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).

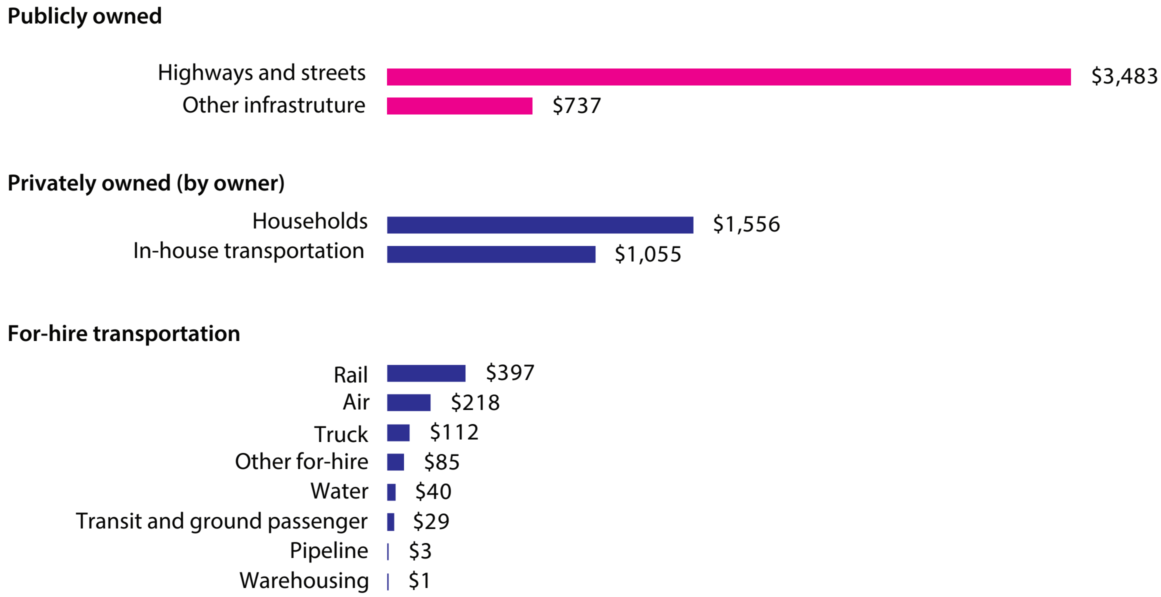
Transportation capital stock is owned by both the public and private sectors. Freight railroad facilities and equipment are almost entirely owned by the private sector, while state and local governments own highways and bridges, airports, seaports, and transit structures.

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]

[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.

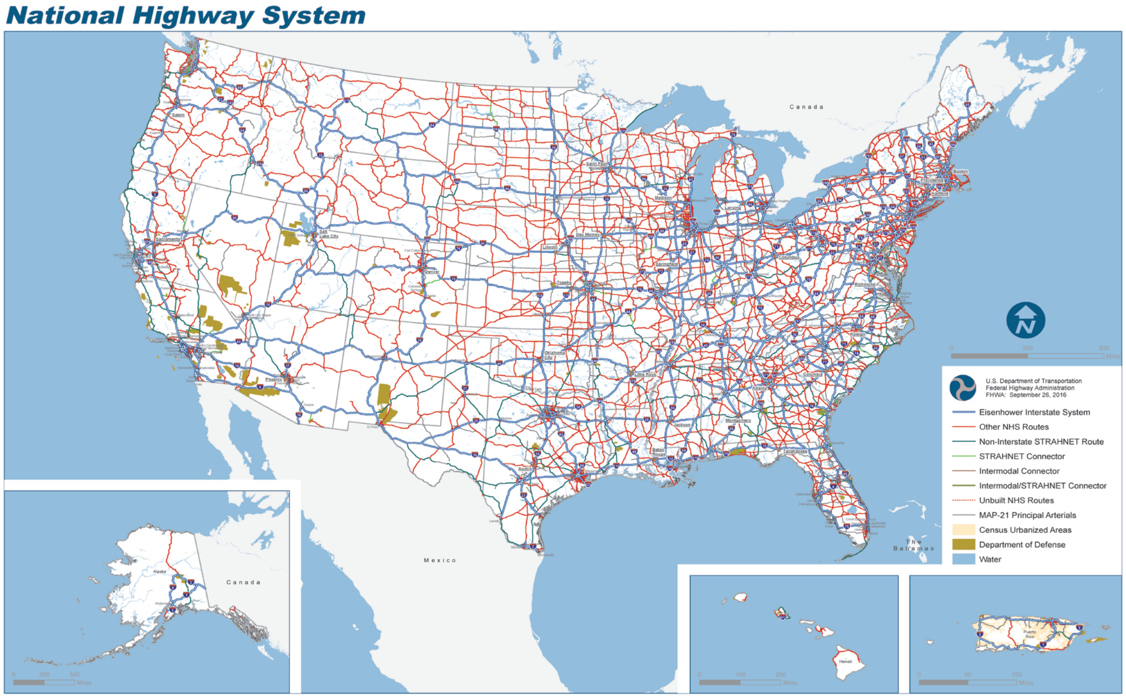
[2] A highway that has a roughness rating greater than 170 inches per mile is considered in poor condition.

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

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.

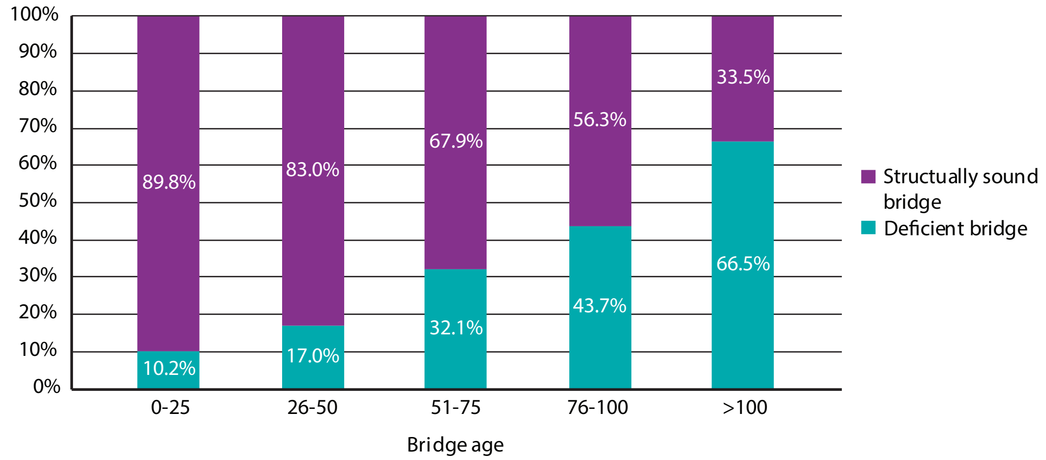
Age alone is not an automatic indicator of structural integrity. For example, the 134-year-old Brooklyn Bridge, due to consistent maintenance and several major rehabilitations, is still deemed safe for daily use, while the I-95

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

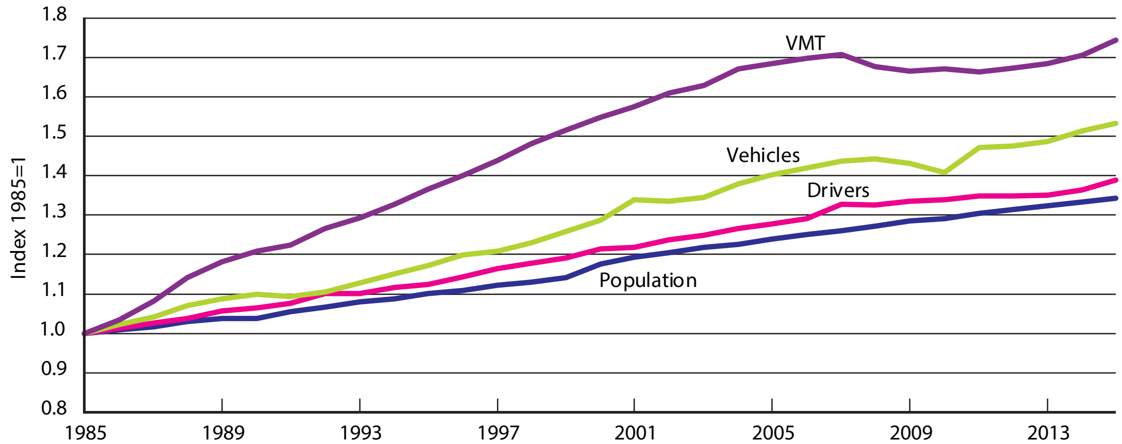
	2000	2010	2014	2015
TOTAL, registered vehicles	**225,821,241**	**250,070,048**	**260,350,938**	**263,610,219**
Light-duty vehicle, short wheelbase	U	190,202,782	187,554,928	189,619,308
Passenger Car	133,621,420	U	U	U
Motorcycle	4,346,068	8,009,503	8,417,718	8,600,936
Light-duty vehicle, long wheelbase	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

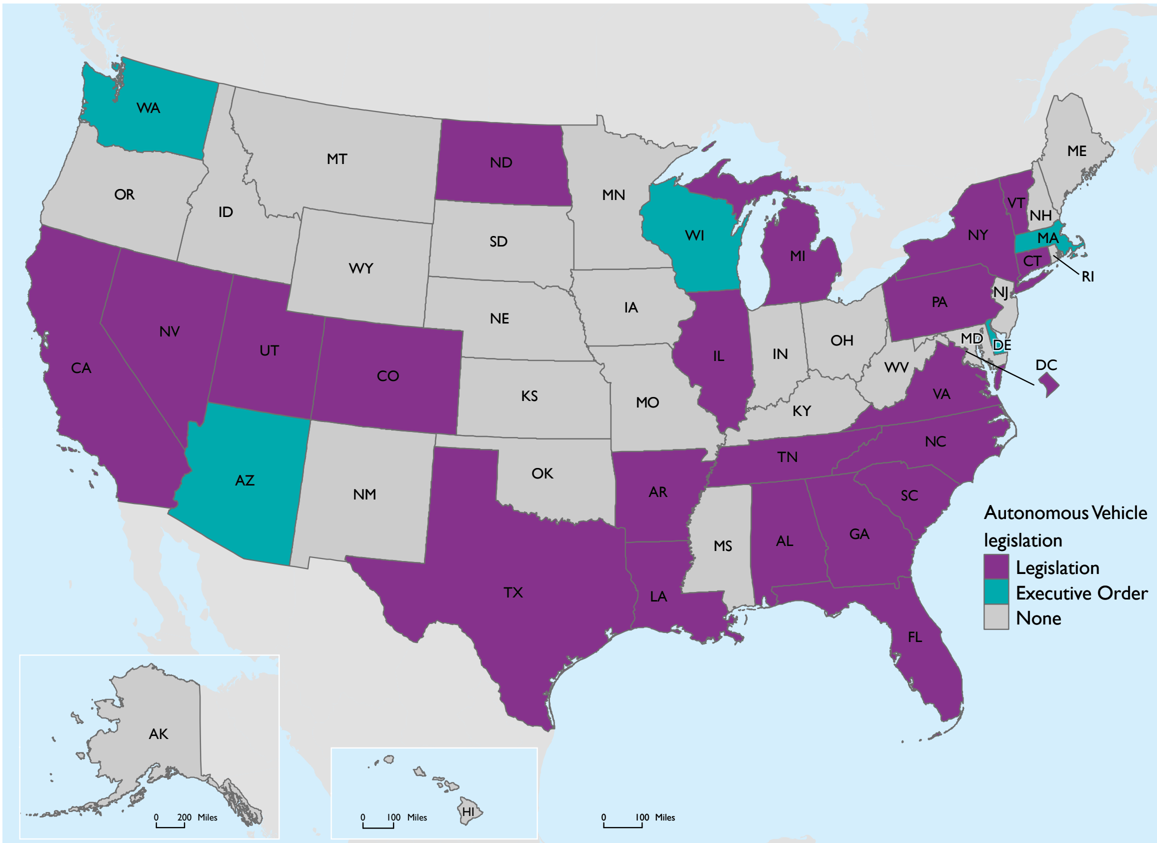
Connected vehicles (CVs) are those that can communicate with:

- 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.

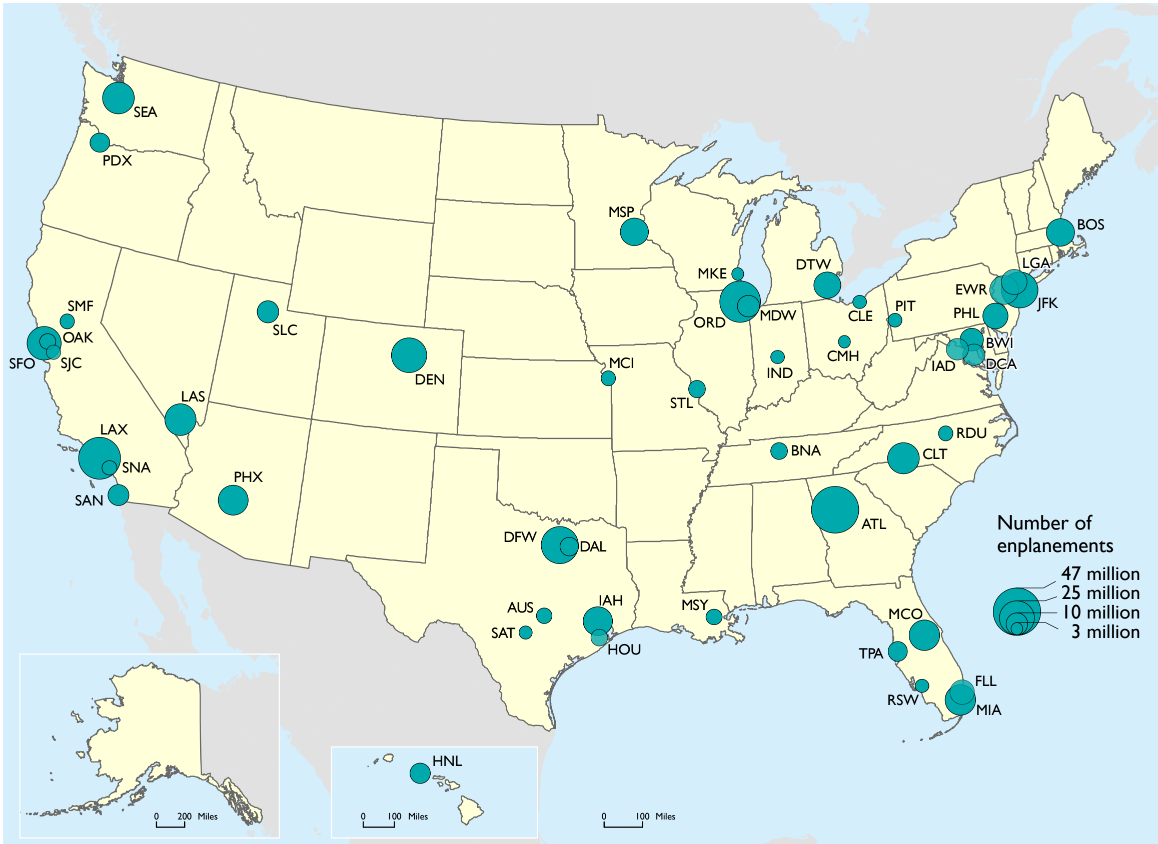
According to USDOT's Biennial Conditions and Performance report, the current total investment across all transit systems is about $16.9 billion annually. Bringing all systems to a state of good repair would require an increase to $17.0 billion per year, with all spending going to system preservation 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

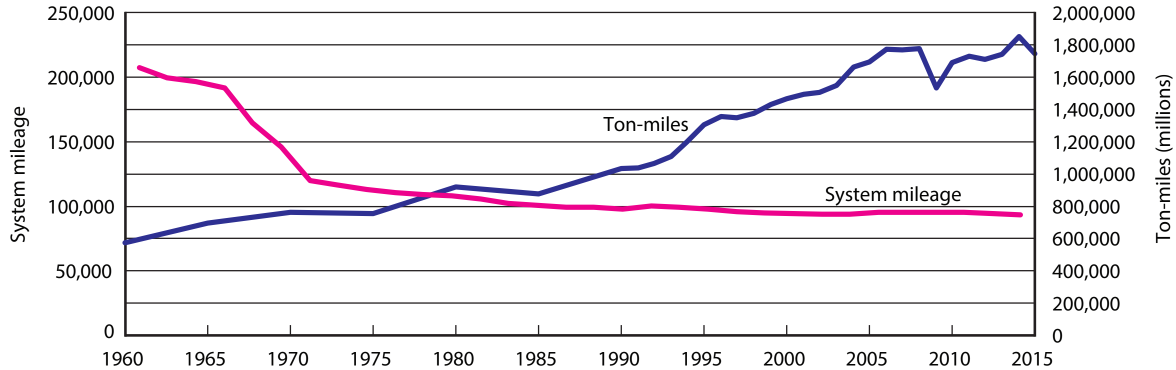
	2000	2010	2013	2014	2015
Equipment and Mileage Operated by Amtrak					
Locomotives	378	282	418	428	423
Passenger cars	1,894	1,274	1,447	1,419	1,428
System mileage	23,000	21,178	21,356	21,356	21,358
Stations	515	519	516	518	518
Passengers (millions)	20.9	28.7	30.9	31.0	30.7
Passenger-miles traveled (millions)	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.

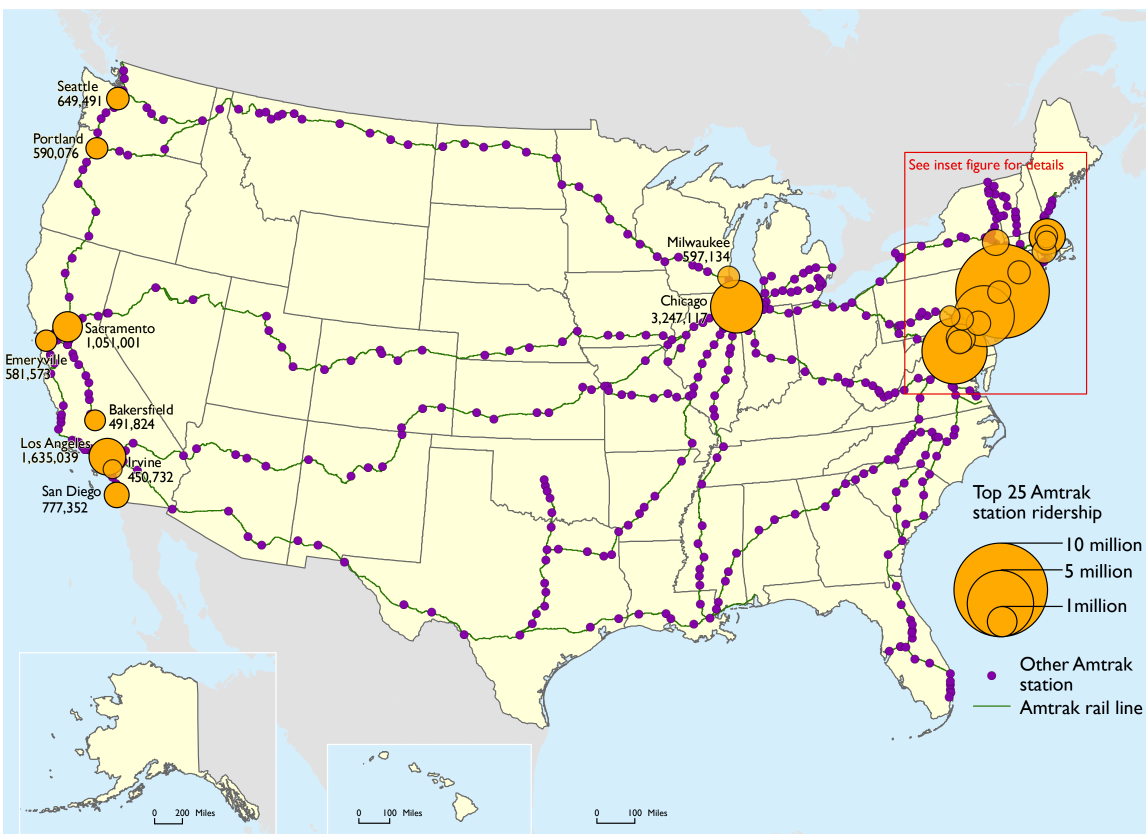
FIGURE 1-7 Class I Railroad System Mileage and Ton-miles of Freight: 1960, 1965, 1970–2015



NOTES: Report was every 5 years until 1970.

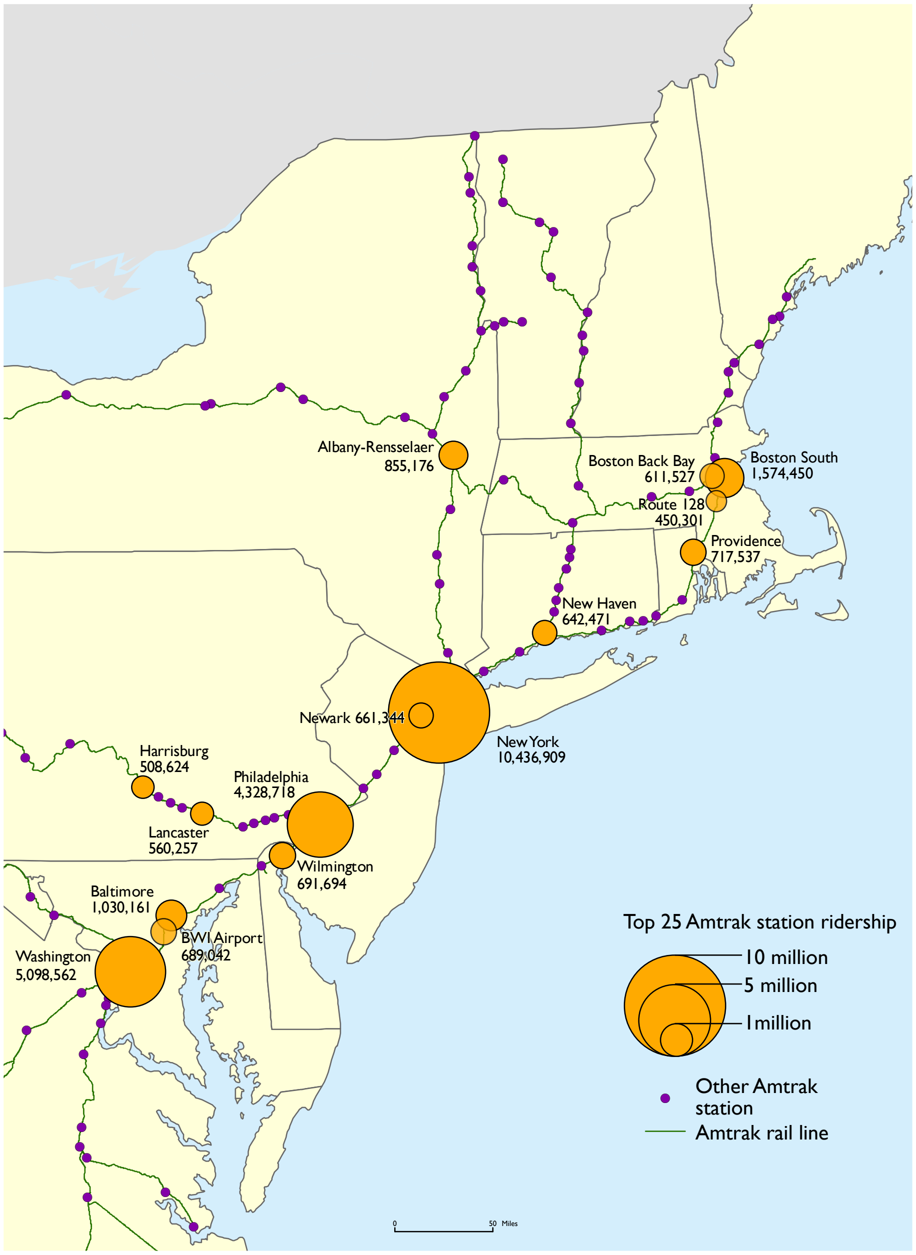
SOURCE: Association of American Railroads, *Railroad Facts*, Statistical Highlights (Washington, DC: Annual Issues).

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

			Main lock chamber only				Outages in 2016[b]			
River	River mile[a]	Lock Name	Length, feet	Width, feet	Age, years	Tons in 2016, millions[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.

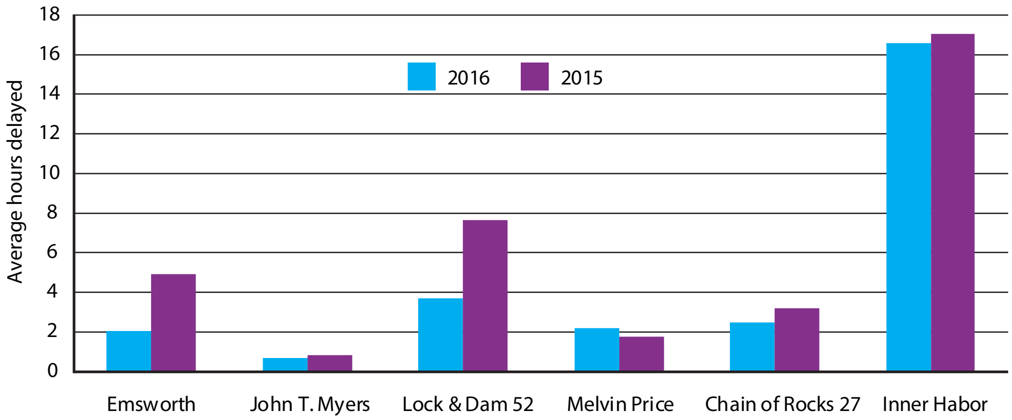
SOURCES: U.S. Army Corps of Engineers, Institute for Water Resources, Navigation Data Center, *Locks by Waterway, Tons Locked by Commodity Group, CY 1993 - 2016.* Available at http://www.navigationdatacenter.us/lpms/cy2013comweb.htm as of May 2017. U.S. Army Corps of Engineers, Institute for Water Resources, 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		•	

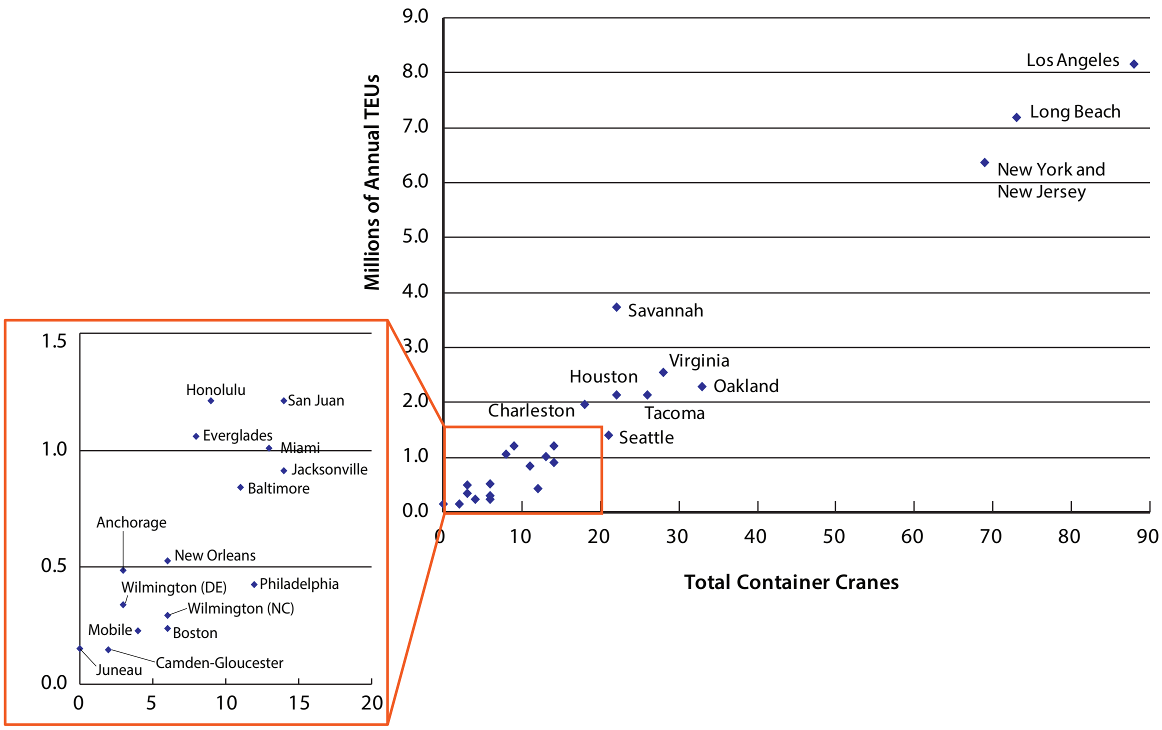
KEY: TEU = twenty-foot equivalent unit.
NOTE: Ports are listed in alphabetical order.
SOURCE: U.S. Department of Transportation (USDOT). Bureau of Transportation Statistics (BTS). *2016. Port Performance Freight Statistics Program: Annual Report to Congress 2016.* Table 4. Available at https://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/PPFS_Annual_Report.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