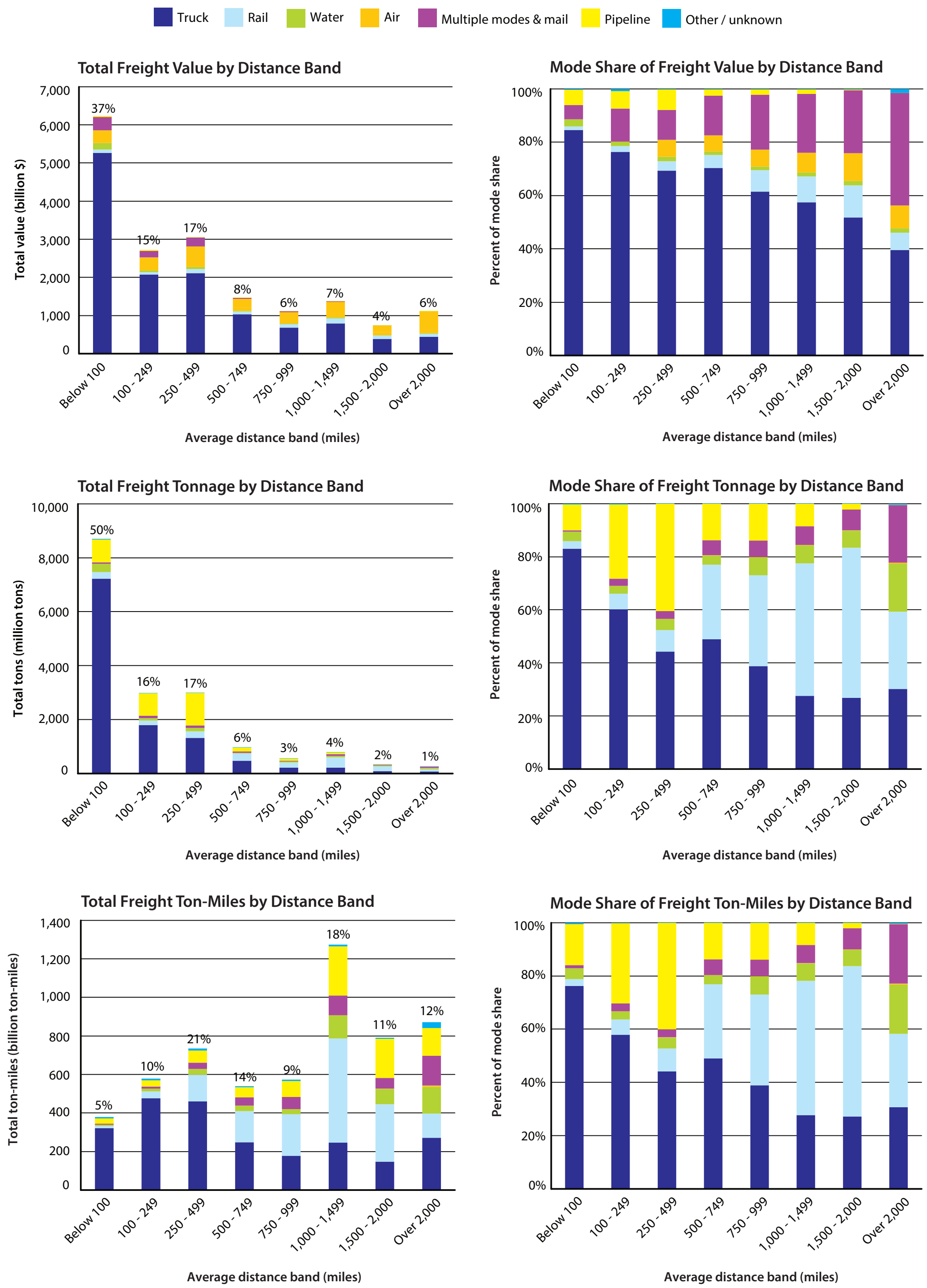
A large percentage of goods movement occurs close to home. Approximately 50.1 percent of the weight and 37.1 percent of the value of goods were moved less than 100 miles between origin and destination in 2015 (figure 3-1). By contrast, 7.6 percent of the weight and 17.1 percent of the value of goods were moved more than 1,000 miles. Distance, as used here, refers to the Great Circle Distance, which is commonly called "as-the-crow-flies." Modal shares of freight vary considerably by distance. While trucks carry the largest shares by value, tons, and ton-miles for shipments moving 750 miles or less, rail is the dominant mode by tons and ton-miles of shipments transported between 750 to 2,000 miles; whereas air and multiple modes account for 49.8 percent of the value of shipments moving more than 2,000 miles [USDOT BTS and FHWA 2017].

Overall, trucks carry the highest percentage of the weight and value of goods in the United States, accounting for 10.8 billion tons of the weight (60.0 percent) and $11.6 trillion of the value (60.7 percent), respectively, in 2015 (table 3-1). However, railroads and inland waterways carry large volumes and tonnages of bulk commodities over long distances. Figure 3-2 helps visualize the large volume of coal moved by rail between the Powder River Basin in Wyoming and the Midwest, in addition to the grains and energy products moved by vessel and barge along the Lower Mississippi River. Rail and water combined accounted for 13.8 percent of the total tonnage and 6.4 percent of the total value of freight moved in the United States in 2015. Air carriers almost exclusively moved high-value, low-weight products. This is underscored by the relatively extreme value-to-weight ratio of air cargo, which is about $115,779 per ton. In comparison, the overall value-to-weight ratio of cargo carried by all modes combined is less than $1,100 per ton. In 2015 pipelines moved nearly 3.3 billion tons of goods, valued at about $1.5 trillion ($436 per ton), while rail moved more tonnage of lesser value—1.6 billion tons valued at $623 billion ($389 per ton) [USDOT BTS AND FHWA 2017].

Shipments moving by water are typically low-value, bulk products similar to those moved by rail.[2] In 2015 the water transportation industry moved 936 million tons worth $636 billion (nearly $680 per ton), representing 5.2

[2] Many shipments moving by rail or water are transferred to another mode for delivery to their final destination. In FAF, these shipments are counted under "multiple modes and mail." Thus the rail and water numbers discussed here may differ from those in other published sources.

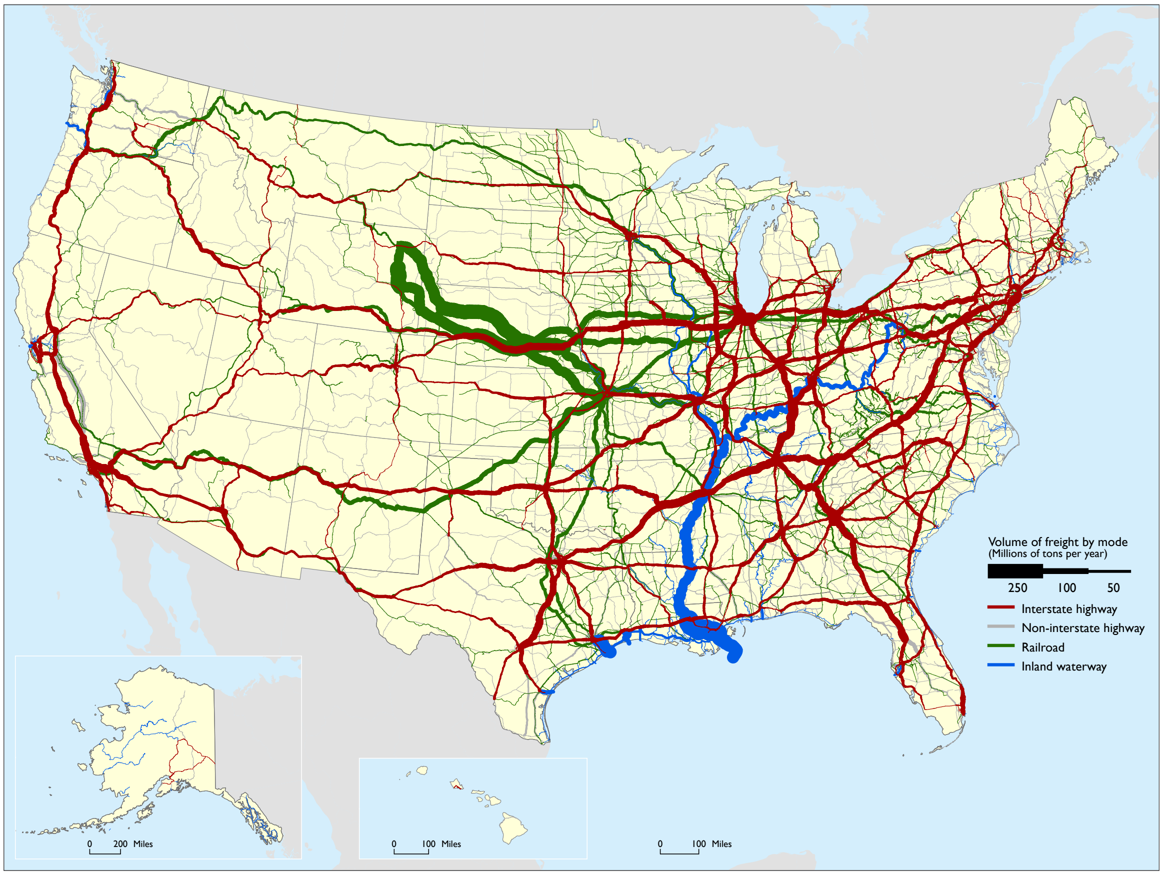
FIGURE 3-1 Value, Tonnage, and Ton-Miles by Distances Traveled: 2015



NOTE: "Other / Unknown" mode includes movements not elsewhere classified such as flyaway aircraft, and shipments for which the mode cannot be determined.

SOURCE: U.S. Department of Transportation, Bureau of Transportation Statistics and Federal Highway Administration, Freight Analysis Framework, version 4.3.1, 2017.

FIGURE 3-2 Freight Flows by Highway, Railroad, and Waterway: 2012



SOURCES: *Highways*: U.S. Department of Transportation, Bureau of Transportation Statistics and Federal Highway Administration, Freight Analysis Framework, version 4.3.1, 2017; *Rail*: Based on Surface Transportation Board, Annual Carload Waybill Sample and rail freight flow assignments done by Oak Ridge National Laboratory, 2017; *Inland Waterways*: U.S. Army Corps of Engineers, Institute of Water Resources, Annual Vessel Operating Activity and Lock Performance Monitoring System data, 2017.

percent of the tonnage and 3.3 percent of the value of all freight shipments [USDOT BTS AND FHWA 2017]. In 2015 approximately 565 million short tons of cargo were moved by vessel along the inland waterways, including the Mississippi River—the Nation's busiest waterway [USACE WCSC 2016].

In comparison with the rail and water modes, air transport carries high-value products, such as electronics, precision instruments, and pharmaceuticals that require quick delivery. Of all modes, the value of air-freight shipments is projected to increase the fastest from 2015 to 2045, growing by more than 300 percent [USDOT BTS AND FHWA 2017]. In 2016 U.S. airlines[3] carried a total of 67.9 billion revenue ton-miles of cargo, including 36.8 billion international and 13.8 billion domestic [USDOT BTS 2016].

Over the last 20 years, the U.S. transportation system has become increasingly

[3] In all service classes (scheduled and nonscheduled).

interconnected. Although freight moved via multiple modes[4] accounted for a small share (7.5 percent) of freight tonnage, 18.7 percent of the value of goods were moved in that way in 2015. FAF projects the total value of multiple mode shipments will more than double between 2015 and 2045, from 1.3 billion tons in 2015 to nearly 3.0 billion tons in 2045 [USDOT BTS AND FHWA 2017].

The growth in intermodal rail freight movement is driven, in part, by global supply chain requirements. Between 2000 and 2016, the railroad industry reported a 48.4 percent increase in rail intermodal traffic [AAR 2017a]. The Association of American Railroads (AAR) reports that rail intermodal traffic accounted for 24 percent of U.S. Class I railroad revenue, more than any other single commodity group. [AAR 2017a]. With the growth in container trade and improvements in information and logistics technologies, greater reliance on intermodal transportation expects to continue.

Value and Weight of Domestic Shipments by State

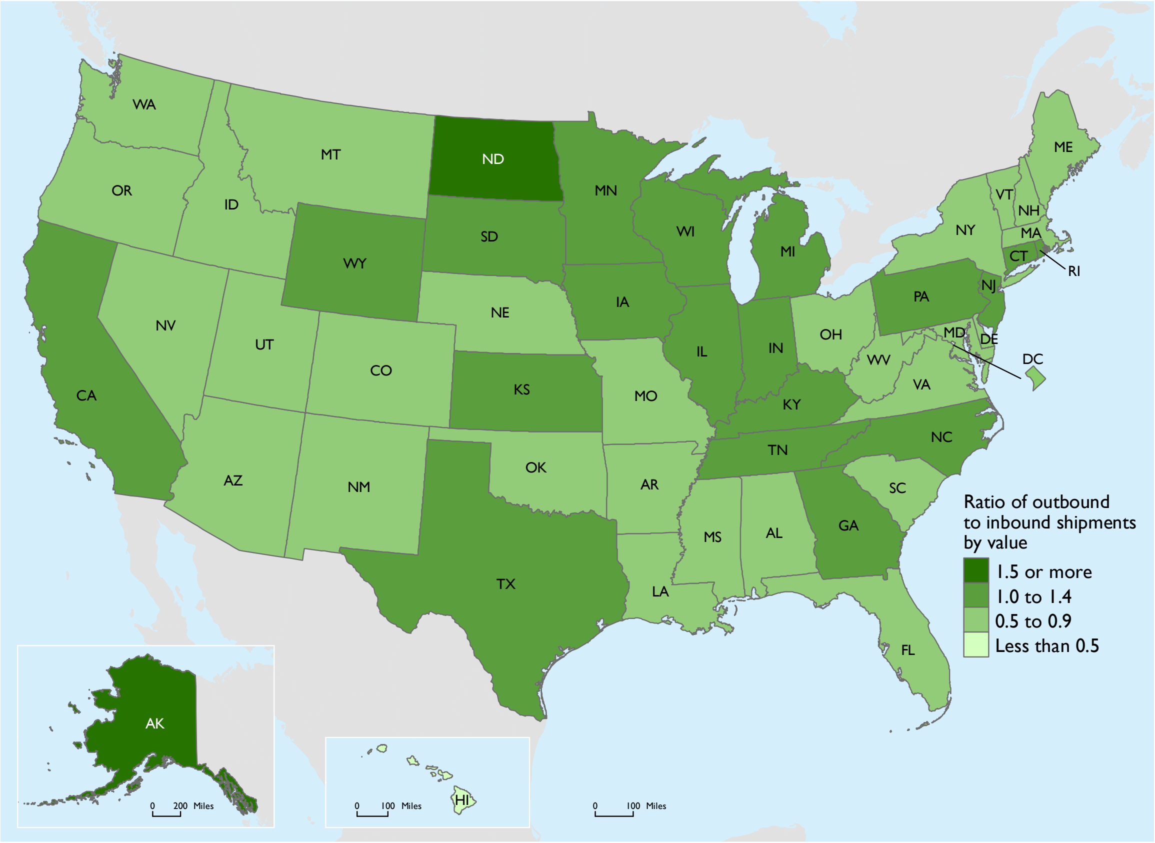
An interconnected freight transportation network contributes to state economic growth by supporting resource development and expanding interstate commerce. Figures 3-3 and 3-4 show the ratios of the value and weight of goods shipped to and from other states. A ratio of outbound to inbound shipments that is greater than 1.0 indicates that a state ships more goods, by value, to markets in other states than it receives from other states, whereas a ratio less than 1.0 indicates that a state imports more goods from other states than it exports.

Alaska and North Dakota have the highest ratios of about 2.0, indicating the value of their exports of goods are about two times more than the value of their imports of goods. Although both states have relatively small populations, they are major oil producers. According to the Freight Analysis Framework, nearly all of the crude petroleum moving out of Alaska was transported by water, while pipeline and rail were the primary modes for moving oil out of North Dakota. Other major states that exported more than they imported were California, Connecticut, and Illinois. Electronics was the top outbound domestic shipment category from California, while mixed freight, such as groceries and convenience store goods, food for restaurants, office supplies, and hardware and plumbing items, was the top export from Connecticut. Coal was the top outbound shipment from Illinois. Hawaii had the lowest ratio of interstate outbound-to-inbound shipments by value at 0.09 because of its distant location from the mainland and resource dependency. Other states with low outbound-to-inbound ratios include Florida and Nevada, partly due to demographics.

The picture changes when looking at the ratio of outbound to inbound shipments by weight. All of the top five net exporters by weight are producers of energy commodities: Wyoming, Alaska, Montana, North Dakota, and West Virginia. According to the Energy Information Administration, Wyoming is the largest U.S.

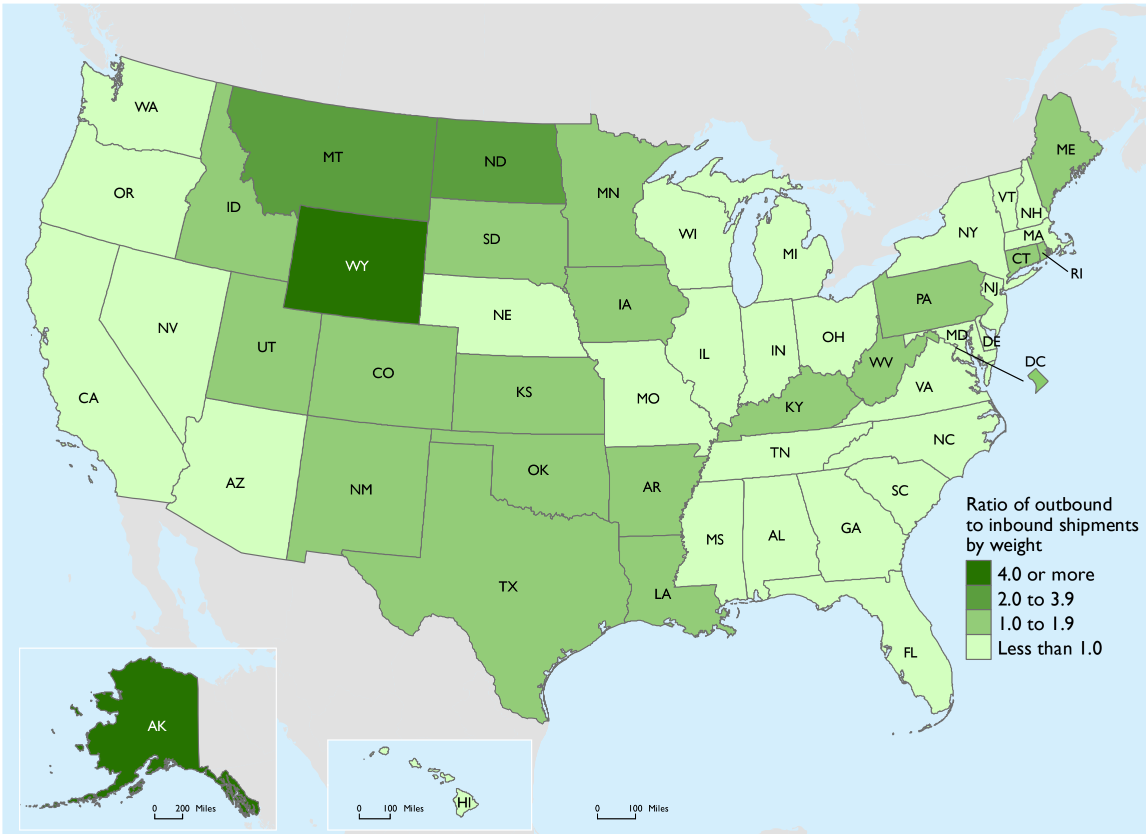
[4] The FAF category for multiple modes and mail includes all multimodal movements and is not limited to traditional intermodal services, such as trailer-on-flatcar and container-on-flatcar rail.

FIGURE 3-3 Ratio of Outbound to Inbound Domestic Shipments by Value: 2015



SOURCE: U.S. Department of Transportation, Bureau of Transportation Statistics and Federal Highway Administration, Freight Analysis Framework, version 4.3.1, 2017.

FIGURE 3-4 Ratio of Outbound to Inbound Domestic Shipments by Weight: 2015



SOURCE: U.S. Department of Transportation, Bureau of Transportation Statistics and Federal Highway Administration, Freight Analysis Framework, version 4.3.1, 2017.

coal producer, followed by West Virginia, while Montana is the sixth largest coal producer. For domestic markets, rail and barge are used to transport coal over long distances, primarily to power plants.

Commodities Moved Domestically

Table 3-3 shows the top 10 commodities moved on the U.S. transportation system in 2015. The leading commodities by weight, comprised entirely of bulk products, accounted for 67.3 percent of total tonnage but only 25.2 percent of the Nation's freight value. The top five commodities by weight included natural gas, gravel; gasoline; cereal grains; nonmetal mineral products [USDOT BTS AND FHWA 2017].

The finding is different when looking at the value of goods shipped. The leading commodities by value are mostly high value-per-ton goods that require rapid delivery, including electronics, motorized vehicles, mixed freight, machinery, and gasoline. In 2015 the top 10 commodities by value

TABLE 3-3 Top Commodities by Weight and Value: 2015

Weight	Millions of tons	Value	Billions of 2012 dollars
Natural gas, coke, asphalt[1]	2,647	Electronics	$1,673
Gravel	1,820	Motorized vehicles	$1,467
Gasoline	1,156	Mixed freight[2]	$1,458
Cereal grains	1,099	Machinery	$1,148
Nonmetal mineral products	1,073	Gasoline	$1,059
Fuel oils	1,039	Natural gas, coke, asphalt[1]	$917
Coal	1,001	Pharmaceuticals	$903
Crude petroleum	912	Fuel Oils	$836
Other foodstuffs	704	Miscellaneous manufacturing products	$791
Waste/scrap	653	Other foodstuffs	$710
Total, all commodities	**17,978**	**Total, all commodities**	**$19,146**

[1]This group includes coal and petroleum products not elsewhere classified such as liquefied natural gas, coke, asphalt, and other products of coal and petroleum refining, excluding gasoline, aviation fuel, and fuel oil.

[2]This group includes items (including food) for grocery and convenience stores, supplies and food for restaurants and fast food chains, hardware or plumbing supplies, office supplies, and miscellaneous.

NOTE: Data in this version is not comparable to similar data in previous years because of updates to the Freight Analysis Framework.

SOURCE: U.S. Department of Transportation, Bureau of Transportation Statistics and Federal Highway Administration, Freight Analysis Framework, version 4.3.1, 2017

accounted for 57.3 percent of total value but only 35.9 percent of total tonnage [USDOT BTS AND FHWA 2017].

The Bureau of Transportation Statistics' Commodity Flow Survey indicates that trucks moved 59.4 percent of the tonnage and 62.8 percent of the value of all hazardous materials shipped from within the United States (table 3-4). However, truck ton-miles of hazardous materials shipments accounted for a much smaller share, about one-third of all ton-miles, because such shipments travel relatively short distances. By contrast, rail accounted for only 4.3 percent of hazardous materials shipments by weight but 27.6 percent of ton-miles.

Flammable liquids, especially gasoline, are the predominant hazardous materials transported in the United States, accounting for 86.4 percent by value, 85.4 percent by weight, and 66.5 percent by ton-miles. The next largest class of hazardous materials, in terms of ton-miles, is corrosive material at 12.3 percent, followed by gases at about 10.8 percent.

International Trade and Transportation

The value of total U.S.-international merchandise trade increased from nearly $2.4 trillion in 2000 to approximately $3.2 trillion in 2016—a 37.6 percent inflation-adjusted increase (in 2009 dollars) [USDOC Census FTD 2017]. Five of the top 10 U.S. trading partners were Asian countries in 2016. Trade value with China grew the fastest, from 5.8 percent of the total value of U.S. merchandise trade in 2000 to 15.9 percent in 2016. In 2000

TABLE 3-4 Hazardous Materials Shipments by Transportation Mode: 2007 and 2012

Transportation mode	Value ($ billions)		Tons (millions)		Ton-miles[1]		Average distance per shipment (miles)	
	2007	2012	2007	2012	2007	2012	2007	2012
All modes, total	**1,448.2**	**2,334.4**	**2,231.1**	**2,580.2**	**323.5**	**307.5**	**96**	**114**
Single modes, total	**1,370.6**	**2,304.7**	**2,111.6**	**2,552.9**	**279.1**	**275.6**	**65**	**68**
Truck[2]	837.1	1,466.0	1,202.8	1,531.4	104.0	96.6	59	56
For-hire	358.8	870.9	495.1	882.3	63.3	62.0	214	150
Private	478.3	595.1	707.7	649.1	40.7	34.5	32	33
Rail	69.2	79.2	129.7	111.0	92.2	84.9	578	808
Water	69.2	217.8	149.8	283.6	37.1	54.9	383	212
Air	1.7	4.4	S	Z	S	Z	1,095	1,120
Pipeline[3]	393.4	537.3	628.9	626.7	S	S	S	S
Multiple modes, total	**71.1**	**29.7**	**111.0**	**27.3**	**42.9**	**31.9**	**834**	**654**
Truck and rail	7.1	13.3	11.7	17.0	10.1	16.6	779	954
Truck and water	23.5	S	36.6	S	12.4	S	1010	1,181
Rail and water	5.2	2.5	5.7	4.6	2.9	1.4	1,506	S
Parcel, U.S. Postal Service, or courier	7.7	10.3	0.2	0.3	0.2	0.2	836	650
Other multiple modes	27.7	0.0	56.8	0.0	17.3	0.0	233	0
Other modes	**6.5**	**0.0**	**8.5**	**0.0**	**1.5**	**0.0**	**58**	**0**

KEY: S = data are not published because estimate did not meet publication standards. By far, the most common reason for suppressing a cell is a high coefficient of variation (greater than 50 percent).; Z = rounds to zero.

[1] Ton-miles estimates are based on estimated distances traveled along a modeled transportation network.

[2] Truck as a single mode includes shipments that went by private truck only or by for-hire truck only.

[3] Excludes crude petroleum shipments.

NOTES: Value-of-shipment estimates have not been adjusted for price changes. Numbers and percentages may not add to totals due to rounding.

SOURCE: U.S. Department of Transportation, Bureau of Transportation Statistics and U.S. Department of Commerce, Census Bureau, *2012 Commodity Flow Survey, Hazardous Materials* (Washington, DC: February 2015), table 1b, available at www.bts.gov/publications/commodity_flow_survey/ as of November 2017

China ranked fourth among U.S. trading partners. Today it is the leading U.S. trade partner by value, followed by Canada, Mexico, Japan, and Germany, respectively, rounding out the top five [USDOC ITA].

In 2016 vessels carried nearly $1.5 trillion in imports to and exports from the United States [USDOC Census FTD 2017]. Container ports provide a link between the global and domestic freight network, utilizing intermodal barge, truck, and rail connections to transport containers filled with consumer goods to their final destinations. U.S. retailers are increasingly dependent on the U.S. transportation system. Particularly, those that build up their inventories in October in anticipation of holiday sales in November and December [CHAMBERS 2012].

U.S. – North American Freight Transportation

North American trade partners—Canada and Mexico—accounted for 29.3 percent (nearly $1.07 trillion) of the value of U.S.-international merchandise trade in 2016. Over the 2000 to 2016 period, combined trade (adjusted for inflation) with Canada and Mexico increased 16.9 percent[5] [USDOC Census FTD 2017]. However, from 2015 to 2016, the value of cross-border freight declined by 3.4 percent in current dollars, largely due to a sharp drop in crude oil and petroleum product prices. However, crude oil prices began to rise during 2016, so an increase in the value of trade with Canada and Mexico in 2017 is likely [USDOT BTS 2017b].

Trucks carried 26.8 percent of the tonnage and 65.5 percent of the value of U.S. merchandise trade with Canada and Mexico, while rail carried 18.2 percent of the tonnage and 15.5 percent of the value in 2016 (table 3-5).

Vehicles and parts (other than railway vehicles and parts) was the top commodity category transported between the United States and Canada. Truck and rail transported nearly all of these, carrying $59.8 and $43.7 billion respectively in 2016 (table 3-6). On the U.S. – Mexico border, electrical machinery was the top commodity with $94.0 billion hauled by truck alone. Electrical machinery is a relatively high value commodity group and was also the top commodity moved by air between the United States and both Canada and Mexico. Pipelines are used almost exclusively to move mineral fuels and transported $45.4 billion between the United States and Canada. Mineral fuels was also the top product moved by vessel between the United States and both Canada and Mexico.

Michigan, which accounts for 13.0 percent of the U.S.-Canada border mileage, was the leading state for freight trade with Canada, amounting to $71.8 billion or 13.2 percent of

[5] The percent increase was calculated by adjusting the 2000 trade data using the CPI Inflation Calculator.

TABLE 3-5 Value and Tonnage of U.S. Merchandise Trade with Canada and Mexico: 2000, 2010, 2015, and 2016

(billions of current U.S. dollars and millions of short tons)

	2000		2010		2015		2016	
Mode	Value	Weight	Value	Weight	Value	Weight	Value	Weight
Truck[1]	429	NA	560	176	712	199	700	205
Rail[1]	94	NA	131	114	165	142	166	139
Air	45	<1	45	<1	43	<1	42	<1
Water	33	194	81	210	73	219	58	194
Pipeline[1]	24	NA	65	107	57	180	50	203
Other[1]	29	NA	37	8	56	38	54	24
Total[1]	**653**	**NA**	**921**	**614**	**1,106**	**778**	**1,069**	**766**

KEY: NA = not available.

[1] The U.S. Department of Transportation, Bureau of Transportation Statistics estimated the weight of exports for truck, rail, pipeline, and other using weight-to-value ratios derived from imported commodities.

NOTES: Numbers may not add to totals due to rounding. 1 short ton = 2,000 pounds. "Other" includes shipments transported by mail, other and unknown modes, and shipments through Foreign Trade Zones. Totals for the most recent year differ slightly from the Freight Analysis Framework (FAF) due to variations in coverage and FAF conversion of values to constant dollars. Source for year 2000 Air & Water data is U.S. Department of Commerce, U.S. Census Bureau, Foreign Trade Division, *FT920 - U.S. Merchandise Trade Selected Highlights* (Washington, DC: December 2000).

SOURCE: U.S. Department of Transportation, Bureau of Transportation Statistics, TransBorder Freight Data, available at www.bts.gov/transborder as of April 2017.

TABLE 3-6 Value of Top 3 U.S. - Canada and U.S. - Mexico Commodities Moved by Mode: 2016
(billions of dollars)

U.S. - Canada		Mode	U.S. - Mexico	
Vehicles and Parts (Other than railway)	59.8	Truck	Electrical Machinery; Equipment and Parts	94.0
Computer-Related Machinery and Parts	50.2		Computer-Related Machinery and Parts	79.2
Electrical Machinery; Equipment and Parts	23.1		Vehicles and Parts (Other than railway)	44.7
All Other	194.2		All Other	154.8
Vehicles and Parts (Other than railway)	43.7	Rail	Vehicles and Parts (Other than railway)	43.7
Plastics and Articles	6.3		Computer-Related Machinery and Parts	8.8
Wood and Articles	5.7		Plastics and Articles	3.0
All Other	32.7		All Other	21.7
Mineral Fuels; Oils and Waxes	45.4	Pipeline	Mineral Fuels; Oils and Waxes	3.9
Organic Chemicals	0.2		Organic Chemicals	-
All Other	0.1		All Other	0.0
Electrical Machinery; Equipment and Parts	5.0	Air	Electrical Machinery; Equipment and Parts	5.3
Computer-Related Machinery and Parts	4.7		Pearls; Stones; Metals and Imitation Jewelry	2.5
Measuring and Testing Instruments	3.7		Computer-Related Machinery and Parts	2.2
All Other	12.7		All Other	5.6
Mineral Fuels; Oils and Waxes	13.6	Vessel	Mineral Fuels; Oils and Waxes	22.4
Aluminum and Articles	0.8		Vehicles and Parts (Other than railway)	6.2
Ores; Slag and Ash	0.8		Organic Chemicals	3.3
All Other	2.7		All Other	8.5
Special Classification Provisions	6.3	Other & unknown	Special Classification Provisions	6.6
Aircraft; Spacecraft and Parts	5.6		Special Trade Transactions	2.4
Mineral Fuels; Oils and Waxes	3.6		Vehicles and Parts (Other than railway)	1.5
All Other	23.1		All Other	4.7

NOTES: Other and unknown modes include, mail; Foreign Trade Zones; powerhouse (electricity); vessels and flyaway aircraft moving under their own power; pedestrians carrying freight; unknown; and miscellaneous other.

SOURCE: U.S. Department of Transportation, Bureau of Transportation Statistics, TransBorder Freight Data, available at www.bts.gov/transborder as of November 2017.

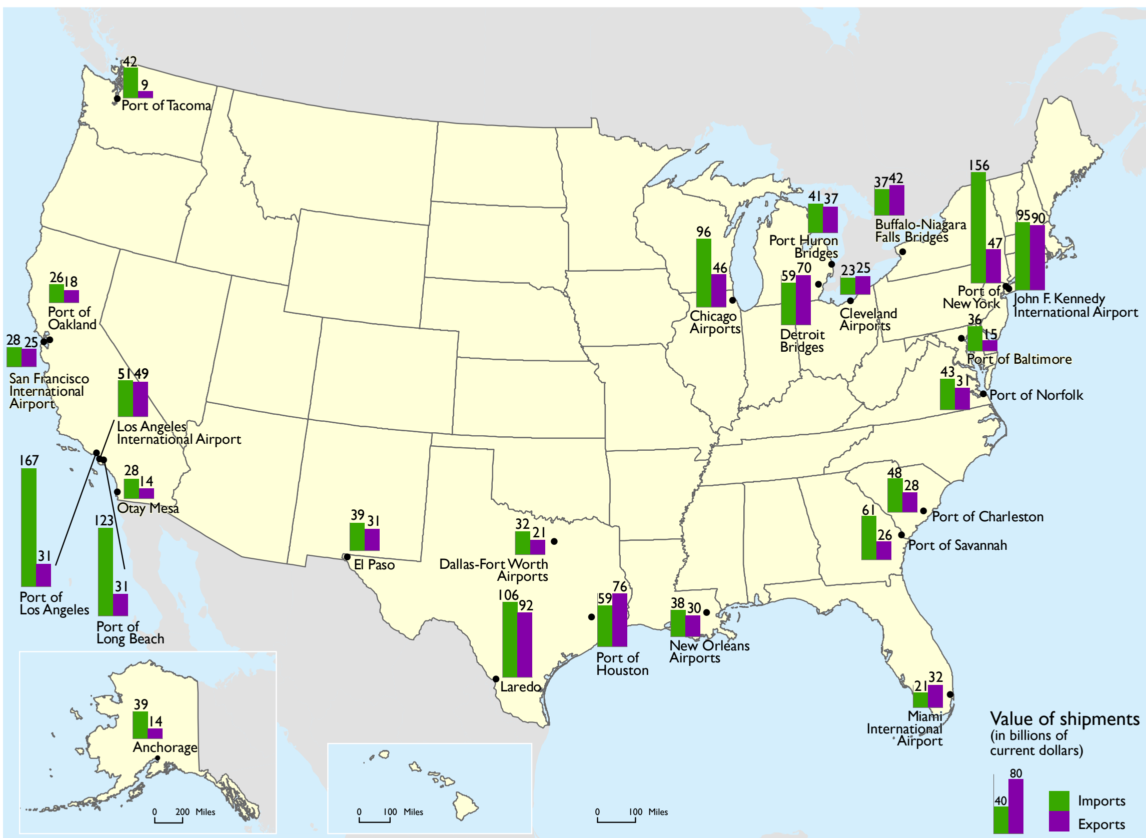
total U.S. trade with Canada in 2016. Michigan has border crossing/entry ports between Detroit, Port Huron, and Sault Ste. Marie and southern Ontario; both Michigan and Ontario have a high concentration of automakers [USDOT BTS 2017b].

Texas, which accounts for 64.2 percent of the U.S.-Mexico border mileage and is home to 11 border crossing/ports-of-entry, led all other states in surface freight with Mexico [USDOT BTS 2017b]. (In total, there are 85 ports-of-entry along the U.S.-Canada border and 25 on the U.S.-Mexico border.) In 2016 Texas freight trade with Mexico amounted to $173.7 billion, or 33.1 percent of total U.S. trade with Mexico. Electrical machinery, including equipment and parts, was the top commodity category transported between the United States and Mexico, followed by vehicles and parts (other than railway vehicles and parts). Trucks were the primary mode for transporting both electrical machinery and vehicles in 2016 [USDOT BTS 2017b].

Freight Transportation Gateways

A large volume of U.S.-international merchandise trade passes through a relatively small number of freight gateways—the entry and exit points for trade between the United States and other countries. According to the U.S. Census Bureau, there are 480 ports of entry, including airports, border crossings, and seaports, that handle international cargo [USDOC Census FTD 2017]. The latest available data show that in 2015, the top 25 gateways in terms of value handled the greatest share of U.S. international merchandise trade (figure 3-5) —$2.4 trillion in current dollars or 64.8 percent of the more than $3.7 trillion in current dollars of total U.S.-international merchandise trade. Twenty of the top 25 gateways handled more imports than exports in 2015, compared to 18 in 2014.

FIGURE 3-5 Top U.S.-International Freight Gateways by Value of Shipments: 2015

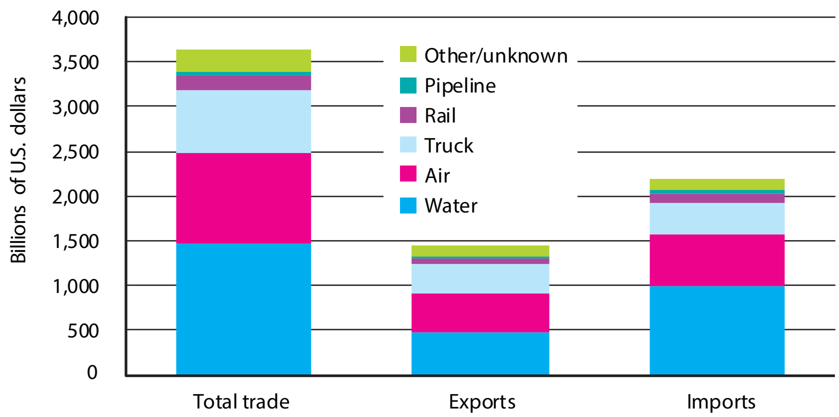


NOTES: **All data**: Flows through individual ports are based on reported data collected from U.S. trade documents and does not include low-value shipments (In general, these are imports valued at less than $1,250 and exports that are valued at less than $2,500). Numbers may not add to totals due to rounding. Air: Data for all air gateways are reported at the port level and include a low level (generally less than 2%-3% of the total value) of small user-fee airports located in the same region. Air gateways not identified by airport name (e.g., Chicago, IL and others) include major airport(s) in that geographic area in addition to small regional airports. In addition, due to U.S. Census Bureau confidentiality regulations, data for courier operations are included in the airport totals for JFK Interna¬tional Airport, Chicago, Los Angeles, Miami, New Orleans, Anchorage, and Cleveland.

SOURCES: Air: U.S. Department of Commerce, U.S. Census Bureau, Foreign Trade Division, USA Trade Online, November 2017. **Land**: U.S. Department of Transportation, Bureau of Transportation Statistics, North American TransBorder Freight Data, available at www.bts.gov//transborder/ as of November 2017. **Water**: U.S. Army Corps of Engineers, Navigation Data Center, special tabulation, November 2017.

Water is the leading transportation mode for U.S.-international trade both in terms of weight and value. Ships moved 40.5 percent of trade value (figure 3-6a) and more than 71.7 percent of trade weight (figure 3-6b) in 2016. By value, the Port of New York on the Atlantic Coast was the leading U.S. water gateway, handling more than $202.6 billion in trade, while on the Pacific coast, the Port of Los Angeles was the second leading water gateway, handling more than $198.4 billion in cargo, also mostly imports (figure 3-5).

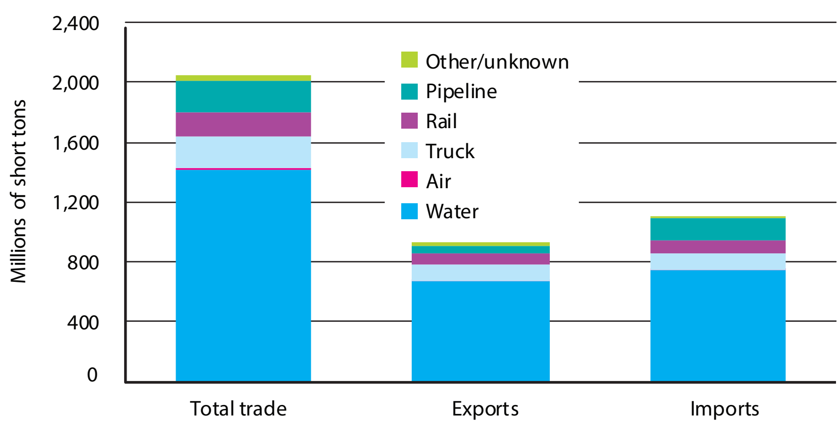
FIGURE 3-6a U.S.-International Merchandise Trade Value by Transportation Mode: 2016



NOTES: Totals for 2016 differ slightly from the Freight Analysis Framework (FAF) due to variations in coverage. Numbers may not add to totals due to rounding.

SOURCES: **Total, water and air data**: U.S. Department of Commerce, U.S. Census Bureau, Foreign Trade Division, *FT920 - U.S. Merchandise Trade: Selected Highlights* (Washington, DC: February 2017). **Truck, rail, pipeline, and other and unknown data**: U.S. Department of Transportation, Bureau of Transportation Statistics, North American TransBorder Freight Data, available at www.bts.gov/transborder/ as of May 2017.

FIGURE 3-6b U.S.-International Merchandise Trade Weight by Transportation Mode: 2016



NOTES: Totals for 2016 differ slightly from the Freight Analysis Framework (FAF) due to variations in coverage. Numbers may not add to totals due to rounding.

SOURCES: **Total, water and air data**: U.S. Department of Commerce, U.S. Census Bureau, Foreign Trade Division, *FT920 - U.S. Merchandise Trade: Selected Highlights* (Washington, DC: February 2017). **Truck, rail, pipeline, and other and unknown data**: U.S. Department of Transportation, Bureau of Transportation Statistics, North American TransBorder Freight Data, available at www.bts.gov/transborder/ as of May 2017.

Air handles less than one-half of one percent of trade weight but 27.5 percent of trade value, due to its focus on high-value, time-sensitive, and perishable commodities. In 2015 John F. Kennedy International airport was the top U.S.-international air gateway by value, handling $185.5 billion in exports and imports, followed by Chicago area airports ($141.8 billion) and Los Angeles International ($99.9 billion) (figure 3-5). By freight tonnage, Memphis International, TN; Ted Stevens Anchorage International, AK; and Louisville International, KY; were the top U.S.-international air gateways, handling about 11.4 million, 8.6 million, and 6.0 million short tons of cargo, respectively, in 2015 [USDOT FAA].

Trucks haul a significant share of imports and exports between the United States and its second and third largest trading partners, Canada and Mexico. In 2016 this resulted in trucks carrying 19.2 percent of the value of total U.S.-international trade (figure 3-6a) and 10.0 percent of the tonnage (figure 3-6b). Laredo, TX, is the top land-border crossing, handling $198.0 billion in trade between the United States and Mexico, while Detroit, MI, ranked second with $129.2 billion (figure 3-7).

Trade growth with Canada and Mexico and the tapping of natural resources, such as oil from the Bakken formation, generates increased north-south traffic flows on a domestic transportation infrastructure that was initially developed along east-west corridors during the westward development of the United States.

Waterborne Freight Transportation

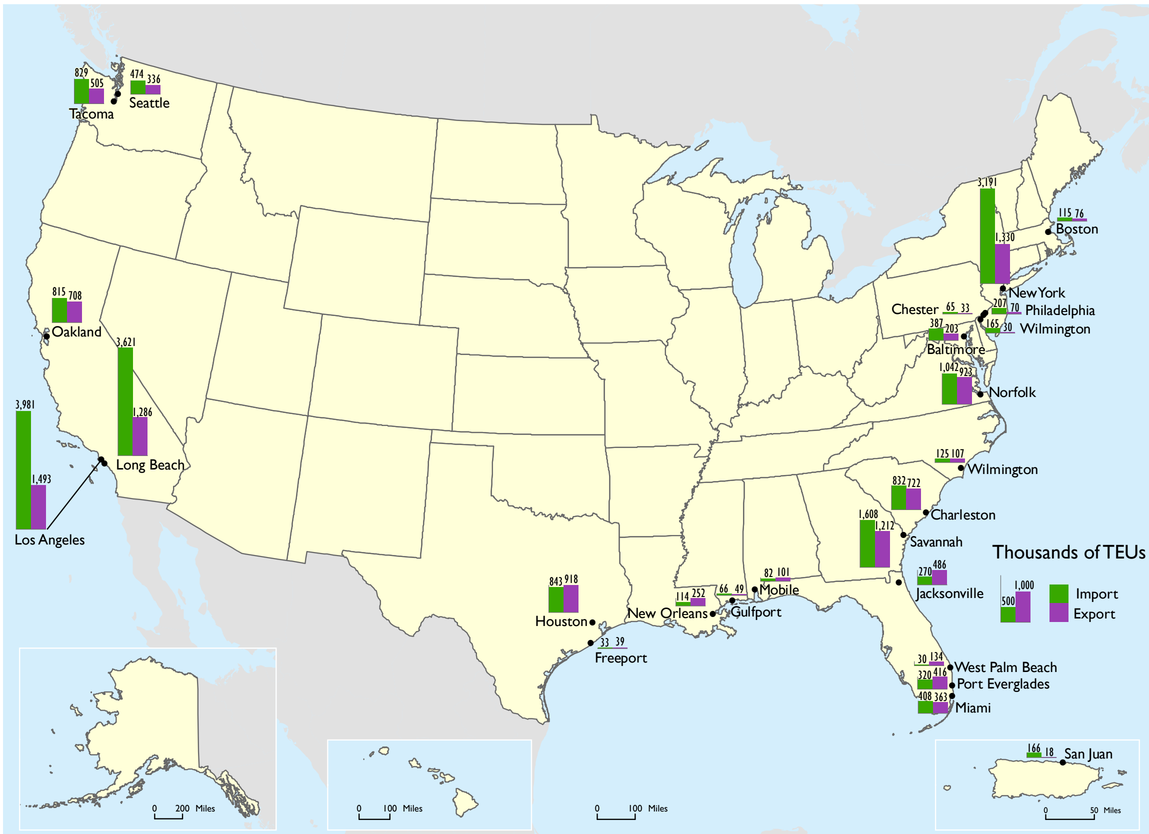
The number of container vessels calling at U.S. ports has increased in recent years. Between 2013 and 2015, vessel calls at U.S. seaports increased by 11.0 percent, from 74,000 in 2013 to 82,000 in 2015, while the tonnage of U.S.-international merchandise trade increased by 0.6 percent. The average displacement of container vessels continued to increase, from 52,421 deadweight tons (dwt) in 2013 to 57,458 dwt in 2015, a 10-percent increase. In 2015 tankers accounted for 40.4 percent of the vessel calls, followed by containerships with 22.8 percent of the more than 82,000 vessel calls [USDOT MARAD 2016a].

In 2015 U.S. seaports handled approximately 32.0 million twenty-foot equivalent units (TEU) of containerized cargo, which is 12.0 percent more than reported in 2010 [USDOT MARAD 2016b]. The ports of Los Angeles and Long Beach on the Pacific coast and the port of New York and New Jersey on the Atlantic coast are the leading container ports. As shown in figure 3-7, container ports are more concentrated along the Pacific and Atlantic coasts.

Bulk cargo, such as coal, crude petroleum, and grain moves predominantly through ports on the Gulf coast and inland waterway system (figure 3-8). The top 25 water ports by tonnage handled 69.1 percent of the weight of all domestic and foreign goods moved by water in 2015. The Port of South Louisiana was the top water gateway by weight, handling 259.1 million short tons, followed by the Port of Houston, moving 240.9 million short tons [USACE WCSC 2017]. A considerable portion of the tonnage moved through these two ports included crude oil and petrochemicals.

U.S.-international trade has had a major impact on all U.S. borders and coasts (figure

FIGURE 3-7 Top 25 Water Ports by TEU: 2015

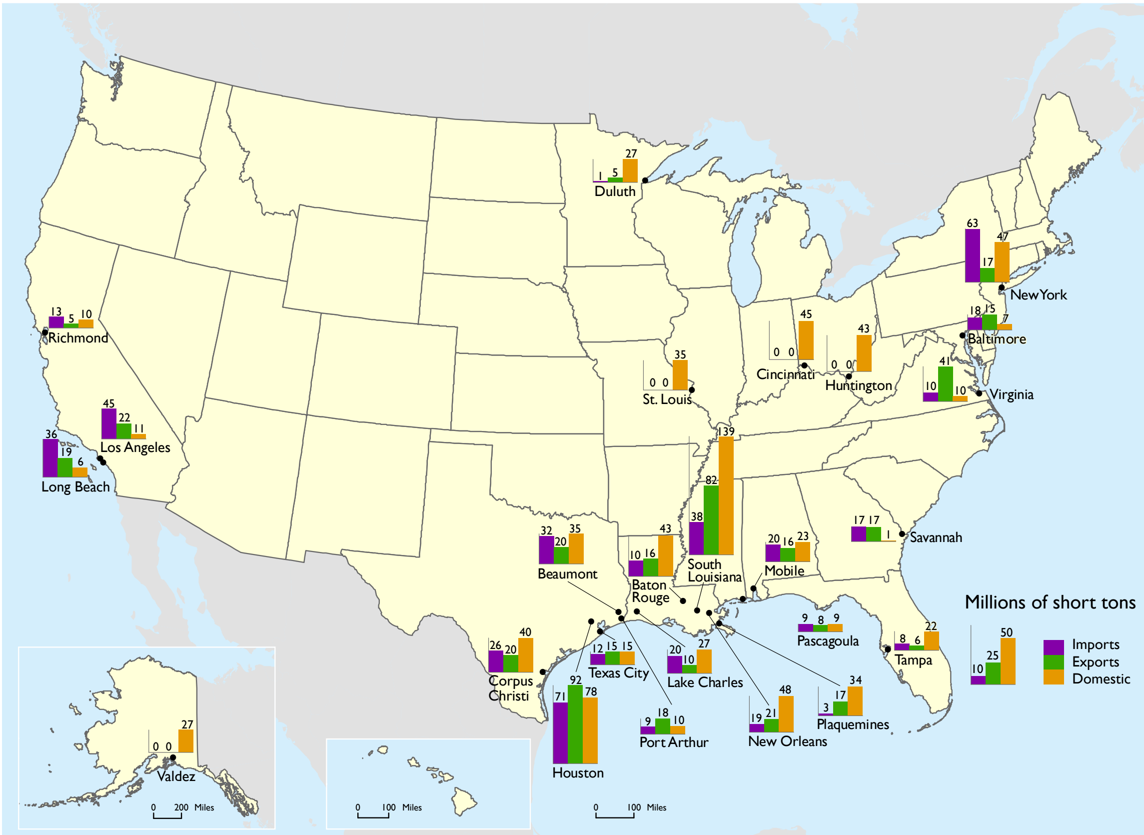


KEY:TEU = Twenty-Foot Equivalent Unit.

SOURCE: U.S. Department of Transportation, Maritime Administration, *U.S. Waterborne Container Trade by U.S. Custom Ports*, available at www.marad.dot.gov/resources/data-statistics/ as of November 2017.

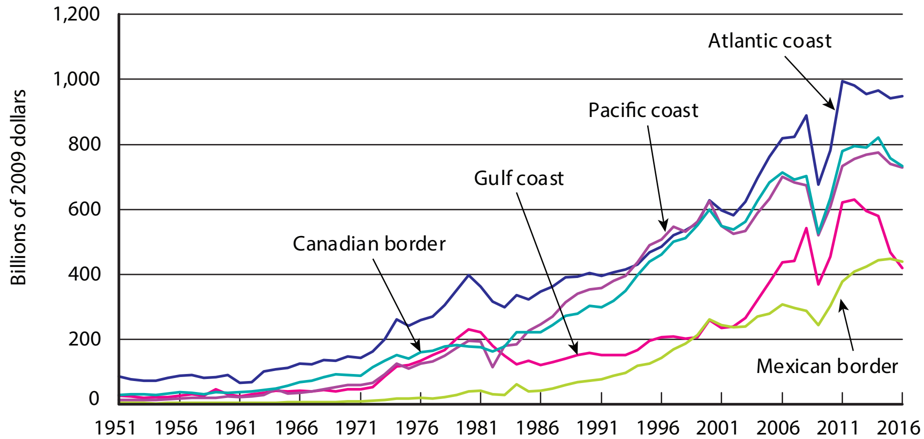
3-9). For example, an increase in trade with China has resulted in a large share of goods moving through Pacific coast ports. The trend toward larger containerships has led to a concentration of liner service at certain ports, specifically terminals that can accommodate larger containerships due to ample overhead clearance, a deep water draft, and intermodal connections, such as double stack rail. The newly expanded Panama Canal allows larger vessels, carrying up to 13,000 TEU, to transit between the Atlantic and Pacific Oceans. Ports and airports on the Atlantic coast continued to account for the largest share in terms of trade value. Although the top ports for containerized cargo are primarily on the Pacific and Atlantic coasts, a significant volume of bulk cargo, such as coal, crude petroleum, and grain, moves through ports on the Gulf coast and inland waterway system.

FIGURE 3-8 Top 25 Water Ports by Tonnage: 2015



SOURCE: U.S. Army Corps of Engineers, Waterborne Commerce Statistics Center, *Tonnage for Selected Ports in 2015*, available at http://www.navigationdatacenter.us/ as of November 2017.

FIGURE 3-9 Value of U.S. International Merchandise Trade by Coasts and Borders: 1951–2016



NOTE: The value of coal shipments through Mobile, AL, are considered proprietary information and are consolidated with ports included under the Atlantic Coast Customs District.

SOURCES: **1951-1970**: U.S. Department of Commerce, Census Bureau, *Historical Statistics of the United States, Colonial Times to 1970, Bicentennial Edition* (Washington, DC: 1975); **1971-1999**: U.S. Department of Commerce, Census Bureau, *Statistical Abstract of the United States* (Washington, DC: annual issues); **2000-2016**: U.S. Department of Commerce, Census Bureau, Foreign Trade Division, *FT920 - U.S. Merchandise Trade: Selected Highlights* (Washington, DC: annual issues). **Implicit GDP Deflator**: U.S. Department of Commerce, Bureau of Economic Analysis, *Current-Dollar and Real Gross Domestic Product*, available at www.bea.gov as of April 2017.

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CHAPTER 4

Transportation System Performance

Highlights

- The average annual delay per commuter rose from 37 hours in 2000 to 42 hours in 2014, a 13.5 percent increase, and the combined hours of delay experienced by all communities across the Nation in 2014 reached 6.9 billion hours—about a third higher than the 2000 total.
- Highway traffic congestion levels have increased over the past 30 years in all urban areas, from the largest to the smallest. Urban highway congestion cost the economy $160 billion in 2014, of which 17.5 percent, or $28 billion, was largely due to congestion that affected truck movements.
- Nearly one million flights, arrived at the gate at least 15 minutes late in 2016, and of those flights nearly 116,000 flights arrived at least 2 hours behind schedule, impacting more than 9 million passengers.
- Amtrak experienced a significant improvement in on-time performance in 2016, with four out of five trains arriving on schedule. On-time improvement was more prominent on long-distance routes.
- Barge tows on the inland waterways experienced an average delay of 2.4 hours navigating a lock in 2016, the largest delay on record and more than double the delay in 2000. Scheduled maintenance and unexpected stoppages due to weather and operational issues resulted in almost 144,000 hours of lock shutdowns, almost 90 percent higher than the 2000 level.

As used here, system performance refers to how efficiently, reliably, and safely people and freight carriers can travel to destinations on the transportation network. This chapter focuses on measures that can be used to assess whether certain aspects of system performance are improving or declining over time.[1] The performance measures discussed are accessibility, congestion, reliability, resiliency, and security. Other aspects of system performance, such as safety, energy usage, and environmental impacts, are discussed separately in other chapters.

System performance measures are often viewed from the perspectives of both the user and the operator. Users are interested in characteristics, such as travel cost, travel time, and the reliability of successfully completing a trip within a certain time, each of which directly affects their ability to accomplish a trip purpose. Owners and operators are concerned with the level of service provided to users and the ability to respond to service disruptions so as to promote reliable and safe mobility and accessibility.

System Accessibility

System accessibility is defined as the ability of travelers and freight shippers to reach key destinations, such as hospitals, job sites, schools, factories, airports, ports, and community centers. The measure most often used is the number of jobs that are accessible within a given travel time. The Center for Transportation Studies, at the University of Minnesota, estimated the accessibility to jobs by private automobile for each of the 11 million U.S. census blocks and analyzed these data in detail for the 50 largest (by population) metropolitan areas [UMN CTS 2016a]. Highway travel times were calculated using a detailed road network and speed data that reflect typical conditions for an 8:00 a.m. Wednesday morning departure.[2] Figure 4-1 shows the national level results for the number of jobs accessible within a 30 minute drive. As might be expected from this study, the map tends to resemble a map of U.S. population density because the calculations weight driving time by the number of jobs. High levels of employment accessibility are seen for the Boston to Washington Northeast Corridor and for the Chicago, Los Angeles, and San Francisco metropolitan areas.

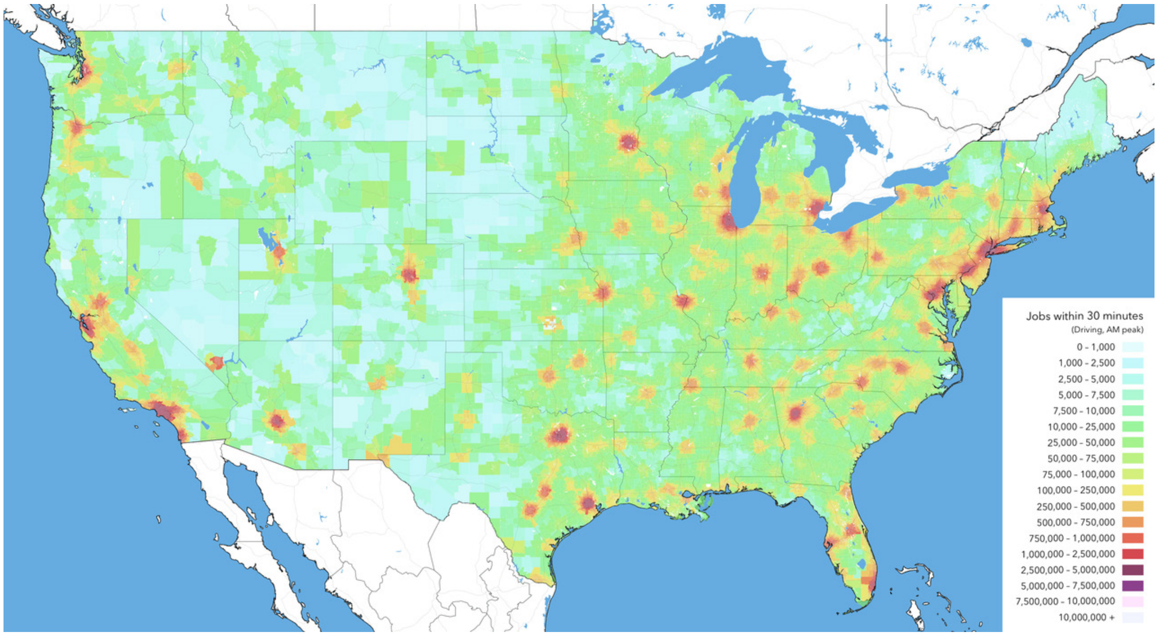
University of Minnesota studies extend the analysis to consider accessibility to jobs by transit and by walking. The transit analysis [UMN CTS 2016a] estimated the accessibility to jobs by transit (and walking to and from transit stops) for each of the 11 million U.S. census blocks, and analyzed these data in detail for 49 of the 50 largest metropolitan areas[3] using transit schedules from 2015. The university also estimated the accessibility to

[1] The *Moving Ahead for Progress in the 21st Century Act* (MAP-21) required the U.S. Department of Transportation to establish performance measures and standards for several program/policy areas. MAP-21 also required statewide and metropolitan transportation planning agencies to establish and use performance-based approaches for transportation decision-making. The *Fixing America's Surface Transportation* (FAST) *Act*, enacted in December 2015, continues these initiatives.

[2] In an earlier study, the Center used a similar methodology to examine changes in job accessibility by auto over the period 1990 to 2010 [UMN CTS 2013]. Those results are summarized in chapter 4 of the 2016 TSAR.

[3] The 41st largest city, Memphis, TN was excluded due to the non-availability of digitized transit schedules.

FIGURE 4-1 Accessibility to Jobs by Auto in 30 minutes: 2015



SOURCES: Center for Transportation Studies, University of Minnesota. 2016. Access Across America: Auto 2015, Report CTS 16-07. Figure 1. Available at http://www.cts.umn.edu/Publications/ResearchReports/, as of May 2017.

jobs by walking in the 50 largest metropolitan areas [UMN CTS 2015]. Table 4-1 shows the total number of jobs reachable within 30 minutes of travel time by auto, transit, and walking for the top 10 metro areas based on total employment. The most jobs reachable within 30 minutes across all the areas are by auto, followed by transit, and then walking.

New York City (NYC) dominates this listing by a wide margin, especially for jobs accessible by transit and walking. Due to its development density and extensive transit resources, NYC has 205,000 jobs accessible by transit within 30 minutes of total travel time and 47,000 jobs accessible within 30 minutes by walking. In contrast, for the city of Atlanta, where the jobs are more dispersed, the comparable accessibility figures for jobs reachable within 30 minutes are about 805,000 by auto, 7,000 by transit, and 3,000 by walking.

Figure 4-2 highlights the job accessibility results for three very different types of urban areas—New York, Atlanta, and San Antonio. The figure depicts the cumulative number of jobs available at increasing values of travel time. (Note that the vertical scales are different for the various graphs.) The New York metropolitan area, with a total of 8.3 million jobs, is densely developed and provides a rich array of intensively used transit and walking options as well as the traditional private automobile. More than three-quarters of the jobs in the New York metro area can be reached by transit within 60 minutes (figure 4-2). Atlanta (2.2 million total

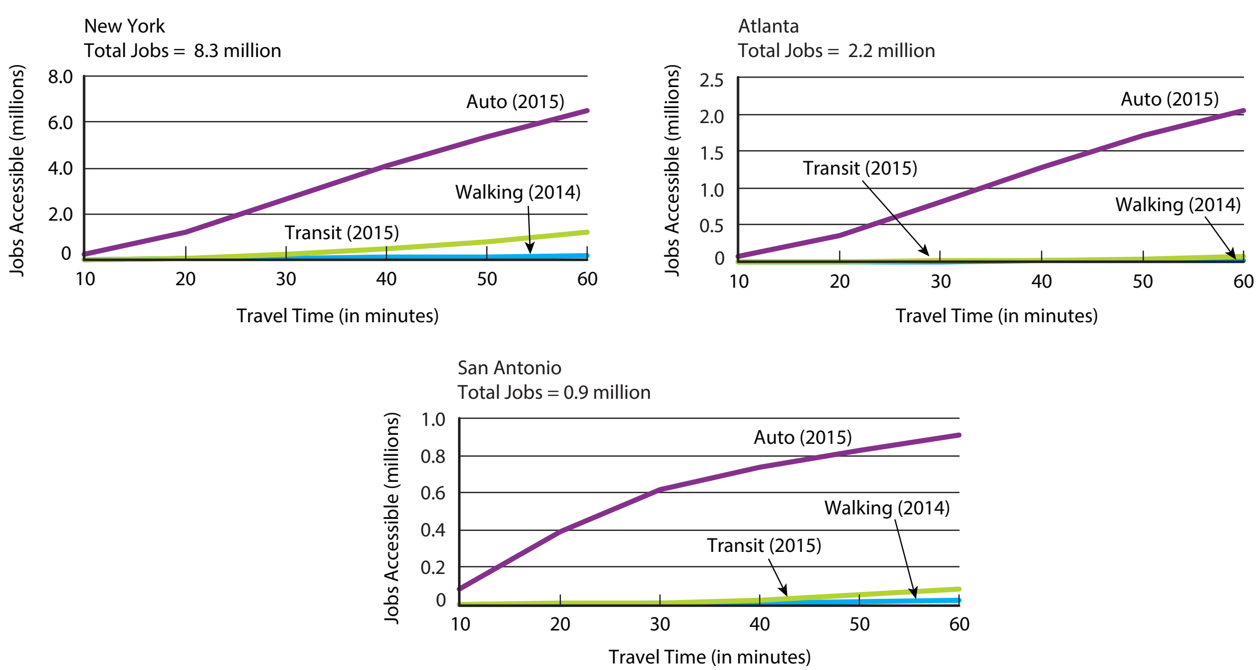
TABLE 4-1 Jobs Reachable by Auto, Transit, or Walking in the Top 10 U.S. Metropolitan Areas

Metropolitan area	Total jobs (2015)	Auto (2015)	Walking (2014)	Transit (2015)	60-minutes transit (2015)
New York	8,271,797	2,630,585	47,338	204,745	1,221,944
Los Angeles	5,364,930	2,323,105	14,490	39,564	358,984
Chicago	4,242,819	1,277,622	13,965	50,586	328,034
Dallas	2,987,734	1,346,253	5,118	9,825	95,130
Philadelphia	2,703,026	992,362	9,929	34,234	193,921
Washington, DC	2,689,299	1,157,426	12,310	46,416	328,133
Houston	2,674,987	1,150,184	6,008	12,666	106,955
Miami	2,256,047	991,891	6,872	14,462	122,624
Boston	2,247,058	938,582	9,988	43,778	271,810
Atlanta	2,245,086	804,812	3,102	6,869	63,956

NOTE: Top 10 status is based on total employment.

SOURCES: **Auto**—Center for Transportation Studies, University of Minnesota. 2016. *Access Across America: Auto 2015*, Report CTS 16-07. Table 2. **Transit**—Center for Transportation Studies, University of Minnesota. 2016. *Access Across America: Transit 2015*, Report CTS 16-09. Table 2. **Walking**—Center for Transportation Studies, University of Minnesota. 2015. *Access Across America: Walking 2014*, Report CTS 15-03. Table 2. All available at http://www.cts.umn.edu/Publications/ResearchReports/ as of May 2017.

FIGURE 4-2 Job Accessibility by Auto, Transit, or Walking in Three Selected Metropolitan Areas



SOURCES: University of Minnesota (UMN), Center for Transportation Studies (CTS).
—2016a. Access Across America: Auto 2015. Report CTS 16-07. Available at http://www.cts.umn.edu/ as of May 2017
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jobs), on the other hand, has a fast but smaller heavy rail system, a large bus system, a more decentralized job and population distribution, and lower accessibility. On average, about half of the jobs in Atlanta and New York can be reached by car in less than 40 minutes. San Antonio (910,000 total jobs in the metro area) is decentralized and automobile-dependent and has no rail transit, but has more jobs accessible by car or transit within 20 minutes than Atlanta.

Congestion

Travelers want to reach a destination in a cost-effective, safe, and reliable manner. The characteristics of making such trips, including travel time, costs, and access to facilities/services, are used to indicate the level of mobility afforded to users.

Highways

Road congestion in urban areas is one of the major causes for travel time delay. The Texas A&M Transportation Institute (TTI) has monitored congestion levels on the U.S. road network since 1982. TTI reports findings in an annual *Urban Mobility Scorecard*[4] on the number of hours of congestion experienced by network users and the associated economic costs [TAMU TTI 2015]. Recent editions of the report provide data for 498 urban areas in the United States.

Table 4-2 shows the estimates for annual hours of delay, the number of gallons of wasted fuel due to delay, the dollar value of delay and wasted fuel, and a measure called the Travel

[4] Prior to 2015 the report was titled the *Urban Mobility Report.*

TABLE 4-2 Annual Congestion Delay and Costs: 2000 and 2005–2014

498 urban areas

Year	Travel Time Index	Delay per commuter (hours)	Total delay (billion hours)	Fuel wasted (billion gallons)	Total cost (billions of 2014 U.S. Dollars)
2000	1.19	37.0	5.20	2.1	$114
2005	1.21	41.0	6.3	2.7	$143
2006	1.21	42.0	6.4	2.80	$149
2007	1.21	42.0	6.6	2.8	$154
2008	1.21	42.0	6.60	2.4	$152
2009	1.2	40.0	6.30	2.4	$147
2010	1.2	40.0	6.40	2.5	$149
2011	1.21	41.0	6.60	2.5	$152
2012	1.21	41.0	6.70	3	$154
2013	1.21	42.0	6.80	3.1	$156
2014	1.22	42.0	6.90	3.1	$160

NOTES: Includes 15 very large urban areas (population over 3 million), 32 large urban areas (population over 1 million but less than 3 million), 33 medium urban areas (population over 500,000 but less than 1 million), 21 small urban areas (population less than 500,000), and 397 other urban areas. 2014 is the most recent year available.

SOURCE: Texas A&M University, Texas Transportation Institute, *2015 Urban Mobility Scorecard*, available at http://d2dtl5nnlpfr0r.cloudfront.net/tti.tamu.edu/documents/mobility-scorecard-2015-wappx.pdf as of May 2017.

Time Index (TTI).[5] For example, a TTI value of 1.21 indicates that a trip taking 30 minutes without congestion will take an average of 21 percent longer, or just over 36 minutes (1.21 × 30), during the peak congestion period.

Road congestion, in terms of amount and cost, has steadily increased since 2000. The exception was the economic recession from the end of 2007 to the middle of 2009, which had a dampening effect on congestion. Congestion in the Nation's urban areas in 2014 cost $160 billion compared to $114 billion in 2000 (2014 dollars).[6] The average yearly delay per commuter rose from 37 hours in 2000 to 42 hours in 2014, a 13.5 percent increase, and the total national hours of delay in 2014 equates to nearly 788 thousand years—about a third higher than the 2000 total. The effects of congestion on truck movements accounted for $28 billion (17.5 percent) of the total congestion cost [TAMU TTI 2015]. In addition, the average commuter:

- wasted 19 gallons of fuel in 2014 (a week's worth of fuel for the average U.S. driver), up from 8 gallons in 1982;
- experienced an average yearly delay of 42 hours in 2014; and
- planned for approximately 2.41 times (freeway only) as much travel time as would be needed in non-congested conditions to arrive at their destination on time 9 out of 10 times [TAMU TTI 2015].

The worst congestion levels (defined as "extreme, severe, or heavy") affected only one in nine trips in 1982, whereas this proportion increased to more than one in three trips in 2014. In addition, the most congested sections of road (labeled extreme and severe) handled only 26.0 percent of all urban road travel, but accounted for 80 percent of peak period delays, as shown in figure 4-3. It is important to note that congestion levels have increased over the past 30 years in all urban areas, from the largest to the smallest. Congestion is worse in the afternoon, but it can occur at any time of the day (figure 4-4). Between 2011 and 2014, the percent of congestion during peak commuting hours declined somewhat, possibly as workers shifted their work schedules to avoid the worst traffic—reducing the severity of the peaks as congestion spread over more hours.

The Federal Highway Administration (FHWA) uses vehicle probe data[7] to compile the *Urban Congestion Trends* report, which tracks congestion measures in the 52 largest urban areas in the United States. While not as comprehensive as the *Urban Mobility Scorecard*, which covers 498 urban areas and all the congestion indicators reported above, the smaller scope of *Urban Congestion Trends* allows for more frequent updates. The latest edition of this report shows that between 2015 and 2016 congestion remained unchanged or marginally improved [USDOT FHWA 2017]. The average duration of daily congestion[8]

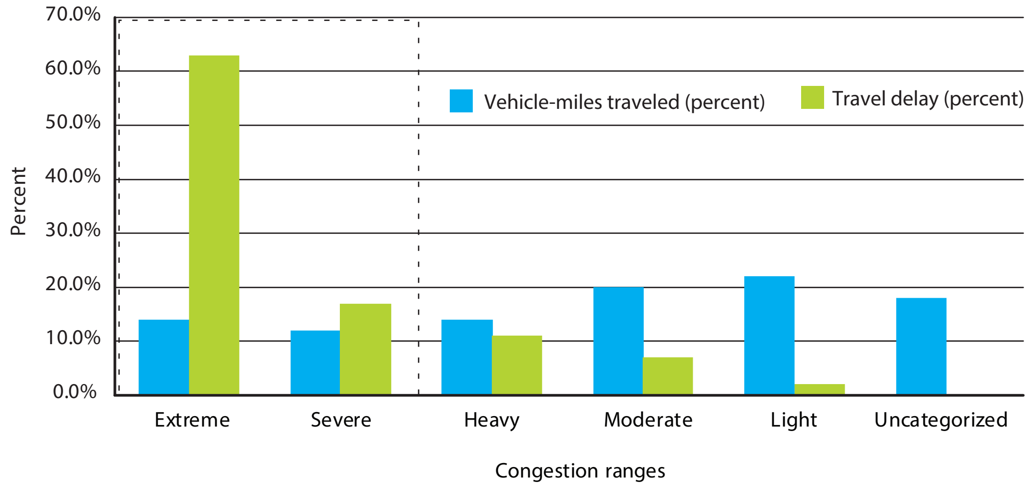
[5] The ratio of the travel time during the peak period to the time required to make the same trip at free-flow speeds.

[6] 2014 is the most recent year available.

[7] Vehicle probe data are based on real-time vehicle positions, typically obtained from the vehicle's GPS receiver or the operator's mobile phone.

[8] Hours of congestion is defined as the amount of time when highways operate at less than 90 percent of free-flow speeds.

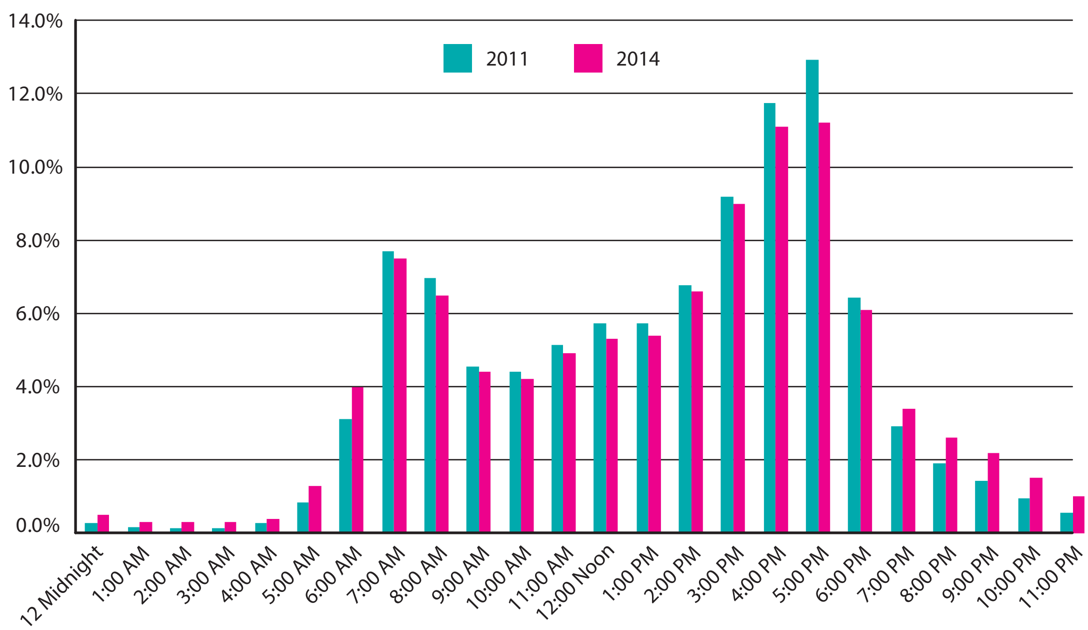
FIGURE 4-3 Vehicle and Travel Delays in Congestion Ranges: 2014



NOTE: 2014 is the most recent year available.

SOURCES: Texas A&M University, Texas Transportation Institute, *2015 Urban Mobility Scorecard*, available at http://d2dtl5nnlpfr0r.cloudfront.net/tti.tamu.edu/documents/mobilicorecard-2015-wappx.pdf as of November 2017.

FIGURE 4-4 Percent of Congestion by Time of Day: 2011 and 2014



NOTE: 2014 is the most recent year available.

SOURCES: Texas A&M University, Texas Transportation Institute, *2015 Urban Mobility Report* (August 2015: full report with exhibits), Exhibit 5. Available at http://tti.tamu.edu/ as of March 2017.

remained almost constant from 4 hours and 40 minutes in 2015 to 4 hours and 43 minutes in 2016, but is 20 minutes lower than the 5 hours and 3 minutes of average duration in 2014.

Countering the overall trend, congestion in 11 urban areas (21 percent) worsened, while that in 10 areas (19 percent) improved. Most (but not all) of the areas with more congestion in 2016 than in 2015 were in the South and on the West coast, while most of the areas with less congestion were in the Northeast [USDOT FHWA 2017]. This is likely related to population changes that are occurring in these regions. Increases in the number of drivers and vehicles in the Sun Belt and Pacific coast areas are outpacing the ability of those areas to implement traffic improvements

Congestion is especially a problem for time-sensitive freight shipments, such as perishable agricultural products, just-in-time manufacturing parts and components, and high-value consumer goods. Various performance indicators are used to monitor time-related system performance. The Federal Highway Administration (FHWA), in cooperation with the American Transportation Research Institute (ATRI), is working to quantify the impact of traffic congestion on truck-based freight at 250 specific locations across the United States. Similar to the TTI, the primary measure is the ratio of uncongested speed to congested speed at key freight locations (often interstate-to-interstate interchanges). For example, a 17.59 mph peak period average speed and a 39.51 mph non-peak period average speed in Chicago yields a ratio of 2.25, suggesting that it takes more than twice as long to travel the same route during the peak travel hours. Some of the most congested truck bottlenecks on freight-heavy highways in 2014 were in Chicago, IL (2.25), Austin, TX (1.90), and Atlanta, GA (1.68) [USDOT BTS 2017].

Another impact of peak-period highway congestion is its effect on access to jobs. The University of Minnesota study of job accessibility by private automobile, discussed earlier [UMN CTS 2016a], included an analysis for the top 50 U.S. metropolitan areas. Accessibility was calculated assuming departure times of 4:00 a.m., representing free-flow conditions, and compared with the results using a start time of 8:00 a.m., representing peak period conditions. The congestion effect is defined as the percentage decrease in the number of jobs that can be reached within specified time thresholds at congested times of day relative to free-flow times. For the top 10 cities as ranked by job accessibility, the number of jobs reachable within a given driving time is typically 10 to 25 percent lower during the congested times of the day.

Aviation

Congestion and delays are not limited to roadways. The average length of commercial airline flight delays has been over 50 minutes every year since 2004 and reached an all-time high of 62 minutes in 2016. During this period the number of arriving domestic flights operated by large U.S. airlines decreased by 21.2 percent, but the enplanements increased by 80.2 percent (table 4-3). Late arrivals peaked at 24.1 percent in 2007, and since then have been in the range of about 17 to 20 percent.

TABLE 4-3 Percentage of All Delayed Flights by Length of Time Delayed: 2004–2016

Year	Total number of arriving flights	Delayed flights	Minutes late					Passengers impacted by > 120 minute delay
			15-29	30-59	60-89	90-119	> 120	
2004	7,129,270	1,421,391	42.3%	31.3%	12.4%	6.1%	7.8%	4,063,357
2005	7,140,596	1,466,065	41.9%	31.2%	12.5%	6.3%	8.2%	4,704,777
2006	7,141,922	1,615,537	40.4%	31.3%	12.9%	6.5%	8.9%	5,347,226
2007	7,455,458	1,804,028	39.1%	31.0%	13.2%	6.9%	9.7%	6,538,474
2008	7,009,726	1,524,735	39.2%	30.6%	13.1%	6.9%	10.2%	6,215,888
2009	6,450,285	1,218,288	40.8%	30.8%	12.8%	6.6%	9.0%	4,356,447
2010	6,450,117	1,174,884	41.2%	30.7%	12.5%	6.6%	9.0%	4,776,924
2011	6,085,281	1,109,872	40.4%	30.1%	12.8%	6.8%	9.8%	5,057,873
2012	6,096,762	1,015,158	40.6%	30.2%	12.7%	6.7%	9.8%	5,691,358
2013	6,369,482	1,269,277	39.8%	30.5%	12.8%	6.9%	10.1%	6,538,060
2014	5,819,811	1,240,528	39.2%	31.3%	12.8%	6.6%	10.0%	7,420,175
2015	5,819,079	1,063,439	38.8%	30.6%	12.8%	6.9%	10.9%	8,236,337
2016	5,617,658	964,239	38.1%	30.0%	13.0%	7.0%	12.0%	9,381,444

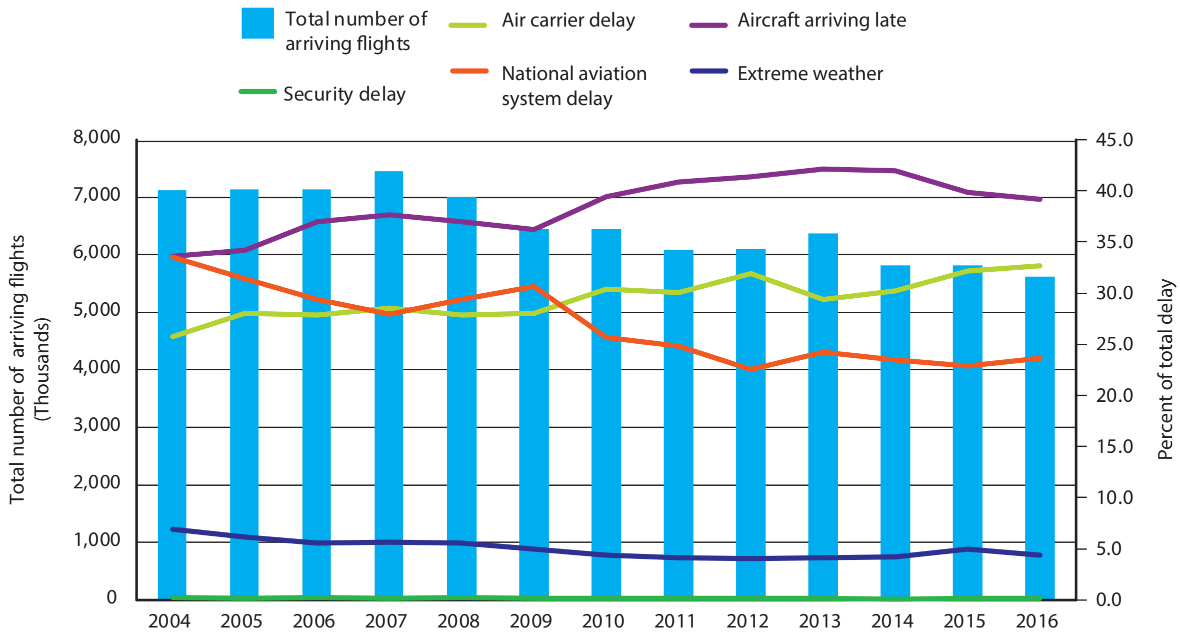
NOTES: For the monthly number of carriers reporting, please refer to the Air Travel Consumer Reports available at http://airconsumer.dot.gov/reports/index.htm. A flight is considered delayed when it arrived at the gate 15 or more minutes later than scheduled. Arriving flights consists of scheduled operations less canceled and diverted flights. Average length of delay is calculated for delayed flights only. Percents may not add to 100 due to rounding.

SOURCE: U.S. Department of Transportation, Bureau of Transportation Statistics, Transtats Database, Airline On-Time Performance, available at http://www.transtats.bts.gov/ as of November 2017.

The average aircraft size (seats per aircraft mile) of major U.S. commercial air carriers increased in 2016 by 2.3 seats, from 149.1 in 2015 to 151.3, which is the highest level since 1994. This trend is forecast to continue through 2037, especially with the retirement of older, smaller narrow-body aircraft (i.e., MD-80s, 737-300/400/500, and 757s). Airlines are retiring these less efficient aircraft and shifting to wide-body and larger narrow-body aircraft [USDOT FAA 2017], which often require more separation in the air and on the ground. Larger aircraft (a.k.a. "heavy") typically require a safety margin or separation of 4 to 8 nautical miles from the following aircraft. This is because of wake turbulence, which is a violent or unsteady movement of air that forms behind an aircraft, especially during takeoff and landing. Operational factors and weather conditions may require additional separation, which may contribute to congestion and delays.

Flight delays are caused by various reasons, ranging from extreme weather to disruptions in airline carrier operations (figure 4-5). The combined effects of non-extreme weather conditions, airport operations, heavy traffic volume, and air traffic control contributed to 23.7 percent of delays in 2016, a 9.8 percentage point improvement from 2004. Flight delays can ripple through the U.S. aviation system as late arriving flights, for whatever reason, delay subsequent flights—the

FIGURE 4-5 National Flight Delays by Cause, Percent of Total Delay Minutes: 2004–2016



NOTES: Air Carrier Delay-the cause of the cancellation or delay was due to circumstances within the airline's control (e.g. maintenance or crew problems, etc.). Aircraft Arriving Late-previous flight with same aircraft arrived late which caused the present flight to depart late. Security Delay-delays caused by evacuation of terminal or concourse, reboarding of aircraft because of security breech, inoperative screening equipment and long lines in excess of 29 minutes at screening areas. National Aviation System Delay-delays and cancellations attributable to the national aviation system refer to a broad set of conditions, including non-extreme weather conditions, airport operations, heavy traffic volume, air traffic control, etc. Extreme Weather-significant meteorological conditions (actual or forecasted) that, in the judgment of the carrier, delays or prevents the operation of a flight.

SOURCE: U.S. Department of Transportation, Bureau of Transportation Statistics, Transtats Database, Airline On-Time Performance, available at http://www.transtats.bts.gov/ as of March 2017.

cause of 39.2 percent of delays for scheduled flights in 2016. Despite the often-heard passenger complaints about long lines and other delays due to TSA check-point screening procedures, that has been the source of only 0.1 percent of flight delays every year from 2011 to 2016.

Waterways

On the inland water network, the U.S. Army Corps of Engineers (USACE) is responsible for 239 lock chambers and monitoring the movements of barges and other commercial vessels. In 2016 barge tows experienced an average delay of 2.4 hours navigating a lock (table 4-4), the largest delay on record and more than double the delay in 2000 [USACE 2017]. Furthermore, the percent of vessels that experienced any delays increased from 35 to 48 percent, impacting more than 360,000 vessels. On average, 9 of every 10 vessels on the Gulf Intracoastal Waterway experienced more than 1 hour of delay in 2016, and more than half of the vessels navigating a lock in the Tennessee River experienced close to 4 hours of delay (table 4-4). The increase in delay is likely due to the aging of the locks in the inland water system.

TABLE 4-4 Lock Characteristics and Delays on Rivers with 5,000 or More Lockages: 2000, 2010, and 2016

	Average Age of Locks (2016)	Total Lockages (2016)	Percent Commercial Lockages (2016)	Average Tow Delay in Minutes			Percent of All Vessels Delayed		
				2000	2010	2016	2000	2010	2016
All Waterways	61	590,218	78	64	80	146	35	36	48
Mississippi River	75	115,769	80	90	81	133	20	19	52
Ohio River	54	95,778	91	52	97	83	31	34	44
Gulf Intracoastal Waterway	54	35,916	98	58	65	76	78	84	91
Illinois Waterway	82	26,020	93	127	53	107	41	29	61
Arkansas River	48	22,307	92	11	13	11	35	23	15
Tennessee River	70	21,058	66	209	122	235	24	24	46
Monongahela River	72	20,781	83	12	11	33	16	18	18
Tennessee Tombigbee Waterway	34	19,845	71	9	3	10	38	10	23
Chicago River	79	11,218	68	5	5	19	1	1	76
Allegheny River	86	9,371	30	8	4	137	7	3	8
Caloosahatchee River	57	9,298	13	5	2	4	26	16	7
Columbia River	49	7,440	96	32	30	38	85	90	77
Cumberland River	56	6,728	73	16	18	139	13	12	31
St. Mary's River	81	5,848	91	27	16	29	26	19	42

NOTES: A lockage is the movement through the lock by a vessel or other matter. Commercial lockages are all those that service vessels operated for purposes of profit and include freight and passenger vessels.

SOURCE: United States Army Corps of Engineers, Navigation Data Center, *Lock Use, Performance, and Characteristics*, (Alexandria, VA: annual issues). Available at www.navigationdatacenter.us/ as of March 2017.

On older systems, the majority of tows must be split into two parts and locked through smaller (e.g., 600-foot) lock chambers, which were not designed to handle today's longer (e.g., 1,200-foot) tows. The average age of locks under jurisdiction of the USACE is over 64 years,[9] and it is expected that delays will likely increase in the absence of needed rehabilitation and reconstruction of key locks.

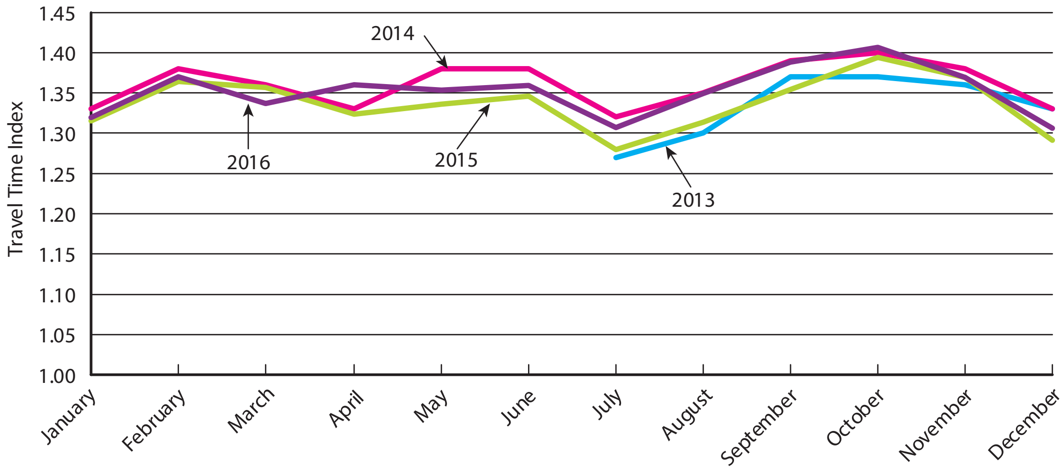
[9] A recent study [TRB 2015] shows that, when adjusted for the dates of major rehabilitation projects, the effective average age of locks is about 10 years less, but that still puts the average age at over 50 years.

System Reliability

Reliability is defined as the level to which one can make trips with some certainty that the actual trip will occur within an expected range of travel times. More reliability means less uncertainty associated with trips due to events such as crashes, vehicle breakdowns, and similar incidents; work zones; unannounced road work; weather; and special events that can often lead to widely varying travel times from one day to the next for the same trip.

Figure 4-6 shows that the Travel Time Index has been trending upward with 2016 levels

FIGURE 4-6 Travel Time Index: July 2013–December 2016



SOURCE: U.S. Department of Transportation, Federal Highway Administration, National Performance Management Research Data Set (NPMRDS), available at https://ops.fhwa.dot.gov/perf_measurement/ as of October 2017.

mostly above 2013 and 2015, indicating that urban traffic congestion has been increasing. The figure also illustrates the effects of seasonality as travel time during the summer months shows a marked decline.

For non-highway modes, different measures can be used to assess system reliability. For passenger transportation, for example, on-time performance is often an indicator of service reliability. Amtrak experienced a significant improvement in on-time performance with a record 83.0 percent on-time performance in 2012, which declined to 71 percent in 2015 but increased to 79 percent in 2016 (table 4-5). Greater improvement is seen for trips over 400 miles in length, where on-time performance jumped from 42.1 percent in 2005 to 63 percent in 2016. The vast majority of passenger train services outside the Northeast Corridor (NEC) are provided over tracks owned by and shared with the Class I freight railroads. As a result, Amtrak's on-time performance is largely dependent on the condition and performance of the host railroads, with the important exception of Amtrak-owned tracks in the NEC (see figure 1-7a and b). Amtrak's recent improvements are likely due to a combination of greater host railroad investments in track and signaling improvements, and Amtrak's investments in newer rolling stock (see chapter 1). Aviation on-time performance was discussed earlier in this chapter.

For USACE inland waterway locks, system unreliability can be measured as the percent of time a lock is unavailable for use (defined as the cumulative periods over a year during which a lock facility was unable to pass traffic). Locks could be unavailable for a number of reasons, ranging from scheduled maintenance, unexpected stoppages due to operational issues, and weather conditions, such as flooding and ice. For example, high water levels and flows shut down 22 locks and stopped cargo movements along the Upper

TABLE 4-5 Amtrak On-Time Performance Trends and Hours of Delay by Cause: 2010–2016

	2010	2011	2012	2013	2014	2015	2016
On-time performance, total percent (weighted)	79.7	78.1	83.0	82.3	72.4	71.2	79.1
Short distance (<400 miles), percent	80.3	79.8	84.5	83.6	75.1	73.3	81.1
Long distance (>=400 miles), percent	74.7	63.6	70.7	71.9	50.6	53.7	63.0
Hours of delay by cause, total	**79,976**	**86,021**	**79,235**	**78,604**	**100,018**	**102,058**	**89,983**
Amtrak[a]	23,404	26,121	21,384	22,379	31,787	31,582	26,339
Host railroad[b]	44,090	48,707	46,564	44,632	57,413	57,701	48,555
Other[c]	12,482	11,192	11,286	11,592	10,816	12,774	15,087

[a] Includes all delays that occur when operating on Amtrak owned tracks and all delays for equipment or engine failure, passenger handling, holding for connections, train servicing, and mail/baggage handling when on tracks of a host railroad.

[b] Includes all operating delays not attributable to Amtrak when operating on tracks of a host railroad, such as track and signal related delays, power failures, freight and commuter train interference, routing delays, etc.

[c] Includes delays not attributable to Amtrak or other host railroads, such as customs and immigration, law enforcement action, weather, or waiting for scheduled departure time.

NOTES: Host railroad is a freight or commuter railroad over which Amtrak trains operate for all or part of their trip. Numbers may not add to totals due to rounding. All percentages are based on Amtrak's fiscal year (October 1–September 30). Amtrak trains are considered on time if arrival at the endpoint is within the minutes of scheduled arrival time as shown on the following chart. Trip length is based on the total distance traveled by that train from origin to destination:

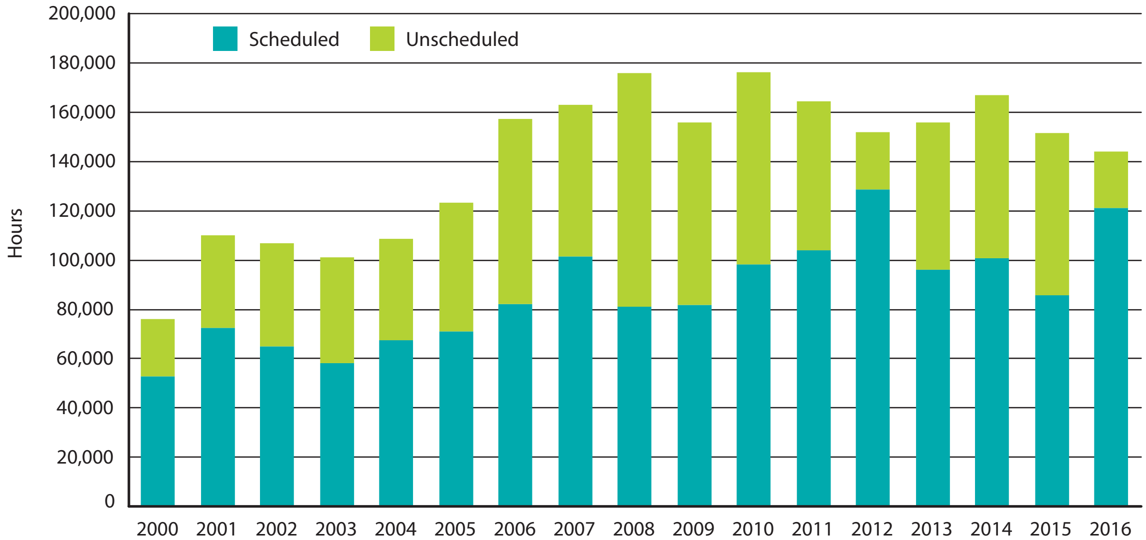
Trip length (miles)	Minutes late at endpoint
0–250	10 or less
251–350	15 or less
351–450	20 or less
451–550	25 or less
> 551	30 or less

SOURCE: U.S. Department of Transportation, Bureau of Transportation Statistics. National Transportation Statistics, Table 1-73. Available at http://www.bts.gov/ as of November 2017.

Mississippi River and its confluences in late April 2013 [USACE 2013]. As shown in figure 4-7, the total number of hours of unavailability in 2016 was almost 144,000, nearly 90 percent higher than the level in 2000. Lock unavailability due to scheduled operations, such as maintenance, ranged from 46 to 85 percent over the period shown and averaged 61 percent. Scheduled downtime was 84 percent of total down time in 2016. Unscheduled lock chamber downtime peaked from 2006 to 2010, over which it averaged about 77,000 hours per year. Over the prior 4 years, unscheduled lost time dropped, averaging about 52,000 hours per year. There were 23,000 hours of unscheduled closures in 2016, which is down 65.4 percent from 2015 and about half the 5-year average.

The U.S. locks of the St. Lawrence Seaway have posted a remarkable record of reliability in recent years. The number of ocean vessel incidents due to mechanical, electrical or structural failures, human factors, or groundings dropped steadily from 29 in 1999 to only 3 in 2016 [SLSDC 2017]. Seaway officials attribute the improvement to the

FIGURE 4-7 Total Number of Hours of Lock Closures: 2000–2016



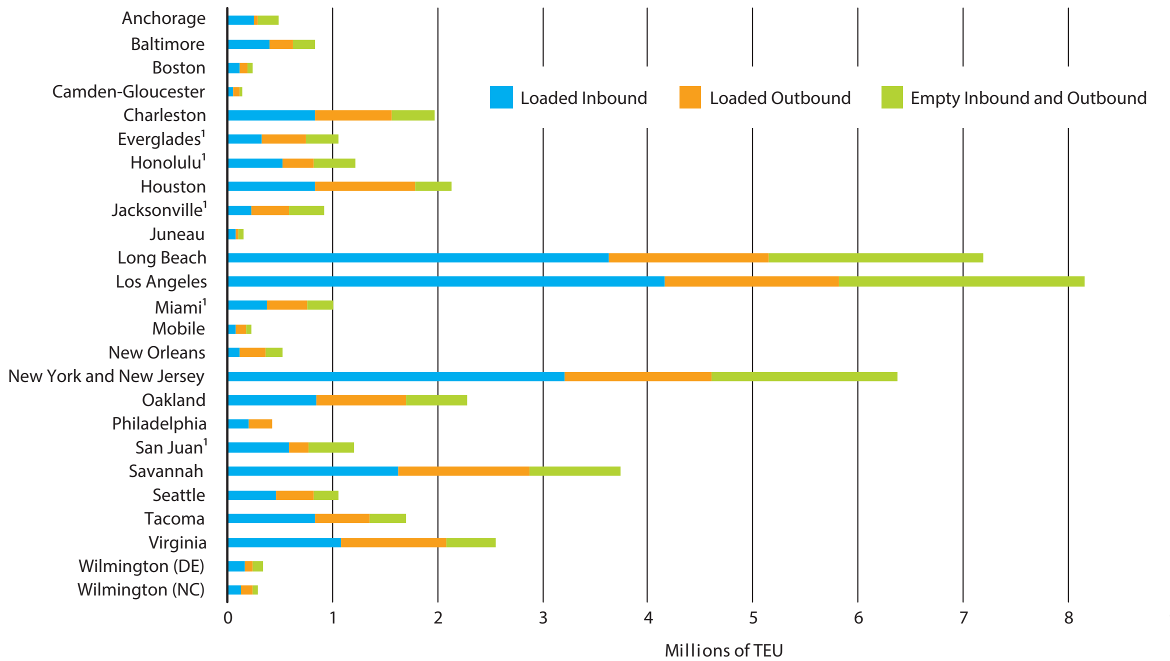
SOURCE: U.S. Army Corps of Engineers, Navigation Data Center, Lock Performance Monitoring System. Locks by Waterway, Locks Unavailability, Calendar Years 1993-2016 (February 2, 2017). Available at http://www.navigationdatacenter.us/ as of March 2017.

Enhanced Seaway Inspection Program that went into effect in 1997, in which inspection activities were concentrated at Montreal at the Seaway's point of entry. Over the past 10 years, lock availability has averaged 99.85 percent and has consistently exceeded the operational goal of at least 99 percent. To maintain this level of safety, efficiency, and reliability, the Saint Lawrence Seaway Development Corp. is investing in new technologies, such as an automated draft information system implemented 5 years ago, and a new hands-free mooring system that will shave as much as 10 minutes from average lockage time at each lock.

In 2015 Congress took action to develop more data and analysis pertaining to the performance of maritime ports. *The Fixing America's Surface Transportation* (FAST) *Act* directs BTS to establish a port performance freight statistics program, and submit an annual report to Congress that includes statistics on capacity and throughput for at least the top 25 ports, as measured by total cargo tonnage, dry bulk tonnage, or twenty-foot equivalent units (TEU) of containers handled [USDOT BTS 2016]. Figure 4-8 displays the 2015 TEU volumes for the top 25 U.S. container ports. Containers tend to carry high value, just-in-time cargo.

Port capacity could be measured by the maximum throughput in tons, TEU, or other units (e.g., number of vehicles) that a port and its terminals can handle over a given period. Precise estimates of port capacity generally require extensive terminal-by-terminal engineering studies, and at the present time are neither nationally available nor nationally consistent. Hence, four indicators of port capacity are reported at this time:

FIGURE 4-8 Annual TEU of the Top 25 Ports by TEU: 2015



[1] Data based on fiscal year not calendar year.

SOURCE: U.S. Department of Transportation. Bureau of Transportation Statistics. 2016. *Port Performance Freight Statistics Program: Annual Report to Congress 2016*. Figure 3. Available at https://www.bts.gov as of May 2017.

1. channel depth,
2. berth length for container ships,
3. number and type of container cranes, and
4. number of on-dock rail transfer facilities.

These four measures indicate the size of a port, which is used as a proxy for its capacity. BTS continues to improve port performance statistics for future annual port performance reports.

System Resiliency

Many parts of the Nation's transportation system are vulnerable to both natural and man-made disruptions. Because of this vulnerability, transportation firms and agencies have become interested in providing a system that is resilient to disruptive impacts. A resilient transportation system has design-level robustness that can withstand severe blows, respond appropriately to threats, and mitigate the consequences of threats through response and recovery operations [USDOT VOLPE 2013].

System Disruptions from Extreme Weather

With the heavy concentration of the Nation's population in urban areas (many along the coasts) and with a strong reliance on the efficient movement of people and goods, recent weather events have resulted in extensive economic and community costs. The U.S.

Department of Commerce (USDOC), National Oceanic and Atmospheric Administration (NOAA) estimated that from 1980 to 2016 the United States experienced 203 weather disasters (or about 5.5 per year on average), including such events as hurricanes, tornadoes, floods, and droughts/wildfires. The overall damage from each of these events exceeded $1 billion, resulting in more than $1.1 trillion cumulative cost to the Nation [USDOC NOAA NCEI 2017]. Part of the physical recovery costs and overall economic impact were due to the damage and disruption to the transportation system.

These extreme events are increasing in frequency, as the annual average for the most recent 5 years (2012–2016) is 10.6 events. In 2016 there were 15 such events, causing 138 deaths and estimated damages of $46.8 billion.

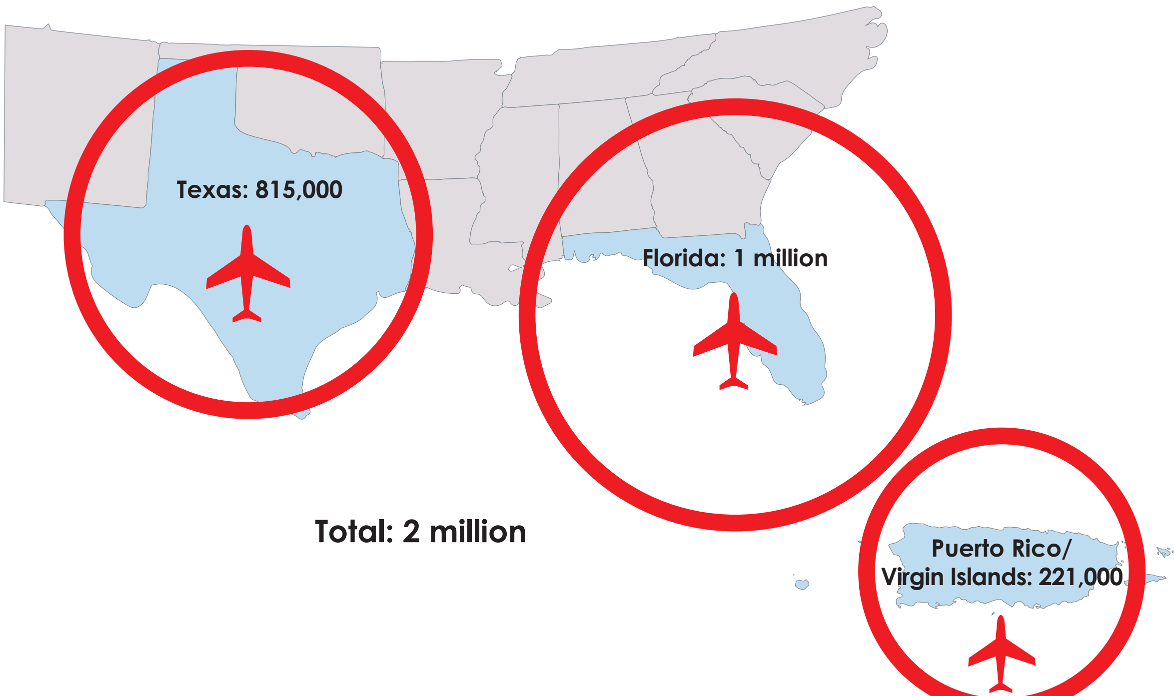
Hurricane Katrina, which hit New Orleans in 2005 and severely impacted the Gulf Coast; and Hurricane Sandy, which devastated the New Jersey, New York, and Connecticut coasts in 2012 and caused record flooding in lower Manhattan; caused severe disruptions of the transportation system. Highways, railroads, and bridges were damaged throughout the regions, and many bridges had to remain closed until their structural safety could be evaluated. In both cases, the regions' major airports were closed for several days, and transit service was severely curtailed for many weeks. Maritime ports had to close for several days, but many had difficulty reopening due to shortages of workers, who were busy dealing with their own losses.

Hurricanes Harvey, Irma, and Maria left a trail of destruction that included the widespread disruption of the aviation system. Even though the system was resilient and bounced back quickly, the Bureau of Transportation Statistics (BTS) estimates that numerous flight cancellations in hurricane-ravaged areas left 2 million would-be passengers without the flights they had booked – 815,000 passengers in Texas, 1 million in Florida, and 221,000 in Puerto Rico and the Virgin Islands (figure 4-9).

Figure 4-10 shows some of the critical U.S. transportation infrastructure, including airports, seaports, and highways near the path of Hurricane/Tropical Storm Harvey. Airport and port operations ceased as the storm passed through the region, placing significant pressure on the numerous petroleum facilities along the Gulf coast, which is home to 45 percent of total U.S. petroleum refining capacity and 51 percent of total U.S. natural gas processing plant capacity [USDOE EIA 2017]. The full impact of the 2017 hurricane season, including the major hurricanes Harvey, Irma, and Maria, are still being assessed.

Other types of extreme weather events also have large impacts. In 2016 widespread flooding in West Virginia, tornados in the Ohio River Valley at the same time, and flooding in Louisiana later in the summer together caused 36 deaths and $11.1 billion in damages. Wildfires in the west and southeast in the second half of 2016 destroyed hundreds of square miles of forestland, closed roads in national parks, and caused 21 deaths and $2.4 billion in estimated damages. A devastating blizzard struck the eastern United States in January of 2016. It is estimated that each day of snow-related shut down in the Northeast results in direct and indirect economic impacts

FIGURE 4-9 Estimated Number of Passengers on Flights Canceled During Hurricanes Harvey, Irma, and Maria: 2016



SOURCE: U.S. Department of Transportation, Bureau of Transportation Statistics, Office of Airline Information, available at www.bts.gov as of November 2017.

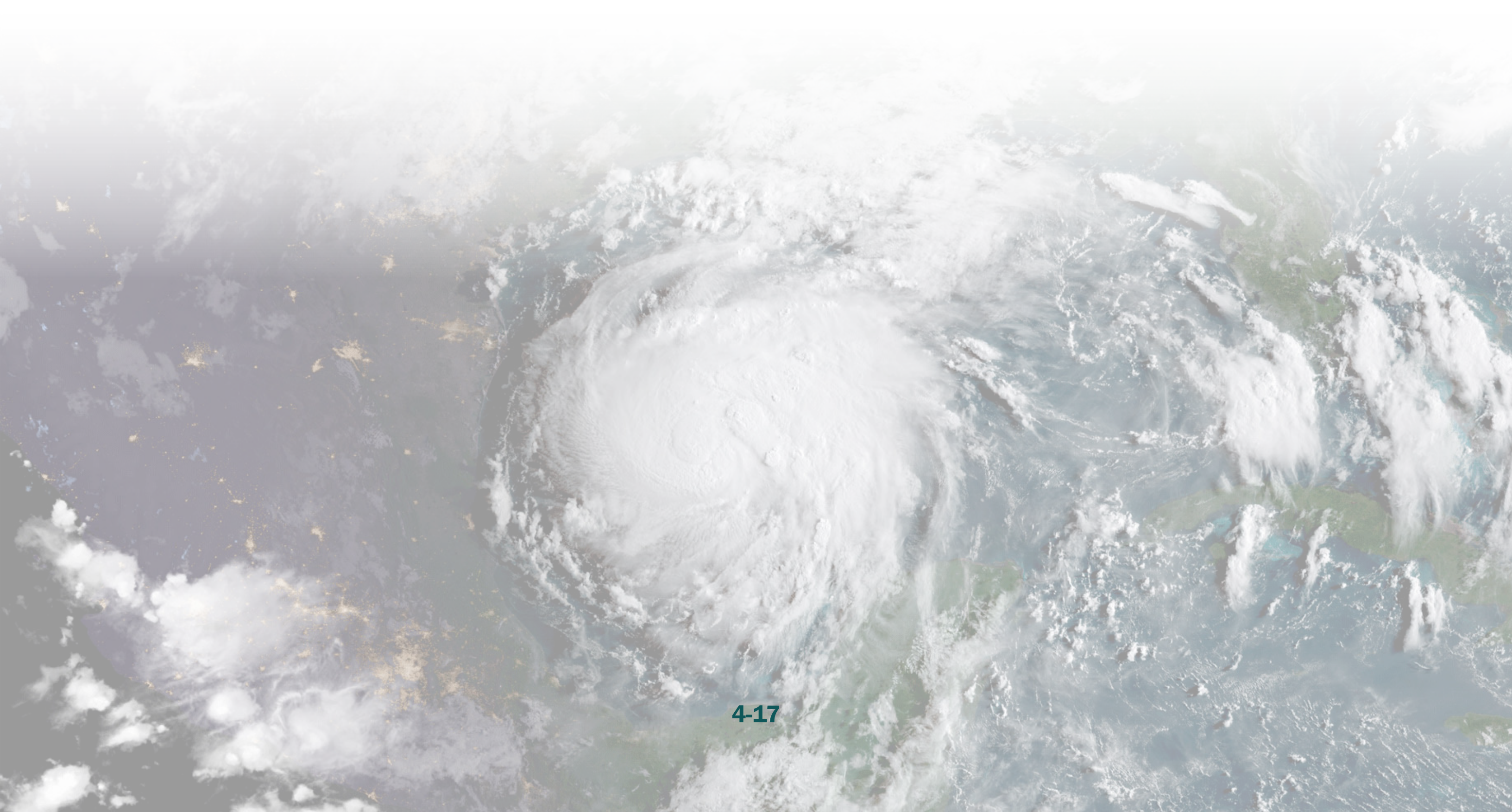
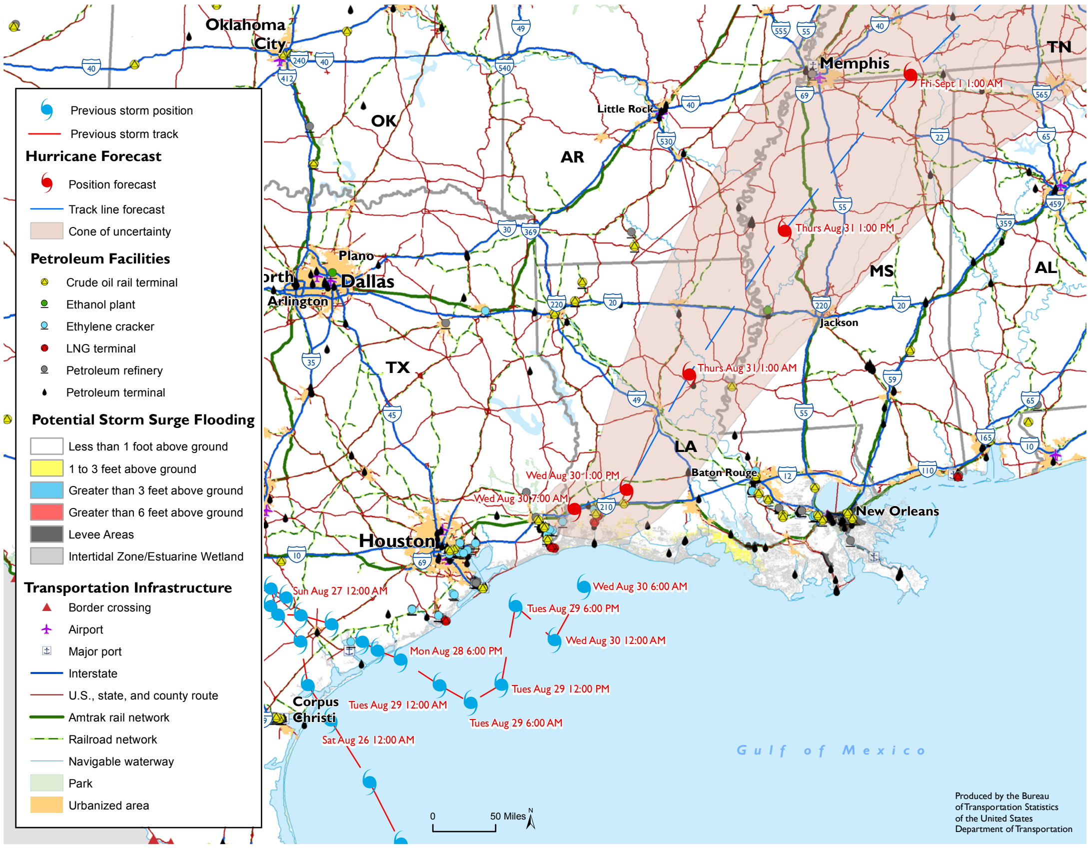


FIGURE 4-10 Selected U.S. Transportation Infrastructure and Hurricane/Tropical Storm Harvey (As of Wednesday Morning, August 30th)



SOURCE: U.S. Department of Transportation, Bureau of Transportation Statistics, Office of Spatial Analysis and Visualization, available at www.bts.gov as of November 2017.

ranging from $250 to $700 million, much of which is due to transportation disruptions [IHS 2015].

Human-Caused Disruptions

Transportation disruptions can also have human causes. For example, a fire under an elevated section of I-85 in Atlanta caused it to collapse, closing the highway for 6 weeks as detailed in box 4-A. Similar impacts were observed in the I-35W bridge collapse in Minneapolis in 2007, which has also been attributed to human causes.

Although the regions impacted by Hurricanes Katrina and Sandy suffered huge losses, as did the other areas affected by the disasters discussed above, one of the key lessons learned from each event was the importance of transportation system resilience. Major transportation facilities—roads, bridges, transit systems, ports, and airports—were in operation within days or weeks of the severe event. In

Box 4-A Atlanta Bridge Collapse

On Thursday, March 30, 2017, a fire that started in some construction materials stored under a bridge on I-85 in Atlanta, between I-75 and GA-400, burned hot enough to cause a section of the northbound lanes to collapse. Although there were no deaths or injuries, both the northbound and southbound lanes had to be closed, which produced massive impacts on travel through downtown Atlanta and throughout the area's transportation system.

The I-85 bridge is close to downtown, providing a major thoroughfare for hundreds of thousands of travelers. Transportation officials advised Atlanta-area travelers that alternative routes would be carrying traffic far exceeding normal levels, and urged them to use public transportation, carpooling, and alternative work schedules and telecommuting during the extended period when that segment of I-85 would be closed. As drivers sought alternate routes, traffic in the morning peak period increased 30 to 50 percent on area roads, and peak-spreading occurred (traffic congestion started earlier and lasted longer than before the I-85 closure). The Georgia Department of Transportation (GDOT) altered signal timing to better handle the increased flows on arterial streets, and local jurisdictions provided officers to keep traffic moving at critical intersections.

The Metropolitan Atlanta Rapid Transit Authority (MARTA) scheduled extra rail and bus service, and area express bus companies added runs from suburban and exurban locations to outlying MARTA rail transit stations. Local media sources quickly sprang into action to provide print and internet maps and guides to assist travelers in using the transit options. The MARTA system experienced a 25 percent increase in ridership and a 45 percent increase in revenue on the first Monday after the bridge collapse. Over the ensuing weeks, the system-wide ridership increase stabilized at 11.5 percent. MARTA made aggressive use of social media to inform commuters of parking availability at its rail stations because all parking spaces were filling early in the day at several stations.

GDOT used the overhead changeable message signs on the highway system to warn through traffic of the closure and provide information on alternative routes. Highway freight carriers and package delivery services used their contingency planners to develop updated routes and schedules. The airlines at Hartsfield-Jackson Atlanta International Airport worked directly with passengers who were being delayed by the collapse effects, and also urged them to use the MARTA system to reach the airport.

GDOT move aggressively to have the damaged structure replaced. As a result, the I-85 lanes (and others that were closed on nearby streets) were all reopened in mid-May 2017, at a cost of more than $16 million. The reopening was 6 weeks after the collapse, 1 month ahead of the anticipated schedule.

SOURCE: U.S. Department of Transportation, Bureau of Transportation Statistics, research using sources cited in the references section 2017 most cases, advanced preparations by state and local government agencies (e.g., moving transit vehicles out of vulnerable areas and establishing emergency management centers) can mitigate disruption to transportation systems [MTA 2012]. The existence of redundant paths in the transportation network provided travel options for both person and freight trips seeking to avoid travel blockages. In all cases, the transportation agencies were able to quickly put critical links in the transportation system back into operation, thus minimizing the economic impact to state and regional economies.

Cybersecurity

Position, navigation, and timing (PNT) services are widely used in all modes of transportation. Global Positioning Systems (GPS) help prevent transportation accidents, aid search and rescue efforts, and speed the dispatch of emergency services [NCO 2014]. The Next Generation Air Transportation System (NextGen) integrates GPS to help increase operational safety and situational awareness for aviation system users, especially during approaches and departures, and while taxiing on the ground [NCO 2014]. Positive Train Control (PTC) works in conjunction with GPS technologies to track train location and speed—data that can be used to prevent train-to-train collisions, overspeed derailments, and the unauthorized movement of trains into work zones [NTSB 2016]. On waterways and especially in ports, GPS helps vessels maneuver around navigational hazards and traffic [NCO 2014]. GPS technologies can help track freight vehicles and their valuable cargo, which may help to reduce the loss of $15 to $30 billion annually in cargo theft and pilferage from commercial motor vehicles [FMCSA 2011].

As with other types of electronic communications, cybersecurity is a serious concern for PNT systems. In particular, GPS spoofing and jamming devices can cause PNT system malfunctions, with potentially severe safety consequences. Spoofing devices deliberately cause GPS transmitters to report erroneous identification or location information. GPS, cellphone, or radar jammers disrupt receipt of radio frequency signals [NOVATEL 2013]. Signal jamming devices can prevent completion of 911 and other emergency calls, and can also interfere with communications networks utilized by police, fire, and emergency medical services. Because signal jamming devices pose such significant risks, Federal law prohibits consumers from operating these devices within the United States, and violations are punishable by fines of up to $112,500 per violation [FCC 2014].

A recent study conducted by the United Kingdom government estimated that the economic impact of a 5-day GPS disruption on the UK transportation system to be at $2.5B, or $500M a day. Given the amount of roadway traffic in the United States is 10 times of that in UK, a simple interpolation of the economic impact of a 5-day GPS disruption on U.S. transportation could be about $25 billion, or $5 billion per day [LONDON ECONOMICS 2017].

In October 2016 NHTSA released proposed guidance for improving motor vehicle cybersecurity, especially since hackers may attempt to gain unauthorized access to vehicle systems for manipulating functionality or retrieving private driver data. The guidance focuses on layered solutions to ensure vehicle systems are designed to protect critical vehicle controls, and to take appropriate and safe actions, even when an attack is successful [USDOT NHTSA 2017].

Security Concerns

The Transportation Security Administration (TSA), of the U.S. Department of Homeland Security, screens people as they pass through security checkpoints at 450 airports and at other passenger checkpoints. In 2016 TSA officers screened more than 738 million passengers (more than 2 million per day), 466 million checked bags, and 24.2 million airport employees [USDHS TSA 2017]. Despite news headlines that report long lines when they do occur, nationwide less than 2 percent of passengers (14.1 million) waited in line for more than 20 minutes in 2015 [USDHS TSA 2016].

These TSA inspections prevented a wide array of prohibited items from being brought onto passenger aircraft, notably 3,391 firearms, 83 percent of which were loaded (see box 4-B). Other prohibited items discovered in checked and carry-on bags included many thousands of knives, swords, and other sharp blades; ammunition; gunpowder, black powder, flashbang grenades, and fireworks; and inert and replica explosive devices. Federal air marshals flew more than a billion miles to help keep the skies secure for travel [USDHS TSA 2016].

International piracy incidents at sea, including attacks, boardings, hijackings, and kidnappings, are another security concern affecting U.S. citizens traveling overseas. Piracy activity has been monitored closely by the Office of Naval Intelligence (ONI), especially after the hijacking of the U.S.-flagged *Maersk Alabama* on April 8, 2009. In 2016 the waters of Southeast Asia experienced 117 piracy events, less than half the abnormally high number of 254 reported for 2015 and 62 percent of the average for 2013–2014. The Gulf of Guinea, in West Africa, had 171 events in 2016, which appears to be about 70 percent above the recent average of about 100 per year. However, most of the increase is due to the inclusion of incidents in the Niger Delta, which were not reported in prior years. The Horn of Africa waters, which have been of major concern since 2009, had only 1 event in 2016 and none in 2015 [USN ONI 2017].

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CHAPTER 5

Transportation Economics

Highlights

- The demand for transportation grew 3.8 percent from 2014 to 2015, down from 4.2 percent from 2013 to 2014.
- Freight transportation services, as measured by the freight Transportation Services Index (TSI), continue to lead the economy, including two economic accelerations following the recession—the first from June 2009 to December 2012 and the second from July 2013 to December 2014.
- Of the transportation modes included in the freight TSI, rail intermodal grew the fastest from June 2009 (the end of the economic recession) to December 2016, rising 50.6 percent.
- Employment in for-hire transportation and transportation-related industries rose steadily from 2011 to 2015, to 13.6 million, exceeding the 2007 pre-recession level of 13.5 million. Employment then declined in 2016 to 13.0 million.
- Total national expenditures on transportation accounted for roughly $1,196 billion of all personal expenditures, making it the fourth largest expenditure category (excluding other) after healthcare, housing, and food.
- Total government transportation revenues continue to fall short of government transportation expenditures. In 2014 government transportation revenues covered 56.7 percent of expenditures. The gap between transportation revenues and expenditures has declined since 2009, when revenues covered 52.5 percent of expenditures.
- The total costs faced by producers of transportation services declined during the 2007 to 2009 recession, and then climbed steadily through 2014. The average price of air, rail, and truck transportation services declined between 2014 and 2016, while water transportation service prices rose in 2015 before falling below their 2014 level in 2016.

Transportation Economics

Transportation plays a vital role in the American economy; it makes economic activity possible and serves as a major economic activity in its own right, contributing directly and indirectly to the economy. Households, businesses, and the government directly consume transportation goods (e.g., vehicles and motor fuel) and services (e.g., passenger and freight air transportation). Transportation indirectly contributes to the economy by enabling the production of goods and services (e.g., by connecting producers to the raw materials for baking bread, etc.) and employing workers in transportation occupations in both the transportation industry and non-transportation industries. Public (government) and private expenditures on transportation facilities, infrastructure, and systems contribute to the economy by enabling the movement of both people and goods domestically and internationally. Transportation not only enables international trade but also is a major good and service traded. The full scope of transportation's role in the economy is available in BTS's *Transportation Economic Trends* Report.

Transportation's Contribution and Role in the Economy

Transportation's Contribution to GDP

Transportation's contribution to the economy can be measured by transportation's contribution to gross domestic product (GDP). GDP is an economic measure of all goods and services produced and consumed in the country. The transportation component of GDP can be measured in terms of investments made and transportation goods and services consumed (collectively known as the demand for transportation) or in terms of the transportation services produced.

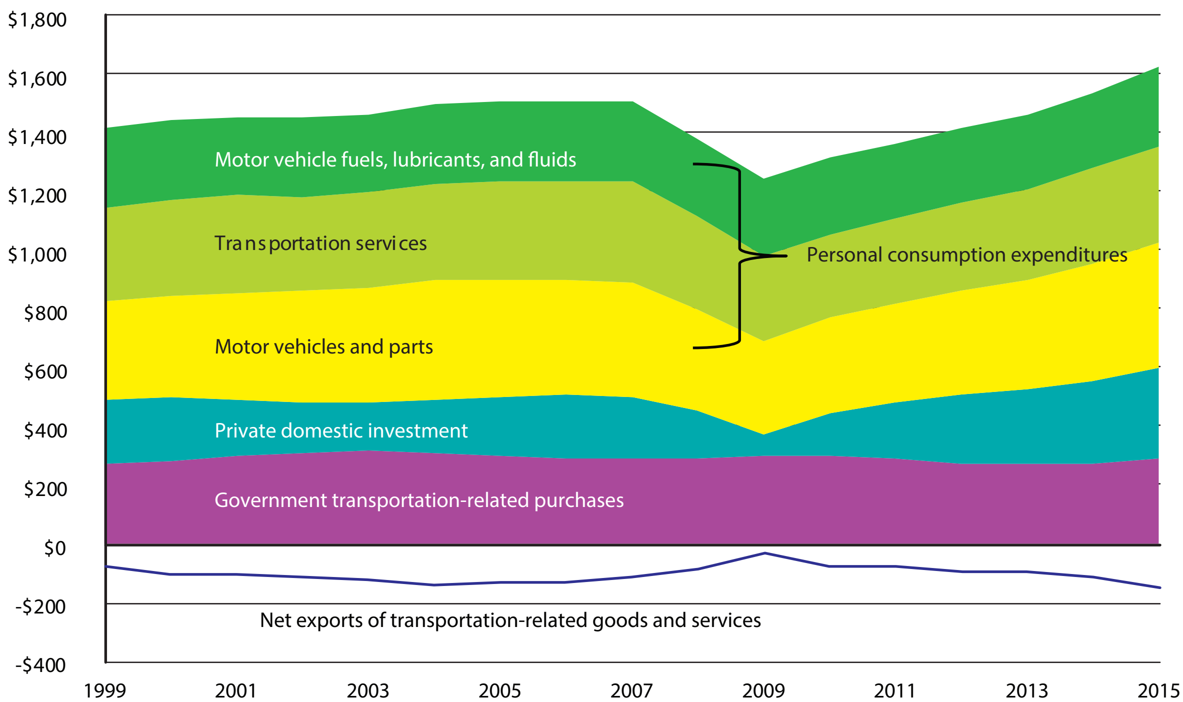
In 2015 the demand for transportation ($1,477.9 billion) included:

1. personal consumption, such as vehicle and motor fuel purchases ($1,020.7 billion, 69.1 percent of transportation demand),
2. private domestic investment in transportation structures and equipment ($314.4 billion, 21.3 percent),
3. government purchases of transportation goods and services ($289.1 billion, 19.6 percent), and
4. net exports (exports minus imports) related to transportation goods and services (-$146.3 billion, -9.9 percent) (as measured in chained 2009 dollars) (figure 5-1).

Altogether, the demand for transportation accounted for 9.0 percent of U.S. GDP.

The demand for transportation grew more slowly (3.8 percent) from 2014 to 2015 than it did from 2013 to 2014 (4.2 percent), when the demand for transportation reached its highest annual growth since the end of the December 2007 to June 2009 economic recession. Growth from 2014 to 2015 fell from the 2013 to 2014 level as imports increased. Imports of transportation related goods and services rose from $436.2 billion in 2014 to $467.4 billion in 2015, while net exports of transportation related goods and services fell from a deficit of $112.1 billion to a deficit of $146.3 billion (as measured in chained 2009 dollars) (figure 5-1).

FIGURE 5-1 U.S. Gross Domestic Product (GDP) Attributed to Transportation-Related Final Demand: 1999–2015 (billions of chained 2009 dollars)



NOTES: Total transportation-related final demand is the sum of total Personal consumption of transportation, total Gross private domestic investment, Net exports of transportation-related goods and services and total Government transportation-related purchases. Net exports is exports minus imports of civilian aircraft, engines, and parts; automotive vehicles, engines, and parts; and transport. Federal purchases and state and local purchases are the sum of consumption expenditures and gross investment. Defense-related purchases are the sum of transportation of material and travel. The Bureau Economic Analysis has changed the reference year for chained dollar estimates from 1999 onward as part of the comprehensive revision of the national income and product accounts in 2014.

SOURCE: U.S. Department of Commerce, Bureau of Economic Analysis, National Income and Product Accounts Tables, tables 1.1.6, 2.3.6, 2.4.6, 3.11.6, 3.15.6, 4.2.6, 5.4.6, and 5.5.6, available at http://www.bea.gov/National/nipaweb/SelectTable.asp?Selected=N as of May 2017.

Transportation's Role in Production

The contribution of transportation to the economy also can be found by examining transportation's role in production. The transportation services used to move wheat from farms to mills, flour from mills to bakers, and bread from bakers to grocery stores, exemplify how transportation enables the production and sale of nearly everything made and consumed in the United States. The U.S. Bureau of Economic Analysis (BEA) produces the U.S. Input-Output (I-O) accounts, which show the inputs each industry uses to produce output, the type of output produced by each industry, and the types of products purchased by final consumers.

With regards to transportation, the I-O accounts show the industries using transportation services provided by transportation firms on a fee basis, called for-hire transportation, and the contribution of for-hire transportation firms to the economy. In 2016 for-hire transportation (including warehousing) contributed $562.9 billion (3.0 percent) to U.S. GDP (current dollars) [USDOC BEA 2017a]. While for-hire transportation contributes less to the economy than other industries, for-hire transportation delivers the raw materials other industries need to produce finished products and deliver finished products to wholesale and retail outlets.

In addition to using for-hire transportation services, many non-transportation industries also undertake transportation activities for their own purposes (called in-house transportation), which the I-O accounts do not explicitly show. BTS developed the Transportation Satellite Accounts (TSAs) to explicitly show in-house transportation operations and thereby estimate the full contribution of transportation to the economy.[1] The TSAs also show the contribution of transportation carried out by households through the use of a household vehicle.

In 2015, the latest year for which comprehensive data are available, transportation's total estimated contribution was $1,033.3 billion. For-hire transportation contributed $543.2 billion (3.0 percent) to the U.S. GDP of $18.4 trillion.[2] Transportation services (air, rail, truck, and water) provided by non-transportation industries for their own use (in-house transportation) contributed an additional $169.9 billion (0.9 percent). Total household transportation, measured by the depreciation associated with households owning motor vehicles, contributed $320.2 billion (1.7 percent). Total household transportation's contribution to GDP was larger than any of the other transportation modes. Trucking contributed the second largest amount, at $281.4 billion. In-house truck transportation operations contributed $138.4 billion, while for-hire truck transportation services contributed $143.0 billion (figure 5-2).

Transportation indirectly contributes to the economy by enabling the production of goods and services. *Industry Snapshots: Uses of Transportation* summarizes the transportation services and related resources used by the seven major non-transportation sectors to produce their goods and services [USDOT BTS 2017c]. Some sectors use more transportation than others. In 2015 the wholesale and retail trade sector used the largest amount of transportation services at $270.7 billion, followed by the information and services sector at $246.7 billion, the manufacturing sector at $202.5 billion, and the government sector at $136.9 billion (figure 5-3).

Looking at the amount of transportation required to produce one dollar of output shows how much a sector depends on transportation. In 2015 the wholesale and retail trade sector required more transportation services to produce one dollar of output than any other sector. The wholesale and retail trade sector required 9.0 cents of transportation services to produce one dollar of output (4.7 cents of in-house transportation operations and 4.3 cents of for-hire transportation services) in 2015 (figure 5-4).

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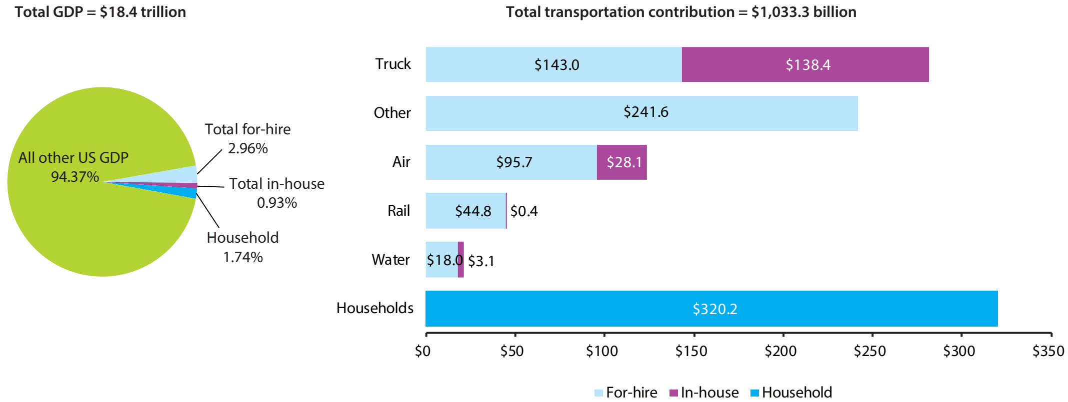
[1] For more information about the Transportation Satellite Accounts, see U.S. Department of Transportation, Bureau of Transportation Statistics, *Transportation Economic Trends*, chapter 2, available at: https://www.bts.gov/content/transportation-economic-trends as of November 2017.

[2] The GDP value in the TSAs is larger than the GDP value published in the National Accounts because it includes the contribution of household transportation. Household transportation covers transportation provided by household for their own use through the use of an automobile.

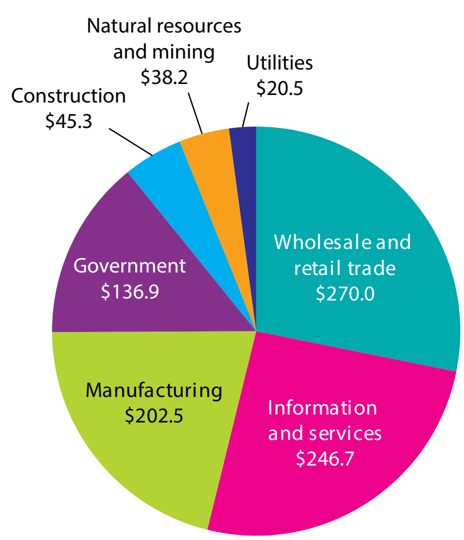
FIGURE 5-2 Contribution of For-Hire, In-House, and Household Transportation to U.S. Gross Domestic Product (2015 Dollars)



NOTES: (a) In-house transportation consists of the services provided by non-transportation industries, including households, for their use. Business in-house transportation includes privately owned and operated vehicles of all body types, used primarily on public rights of way, and the supportive services to store, maintain, and operate those vehicles. Household transportation covers transportation provided by households for their own use through the use of an automobile. (b) For-hire transportation consists of the services provided by transportation firms to industries and the public on a fee-basis. (c) Other for-hire transportation includes: pipeline, transit and ground passenger transportation, including state and local government passenger transit; sightseeing transportation and transportation support; courier and messenger services; and warehousing and storage. (d) Gross domestic product (GDP) increased from value reported by the Bureau of Economic Analysis in I-O use table by total output from the household production of transportation services.

SOURCE: U.S. Department of Transportation, Bureau of Transportation Statistics, Transportation Satellite Accounts, available at www.bts.gov, as of May 2017.

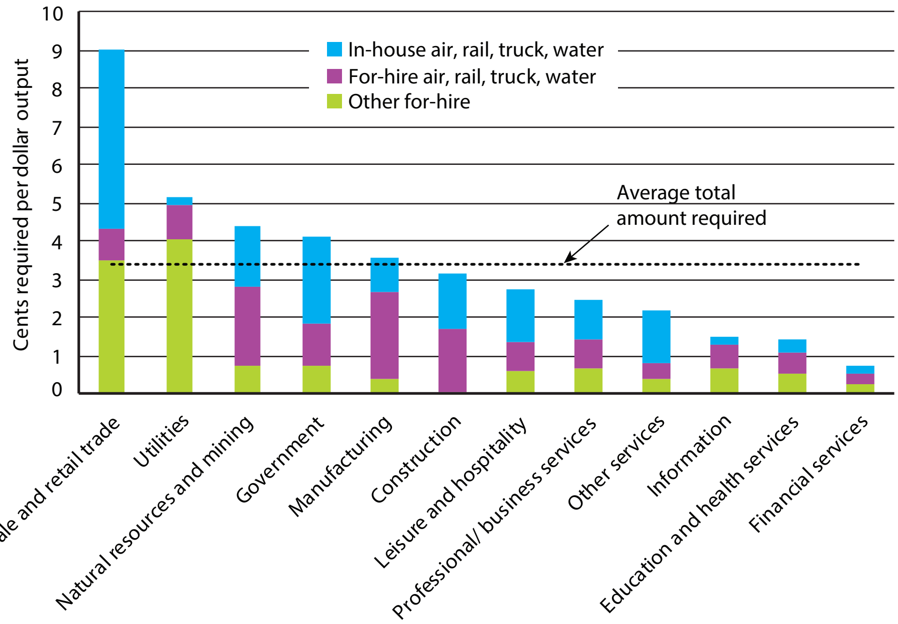
FIGURE 5-3 Use of Transportation by Industry, 2015 (current dollars, billions)



NOTES: In-house transportation consists of transportation services (air, rail, truck, and water) provided by non-transportation industries for their own use. For-hire transportation consists of the services provided by transportation firms to industries and the public on a fee-basis. Airlines, railroads, transit agencies, common carrier trucking companies, and pipelines are examples of for-hire transportation industries.
"Other" for-hire transportation includes: Transit and passenger ground transportation (excluding State and local government passenger transit); Pipeline; Sightseeing transportation and transportation support; Parcel delivery, courier, and messenger services (excluding U.S. Postal Service); Warehousing and storage; and Other transportation and support activities.

SOURCE: U.S. Department of Transportation, Bureau of Transportation Statistics, Transportation Satellite Accounts, available at http://www.bts.gov as of May 2017.

FIGURE 5-4 Transportation Required per Dollar of Output by Sector, 2015



NOTES: In-house transportation consists of transportation services (air, rail, truck, and water) provided by non-transportation industries for their own use. For-hire transportation consists of the services provided by transportation firms to industries and the public on a fee-basis. Airlines, railroads, transit agencies, common carrier trucking companies, and pipelines are examples of for-hire transportation industries.
"Other" for-hire transportation includes: Transit and passenger ground transportation (including state and local government passenger transit); Pipeline; Sightseeing transportation and transportation support; Courier and messenger services; Warehousing and storage; and Other transportation and support activities.

SOURCE: U.S. Department of Transportation, Bureau of Transportation Statistics, Transportation Satellite Accounts, available at http://www.bts.gov as of May 2017

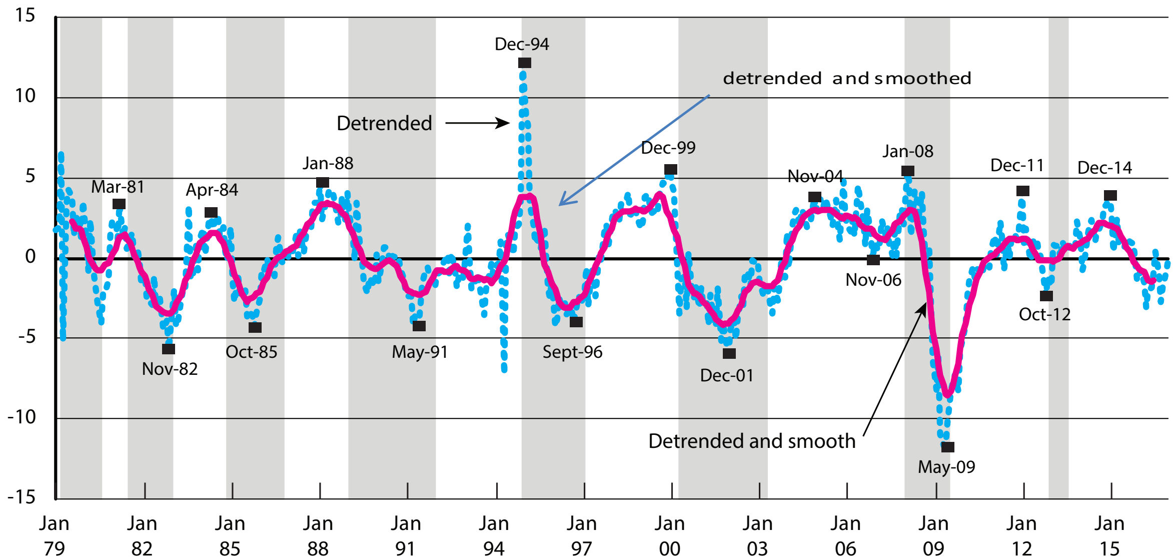
Transportation and Economic Cycles

Transportation activities have a strong relationship to the economy. BTS developed the Transportation Services Index (TSI) to measure the volume of freight and passenger transportation services provided monthly by the for-hire transportation sector.[3] BTS research shows that changes in the TSI occur before changes in the economy, making the TSI a useful potentially leading economic indicator [USDOT BTS 2014]. This relationship is particularly strong for freight traffic.

Figure 5-5 illustrates the relationship between the freight TSI and the national economy from 1970 to 2016. The dashed blue line shows the freight TSI detrended to remove long-term changes. The red line shows the freight TSI detrended and smoothed to eliminate month-to-month volatility. The gray bars represent economic slowdowns, or periods when economic growth slows below normal rates and unemployment rises as a result. The marked peaks and troughs show that the freight

[3] For more information about the Transportation Services, see U.S. Department of Transportation, Bureau of Transportation Statistics, Transportation Economic Trends, chapter 1, available at: https://www.bts.gov/content/transportation-economic-trends as of November 2017.

FIGURE 5-5 Detrended Freight TSI, Detrended and Smoothed Freight TSO and Growth Cycles: January 1979–December 2016



NOTE: Shaded areas indicate decelerations in the economy (growth cycles). Detrending and smoothing refer to a statistical procedure that makes it easier to observe changes in upturns and downturns of the data. Detrending removes the long term growth trend and smoothing eliminates month to month volatility.

SOURCE: U.S. Department of Transportation, Bureau of Transportation Statistics, Transportation Services Index, available at www.bts.gov as of May 2017.

TSI usually peaks before a growth slowdown begins and hits a trough before a growth slowdown ends.

BTS research shows two economic accelerations followed the Great Recession; the first from June 2009 to December 2012 and the second from July 2013 to December 2014 [USDOT BTS 2017e]. The freight TSI lead both of these accelerations; however, the relationship between the freight TSI and growth cycles changed somewhat. The freight TSI reached a peak in December 2011 and turned downwards 12 months in advance of an economic deceleration that began in December 2012. After the peak in December 2011, the freight TSI reached a trough in October 2012 and turned upwards. The trough in the freight TSI in October 2012 occurred before the growth cycle peaked in December 2012, which marked the start of an economic deceleration. Historically, the freight TSI has not hit a trough and turned upwards before the onset of an economic deceleration. The economic deceleration begun in December 2012 ended in July 2013. The freight TSI peaked in December 2014 and turned downwards at the same time as the growth cycle.

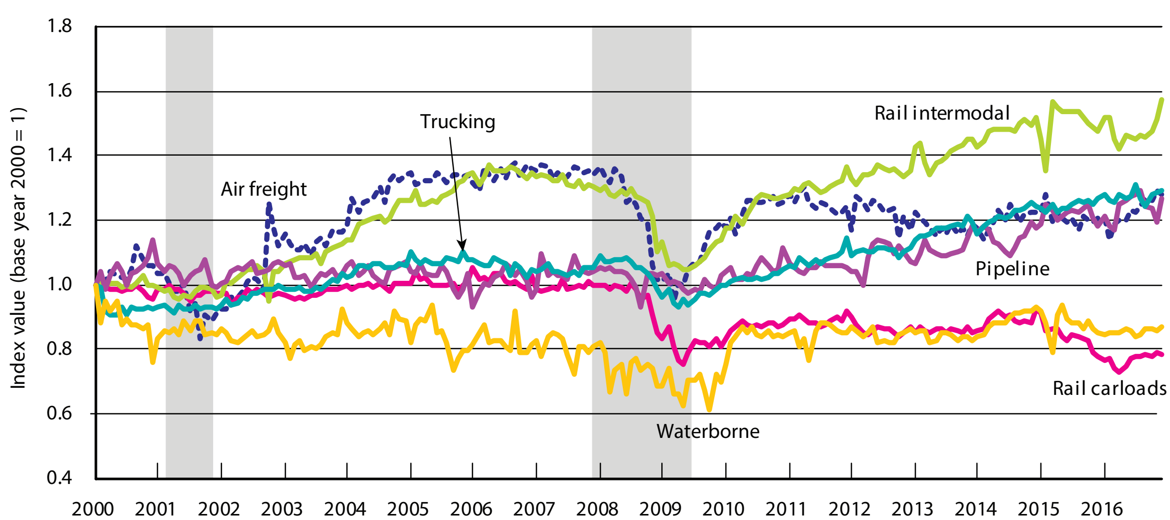
The Great Recession from December 2007 to June 2009 separated two distinct periods in the growth of freight transportation services. The freight TSI grew well above the long-term trend from the pre-recession November 2004 peak to the January 2008 peak. Post-recession growth from the December 2011 peak to the

December 2014 peak exceeded the long-term trend but less significantly and short of the fast-paced growth prior to the recession. This trend contrasts with the growth pattern of gross domestic product, which grew just as rapidly from December 2011 to December 2014 (a compound annual growth rate of 2.1 percent) as it did from November 2004 to January 2008 (a compound annual growth rate of 2.0 percent). The varying trends suggest that transportation has recovered more slowly than the economy as a whole [USDOT BTS 2017f].

Figure 5-6 shows the changes in freight movement by the transportation modes included in the freight TSI. Rail intermodal, trucking, and pipeline all have grown steadily since June 2009, whereas air freight and waterborne show little growth after initial recovery. Rail intermodal[4] grew the fastest, rising 50.6 percent from June 2009 (the end of the economic recession) to December 2016. Competitive pricing, track upgrades, and investment in rail intermodal terminals and other infrastructure all contributed to the rapid growth of rail intermodal traffic [AAR 2016]. Trucking grew the second fastest at 37.8 percent, followed by pipeline at 29.6 percent, waterborne at 23.2 percent, and air freight at 21.7 percent. Rail carloads declined 0.8 percent from June 2009 to December 2016. Data from *Railroads and Coal* suggests that the weakness in rail carload shipments is due to a weakness in coal shipments. Total coal shipped by Class I railroads peaked in 2008 at 878.6 million tons and dropped to 491.7 million tons in 2016 [AAR 2010 and 2017].

[4] Rail intermodal is the transporting of shipping containers and truck trailers on railroad flat cars.

FIGURE 5-6 Freight TSI Modal Data, January 2000–December 2016



NOTE: Data are seasonally adjusted and indexed

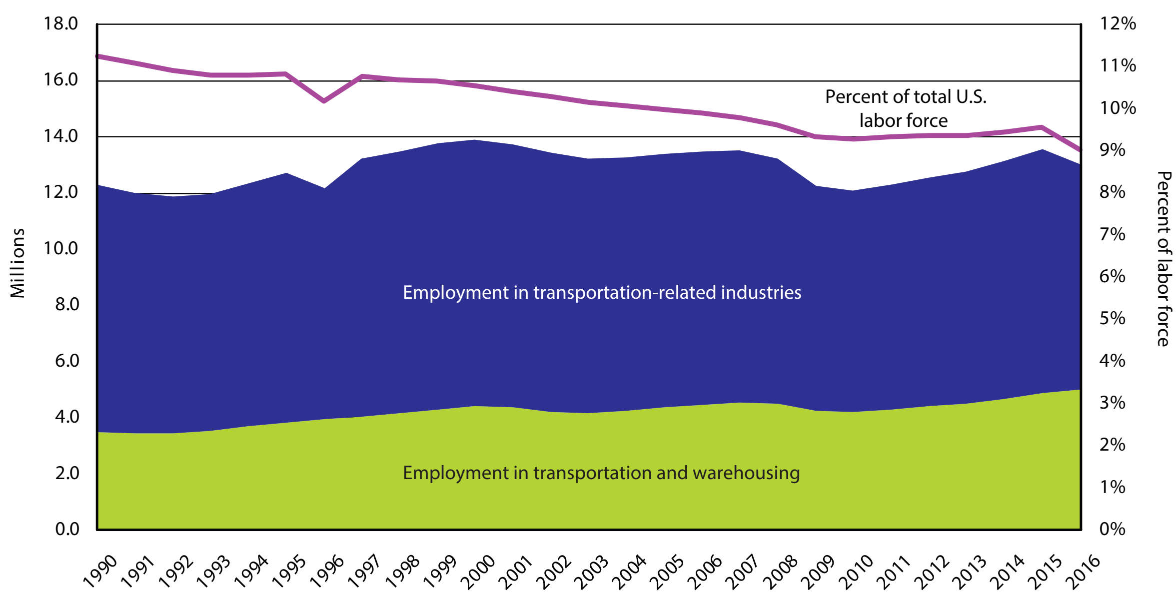
SOURCE: U.S. Department of Transportation, Bureau of Transportation Statistics, seasonally adjusted transportation data, available at www.bts.gov as of May 2017.

Transportation-Related Employment and Wages

The transportation and warehousing sector and related industries employ over 13.0 million people in a variety of roles, from driving buses to manufacturing cars to building and maintaining ports and railroads. Figure 5-7 shows the number and percentage of workers employed by for-hire transportation and transportation-related industries in the United States from 1990 to 2016. In 1990, 12.3 million workers were employed in for-hire transportation and transportation-related industries. Employment rose to a high of 13.9 million workers in 2000 but declined to 13.2 million in 2003 due to the March to November 2001 economic recession and to the aftermath of September 11, 2001. Employment declined further to a low of 12.1 million in 2010 due to the 2007 to 2009 recession. Employment rose steadily from 2011 to 2015, rising to 13.6 million in 2015 to exceed the 2007 pre-recession level of 13.5 million. Employment declined to 13.0 in 2016 because the decline in transportation related employment more than offset increased employment in transportation industries. The percentage of American workers employed in for-hire transportation and transportation-related industries, however, has continued its decline from 11.3 percent of the U.S. labor force in 1990 to 9.0 percent in 2016. [USDOT BTS 2017d]

The for-hire transportation sector (transportation service providers and warehousing) is a major source of employment in the United States, employing 5.0 million

FIGURE 5-7 Employment in Transportation and Transportation-Related Industries in the United States: 1990–2016



SOURCE: U.S. Department of Transportation, Bureau of Transportation Statistics, National Transportation Statistics, Table 3-23, available at www.bts.gov as of May 2017.

in 2016 (figure 5-7). The sector's labor force declined during the 2007 to 2009 recession and continued to fall through 2010, after which it rose steadily. The sector's labor force rose above the 2007 level in 2014 and reached an all-time high of 5.0 million in 2016 [USDOT BTS 2017d]. Additional persons work as independent contractors for private transportation providers, such as drivers for independent, on-demand ride-services (e.g., Uber and Lyft) but are not counted in the totals (see box 5-A).

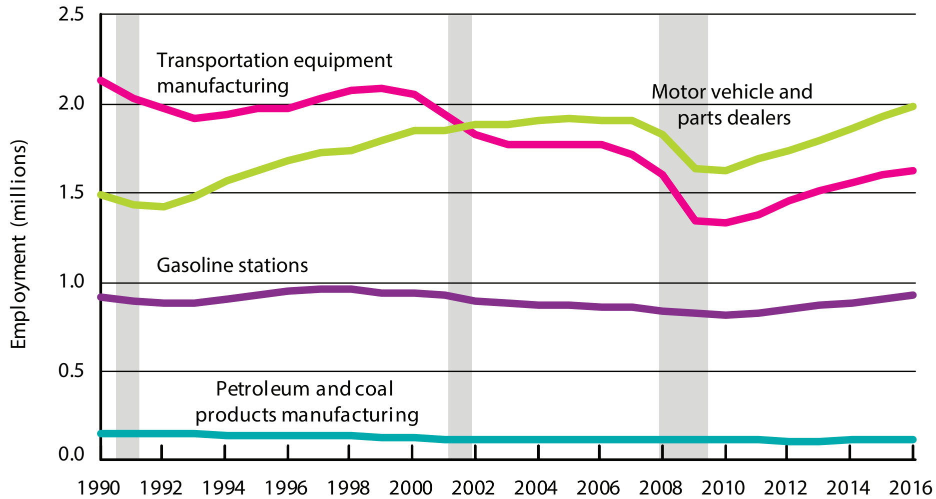
Transportation also leads to employment in related industries that provide the goods and services needed to produce transportation. These transportation industries include motor vehicle and parts dealers, transportation equipment manufacturing, gasoline stations, and petroleum and coal products manufacturing. A notable shift in transportation-related employment occurred between 1990 and 2016. From 1990 through 2001, transportation equipment manufacturing was the largest transportation-related industry. However, employment in transportation equipment manufacturing declined 9.0 percent during this period, while employment in the motor vehicle and parts dealers industry grew 24.1 percent. This led to motor vehicle and parts dealers becoming the largest transportation-related employer in 2002. Employment in motor vehicle and parts dealers overall grew by 32.6 percent from 1990 to 2016, while employment in transportation equipment manufacturing declined 23.9 percent (figure 5-8).

Workers with transportation occupations overall earned, at $30,730, a lower median wage than workers of all occupations ($37,040) in 2016 [USDOL BLS 2017b]. Annual wages earned by transportation and transportation-related workers vary widely across transportation occupations. For example, air traffic controllers, airline pilots, and aerospace engineers earned an annual median wage of more than $100,000 in 2016, while the largest transportation-related occupation, heavy and tractor-trailer truck drivers, earned an annual median wage of $41,340. The top-five highest wage transportation-related occupations collectively employ fewer workers (294,660), while the lowest-five wage occupations employ 3.6 times more workers (1.0 million). (figure 5-9)

Box 5-A Independent, On-Demand Ride Services Employment

The launch and spread of independent, on-demand ride-services (see box 2-A), such as Uber and Lyft, has created new employment opportunities in transportation. Persons who provide ride services are considered independent contractors. Independent contractors are not counted in official U.S. job counts. In 2005 the Bureau of Labor Statistics (BLS) estimated there were 403,000 independent contractors in the transportation and material moving occupations as compared to 7.8 million workers with traditional arrangements [USDOL BLS 2005]. BLS plans to include the Contingent Worker Supplement in the 2017 Current Population Survey to capture on-demand services employment.

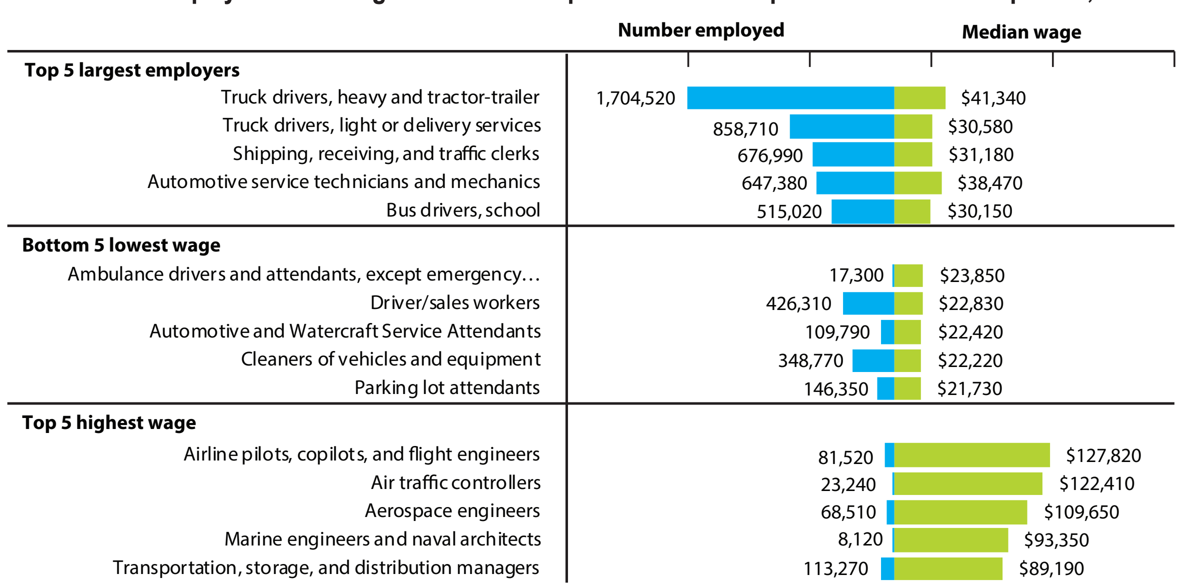
FIGURE 5-8 Employment in Selected Transportation-Related Industries, 1990 to 2016



NOTE: Shaded areas indicate U.S recessions, as defined by the National Bureau of Economic Research.

SOURCE: U.S. Department of Transportation, Bureau of Transportation Statistics, National Transportation Statistics, Table 3-23, available at www.bts.gov as of May 2017.

FIGURE 5-9 Employment and Wages in Select Transportation and Transportation-Related Occupations, 2016



KEY: SOC = Standard Occupational Classification

NOTE: Transportation and transportation-related occupations from U.S. Department of Transportation, Bureau of Transportation Statistics, National Transportation Statistics, Table 3-24, available at www.bts.gov

SOURCE: U.S. Department of Labor, Bureau of Labor Statistics, Occupational Employment and Wages, available at http://www.bls.gov/oes as of May 2017.

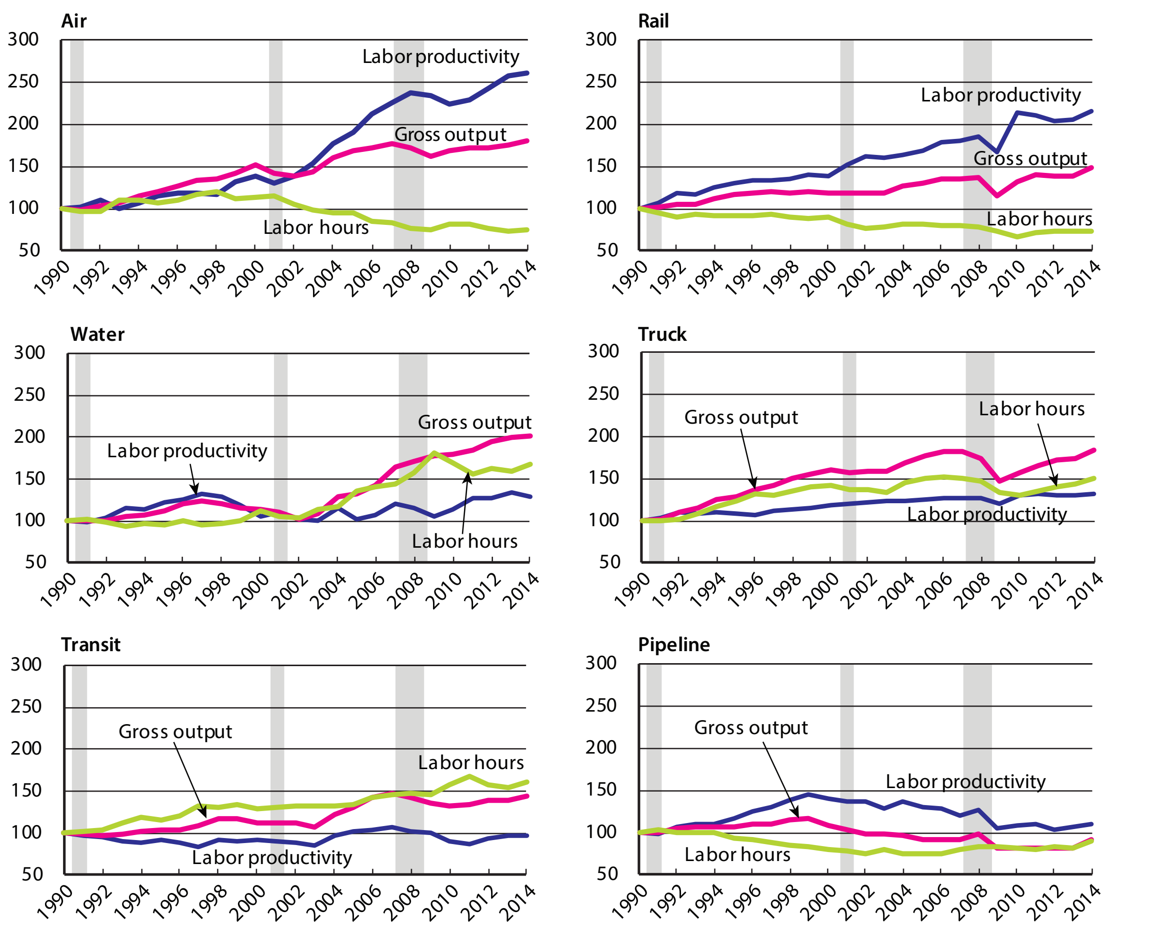
Transportation Productivity

The size of the transportation workforce depends on the demand for transportation and on firms' utilization of the workforce relative to other inputs, such as capital, energy, materials, and services. Economists measure how efficiently firms use inputs through economic productivity. Economic productivity is the ratio of total output to the inputs used in the production process.

Productivity increases when a business produces the same output using fewer (or lower-cost) inputs. The business may then choose to produce more output, lower prices, invest in the business, or return income to shareholders.

There are two main measures of transportation productivity: labor (single-factor) productivity and multifactor productivity (MFP). Labor productivity measures the output per unit of labor

FIGURE 5-10 Labor Productivity Indices for Selected Transportation Industries: 1990–2014 Index, 1990 = 100



NOTE: Data in this figure are not comparable to the data published in previous editions due to change in data used. Labor hours is the total number of number of hours worked by all workers in a sector to produce gross output. Gross output is the total value of goods and services produced by the sector. Gross output includes the value of the goods and services used to produce the sector output. Labor productivity measures a sector's output per unit of labor input. Shaded areas indicate U.S recessions, as defined by the National Bureau of Economic Research.

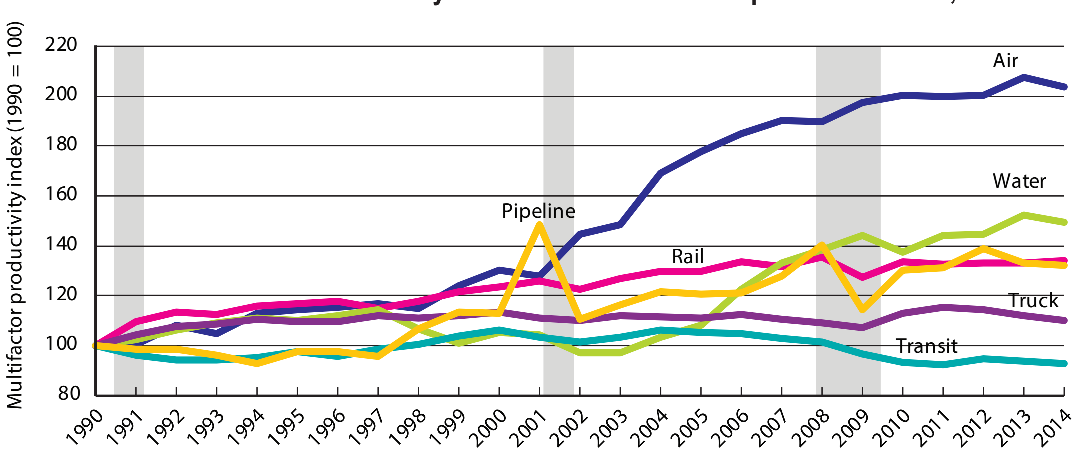
SOURCE: U.S. Department of Labor, Bureau of Labor Statistics, Major Sector Productivity, http://www.bls.gov as of May 2017.

input, while MFP measures the output per unit as a weighted average of multiple factors, such as fuel, equipment, and materials.

While MFP is a more comprehensive measure of economic performance, labor productivity is easier to measure and continues to have a broad appeal. Figure 5-10 illustrates changes in labor productivity for selected transportation sectors from 1990 to 2014. Air transportation experienced the largest increase in labor productivity among all, increasing 160.5 percent (figure 5-10). Air transportation's labor productivity grew most notably between 2001 and 2008. The gains during this period come from legacy carriers adopting aggressive labor-saving initiatives and from large output gains among low-cost carriers [USDOL BLS 2017c]. Rail transportation experienced the second largest gains in labor productivity, increasing by 116.3 percent. These gains are the result of labor-saving technologies automating operational and administrative tasks [Kriem]. Labor-saving initiatives in air and rail resulted in a decline in the labor hours required to produce a dollar of air and rail transportation services from 1990 to 2014. During the same period, smaller labor productivity increases occurred in truck (32.1 percent) and water (28.9 percent). Labor productivity in pipeline transportation grew 9.5 percent despite declining from 2000 through 2014. Labor productivity in transit transportation declined 3.0 percent due to the total amount of hours required to produce output (labor hours) rising faster than output.

From the perspective of output per unit of multiple inputs (e.g., fuel, equipment, and materials), air transportation had the largest increase from 1990 to 2014, growing 103.5 percent (figure 5-11). The gain in air transportation reflects an 80.1 increase in output and an 11.5 percent decline in combined inputs. Combined inputs fell, despite an increase in capital services, because of declines in labor inputs and intermediate inputs. The increase in capital services and the decline in labor follow from the air transportation sector adopting labor-saving technologies, such as self-service kiosks.

FIGURE 5-11 Multifactor Productivity Indices for Selected Transportation Sectors, 1990 to 2014



NOTE: Shaded areas indicate U.S recessions, as defined by the National Bureau of Economic Research.

SOURCE: U.S. Department of Labor, Bureau of Labor Statistics, Major Sector Productivity, http://www.bls.gov as of May 2017.

Water transportation experienced the second largest increase in MFP, growing 49.3 percent from 1990 to 2014, despite declining 15.2 percent from 1997 to 2003 (figure 5-11). The MFP of rail transportation grew steadily over the entire period but more slowly, increasing 34.2 percent. MFP in pipeline transportation had a smaller increase of 31.9 percent over the same period and showed more year-to-year variation than other modes. Truck transportation's MFP grew marginally at 9.8 percent, while the transit sector experienced a decline of 7.2 percent.

The impact of productivity on transportation companies can be seen through changes in the price charged per unit of output. For for-hire passenger transportation, the unit of output is passenger-miles, and the measure of what travelers pay is the average revenue per passenger-mile. For for-hire freight transportation, the unit of output is ton-miles, and the measure of what freight shippers pay is the average freight revenue per ton-mile. For modes where users do not typically pay per use, like driving a personal vehicle, complete data are difficult to obtain. Increases in productivity often reduce business costs, which allow transportation companies to offer lower prices.

Figure 5-12 shows nominal changes in revenue per passenger-mile relative to the index for all consumer expenditures (CPI) for three industries: domestic air carriers, commuter rail, and Amtrak/intercity rail. Nominal changes that are greater than changes in the CPI indicate real increases in revenue. Amtrak/intercity rail experienced the largest growth in revenue per passenger-mile, increasing 165.8 percent from 1990 to 2015 (latest available year), while commuter rail increased 95.9 percent from 1990 to 2016. Both Amtrak/intercity rail and commuter rail experienced steady growth. In contrast, domestic air carrier revenue per passenger-mile fell after the September 2001 terrorist attacks, began to rise after reaching a low in 2002, and then fell again during the Great Recession to its 2002 level in 2009. Between 2009 and 2014, domestic air carrier revenue per passenger-mile rose 21.0 percent but then fell 7.3 percent between 2014 and 2016.

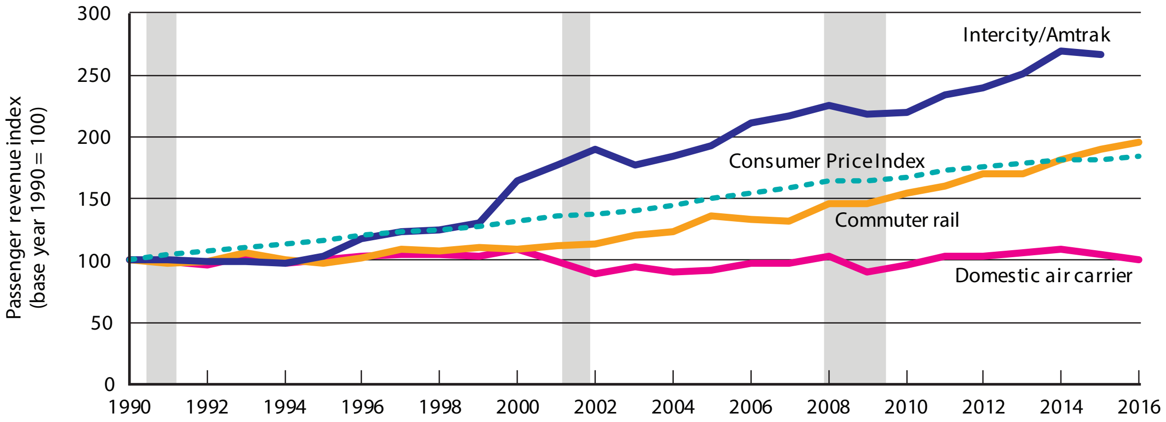
The increases in revenue per passenger-mile are partly due to an increase in the overall price of goods and services. The CPI, which measures overall changes in prices, increased by 83.6 percent from 1990 to 2016, indicating that Amtrak/intercity and commuter rail were the only industries with real increasing revenue per passenger-mile during the period.

Figure 5-13 shows the average freight revenue per ton-mile for air, truck, rail, and pipeline. Nominal freight revenue per ton-mile increased for all freight modes. Domestic air carriers experienced the largest increase in revenue per ton-mile, increasing 145.9 percent from 1990 to 2014 before falling 11.6 percent from the 2014 level between 2015 and 2016. Class I railroads experienced a smaller increase in revenue per ton-mile of 50.1 percent in the same period due to an initial decline.

Sources of Economic Growth

The BEA/BLS Integrated Production Accounts show the contribution of labor, capital, and MFP to economic growth. Based on the accounts, transportation's contribution has

FIGURE 5-12 Revenue per Unit of Output for Passenger Transportation Modes: 1990–2016



NOTE: Shaded areas indicate U.S recessions, as defined by the National Bureau of Economic Research.

SOURCES: U.S. Department of Transportation, Bureau of Transportation Statistics, National Transportation Statistics, Table 3-20, available at www.bts.gov as of November 2017

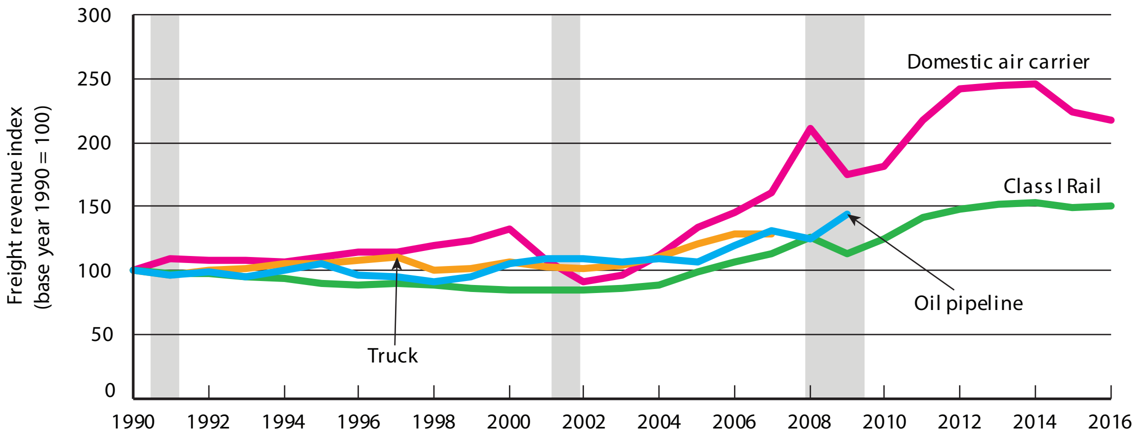
Air carrier, domestic, scheduled service (passenger): Domestic air carrier revenue includes baggage fees and reservation changes fees.
U.S. Department of Transportation, Bureau of Transportation Statistics, Office of Airline Information, TranStats Database, T1: U.S. Air Carrier Traffic and Capacity Summary by Service Class, available at http://www.transtats.bts.gov/DL_SelectFields.asp?Table_ID=264&DB_Short_Name=Air%20Carrier%20 Summary as of Aug. 31, 2015 and Air Carrier Financial Reports, Schedule P-1.2, available at http://www.transtats.bts.gov/databases.asp?Mode_ID=1&Mode_Desc=Aviation&Subject_ID2=0 as of November 2017.

Commuter rail: 1990-2001: American Public Transportation Association, 2011 Public Transportation Fact Book (Washington, DC: 2011), tables 2 and 42 (passenger fares / passenger-miles).
2002-14: U.S. Department of Transportation, Federal Transit Administration, National Transit Database, Data Tables 19 and 26 (Washington, D.C.: Annual reports), available at https://www.transit.dot.gov/ntd as of November 2017.
2015-16: U.S. Department of Transportation, Federal Transit Administration, National Transit Database, Annual Data Tables: Service and Annual Database: Fare Revenue, available at https://www.transit.dot.gov/ntdhtm as of November 2017.

Intercity / Amtrak: 1990-2002: National Passenger Rail Corporation (Amtrak), Amtrak Annual Report, Statistical Appendix (Washington, DC: Annual Issues) (transportation revenues / passenger-miles).
2003-13: Association of American Railroads, Railroad Facts (Washington, DC: Annual Issues), p. 77 and similar pages in previous editions (passenger revenue/revenue passenger-miles).
2014-15: Amtrak, Monthly Performance Review for September 2015 (November 13, 2015), Tables A.2-2, A4-2, available at https://www.amtrak.com/ccurl/322/821/Amtrak-Monthly-Performance-Report-September-2015-Preliminary-Unaudited.pdf as of Mar. 28, 2017.

Consumer Price Index: U.S. Department of Labor, Bureau of Labor Statistics, Consumer Price Index-Urban, U.S. All Items Indexes, available at http://www.bls.gov/cpi/ as of November 2017.

FIGURE 5-13 Revenue per Unit of Output of Freight Transportation Modes: 1990–2016



NOTE: Shaded areas indicate U.S recessions, as defined by the National Bureau of Economic Research.

[a] For 1990 and later, air carriers that did not report both financial data and all months of traffic data for a given period were excluded from the calculations. Cargo revenue includes both scheduled and charter property revenue and mail revenue.
[b] General freight common carriers, most of which are LTL (less-than-truckload) carriers.

SOURCES: Air carrier, domestic, scheduled service (freight): U.S. Department of Transportation, Bureau of Transportation Statistics, TranStats Database, T-1, Schedule P-11, and Schedule P-12 data, available at http://www.transtats.bts.gov/ as of Sep. 1, 2015, special tabulation.
Truck: 1990-2003: Eno Transportation Foundation, Inc., Transportation in America (Washington, DC: 2007), p. 46.
2004-07: U.S. Department of Commerce, U.S. Census Bureau, 2009 Transportation Annual Survey (Washington, DC: January 2011), Table 2.1, available at http://www.census.gov/services/ as of Aug. 9, 2011, special tabulation.
Class I rail: Association of American Railroads, Railroad Facts (Washington, DC: Annual Issues), p. 34 and similar pages in previous editions.

been smaller than other sectors. Prior to the 2007 to 2009 economic recession and between 2003 and 2007, transportation—with an average annual growth rate of 0.14 percent—contributed significantly less than the manufacturing, service, and finance—which all had average annual growth rates in excess of 0.50 percent (figure 5-14). During that period, the U.S. economy grew on average 2.73 percent per year. During the 2007 to 2009 economic recession, almost all sectors, including transportation, experienced negative growth. Since the recession, transportation has contributed positively to economic growth. However, transportation's average annual contribution to economic growth of 0.06 percent from 2009 to 2014 (the latest available year) is below its 2003-2007 pre-recession level of 0.14 percent.

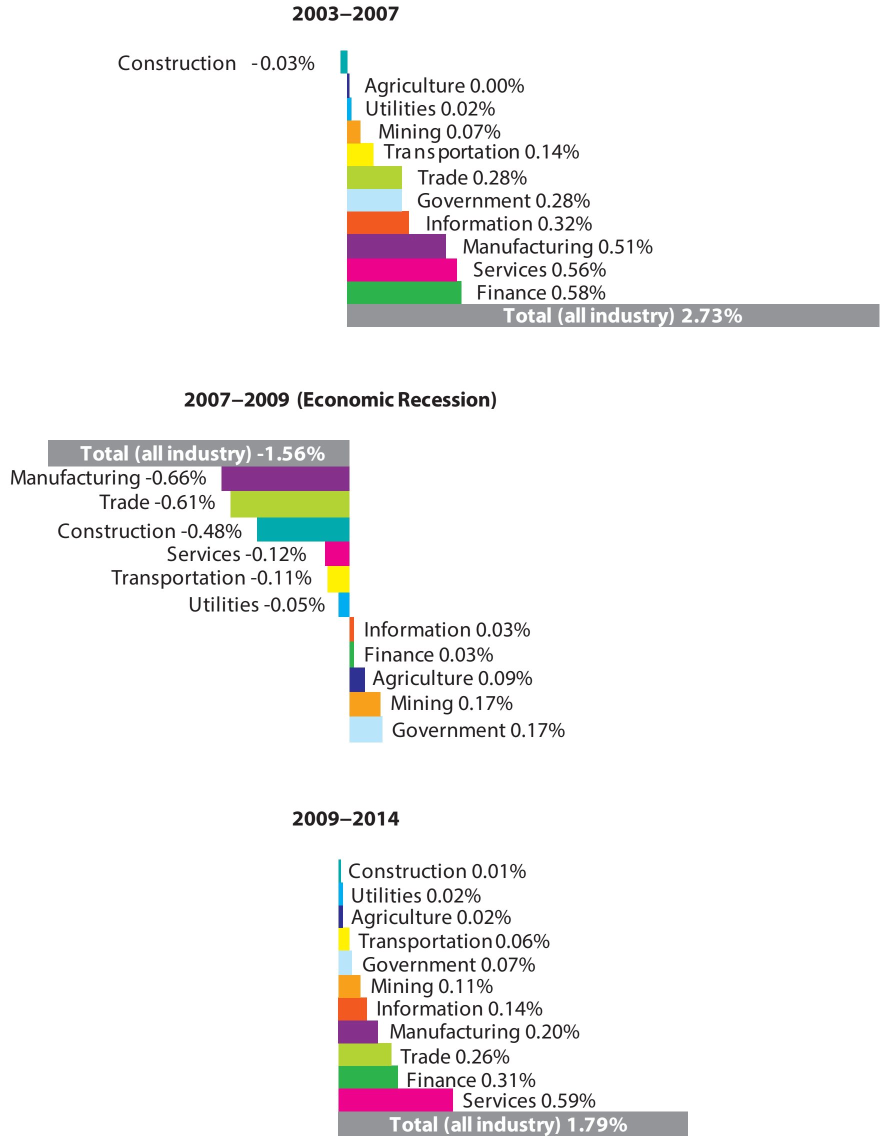
Transportation Expenditures and Revenues

Household Spending

In 2016 total national expenditures on transportation by and on behalf of U.S. households amounted to $1,196 billion, making it the fourth largest expenditure category (excluding other) after healthcare, housing, and food (figure 5-15). Ninety-one percent of personal transportation expenditures went to the purchase, operation, and upkeep of personal vehicles [USDOC BEA 2017b].

Between 2000 and 2016, household transportation expenditures increased 42.7

FIGURE 5-14 Sources of Economic Growth: Average Annual Growth Rate by Industry

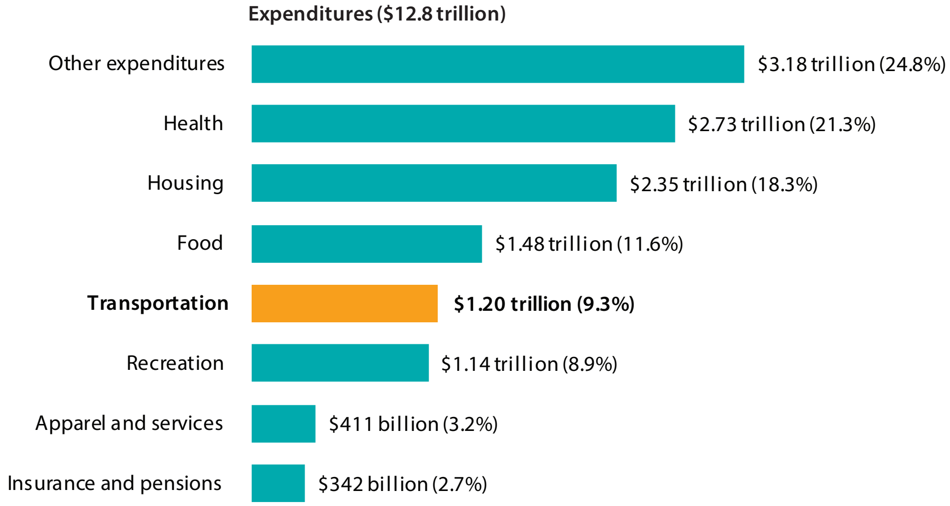


NOTES: Finance includes: Finance and insurance and Real estate rental and leasing. The service sector includes: Professional and business services; Education and health services; Leisure and hospitality; and Other services (NAICS 54-81).

SOURCE: U.S. Department of Commerce, Bureau of Economic Analysis, Integrated Industry-Level Productivity Account, http://www.bea.gov as of May 2017.

percent, from $838 billion to $1,196 billion. The growth in total expenditures outpaced the growth in transportation expenditures, increasing 88.8 percent, from $6.79 trillion to $12.82 trillion over the same period. Expenditure growth for healthcare (145.6 percent), housing (93.5 percent), and food (83.5 percent) outpaced expenditure growth for transportation. As a result, the percentage of total expenditures for transportation declined from 12.3 percent in 2000 to 9.3 percent in 2016. [USDOC BEA 2017b]

FIGURE 5-15 Total National Household Expenditures (major expenditure categories), 2016



NOTES: "Other expenditures" include alcoholic beverages purchased for off-premises consumption; furnishings, household equipment, and routine household maintenance; education; accommodations; financial services (excluding pension funds); other goods and services; net foreign travel and expenditures abroad by U.S. residents; and final consumption expenditures of nonprofit institutions serving households.

SOURCE: U.S. Department of Commerce, Bureau of Economic Analysis, National Income and Product Accounts Tables, Table 2.5.5, 2.4.5U, available at http://www.bea.gov/iTable/index_nipa.cfm as of August 2017.

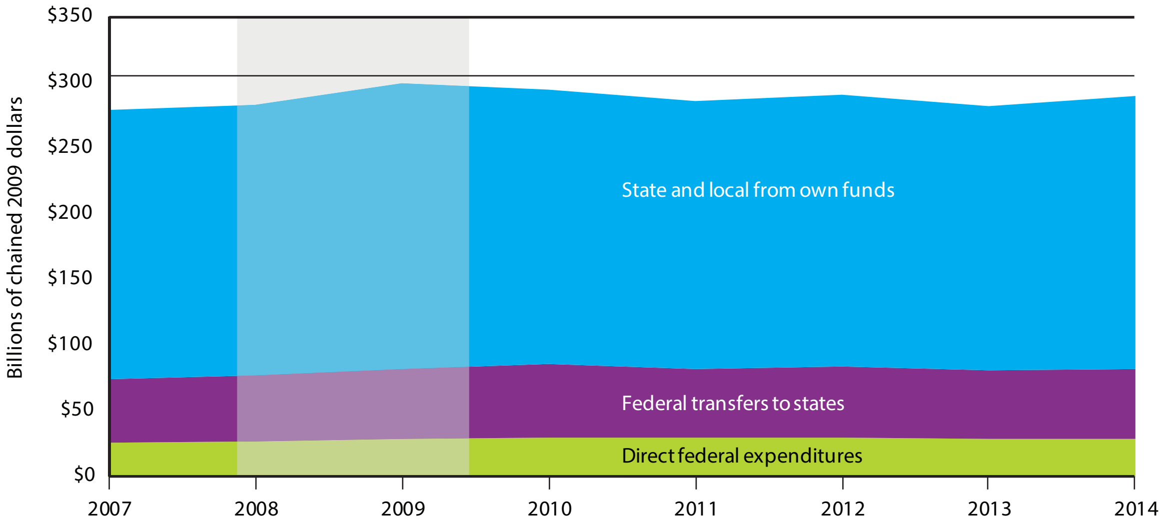
Public and Private Sector Expenditures and Revenue

Expenditures

Most government spending on transportation takes place at the state and local levels, although state and local capital expenditures are often paid for in part with federal funds (figure 5-16). In 2014 the Federal Government spent $32.8 billion on transportation (excluding federal grants to states), and state and local governments spent $291.2 billion (including expenditures paid with federal grants). In real 2009 dollars, transportation expenditures at all levels of government have increased since 2007. From 2007 to 2014, real direct federal expenditures increased by 10.4 percent (from $25.6 billion to $28.2 billion). Real federal transfers to states increased 10.7 percent (from $48.8 billion to $54.1 billion), while real state and local expenditures (excluding expenditures paid for with federal funds) increased by only 1.7 percent (from $204.3 billion to $207.8 billion). Governments increased transportation spending following the 2007 to 2009 recession to stimulate the economy. In 2009 the Federal Government enacted the American Recovery and Reinvestment Act of 2009, which authorized $48.1 billion in transportation stimulus spending. As a result, transportation expenditures by the Federal Government (direct federal expenditures and federal transfers to states) reached a peak in 2010 at $85.2 billion.

Most federal spending (excluding federal grants to states) is for aviation ($16.9 billion in 2014, or 51.7 percent) followed by water ($8.3 billion, or 25.3 percent) and highways ($3.2

FIGURE 5-16 Federal, State, and Local Government Expenditures, 2007 to 2014 (billions of chained 2009 dollars)



NOTES: Shaded area indicates economic recession.net foreign travel and expenditures abroad by U.S. residents; and final consumption expenditures of nonprofit institutions serving households.

SOURCE: U.S. Department of Transportation, Bureau of Transportation Statistics, Government Transportation Financial Statistics, available at www.bts.gov.

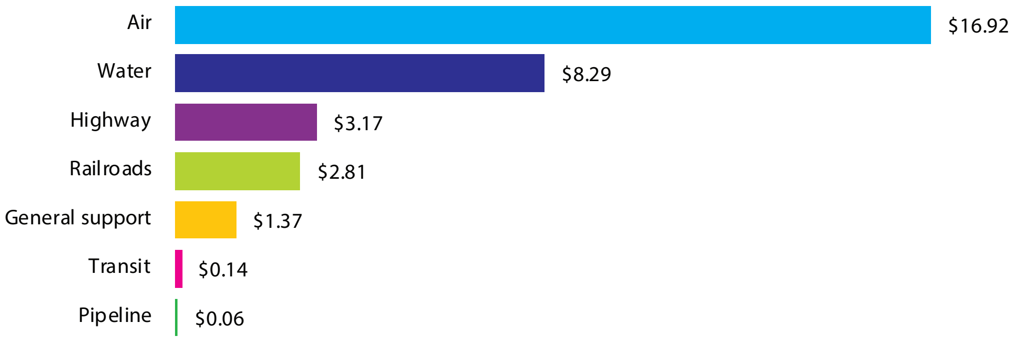
billion, or 9.7 percent) (figure 5-17). In real 2009 dollars, federal highway peaked in 2011 with the recession stimulus spending, and then declined. [USDOT BTS 2017a]

In 2014, most state and local spending (including expenditures paid for with federal grants) on transportation went to highways ($203.9 billion, or 70.0 percent) and transit ($59.6 billion, or 20.5 percent) (figure 5-18). In real 2009 dollars, both state and local highway and transit expenditures have increased from 2007 to 2014—highways by 2.2 percent and transit by 12.0 percent. Highway and transit spending peaked in 2009 as a result of transportation stimulus spending. [USDOT BTS 2017a]

In 2016 private and public spending on transportation construction totaled $133.2 billion (figure 5-19). The public sector is the major funding source for transportation infrastructure construction, especially for streets and highways. In 2016 the value of government-funded (public) construction underway accounted for 90.8 percent ($120.9 billion) of total spending on transportation construction, and private transportation construction accounted for the remaining 9.2 percent ($12.2 billion). Approximately three-quarters of government-funded investment was for highways ($90.5 billion); the remainder supported the construction of air, land, and water transportation facilities ($30.4 billion). Investment has been growing since 2002

FIGURE 5-17 Federal Transportation Expenditures by Mode: 2014 (billions)

Total Federal Transportation Expenditures = $32.7 billion

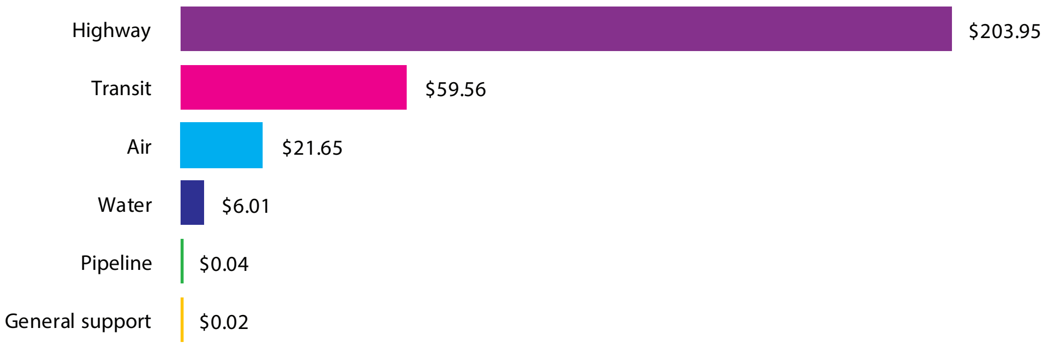


NOTES: Federal expenditure includes direct federal spending, excluding grants to state and local governments. State and local expenditure includes outlays from all sources of funds including funds from Federal grants.

SOURCE: US Department of Transportation, Bureau of Transportation Statistics, Government Transportation Financial Statistics 2017, available at www.bts.gov as of December 2017.

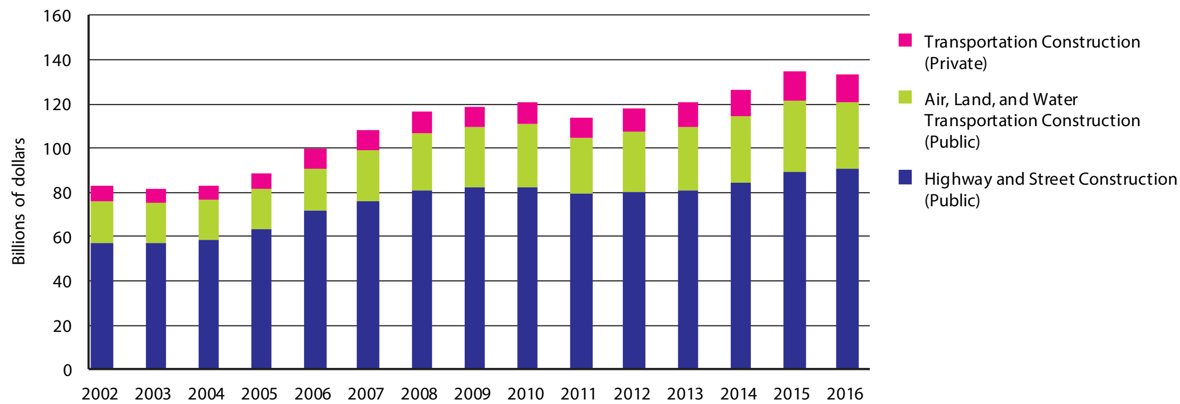
FIGURE 5-18 State and Local Expenditures by Mode: 2014 (billions)

Total State and Local Transportation Expenditures = $291.2 billion



SOURCE: US Department of Transportation, Bureau of Transportation Statistics, Government Transportation Financial Statistics 2017, available at www.bts.gov as of December 2017.

FIGURE 5-19 Value of Transportation Infrastructure Construction Put in Place (current dollars): 2002–2016



SOURCE: U.S. Department of Commerce, Census Bureau, Value of Construction Put in Place, Not Seasonally Adjusted (2002-2016), available at http://www.census.gov/ as of May 2017.

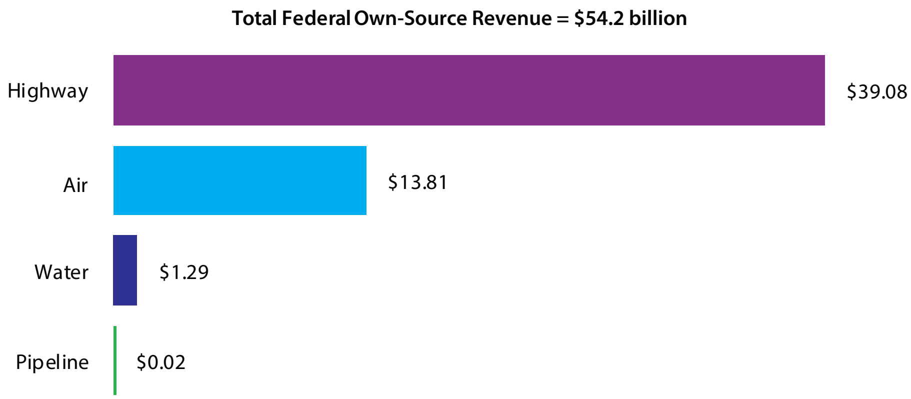
despite a slight decline in 2011 associated with the terminus of *American Recovery and Reinvestment Act of 2009* (Pub. L. 111–5) stimulus spending on transportation and a slight decline in 2016 ($1.8 billion decrease from 2015). [USDOC CENSUS 2017]

Revenue

Government transportation revenue comes from user taxes and fees, such as gasoline taxes and tolls, air ticket taxes and fees, and general revenues, as well as income from investing transportation funds and receipts from fines and penalties. In 2014 government revenue collected and dedicated to transportation programs totaled $355.7 billion. A portion of this revenue ($183.6 billion, or 51.6 percent) comes from taxes and charges levied on transportation-related activities, while $172.1 billion (48.4 percent) comes from non-transportation-related activities but supports transportation programs (e.g., state or local sales or property taxes used to finance transportation projects). In real 2009 dollars, total revenue collected by the government and dedicated to transportation programs increased by 9.9 percent from 2007 to 2014. [USDOT BTS 2017a]

Highway and air transportation, which have trust funds supported by dedicated taxes, accounted for 97.6 percent of federal transportation revenue in 2014. The Federal Government collected $39.1 billion (72.1 percent) in highway revenues (from the Highway Trust Fund) and $13.8 billion (25.5 percent) in aviation revenues (almost entirely from the Airport Airway Trust Fund), as well as $1.3 billion (2.4 percent) in water transportation revenues and $0.02 billion (0.03 percent) in pipeline revenues (figure 5-20). In real 2009 dollars, Highway Trust Fund revenues decreased by 16.9 percent from 2007 to 2014 [USDOT BTS 2017a]. The Federal Government has not increased the federal taxes for gasoline and diesel—18.4 cents per gallon for gasoline and 24.4 cents per gallon

FIGURE 5-20 Federal Own-Source Revenue by Mode: 2014 (billions)



NOTE: Own-source refers to taxes and charges levied on transportation-related activities and used specifically for transportation purposes.

SOURCE: US Department of Transportation, Bureau of Transportation Statistics, Government Transportation Financial Statistics 2017, available at www.bts.gov as of December 2017.

for diesel—since October 1997, causing real revenues to decline. Revenues also declined because vehicle gas mileage improved over the last two decades and because vehicle-miles traveled declined during the 2007 to 2009 recession.

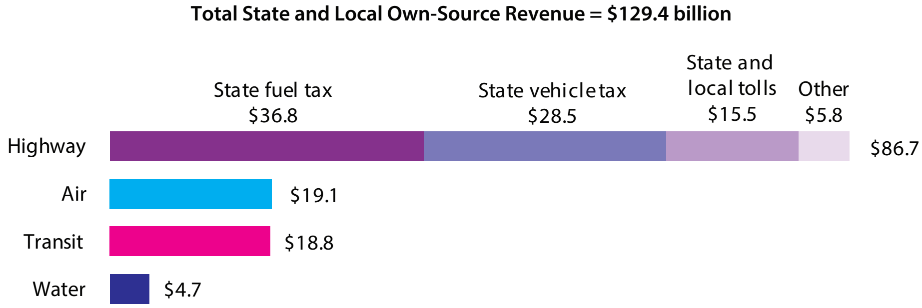
State and local governments collected $247.3 billion of the $355.7 billion government transportation revenues. Of this revenue, the state and local governments collected $129.4 billion from transportation-related activities, most of which is from highway revenue sources ($86.7 billion, or 67.0 percent of transportation revenue in 2014), which include fuel taxes, motor vehicle taxes, and tolls (figure 5-21). Aviation-related revenue ($19.1 billion, 14.8 percent) comes from landing fees, terminal area rentals, and several other sources. Transit revenue ($18.8 billion, 14.6 percent) is almost entirely from fares.

Revenue collected from transportation-related activity and dedicated to transportation programs continues to fall short of government transportation expenditures. In 2014 transportation revenues covered 56.7 percent of expenditures. The gap between transportation revenues and expenditures has declined since 2009 and 2010, when revenues covered 52.5 percent of expenditures [USDOT BTS 2017a]. When revenues do not cover expenditures, general tax receipts (e.g., from sales and property taxes), trust fund balances, and borrowing are needed to cover shortages.

Cost of Transportation

The movement of goods and people requires the use of resources—labor, equipment, fuel, and infrastructure. The use of these resources is the cost of transportation. Producers and users of transportation services pay for the resources. Users of transportation services include businesses, government, and households. Businesses pay for transportation to acquire inputs for the goods they make and to deliver final products to consumers. Households

FIGURE 5-21 State and Local Own Source Revenue by Mode: 2014 (billions)



NOTE: Own-source refers to taxes and charges levied on transportation-related activities and used specifically for transportation purposes.

SOURCE: US Department of Transportation, Bureau of Transportation Statistics, Government Transportation Financial Statistics 2017, available at www.bts.gov as of December 2017.

purchase resources, such as motor vehicles and motor vehicle fuel, for travel by automobile.

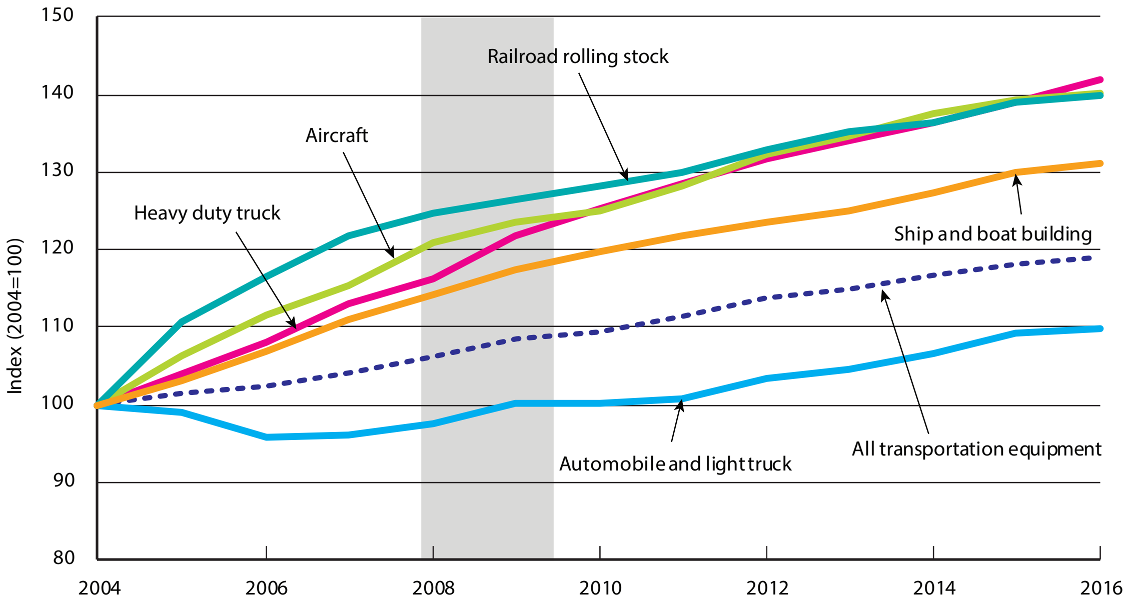
Costs Faced by Producers of Transportation Services

There are two types of transportation services provided: freight transportation services provided to producers of goods and service (e.g., trucking and air freight); and passenger transportation services provided to both producers and household consumers. The major inputs to produce transportation services include transportation equipment, fuel, labor, other materials and supplies, as well as the depreciation of items like airplanes, trucks, railroad locomotives and freight cars, trucking terminals, and railroad track and other infrastructure. The price of these inputs impacts the price of for-hire freight and passenger transportation services.

The costs faced by producers of transportation services for purchasing transportation equipment increased continuously between 2004 and 2016, except for automobiles and light-duty motor vehicles (figure 5-22).[5] The costs faced when purchasing automobiles and light-duty vehicles declined between 2004 and 2006, rose slightly in 2008 and 2009 (but remained below its 2004 level), leveled off in 2010, and finally increased in 2011 through 2016. The costs faced for railroad, aircraft, heavy-duty truck, and ship and boat manufacturing increased more than for all transportation equipment combined. This increase in equipment prices potentially impacts the profitability and purchase decisions of transportation sectors, the transportation costs for transportation users, and/or prices in other sectors that use transportation services, such as wholesale, retail, and warehousing and storage industries.

[5] The Bureau of Labor Statistic's Producer Price Index (PPI) for transportation equipment (which includes indexes for automobile and light motor vehicles, aircraft, railroad rolling stock, heavy-duty trucks, ships and boats, and all transportation equipment) reflects changes in transportation equipment prices faced by transportation service providers. The actual prices transportation service providers pay may differ from the prices sellers receive for the transportation equipment they sell because of government subsidies, sales and excise taxes, and distribution costs.

FIGURE 5-22 Average Price Change in Purchasing Transportation Equipment Faced by Transportation Providers: 2004–2016



NOTE: Annual averages. Rebased to 2004. 2016 data are preliminary and subject to revision. Aircraft are civilian aircraft only. Shaded areas indicate U.S recessions, as defined by the National Bureau of Economic Research.

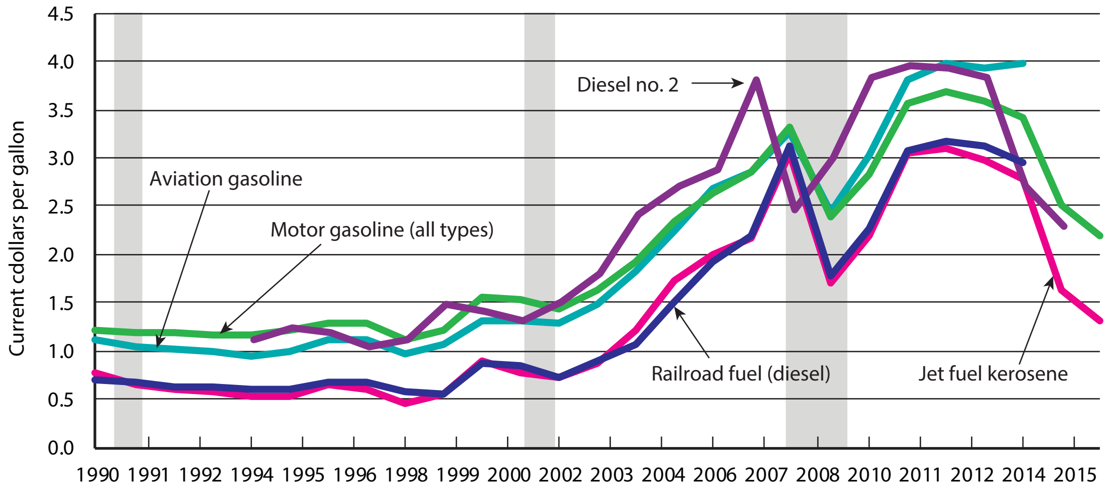
SOURCE: U.S. Department of Labor, Bureau of Labor Statistics, Producer Price Index Industry Data, available at http://www.bls.gov as of May 2017.

Transportation fuel prices also impact the price of freight and passenger transportation and the demand for transportation. An increase in fuel prices, for instance, may reduce the demand for transportation modes reliant on that fuel and shift demand to transportation modes that use less costly fuels. Average annual fuel prices for all classes of transportation fuels, except aviation gasoline and railroad diesel fuel, peaked in 2012 and have since declined. The average annual fuel price for gasoline peaked at $3.70 in 2012 and declined 40.4 percent to $2.20 in 2016 (figure 5-23). The most recent data for aviation gasoline and railroad diesel fuel show little change in price between 2012 and 2014 (the most recent year for which data are available).

Costs Faced by Purchasers of Transportation Services

The prices that transportation companies charge for transportation impact freight shippers' and travelers' transportation decisions. Despite periods of modest decline, businesses purchasing transportation services saw an overall increase in the relative prices for air, rail, truck, water, and pipeline transportation services between 2004 and 2016. During that time the costs faced by businesses to purchase rail services grew by 54.7 percent, more rapidly than that for any other transportation mode, except pipeline, which grew 128.1 percent. The costs faced to purchase truck, water, and air transportation

FIGURE 5-23 Sales Price of Transportation Fuel to End-Users (dollars/gallon): 1990–2016



NOTE: Aviation and railroad fuel data through 2014. Shaded areas indicate U.S recessions, as defined by the National Bureau of Economic Research.

SOURCE: All data except railroad fuel: U.S. Department of Energy, Energy Information Administration, Monthly Energy Review (Washington, DC: April 2016), tables 9.4 and 9.7, available at http://www.eia.doe.gov/emeu/mer/prices.html as of May 2017.
Railroad fuel: Association of American Railroads, Railroad Facts (Washington, DC: Annual Issues), p. 61.

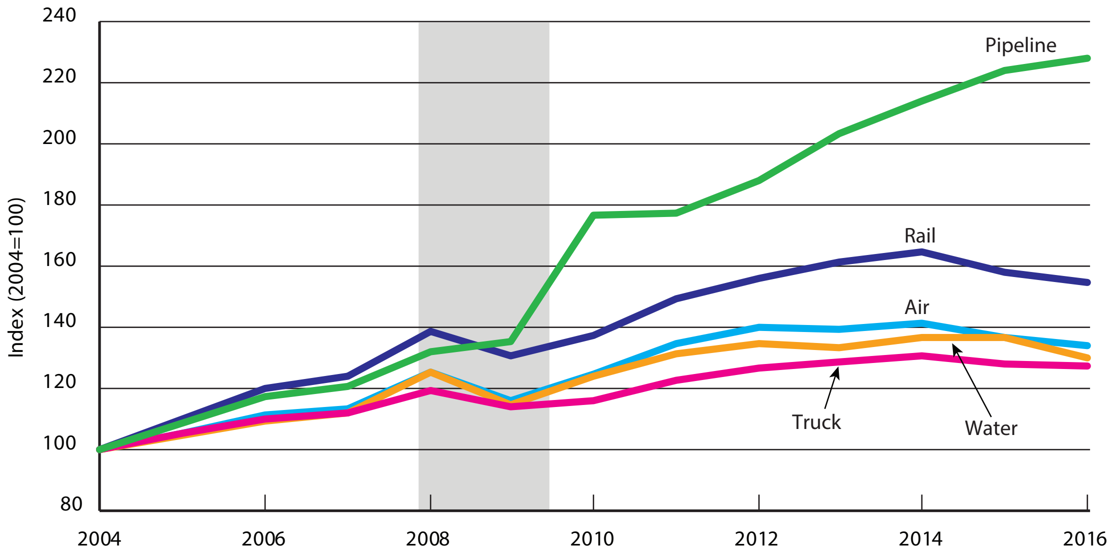
services also increased, with trucking services growing at a slightly slower rate (27.4 percent) than water (29.9 percent) and air (33.9 percent). Transportation service prices declined during the 2007 to 2009 recession, after which they climbed steadily through 2014. The average price of air, rail, and truck transportation services declined between 2014 and 2016, while water transportation service prices rose in 2015 but then declined below the 2014 level in 2016 (figure 5-24).

Costs Faced by Households

The costs households face for transportation services (e.g., air travel) and goods used for transportation (e.g., motor vehicle fuel) impact households' spending decisions. Most passenger travel in the United States is by personal motor vehicle. The cost of owning and operating personal motor vehicles impacts household travel behavior—what mode households choose, how often they travel, and how far.

The cost of owning and operating a personal motor vehicle includes insurance, license, registration, taxes, depreciation, and finance charges (ownership costs) as well as gasoline, tires, and maintenance (operating costs). In 2015 it cost 57.1¢ per mile to own and operate a personal motor vehicle. Ownership costs continue to account for nearly three-fourths of the total annual cost of owning and operating a personal motor vehicle on a cents-per-mile basis. Looking at operating costs, the cost of both gasoline (the largest operating cost) and maintenance grew from 1990 through 2015, while the cost of tires rose from 1990 through 2003, declined in 2004, and then increased

FIGURE 5-24 Average Changes to Transportation Prices Faced by Businesses Purchasing Transportation Services: 2004–2016



NOTE: Annual averages. Rebased to 2004. Shaded areas indicate U.S recessions, as defined by the National Bureau of Economic Research.

SOURCE: U.S. Department of Labor, Bureau of Labor Statistics, Producer Price Index Industry Data, available at http://www.bls.gov as of May 2017.

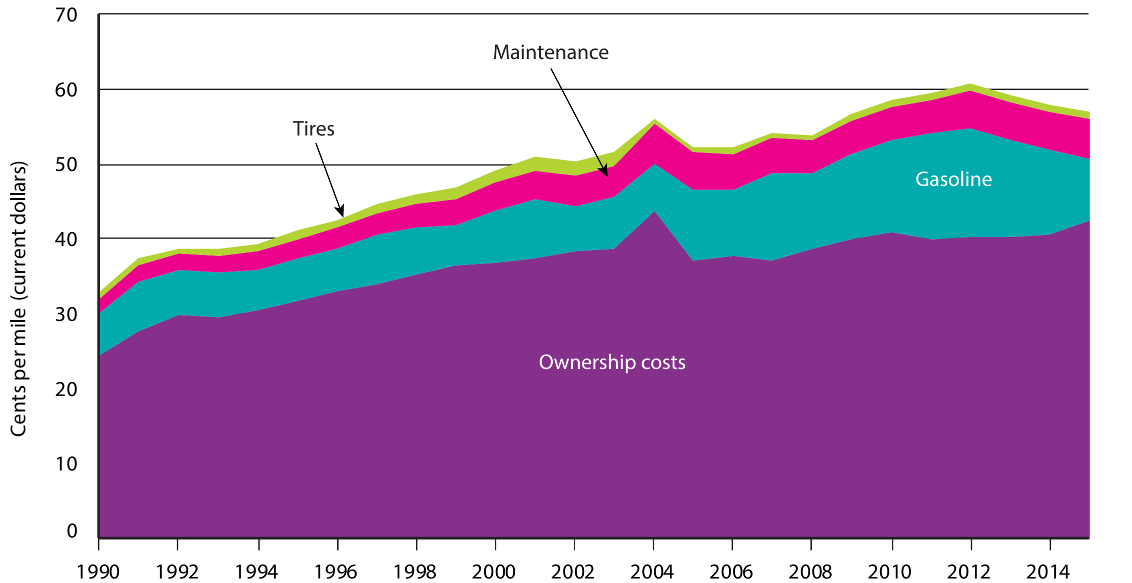
slightly between 2008 and 2015. In the most recent years, the average total cost of gasoline per mile fell from a high of 14.5¢ per mile in 2012 to 8.5¢ in 2015. This decline contributed significantly to the steady decline in the average total cost of owning and operating a personal motor vehicle (assuming 15,000 vehicle-miles per year), which peaked at 60.8¢ in 2012 and fell to 57.1¢ per mile in 2015 (figure 5-25).

According to the Consumer Price Index for Urban Consumers (CPI-U)[6], the average price of owning and operating a personal motor vehicle (private transportation in the CPI-U) rose 59.5 percent between 1990 and 2016, albeit less than for all goods and services (83.6 percent). Of personal motor vehicle ownership and operating costs, motor vehicle insurance prices increased the most between 1990 and 2016, growing 175.0 percent. The average price of new vehicles grew the least, increasing only 21.4 percent over the same period. [USDOL BLS 2017a]

The total average price of owning and operating a personal motor vehicle grew less (at 59.5 percent) than the average cost of public transportation (86.1 percent) between 1990 and 2016 [USDOL BLS 2017a]. The rise in airfare and intracity transportation prices drove the growth in public transportation prices between 1990 and 2016 (figure 5-26).

[6] The Consumer Price Index for Urban Consumers (CPI-U) measures the change in prices paid by urban consumers for particular goods and services, such as ones related to transportation.

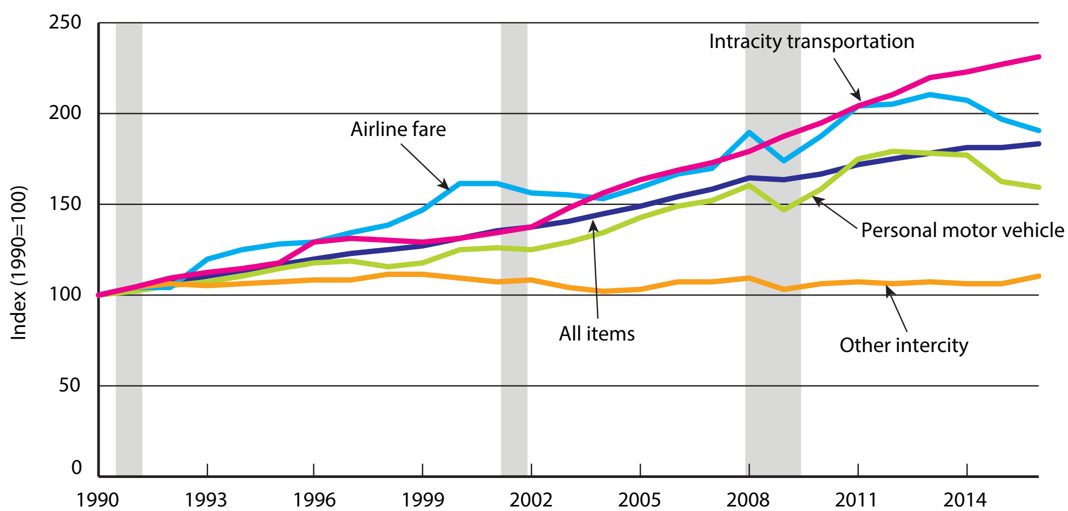
FIGURE 5-25 Average Cost of Owning and Operating an Automobile (assuming 15,000 vehicle-miles per year): 1990–2015



NOTE: Figure reflects the average cost of operating a vehicle 15,000 miles per year in stop and go conditions. Ownership costs include insurance, license, registration, taxes, depreciation, and finance charges.

SOURCE: American Automobile Association, Your Driving Costs (Heathrow, FL: Annual Issues), available at http://www.aaapublicaffairs.com as of August 2016.

FIGURE 5-26 Average Changes to Transportation Prices Paid by Urban Consumers: 1990–2016



NOTE: Annual averages. Rebased to 1990. Shaded areas indicate U.S recessions, as defined by the National Bureau of Economic Research.

SOURCE: U.S. Department of Labor, Bureau of Labor Statistics, Consumer Price Index (CPI-U) Data, available at http://www.bls.gov as of May 2017.

Transportation as a Component of International Trade

Transportation and Trade

Transportation enables the export of American goods and services and connects U.S. businesses to sources of raw materials and consumers to imported goods. An efficient and reliable domestic transportation system with good connections to the international transportation system supports the United States in the global marketplace. Transportation not only enables international trade but also is a major good and service traded.

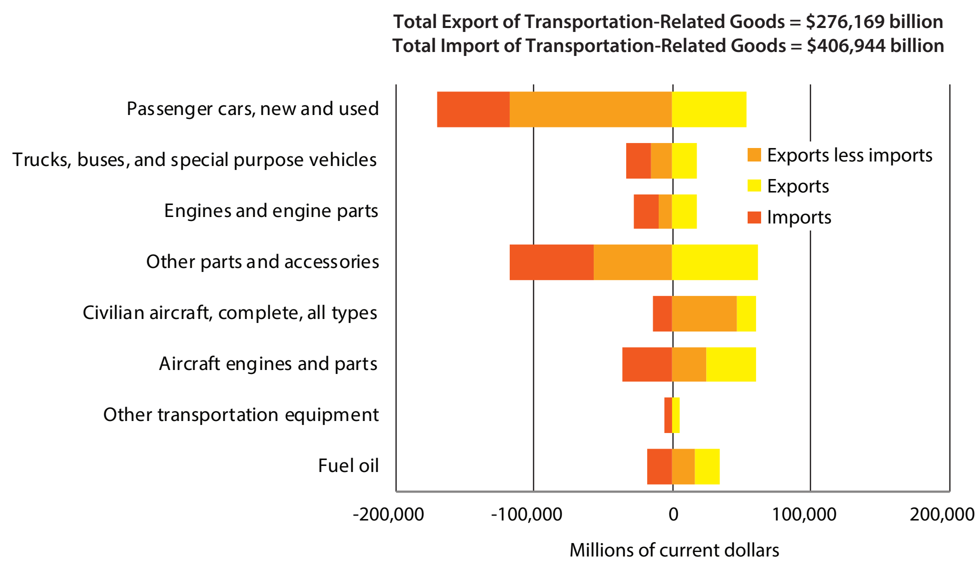
The value of goods traded (the total value of exports and imports) was $3.7 trillion in 2016 (current dollars). After accounting for inflation, the real value of goods traded grew from 2000 to 2016, despite a slight decline during the 2007 to 2009 recession. Exports account for an increasing share of the total value of goods traded, but imports in goods continue to exceed exports. In 2016 the goods deficit (exports minus imports) was $749.9 billion in current dollars [USDOC BEA 2017e].

In 2016, 18.6 percent ($683.1 billion) of all goods traded internationally were related directly to transportation.[7] Fuel oil comprised an additional 1.4 percent of all goods traded in 2016 [USDOC BEA 2017d]. Across all goods traded related to transportation, new and used passenger cars accounted for the largest share. In 2016 imports of transportation-related goods exceeded exports except for civilian aircraft, aircraft engines and parts, and fuel oil[8] (figure 5-27).

[7] Includes automotive vehicles, parts, and engines; civilian aircraft, engines, and parts; and other transportation equipment.

[8] Fuel oil is a petroleum product used, for example, to heat homes.

FIGURE 5-27 U.S. Trade of Transportation-Related Goods: 2016



SOURCE: U.S. Department of Commerce, Bureau of Economic Analysis, International Transactions (ITA), Table 2.1 U.S. International Trade in Goods. Interactive, Annual. Available at http://www.bea.gov/itable/ as of May 2017.

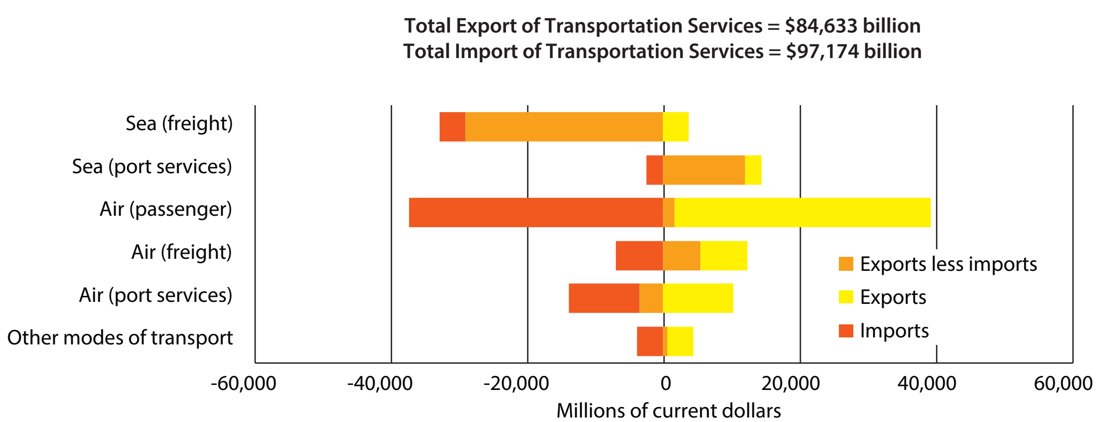
Transportation services are used to move goods from and to the United States. In 2016, $1.8 trillion (14.5 percent) of all services traded were related directly to transportation [USDOC BEA 2017c]. The value of transportation services traded captures:

1. passenger fares paid by U.S. residents to foreign airline carriers and foreign vessel operators as well as the passengers fares paid by foreign residents to U.S. airline carriers and U.S. vessel operators,
2. the freight charges for moving goods from and to the United States, and
3. the expenses that transportation companies incur in foreign ports (i.e., goods and services procured by foreign carriers in U.S. ports and by U.S. carriers in foreign ports) [USDOC BEA 2017f]

The fares and fees received by U.S. carriers to move goods and people to foreign countries exceeds the fares and fees received by foreign carriers bringing goods and people to the United States. However, since 2007 the amount received by foreign carriers for bringing goods and people to the United States accounts for an increasing share of total fares and fees paid to move goods and people to and from the United States [USDOC BEA 2017c].

Air passenger transportation accounted for the largest share of the total fares and fees paid to move goods and people to and from the United States, followed by sea freight transportation. For all modes except sea freight transportation, the fares and fees paid to move goods and people to foreign countries nearly equaled the fares and fees received by foreign carriers bringing goods and people to the United States. For goods moved by sea, the fares and fees received by foreign-operated vessels to bring goods to the United States exceeded the fares and fees paid to move goods to foreign countries (figure 5-28).

FIGURE 5-28 U.S. Trade of Transportation Services



NOTE: Port services are the expenses that transportation companies incur in foreign ports (i.e., goods and services procured by foreign carriers in U.S. ports and by U.S. carriers in foreign ports), excluding purchases of fuel which are counted in the goods exports and imports account.

SOURCE: U.S. Department of Commerce, Bureau of Economic Analysis, International Transactions (ITA), Table 3.1 U.S. International Trade in Goods. Interactive, Annual. Available at http://www.bea.gov/itable/ as of May 2017.

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CHAPTER 6

Transportation Safety

Highlights

- Highway deaths per 100 million vehicle-miles traveled rose from a historic low of 1.08 in 2014 to 1.18 in 2016 as deaths climbed from 32,744 to 37,461—a 14.4 percent increase in 2 years.
- Pedestrian deaths are the most since 1990. Pedestrian fatalities rose by over 1,000 between 2014 and 2016, reaching 5,987 in 2016—a 21.9 percent increase over the period and the most since 1990.
- Deaths of motorcycle riders grew from 4,594 in 2014 to 5,286 in 2016—a 15.1 percent increase. The rate of motorcyclist fatalities per vehicle mile of travel is 29 times greater than that for passenger car occupants. Also, they are 5 time more likely to be injured. Helmet use declined from 71 percent in 2000 to 65 percent in 2016.
- The estimated number of people injured in highway motor vehicle crashes increased by about 105,000 between 2014 and 2015, reaching 2.44 million.
- Alcohol use continues to be a major factor in transportation deaths and injuries. In 2016, 25 percent of motorcycle operators involved in fatal crashes were alcohol impaired, and alcohol use was the leading factor in 15 percent of fatal recreational boating accidents where the accident cause was known.
- It has been estimated that 3,258 motor vehicle occupants and motorcyclists who died in crashes in 2016 might have lived if they had used seat belts or motorcycle helmets, and 83 percent of the boaters who drowned in 2016 were not wearing a life jacket.
- Some 1,132 children aged 14 and under died, and an estimated 178,000 were injured in motor vehicle-related incidents in 2015—an average of about 3 deaths and 487 injuries a day.
- In the 2006 to 2015 period, a total of 301 school-aged children (18 and under) died in school transportation-related crashes—about 30 deaths per year on average.
- Trespassing-related fatalities accounted for 57.2 percent of the railroad deaths in 2016, and highway-rail crossing fatalities accounted for another one-third.
- Speeding continues to be the number one cited driver-related factor in highway fatal crashes. Almost half of speeding drivers in fatal crashes were found to have been drinking.

In 2016 total transportation fatalities were 39,565. Transportation fatalities are down from 44,582 in 2000, but up from 35,171 in 2010 and 37,501 in 2015 [table 6-1]. Overall, they have been consistently below 40,000 in recent years, but inching upward. This upward movement is primarily driven by highway fatalities.

Despite the 2015 and 2016 fatality increases, highway safety—and transportation safety as a whole—have improved in recent decades, resulting in a notable decline in fatalities and injuries. Even with growth in the U.S. population, more system users, and increased travel by all modes (as discussed in chapters 1 through 3), there were about 5,000 fewer total transportation fatalities in 2016 than in 2000—about 11 percent less. Still, transportation accounted for 25.2 percent of the total deaths resulting from unintentional injury in the United States in 2015 [USDHHS CDC VITALITY 2016].

As shown in box 6-A, the timeframe and definitions used to attribute a fatality to a transportation crash or accident differ among modes, reflecting different data collection methods, reporting periods, and information management systems of the various reporting agencies. For example, a death that occurs within 30 days of a crash involving highway vehicles is considered a highway fatality, while a death that occurs within 180 days of a rail

Box 6-A Fatality Definition by Mode

Mode (Source)	Definition	Citation
Air	Fatal injury means any injury which results in death within 30 days of the accident.	49 CFR 830.2
Hazardous material	Fatalities must be reported as soon as practical, but no later than 12 hours after the incident and death resulting from injury must be reported within 1 year of the date of incident.	49 CFR 171.15 and 49 CFR 171.16
Highway	Fatality means any injury which results in the death of a person at the time of the motor vehicle accident, or within 30 days of the accident.	49 CFR 390.5
Pipeline	Fatalities reported as soon as practical, but not more than 30 days after detection of an incident.	49 CFR 191.3 and 195.50
Railroad	Fatality means the death of a person within 24 hours of an accident. Also if an injured person dies within 180 days from the date of the injury.	49 CFR 840.2 and FRA Guide for Preparing Accident/Incident Reports
Rail transit	A fatality at the scene; or where an individual is confirmed dead within 30 days of a rail transit-related incident.	49 CFR 659.33
Recreational boating	Fatality means a person dies within 24 hours of the accident. Within 10 days of the occurrence or death if an earlier report is not required.	33 CFR 173 and 174

incident is considered a rail-related death. Such definitional differences pose challenges when comparing safety performance across modes of transportation.[1]

Fatalities by Mode

As shown in figure 6-1, there has been a major decrease in both the number and rate of highway fatalities over the last half century—with deaths per hundred million miles of highway vehicle travel falling from 5.50 in 1966 to a low of 1.08 in 2014, followed by a rise to 1.15 in 2015 and 1.18 in 2016.[2]

While figure 6-1 shows that the most dramatic improvement occurred in the 1970s and 1980s, progress continues despite growth in the U.S. population and number of drivers (see figure 6-2). However, highway fatalities increased by 14.4 percent between 2014 and 2016.

Despite recent increases in the number of highway fatalities, the highway mode has accounted for much of the overall reduction in transportation fatalities from 2000 to 2016. Other modes, however, including air carriers, railroads, transit, and recreational boating, also show improved safety records (Table 6-1). In 2016 more than 37,000 died in highway crashes and about 2,200 people died in accidents involving the non-highway modes. Relatively few passengers die in train or bus crashes in an average year; however, several hundred people on foot or people in motor vehicles die when struck by a train or by transit vehicles. Both general aviation and recreational boating result in the deaths of several hundred people each year—but this toll is far less than in earlier decades.

Highway

The USDOT National Highway Traffic Safety Administration (NHTSA) released preliminary 2016 and revised 2015 fatality data in October 2017. The data show two consecutive years of growth in highway fatalities. From an historic low of 32,744 fatalities in 2014, fatalities increased by over 4,700 over the next 2 years—reaching 37,461 in 2016. NHTSA noted that the last time the United States had this magnitude of back-to-back years of fatality increases was from 1963 to 1964 [USDOT NHTSA 2017a]. NHTSA found that distracted driving and drowsy driving-related fatalities declined, while deaths related to other reckless behaviors – including speeding, alcohol impairment, and not wearing seat belts—continued to increase. Motorcyclist and pedestrian deaths accounted for more than a third of the year-to-year increase [USDOT NHTSA 2017l].

Highway fatalities grew at a faster rate between 2014 and 2015 (8.3 percent) than between 2015 and 2016 (5.7 percent). Table 6-2 shows fatality change by highway component between 2014 and 2016; as shown, nearly all categories of highway fatalities increased in the two-year period.

The biggest numerical increases in fatalities between 2014 and 2016 were for occupants of passenger cars and light trucks, and pedestrians—each increasing by more than

[1] For further discussion of these different definitions, see chapter 6 of *Transportation Statistics Annual Report 2015* Box 6-B.

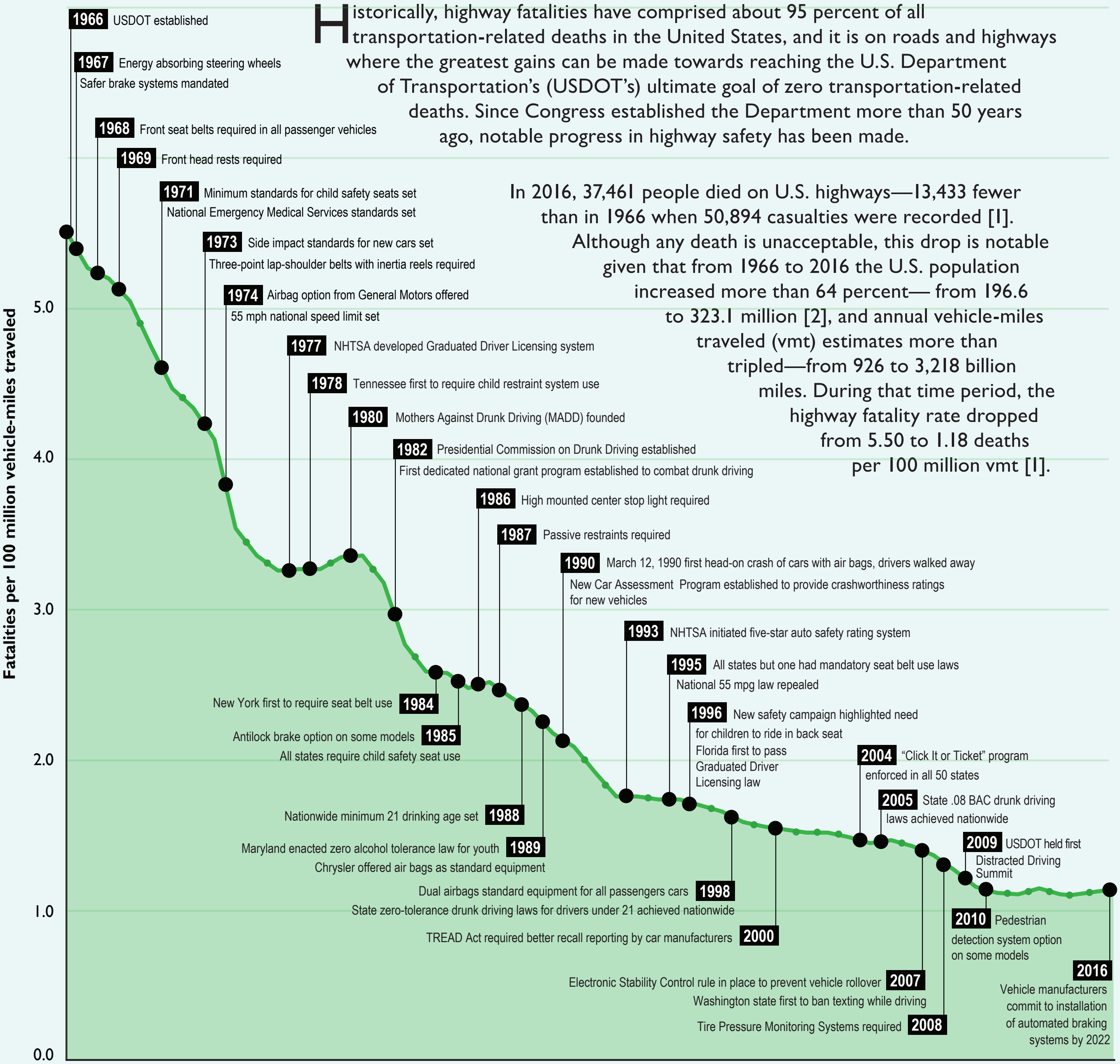
[2] The USDOT National Highway Traffic Safety Administration notes that the 2014 rate was the lowest since the agency began collecting fatality data through the Fatality Analysis Reporting System in 1975.

Figure 6-1: Highway Safety Improvements—1966 to 2016

Using 1966 as the base year, this graph plots the cumulative effect of safety innovations, over time, on annual highway fatalities per 100 million vehicle-miles traveled.

Historically, highway fatalities have comprised about 95 percent of all transportation-related deaths in the United States, and it is on roads and highways where the greatest gains can be made towards reaching the U.S. Department of Transportation's (USDOT's) ultimate goal of zero transportation-related deaths. Since Congress established the Department more than 50 years ago, notable progress in highway safety has been made.

In 2016, 37,461 people died on U.S. highways—13,433 fewer than in 1966 when 50,894 casualties were recorded [1]. Although any death is unacceptable, this drop is notable given that from 1966 to 2016 the U.S. population increased more than 64 percent— from 196.6 to 323.1 million [2], and annual vehicle-miles traveled (vmt) estimates more than tripled—from 926 to 3,218 billion miles. During that time period, the highway fatality rate dropped from 5.50 to 1.18 deaths per 100 million vmt [1].



Fatalities per 100 million vehicle-miles traveled climbed from 1.08 in 2014 to 1.18 in 2016 as fatalities increased 14.4 percent.

1966—A Pivotal Year for Highway Safety

Fifty-one years ago, on September 9, 1966, in answer to an alarming growth in annual highway-related deaths, President Lyndon Johnson signed both the National Traffic and Motor Vehicle Safety Act and the Highway Safety Act into law [3]. And on October 15, 1966, Congress established the USDOT with a multimodal mission to "Serve the United States by ensuring a fast, safe, efficient, accessible and convenient transportation system ..." [4]. This legislation also established the agency that 4 years later would become the National Highway Traffic Safety Administration (NHTSA).

Although these actions firmly established the Federal Government's responsibility for setting and enforcing transportation safety standards for all modes of transportation, the greatest impact would be on highway safety.

A Snowball Effect

Since 1966 there has been a dramatic drop in highway deaths. Many factors are responsible for this decrease—both regulatory and social:

• Safer vehicle designs and new safety technologies, such as seat belts, air bags, and electronic stability control, combined with programs to increase the use of seat belts and other safety equipment. NHTSA estimates that these technologies saved more than 600,000 lives from 1960 through 2012—nearly 28,000 in 2012 alone, of which more than half were saved by seat belts [5].

• Safer roads, including major new infrastructure, such as completion of the Interstate Highway System and gradual improvements to existing roads, such as guardrails, lighting, and rumble strips.

• Behavioral safety programs, such as high-visibility enforcement and child occupant protection campaigns, have encouraged more people to buckle up, use appropriate child safety seats, and to drive sober.

• More comprehensive and standardized emergency medical services, more effective transport and trauma treatment, and developments in medicine that made injuries more survivable [5].

While it is not possible to pin an exact number of lives saved to a particular safety factor, regulatory or otherwise, it is possible to show the cumulative effect of these innovations over time.

The 1960s

The decade of the 60s would see highway fatalities increase 47.1 percent, from 36,399 deaths in 1960 to 53,543 deaths in 1969. In near parallel, vehicle-miles traveled (vmt) increased 47.8 percent, from about 720 billion to more than 1 trillion miles during that same time period. The number of highway fatalities would continue to increase well into the 1970s, until the effects of new regulations and social reforms finally kicked in.

The 1970s

From 1970 through 1979, nearly a half million lives (498,356) were lost on U.S. roads. In 1972 U.S. highways would claim 54,589 lives—the highest number ever recorded. But as the decade closed, highway deaths per 100 million vmt had dropped from 4.74 in 1970 to 3.34 by 1979, even as vmt increased 37.8 percent. Still, the 51,093 lives lost in 1979 nearly matched the 52,627 lost in 1970 [6].

The 1980s

At last, the decade of the 80s would show a notable drop in highway deaths, with 5,500 fewer lives lost in 1989 than in 1980 (45,582 v. 51,091). Even more remarkable, this drop occurred in the face of a 37.6 percent increase in vmt and a population that grew by nearly 20 million, pushing down the number of lives lost from 3.35 to 2.17 per 100 million vmt.

The 1990s

At first glance the drop in the annual number of lives lost at the beginning of the decade (44,599) versus those lost at the end of the decade (41,717) might seem unremarkable. But from 1990 through 1999 the U.S. population increased by more than 23 million, while the rate of lives lost on U.S. highways continued to fall, from 2.08 to 1.55 per 100 million vmt—a nearly 72 percent drop from the 5.50 deaths per 100 million vmt recorded in 1966.

A New Century

The first years of the 21st century saw the highway fatality rate per 100 million vmt drop nearly 23 percent, falling from 1.53 deaths per 100 million vmt in 2000 to 1.18 by 2016 [1]. By 2004 the 0.08 blood alcohol limit and the "Click It or Ticket" campaign were enforced nationwide. Distracted driving emerged as a new challenge, and intelligent transportation systems, electronic stability controls, and the advent of self-driving cars ushered in a new era of innovations designed to mitigate the effects of human error.

Getting to Zero

A number of active safety systems are now available or are under development: forward collision warning, active braking, rear-view backup cameras, parking assist, lane departure, and blind spot warning—all technologies aimed at reducing or eliminating the effects of human error. In addition to these systems, connected and automated vehicle technologies are poised to play prominent roles in further reducing highway fatalities.

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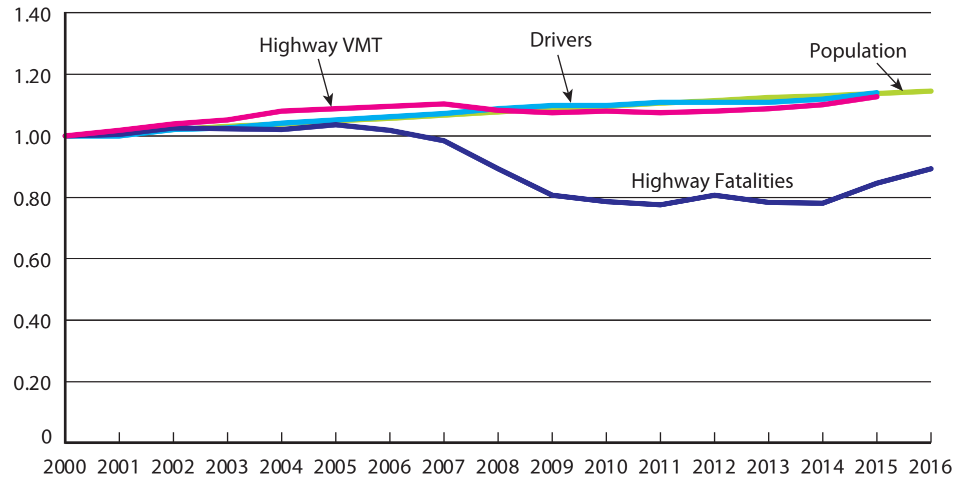
[5] U.S. Department of Transportation, National Highway Traffic Safety Administration, *Lives Saved by Vehicle Safety Technologies and Associated Federal Motor Vehicle Safety Standards, 1960 to 2012*, January 2015, www.its.dot.gov as of May 25, 2016.

[6] U.S. Department of Transportation, Federal Highway Administration, Office of Highway Policy Information, *Highway Statistics Series*, www.fhwa.dot.gov as of May 25, 2016.

FIGURE 6-2 Licensed Drivers, Resident Population, Highway Fatalities, Highway Vehicle-miles Traveled (VMT): 2000–2016



SOURCE: Drivers and Resident Population: U.S. Department of Transportation (USDOT), Federal Highway Administration, *Highway Statistics 2015*, tables DV-1C, available at http://www.fhwa.dot.gov/policyinformation/statistics/2015 as of October 2017. **Highway Fatalities and Highway VMT**: USDOT, Bureau of Transportation Statistics, *National Transportation Statistics*, tables 1-35 and 2-1, available at www.bts.gov as of October 2017

TABLE 6-1 Transportation Fatalities by Mode: Selected Years

	2000	2010	2015	2016	Change from 2015
TOTAL fatalities	**44,582**	**35,171**	**37,501**	**39,565**	↑
Air, total	764	477	404	412	↑
Highway, total	41,945	32,999	35,485	37,461	↑
Railroad, total[1]	937	735	751	791	↑
Transit rail, total[2]	197	120	151	148	↓
Water, total	701	821	700	737	↑
Pipeline, total	38	19	10	16	↑
Other counts, redundant with above					
Railroad, trespasser deaths not at highway-rail crossing	463	441	452	487	↑
Railroad, killed at public crossing with motor vehicle	306	136	127	131	↑
Rail, passenger operations	220	215	251	277	↑
Rail, freight operations	717	520	500	514	↑
Transit, non-rail	98	100	103	108	↑

[1] Includes Amtrak, Alaska Railroad, commuter railroads and freight railroads, and certain transit rail agencies reporting to the Federal Railroad Administration.

[2] Includes heavy rail transit (e.g., subway systems), light rail, streetcar rail, monorail and other track based transit operations reporting to the Federal Transit Administration.

NOTES: To reduce double counting, the following adjustments are made to **Total Fatalities**: For **Railroad**, fatalities involving motor vehicles at public highway-rail grade crossings are excluded because such fatalities are assumed to be included in Highway fatalities. For **Transit**, non-rail modes, including aerial tramway, motor bus, bus rapid transit, commuter bus, demand response, demand taxi, ferryboat, jitney, publico, trolleybus, and vanpool fatalities are excluded because they are counted as Transit, Water, and Highway fatalities. **Water** includes commerical and recreational vessels. **Other counts, redundant with above** help eliminate double-counting in the Total Fatalities.

SOURCES: **2000 and 2010**: Various sources as cited by U.S. Department of Transportation, Bureau of Transportation, National Transportation Statistics, table 2-1, available at www.bts.gov as of October 2017. **2015 and 2016**: Preliminary or revised data from the same sources cited in Table 2-1.

TABLE 6-2 Change in Highway Fatalities Between 2014, 2015, and 2016

TABLE 6-2a: 2014–2015

	2014		2015		Net increase	Percent change
Total Highway Fatalities	**32,744**	**100.0%**	**35,485**	**100.0%**	**2,741**	**8.37**
Passenger car occupants	11,947	36.5%	12,761	36.0%	814	6.81
Light truck occupants	9,103	27.8%	9,878	27.8%	775	8.51
Pedestrians	4,910	15.0%	5,495	15.5%	585	11.91
Motorcyclists	4,594	14.0%	5,029	14.2%	435	9.47
Other highway incidents[1]	761	2.3%	779	2.2%	18	2.37
Pedalcyclists	729	2.2%	829	2.3%	100	13.72
Large truck occupants	656	2.0%	665	1.9%	9	1.37
Bus occupants	44	0.1%	49	0.1%	5	11.36

TABLE 6-2b: 2015–2016

	2015		2016		Net increase	Percent change
Total Highway Fatalities	**35,485**	**100.0%**	**37,461**	**100.0%**	**1,976**	**5.57**
Passenger car occupants	12,761	36.0%	13,412	35.8%	651	5.10
Light truck occupants	9,878	27.8%	10,302	27.5%	424	4.29
Pedestrians	5,495	15.5%	5,987	16.0%	492	8.95
Motorcyclists	5,029	14.2%	5,286	14.1%	257	5.11
Other highway incidents[1]	779	2.2%	872	2.3%	93	11.94
Pedalcyclists	829	2.3%	840	2.2%	11	1.33
Large truck occupants	665	1.9%	722	1.9%	57	8.57
Bus occupants	49	0.1%	40	0.1%	-9	-18.37

TABLE 6-2c: 2014–2016

	2014		2016		Net increase	Percent change
Total Highway Fatalities	**32,744**	**100.0%**	**37,461**	**100.0%**	**4,717**	**14.41**
Passenger car occupants	11,947	36.5%	13,412	35.8%	1,465	12.26
Light truck occupants	9,103	27.8%	10,302	27.5%	1,199	13.17
Pedestrians	4,910	15.0%	5,987	16.0%	1,077	21.93
Motorcyclists	4,594	14.0%	5,286	14.1%	692	15.06
Other highway incidents[1]	761	2.3%	872	2.3%	111	14.59
Pedalcyclists	729	2.2%	840	2.2%	111	15.23
Large truck occupants	656	2.0%	722	1.9%	66	10.06
Bus occupants	44	0.1%	40	0.1%	-4	-9.09

[1]Includes occupants of other vehicle types, other nonmotorists, and unknown.

SOURCES: **2014**: U.S. Department of Transportation, Bureau of Transportation, National Transportation Statistics, table 2-1, available at www.bts.gov as of October 2017. **2015 and 2016**: Preliminary or revised data from the same sources cited in table 2-1.

1,000. The largest percentage increase was for pedestrians, up 21.9 percent in two years. Deaths of motorcyclists and pedalcyclists also increased over 15 percent [USDOT NHTSA 2017a].

In 2016 occupants of passenger cars and other light-trucks (e.g., sport utility vehicle, minivan, and pickup truck) comprised 35.8 and 27.5 percent, respectively of all highway fatalities (table 6-2). Pedestrian fatalities increased by almost 9 percent between 2015 and 2016. The share of bicyclist, motorcycle, large-truck, and bus occupant fatalities changed little, while the numbers increased.

Even with the recent spike in the highway fatalities, the overall rate of highway fatalities per 100 million VMT declined 22.6 percent from 1.53 in 2000 to 1.18 in 2016 (figure 6-3). Over time, occupant protection devices, advances in vehicle design, improved road design, graduated driver licensing for teenagers, expanded education and enforcement of drunk-driving laws, and many other preventative measures contributed to declines in highway vehicles deaths and injuries. Improvements in emergency medical response capabilities also played a role.

Not all categories of highway fatalities are lower today than in 2000, however. In 2016, 5,286 motorcyclists died—nearly 2,400 more than in 2000 and 692 more than in 2014, a 15-percent increase in 2 years. Growing ridership is a contributing factor to this increase. The rate of motorcyclist fatalities per vehicle mile of travel is 29 times greater than that for passenger car occupants in 2015 [NHTSA 2017c].

Deaths of bicyclists and other human-powered cyclists in 2016 are also higher than in 2000. More than 6,800 pedestrians and bicyclists died in highway accidents in 2016. Pedestrians and bicyclists—who often share the roads with motor vehicles—accounted for 17.2 percent of total transportation-related deaths in 2016, compared to 12.4 percent in 2000.

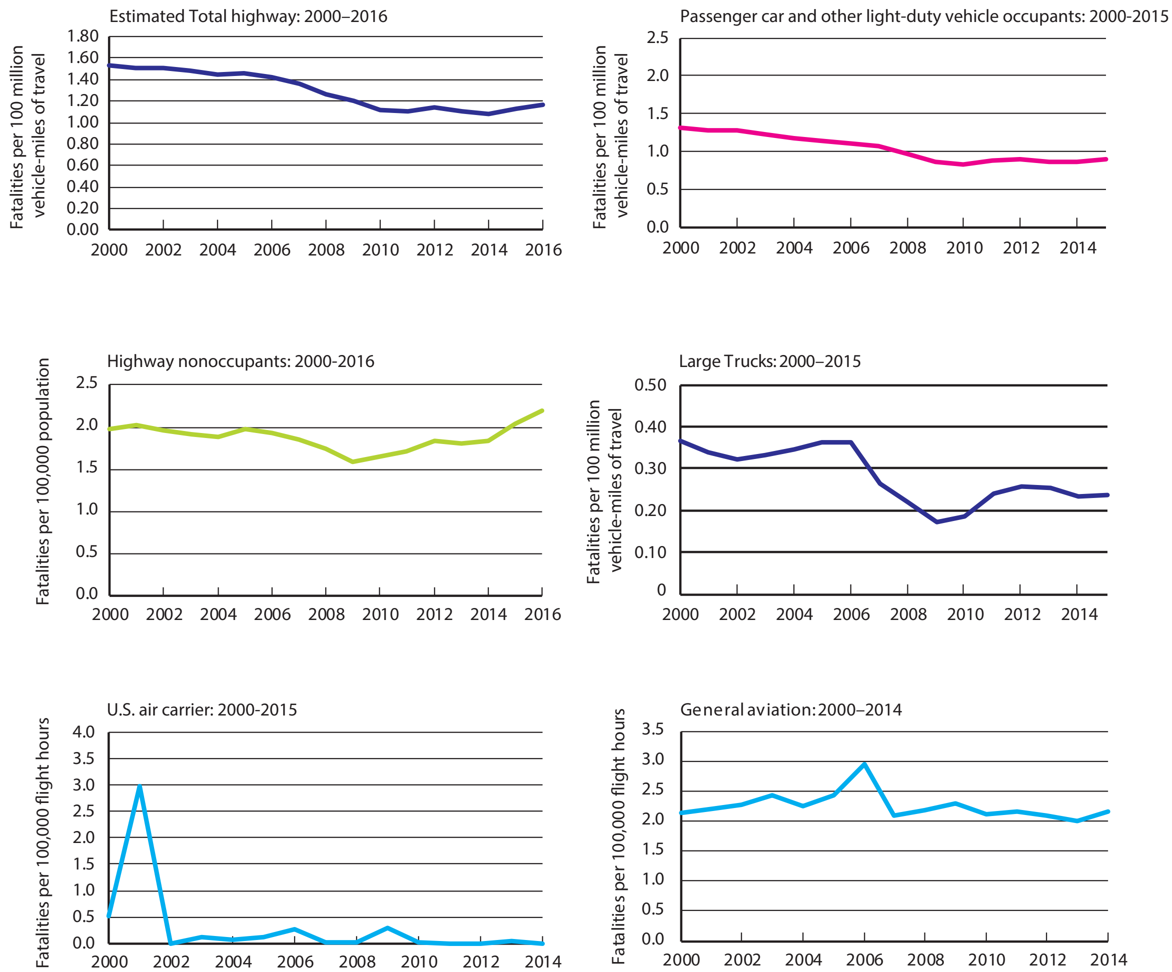
Pedestrian deaths were just under 6,000 in 2016. Figure 6-3 shows fatality rates (measured per 100,000 U.S. population) of nonoccupants[3] declined between 2000 and 2014, before rising in 2015 and again in 2016. In 2015 the fatality rate climbed above the rate reached in 2000 (2 fatalities per 100,000 population), but it remains about half the nonoccupant fatality rate of 1980, when pedestrian deaths totaled 8,070.

Per a recent National Highway Safety Administration report, pedestrians are more likely to be struck in the dark (74 percent of pedestrian fatalities) and away from intersection crosswalks. Only 18 percent of pedestrian fatalities are at intersections: the remainder were struck while crossing at non-intersections (72 percent of fatalities), on the shoulder or roadside (5 percent), or while in other locations, such as parking or bicycle lanes, median strips, or sidewalks (5 percent) [USDOT NHTSA 2017d].

An estimated 19 percent of the U.S. population lives in rural areas. However, rural fatalities disproportionally accounted for 49 percent of all traffic fatalities in 2015. In 2015 the fatality rate was 2.6 times higher in rural areas than

[3] Nonoccupants includes pedestrians, bicyclists, and others outside motor vehicles when struck.

FIGURE 6-3 Fatality Rates for Select Modes of Transportation: Most Recent Years Available



NOTE: *Light-duty vehicles* includes passenger car, vans, mini-vans, sport utility vehicles, pickup truck and other light truck occupants. *Air carrier* fatalities resulting from the Sept. 11, 2001 terrorist acts include only onboard fatalities. *Total highway fatalities* is based upon preliminary estimated.

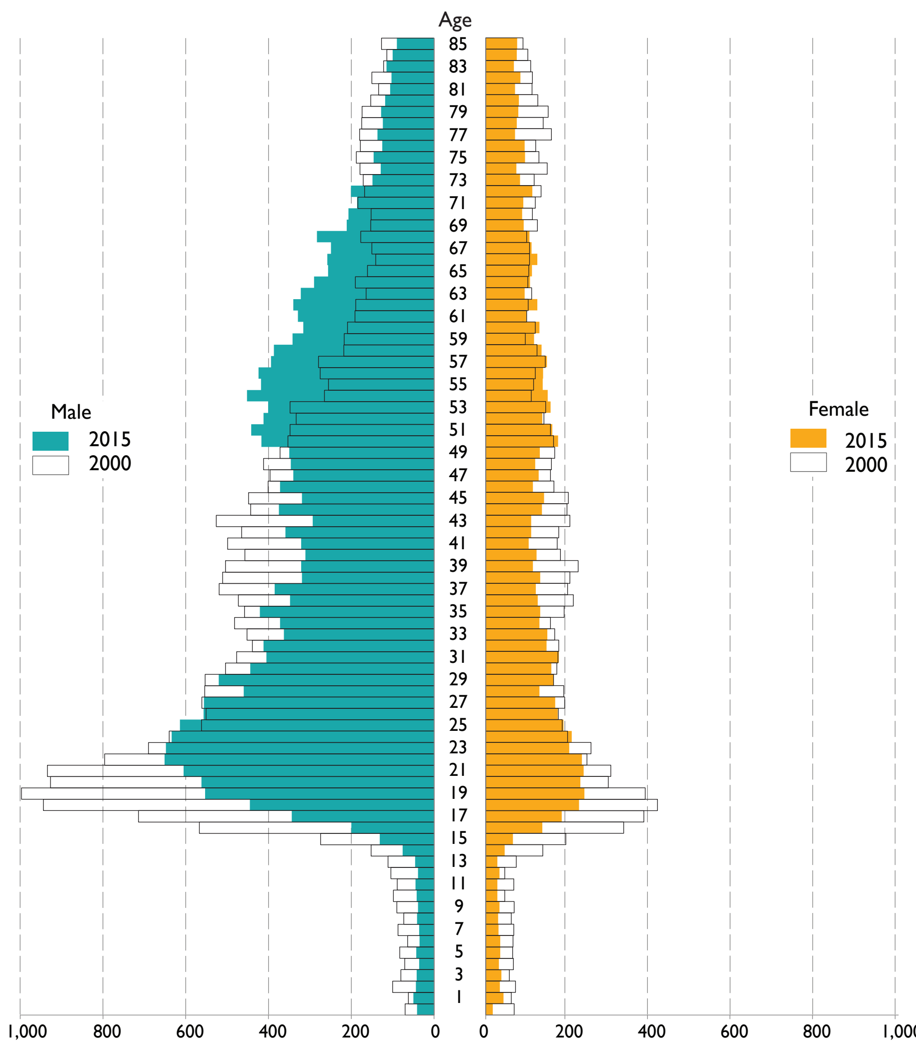
SOURCE: Calculated by U.S. Department of Transportation (USDOT), Bureau of Transportation Statistics (BTS) based upon multiple sources as cited in USDOT, BTS, National Transportation Statistics. Tables 2-9, 2-14, 2-17, 2-19, 2-21, 2,22, and 2-23A1:P52ov as of October 2017.

in urban areas (1.84 and 0.71, respectively). Rural fatalities decreased by 28 percent between 2006 and 2015, while urban fatalities decreased by only 18 percent during this time [USDOT NHTSA 2017d].

The population ratio of males to females is 0.97 (about 5 million more females than males) in the United States [USDOC CENSUS 2016]. Yet the ratio of highway fatalities is about 2.5 males-to-females. This difference is partially because males, on average, drive more than females and thus have a higher rate of exposure to crashes. Based on the latest National Household Travel Survey data, males travel about 40.9 miles per day while females drive about 31.5 miles per day. Also, it is notable that males constitute 70 percent of pedestrian fatalities.

As in 2000, the number of males killed on U.S. highways exceeded the number of female fatalities for all age groups in 2015. Overall, males comprised 68.3 percent of highway fatalities in 2000 and 70.9 percent in 2015. Persons under the age of 30 continued to have the highest fatality numbers in 2015, although highway deaths for that age group were lower than for the same age grouping in 2000. The number of highway fatalities for males in their late 40s to late 60s was higher in 2015 than it was for the men who were in the same age group in 2000 (figure 6-4a). This cohort of males in 2015 was more numerous than their 2000 cohort and drove more miles—factors that likely contributed to the higher number of fatalities.

FIGURE 6-4a Fatalities Number by Age and Sex: 2015

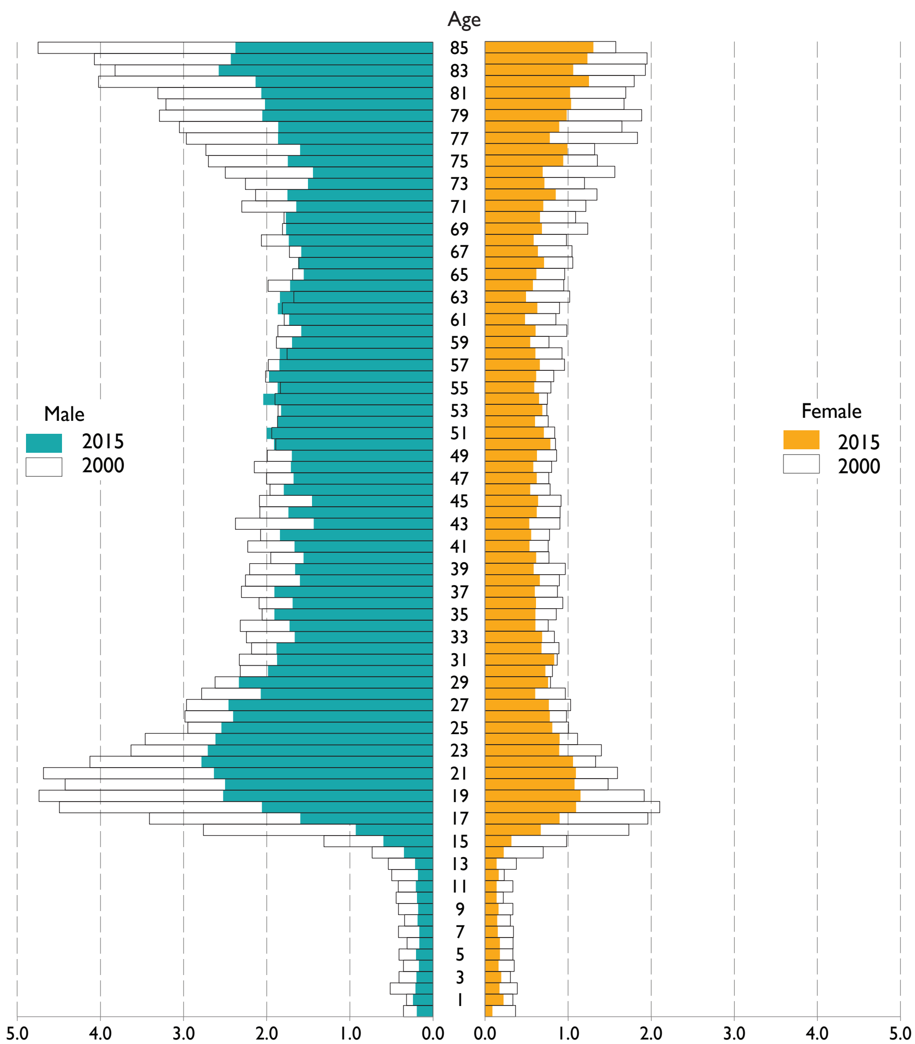


SOURCE: U.S. Department of Transportation, National Highway Traffic Safety Administration, Fatality Analysis Reporting System, available at ftp.nhtsa.dot.gov as of March 2016.

Since 2000 there has been a considerable decrease in highway fatalities per capita across all age groups for both genders. The greatest numbers of fatalities per capita age group in both 2015 and 2000 were among males between the ages of 18 and 30, followed by males 79 and older. Female fatalities per capita in both 2015 and 2000 peaked for those between 16 and 27 years of age, followed by females over the age of 80. The 2000 rates were again higher across all age groups and both genders (figure 6-4b).

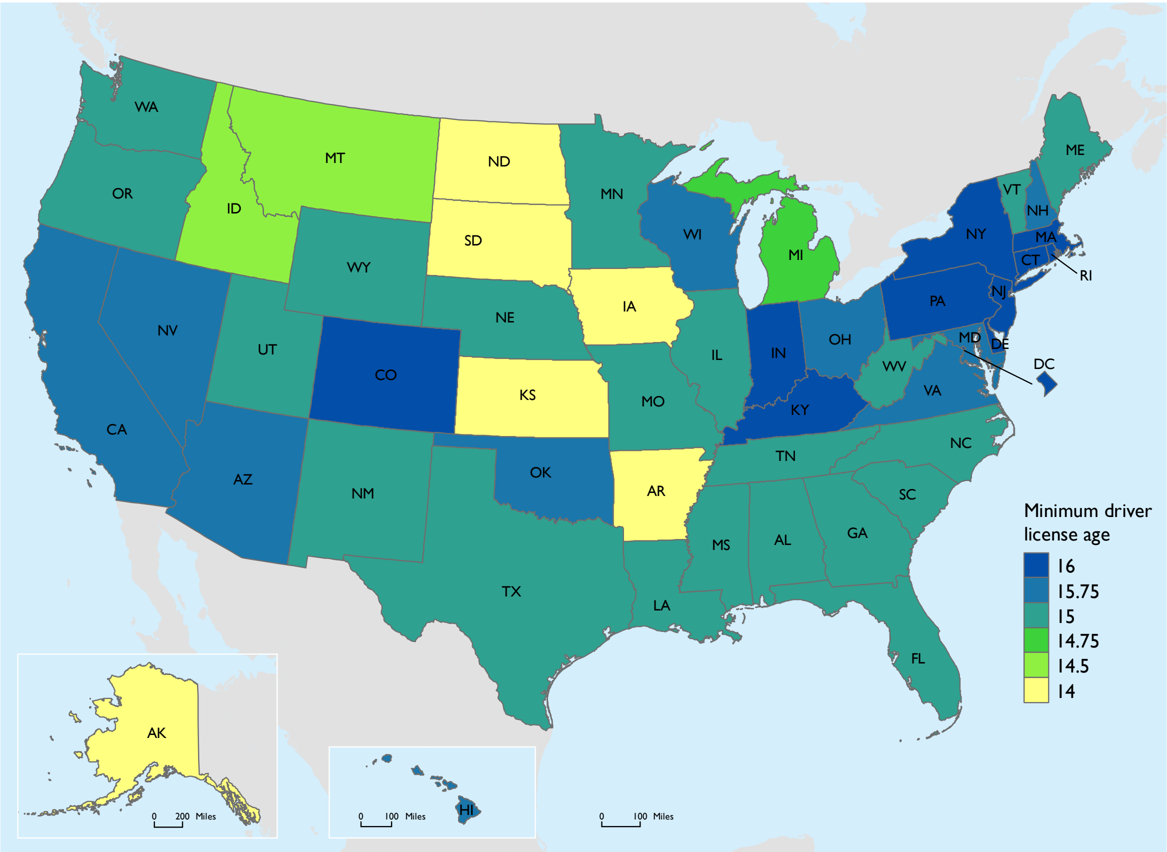
The minimum age for getting a driving license varies among states, ranging from14 to 16 years of age (figure 6-5). At least 48 states have established some form of graduated driver licensing (GDL) program to help

FIGURE 6-4b Fatalities Rate by Age and Sex: 2015



SOURCE: U.S. Department of Transportation, National Highway Traffic Safety Administration, Fatality Analysis Reporting System, available at ftp.nhtsa.dot.gov as of March 2016.

FIGURE 6-5 Minimum Driver License Age: June 2017



NOTES: States have a wide variety of conditions that novice or teen drivers must meet as they progress to full licensure. For a listing of these requirements in a specific state, consult the source document website.

SOURCE: Governors Highway Safety Association, *Teen and Novice Drivers*, available at http://www.ghsa.org/state-laws/issues/Teen-and-Novice-Drivers as of June 2017.

inexperienced, young drivers safely gain experience while limiting their exposure to high-risk driving conditions, such as night driving and carrying teenage passengers during early months of licensure [GHSA]. A recent review of state GDL program evaluations found that the program was effective in improving 16 and 17-year-old drivers' crash outcomes by 16 and 11 percent, respectively[4] [Masten, S.V., et al.].

Motor vehicle crashes continue to be the leading cause of death for teens aged 16 to 20 years [USDHHS CDC WISQARS 2015]. Teenagers and young adults had the highest fatality numbers and fatality rates per 100,000 residents in 2015, although their deaths have declined considerably since 2000. A potential contributing factor is that those under the age of 30 in 2015 drove fewer miles than their counterparts in 2000, reducing the exposure to highway crashes.

Not surprisingly, children aged 14 and under have the lowest number and rate of fatalities—yet over 1,000 children in this age range die every year in motor vehicle crashes and incidents. In 2015 children aged 14 or younger comprised about 19 percent of the U.S. population and about 3 percent, or 1,132, of U.S. motor vehicle fatalities. This was a 5-percent increase from 2014, but a 37-percent decrease compared to 2006. Of the children killed, 824 (73 percent) were motor vehicle occupants; about 25 percent were pedestrians and bicyclists, and the remaining 2 percent were other/unknown nonoccupants. An estimated 178,000 children were also injured. [USDOT NHTSA 2017i].

Expressed daily, about 3 children died and 487 children were injured each day in motor vehicle incidents in 2015. Children who died in crashes were more likely to be unrestrained when their drivers were unrestrained; when the driver didn't wear a seat belt, 66 percent of the children were likewise unrestrained. Box 6-b discusses the challenges and risks children face traveling to and from school.

Aviation

U.S. air carriers had zero fatalities in 2015 and 2016. In fact, in 6 of the last 16 years there were no fatalities recorded for flights by U.S. air carriers. During the other years, fatalities per 100,000 flight hours ranged from 0.1 to 3.0—the larger number dating to 2001 when five passenger planes crashed, including the four hijacked by terrorists on September 11 of that year. Since 2001 the air carrier fatality rate has remained stable and low.

General aviation (GA) fatalities have numbered in the hundreds every year since at least 1960. In 2016 some 386 people were killed in GA accidents, compared to 378 in 2015, and 424 in 2014. GA fatalities have dropped appreciably from previous decades. In the 10 years spanning 1990 to 1999, an average of 716 persons per year died in GA accidents, followed by a drop to an average of 567 deaths per year in the following decade. The annual average for the 2010–2016 period was 417 fatalities.

[4] The study was unable to reach firm conclusions about the association between GDL and crash outcomes for drivers 18 to 20 years of age, finding it difficult to disentangle the mixture of people with and without GDL training. Most states do not require GDL for applicants for driver licenses who are 18 and older.

Box 6-B Student Traffic Safety

Most children go to school every school day. As was discussed in box 2-A in chapter 2, most children are transported to and from school in motor vehicles, either a personal or family vehicle (45 percent in 2009) or a school bus (39 percent). Relatively few (15 percent or less) walk or bike.

How safe are their trips to and from school? NHTSA found that, in the 10 years between 2006 and 2015, a total of 301 school-aged children (18 and under) died in school transportation-related crashes [USDOT NHTSA 2017j]. This amounts to about 30 school-children deaths per year on average. Over the 10-year period, 54 of the children who died were occupants of school buses or other school-transportation vehicles (about 5.4 fatalities per year), and 137 were school children occupying other vehicles, such as a family vehicle (13.7 fatalities per year). Children who were on foot accounted for 102 fatalities, while bicyclists and other pedalcyclists comprised 8 deaths—for a combined average of 11 fatalities per year.

About 64 percent of the school-age pedestrians that died were struck by a school bus or a vehicle functioning as a school bus, while 36 percent of pedestrian deaths of school children involved other vehicles. Over one-fifth of the school bus-child pedestrian fatalities occurred as the bus was starting up in the road, while about 11 percent of the school children pedestrian fatalities happened as another vehicle type passed or overtook a vehicle.

The above statistics indicate that some school-children fatalities happen as children approach or walk away from their transport vehicle as they go to and from school. A recent U.S. General Accountability Office study reports that, when participating school bus drivers were asked to note the number of times a vehicle illegally passed the bus when stopped to pick up or drop off students, these drivers reported 74,000 instances in a single day [USGAO 2017].

The total number of people of all ages who died in school-transportation related crashes over the 2006 to 2015 year period was 1,313—or about 131 per year on average. This was about 100 more deaths of people per year than the 30 school-aged children who died annually [NHTSA 2017i].

The GA fatality rate per 100,000 flight hours has fluctuated (figure 6-3). While the number of fatalities was fewer in 2016 (386 people) compared to 2000 (596 people), the number of flight hours in 2014 was 35 percent less, resulting in a higher fatality rate. Another metric of GA safety is the fatal accident rate per 100,000 flight hours. This rate is the same whether a plane has one or many occupants who die in a crash. According to preliminary estimates, the GA fatal accident rate for fiscal year 2016 (October 1, 2015 through September 30, 2016) was 0.91 per 100,000 flight hours, compared to a 1.08 fatal accident rate averaged over the five prior fiscal years [USDOT FAA 2017a].

Most general aviation accidents involve single-engine, piston-powered airplanes, which account for slightly more than 60 percent of general aviation aircraft and just over half of general aviation flight hours [USDOT FAA 2014]. The loss of inflight control contributes to the majority of fatalities, whereas loss of control on the ground and engine-related system malfunctions were associated with the majority of nonfatal accidents [NTSB 2014a]. General aviation accidents are widely dispersed across the country. In 2014 nearly two-thirds of fatal general aviation accidents resulted in a single fatality, another quarter resulted in two fatalities, and the remainder yielded multiple fatalities.

In addition to general aviation, many fatalities each year result from crashes involving air taxis and other commercial on-demand air services, and commuter planes with less than 10 seats. Preliminary data show 27 fatalities from these services in 2016, above the 2010-2015 annual average of 24. The safety trend in air taxi and similar services seems to be improving, averaging 43 deaths per year between 2000 and 2009 compared to nearly 64 deaths annually between 1990 and 1999.

The popularity of unmanned aircraft systems (UAS) or "drones" poses several challenges for aviation safety (box 6-C). There are now more than one million UAS in the United States, and there are increasing sightings of unauthorized drones from the air and near airports.

Recreational Boating

There were 701 recreational boating deaths in 2016. The year 2016 was the third successive year of boating fatality increases. From a historic low of 560 in 2013, boating fatalities rose to 610 deaths in 2014 and 626 deaths in 2015. While still fewer than in the 1990s when

Box 6-C Unmanned Aircraft and Aviation Safety

Estimates suggest that people in the United States now own over one million unmanned aircraft systems (UAS), commonly known as drones, with the number growing each year. Recreational and other unregulated use of drones presents safety risks to manned aircraft, their crews, airline passengers, and anyone below their flight paths. Unauthorized UAS flights reportedly interfered with aerial tankers battling wildfires, which grounded the tankers and put firefighters on the ground at greater risk [USDOT FAA 2015a].

The number of unmanned aircraft sightings by pilots while in flight have increased rapidly, from 238 in 2014, to about 1,210 in 2015, to 1,274 in just the first 8 months of 2016. The sightings come from pilots of all aircraft types, including large, commercial passenger aircraft.

The prospect of a drone damaging a commercial flight has attracted worldwide concern [The Guardian 2016]. While there have been several reports by pilots claiming a collision between UAS and their planes, FAA investigations usually found that the collisions were explained by damage from such events as a bird strike or structural failure, not a UAS [USDOT FAA 2017a]. In October 2017, however, a civilian drone collided with and damaged a military helicopter, which landed safely [USA Today].

Prior to operating unmanned aircraft, the Federal Aviation Administration (FAA) requires people to file a paper registration application for drones weighing 55 pounds or more. In December 2015, FAA also issued an interim final rule for online registration of drones weighing from 0.55 pounds up to just under 55 pounds, as an alternative to filing a paper application. Very light drones that weigh less than 0.55 pounds do not have to be registered [USDOT FAA 2015c].

As of the end of 2016, some 670,000 drones had been registered in the United States [USDOT FAA 2017b].

fatalities averaged about 800 per year, the 2016 fatality number is similar to the annual average of about 700 between 2000 and 2009. According to the U.S. Coast Guard (USCG), many boating fatalities occurred on calm protected waters, in light winds, or with good visibility. Alcohol use, operator distraction, or a lack of training continued to play key roles in fatal recreational boating accidents. Where cause of death was known, about 80 percent of people who died in recreational boating incidents drowned, and 83 percent of these people were not wearing life jackets [USDHS USCG 2017]. While most of the deaths—481 in 2016—involved motorized boats, people in kayaks and canoes accounted for 22 percent of the fatalities.

Because of a lack of reliable nationwide measures of recreational boat usage, such as operational hours, boating fatality rates have historically been based on the ratio of fatalities to the total number of registered boats, a number subject to great uncertainty. An initial 2011 survey of boating participants and boat owners estimated that there were about 2.973 billion person-hours of boating in that year. As there were 758 boating deaths in 2011, this would be about 25.5 deaths per 100 million exposure hours that year for all categories of boats [USDHS USCG 2011 undated]. A 2012 survey of boat owners and other data showed a lower overall rate of 18 deaths per 100 million exposure hours, based on 3.584 billion person hours of exposure and 648 deaths that year.[5] The USCG cautions that the methodologies used in the two surveys were different, concluding that it was confident that the 2012 survey resulted in an enhanced exposure estimate, but was not necessarily confident in the higher number derived [USDHS USCG 2012 undated].

Railroad Operations[6]

In 2016, 791 people died from railroad-related accidents (table 6-1). The FRA attributes 277 deaths to passenger train operations and 514 deaths to freight train operations, which involve far more train miles than passenger train-miles [USDOT FRA 2017a]. Unlike highway crashes, boating, or aviation accidents, most fatalities associated with train operations occur outside the train, such as people who are struck by trains while on track rights-of-way or people in cars struck at highway-rail grade crossings. Very few train passengers or crew members die in train accidents. In the 10 year period 2007 to 2016 period, the fatality count for passengers on the train was 45—less than 5 per year—but a total of 7,749 people died in railroad accidents or incidents.[7]

Several hundred people die every year when struck by trains while on railroad property or rights of way. If they were unauthorized, they are classified trespassers. Trespassers accounted for 57.2 percent of the total railroad fatalities between 2007-2016, or 443 deaths per year on average. The number of trespasser deaths fell for several years after 2007, reaching a low of 400 in 2011. However, the

[5] The 648 fatality number differs from Recreational Boating Statistics, which states that there were 651 boating fatalities in 2012.

[6] Data in this section is as reported to the Federal Railroad Administration as of February 2017. Data may change as FRA receives additional or amended reporting is received from reporting railroads.

[7] Another 29 passengers died as a result of a non-train related incident (e.g., health related deaths).

drop was of short duration; since then, the fatality toll has risen, reaching 487 in 2016—not so far below the average of 516 fatalities per year in the 1990s.

Highway-rail grade crossing fatalities averaged about 260 per year in the 2007-2016 period, or roughly one-third of the total railroad-related fatalities. The number is far fewer than in the 1990s, when the annual grade crossing fatality count averaged about 550 people per year [USDOT FRA 2017a].[8]

A recent statistical description of highway grade crossing accidents over a 10-year period found that only 5 percent of the accidents involved pedestrians; motor vehicles, led by automobiles, comprised the remainder. Male drivers were involved in over 70 percent of the accidents, and had a much higher accident risk rate than females even when their greater travel miles was taken into account. Drivers 19 years and younger and drivers 70 and older, while having relatively few accidents, had the highest accident risk rates when driving mileage by age cohort was taken into account [USDOT FRA 2017b].

[8] Counts of highway-grade crossing fatalities are reported to both rail and highway agencies. In Table 6-1, to avoid double-counting, these fatalities are included in the overall count for highways, but not for rail.

Many grade crossings are the locations of repeated incidents, as shown in table 6-3. The list shows crossing locations where 10 or more incidents were reported to the Federal Railroad Administration (FRA) between 2006 and 2016. These incidents involve not only fatalities or injuries, but could also include property damage incidents. Four of the 15 crossings are in the Phoenix, Arizona, metropolitan area. Many trespassing and grade crossing fatalities are the result of suicides. According to FRA, there were 226 suicides in 2016.

TABLE 6-3 Railroad Grade Crossings With 10 Or More Incidents: 2006–2016

Street	City	State	Total Incidents	Total Fatalities	Total Injuries
Thomas Rd	Phoenix	Arizona	24	0	2
35th Avenue	Phoenix	Arizona	21	0	4
43rd & Camelback	Glendale	Arizona	19	0	3
Front St	Ashdown	Arkansas	16	4	4
27th Avenue	Phoenix	Arizona	15	0	4
Midland Ave	Elmwood Park	New Jersey	14	1	4
Mcgalliard Rd	Muncie	Indiana	14	0	3
N Foster Dr.	Baton Rouge	Louisiana	13	0	0
Bellville Street	Evergreen	Alabama	13	5	1
Industrial Road	Pascagoula	Mississippi	12	0	7
Bessemer Ave	Cleveland	Ohio	12	0	1
Mykawa Road	Houston	Texas	12	0	5
Bethany Home Rd	Glendale	Arizona	10	0	1
Isabella/Plant St	Waycross	Georgia	10	0	1
Castilia St	Memphis	Tennessee	10	2	4

SOURCE: U.S. Department of Transportation, Federal Railroad Administration, *List of Railroad Crossings with Most Incidents over Last Decade*, available at https://www.fra.dot.gov/eLib/details/L17404 as of November 2017.

TABLE 6-4 Transportation Injuries by Mode: 2000, 2010, 2014, and 2015

	2000	2010	2014	2015
TOTAL	**3,218,900**	**2,259,731**	**2,350,490**	**2,443,175**
Air	359	278	266	284
Highway	3,189,000	2,239,000	2,338,000	2,424,000
Railroad	12,057	(R) 8,378	8,702	9,070
Transit	56,697	(R) 25,376	24,045	24,252
Water	4,355	3,770	4,090	3,231
Pipeline	81	(R) 103	95	49
Other counts, redundant with above				
Railroad, injured at public crossing with motor vehicle	1,029	718	663	812
Transit non-rail	42,713	(R) 16,705	16,532	16,839
Transit rail	13,984	(R) 8,671	7,513	7,390

NOTES: Water for the year 2000 only includes recreational boating and does not include additiional categories of water injuries that are included in the 2010 to 2014 data. The sum of the modal numbers is greater than the **TOTAL** because some injuries are counted in more than one mode. *Other counts, redundant with above* help eliminate double counting in the injury **TOTAL**, as follows: For *Railroad, injuries involving motor vehicles at public highway-rail grade crossings* are excluded because such injuries are assumed to be included in Highway injuries. For *Transit, non-rail* mode injuries, including aerial tramway, motor bus, bus rapid transit, commuter bus, demand response, demand taxi, ferryboat, jitney, publico, trolleybus, and van-pool are excluded because they are assumed to be counted as Water and Highway injuries. Please see the National Transportation Statistics table 2-2 for complete source notes and an expanded time-series.

SOURCES: Various sources as cited U.S. Department of Transportation, Bureau of Transportation, *National Transportation Statistics*, table 2-2. Available at www.bts.gov as of April 2016.

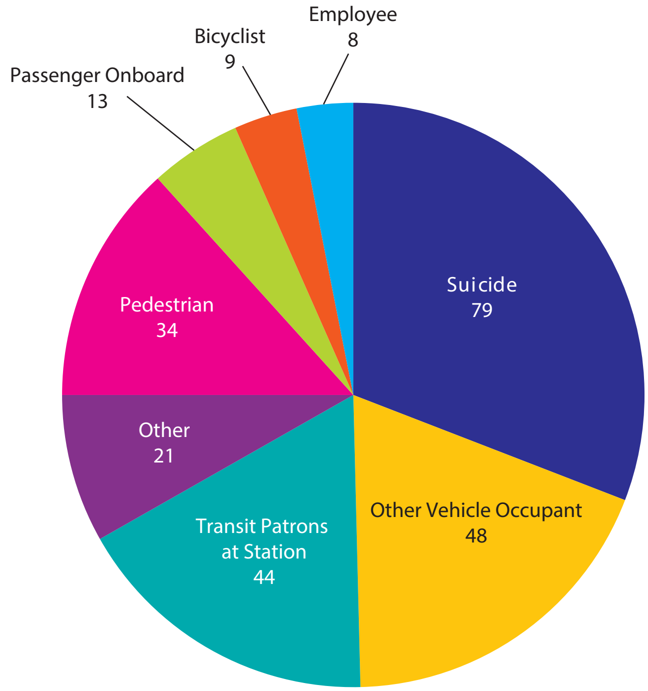
Transit

There were 256 transit fatalities in 2016, slightly above the 2010 to 2015 average of about 245 per year.[9] Like the railroad mode, most of the fatalities in transit-related accidents are not passengers or transit employees on the vehicle. According to the Federal Transit Administration (FTA), passengers on transit vehicles accounted for roughly 5.1 percent of the 2016 fatalities, and transit workers (including contractors) about 3.1 percent. Another 17.2 percent were transit patrons arriving at, waiting, or leaving transit facilities. Pedestrians and bicyclists who were not patrons accounted for 16.8 percent of the transit fatalities, and 18.8 percent of the fatalities were people in nontransit vehicles. About 30.9 percent of the transit fatalities in 2016 were considered suicides (figure 6-7).[10]

[9] Rail transit accounts for slightly more than half of the transit fatalities reported to Federal Transit Administration (FTA) (Table 6-1): however, commuter rail and Port Authority Trans Hudson heavy rail system safety data are counted in Federal Railroad Administration data, not FTA.

[10] In table 6-1 and figure 6-7, the number of transit passenger fatalities includes both passengers on the vehicle and those struck while waiting to get on or who have just gotten off the vehicle. Pedestrians killed in transit accidents on highways, such as pedestrians struck by a transit bus, are reported as highway-related pedestrian deaths in table 6-1. To avoid double counting, pedestrians killed in transit accidents are included in table 6-1 under "Other counts, redundant with above" as "transit, nonrail."

FIGURE 6-7 Transit Fatalities by Category: 2016



NOTES: Pedestrian fatalities includes in crossings, not incrossings, and walking along track.

SOURCE: U.S. Department of Transportation, Federal Transit Administration, National Transit Database, available at https://www.transit.dot.gov/ntd as of November 2017.

Other Modes

There were about 36 fatalities involving waterborne commercial vessels in 2015; this was less than the 2010–2015 average of 78 deaths per year. Pipeline-related fatalities averaged about 16 deaths per year in the 20 years between 1997 and 2016. There were 12 pipeline fatalities in 2015 and 16 fatalities in 2016 arising from all pipeline incidents.[11] Gas pipelines (especially gas transmission pipelines) account for most of the fatalities in most years [USDOT PHMSA].

[11] The USDOT Pipeline and Hazardous Materials Administration groups pipeline incidents under three classifications—serious, significant, and all. The fatality data above are taken from the July 2017 all incidents data pull. Data may change as PHMSA receives additional or amended reports from pipeline entities.

Injured People by Mode

Injuries in most modes declined between 2000 and 2015. In addition to the fatality data, NHTSA also estimates highway injuries. Unlike fatalities, which are tallied from police accident reports, injuries are estimated from a sample and are subject to sampling errors. Estimated injuries in the highway modes, which account for over 99 percent of transportation injuries, fell from 3.19 million in 2000 to 2.34 million in 2014, before increasing to 2.44 million in 2015—still well below the 2000 level (table 6-5).[12] Not all highway vehicle categories had a decline in injuries over the 15-year period. Motorcyclist injuries rose from about 58,000 in 2000 to 92,000 in 2014, before falling to 88,000 in 2015 [USDOT BTS NTS 2017]. NHTSA estimated that about 6,700 people per day were injured in motor vehicle crashes in 2015.

In addition to the people injured on the Nation's highways, about 20,000 people were injured in nonhighway-related transportation incidents. Rail and rail transit together accounted for about 16,000 of these nonhighway injuries. These numbers do not count people injured in highway-rail crossing incidents, as they are assumed to be included in the highway mode estimate. The water modes had about 3,400 injured people—mostly from recreational boating.

[12] NHTSA had yet to estimate 2016 injuries when this chapter was prepared.

The injury rate for highway crashes per vehicle mile of travel in 2015 was about one-third less than it was in 2000 (figure 6-8). According to the latest National Household Travel Survey, the average occupancy rate[13] for all vehicle types is 1.67. Motorcycles have a 1.16 occupancy rate, which is less than passenger cars (1.55). Large trucks also accounted for 4 percent of all registered vehicles and 9 percent of the total vehicle miles traveled, but only 4 percent of all vehicles involved in injury crashes. Large truck occupant injury rates were 1 to 10 compared to that of passenger car and light-duty truck occupants.

[13] Number of persons per vehicle trip

TABLE 6-5 Fatalities by Highest Blood Alcohol Concentration (BAC) in Highway Crashes: 2000, 2010, 2015 and 2016

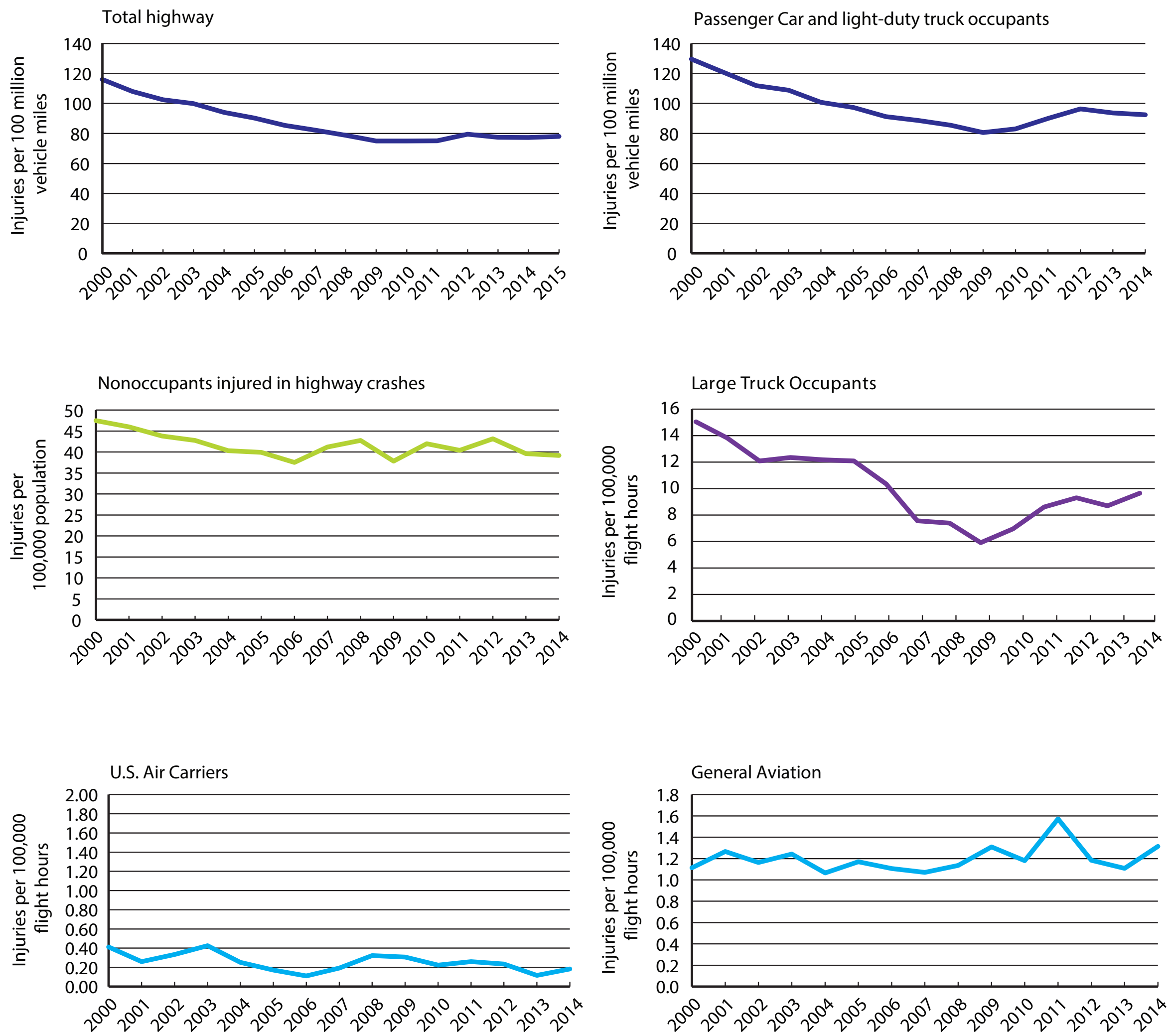
	2000	2010	2015	2016
Total fatalities	**41,945**	**32,999**	**35,485**	**37,461**
Fatalities in alcohol-related crashes (BAC = .01+)	**15,746**	**11,906**	**12,257**	**12,514**
Percent	37.5%	36.1%	34.5%	33.4%
BAC = 0.00				
Number	26,082	21,005	23,119	24,851
Percent	62.2%	63.7%	65.2%	66.3%
BAC = 0.01 - 0.07				
Number	2,422	1,771	1,937	2,017
Percent	5.8%	5.4%	5.5%	5.4%
BAC = 0.08+				
Number	13,324	10,136	10,320	10,497
Percent	31.8%	30.7%	29.1%	28.0%

KEY: BAC = blood alcohol concentration.

NOTES: *Total fatalities* include those in which there was no driver or motorcycle rider present. BAC values have been assigned by U.S. Department of Transportation, National Highway Traffic Safety Administration (NHTSA) when alcohol test results are unknown. *Alcohol-related crashes* pertain to the BAC of the driver and nonoccupants struck by motor vehicles. For some years, numbers for Fatalities in alcohol-related crashes (BAC = .01+) may not add to totals due to rounding.

SOURCE: U.S. Department of Transportation (USDOT), National Highway Traffic Safety Administration as cited in Bureau of Transportation Statistics, *National Transportation Statistics*,table 2-26, available at http://www.bts.gov as of November 2016.

FIGURE 6-8 Injury Rates for Select Modes: 2000–2014, 2015



NOTES: *Passenger car occupants* includes passenger car and light truck occupants. *Highway nonoccupants* includes pedestrians and bicyclists. *Air* includes serious injuries only. *Nonoccupant* includes pedestrians and riders of nonmotorized bicycles and other pedal-powered vehicles. **Total Highway, Passenger Car Occupants, and Motorcycle Operators**: When comparing highway data from 2006 and before to data from later years, it needs to be understood that a revised methodology for estimating registered vehicles and vehicle miles traveled by vehicle type for the highway modes was applied to 2007 data and beyond, and this difference in methodologies needs to be taken into account.

SOURCE: Calculated by U.S. Department of Transportation (USDOT), Bureau of Transportation Statistics (BTS) based upon multiple sources as cited in USDOT, BTS, *National Transportation Statistics*. Tables 1-35, 2-2, 2-9, and 2-14. Available at www.bts.gov as of April 2016.

Costs of Motor Vehicle Crashes

A 2014 study by the Centers for Disease Control and Prevention focused on the health burden and medical costs of both fatal and nonfatal injuries to highway motor vehicle occupants in crashes. The medical costs of fatal injuries in 2011 totaled about $266 million, the latest year for which medical cost data are available. Nonfatal injuries to motor vehicle occupants from crashes in 2012 involved an estimated 2.5 million visits to emergency rooms or other emergency departments, with an estimated 188,000 visits resulting in hospitalization and lifetime costs of $18.4 billion. Put another way, in 2012 there were about 6,900 emergency department visits and over 500 hospitalizations per day resulting from nonfatal crash injuries to motor vehicle occupants [USHSS CDC 2014].

Medical costs are only one component of the costs of crashes. A separate study of the broader economic costs of motor vehicle crashes estimated these costs as $242 billion in 2010 (the latest year for which economic estimates are available) [USDOT NHTSA 2015e]. These economic costs include the following:

- lost workplace productivity—$57.6 billion (23.8 percent of economic costs),
- lost household productivity—$19.7 billion (8.2 percent),
- property damage—$76.1 billion (31.4 percent),
- medical expenses—$23.4. billion (10 percent),
- congestion impacts—$28 billion (11.6 percent), and
- other crash-related costs—$37.0 billion (15.3 percent).

If averaged across the U.S. population in the study year, motor vehicle crashes cost nearly $784 per person in 2010. When factoring in the $594 billion in comprehensive costs from the loss of life, pain, and injuries, the cost of 2010 motor vehicle crashes totaled about $836 billion. Of this total, economic costs represent 29 percent and lost quality of life represent 71 percent [USDOT NHTSA 2015e].

Compared to other motor vehicle crashes, these costs disproportionately involve motorcycle riders who die or incur serious injuries in crashes [USDOT NHTSA 2015e]. Motorcycles provide little protective shielding to riders, compared to enclosed vehicles; also, there has been a dramatic increase in motorcycle vehicles-miles traveled. Measured by VMT, a motorcyclist in a crash was about 30 times more likely to die than a passenger car occupant and 5 times more likely to be injured, according to the study. In 2010 motorcycle crashes cost $12.9 billion in economic impacts and $66 billion in comprehensive societal costs.

Selected Contributing Factors

A multitude of human, environmental, and vehicle factors contribute to transportation crashes. The most commonly cited causes involve driver or operator errors or risky behaviors, such as speeding, and operating vehicles or carrying out transportation operations while under the influence of alcohol or drugs, while distracted, or while fatigued. Environmental factors include roadway or infrastructure design (e.g., short runway, no road shoulders), hazards (e.g., utility poles at the side of the road, hidden rocks under water), and operating conditions (e.g., fog, turbulence, choppy waters, wet roads). Vehicle factors include equipment- and maintenance-related failures (e.g., tire separations, defective brakes or landing gear, engine failure, and worn out parts) [GAO 2003]. Often it is hard to delineate among the various factors. For example, an impaired or fatigued driver may ignore dashboard alerts about potentially dangerous equipment problems (e.g., low tire pressure), or continue to operate the vehicle when unsafe weather conditions would make it prudent to stop.

Human factors are more likely than not to be recorded for fatal crashes involving passenger vehicles. In 2015 one or more driver-related human factors were recorded for two-thirds (66.6 percent) of the drivers of highway passenger vehicles (cars, vans, pickup trucks, and sport utility vehicles) involved in single-vehicle fatal crashes and 50.7 percent of drivers of passenger vehicles involved in multivehicle fatal crashes [USDOT FMCSA 2017]. For comparison, one or more (driver-related) human factors were recorded for 51.3 percent of the drivers of large trucks involved in single-vehicle fatal crashes and for one-third (33.3 percent) of the drivers of large trucks involved in multivehicle fatal crashes [USDOT FMCSA 2017a].

Speeding topped the law enforcement list for driver-related factors for drivers of both passenger vehicles and large trucks in fatal crashes. Impairment (fatigue, alcohol, illness, etc.) closely followed speeding as the second most cited factor for passenger vehicle drivers, while distracted/inattentive driving was second on the list for large-truck drivers [USDOT FMCSA 2017a]. In 2015 vehicle factors, most commonly truck tires, were recorded for 6.4 percent of the large trucks involved in fatal crashes and 2.9 percent of the passenger vehicles involved in fatal crashes [USDOT FMCSA 2017a].

Alcohol Abuse

All 50 States and the District of Columbia limit Blood Alcohol Concentration (BAC) to 0.08 percent while operating a highway vehicle [USDHHS NIH NIAAA 2014]. An average of 1 alcohol-impaired-driving fatality occurred every 50 minutes in 2016. The portion of people killed “inside the vehicle” such as passenger cars and light trucks account for about two-thirds of the fatalities, while those “outside the vehicle” including motorcyclist, pedestrians, bicyclist, and other nonoccupants account for about a third. Alcohol impairment “inside” or “outside” the vehicle may have been a contributing factor in the fatal crash [USDOT NHTSA 2017d]. Table 6-5 shows that about 10,500 people were killed in motor vehicle crashes in 2016 in which a driver or fatally struck nonoccupant or both had a BAC of 0.08 or higher.[14]

[14] According to the USDOT National Highway Traffic Safety Administration, an alcohol-impaired crash involves at least one driver or motorcycle operator with a Blood Alcohol Concentration (BAC) of at least 0.08 gram per deciliter. Crashes where the BAC of the driver or operator measures over 0.01 are considered alcohol-related or alcohol-involved crashes.

TABLE 6-6 Distraction-Affected Motor Vehicle Crashes: 2010–2015

Total crashes	2010	2011	2012	2013	2014	2015
Total	**5,419,000**	**5,338,000**	**5,615,000**	**5,687,000**	**6,064,000**	**6,296,000**
Fatal crash	30,296	29,867	31,006	30,202	30,056	32,166
Injury crash	1,542,000	1,530,000	1,634,000	1,591,000	1,648,000	1,715,000
PDO crash	3,847,000	3,778,000	3,950,000	4,066,000	4,387,000	4,548,000

Distraction-affected crashes	2010	2011	2012	2013	2014	2015
Total	**900,000**	**826,000**	**908,000**	**904,000**	**967,000**	**885,000**
Percent of total crashes	**16.6**	**15.5**	**16.2**	**15.9**	**15.9**	**14.1**
Fatal crash	2,993	3,047	3,098	2,923	2,972	3,196
Percent of fatal crashes	9.9	10.2	10.0	9.7	9.9	9.9
Injury Crash	279,000	260,000	286,000	284,000	297,000	265,000
Percent of injury crashes	18.1	17.0	17.5	17.9	18.0	15.5
PDO crash	618,000	563,000	619,000	616,000	667,000	617,000
Percent of PDO crashes	16.1	14.9	15.7	15.2	15.2	13.6

KEY: PDO = property damage only.

SOURCE: U.S. Department of Transportation (USDOT), National Highway Traffic Safety Administration (NHTSA). *Distracted Driving 2014* (April 2016), Table 6. Available at http://www-nrd.nhtsa.dot.gov/ as of October 2017.

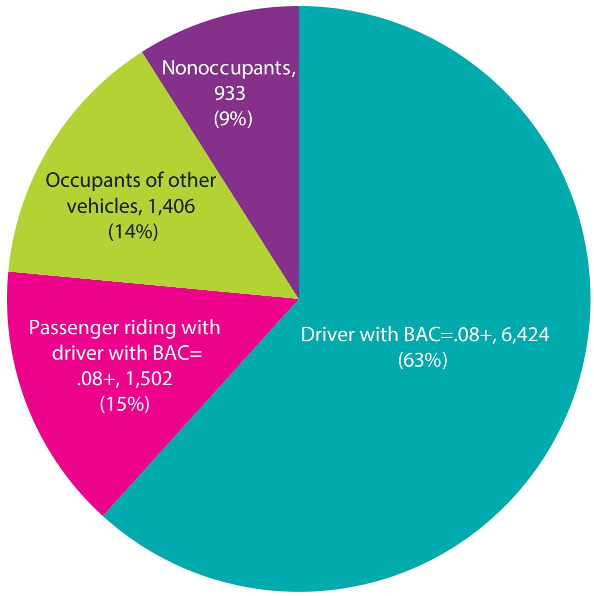
Figure 6-9 displays who died in fatal crashes when the driver had a BAC of 0.08 or higher. Drivers accounted for over 6,400 (63 percent) of the fatalities; about 2,900 were either passengers in the vehicle with an impaired driver or occupants of other vehicles (29 percent), and more than 900 were pedestrians or other nonoccupants (9 percent). Some 25 percent of motorcycle operators in fatal crashes are alcohol-impaired, the highest share of any highway motor vehicle drivers.

As for recreational boating, alcohol use is perennially listed by the USCG as the leading contributing factor in fatal boating accidents. The USCG found alcohol use to be the primary cause in 15 percent of fatal boating accidents in 2016, resulting in 87 deaths. Alcohol presence was noted in the deaths of an additional 46 people, but was not determined to be an accident cause [USDHS USCG 2017]. As of January 1, 2016, 47 States and the District of Columbia limit BAC to 0.08 percent for operators of recreational boats. The remaining three States—North Dakota, South Carolina, and Wyoming—have a 0.10 percent standard. In 2015 Michigan lowered its BAC from 0.10 to 0.08 percent [USDHHS NIH NIAAA 2017].

Speeding coupled with drinking are common factors in many highway crashes. Some 27 percent of traffic fatalities in 2015 were in crashes in which one or more drivers were speeding. Younger male drivers are especially prone to speeding, with nearly one-third (32 percent) of 15 to 24 year old males in fatal crashes found to have been speeding. Some

FIGURE 6-9 Fatalities, by Role, in Crashes Involving at Least One Driver with a BAC of .08 or Higher: 2016

Total fatalitiesinvolving BAC ≥ 0.08 % = 10,497



NOTES: Nonoccupants includes pedestrians, pedalcyclists, and others not listed above.

SOURCE: U.S. Department of Transportation (USDOT), National Highway Traffic Safety Administration, *Traffic Safety Facts: Alcohol-Impaired Driving* (Annual Issues), available at http://www-nrd.nhtsa.dot.gov/ as of November 2017.

45 percent of speeding drivers in fatal crashes were found to have been drinking compared to 20 percent among non-speeding drivers in fatal crashes [USDOT NHTSA 2017e]

Substance Abuse

A recent study by the National Transportation Safety Board (NTSB) analyzed toxicology reports on about 6,700 pilots who died in crashes between 1990 and 2012 to attempt to establish baseline data. About 96 percent of the crashes were in general aviation because there were few commercial aviation crashes during that period. The toxicology information was available because the Federal Aviation Administration is able to conduct this testing in follow-up fatal crash investigations.

The NTSB examined illegal drugs (which were assumed to be impairing) and certain legally obtained over-the-counter (OTC) drugs that were considered potentially impairing. These legal pharmaceuticals were considered potentially impairing if the packaging contained a Food and Drug Administration label warning of possible effects from routine usage (e.g., cautions about driving or operating machinery, or possible side effects such as sedation, hallucinations, or behavior changes.) The toxicology results showed increased "use of all drugs, potentially impairing drugs, drugs used to treat potentially impairing conditions, drugs designated as controlled substances, and illicit drugs" during the 23-year period. Diphenhydramine, an antihistamine with sedating properties, was the most common drug found in the toxicology reports that was thought to be potentially impairing. Diphenhydramine is found in many over-the-counter allergy formulations, cold medications, and sleep aids. NTSB found few cases of illicit drug use, but noted that there was an increase in positive tests for marijuana usage during the last 10 years of the study (2002 to 2012).

The NTSB examined whether pilots who had used potentially impairing drugs had increased risk of involvement in certain accident types. However, it found no statistically significant difference in the distribution of accident events from 2008 through 2012 in crashes involving pilots with and without evidence of potentially impairing drugs [NTSB 2014b].

In recent years, several States have legalized or are considering legalizing the use of marijuana. This trend has raised concerns about the effects of marijuana use on driver performance and traffic safety. The American Automobile Association (AAA) Foundation for Traffic Safety conducted several studies to quantify the prevalence of driving under the influence of marijuana. The AAA's annual online sample survey on traffic safety culture reported that 4.6 percent of respondents reported that they drove within 1 hour of using marijuana. (The annual survey was conducted from 2013 to 2015 and included 6,612 respondents.) Male drivers, 18 to 24 years of age, and those who lived in the Midwest were most likely to report having driven within 1 hour of using marijuana. Moreover, drivers who reported using marijuana within 1 hour of driving were less likely to believe that using marijuana increased the risk of crashing and more likely to believe that such usage does not affect or decreases the risk of crashing [AAA 2016a].

Another AAA study focused on marijuana involvement in fatal crashes in Washington State from 2010 to 2014. Using toxicology test data from the Washington State Safety Commission, AAA found that the number of drivers in marijuana-involved fatal crashes more than doubled from 49 (8.3 percent) in 2013 to 106 (17.0 percent) in 2014. Prior to legalization in December 2012, the number and proportion of drivers testing positive for marijuana were fairly stable, but then began to rise about 9 months after the law was passed [AAA 2016b].

Distraction and Fatigue

Distracted and fatigued vehicle operators are found in all modes of transportation, including airline pilots, bus drivers, train engineers, and tugboat operators [NTSB 2014c]. In 2015, 3,196 fatal highway crashes and an estimated 265,000 injury crashes involved distracted drivers. This was about 10 percent of fatal crashes, 15 percent of injury crashes, and 14 percent of property-damage-only crashes involving a motor vehicle (table 6-6). Drivers under the age of 30 are disproportionately represented in distraction-affected fatal crashes, and especially drivers aged 15 to 19 years [USDOT NHTSA 2017f]. Figures 6-10a and 6-10b show the trend on the percent of distracted driving-related highway fatalities and injuries (the fatality data begin with 2010

FIGURE 6-10a Distracted Driving Fatalities: 2010-2015

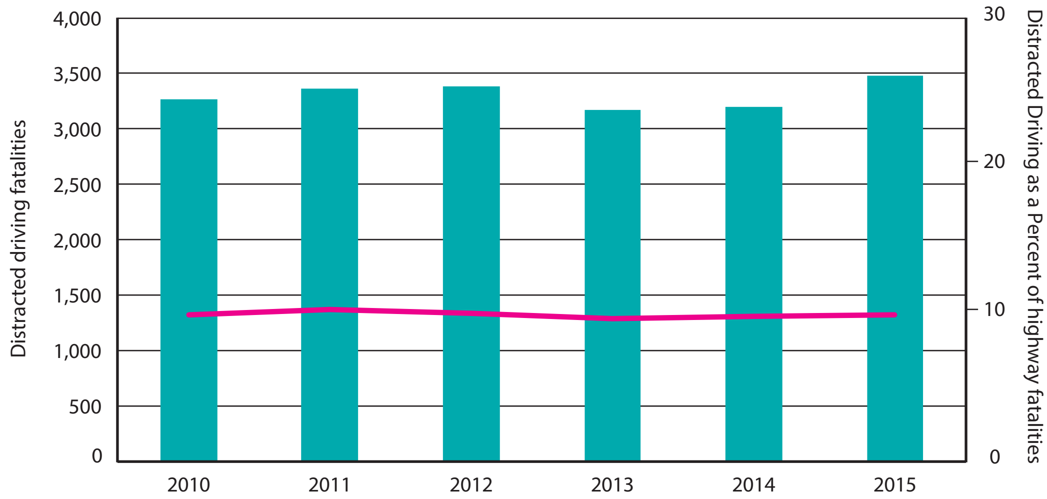
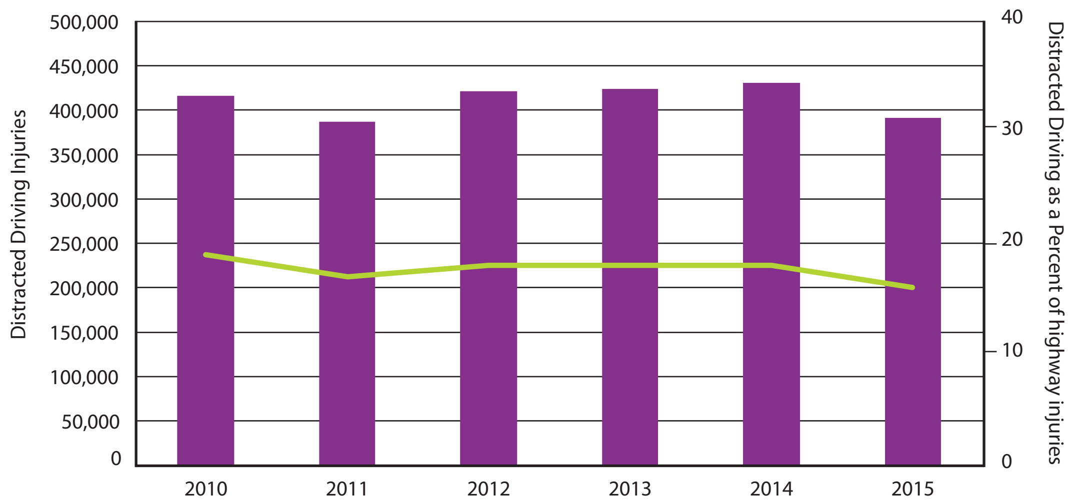


FIGURE 6-10b Distracted Driving Injuries: 2010-2015



NOTES: Distracted driving involves any activity that could divert a person's attention away from the primary task of driving, such as texting, using a cell phone, eating and drinking, grooming, using a navigation system, adjusting a radio, etc. Distracted driving fatality data for 2010 and on are not comparable with previous years due to changes in methodology.

SOURCE: U.S. Department of Transportation, National Highway Traffic Safety Administration, Traffic Safety Facts, Research Note, *Distracted Driving 2014*, available at www.nhtsa.gov as of April 2016.

due to a change in methodology, making earlier data not comparable).

Some 3,477 people died in distraction-affected crashes in 2015, and about 391,000 were injured. Vehicle occupants comprised 84 percent of the fatalities. There were 551 nonoccupants who died, mostly pedestrians in distraction-affected crashes. It is not known how many nonoccupants were also distracted when struck (e.g., walkers absorbed in a cell phone conversation).

Although many other activities (e.g., eating, sipping coffee, smoking, grooming, tending to a child, adjusting a radio) are distracting to drivers, bicyclists, and pedestrians, cell phone use and texting have received the most attention as these devices have attained nearly universal usage in the last few years. Cellphones were in use in about 14 percent of fatal crashes involving a distracted driver in 2015, comprising about 1.4 percent of all fatal crashes [USDOT NHTSA 2017f]. Figure 6-11 shows that 14 States, the District of Columbia, and Puerto Rico prohibit drivers' use of handheld cellphones; and 47 states plus the District of Columbia and Puerto Rico ban texting while driving.

In 2014[15] drowsy and fatigued driving was considered a related factor in 846 highway fatalities (2.6 percent). However, it is likely that fatigue-related crashes are underestimated [AAA 2014]. Measuring the exact number of drowsing-related fatalities is difficult, although research is underway to improve methods. Drowsy-driving crashes often occur in rural areas, with the vehicle going off the road at high speed without braking and with no other vehicle occupant besides the driver [USDOT NHTSA 2016e]. About 57 percent of fatal crashes in rural areas involve a single-vehicle [IIHS].

Distracted or inattentive driving by commercial motor vehicle drivers was a contributing factor in 6.1percent of fatal crashes involving large trucks in 2015 [USDOT FMCSA 2017a]. In addition, truck driver impairment (e.g., fatigue, drugs/alcohol, illness, etc.) was a factor in 3.3 percent of fatal crashes [USDOT FMCSA 2017a].

Lives Saved by Occupant Protection Equipment

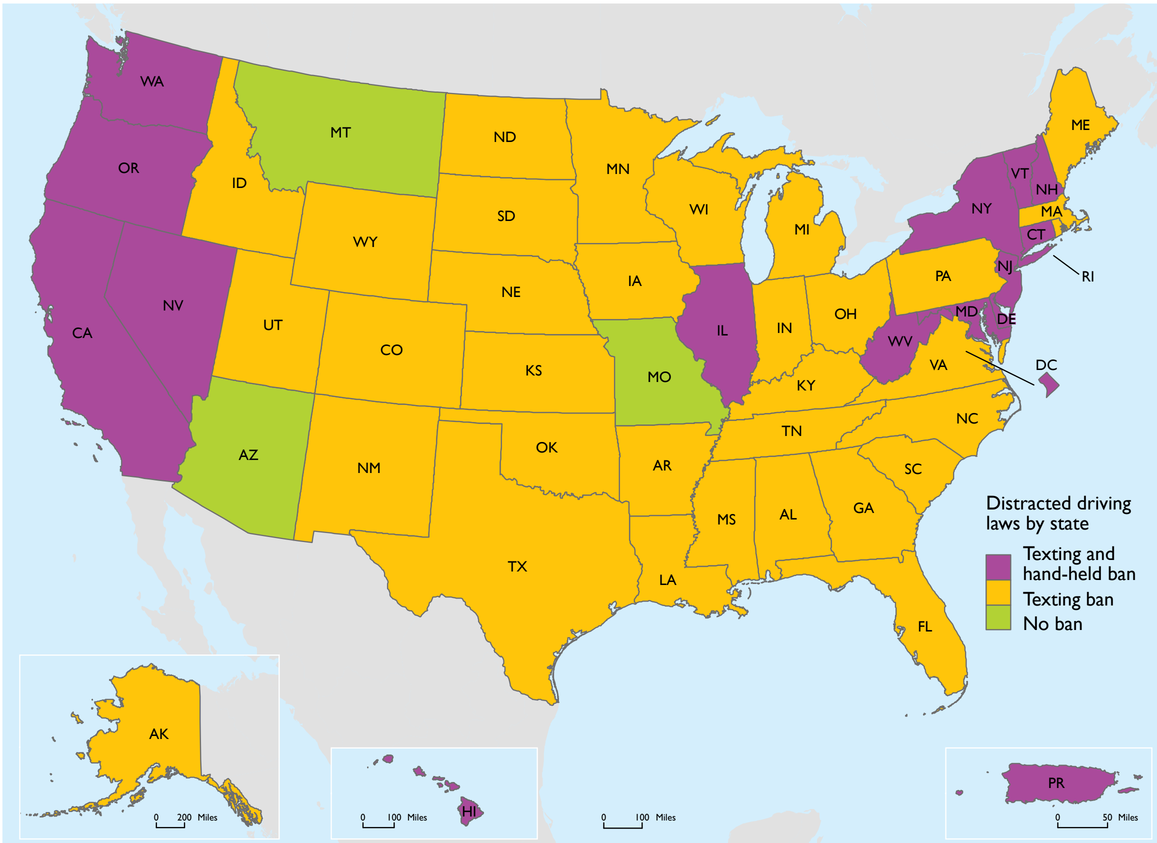
When properly used, safety devices significantly reduce the risk of death or serious injury. The NHTSA estimated that more than 20,000 lives were saved on the highways in 2016—up from more than 17,000 in 2010—by occupant protection devices, including seat belts, frontal air bags, child restraints, and motorcycle helmets, as shown in table 6-8. Seat belts saved over 14,000 lives, frontal air bags about 2,800, child restraints about 300, and DOT-compliant motorcycle helmets nearly 1,900 lives in 2016 (table 6-7).

Seat Belt Use

About 90.1 percent of occupants of cars, vans, and sport utility vehicles (SUVs) used safety belts in 2016, up from 70.7 percent in 2000 and 85.1 percent in 2010, and 88.5 percent in 2015 [USDOT NHTSA 2017g, 2016g]. Pickup truck occupants had the lowest usage at 83 percent in 2015, up from 81percent in 2014 (Table 6-8).

[15] 2015 data are not available.

FIGURE 6-11 State Laws on Distracted Driving: July 2017



NOTES: A primary law means that an officer can ticket the driver for the offense without any other traffic violation taking place. A secondary law means an officer can only issue a ticket if a driver has been pulled over for another violation (like speeding). Hand-held Cell Phone Use: 14 states, D.C., Puerto Rico, Guam and the U.S. Virgin Islands prohibit all drivers from using hand-held cell phones while driving. All are primary enforcement laws—an officer may cite a driver for using a hand-held cell phone without any other traffic offense taking place. Text Messaging: Washington was the first state to pass a texting ban in 2007. Currently, 47 states, D.C., Puerto Rico, Guam and the U.S. Virgin Islands ban text messaging for all drivers.

SOURCE: U.S. Department of Transportation, National Highway Traffic Safety Administration, *State Laws on Distracted Driving*, available at http://www.distraction.gov/stats-research-laws/state-laws.html as of November 2017.

TABLE 6-7 Estimated Lives Saved by Selected Safety Features: 2000, 2010, 2015, and 2016

	2000	2010	2015	2016
Child Restraints, Age 4 and Younger	479	303	272	328
Seat Belts, Age 5 and Older	12,882	12,670	14,067	14,668
Frontal Air Bags, Age 13 and Older	1,716	2,403	2,596	2,756
Motorcycle Helmets, All Ages	872	1,551	1,800	1,859
Minimum Drinking Age Law	922	560	542	552

SOURCE: U.S. Department of Transportation, National Highway Traffic Safety Administration, National Center for Statistics and Analysis, *Traffic Safety Facts* (Washington, DC: Annual Issues). Available at http://www-nrd.nhtsa.dot.gov/ as of October 2017 as cited in USDOT, Bureau of Transportation Statistics, *National Transportation Statistics*, table 2-31. Available at http://www.bts.gov as of November 2017.

TABLE 6-8 Safety Belt and Motorcycle Helmet Use: 2000, 2010, 2015, and 2016
Percent

	2000	2010	2015	2016
Overall safety belt use	**71**	**85**	**89**	**90**
Drivers	72	86	89	91
Right-Front Passengers	68	83	87	89
Passenger cars	74	86	90	91
Vans and sport utility vehicles	U	88	90	92
Pickup trucks	U	75	81	83
Motorcycle helmet use[b]	**71**	**54**	**61**	**65**
Operators	72	55	64	68
Passengers	62	51	46	53

KEY: U = data are unavailable.

[a] Seat belt use is as of the Fall each year. Motorcycle helmet use is as of the Fall each year.

[b] Only those operators and riders wearing safety helmets that met U.S. Department of Transportation (DOT) standards are counted. Those safety helmets that do not meet DOT standards are treated as if the operator/rider were not wearing a helmet.

NOTE: Occupants of commercial and emergency vehicles are excluded.

SOURCE: U.S. Department of Transportation (USDOT), National Highway Traffic Safety Administration, Traffic Safety Facts: Research Notes, *Seat Belt Use* (Annual issues); and *Motorcycle Helmet Use—Overall Results* (Annual issues). Available at http://www-nrd.nhtsa.dot.gov as of October 2017 as cited in USDOT, Bureau of Transportation Statistics, *National Transportation Statistics*, table 2-30, available at http://www.bts.gov as of November 2017.

Regionally, in 2015, seat belt use is highest in the western United States (about 95 percent) and lowest in the Midwestern states (82 percent). States with primary enforcement laws, allowing police to ticket vehicle occupants solely for not wearing seat belts, have higher belt usage (91 percent in 2015) than states with weaker enforcement (79 percent) [USDOT NHTSA 2016e].

Seat belt use is most effective in conjunction with air bags, which deploy automatically in crashes. Recalls to replace defective airbags and other occupant protection equipment sometimes are undertaken, most dramatically in the ongoing case of airbags outlined in box 6-d.

Helmet Use

DOT-compliant motorcycle helmets reduce the risk of dying in a motorcycle crash and also reduce emergency medical care, hospitalization, intensive care, rehabilitation, and long-term care following crashes [NTSB 2010]. Overall usage of DOT-compliant helmets has declined from 71.0 percent in 2000 to 65.3 percent in 2016 (table 6-8). Only 19 states and the District of Columbia have a universal helmet law, 28 states have a partial law covering certain riders and passengers (e.g., those under the age of 18), and 3 states (Illinois, Iowa, and New Hampshire) have no motorcycle helmet law (figure 6-12). Helmet use seems partially correlated to state

Box 6-D Air Bag Recall

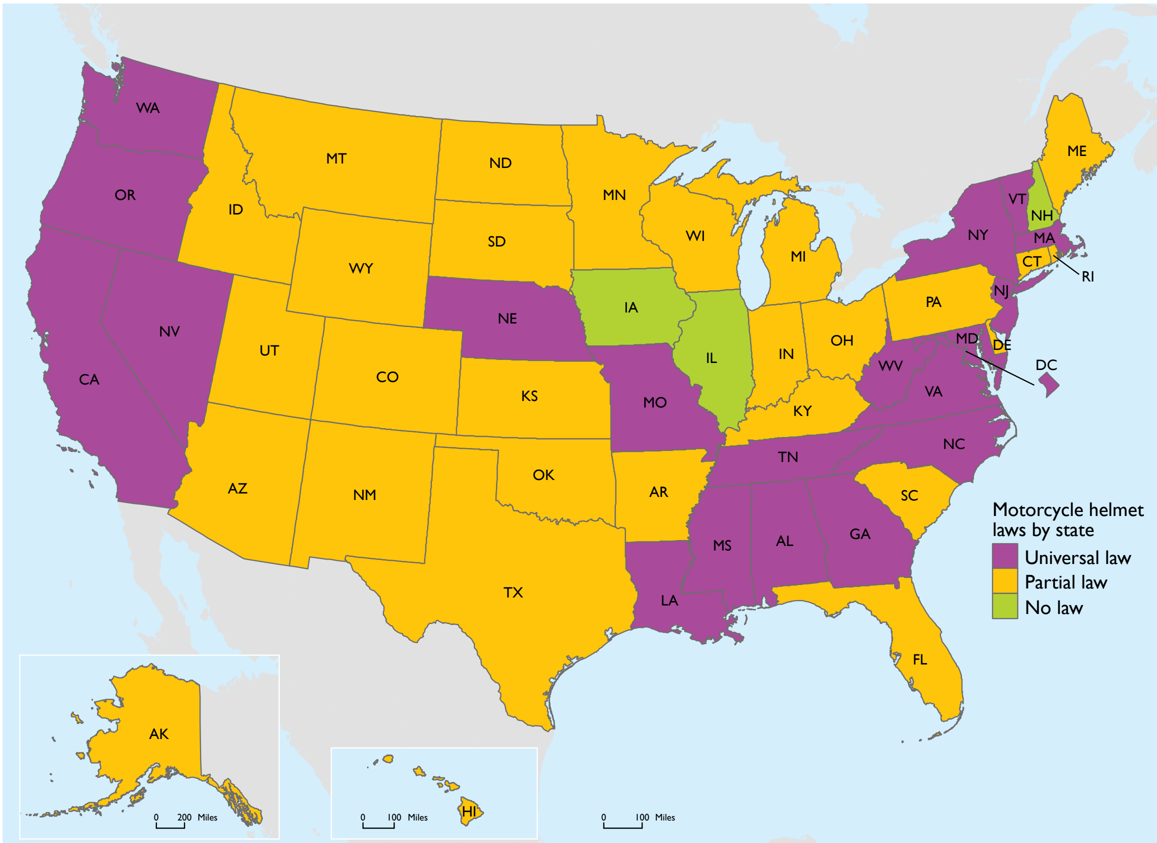
According to the National Highway Transportation Safety Administration (NHTSA), Takata air bags have been installed in tens of millions of U.S. vehicles. As of early October, 2016, 11 U.S. fatalities and more than 100 injuries have been linked to a defect in the airbag inflator and propellant devices, causing them to rupture and send metal shards into vehicle occupants during a crash [USDOT NHTSA 2016c and 2016h]. The root cause of the ruptures is the degradation of the ammonia nitrate propellant over time and when exposed to high humidity and fluctuating high temperatures, which in turn causes the propellant to burn too quickly and rupture.

NHTSA, which is charged with ensuring the safety of motor vehicles in the United States, initiated a formal defect investigation of the Takata air bag inflators in June 2014 [USDOT NHTSA 2015f], which resulted in a recall of 28.8 million airbags. Of that total, nearly 11.4 million have been repaired (5.1 million passenger-side air bags and 6.3 million driver side air bag) as of October 7, 2016 [USDOT NHTSA 2016b].

On May 4, 2016, NHTSA expanded the recall to include an additional 35–40 million air bag inflators to the already recalled 28.8 million. The expanded recall of inflators means that all Takata ammonium nitrate-based propellant air bag inflators that do not have a chemical drying agent, also known as a desiccant, will be recalled. The expanded recall will be handled in five phases over the May 2016 to December 2019 period, and based on risk factors, such as an inflator's age and its exposure to high humidity and fluctuating high temperatures [USDOT NHTSA 2016c].

The Takata air bag recall is the largest safety recall in U.S. history. Takata reached an agreement with NHTSA to pay $200 million in civil penalties and to phase out supplying ammonium nitrate inflators to fulfill existing contracts by no later than December 31, 2018 [USDOT NHTSA 2015a]. In January 2017, Takata agreed to plead guilty to wire fraud and to pay $1 billion in criminal penalties for fraudulent conduct in selling the defective inflators [USDOJ 2017]. In June, 2017, Takata filed for bankruptcy. Federal law (Section 3012A of Title 49 of the U.S. Code) specifies recall obligations in the event of bankruptcy, indicating that filing a bankruptcy petition does not negate the manufacturers recall duties [USDOT NHTSA 2013].

FIGURE 6-12 State Laws on Motorcycle Helmet Use: August 2017



SOURCE: Insurance Institute for Highway Safety, *Motorcycle Helmet Use*, available at www.iihs.org as of August 2017.

requirements. In 2016, 79.6 percent of riders wore DOT-compliant helmets in states that required helmet use, while 53.5 percent of riders wore DOT-compliant helmets in states that do not require their use [USDOT NHTSA 2017h]. Noncompliant helmets were worn by 14.9 percent of riders in states requiring helmet use and 3.6 percent in states not requiring helmet use. In 1975, 47 states and the District of Columbia had adopted universal helmet use laws that required motorcycle helmets for all riders, but many states have subsequently made their helmet laws less restrictive [COSGROVE 2007].

Life Jackets and Boat Safety Training

About 8 out of 10 people who died in boating accidents in 2016 drowned, and about 83 percent of those who drowned were not wearing a life jacket [USDHS USCG 2017]. Even if not legally required, operators of boats can insist that their passengers wear life jackets. Most states require mandatory recreational boating education and safety training courses, but eight states do not (Alaska, Arizona, California, Idaho, Maine, South Dakota, Utah, and Wyoming). Boater education helps reduce the risk of boating accidents and death [NTSB

2013], and about 42.6 percent of U.S. boat owners have taken a boating safety course. Most boating fatalities occur on vessels in which the operator had no formal instruction in boating safety. Only 13 percent of deaths in fatal boating accidents in 2016 occurred in boats operated by a person known to have received a certificate for boating safety from such providers—an improvement from 23 percent in 2014 [USDHS USCG 2017].

Traffic Safety Enforcement

Traffic safety enforcement promotes good driving habits (e.g., wearing a safety belt) and discourages unsafe behaviors (e.g., impaired driving) [USDOT NHTSA 2014b]. According to the Bureau of Justice Statistics, in 2011 about 10.2 percent of the Nation's 212.3 million drivers were stopped by police while operating a motor vehicle, 5.3 percent of these drivers were ticketed, 3.4 percent were given a verbal or written warning, and 1.4 percent were allowed to proceed with no enforcement action taken [USDOJ BJS 2013].

Speeding was cited as the leading reason for a traffic stop, accounting for 46.5 percent, followed by vehicle defects (e.g., broken tail light) with 14.1 percent. Males were more likely to be stopped and ticketed than females, accounting for 58.8 percent of ticketed drivers. Drivers who were 25 to 34 years of age accounted for about 22.4 percent of stopped drivers, which is the highest percentage among all age groups [USDOJ BJS 2013]. However, this age group accounted for only 13.7 percent of VMT [USDOT FHWA 2011].

In 2015, according to the Federal Bureau of Investigation, law enforcement agencies across the country made an estimated 1.1 million arrests for driving under the influence [USDOJ FBI 2017]. Males accounted for three out of four DUI arrests [USDOJ FBI 2017]. Studies have shown sobriety checkpoints are an effective countermeasure to reduce alcohol-impaired driving, reducing alcohol-related crashes by roughly 20 percent [USDHHS CDC NCI 2015].

The Federal Motor Carrier Safety Administration (FMCSA) is responsible for reducing crashes, injuries, and fatalities involving the Nation's approximately 521,200 interstate freight carriers, 13,300 interstate passenger carriers, and 16,600 interstate hazardous material carriers [USDOT FMCSA 2017b]. In fiscal year 2016, over 3.4 million roadside inspections were conducted (table 6-9). Over 34,670 warning letters were issued to carriers whose safety data showed a lack of compliance with motor carrier safety regulations and whose safety performance had fallen to an unacceptable level [USDOT FMCSA 2017c]. Table 6-9 shows the number of inspection, which may result in out-of-service (OOS) violations that must be corrected before the driver or vehicle can return to service. Vehicle violations, such as defective lights, worn tires, or brake defects put 27.7 percent of inspected vehicles out-of-service.

To comply with Federal hours of service regulations, truck drivers are required to take 10 consecutive hours off after driving a maximum of 11 hours and to take 30-minute rest periods after 8 hours of driving [USDOT FMCSA 2011]. Consequently, drivers need to find parking facilities that will give drivers

TABLE 6-9 Inspection Summary: 2010 and 2016

	2010	2016
Roadside inspections	**3,569,373**	**3,418,886**
With no violations	1,225,324	1,418,401
With violations	2,344,049	2,000,485
Driver inspections	**3,470,871**	**3,300,964**
With OOS Violations	183,350	187,597
Driver OOS Rate	5.3%	5.7%
Vehicle inspections	**2,413,094**	**2,348,391**
With OOS Violations	480,416	650,909
Vehicle OOS Rate	19.9%	27.7%
Hazardous material inspections	**211,154**	**200,479**
With OOS Violation	9,210	10,373
Hazmat OOS Rate	4.4%	5.2%

KEY: OOS = out-of-service.

NOTES: *Driver Inspections* were computed based on inspection levels I, II, III, and VI. *Vehicle Inspections* were computed based on inspection levels I, II, V, and VI. *Hazmat Inspections* were computed based on inspection levels I, II, III, IV, V, and VI when hazardous materials were present. *Roadside inspection* OOS rates depicted in this table include both large trucks and buses. For more information on roadside inspections and inspection levels, please refer to https://csa.fmcsa.dot.gov.

SOURCE: U.S. Department of Transportation, Federal Motor Carrier Safety Administration, Motor Carrier Management Information System (MCMIS), *Roadside Inspection Activity Summary for Fiscal Years*, October 2017.

off-road places to stop to rest while not posing a safety hazard to others on the road.

A 2015 FHWA survey showed a shortage of truck parking facilities, especially along major freight corridors, such as I-95, I-40, and I-10, and in metropolitan areas [USDOT FHWA 2015]. Also, many states do not allow overnight or extended parking at public rest areas [USDOT FHWA 2012]. The shortage of truck parking facilities poses a safety risk not only to truck drivers but also other motorists, as some commercial drivers could decide to drive on while tired or to park in unsafe locations along road shoulders and highway entrance and exit ramps [USDOT FHWA 2015]. Driver violations put 5.7 percent out-of-service, often due to noncompliance with hours-of-service regulations. As was discussed earlier, fatigue is a factor in many crashes.

Hazardous Materials Transportation

Transporting hazardous materials requires special precautions, handling, and packaging. There are specialized safety regulations, standards, and reporting systems in place for pipelines, rail, highway, air, and marine vehicles that transport hazardous materials.

These special requirements recognize that incidents involving the transportation of hazardous materials can affect the environment in addition to potentially risking injury and death. Table 6-10 shows that, in 2016, more than 18,200 hazardous materials incidents (excluding pipeline incidents) were reported to the USDOT Pipeline and Hazardous Materials Administration (PHMSA)—up from about 16,500 in 2015 [USDOT PHMSA 2017b].

About 1.4 percent of hazardous materials transportation incidents in 2016 were the result of an accident (e.g., vehicular crash or train derailment). About 90 percent of these incidents related to the movement of hazardous materials occurred on highways or in truck terminals. Most hazardous materials incidents occur because of human error or package failure, particularly during loading and unloading.

The above incidents do not include pipelines which are reported separately to PHMSA. Table 6-11 provides a summary of all 635 hazardous liquid-related and gas-related pipeline incidents reported in 2016, which resulted in 17 fatalities, 82 injuries, and $308 million in property damage (down from $1.7 billion in 2010, reflecting the incident specific nature of property damage). Hazardous liquids accounted for well over half the incidents and property damage. Gas distribution and transmission accounted for all but one of the fatalities and all of the injuries in 2015 (table 6-11).

TABLE 6-10 Hazardous Materials Transportation Incidents: 2010 and 2014–2016

	2010	2014	2015	2016
Total incidents	**14,795**	**17,401**	**16,588**	**18,238**
Total vehicular accident / derailment incidents	**358**	**351**	**286**	**263**
Vehicular accident-related percent of total incidents	**2.4**	**2.0**	**1.7**	**1.4**
Air	1,295	1,327	1,074	1,198
Vehicular accident-related	2	3	2	3
Highway	12,648	15,310	14,923	16,485
Vehicular accident-related	320	330	251	235
Rail	747	717	567	544
Vehicular accident-related / derailment incidents	35	18	32	24
Water[1]	105	47	24	11
Vehicular accident-related	1	0	1	1

[1] Water include only packages (nonbulk) marine. Non-packaged (bulk) marine hazardous material incidents are reported to the U.S. Coast Guard and are not included.

NOTES: *Incidents* are defined in the Code of Federal Regulations (CFR): 49 CFR 171.15 and 171.16 (Form F 5800.1). Each modal total also includes fatalities caused by human error, package failure, and causes not elsewhere classified. *Accident-related* are the result of a vehicular crash or accident damage (e.g., a train derailment).

SOURCE: U.S. Department of Transportation, Pipeline and Hazardous Materials Safety Administration, Office of Hazardous Materials Safety, *HAZMAT Intelligence Portal* (as of April 17, 2016), available at https://hip.phmsa.dot.gov/ as of April 2017.

TABLE 6-11 All Reported Hazardous Liquid and Gas Incidents: 2010–2016

	TOTAL - all reported					
	Number	Fatalities	Injuries	Property damage as reported	Barrels spilled (Haz Liq)	Net barrels lost (Haz Liq)
2010	586	22	108	$1,692,500,877	100,558	49,452
2011	592	14	56	$426,551,870	89,110	57,375
2012	573	12	57	$229,613,337	45,884	29,247
2013	619	9	44	$349,961,947	117,467	85,598
2014	707	19	95	$310,257,400	47,083	21,686
2015	715	12	49	$344,188,043	103,607	81,953
2016	635	17	82	$308,344,675	86,154	53,083

KEY: *Haz Liq* = Hazardous Liquid, *LNG* = Liquefied Natural Gas, R = revised, U = Data unavailable.

NOTES: *Hazardous Liquid* includes crude oil; refined petroleum products (e.g., gasoline, diesel, kerosene); highly volatile, flammable, and toxic liquids (e.g., propane); liquid carbon dioxide; and biodiesel. *Gross Barrels Spilled* is the amount before clean-up, whereas *Net Barrels Lost* is the amount after clean-up is attempted.

Incident means any of the following events: 1) An event that involves a release of gas from a pipeline, or of liquefied natural gas, liquefied petroleum gas, refrigerant gas, or gas from an LNG facility, and that results in one or more of the following consequences: i) A death, or personal injury necessitating in-patient hospitalization; ii) Estimated property damage of $50,000 or more. *Accident* is a failure in a pipeline system in which there is a release of the hazardous liquid or carbon dioxide transported resulting in any of the following: a) Explosion or fire not intentionally set by the operator. b) Release of 5 gallons (19 liters) or more of hazardous liquid or carbon dioxide.

Please see the Pipeline and Hazardous Materials Safety Administration's Incident Report Criteria History for a complete definition of past and present reporting requirements, which is available at https://hip.phmsa.dot.gov/Hip_Help/pdmpublic_incident_page_allrpt.pdf as of April 2016.

SOURCE: U.S. Department of Transportation, Pipeline and Hazardous Materials Safety Administration, Office of Hazardous Materials Safety, *HAZMAT Intelligence Portal*. Available at https://hip.phmsa.dot.gov/ as of April 2017.

A new challenge for freight transportation safety relates to accidents involving tanker trucks and trains carrying hazardous materials. Chapter 3 discusses the rapid growth in domestic transportation, some of which involves hazardous materials. According to the Commodity Flow Survey (CFS), liquid hazardous materials tonnage increased 15.6 percent between 2007 and 2012; part of the increase could be a result of increased CFS coverage [USDOT BTS 2015]. Some 58.7 percent of hazardous liquid tonnage was moved by truck and 2.1 percent by rail in 2012. As for flammable solids, rail moved 32.9 percent of the tonnage and trucks transported 59.7 percent. Liquid hazardous materials include gasoline, fuel oils, and ethanol, while flammable solids include metal powders, shavings, and cuttings; rubber scrap; and molten sulfur, among other spontaneous combustible materials.

There has been a dramatic increase in hazardous liquid train traffic, as discussed in chapter 3, and several derailments resulting in explosions and fireballs have occurred in this country, resulting in evacuations of several communities. In Canada, the rail catastrophe in Lac-Mégantic, Quebec, resulted in 47 deaths in 2013. See box 6-E for more on rail tank car safety.

Box 6-E Rail Tank Car Safety

Section 7308 of the *Fixing America's Surface Transportation Act* (FAST Act; P. L. 114-94; December 4, 2015) requires the U.S. Department of Transportation (DOT) to assemble and collect data on rail tank cars transporting Class 3 flammable liquids. The objective of this legislation is to track the progress in upgrading the rail tank car fleet to new safety requirements. By the end of 2029, rail tank cars carrying class 3 flammable liquids must meet the DOT-117 or DOT-117R specification or equivalent.

According to the recent BTS report, 81,027 tank cars were used in 2016 to transport Class 3 flammable liquids, accounting for 20 percent of all tank cars. Most of these tank cars were non-jacketed DOT-111 specification (53 percent of the fleet), followed by the non-jacketed CPC-1232 (15 percent) and the jacketed CPC-1232 (10 percent).[1] The newer DOT-117 and 117R tank cars grew from less than 100 cars in 2013 (76 cars) to 7,181 tank cars, or approximately 9 percent of the fleet used to transport Class 3 flammable liquids in 2016.

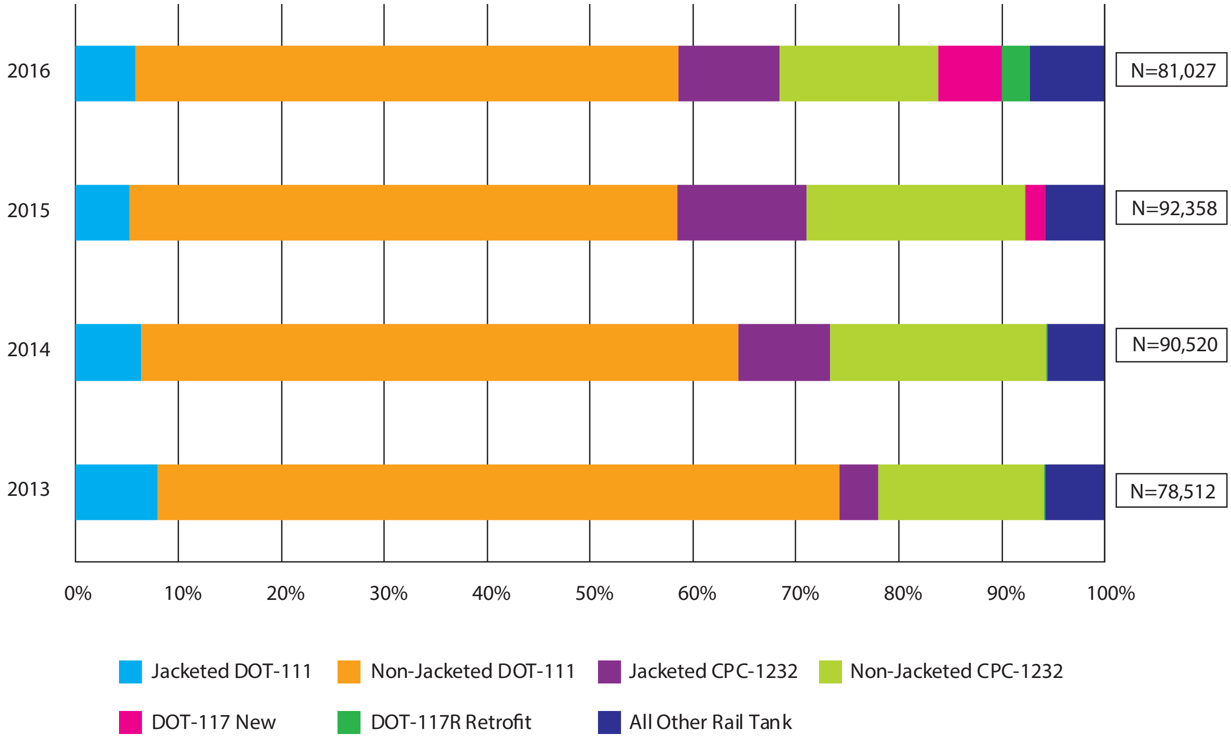
[1] Jacketed tank cars have a layer of insulation/thermal protection between the tank shell and jacket that stabilizes the temperature of the liquid contained in the tank car, and reduce the conductivity of heat from outside sources to the contents of the tank car.

As of the end of 2016, 9 percent of the tank cars used to carry Class 3 flammable liquids met the new safety requirements, a dramatic increase from the 2 percent in 2015. Among the fleet of rail tank cars that meet the DOT- 117 specification, 70 percent (4,966 tank cars) are new and 30 percent (2,215 tank cars) have been retrofitted. While the DOT-117 and DOT-117R tank cars carry a variety of flammable liquids, nearly 9 out of 10 of these tank cars carry crude oil or ethanol (41 percent and 46 percent, respectively).

While the non-jacketed DOT-111 tank cars still represent most of the fleet used to transport flammable liquids, with 42,714 tank cars in operation in 2016, their numbers have declined since 2013 when 52,021 DOT-111 tank cars (66 percent of the fleet) were reported carrying flammable liquids on the railroads. In addition, the percentage of non-jacketed DOT-111 cars carrying crude oil has also shown a noticeable decline. In 2013, 25 percent of these cars transported crude oil as compared to less than 1 percent in 2016.

For the complete *Fleet Composition of Rail Tank Cars That Transport Flammable Liquids: 2013–2016* report, please visit the BTS website at http://www.bts.gov.

FIGURE 6-13 Fleet Composition of Rail Tank Cars Carrying Class 3 Flammable Liquids: 2013–2016



NOTE: All Other Rail Tank Cars includes DOT-105, DOT-112, DOT-114, DOT-115, DOT-120, and DOT-211.

SOURCE: U.S. Department of Transportation, Bureau of Transportation Statistics. Special analysis based on data provided by the Association of American Railroads: *UMLER® and TRAIN II® rail tank car and annualized rail tank car movements, 2013-2016*, as of June 7, 2017.

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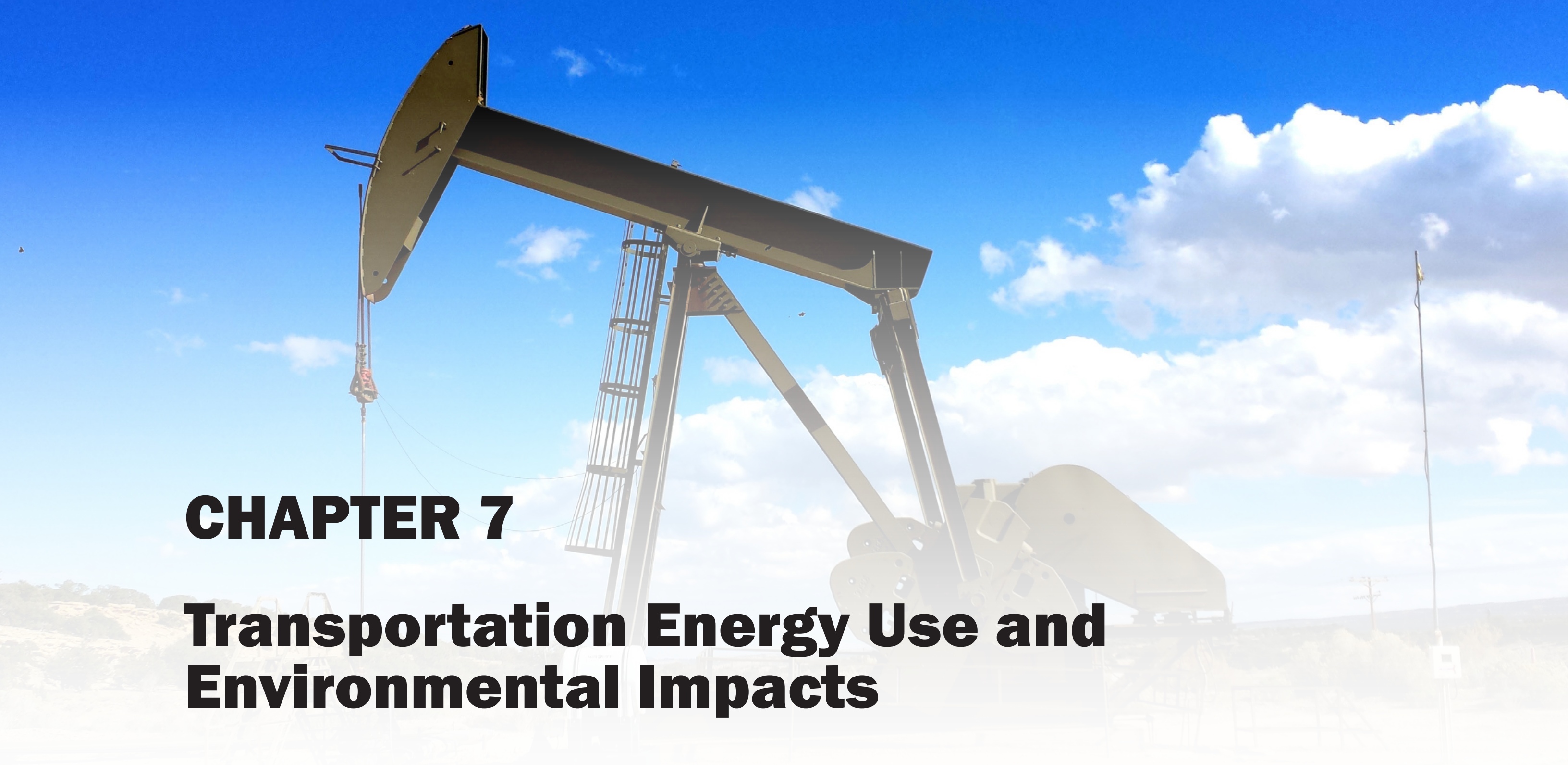


CHAPTER 7

Transportation Energy Use and Environmental Impacts

Highlights

- The energy required to move one person one mile or one ton of freight one mile has generally declined over time.
- Transportation continues to rely almost entirely on petroleum to move people and goods. However, the sector's dependence has decreased from a peak of 97.3 percent in 1978 to 92.2 percent in 2016. This is due in part to increased blending of domestically produced ethanol in gasoline and improved fuel economy.
- Increased domestic oil production sharply reduced transportation's dependence on imported oil, from a high of 60.3 percent in 2005 to 24.8 percent in 2015.
- The highway mode continues to dominate transportation energy use, accounting for 61.6 percent of total transportation energy use.
- Transportation is the second largest producer of greenhouse gas emissions (GHG), accounting for 27.0 percent of total U.S. emissions in 2015.
- Overall, greenhouse gases and the six other most common air pollutant emissions from transportation, with the exception of particulate matter (PM-10), are below their 2000 levels, and continued to decline from 2009 to 2016 due to many factors, including motor vehicle emissions controls and technological advancements, such as electric vehicles have contributed to considerable reductions.
- Reductions in transportation's air emissions have contributed to improved air quality in the Nation's urban areas. On average, air quality was good for 247 days in 2015 compared to 192 days in 2000.
- Over 97 percent of the U.S. population has potential to be exposed to aviation and interstate highway noise at levels below 50 decibels (equivalent to the sound of a humming refrigerator).

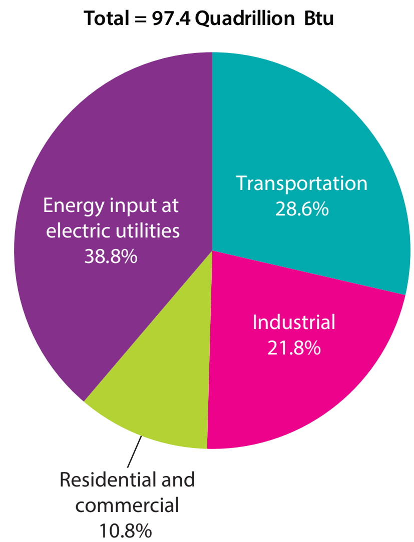
This chapter reviews the patterns and trends in transportation energy use, other aspects of energy associated with our Nation's transportation system, and transportation's impact on the environment. Energy use is closely tied to the transportation sector because most vehicles in the U.S. rely on petroleum as a fuel. Therefore, developments in domestic oil production, alternative fuels, and improvements in vehicle energy efficiencies play a critical role in the vitality of the transportation system. Environmental impacts under consideration include greenhouse gas (GHG) emissions caused by the transportation sector, petroleum spills, noise, and other impacts. These energy and environmental aspects of the transportation system are also important measures of performance, along with such primary measures as system reliability, efficiency, and safety.

U.S. dependence on imported oil is trending lower than in prior years as a result of increased domestic production, improved fuel economy for vehicles, and the growth in alternative energy sources. U.S. dependence on imported oil peaked at 60.3 percent in 2005, but has since decreased by more than half, to 24.8 percent in 2015 [USDOE EIA 2017c]. In 2015 this dependence was at its lowest since 1971, but with increasing fuel efficiency and reduced fuel prices, people are driving more miles on average and demand for less fuel-efficient sport utility vehicles (SUVs). Car and truck SUVs achieved a record market share of 38 percent in model year 2015 [US EPA 2017f].

In 2016 the U.S. transportation sector used 27.5 quadrillion Btu (British thermal unit) of energy, second only to electricity generation, but down from the peak of 28.8 quadrillion Btu in 2007 (figures 7-1 and 7-2). Transportation activities relied on petroleum for 92.2 percent of the transportation-related energy used in 2016, down from a record 97.3 percent in 1978. In 2016, the U.S. consumed more than 19.6 million barrels of oil per day, of which 13.9 million barrels (70.9 percent) were consumed by the U.S. transportation system [USDOE EIA 2017c]. Despite transportation's continued dependence on petroleum, recent trends show small reductions in greenhouse gas emissions and sharply reduced emissions of other air pollutants.

Greenhouse gas (GHG) emissions (carbon dioxide, hydrofluorocarbons, methane, and nitrous oxide) have historically closely paralleled transportation energy use and, as a result, were 4.9 percent lower in 2015 than in 2010, while transportation sector GHG emissions decreased by 1.2 percent [USEPA 2017a]. Overall, the transportation sector contributed 27 percent of total U.S. GHG emissions in 2015, second only to electricity generation at 29 percent. Transportation sector GHG emissions peaked in 2005, but trended downward in the following years with a low point in 2012. The decline was due to increased use of alternative fuels and improved fuel economies related to manufacturers' efforts to make driving more affordable as fuel prices were increasing. Since then GHG emissions have begun to increase due to increases in both miles traveled and use of sport utility vehicles (SUVs) and light trucks associated with lower fuel prices mentioned earlier [USEPA 2017a].

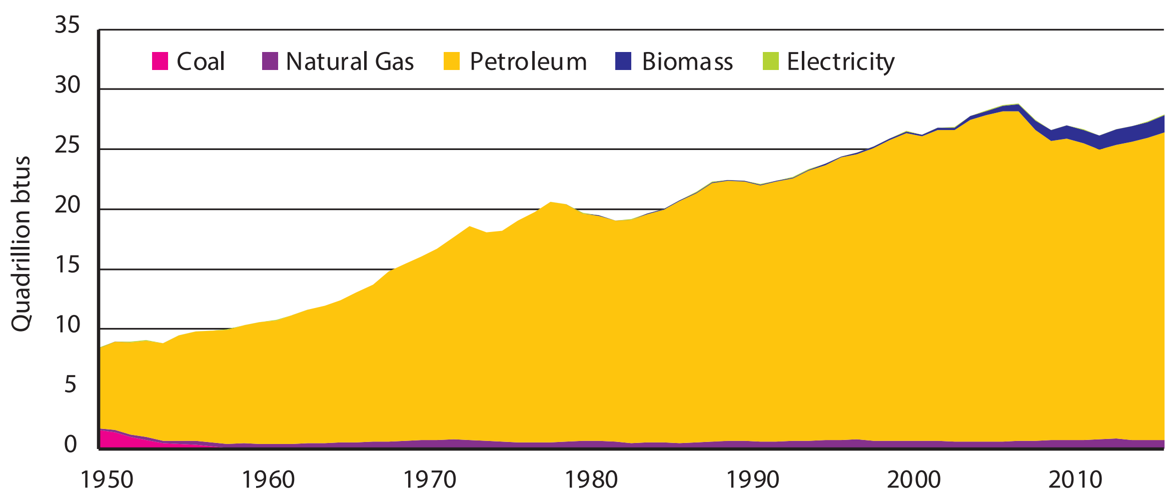
FIGURE 7-1 U.S. Energy Use by Sector: 2016



NOTES: The data for *Residential, Commercial, and Industrial* sectors include only fossil fuels consumed directly. Most renewable fuels are not included. The data for the *Transportation* sector includes only fossil and renewable fuels consumed directly. The data for *Electric* utilities includes all fuels (fossil, nuclear, geothermal, hydro, and other renewables) used by electric utilities.

SOURCE: U.S. Department of Energy, Energy Information Administration, Monthly Energy Review, Table 2-1, Available at http://www.eia.gov/totalenergy/ as of April 2017.

FIGURE 7-2 Transportation Energy Use by Energy Source: 1950–2016



SOURCE: U.S. Department of Energy, Energy Information Administration, Monthly Energy Review, table 2.5. Available at http://www.eia.gov as of April 2017.

Energy Use Patterns and Trends

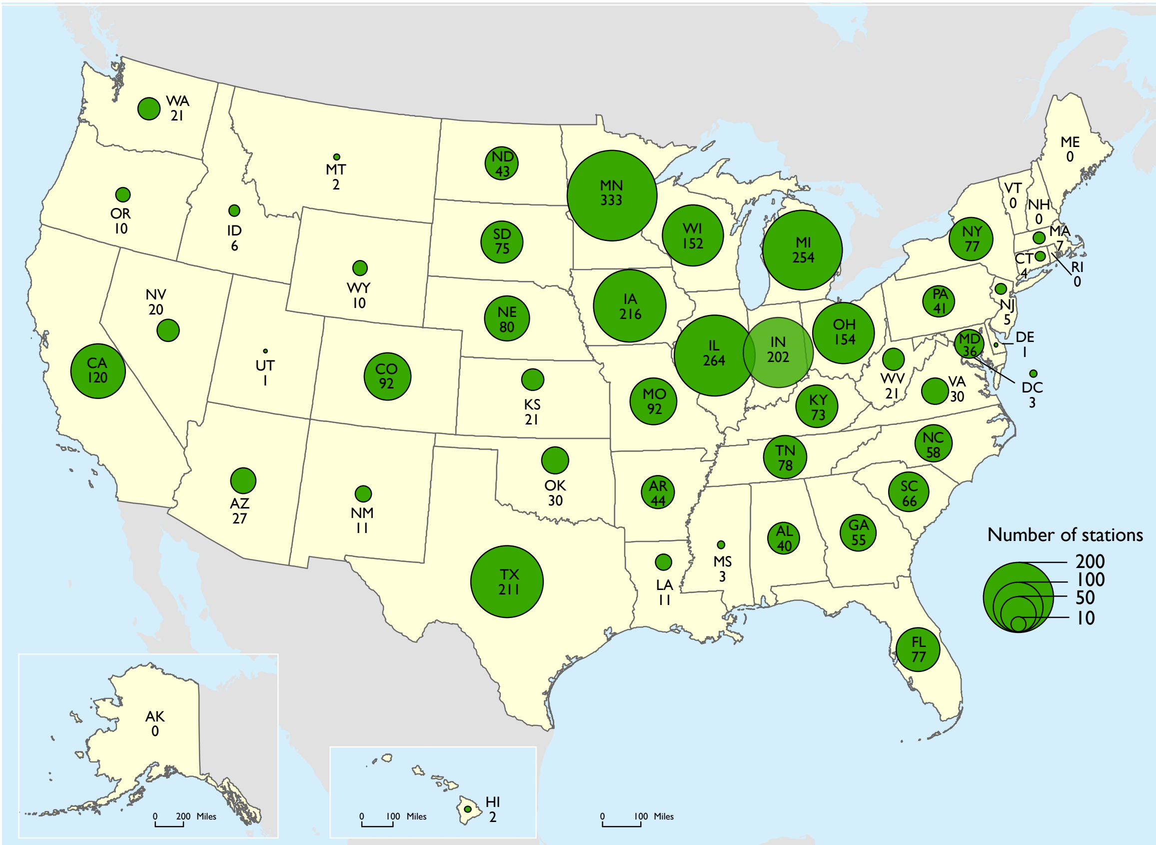
Transportation's petroleum dependence decreased from 96.5 percent in 2005 to about 92.1 percent in 2016, chiefly due to increased blending of domestically produced ethanol from biomass in gasoline [USDOE EIA 2017c]. Today almost all gasoline sold in the United States contains 10.0 percent ethanol (E10). Nearly all transportation-related natural gas consumption, shown in figure 7-2, is used to fuel pipeline compressors. Natural gas use by motor vehicles remains a small fraction of total transportation energy use (figure 7-2).

Transportation's petroleum use is expected to remain at about 13.5 million barrels per day through 2050 and beyond, even though more stringent fuel economy standards may produce decreases in the amount of gasoline used by personal vehicles [USDOE EIA 2017a]. Additionally, as vehicles become more fuel efficient and new technologies for alternative fuel sources to power vehicles continues to grow including all electric vehicles (box 7-A), less petroleum will be required for a similar level of personal travel miles (see sections 7-4 through 7-6). This improvement in fuel efficiencies and a drop in fuel prices recently has led to an increase in personal vehicle miles traveled contributing to the relatively stable petroleum use. This leveling off of petroleum consumption is also expected because declining personal vehicle petroleum use is projected to be offset by growth in petroleum demand by other modes, particularly medium- and heavy-duty trucks and air. For example, U.S. domestic air carrier miles flown has increased by 10 percent since 2000, but this has been somewhat offset by increased fuel efficiencies of the aircraft.

Alternative fuel use (excluding gasohol) by motor vehicles increased by 12.7 percent from 2010 to 2011 (the latest year for which data are available) [USDOE EIA 2017b]. Total alternative fuel use exceeded 500 million gasoline-equivalent gallons in 2011. In comparison, gasoline consumption in the United States grew from about 134 billion gallons in 2011 to more than 140 billion gallons in 2015—approximately 385 million gallons per day [USDOE EIA 2017c]. In terms of overall energy consumption, compressed and liquefied natural gas accounted for almost one-half of the total alternative energy used by transportation activities, followed by E85, propane, electricity, and hydrogen. E85 is a blend of between 51 and 85 percent denatured ethanol and gasoline and can be used safely by approximately 20 million flex-fuel vehicles operating on U.S. roads [USDOE AFDC 2017a]. However, E85 is predominantly available in the Midwest corn-belt states as indicated in figure 7-3.

The highway mode dominates transportation energy use (figure 7-4). Highway vehicles accounted for 84.0 percent of the total and used five times more energy than all other modes combined in 2015. Light-duty vehicles (passenger cars, SUVs, minivans, and pick-up trucks) accounted for 73.3 percent of highway energy use and 61.6 percent of total transportation energy use. Air transport came in a distant second with 6.5 percent of transportation energy use, but this number excludes energy for international flights. Jet fuels supplied to international flights originating in the United States amounted to 931.6 trillion Btu [USEPA 2015a], which is nearly five times the amount of fuel used by

FIGURE 7-3 E85 Refueling Stations by State: 2016



SOURCE: U.S. Department of Energy, Alternative Fuels Data Center, *Alternative Fueling Station Counts* (as of 03/16/2017), available at http://www.afdc.energy.gov/fuels/stations_counts.html as of March 2017.

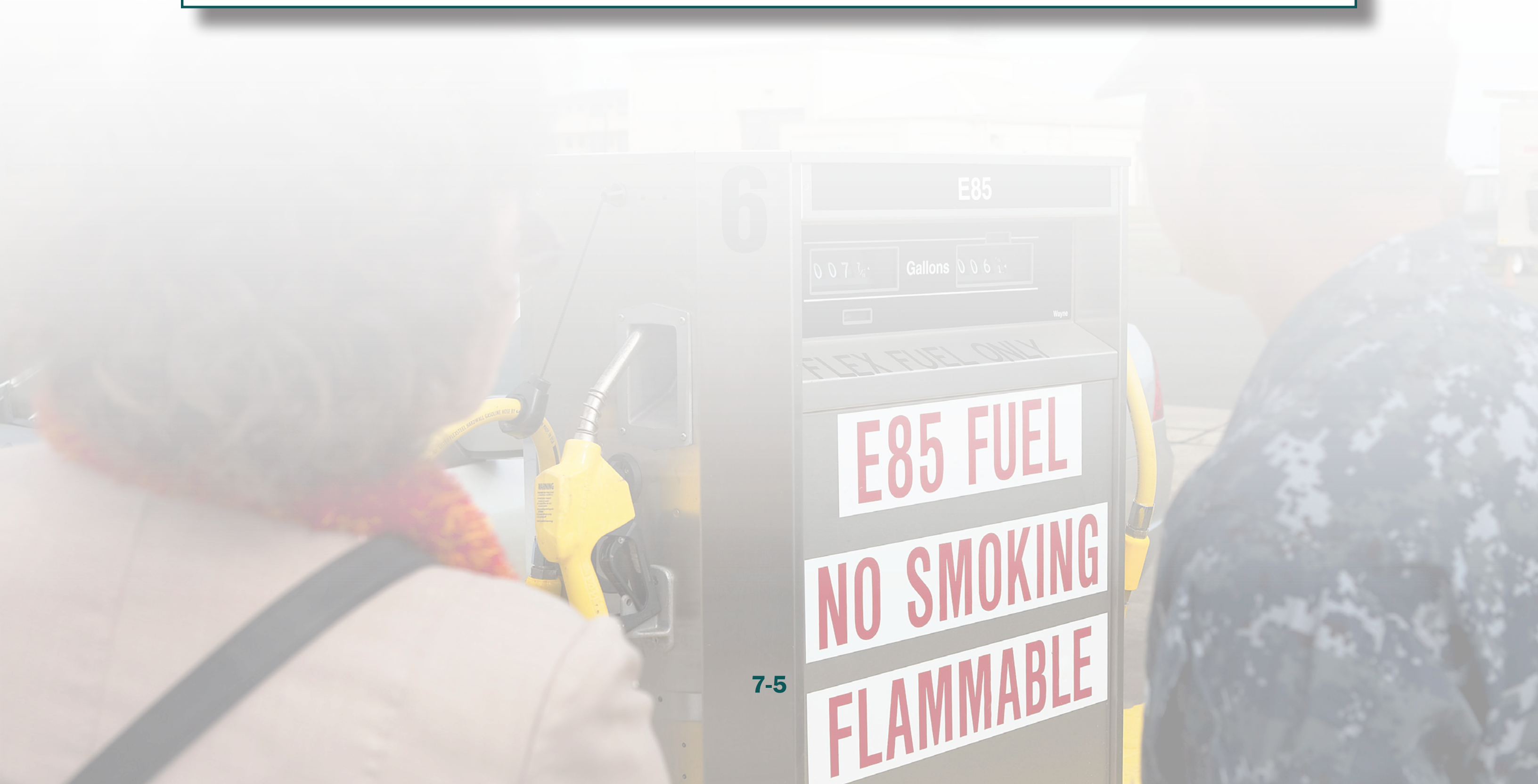
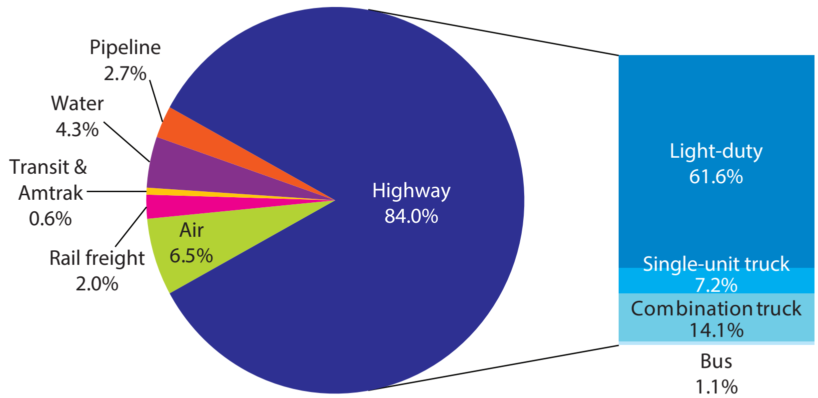


FIGURE 7-4 Energy Use by Mode of Transportation: 2015



NOTES: The following conversion rates were used: Jet fuel = 135,000 Btu/gallon. Aviation gasoline = 120,200 Btu/gallon. Automotive gasoline = 125,000 Btu/gallon. Diesel motor fuel = 138,700 Btu/gallon. Compressed natural gas = 138,700 Btu/gallon. Distillate fuel = 138,700 Btu/gallon. Residual fuel = 149,700 Btu/gallon. Natural gas = 1,031 Btu/ft3. Electricity 1kWh = 3,412 Btu, negating electrical system losses. To include approximate electrical system losses, multiply this conversion factor by 3.

SOURCE: Air–Bureau of Transportation Statistics, Office of Airline Information. **Rail**–Association of American Railroads. **Transit**–Federal Transit Administration. **Amtrak**–National Railroad Passenger Corporation (Amtrak), personal communication with Energy Management Department and Government Affairs Department. **Water**– U.S. Department of Energy, Energy Information Administration and U.S. Department of Transportation, Federal Highway Administration. **Pipeline**– U.S. Department of Energy, Energy Information Administration. **Highway**– Federal Highway Administration as cited in U.S. Department of Transportation, Bureau of Transportation Statistics, *National Transportation Statistics*, table 4-6, available at www.bts.gov as of March 2017.

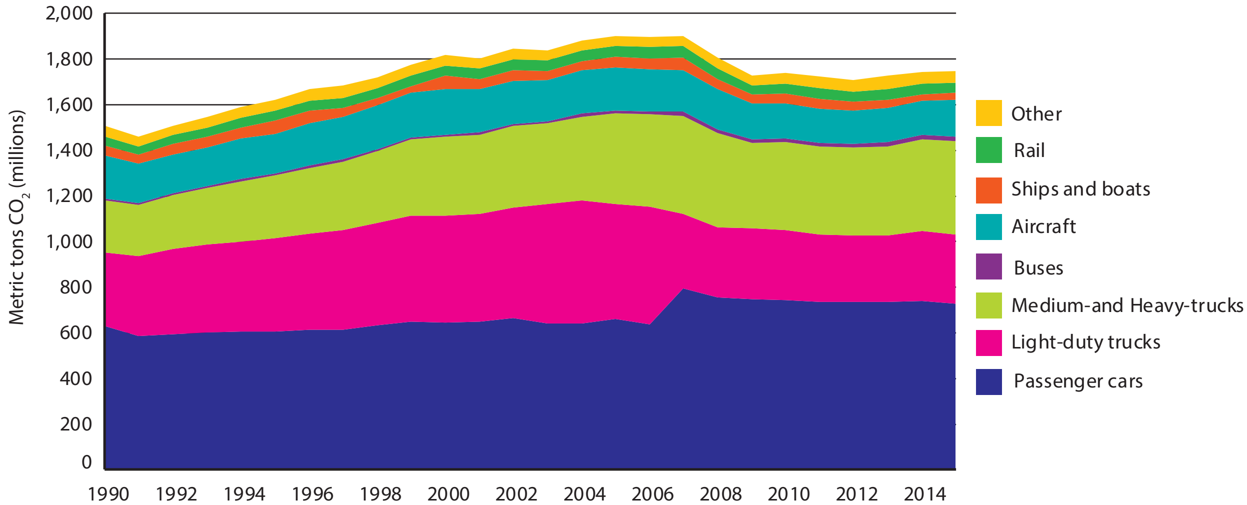
domestic flights. Water transportation is third with 4.3 percent, but once again most of the energy used in international shipments is not included in this figure. An estimated 455.2 trillion Btu were supplied to international ships at U.S. ports [USEPA 2015a], an amount more than double that used by domestic waterborne shipping. Rail freight accounted for 2.0 percent of transportation energy use, although it carries roughly 30 percent of U.S. freight ton-miles. Pipelines used 2.7 percent of transportation energy, much of which is natural gas to fuel pipeline compressors. Transit operations accounted for 0.6 percent of transportation energy use.

Greenhouse Gas Emissions

Total transportation greenhouse gas (GHG) emissions were 4.0 percent lower in 2015 than in 2000. Both the recession and the improvements in availability of energy efficient vehicles likely contributed to this reduction [USEPA 2017a].

Despite the long-term emissions decrease, the transportation sector remains the second largest producer of greenhouse gas (GHG) emissions, accounting for approximately 27.0 percent of total U.S. emissions in 2015 [USEPA 2017a]. Electricity generation is the highest GHG producer. In recent years, transportation-related GHG emissions have been trending upward, but are below the 2005 peak (figure 7-5). Carbon dioxide (CO_2) produced by the combustion of fossil fuels in internal combustion engines is the predominant GHG emitted by the transportation sector. In 2015 passenger cars were the largest source of CO_2 from transportation, accounting for

FIGURE 7-5 CO_2 Greenhouse Gas Emissions by Mode: 1990–2015



NOTES: *Other* greenhouse gas emissions are from motorcycles, pipelines, and lubricants. International bunker fuel emissions (not included in the total) result from the combustion of fuels purchased in the United States but used for international aviation and maritime transportation. *U.S. Total, all modes; Aircraft; and Ships and boats* include emissions data for only domestic activity only as do all other data shown. International emissions from bunker fuels purchased in the United States are not included. Alternative-fuel vehicle emissions are allocated to the specific vehicle types in which they were classified (i.e., Passenger cars, *Light-duty trucks, All other trucks,* and *Buses*).

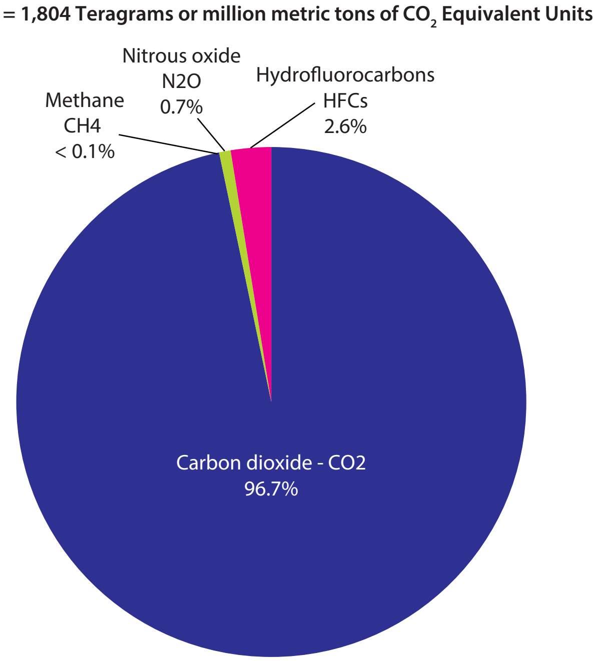
SOURCE: U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2015* (2017), table 2-13, available at http://epa.gov/climatechange/emissions/usinventoryreport.html as of March 2017.

41.6 percent, followed by freight trucks (23.5 percent) and light-duty trucks (17.4 percent). Domestic operation of commercial aircraft produced 9.1 percent of transportation CO_2 emissions; however, as mentioned in chapter 2, there are now more air passenger miles in international flights originating and ending in the United States than there are domestic passenger miles, leaving much of the air travel emissions unaccounted for. Pipelines were responsible for 3.0 percent of emissions, followed by rail (2.5 percent) and ships and boats (1.8 percent) [USEPA 2017a].

Hydrofluorocarbons (HFC), methane (CH_4), and nitrous oxides (N_2O) are the other principal GHGs emitted by the transportation sector. Each GHG is reported using a common metric of equivalent grams of CO_2 for each emission (figure 7-6). HFCs, such as those once used in automotive air conditioners, are second in abundance behind CO_2. HFCs are the most detrimental GHGs known. GHG emission regulations for personal vehicles give manufacturers credits for reducing these HFC emissions, and it is likely that these emissions will decrease in the future. Nitrous oxides are chiefly produced in the catalytic converters of motor vehicles, and a very small quantity of methane emissions is produced by incomplete combustion of fossil fuels or by leakage.

Because 96.7 percent of transportation GHG emissions are CO_2 produced by fossil fuel combustion and because petroleum comprises 92.2 percent of transportation energy use,

FIGURE 7-6 Transportation-Related Greenhouse Gas Emissions: 1990–2015



NOTES: The data for the transportation sector includes only fossil and renewable fuels consumed directly. The data for Non-Transportation includes the Residential, Commercial, and Industrial sectors, which include only fossil fuels consumed directly, and electric utilities, which includes all fuels (fossil, nuclear, geothermal, hydro, and other renewables) used by electric utilities. Most renewable fuels are not included. Totals may not add to 100% due to rounding.

SOURCE: U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2015*, **table 2-12 and table ES-6, available at** http://epa.gov/climatechange/emissions/usinventoryreport.html **as of March 2017.**

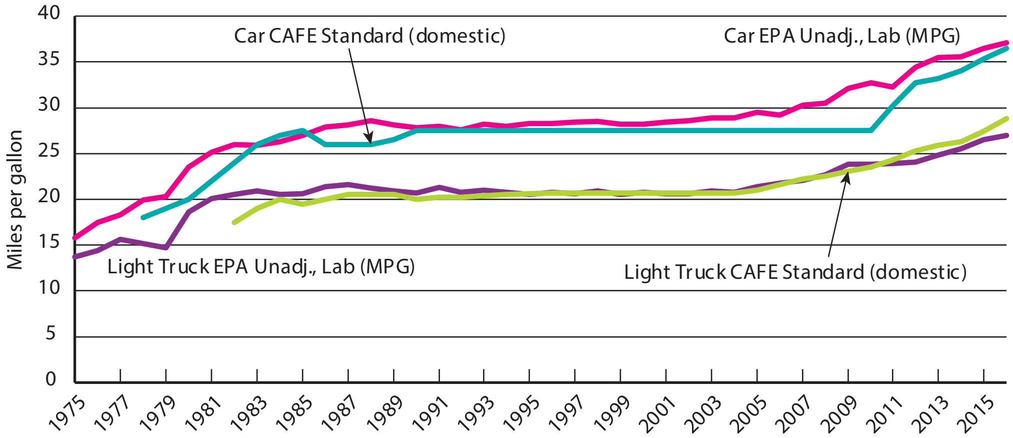
modal GHG emissions closely track modal energy use. Transportation GHG emissions increased from 2000 to 2007 (figure 7-5), fell by 5.0 percent during the economic recession in 2008, and then stabilized at slightly under 1,800 teragrams (million metric tons) in the 2009 to 2015 period with a slight increase from 2014 to 2015 [USEPA 2017a]. The short-term decrease in economic activity and the related decline in transportation demand contributed, in part, to the decrease in CO_2 emissions during the recession.

Evident in figure 7-7 are the results of the U.S. Environmental Protection Agency's (EPA's) decision to change the definitions of passenger cars and light trucks in 2007. Many vehicles formerly classified as light trucks, but designed predominantly for passenger transportation, were reclassified as passenger cars, causing an apparent jump in passenger car emissions that were offset by a compensating drop in light-truck emissions.

Energy Efficiency

Historically, improvements in the efficiency in energy use have reduced energy consumption in the transportation sector. Fuel economies of passenger cars and light trucks have closely tracked the Corporate Average Fuel Economy

FIGURE 7-7 Car and Light Truck Corporate Average Fuel Economy (CAFE) and Miles per Gallon (MPG): Model Years 1975–2016



KEY: MPG = Miles per Gallon; EPA = U.S. Environmental Protection Agency; P = preliminary; R = revised.

NOTES: Corporate Average Fuel Economy (CAFE) standards, which must be met at the manufacturer level were established by the *U.S. Energy Policy and Conservation Act of 1975* (PL 94-163). EPA Unadjusted, Laboratory (MPG) estimates are based upon standardized laboratory tests and do not account for factors that may affect actual roadway fuel economies such as aerodynamics, climate, etc.

SOURCE: All Car and All Truck CAFE Stds: Davis, S.C., S.W. Diegel and R.G.Boundy. *Transportation Energy Data Book*, Edition 35 (October 2016), Oak Ridge National Laboratory, Oak Ridge, TN. Tables 4-21 and 4-22. Available at cta.ornl.gov/data as of April 2016. **Car and All Truck EPA MPG**: U.S. Environmental Protection Agency (EPA), **Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 - 2016**. Table 9.1. Available at http://epa.gov/otaq/fetrends.htm as of March 2017.

(CAFE) standards since they took effect in 1978 (figure 7-7). The miles per gallon (mpg) values shown in figure 7-7 are the unadjusted, laboratory test values on which compliance with the standards is based. These values do not account for factors that affect highway fuel efficiency such as wind and vehicle aerodynamics. The actual mpg values seen on window stickers and in public advertising are adjusted downward to better represent the fuel economy drivers will likely experience on the road.[1]

The average 25.6 mpg (preliminary estimates) for model year 2016 for all models was down slightly from 24.8 mpg in 2015, due to increased consumer demand for less fuel efficient light trucks and SUVs associated with low fuel costs as discussed earlier [USEPA 2017f]. These mpg results are up significantly from 1975, the start of the era of fuel economy improvements as vehicle-miles traveled grew faster than fuel consumption (figure 7-8). However, drops in fuel use are tempered somewhat by increases in travel stimulated by improvements in fuel economy, a phenomenon known as the “rebound effect.” Fuel price declines have been a factor in an increase in individual miles driven on an annual basis.

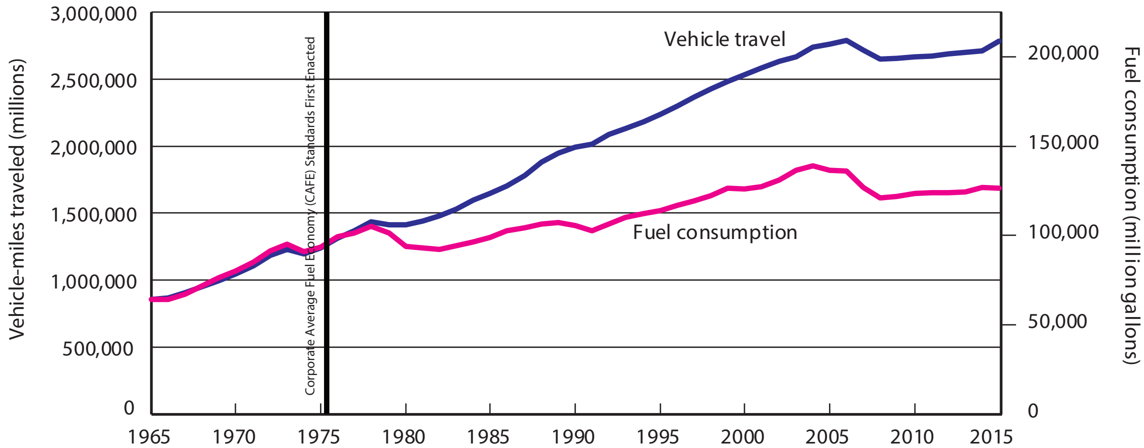
[1] The apparent decrease in on-road fuel economy estimates after 2005 more likely reflects a change in the definitions of passenger cars and light trucks and the methods used to estimate their travel and fuel use than an actual decrease in mpg. Another change in reporting occurred when the U.S. Department of Transportation (USDOT), Federal Highway Administration (FHWA), started using the classifications of short- and long-wheelbase light-duty vehicles in 2007 rather than the previous categories of passenger cars and two-axle, four-tire trucks. As a result, the post 2006 on-road fuel economy data are not consistent with the data from 2006 and earlier years, unless the categories are combined

For example, regular gasoline prices in the U.S. dropped to an average of $2.14 per gallon in 2015 down from $3.62 per gallon in 2012, the highest annual average since 2000 [USDOE EIA 2017d]. When gas prices were at high levels, auto manufacturers focused on small, fuel-efficient vehicles. With the price decline, drivers are again demanding the large trucks and SUVs of earlier years, but due to CAFE standards, they are now more fuel efficient with the new diesel and hybrid and/or electric options today (see sections 7-4 to 7-6) [WOODYARD 2015].

On August 28, 2012, the USDOT and the EPA set fuel economy and GHG emissions standards for passenger cars and light trucks through 2025. Nominally, the standards require a total fleet average of 54.5 mpg (163 grams of CO_2 equivalent) for new personal vehicles by 2025 [USEPA 2012]. However, these standards are based on laboratory test cycles rather than real world driving and do not consider the many ways manufacturers can earn fuel economy credits. Credits may be earned for solar panels on hybrids, engine shut off at idle, and other features that improve on road fuel economy but which are not reflected in the test cycle.

Furthermore, the new standards vary with the size of the vehicles a manufacturer produces. Medium- and heavy-duty highway vehicles (e.g., combination trucks and buses) are the second largest energy users among modes, accounting for 23.0 percent of transportation energy use in 2015 [ORNL 2015]. In 2011 the USDOT and the EPA announced the first fuel economy and emission standards for this vehicle class for model years 2014 –2018

FIGURE 7-8 Vehicle-Miles of Travel and Fuel Use by Personal Vehicles: 1965–2015



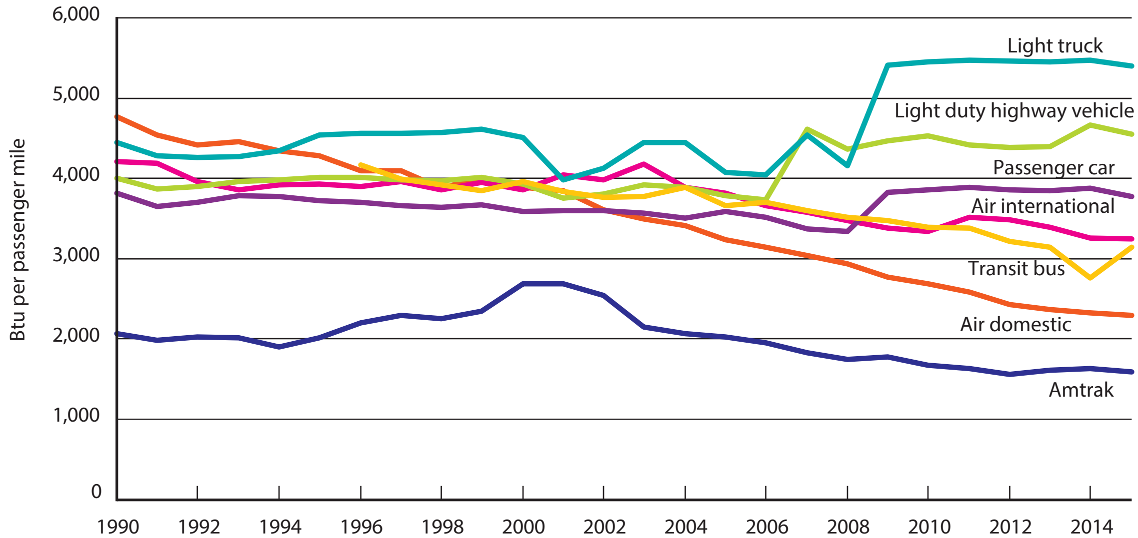
NOTES: Includes passenger cars, light trucks and motorcycles for year 1965. The definition of light-duty vehicle was changed after 2006, affecting the vehicle types included in the personal vehicle category.

SOURCE: U.S. Department of Transportation, Federal Highway Administration, *Highway Statistics* (multiple years), Table VM-1, available at http://www.fhwa.dot.gov/policyinformation/statistics.cfm as of March 2017.

[USEPA 2011]. By 2018 the requirements for combination tractor trailers specify fuel economy improvements ranging from 9 to 23 percent, depending on the truck type. Similar improvements are required for the diverse class of single unit commercial trucks and buses—vehicles as various as delivery trucks, dump trucks, cement mixers, and school buses. If a manufacturer produces mostly large vehicles, then its actual fuel economy requirement will be lower than if it produces mostly small vehicles. Taking all these factors into account, USDOT and EPA estimated that manufacturers would achieve fuel economy levels of 46.2 to 47.4 mpg on the laboratory test cycles [FEDERAL REGISTER 2012]. Fuel economies achieved in actual driving would likely be 15 to 20 percent lower. New fuel-economy standards were developed for model years 2022-2025 that would be even more stringent than before, but at present are on hold as they are being re-reviewed.

The energy intensities of passenger modes have generally declined over time, with five out of six passenger modes now averaging less than 4,000 Btu per person-mile, or about 30 person-miles per gallon of gasoline equivalent (figure 7-9). These declines are largely the result of more aerodynamic vehicles and efficient engines as well as improved operating efficiencies (e.g., higher air carrier load factors). From 2000 to 2014, the energy intensity of short- and long-wheel base light-duty vehicles and bus transit rose likely due to increased fuel efficiencies, while the energy intensity of other passenger modes—air and Amtrak—declined. The energy intensity of rail freight transport decreased from 14,826 Btu/car-mile in 2000 to 14,421 in 2014. Moving one ton of freight one mile in 2014 required 88.4 percent as much energy as it did in 2000. This reduction was accomplished mostly through reducing energy use per freight car-mile by about 2.1 percent [USDOT BTS NTS

FIGURE 7-9 Energy Intensity of Passenger Modes: 1990–2015 (Btu per passenger mile)



NOTES: Light-duty highway vehicles include passenger cars, light trucks, vans, and sport utility vehicles. Highway data for 2007-2011 were calculated using a new methodology and are not comparable to previous years. A change in vehicle occupancy rates derived from the National Household Travel Surveys results in a shift of highway passenger-miles between 2008 and 2009. Energy Intensity (Btu per Passenger mile) = Energy Use (Btu) / Passenger Miles, Energy Use calculated by using fuel and electricity usage and converting to energy by using BTS conversion rates. The following conversion rates were used: Diesel =138,700 Btu/gallon. Compressed natural gas = 22,500 Btu/gallon. Bio-Diesel = 126,200 Btu/gallon. Liquefied natural gas = 84,800 Btu/gallon. Gasoline = 125,000 Btu/gallon. Liquefied petroleum gas = 91,300 Btu/gallon. Methanol = 64,600 Btu/gallon. Ethanol = 84,600 Btu/gallon. Bunker fuel = 149,700 Btu/gallon. Kerosene = 135,000 Btu/gallon. Grain additive = 120,900 Btu/gallon. Electricity 1KWH = 3,412 Btu, negating electrical system losses. This table includes approximate electrical system losses, and thus the conversion factor is multiplied by 3.

SOURCE: Highway–Federal Highway Administration. **Air**–Bureau of Transportation Statistics, Office of Airline Information. **Amtrak**–National Railroad Passenger Corporation (Amtrak), personal communication with Energy Management Department and Government Affairs Department and Association of American Railroads. **Transit**–Federal Transit Administration as cited in U.S. Department of Transportation, Bureau of Transportation Statistics, *National Transportation Statistics*, table 4-21, 4-22, 4-24, and 4-16, available at www.bts.gov as of November 2017.

2017]. To reduce both fuel consumption and emissions, ships are now are using alternative power sources to power air conditioning and other functions while docked. Trucking fleets are both leveraging new hybrid diesel technology as well as platooning where they utilize automated driving technology allowing them to drive less than 1 second apart to reduce fuel consumption and improve efficiencies.

Alternative Fuels and Vehicles

A large part of the growing use of biofuels (represented as biomass) in transportation, an over 900 percent increase from 2000 to 2016, shown in figure 7-2, can be attributed to the requirements of the Federal Renewable Fuels Standard (RFS). Enacted as part of the *Energy Policy Act of 2005* (Pub. L. 109-58) and extended by the *Energy Independence and Security Act of 2007* (Pub. L. 110-140), the RFS requires the introduction of increasing amounts of renewable energy into gasoline and diesel fuels each year, ultimately reaching 36 billion gallons by 2022 [USLOC CRS 2013b and 2015]. At least 16 billion gallons are required to be cellulosic ethanol, and no more than 15 billion gallons can be ethanol produced from corn starch. In 2014 the U.S.

consumed nearly 13.5 billion gallons of fuel ethanol and 1.4 billion gallons of biodiesel [USDOE EIA 2017c]. Therefore, we are near the goal for ethanol already, but not so in terms of biodiesel.

More than 39 billion gallons of diesel fuel were consumed by vehicles in 2015 compared to 33 billion gallons in 2000 [USDOE EIA 2017e]. Diesel vehicles offerings, including new, clean diesel technologies are hitting the market, and these vehicles are providing more fuel efficiencies than similar-sized gasoline engines. Diesel fuel can provide up to 15 percent more energy than the equivalent amount of gasoline [USDOE and US EPA 2016]. These vehicles are a small percentage of the Nation's fleet of motor vehicles, mostly medium and heavy trucks. In 2015 there were an estimated 1.74 million turbocharged direct injection (TDI) light-duty diesel vehicles in the United States out of 210.2 million conventional cars and light-duty trucks [USDOE ORNL 2017].

Flexible-fuel vehicles (FFVs) can safely use mixtures of up to 85 percent ethanol (E85) with gasoline. FFVs accounted for 75.7 percent of the nearly 19.7 million alternative fuel vehicles operating on U.S. roads in 2015 [USDOE EIA 2017a]. However, most on-road FFVs are fueled with gasoline or gasoline/E10 blends only. Until 2016 automobile manufactures could earn extra credits toward meeting CAFE standards by making and selling FFVs. Future FFV sales are uncertain because the credits will be largely phased out unless actual use of E85 increases substantially. Together, liquid petroleum gas/propane and compressed/liquefied natural gas-powered vehicles accounted for approximately 4.5 percent of alternative fuel vehicles in use in 2015 [USDOE EIA 2017a].

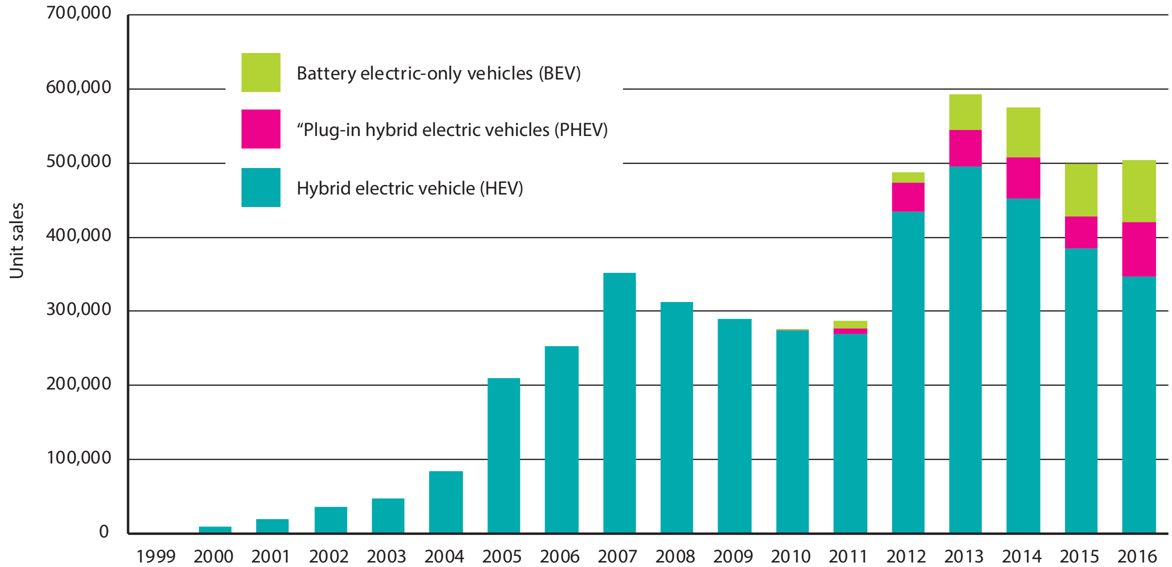
Alternative Refueling/Recharging

The first mass-produced hybrid electric vehicle (HEV), powered by an internal combustion engine and an electric motor, was introduced in 1999. Hybrid vehicles have become popular as a replacement for traditional gasoline- or diesel-fueled vehicles. HEV sales grew from 17 vehicles in 1999 to a high of 592,000 in 2013 (including plug-in hybrid and battery-powered vehicles) before declining, likely due to a drop in gasoline prices that made these vehicles less attractive to buyers. In 2016 about 504,000 HEV/electrics were sold in the United States (figure 7-10).

In 2010 just 19 electric-only and 326 plug-in hybrid vehicles were sold. By 2016 these numbers were 84,000 and 73,000, respectively [HYBRIDCARS 2017]. Over the same period, the number of new to the market makes and models of battery electric-only vehicles increased from 3 to 15, while plug-in hybrid offerings increased from 1 to 17 [USDOE and USEPA 2017b]. Electrically driven motor vehicles are gaining popularity in the consumer market.

The first mass-produced "plug-in" hybrid electric vehicles (PHEV), able to draw electric power from the utility grid and store it on-board, were sold in 2010. Hybrid electric vehicles (HEV), PHEVs, and battery electric vehicles (BEV) saw a 69.1 percent rise in sales from 2015 to 2016 and comprised about 2.9 percent of the 17.5 million vehicle sales in 2016 [HYBRIDCARS 2016]. However, automakers share must reduce costs, overcome the market's

FIGURE 7-10 Sales of Hybrid, Plug-in Hybrid and Battery Electric Vehicles: 1999–2016



SOURCE: HybridCars, December Dashboards, Annual Issues, available at www.hybridcars.com as of March 2017.

Box 7-A Electric Vehicles

All-electric vehicles (i.e., those powered solely by an electric motor not requiring other fuel) have a long history, with the earliest battery powered vehicles produced prior to 1900 before losing out in the market to gasoline powered vehicles [USDOE 2016].

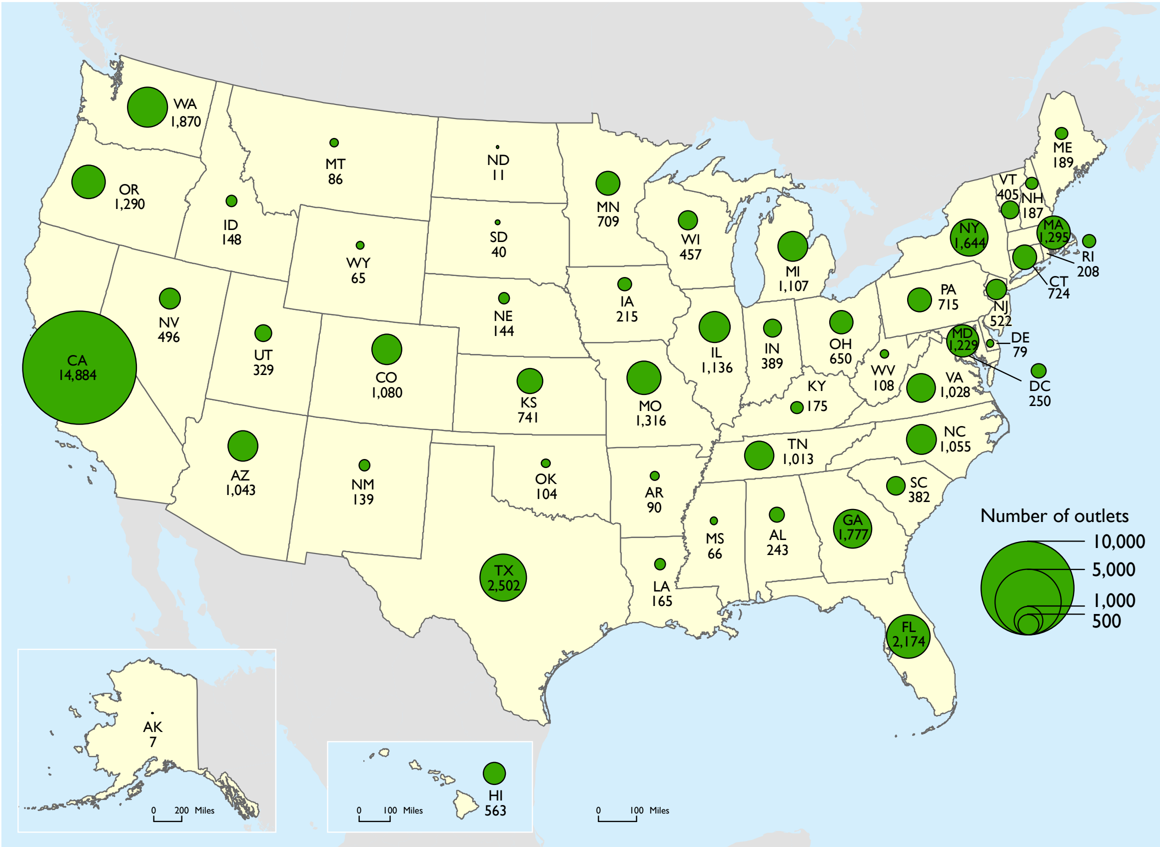
Today, all-electric vehicles are taking a larger share of the market with over 87,000 units sold in 2016 compared to over 70,000 plug-in hybrid electric vehicles. For model year 2017, at least 12 models of all-electric vehicles and 17 models of plug-in hybrid electric vehicles (PHEVs) exist [USDOE ORNL 2016].

Today, the typical driving range for all-electric vehicles is 60 to 120 miles [USDOE 2017f]. Today's batteries hold more charge and take up less space in the vehicle. Battery capacities in all-electric vehicles today range from 22 kW-hrs to 100 kW-hrs, which exceed the capacity range for PHEVs (7.1 to 33 kW-hrs). Battery costs continue to go down for consumers as new technologies emerge. Public electric charging stations/outlets have increased from about 3,500 in 2011 to over 42,000 in 2016 [USDOE ORNL 2016].

The EIA's Annual Energy Outlook projects that battery-electric vehicles will surpass PHEVs sales nearly doubling PHEV sales by the year 2040. This demand is partially driven by incentivized programs such as California's Zero-Emission Vehicle regulation that has been replicated in 9 other states. The trend is expected to continue to combat air quality concerns and mitigate climate change [USDOE ORNL 2016].

Considerable progress has been made in creating a nationwide recharging infrastructure. As of May 2017, there were more than 18,000 recharging stations including privately owned stations with more than 49,000 nonresidential charging outlets across the United States, up from almost 3,400 outlets in 2011 [USDOE AFDC 2017c]. The distribution of electric vehicle recharging stations (figure 7-11) tends to favor states that have opted into California's Zero Emission Vehicles (ZEV) standards.

FIGURE 7-11 Electric Vehicle Refueling Stations by State: March 2017



SOURCE: U.S. Department of Energy, Alternative Fuels Data Center, *Alternative Fueling Station Counts* (as of 03/16/2017), available at http://www.afdc.energy.gov/fuels/stations_counts.html as of March 2017.

unfamiliarity with the new technology, decrease the length of time required for recharging batteries, increase the distance that can be driven on one charge and further, develop recharging infrastructure to increase market share.

Liquid petroleum gas/propane and compressed/liquefied natural gas-powered vehicles accounted for approximately 4.5 percent of alternative fuel vehicles in use in 2015 [USDOE EIA 2017a]. California, Texas, Oklahoma, and New York have wide distribution and availability of compressed and liquefied natural gas refueling stations (figure 7-12). These states have among the highest number of CNG/LNG vehicles registered.

Transportation's Energy Outlook

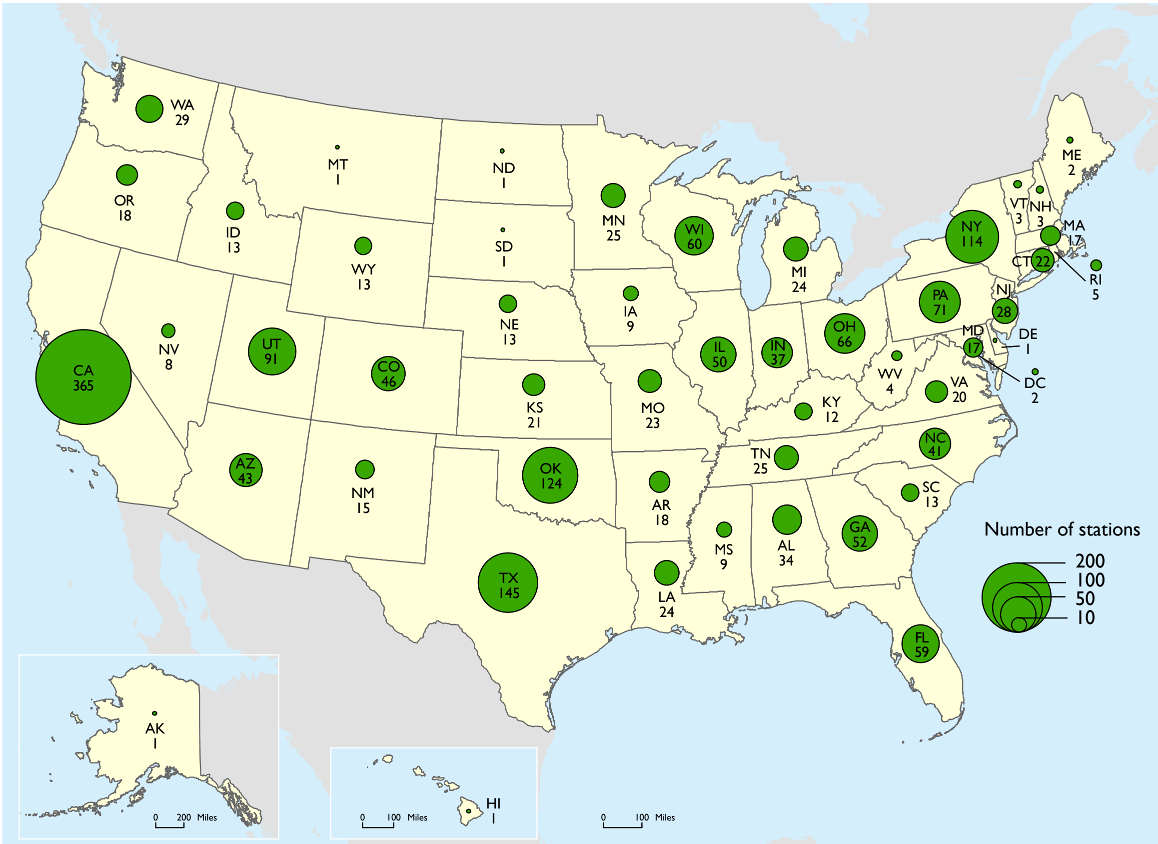
The EIA has projected the likely effects of current trends and existing policies on transportation's future energy use and GHG emissions. Transportation energy use is projected to remain at or near the current level of 27 quadrillion Btu through 2050 [USDOE EIA 2017a]. Existing fuel economy and GHG emissions standards are expected to decrease light-duty vehicle energy use by 15.8 percent by 2050, resulting in approximately 13.5 quadrillion Btu of energy use for 2050 (figure 7-13). Most of this reduction is expected to be offset by growth in energy use by medium- and heavy-duty trucks, although that could change if fuel economy and emissions standards for those vehicles are further tightened.

For all other modes, activity growth is approximately balanced by improvements in energy efficiency. These projections are based on existing policies and increasing oil prices which have declined in recent years; therefore, the projections are subject to change as has been seen in recent years with the decline in petroleum prices. Natural gas use by motor vehicles in compressed and liquefied form is projected to increase from just 0.06 quads in 2015 to 0.52 quads by 2050 [USDOE EIA 2017a]. EIA attributed all of the projected increase in natural gas use by motor vehicles to medium- and heavy-duty trucks and buses.

According to the EIA, the 2011–2025 fuel economy standards coupled with the anticipated second phase of fuel efficiency regulations are planned to take effect in 2027. Together with the market's response to higher gasoline prices, these fuel efficiency regulations are projected to save personal vehicle owners about 26 billion gallons of motor fuel in 2050, if consumption would have remained at the same level of vehicle travel without any increase in fuel economy (figure 7-14).

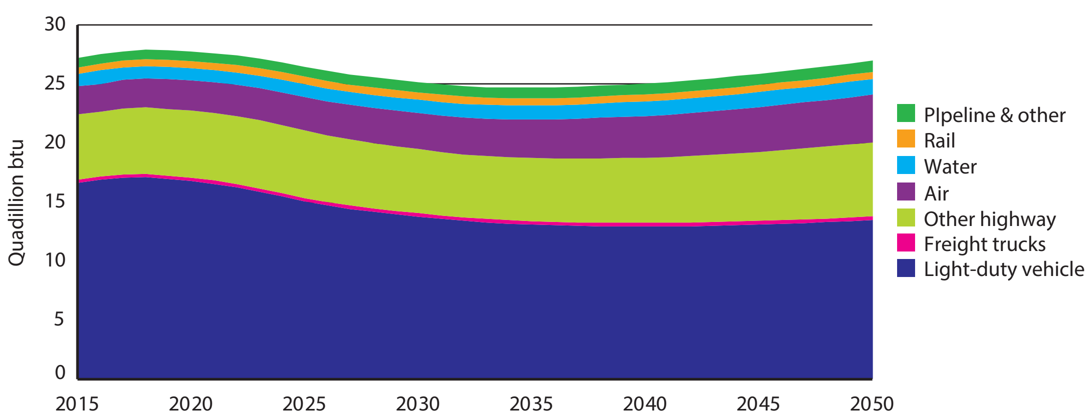
By fuel type, EIA projects gasoline use to decline from 17.0 quads in 2015 (actual) to 13.4 in 2050, in line with light-duty vehicle energy use. Diesel fuel use is projected to increase from 6.6 in 2015 to 7.0 quads in 2050, which is consistent with the growth of truck freight energy use. E85 will increase but will still amount to only 0.17 quads of transportation energy in 2050. Interestingly, electricity is anticipated to have the second highest increase next to gasoline over the 2015 to 2050 time period, going from 0.03 quads to 0.41 quads per year. Hydrogen is projected to lead in terms of growth, from 0.0 at present to 0.08 quads per year [USDOE EIA 2017a]. The growth in new technologies that make

FIGURE 7-12 Alternative Fuel Stations by State: March 2017



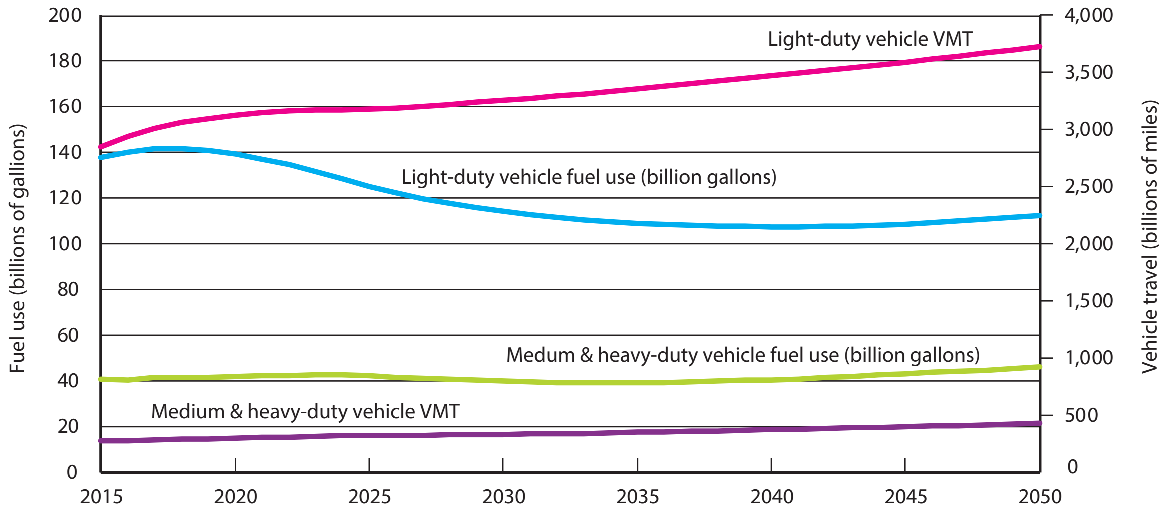
SOURCE: U.S. Department of Energy, Alternative Fuels Data Center, *Alternative Fueling Station Counts* (as of 03/16/2017), available at http://www.afdc.energy.gov/fuels/stations_counts.html as of March 2017.

FIGURE 7-13 Transportation Energy Use: 2015 Projected to 2050



SOURCE: U.S. Department of Energy, Energy Information Administration, *Annual Energy Outlook 2017*. Transportation Sector Energy Use by Mode and Type. Available at http://www.eia.gov/forecasts/aeo/ as of March 2017.

FIGURE 7-14 Highway Vehicle Fuel Use and Travel: 2015 Projected to 2050



KEY: VMT = Vehicle-miles Travelled.

SOURCE: U.S. Department of Energy, Energy Information Administration, *Annual Energy Outlook 2017*. Reference Case table 7. Available at http://www.eia.gov/forecasts/aeo/ as of March 2017.

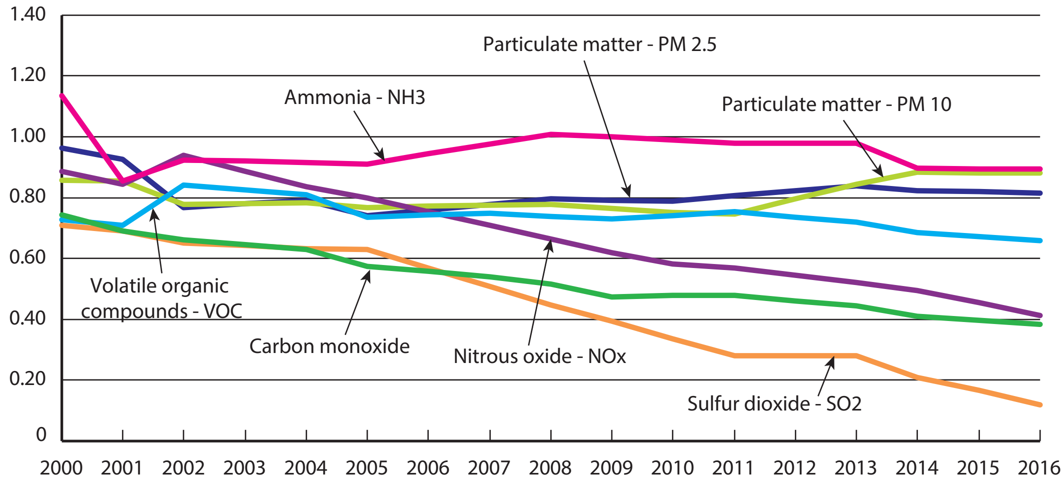
these fuel sources more affordable and easily accessible for both electric and hydrogen-powered vehicles are the driving forces behind this projected trend.

Air and Water Quality, Noise, and Habitat Impacts

Beyond the greenhouse gases addressed earlier in the chapter, vehicle emissions controls and other policies have reduced transportation's other six most common criteria air pollutant emissions to below 2000 levels, a trend that continued through 2016 with the exception of particulate matter 10 (PM-10), which have remained constant from 2014 to 2016 (figure 7-15). PM-10 refers to small, inhalable particles smaller than 10 micrometers in diameter that form from complex reactions of chemicals, such as sulfur dioxide (SO_2) and nitrogen oxides (NOx). Particulate matter can also be emitted directly from sources such as construction sites, smokestacks, or fires. Transportation's share of total U.S. PM-2.5 emissions decreased by 15.4 percent from 2000 to 2016, while the share of PM-10 emissions increased by 2.9 percent over the same period.

Smog-forming emissions of volatile organic compounds (VOC) and NOx were 9.4 and 53.6 percent lower, respectively, in 2016 than they were in 2000. In recent years, NOx emissions have decreased more rapidly, partly due to more advanced diesel emission controls and the use of cleaner, ultra-low sulfur diesel fuel. Diesel-fueled vehicles make up 4 percent of the total transportation fleet with the majority of the diesel vehicles being medium and heavy trucks [USDOE EIA 2015].

FIGURE 7-15 Indexes of Key Air Pollutant Emissions from U.S. Transportation: 2000–2016



SOURCE: U.S. Environmental Protection Agency, *National Emissions Inventory Air Pollutant Emissions Trends Data, 1970-2016*, Average Annual Emissions All Criteria Pollutants, Available at https://www.epa.gov/air-emissions-inventories/air-pollutant-emissions-trends-data as of March 2017.

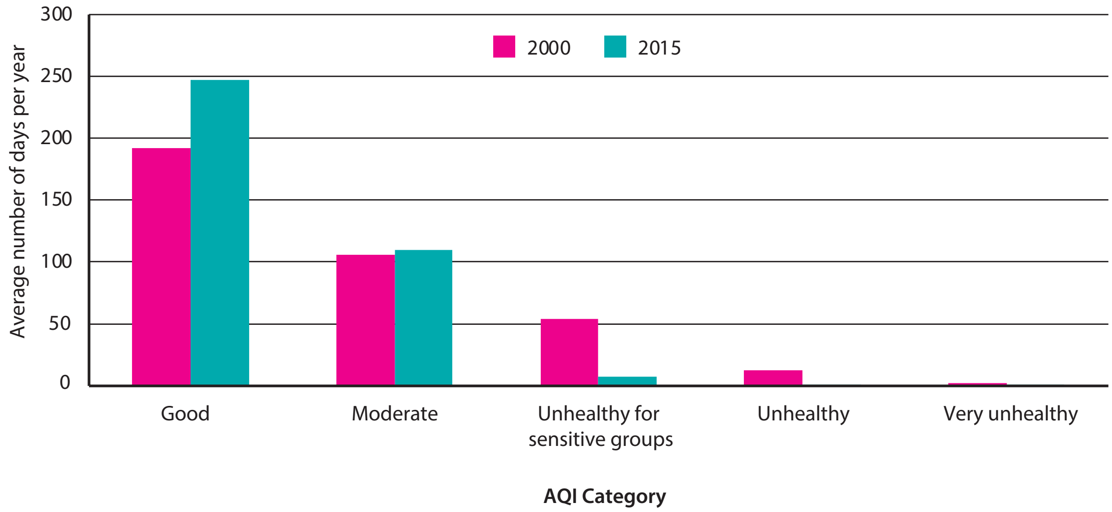
Emissions of SO_2 were 83.4 percent lower in 2016 than in 2000, due in large part to reductions in the sulfur contents of gasoline and diesel fuel. The *Clean Air Act of 1970* led to the reduction in lead emissions, once a major air pollutant from transportation; lead is not shown in figure 7-15 because it has been virtually eliminated from transportation with the phase-out of leaded gasoline.

Emissions of ammonia (NH3), another air pollutant, also shows a significant decline from 2000 levels with a reduction of 21.4 percent in 2016 [USEPA 2017d]. Transportation comprised 2.4 percent of total U.S. emissions of ammonia in 2014 [USEPA 2016b].

Reductions in transportation's air emissions have contributed to improved air quality in the Nation's urban areas. Figure 7-16 compares air quality days for 169 continuously monitored urban areas in 2000 and in 2015. The average number of days from the 169 urban areas in which air quality was reported to be unhealthy for sensitive groups (e.g., people with lung disease, young children, and older adults) dropped from 53.6 in 2000 to 6.9 in 2015; the average number of days with unhealthy air quality for the population as a whole declined from 12.2 in 2000 to 0.9 in 2015, and the total number of very unhealthy days (which could trigger health emergency warnings for the public) decreased from an average of 1.8 in 2000 to 0.1 in 2015. The great majority of days had good or moderate (192 good and 106 moderate) air quality in 2000 and again in 2015 (247 good and 110 moderate). On average, air quality in these cities was good for 247 days in 2015, which was a substantial increase compared to 192 days in 2000 [USEPA 2017b].

Pipelines, ships and barges, railroad cars, and tank trucks are among the sources of spills of

FIGURE 7-16 Air Quality Index (AQI) Across 169 U.S. Cities: 2000 and 2015



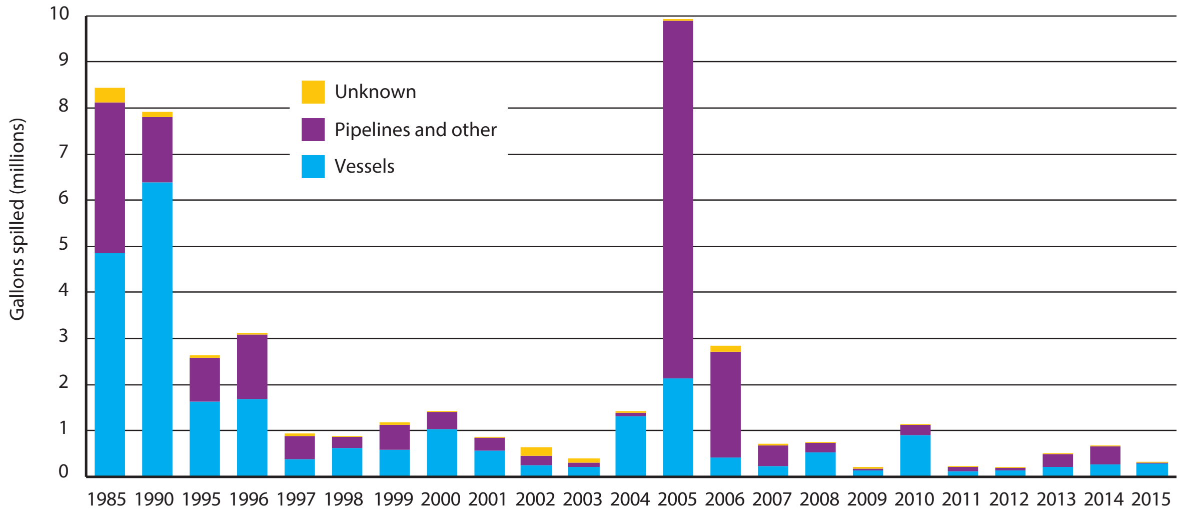
NOTES: Based on number of days in the year in which an AQI measurement was reported from any monitoring site in the county or Metropolitan Statistical Area to the Air Quality Statistics database.
Days Good: number of days in the year having an AQI value 0-50
Days Moderate: number of days in the year having an AQI value 51-100
Days Unhealthy for Sensitive Groups: number of days in the year having an AQI value 101-150
Days Unhealthy: number of days in the year having an AQI value 151-200
Days Very Unhealthy: number of days in the year having an AQI value greater than 201. This includes the AQI categories very unhealthy and hazardous.

SOURCE: U.S. Environmental Protection Agency, Air Quality Index Information. Available at http://www.epa.gov/airtrends/aqi_info.html as of June 2016.

crude oil and petroleum products into surface waters and navigable waterways. The annual volume spilled varies greatly from year to year and is strongly affected by infrequent, large events (figure 7-17). For example, in 2005 Hurricane Katrina caused numerous spills into navigable waterways from a variety of sources in Louisiana and Mississippi as the volume of petroleum spilled jumped to 9.9 million gallons, more than three times the amount of petroleum spilled in any other year from 1995 through 2015. While the number fluctuates from year-to-year, the 1,375 spill incidents from vessels in 2015 were slightly less than the 1,508 incidents in 2010 of and considerably less than the 5,560 in 2000. The 681 spill incidents from pipelines and other non-vessel sources into navigable waters in 2015 show a similar declining trend from the 1,008 incidents in 2010 and 1,645 in 2000, indicating improvements in safety measures for all petroleum transport modes.

Additionally, the USDOT Pipeline and Hazardous Materials Safety Administration (PHMSA) reports that the number of serious pipeline incidents from 2010 to 2015 was trending down from 34 to 28, until increasing to 37 in 2016. Many of these incidents were either by excavation equipment or vehicles not involved in excavation intersecting with gas pipelines (or gas transmission pipelines). As mentioned in chapter 6, pipeline-related fatalities averaged about 16 deaths per year

FIGURE 7-17 Petroleum Spills Impacting Navigable Waterways: 1985, 1990, and 1995–2015



NOTES: The spike in Gallons spilled for 2005 can be attributed to the passage of Hurricane Katrina in Louisiana and Mississippi on Aug. 29, 2005, which caused numerous spills approximating 8 million gallons of oil in U.S. waters. The largest spill in U. S. waters began on April 20, 2010 with an explosion and fire on the mobile offshore drilling unit (MODU) DEEPWATER HORIZON. Subsequently, the MODU sank, leaving an open exploratory well to discharge crude oil into the Gulf of Mexico for several weeks. The most commonly accepted spill amout from the well is approximately 206.6 million gallons, plus approximately 400,000 gallons of oil products from the MODU. The totals in this table may be different from those that appear in the source, due to rounding by the source.

SOURCE: U.S. Department of Transportation, Bureau of Transportation Statistics, *National Transportation Statistics*, Table 4-54, Available at http://www.bts.gov as of May 2017.

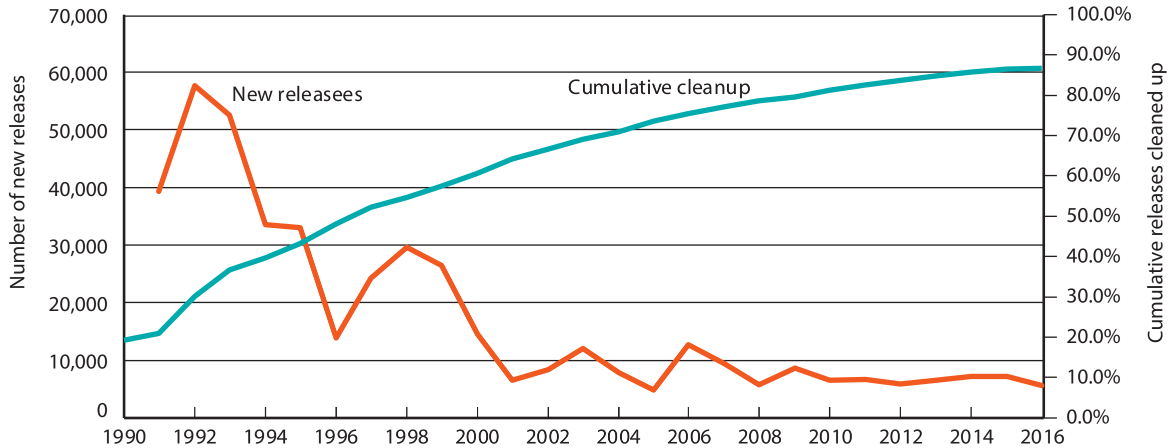
in the period of 1997 to 2016. In 2016 there were 17 fatalities across all types of pipeline incidents [PHMSA 2016].

In 1985, in response to a congressional requirement, EPA began an effort to regulate underground storage tanks that can contaminate ground water, to clean up leaks, and prevent future leaks [USEPA 2017c]. Since then, the number of new leaks from storage tanks has been reduced by nearly an order of magnitude, and over 86 percent of all leaks have been cleaned up (figure 7-18).

Pollution of waterways from spills, however, is not the only environmental challenge posed by marine transportation. Port and vessel operations can negatively impact air quality and have other detrimental impacts on the environment through emissions during idling, moving cargo from one mode of transport to the other, etc. But recent trends in alternate marine power (AMP), such as ships shifting to shore-side power while docked for basic ship functions such as lights and air-conditioning, and low-sulfur fuel are helping lesson the impacts [MARINE INSIGHT 2016].

As rainwater or snowmelt runs off transportation infrastructure, like roads, parking lots, and bridges, it picks up de-icing salts, rubber and metal particles from tire wear, antifreeze and lubricants, and other wastes that may have been deposited on infrastructure

FIGURE 7-18 Leaking Underground Storage Tank Releases and Cleanup: 1990-2016



NOTES: All data are cumulative from the start of the U.S. Environmental Protection Agency's Underground Storage Tank program, which began in 1984. Data represent fiscal year, October 1 through September 30.

SOURCE: U.S. Department of Transportation, Bureau of Transportation Statistics, *National Transportation Statistics*, Table 4-55, Available at http://www.bts.gov as of March 2017.

surfaces. The runoff carries these contaminants into streams, lakes, estuaries, and oceans. An in-depth study of road-salt impacts on water quality examined U.S. Geological Survey historical data collected between 1969 and 2008 from 13 northern and 4 southern metropolitan areas. During the November to April period, when road salt application is most common, the concentration of chloride (an ingredient of salt) chronically surpassed EPA's water-quality criteria at 55 percent of the monitoring locations in northern metropolitan areas; chloride levels acutely surpassed the criteria at 25 percent of these northern stations. From May to October, only 16 percent of the northern stations chronically exceeded the criteria, and just 1 percent showed acute exceedances. At southern sites, where road salt is less frequently applied, there were few samples in any season that exceeded the chronic water-quality criteria, and none exceeded the acute criteria [CORSI, ET AL. 2010].

Highways and other transportation infrastructure also affect wildlife via road kills, habitat loss, and habitat fragmentation. Numerous projects have been undertaken across the United States to mitigate these impacts, from salamander and badger tunnels to mountain goat underpasses on highways to fish passages through culverts. There are no systematic estimates of the numbers of wildlife killed by transportation vehicles in the U.S. In general, the number of bird kills exceeds the number of mammals killed. Insurance industry records indicate that there are between one and two million reported collisions between animals and vehicles each year. These numbers only include reported incidents; collisions with small animals resulting in no vehicle or human damage are not generally reported [GASKILL 2013].

Transportation noise is pervasive and difficult to avoid in the United States [USDOT FHWA HEP 2006]. It is generated by engines, exhaust, drive trains, tires, and aerodynamic drag. At freeway speeds tire-pavement noise dominates for highway vehicles, while exhaust and aerodynamic noise dominate for aircraft. In the U.S. there are over 2,700 linear miles of noise barriers to protect the public. The known investment by 27 states in noise barrier construction is on the order of $1.2 billion. However, in a survey of states in 2010, many states had difficulty in determining the amounts invested in these efforts [USDOT FHWA 2010].

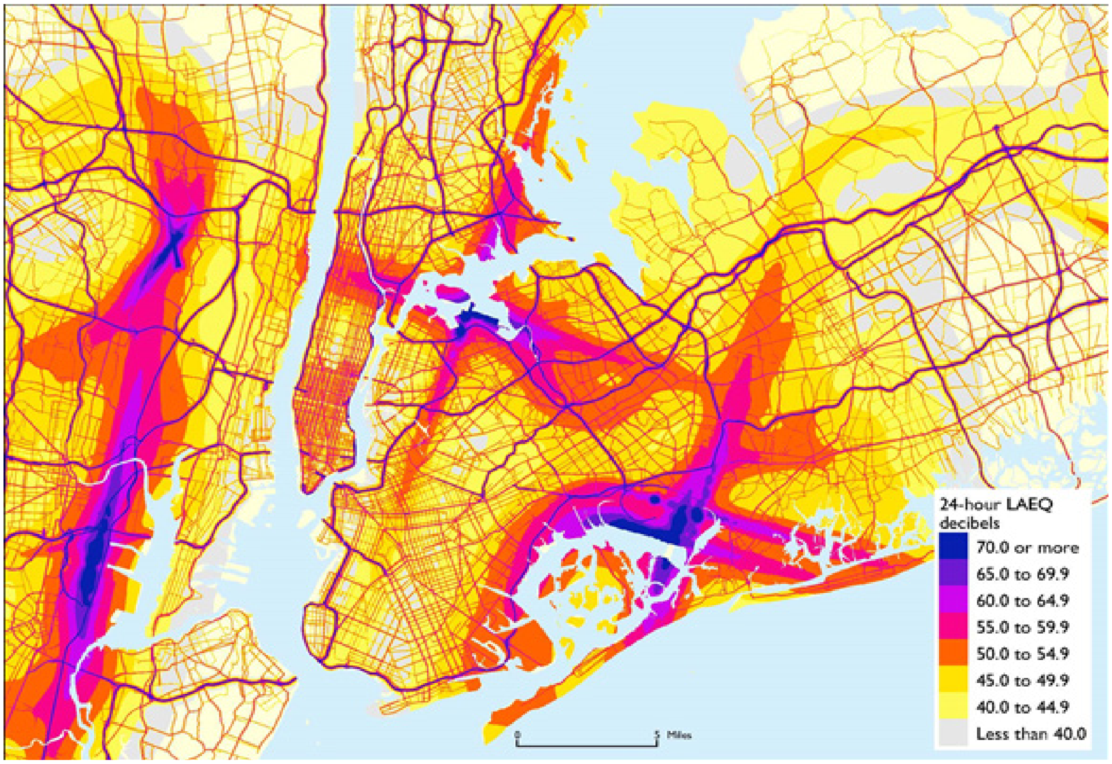
Although highways are the most widespread source of transportation noise, exposure to transportation noise is systematically measured only for aircraft. In 2014, 321,000 individuals lived in high noise (>65 dB) areas around U.S. airports. The number was down from nearly 7 million over 30 years ago and 847,000 in 2000. The number was reduced through a combination of changes in engine and airframe design and operational strategies [USDOT BTS NTS 2017]. Take-off and landing operations are the primary source of annoying aircraft noise, which per dB is generally more annoying to the public than highway or rail noise.

Until recently, a national transportation noise exposure inventory did not exist, but BTS in conjunction with the John A. Volpe National Transportation Systems Center has been working to develop a national, multimodal transportation noise inventory. The outcome of this effort is the recently released National Transportation Noise Map which shows the potential for noise exposure from interstate highways and airports. Over time, additional layers will be added to track and evaluate trends in potential noise exposure at multiple levels (local, State, Federal) and across modes [USDOT BTS NTNM 2017].

The new noise data provides an estimate of the percentage of the U.S. population that has the potential to be exposed to aviation and interstate road noise at both the national and county-level. The data shows that over 97 percent of the U.S. population has potential to be exposed to aviation and interstate highway noise at levels below 50 decibels (equivalent to the sound of a humming refrigerator). Less than one-tenth of a percent of the population has potential to be exposed to noise levels of 80 decibels or more (equivalent to the sound of a garbage disposal). Figure 7-19 shows 2014 aviation and highways noise for the New York City Metropolitan area. Darker areas indicate 24-hour LAEQ (an equivalent continuous level of noise over a given period measured in decibels) decibels of 70.0 or higher. They are near major international airports such as John F. Kennedy, Newark Liberty, and LaGuardia. Table 7-2 provides a comparison of the level of noise in LAEQ in decibels and how it compares with common everyday sounds, aviation noise levels, and highway noise levels as a reference [UDOT BTS NTNM 2017].

Unwanted noise can have a variety of impacts including annoyance, sleep disruption, interference with communication, adverse impacts on health and academic performance, and consequent reductions in property values. There is almost no part of the U.S. in which transportation noise is not noticeable [WAITZ

FIGURE 7-19 Transportation Noise Map: 2014



KEY: LAEQ = Equivalent Continuous Sound Level

SOURCE: U.S. Department of Transportation, National Transportation Noise Map press release, imbedded table, Available at https://www.transportation.gov/highlights/national-transportation-noise-map as of July 2017.

2007; UDOT BTS NTNM 2017]. When transportation noise levels are below 50 decibels (dB), the level of annoyance in the population is negligible, but when noise levels exceed 69 dB, impacts can be severe.

In addition to the primary performance measures of how efficiently, reliably, and safely people and goods move on the system, transportation's energy usage and its environmental impacts are also important measures of how well the transportation system performs. In recognition of this, there have been efforts to mitigate transportation's dependence on petroleum and environmental impacts. As detailed in this chapter, transportation has become more efficient over the past few decades in its use of energy and has reduced many of its environmental impacts even though activity levels have increased. It continues, however, to be the second leading emitter of greenhouse gases in the United States and has had other major impacts on the environment, such as oil pollution, habitat loss, and noise. Going forward, appropriate and accurate data will be needed to monitor progress and determine whether societal efforts to improve the system's performance are having the desired effect.

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CHAPTER 8

The State of Transportation Statistics

Highlights

- Progress is being made on the availability of transportation statistics, such as the establishment of an annual Port Performance Freight Statistics Program and implementation of the Repository and Open Science Access Portal, but long-standing information gaps remain.
- Extensive data are available on local passenger travel and most long-distance freight movement, but data gaps persist for most forms of long-distance surface passenger travel, domestic movement of international trade, and local freight movement.
- Cost data are available for most forms of passenger travel, but are limited for freight movement.
- Substantial data are available on crashes related to transportation, but the availability of data on causation of safety problems varies by mode of transportation, and the integration of data on motor vehicle crashes, the conditions surrounding each crash, and consequences of the crash remains elusive.
- “Big data” and other alternative data sources may offer ways to update, validate, and improve the detail of traditional statistics. Research is needed to determine the reliability and validity of statistics derived from blended sources, to establish institutional arrangements for access to large proprietary databases, and to integrate these new data sources with traditional forms of data and analysis to provide effective information for decision makers.
- The Bureau of Transportation Statistics (BTS) has achieved significant progress in improving the state of transportation statistics over the last 25 years and will continue to create increasingly robust, timely, credible statistics that support evidence-based decision making and that are useful and used throughout the Nation.

Congress requires that the *Transportation Statistics Annual Report* includes an assessment of the state of transportation statistics and efforts to improve those statistics. Transportation statistics cover the following:

- transportation safety;
- the state of good repair of transportation infrastructure;
- the extent, connectivity, and condition of the transportation system;
- economic efficiency across the entire transportation sector;
- the effects of the transportation system on global and domestic economic competitiveness;
- demographic, economic, and other variables influencing travel behavior;
- transportation-related variables that influence the domestic economy and global competitiveness;
- economic costs and impacts for passenger travel and freight movement;
- intermodal and multimodal passenger movement;
- intermodal and multimodal freight movement; and
- consequences of transportation for the human and natural environment.[1]

This chapter reviews the current strengths and weaknesses of transportation statistics, identifies major gaps in those statistics, and explores new data sources that could be used to fill the gaps. The chapter concludes with transportation perspectives on recent recommendations of the Commission on Evidence-Based Policymaking.

Strengths and Weaknesses of Current Statistics on the Extent, Use, Condition, and Performance of the Transportation System

Table 8-1 summarizes existing statistics on the extent, use, condition, and performance of the transportation system as well as gaps in those statistics. Statistics are generally available to the public for aviation, highways, transit systems, and waterways because the Federal Government operates the aviation and inland waterway systems and provides financial assistance for highways and transit systems. Publicly available statistics on railroads and ports are limited because those entities are either privately owned or privately operated on leased public facilities.

BTS publishes the underlying data on the extent and characteristics of the Nation's transportation network in the National Transportation Atlas Database (NTAD). Until 2016 the NTAD was published once each year, but now BTS has established a system to update the NTAD continuously as new geo-spatial data files are made available. BTS has also added the National Transit Map to the NTAD in 2016, filling a long-standing data gap.

While extensive statistics exist on the extent, use, condition, and performance of the transportation system, some of the underlying data are collected for different reasons and are

[1] 49 U.S.C. § 6302(b)(3)(B)(vi)

TABLE 8-1 Statistics on the Extent, Use, Condition, and Performance of the Transportation System

Topic	Coverage of existing statistics	Major gaps in existing statistics	Why the gaps matter
Extent of and geographic access to the transportation system	• Multiple versions of the highway and rail networks • Detailed representation of the waterway network • Intermodal passenger connectivity database • National Transit Map	• Piecemeal representation of intercity bus networks • Little data on availability of social service and non-profit transportation; taxi and taxi-like services	• Identify portions of the transportation network that are vulnerable to disruption • Identify localities that are isolated from economic opportunities, social services, and upward mobility
Vehicle, aircraft, train, and vessel volumes	• Number of vehicles on highway segments • Number of aircraft by airport; number of car-loadings by rail segment; number of vessels by port and waterway	• Inconsistent differentiation among types of highway vehicles (car, bus, truck) • Market penetration of motor vehicle automation equipment	• Different vehicle types have very different consequences for traffic flow and congestion, pavement and bridge wear, exposure to safety risks, and air quality • Motor vehicle automation has major implications for safety
Condition and performance	• Condition and reliability of highways by segment, transit by property, and inland waterways by facility • Reliability of commercial aviation by flight and airport and by causes of delay	• Condition and reliability of freight railroads • Non-comparable capacity data across ports • Condition of urban bus and rail transit maintenance facilities, and rail transit infrastructure • Comprehensive metrics for identifying network resiliency	• Identify bottlenecks, vulnerabilities to disruption, and other potential losses of efficiency in moving freight and passengers to guide investments in transportation facilities and rolling stock

not comparable across parts of the system. In response to the lack of comparable data on ports, Congress directed BTS, in the *Fixing America's Surface Transportation (FAST) Act of 2015,* to establish a port performance freight statistics program to annually publish nationally consistent measures of port capacity and throughput.[2] As required by the FAST Act, BTS convened a working group that recommend measures and methods for obtaining the measures, and published the recommendations and initial statistics in the first annual report [USDOT BTS 2017a].

Most current and planned statistics on performance are from the perspective of those who build and operate the transportation system. This perspective is important but incomplete unless it is complemented by performance measures from the user's perspective. For example, a system designed to spread delay evenly over all travelers may be better tolerated than a system that concentrates the same total delay on only a portion of the travelers, causing missed connections, deliveries, or appointments. Delay also matters more for some purposes than others. Delay is critical for responses to medical emergencies but may only be a minor irritant for leisurely sightseeing. In freight transportation, delay is generally a greater problem for perishable or high-valued goods than for bulk commodities. Statistics on travelers, shippers, and carriers

[2] Section 6018 of Public Law 114-94, Dec. 4, 2015

who use the transportation system, on the purposes of travel, and on the goods being moved are required to understand whether problems with transportation system performance warrant public action.

Strengths and Weaknesses of Current Statistics on Passenger Travel

Table 8-2 summarizes existing statistics on passenger travel and gaps in those statistics. Existing statistics include total travel on sections of the transportation system and characteristics of the travelers and trips.

National statistics on total travel by portion of the transportation system are drawn from sources, such as the border crossing data from Customs and Border Protection [USDHS CBP OFO 2015], the Federal Transit Administration's National Transit Database [USDOT FTA NTD 2014], the BTS monthly passenger enplanement data [USDOT BTS 2012a], and the National Census of Ferry Operators [USDOT BTS 2017c].

Statistics on the characteristics of travelers and trips come from the National Household Travel Survey (NHTS), sponsored mainly by the Federal Highway Administration (FHWA) and several states and metropolitan planning organizations [USDOE ORNL 2015]. The NHTS collects information on individual trips and the demographic and other characteristics of the traveler that influence his or her decision on when, how, and how far to travel. Although the NHTS collects all personal travel taken by all modes of transportation, it mainly captures local travel. The high cost of conducting this type of nationwide survey has limited

TABLE 8-2 Transportation Statistics on Passenger Travel

Topic	Coverage of existing statistics	Major gaps in existing statistics	Why the gaps matter
Intercity and international travel	• Volumes and origin-destination patterns of commercial aviation passengers • Amtrak ridership • Volumes of people and number of motor vehicles at border crossings	• Origins, destinations, and volumes of travelers by personal vehicles, buses, and general aviation • Amount of travel by demographic characteristics of travelers • Domestic travel of international visitors by traveler and trip characteristics	• Guide investments in airports, intercity rail passenger service, and interregional highways • Maximize the economic benefits of travel and tourism • Evaluate regulations related to the total contribution of local and long-distance travel to safety risks and environmental problems
Local travel	• Sporadic national volumes and demographic patterns of travelers by type of place • Transit ridership by property • Detailed origin-destination patterns of journeys-to-work and demographic characteristics of commuters • Geographic and demographic patterns of all resident travelers in metro areas that have conducted local surveys	• Pedestrian and bicycle travel • Local travel other than commuting in metro areas that have not conducted local surveys • Ridership and social and economic benefits of transportation services provided by social service and non-profit organizations • Growth of ride-hailing and relationship to transit ridership	• Guide investments in streets and public transportation • Manage exposure to safety risks • Provide physical connections between mobility-challenged citizens and services and employment opportunities

the frequency of this survey to once every 5 to 8 years. Despite these limitations, NHTS remains the only national source that provides the comprehensive data needed to understand travel decisions and predict travel demand. NHTS data collected in 2017 will be released in 2018.

The Census Bureau's American Community Survey (ACS) is another commonly used source of passenger travel information. The ACS collects commute-to-work data from an annual survey of the population. This survey provides small-area information every year, unlike the once-per-decade information formerly provided by the decennial census. The ACS also provides statistics for small units of geography aggregated over several years, while metropolitan statistical areas are the most detailed level of geography covered by the NHTS [USDOC ACS 2011].

Strengths and Weaknesses of Current Statistics on Freight Movement

In addition to travelers, the transportation system serves the movement of freight. Table 8-3 summarizes existing statistics on freight

TABLE 8-3 Transportation Statistics on Freight Movement

Topic	Coverage of existing statistics	Major gaps in existing statistics	Why the gaps matter
International freight movement	• Volumes and value of freight at international gateways • Value of trade by country	• Domestic transportation of international trade, including domestic leg of imports, exports, and movements between foreign origins and destinations that pass through the United States	• Support connections between local and global economies • Assess the role international flows play in domestic travel • Assess the role of transportation in U.S. international economic competitiveness
Intercity freight movement	• Tonnage and value of region-to-region flows by commodity and mode	• County to county flows of freight by truck • Relationships between industry supply chains and region-to-region commodity flows • Highway routes used between specific origins and destinations by vehicle type • Pipeline volumes by segment	• Guide investments in transportation facilities • Give local economies access to suppliers and markets • Manage exposure to safety risks • Understand the consequences of safety and other regulations • Expand access to international opportunities of poorly served areas • Diagnose and address freight bottlenecks that are barriers to economic development and competitiveness • Pipeline volumes affect markets of competing modes and exposure to safety risks
Local freight movement	• Freight movement only where state and metro area surveys are conducted	• County-to-county and intracounty flows of freight • Freight passing through the local area to and from distant locations	• Guide investments in last-mile transportation facilities • Support local supply chains • Assess the impacts on local congestion of freight movements • Manage exposure to safety risks

movement and gaps in those statistics.

Due to the magnitude and complexity of freight transportation, no single data collection provides a comprehensive picture of annual freight movement from origin to destination by all modes of transportation and by all commodity types. Among the various data sources, the Commodity Flow Survey (CFS), cosponsored by BTS and the Census Bureau, provides the most comprehensive coverage of U.S. freight flows. The CFS is the only source of nationwide data on domestic freight shipments by manufacturing, mining, wholesale, and selected retail industries covering all modes of transportation. It also provides comprehensive data on domestic hazardous material shipments. The CFS is conducted every 5 years as part of the Economic Census.

The Freight Analysis Framework (FAF) builds on the CFS to provide national estimates of total freight movement by mode of transportation and type of commodity for over 130 regions based on states and metropolitan areas. The CFS covers roughly two-thirds of the tonnage and value measured in the FAF. The remaining freight is measured from multiple, publicly available data sources, such as the data on freight flows across U.S. land borders and data on the international movement of air cargo collected by BTS [USDOT BTS 2012b].

The FAF is based on observed data wherever possible, but must turn to models and assumptions to fill the remaining data gaps in the 5-year benchmarks and to make annual updates and forecasts. Among the data gaps in the 5-year benchmarks requiring significant modeling are shipments from farms, the movement of municipal solid waste, and the domestic transportation of foreign trade. While movements of goods between U.S. international gateways and foreign countries are tracked continuously, movements of international trade between gateways and domestic origins for exports and domestic destinations for imports have not been observed directly since the 1970s. The FAF includes benchmarks every 5 years based on the CFS, annual estimates, and 30-year forecasts.

The freight system is undergoing significant changes as online shopping becomes more prevalent and new delivery technologies are deployed. New forms of data collection may be required to capture potential changes in freight flows caused by e-commerce, shifts in supply chains, and other developments in the economy.

Strengths and Weaknesses of Current Statistics on Transportation's Role in the Economy

Table 8-4 summarizes existing statistics on the role of transportation in the economy and gaps in those statistics. Statistics cover how much the Nation spends on transportation, how transportation costs have changed, how many people are employed in transportation companies and occupations, and how transportation contributes to economic output.

Transportation's role in the economy is derived from statistics on expenditures by households and businesses for transportation services, employment in transportation industries and occupations, and the value of transportation

TABLE 8-4 Statistics on Transportation's Role in the Economy

Topic	Coverage of existing statistics	Major gaps in existing statistics	Why the gaps matter
Transportation capital stocks	• National estimates of the value of transportation capital stocks • State inventories of public capital stocks for asset management systems	• National economic return on future capital stock investment by mode • Economic return to states on facility specific investments	• Fiscally constrained public investment is hampered by inability to match transportation investments to economic returns.
Transportation expenditures and investments	• Total transportation expenditures and investments by households, businesses, and government	• Borrowing by public and private entities to support transportation investment	• Capacity of financial system to support public and private investments in transportation
Transportation costs and prices	• Gasoline and diesel prices • Costs of automobile ownership • Air carrier costs for selected categories • For-hire carrier price indices • Cost to maintain highway, transit and waterway condition	• Trucking costs by type of cost • Rail costs based on actual operating expenses rather than regulatory formula • Comprehensive costs for bus, general aviation, pipeline • Cargo damage and loss • Comprehensive estimates of cost savings from congestion reduction.	• Cost data are used by businesses and consumers to make transportation choices and by government to identify the economic consequences of transportation investments and regulations
Transportation's contribution to the economy	• Transportation as a share of Gross Domestic Product by sector of the economy • Transportation embedded in other industries (the Transportation Satellite Account) • Transportation employment	• Economic and social activity enabled by transportation • Value travel time by households using the transportation system	• Input to establishing the appropriate size of investment programs and levels of revenue collection

to the economy. These statistics come from the Census Bureau, the Bureau of Economic Analysis (BEA), and the Bureau of Labor Statistics, each of which treats transportation as a significant sector of the economy.

For-hire transportation is one of the many sectors covered in the Economic Census, conducted every 5 years. This sector is also covered in the Census Bureau's Services Annual Survey, which collects operating revenue and other industry-specific data. BEA uses these data to estimate the flow of expenditures among sectors of the economy in order to understand how changes in the costs in a specific sector affect the rest of the economy. BTS expands on this accounting in its Transportation Satellite Account to include the sizable contribution to the economy made by in-house transportation services within non-transportation industries, such as truck fleets operated by large retail companies. BTS also estimates the economic contribution of personal transportation that falls outside the standard accounting of gross domestic product.

Transportation is not often highlighted in monthly national economic statistics. To provide a perspective on transportation's role in a dynamic economy, BTS developed the monthly Transportation Services Index (TSI) [USDOT BTS 2012c]. This index is based on activity in all modes of for-hire passenger and freight transportation services, and affords a better understanding of the relationship between transportation and the current and future course of the economy.

Strengths and Weaknesses of Current Statistics on the Unintended Consequences of Transportation

In addition to the intended economic activity that transportation creates, transportation has unintended impacts on safety, energy consumption, the environment, and communities. Table 8-5 summarizes existing statistics and gaps in those statistics.

Of the unintended consequences, safety is the main focus for several of the largest statistical programs in the U.S. Department of Transportation (USDOT). The National Highway Traffic Safety Administration (NHTSA) and the Federal Motor Carrier Safety Administration (FMCSA) account for 40 percent of the expenditures on major statistical programs in the Department [EOP OMB 2015]. The Pipeline and Hazardous

TABLE 8-5 Statistics on the Unintended Consequences of Transportation

Topic	Coverage of existing statistics	Major gaps in existing statistics	Why the gaps matter
Safety	• Transportation fatalities and injuries for all modes • Safety incidents involving hazardous materials; precursor events (close calls) for aviation, selected transit, and off-shore oil extraction and transport	• Risk factors • Exposure by type of safety risk • Precursor events (close calls) for most forms of surface transportation • Disabilities and medical costs related to transportation injuries	• Effective reduction of transportation-related casualties and property loss depends on detailed understanding of safety risks and causes of safety incidents • Measures of safety program effectiveness guide public investments and regulations
Energy consumption, green house gasses, air quality	• Air quality by type of pollutant and airshed • Relationship of vehicle emissions to type of vehicle and vehicle speed	• In-use fuel economy and emissions • Amount of vehicle travel by type of vehicle and vehicle speed in each airshed	• Estimates of air quality issues are based primarily on laboratory conditions and assumed operating patterns and should be tested against actual operating conditions
Noise, water quality, habitat dislocation	• Noise footprints around airports • National Transportation Noise Map • Environmental disruptions related to individual transportation projects	• Impacts of new street lighting technology • Natural habitat disruption	• Deployment of LED street lights raises community concerns with environmental quality and health issues • Geographic distributions of habitat disruption identify mitigation investment needs and target mitigation measures
Community disruption	• Social and economic characteristics of populations adjacent to transportation facilities	• Social and economic connections among urban neighborhoods and among rural locations	• Improve planning to avoid or mitigate community disruption from transportation facilities and to provide physical connections between mobility-challenged citizens and services and employment opportunities

Materials Safety Administration (PHMSA) and FHWA also have large-scale safety programs in place. Altogether, the Department's annual expenditures on safety data exceed $50 million.

In addition to its long-standing safety data programs, USDOT is exploring new sources of information and new analytical strategies to better understand safety risks. The Safety Data Initiative includes pilot efforts to integrate and analyze large databases, including real-time data sets that have not been previously tapped for risk analysis. The initiative focuses primarily on highway safety, which accounts for the preponderance of transportation fatalities.

In comparison to highway fatalities, the relatively low fatality rates of commercial aviation, railroads, transit, and pipelines do not reduce the need for data to understand risks and maintain or improve the safety of these modes. The focus of data programs for these modes goes beyond determining causes of infrequent crashes to understanding circumstances surrounding near misses or other mishaps that could have resulted in a serious incident. To identify safety problems and develop information for mitigating those problems, BTS provides a close calls reporting system that allows individuals and companies to report problems without fear of retaliation. Anonymity of respondents is assured under the *Confidential Information Protection and Statistical Efficiency Act.*[3] The Metrorail and bus operations of the Washington Metropolitan Area Transit Authority and the off-shore oil extraction industry currently use this BTS authority and service.

[3] Title V of Public Law 107-347, Dec. 17, 2002

The areas of energy consumption and related environmental emissions are another focus of statistics on unintended consequences of transportation. The transportation sector accounts for more than two-thirds of the petroleum consumed in the country and produces between one-quarter and one-third of all of the carbon dioxide (CO_2) emitted by the Nation's energy consumption. The U.S. Department of Energy has a major data program that tracks energy consumption by transportation sector [USDOE EIA 2015], and transportation's contributions to greenhouse gases and other emissions are tracked by the Environmental Protection Agency [USEPA OTAQ 2015]. While individual agencies compile information to meet specific needs, integrating these data and developing analytical techniques from many disciplines are the keys to effectively using these data sources to reduce transportation-related energy consumption and emissions. For example, the relationships between vehicle usage patterns and energy usage intensity are crucial to measuring and assessing the effectiveness of different energy and emission reduction opportunities and policies. Unfortunately, with the discontinuation of the Vehicle Inventory and Use Survey (VIUS) in 2002, much of the data necessary to help make these assessments are now at least 15 years out of date [USDOC CB VIUS 2002]. A plan by BTS and its partners to revive the VIUS is currently under consideration. An influx of new VIUS data might prove invaluable for tracking the deployment of driver assistance technology for collision avoidance, lane tracking, and other steps toward full vehicle automation. The VIUS is also essential for measuring the economic activities performed by motor vehicles.

Energy and safety concerns converge in the transportation of crude petroleum, ethanol, and other hazardous cargos by railroad. In response to the FAST Act,[4] BTS worked with the Association of American Railroads to measure the use of tank cars for carrying these cargos—distinguishing tank cars that meet new standards from those that have not yet been brought up to standard. BTS published summary statistics in its first annual report [USDOT BTS 2017b]. BTS is also collecting data that tracks the construction of new tank cars and the conversion of old tank cars to the new standards.

Statistical Information Gaps and Challenges

Considering the wide range of transportation data sources and information needs for public decisions, key gaps in statistical information are apparent:

- Long-distance, intercity travel remains poorly measured for surface modes of transportation.
- Understanding the domestic movement of international trade is based on models and assumptions more than on data from observations.
- Basic performance measures for public use are much improved for some modes, such as trucking and commercial aviation, but are lacking for other modes, such as freight railroads.
- Cost data are available for most forms of passenger travel but are limited for freight movement.
- The value of transportation to the economy and society is poorly articulated.
- Availability of data on causation of safety problems varies by mode of transportation.
- Integration of data on motor vehicle crashes, the conditions surrounding each crash, and consequences of the crash remains elusive.
- Data on highway vehicle use by vehicle characteristics, type of user, energy consumed, and economic activity have not been collected since 2002.

Of the major data gaps, intercity passenger travel is particularly significant. While data are available on the number of trips on commercial aircraft and intercity rail, long-distance travel in personal vehicles, intercity bus, and general aviation are poorly understood. The demographic characteristics of the long-distance traveler by any mode have not been measured for almost two decades. The last survey of intercity travel was conducted in 1995. As a consequence, current discussions about trends in passenger travel and the consequences of travel are dominated by measures of local travel. This limitation may result in misguided conclusions because long-distance travel involves different trip purposes and conditions than local travel, and one long-distance trip can generate as many miles of travel as dozens or even hundreds of local trips. Without information on long-distance travel, decision makers do not know how local congestion affects long-distance travel, how long-distance travel contributes to

[4] Section 7308 of of Public Law 114-94, Dec. 4, 2015

local congestion and the local economy, and how the total of local and long-distance travel contributes to safety risks and environmental problems.

The tables in this chapter include many areas of improved statistical information in recent years. The FAF, built primarily on data collected by BTS, provides a comprehensive picture of goods movement throughout the United States. The Transportation Satellite Account, featured in chapter 6, provides a more complete accounting of transportation's role in supporting other sectors of the national economy. The safety tables in *National Transportation Statistics* enumerate fatalities and injuries across all modes of transportation with double counting removed.

Other BTS contributions in 2017 to improved statistical information include:

- Publication in January of the first *Port Performance Freight Statistics Program Annual Report* [USDOT BTS 2017a].
- Release in March of the first edition of the National Transportation Noise Map and Database.
- Publication in September of the first annual report on *Fleet Composition of Rail Tank Cars that Transport Flammable Liquids* [USDOT BTS 2017b].
- Implementation in October of the Repository and Open Science Access Portal (ROSA-P), providing access to full-text electronic publications, datasets, and other resources for the transportation community, including all USDOT-funded research under the USDOT Public Access Plan.
- Release in November of the biennial National Census of Ferry Operators [USDOT BTS 2017c].
- Innovative use of vessel tracking data from the U.S. Coast Guard's Automatic Identification System (AIS) for measuring ship dwell times in the second edition of the *Port Performance Freight Statistics Program Annual Report* and for measuring route miles in the National Census of Ferry Operators.
- Enhancement throughout the year of the BTS website for improved access to transportation statistics.

Efforts to improve statistical information are underway throughout USDOT. For example, FHWA completed data collection for a new NHTS and has launched a major content review of its Highway Performance Monitoring System. Efforts to improve data management in support of statistical information are also underway, such as NHTSA's implementation of an Electronic Data Transfer Pilot to establish direct links between State and NHTSA databases for improved quality, reduced costs, and improved timeliness.

BTS and its partners are exploring data sources beyond traditional surveys to fill information gaps. These sources include:

- Administrative records, such as vehicle registration files and police reports from highway crashes.
- Sensors, such as the rubber hoses stretched across highways to count traffic, engine monitors to estimate fuel economy, and the

positions reported by cell phones to track travel and by transponders to track ships and aircraft.

- Imagery, such as traffic monitoring cameras and satellite photos.
- Crowd sourcing, such as Open Street Map for tracking changes in the highway network and Waze for tracking highway disruptions.
- Web scraping, such as the Billion Prices Project, to track the prices of consumer goods.

While these data sources show great promise, the availability of data alone does not assure that robust statistics exist to help answer the questions of decision makers. Significant quality issues, inadequate methods for analyzing data to create useful information, and confidentiality concerns can undermine the effectiveness of these data for credible, public statistics.

Statistical agencies have extensive, well-established methods identifying and controlling for error in data from sample surveys, but not for dealing with error in data from sources other than surveys. Some sources of error in alternative data sources are analogous to those found in surveys; for example, sensor failure can be treated like survey non-response. Other sources of error may require very different approaches to identification and correction. The challenge is compounded when data are blended from many sources for an estimate: might the individual sources of error cancel each other out or compound one another? The Federal Committee on Statistical Methodology is working to establish a framework in 2018 for identifying and measuring error in alternative and blended data.

BTS and its partners are also exploring new analytical methods for creating useful information from the new data sources. Frequently labeled “big data analytics,” these methods were originally developed to make short-term forecasts from very large datasets. These methods are being adapted by private shippers to monitor and manage supply chains, and are now being explored by public agencies as early indicators of changing social and economic conditions and of emerging safety problems. The potential for adapting these forecasting methods to prediction and understanding of complex, uncontrolled transportation phenomena remains unproven. In any case, traditional statistical methods are still needed to avoid confusing correlation with causation and misleading public decisions.

All data sources and estimation methods have quality issues, and understanding whether the quality problems are large or small is central to appropriate uses and to credibility of the resulting statistics. Credibility also depends on the perception that the information is free of political influence. To assure objectivity, the Office of Management and Budget exempts the products of BTS and all other principle federal statistical agencies from political review through Statistical Policy Directive No. 1 [EOP OMB 2014].

Evidence-Based Policy Making

Congress directed BTS to ensure that the Bureau’s statistics support transportation decision making.[5] This mandate is consistent with the current emphasis of the Congress and the Executive Branch on evidence-based decision making throughout the Federal Government. "Agencies are encouraged to allocate resources to programs and practices backed by strong evidence of effectiveness while trimming activities that evidence shows are not effective" [EOP OMB 2013a]. Congress established a Commission on Evidence-Based Policymaking in 2016 to recommend approaches for integrating administrative, survey, and other data into evidence of the effectiveness of public programs.[6]

The Commission's final report, issued in 2017, recommends:

- establishment of an annual "learning agenda" and a chief evaluation officer in each executive department to develop evidence on the effectiveness of the department's programs;
- establishment of a National Secure Data Service to facilitate access to confidential data for developing evidence while protecting confidentiality and assuring transparency of evidence-building methods;
- adoption of state-of-the-art database, cryptography, and privacy-preserving, and privacy-enhancing technologies for confidential data used in decision making;
- use of administrative data collected from states for statistical purposes; and
- improvements to administrative processes and changes to statutes to further the development of evidence.

The Commission also recommends that each department assign a Principal Statistical Agency head or other appropriately qualified senior official to coordinate access to and stewardship of the department's data resources for evidence building in collaboration with senior department information technology, privacy, and other leaders [CEP 2017]. The Service and Methods Demonstration Program for transit in the 1970s is one approach that USDOT could use for establishing a multimodal learning agenda for transportation [USDOT UMTA 1979].

Looking Ahead

The transportation community must juggle the demands of evidence-based decision making and the development and interpretation of new data sources with the maintenance and improvement of traditional statistics on which decision makers and planers are dependent. BTS has direct control over a small portion of the data sources highlighted in this chapter, but it has a leadership role in many external data sources as the principal Federal statistical agency for transportation [EOP OMB 2014].

While other prominent data programs exist in USDOT:

- BTS is the Department's only source of statistics that covers all modes of transportation.
- BTS is the Federal Government's primary source of original information on commercial aviation.

[5] 49 U.S.C. § 6302(b)(3)(B)(i)

[6] Public Law 114-140, Mar. 30, 2016

- BTS is the only part of USDOT that is designated by the Office of Management and Budget (OMB) as a Principal Federal Statistical Agency and covered by all Statistical Policy Directives.

BTS recognizes that it must evolve its statistical products, data collection methods, and expertise to provide effective services to the transportation community in a rapidly changing world. As a 21st Century statistical agency, BTS must:

- Provide fresh, recent information in small bytes.
- Be flexible and nimble to address emerging issues.
- Focus on new technology for collection and delivery of information, especially through mobile devices and apps.
- Adhere to Statistical Policy Directives of the Office of Management and Budget to assure that statistics are objective, accurate, timely, and credible.

Toward these ends, BTS will expand its statistical products, publish to the web immediately rather than wait for printed reports, continue to streamline its data processing procedures, and implement new ways for the transportation community to find and use information on the BTS website. BTS will also continue to operate and improve the National Transportation Library, which is making transportation information, statistics, databases, and research findings from throughout USDOT transparent and accessible to the public under the government-wide Open Data Policy [EOP OMB 2013b]. All BTS products and the collections of the National Transportation Library are available on the internet at www.bts.gov.

As resources permit, BTS is undertaking research to explore alternative data sources and new methods of estimating statistics on the extent and use of the transportation system and on the consequences of transportation. New data sources are critical for replacing surveys that suffer from declining response rates and increasing costs. BTS is looking at new approaches to measure phenomena, such as passenger travel and freight movement, for which traditional surveys are decreasingly effective. BTS is working with the other principal Federal statistical agencies to explore the use of administrative records, data from sensors, and advanced data mining analytics. BTS has initiated a major research program to develop methods for supplementing and enhancing portions of the FAF and reducing respondent burden for the CFS in 2022. In addition to research, BTS is continuing to work with its partners in USDOT and the principal Federal statistical agencies to identify and resolve significant problems with comparability and quality of transportation statistics.

BTS recognizes the need to take a more active role with its partners to assist with performance measurement and evidence-based decision making. BTS provides statistical expertise to advise the design of performance measures and program evaluations, portals to data that can be used in performance measurement and program evaluations, and public access to statistics created by performance measurement and program evaluations.

BTS has achieved significant progress in improving the state of transportation statistics over the last 25 years. The Bureau will continue to strive in the years ahead to create increasingly robust, timely, credible products in each of the topic areas identified in legislative mandates and departmental goals. BTS will continue to enhance timeliness, improve the quality of its products, and produce statistics that are useful, relevant, and used throughout the Nation.

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GLOSSARY

Air carrier: Certificated provider of scheduled and nonscheduled services.

Alternative fuel (vehicle): Nonconventional or advanced fuels or any materials or substances, such as biodiesel, electric charging, ethanol, natural gas, and hydrogen, that can be used in place of conventional fuels, such as gasoline and diesel.

Arterial: A class of roads serving major traffic movements (high-speed, high volume) for travel between major points.

Block hours: The time elapsed from the moment an aircraft pushes back from the departure gate until the moment of engine shutoff at the arrival gate following its landing.

Bus: Large motor vehicle used to carry more than 10 passengers, including school buses, intercity buses, and transit buses.

Capital stock (transportation): Includes structures owned by either the public or private sectors, such as bridges, stations, highways, streets, and ports; and equipment, such as automobiles, aircraft, and ships.

Chained dollars: A method of inflation adjustment that allows for comparing in dollar values changes between years.

Class I railroad: Railroads earning adjusted annual operating revenues for three consecutive years of $250,000,000 or more, based on 1991 dollars with an adjustment factor applied to subsequent years.

Commercial air carrier: An air carrier certificated in accordance with Federal Aviation Regulations Part 121 or Part 127 to conduct scheduled services on specified routes.

Commuter rail: Urban/suburban passenger train service for short-distance travel between a central city and adjacent suburbs run on tracks of a traditional railroad system. Does not include heavy or light rail transit service.

Consumer Price Index (CPI): Measures changes in the prices paid by urban consumers for a representative basket of goods and services.

Current dollars: Represents the dollar value of a good or service in terms of prices current at the time the good or service is sold.

Deadweight tons: The number of tons of 2,240 pounds that a vessel can transport of cargo, stores, and bunker fuel. It is the difference between the number of tons of water a vessel displaces "light" and the number of tons it displaces when submerged to the "load line."

Demand-response: A transit mode comprised 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.

Directional route-miles: The sum of the mileage in each direction over which transit vehicles travel while in revenue service.

Directly operated service: Transportation service provided directly by a transit agency, using their employees to supply the necessary labor to operate the revenue vehicles.

Distribution pipeline: Delivers natural gas to individual homes and businesses.

E85: A gasoline-ethanol mixture that may contain anywhere from 51 to 85 percent ethanol. Because fuel ethanol is denatured with approximately 2 to 3 percent gasoline, E85 is typically no more than 83 percent ethanol.

Energy intensity: The amount of energy used to produce a given level of output or activity, e.g., energy use per passenger-mile of travel. A decline in energy intensity indicates an improvement in energy efficiency, while an increase in energy intensity indicates a drop in energy efficiency.

Enplanements: Total number of revenue passengers boarding aircraft.

Expressway: A controlled access, divided arterial highway for through traffic, the intersections of which are usually separated from other roadways by differing grades.

Ferry boat: A vessel that provides fixed-route service across a body of water and is primarily engaged in transporting passengers or vehicles.

Flex fuel vehicle: A type of alternative fuel vehicle that can use conventional gasoline or gasoline-ethanol mixtures of up to 85 percent ethanol (E85).

Footprint (vehicle): The size of a vehicle defined as the rectangular "footprint" formed by its four tires. A vehicle's footprint is its track (width) multiplied by its wheelbase (length).

For-hire (transportation): Refers to a vehicle operated on behalf of or by a company that provides services to external customers for a fee. It is distinguished from private transportation services in which a firm transports its own freight and does not offer its transportation services to other shippers.

Freeway: All urban principal arterial roads with limited control of access not on the interstate system.

Functionally obsolete bridge: 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.

GDP (gross domestic product): The total value of goods and services produced by labor and property located in the United States. As long as the labor and property are located in the United States, the suppliers may be either U.S. residents or residents of foreign countries.

General aviation: Civil aviation operations other than those air carriers holding a Certificate of Public Convenience and Necessity. Types of aircraft used in general aviation range from corporate, multiengine jets piloted by a professional crew to amateur-built, single-engine, piston-driven, acrobatic planes.

Heavy rail: High-speed transit rail operated on rights-of-way that exclude all other vehicles and pedestrians.

Hybrid vehicle: Hybrid electric vehicles combine features of internal combustion engines and electric motors. Unlike 100% electric vehicles, hybrid vehicles do not need to be plugged into an external source of electricity to be recharged. Most hybrid vehicles operate on gasoline.

In-house (transportation): Includes transportation services provided within a firm whose main business is not transportation, such as grocery stores that use their own truck fleets to move goods from warehouses to retail outlets.

Interstate: Limited access divided facility of at least four lanes designated by the Federal Highway Administration as part of the Interstate System.

International Roughness Index (IRI): A scale for roughness based on the simulated response of a generic motor vehicle to the roughness in a single wheel path of the road surface.

Lane-mile: Equals one mile of one-lane road, thus three miles of a three-lane road would equal nine lane-miles.

Large certificated air carrier: Carriers operating aircraft with a maximum passenger capacity of more than 60 seats or a maximum payload of more than 18,000 pounds. These carriers are also grouped by annual operating revenues: majors—more than $1 billion; nationals—between $100 million and $1 billion; large regionals—between $20 million and $99,999,999; and medium regionals—less than $20 million.

Light-duty vehicle: Passenger cars, light trucks, vans, pickup trucks, and sport/utility vehicles regardless of wheelbase.

Light-duty vehicle, long wheelbase: Passenger cars, light trucks, vans, pickup trucks, and sport/utility vehicles with wheelbases longer than 121 inches.

Light-duty vehicle, short wheelbase: Passenger cars, light trucks, vans, pickup trucks, and sport/utility vehicles with wheelbases equal to or less than 121 inches and typically with a gross weight of less than 10,000 lb.

Light rail: Urban transit rail operated on a reserved right-of-way that may be crossed by roads used by motor vehicles and pedestrians.

Linked trip: A trip from the origin to the destination on the transit system. Even if a passenger must make several transfers during a journey, the trip is counted as one linked trip on the system.

Local road: All roads not defined as arterials or collectors; primarily provides access to land with little or no through movement.

Long-distance travel: As used in this report, trips of more than 50 miles. Such trips are primarily served by air carriers and privately owned vehicles.

Major collector: Collector roads that tend to serve higher traffic volumes than other collector roads. Major collector roads typically link arterials. Traffic volumes and speeds are typically lower than those of arterials.

Minor arterial: Roads linking cities and larger towns in rural areas. In urban areas, they are roads that link, but do not enter neighborhoods within a community.

Minor collector: Collector roads that tend to serve lower traffic volumes than other collector roads. Traffic volumes and speeds are typically lower than those of major collector roads.

Motorcoach: A vehicle designed for long-distance transportation of passengers, characterized by integral construction with an elevated passenger deck located over a baggage compartment. It is at least 35 feet in length with a capacity of more than 30 passengers.

Motorcycle: A two- or three-wheeled vehicle designed to transport one or two people, including motorscooters, minibikes, and mopeds.

Multiple Modes and Mail: the Freight Analysis Framework (FAF) and the Commodity Flow Survey (CFS) use “Multiple Modes and Mail” rather than “Intermodal” to represent commodities that move by more than one mode. Intermodal typically refers to containerized cargo that moves between ship and surface modes or between truck and rail, and repeated efforts to identify containerized cargo in the CFS have proved unsuccessful. Multiple mode shipments can include anything from containerized cargo to bulk goods such as coal moving from a mine to a railhead by truck and then by rail to a seaport. Mail shipments include parcel delivery services where shippers typically do not know what modes were involved after the shipment was picked up.

National Highway System (NHS): This system of highways designated and approved in accordance with the provisions of 23 United States Code 103b Federal-aid systems.

Nominal dollars: A market value that does not take inflation into account and reflects prices and quantities that were current at the time the measure was taken.

Nonself-propelled vessels: Includes dry cargo, tank barges, and railroad car floats that operate in U.S. ports and waterways.

Oceangoing vessels: Includes U.S. flag, privately owned merchant fleet of oceangoing, self-propelled, cargo-carrying vessels of 1,000 gross tons or greater.

Offshore gathering line: A pipeline that collects oil and natural gas from an offshore source, such as the Gulf of Mexico. Natural gas is collected by gathering lines that convey the resource to transmission lines, which in turn carry it to treatment plants that remove impurities from the gas. On the petroleum side, gathering pipelines collect crude oil from onshore and offshore wells. The oil is transported from the gathering lines to a trunk-line system that connects with processing facilities in regional markets.

Offshore transmission line (gas): A pipeline other than a gathering line that is located offshore for the purpose of transporting gas from a gathering line or storage facility to a distribution center, storage facility, or large volume customer that is not downstream from a distribution center.

Onshore gathering line: A pipeline that collects oil and natural gas from an onshore source, such as an oil field. Natural gas is collected by gathering lines that convey the resource to transmission lines, which in turn carry it to treatment plants that remove impurities from the gas. On the petroleum side, gathering pipelines collect crude oil from onshore and offshore wells. The oil is transported from the gathering lines to a trunk-line system that connects with processing facilities in regional markets.

Onshore transmission line (gas): A pipeline other than a gathering line that is located onshore for the purpose of transporting gas from a gathering line or storage facility to a distribution center, storage facility, or large volume customer that is not downstream from a distribution center.

Particulates: Carbon particles formed by partial oxidation and reduction of hydrocarbon fuel. Also included are trace quantities of metal oxides and nitrides originating from engine wear, component degradation, and inorganic fuel additives.

Passenger-mile: One passenger transported one mile. For example, one vehicle traveling 3 miles carrying 5 passengers generates 15 passenger-miles.

Person-miles: An estimate of the aggregate distances traveled by all persons on a given trip based on the estimated transportation-network-miles traveled on that trip. For instance, four persons traveling 25 miles would accumulate 100 person-miles. They include the driver and passenger in personal vehicles, but do not include the operator or crew for air, rail, and transit modes.

Person trip: A trip taken by an individual. For example, if three persons from the same household travel together, the trip is counted as one household trip and three person trips.

Personal vehicle: A motorized vehicle that is privately owned, leased, rented or company-owned and available to be used regularly by a household, which may include vehicles used solely for business purposes or business-owned vehicles, so long as they are driven home and can be used for the home to work trip (e.g., taxicabs, police cars, etc.).

Planning Time Index (PTI): The ratio of travel time on the worst day of the month compared to the time required to make the same trip at free-flow speeds.

Post Panamax vessel: Vessels exceeding the length or width of the lock chambers in the Panama Canal. The Panama Canal expansion project, slated for completion in 2015, is intended to double the canal's capacity by creating a new lane of traffic for more and larger ships.

Real dollars: Value adjusted for changes in prices over time due to inflation.

Self-propelled vessels: Includes dry cargo vessels, tankers, and offshore supply vessels, tugboats, pushboats, and passenger vessels, such as excursion/sightseeing boats, combination passenger and dry cargo vessels, and ferries.

Short ton: A unit of weight equal to 2,000 pounds.

Structurally deficient (bridge): 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.

TEU (twenty-foot equivalent unit): A TEU is a nominal unit of measure equivalent to a 20' x 8' x 8' shipping container. For example, a 50 ft. container equals 2.5 TEU.

Tg CO_2 Eq.: Teragrams of carbon dioxide equivalent, a metric measure used to compare the emissions from various greenhouse gases based on their global warming potential.

Ton-mile: A unit of measure equal to movement of 1 ton over 1 mile.

Trainset: One or more powered cars mated with a number of passenger or freight cars that operate as one entity.

Transit bus: A bus designed for frequent stop service with front and center doors, normally with a rear-mounted diesel engine, low-back seating, and without luggage storage compartments or rest room facilities. Includes motor and trolley bus.

Transmission line: A pipeline used to transport natural gas from a gathering, processing, or storage facility to a processing or storage facility, large volume customer, or distribution system.

Transportation Services Index (TSI): A monthly measure indicating the relative change in the volume of services over time performed by the for-hire transportation sector. Change is shown relative to a base year, which is given a value of 100. The TSI covers the activities of for-hire freight carriers, for-hire passenger carriers, and a combination of the two. See www.bts.gov for a detailed explanation.

Travel Time Index (TTI): The ratio of the travel time during the peak traffic period to the time required to make the same trip at free-flow speeds.

Trip-chaining: The practice of adding daily errands and other activities, such as shopping or going to a fitness center, to commutes to and from work.

Trolley bus: See transit bus.

Unlinked trips: The number of passengers who board public transportation vehicles. Passengers are counted each time they board vehicles no matter how many vehicles they use to travel from their origin to their destination.

Vehicle-mile: Measures the distance traveled by a private vehicle, such as an automobile, van, pickup truck, or motorcycle. Each mile traveled is counted as one vehicle-mile regardless of number of passengers.