chapter 5

People, Energy, and the Environment

"The transportation enterprise must be equitable, flexible, and sensitive to environmental issues. We must keep in mind that transportation is a means—not an end; the common good must take priority over specific group's opposition to projects."

Christopher Zearfoss
Acting Deputy Mayor, City of Philadelphia
2025 Visioning Session, Sept. 14, 2000, Philadelphia, PA.

"25 years from now, alternative fuel vehicles, hybrid electrics, and fuel cells will have a large market share"

Vision of the Denver Roundtable
2025 Visioning Session, Denver CO, Apr. 4, 2000

"Transportation needs to focus more on 'how can it best accommodate and work for people with disabilities,' instead of 'how can we comply with the rules and regulations'."

Debbie Kaplan, World Institute on Disability
2025 Visioning Session, Berkeley, CA, June 24, 2000

chapter 5

People, Energy, and the Environment

Patterns of demographic change stamp their image indelibly on the transportation system. By 2025, the U.S. population is expected to grow by nearly 23 percent, and the number of Americans in older age groups will multiply as "baby boomers" continue to enter their senior years. For these aging Americans, funds formerly devoted to buying homes, raising children, and paying for college are becoming available as discretionary income, increasing the freedom to travel. These household composition shifts, changes in labor force participation and household income, and shifts in licensing and vehicle ownership all affect transportation and individual mobility.

These demographic changes are transforming the day-to-day life of American households and altering the demands and challenges facing the transportation enterprise. Increased awareness of other peoples and increased global activity create a greater interest in travel. At the same time, Americans share a greater sensitivity to the importance of the environment and the close interaction between transportation activities and environmental impacts, as well as the use of energy and other natural resources.

Transportation, as the major energy-using sector of the U.S. economy, plays a major role in both energy conservation and the environment. As demographic shifts occur, levels of energy use will change, and their combined impact on the environment will shift. Although an adequate fuel supply is available to American consumers, the United States is becoming increasingly dependent on imported oil. Patterns of energy use, petroleum dependence, and the sustainability of energy supplies will greatly influence our future transportation options.

Addressing concerns over the environmental impact of transportation is now a fundamental part of transportation decisionmaking. The interdependence between transportation and the environment continues to require great care in keeping the two appropriately balanced. For example, automobiles are more fuel efficient and emit significantly fewer pollutants than did their 1975 counterparts, and the use of transportation funding in the nation's metropolitan area is tied directly to the steps needed to maintain air quality. The Transportation Efficiency Act for the 21st Century (TEA-21) strengthens metropolitan and statewide planning and has been called one of the most important pieces of legislation passed by Congress in recent years. TEA-21 continues and strengthens the Intermodal Surface Transportation Efficiency Act's (ISTEA's) emphasis on the environment. It improves communities and quality of life through transportation and transit enhancements and protects and

"This is truly a mountaintop moment for America. We are strong and prosperous. Our automotive and related industries – which employ about one out of seven Americans – are leading the world. I believe we have to use this moment to make the investments that will keep our progress and prosperity going far into the future. By reducing our dependence on foreign oil; by reducing greenhouse gas emissions; and by positioning the American auto industry as the world leader in a crucial new market in this new economy."

Vice President Al Gore
Mar. 30, 2000

enhances the environment through several programs, including the Congestion Mitigation and Air Quality Program (CMAQ). TEA-21 significantly increases funding for the CMAQ program, creates new transit enhancements program, provides additional incentives to foster use of alternative modes of transportation, and increases funding for recreational trails program.

Each of these factors—people, energy, and the environment—influence transportation demand, some positively, some negatively, and each leads to changes in the markets served by the transportation enterprise. This chapter looks at mobility trends and access for people, energy use, and impacts of transportation on our environment over the last 25 years. It also highlights key issues for the future.

"Regardless of where we Americans live or where we stand on the economic scale, one thing that unites us is our desire for a high quality of life, safe communities, healthy open spaces, and reduced congestion."

Vice President, Al Gore
Livable Communities Initiative
Feb. 4, 2000

Mobility and Access

Mobility—the freedom to travel without undue restraint—must be available to all Americans. Travel has always contributed to Americans' enjoyment of their lives and leisure. When transportation does not work well, it can be a source of great personal frustration and economic loss. Safe and efficient transportation, by contrast, supports the freedom and access Americans have always cherished. Travel includes local, long-distance, and international travel by all modes of transportation. Local travel includes daily activities—work, school, shopping, personal business, social activities, and recreation. Intercity travel generally includes long-distance travel or an overnight stay away from home. Taken together, local and intercity travel represent total national travel. International travel encompasses travel by air and water, as well as travel by highway and railway to and from Canada and Mexico. This section summarizes national trends in the demand for and use of transportation services by household and demographic characteristics. Discussions focus on the various transportation users and the implications of past and current trends for future transportation services.

Local Travel: America is a nation of prodigious travelers. Local travel has grown by 50 percent since the mid-1970s. In the mid-1990s, people traveled an average of 14,000 mile per year in and around their communities (table 5-1) [USDOT FHWA Various years]. Local travel activity focuses on the household and involves many different daily activities. For the past two decades, growth in local travel has exceeded population growth for several reasons, including household income, household composition shifts, changes in labor force participation, and shifts in licensing and vehicle ownership.

Demographic Trends: Demographic factors are among the most important considerations in any projection of future transportation demand. Changes in the size and composition of the American population have a major impact on the growth of our labor force and on demands for a variety of consumable items, including transportation. The dominant demographic story of the post-World War II period has been the birth and aging of the baby boom generation. The movement of this generation from early adulthood through the beginning of their retirement years provided the demographic theme for the past quarter century.

Lower birth rates, the maturation of the baby boomers' offspring, and changing trends in society (e.g., later marriage, greater longevity, and higher divorce rates) have all served to decrease household sizes in the later years of the 20th century (table 5-2). If our current population of 275 million people were contained in households of the size prevalent in 1975, they would comprise 88 million households instead of the 100 million households in America today. Because much of the demand for transportation is household-based, implications for

Table 5-1

Population and Passenger Travel in the United States: 1977 and 1995

	1977	1995	Percentage increase 1977 to 1995
Resident population (thousands)	219,760	262,761	20
Annual local person trips (travel day) (millions)[1]	211,778	378,930	79
Annual long-distance person trips (millions)	521	1,001	92
Local person trips per capita, one way (per day)[1]	2.4	4.3	47
Long-distance trips per capita, roundtrip (per year)	2.5	3.9	56
Local person-miles (millions)[1]	1,879,215	3,411,122	82
Long-distance person-miles (millions)	382,466	826,804	116
Local person-miles per capita[1] (annually)	9,470	14,115	49
Long-distance person-miles per capita (annually)	1,796	3,129	74
Local mean trip length (miles)	8.9	9.0	1
Long-distance mean trip length (miles)	733	826	13

[1] Persons over 5 years of age.

Notes: Data used for local travel are from the travel-day file and include trips of all lengths made by respondents on a single day. About 95 percent of these trips were 30 miles or less.

Source: U.S. Department of Transportation, Bureau of Transportation Statistics, 1995 American Travel Survey, data; U.S. Department of Commerce, Census Bureau, *National Travel Survey, Travel During 1977* (Washington, DC: 1979); U.S. Department of Commerce, Census Bureau, *Statistical Abstract of the United States 1998* (Washington, DC: 1998); U.S. Department of Transportation, Federal Highway Administration, *Summary of Travel Trends: 1995 Nationwide Personal Transportation Survey* (Washington, DC: 1999).

Table 5-2

Average Household Size: 1970-98

Year	Number of persons
1970	3.14
1980	2.76
1990	2.63
1998	2.62

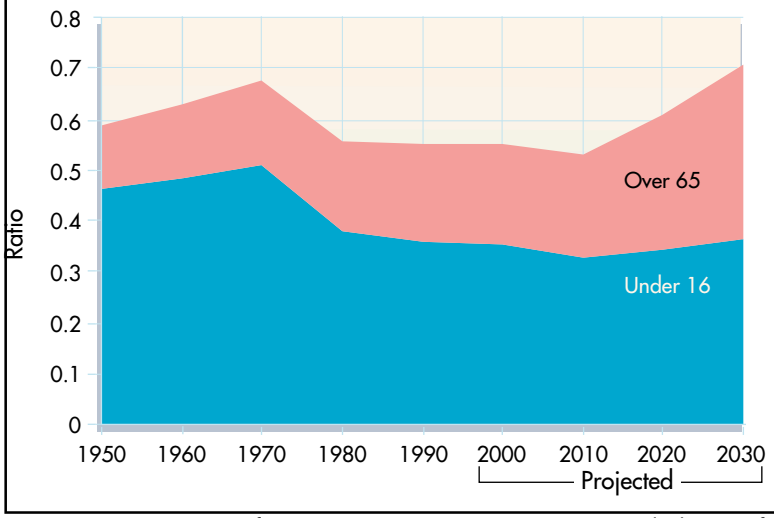
Source: U.S. Department of Commerce, U.S. Census Bureau, *Statistical Abstract of the United States* (Washington, DC: 1998).

the transportation enterprise are immense. Food shopping and other household chores generate substantial travel. The estimated 12 million additional households spawned by today's demographic trends contribute greatly to the increase in both local and long-distance travel.

Further, the smaller size of households reflects lower dependence ratios—the ratio of those not of working-age (under 16 and over 65), to those of working age (figure 5-1). This means that more persons in each household are fundamentally responsible for supporting themselves rather than also supporting spouses, children, or parents. This has been the most important factor responsible for increases in discretionary time and discretionary income, leading to more leisure travel. Figure 5-1 illustrates the dependence ratio in 1970 where the baby

Figure 5-1

Dependence Ratio: 1950-2030



Source: U.S. Department of Commerce, U.S. Census Bureau, *Statistical Abstract of the United States* (Washington, DC: Various years); U.S. Census Bureau, *Projections of the Resident Population by Age, Sex, Race, and Hispanic Origin: 1999 to 2100* (Washington, DC: 2000).

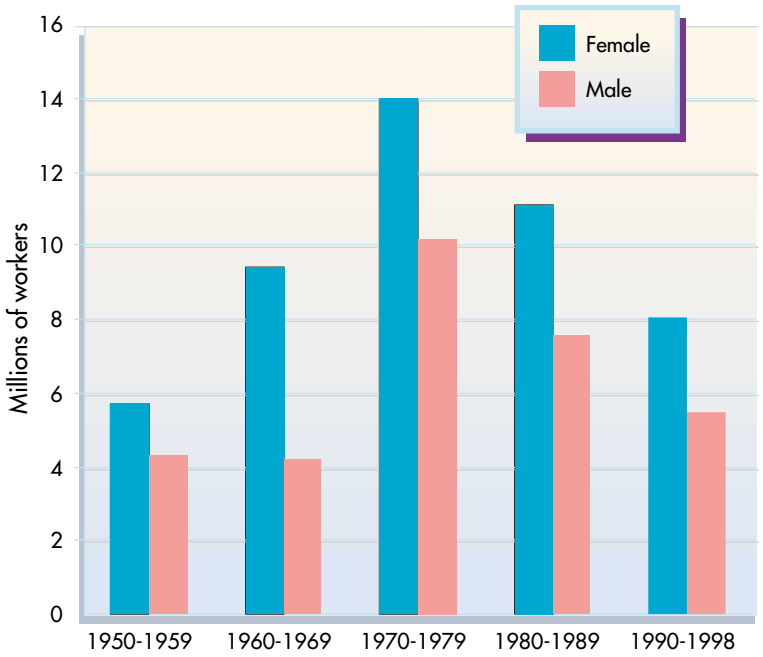
boomers, as children, dominated the dependence structure and in 2010 where they begin to dominate again as the older population.

One of the most impressive trends of the U.S. economy over the past 25 years has been the absorption of an expanding working-age population into the labor market as the baby boom generation moved from childhood into adulthood. Since the 1970s, the economy has been creating jobs at about twice the rate of population growth.

One facet of the trends in this period was the growth in workers that resulted from baby boomers coming of working age from the mid-1960s through the mid-1980s. Another facet was the enormous growth in women joining the labor force during that period (figure 5-2). In the 1980s, we added more people to the labor force than to the total population. In the 1970s and 1980s there was a discernible spike in the growth of the workforce and, therefore, in the number of commuters. From 1990 through 1999, another 13.5 million workers were added to the labor force [USDOL BLS 2000]. The female share of the labor force rose from 29 percent to about 47 percent from 1950 through 1999 [USDOC Census 1978; USDOL BLS 2000].

Figure 5-2

Additions to the Labor Force per Decade: 1950-2000



Source: U.S. Department of Commerce, U.S. Census Bureau, *Statistical Abstract of the United States* (Washington, DC: 1998); U.S. Department of Labor, Bureau of Labor Statistics, *Employment Status of the Civilian Noninstitutional Population 16 Years and Over by Sex, 1967 to Date*, available at http://www.bls.gov/pdf/cpsaat2.pdf, as of Aug. 9, 2000.

Since 1975, traffic volume and transportation characteristics, including trip chaining, have been affected by the labor force trends. Trip chaining is a term used to describe a pattern of travel first evident during the early 1970's energy crisis when households began to incorporate a number of stops for different purposes into one trip to save fuel. Both men and women began to conduct their household chores (i.e., dropping off children and dry cleaning) on the way to and from work and making stops on the way home (i.e., grocery shopping and picking up children).

In 1995, about 33 percent of women made stops on their way to work, compared with 19 percent of men; 61 percent of women made stops on their way home from work, compared with 46 percent of men [McGuckin & Murakami 1999]. While trip chaining represents a time- and fuel-efficient approach to travel, it adds to congestion in peak commuter periods and makes carpooling and transit use difficult.

Another key change in travel from women's increased labor force participation was that by 1990, 70 percent of workers lived in households with two or more workers. Having these dual-worker households has changed the character of local travel. One effect is that many

carpools are now really family activities with two or more household members participating. But more significantly, multiworker households change the nature of the work-home relationship. Both the potential for and impact of living near the workplace are changed when one worker chooses to move. As a result, the other worker or workers in the household may be located further from their work. It also creates the need for joint leisure travel planning, which has changed to more frequent trips of shorter duration. Multiworker households also may choose to be located in larger metropolitan areas where more job opportunities are available.

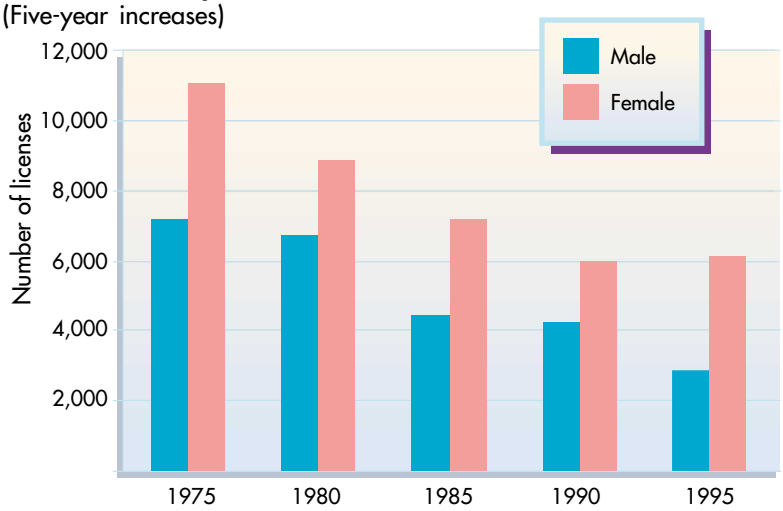
Household Income: One measure of the value that Americans place on mobility is that they spend a relatively large share of their incomes on transportation. Only expenditures on housing exceed those for transportation in the typical household budget [USDOL BLS 1998]. A key factor in recent travel growth is increased household income, which has a substantial impact on both trip frequency and trip length. Study of income and travel behavior relationships supports the observation that transportation is both a necessity and a discretionary good. For many lower income households, transportation spending is a necessity that consumes a significant share of total expenditures. Transportation spending ranges from about $2,500 for the lowest income quintile to nearly $12,500 per year for households with the highest income quintile. About 94 percent of all spending is related to the acquisition, operation, and upkeep of motor vehicles. The remainder goes to air travel, local transit, and miscellaneous purchases and rentals.

Licensing and Vehicle Ownership Patterns: On average, the adult population of the United States has reached saturation levels in drivers licenses. Saturation is a term used to describe the point at which the number of drivers licenses equals or nearly equals the number of people legally eligible to obtain a license. Older age groups—those born before the advent of the auto age—still have low levels of licensing, but these groups are being replaced by high license-holding groups as they age. In the past three decades, the number of people holding licenses increased by more than 70 percent—men by 50 percent and women by nearly 100 percent [USDOT FHWA, Various years]. However, the rate of growth in the number of new licensees has decreased within the same time period (figure 5-3) [USDOT FHWA Annual issues].

Although the number of people holding a license, on average, has greatly increased since 1975, licensing levels remain skewed by racial and ethnic group. For the most part, license saturation has occurred among the white population. Among most minority groups, there still is significant potential for growth, particularly among minority women (table 5-3). The

Figure 5-3

Drivers Licenses by Sex: 1975-95
(Five-year increases)



Source: U.S. Department of Transportation, Federal Highway Administration, *Highway Statistics, Summary to 1995* (Washington, DC: 1997).

Table 5-3

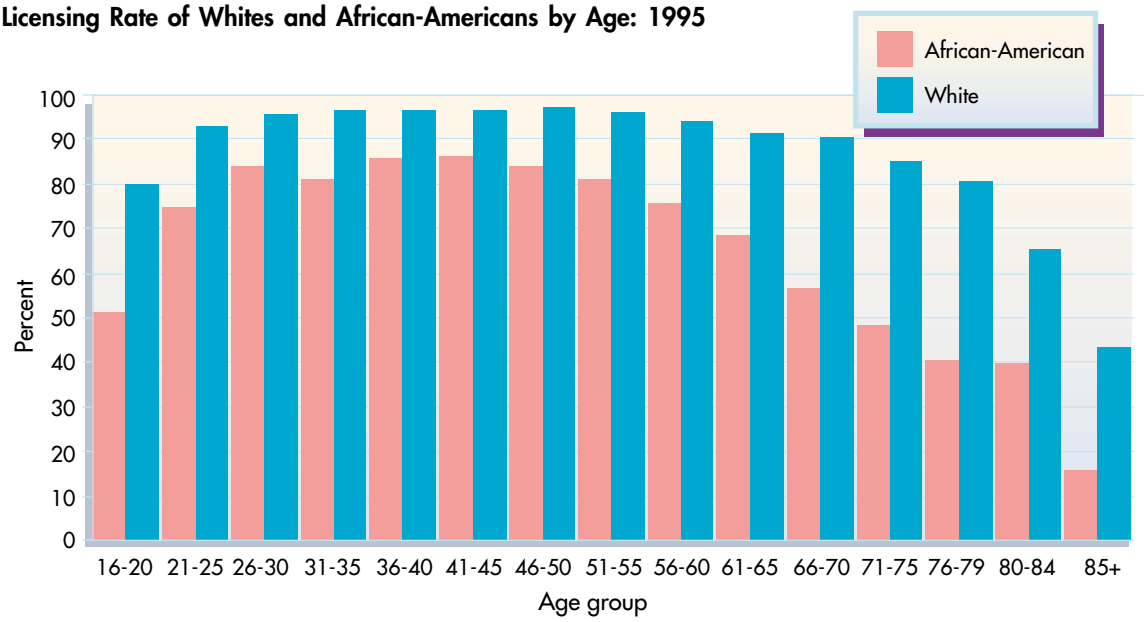
Licensing by Race/Ethnicity: 1995
(Percent)

	Male	Female
White	95	90
African-American	81	69
Asian	93	80
Hispanic	87	74

Source: U.S. Department of Transportation, Federal Highway Administration, 1995 Nationwide Personal Transportation Survey data (Washington, DC: 2000), available at www.cta.ornl.gov/npts, as of October 2000.

Figure 5-4

Licensing Rate of Whites and African-Americans by Age: 1995



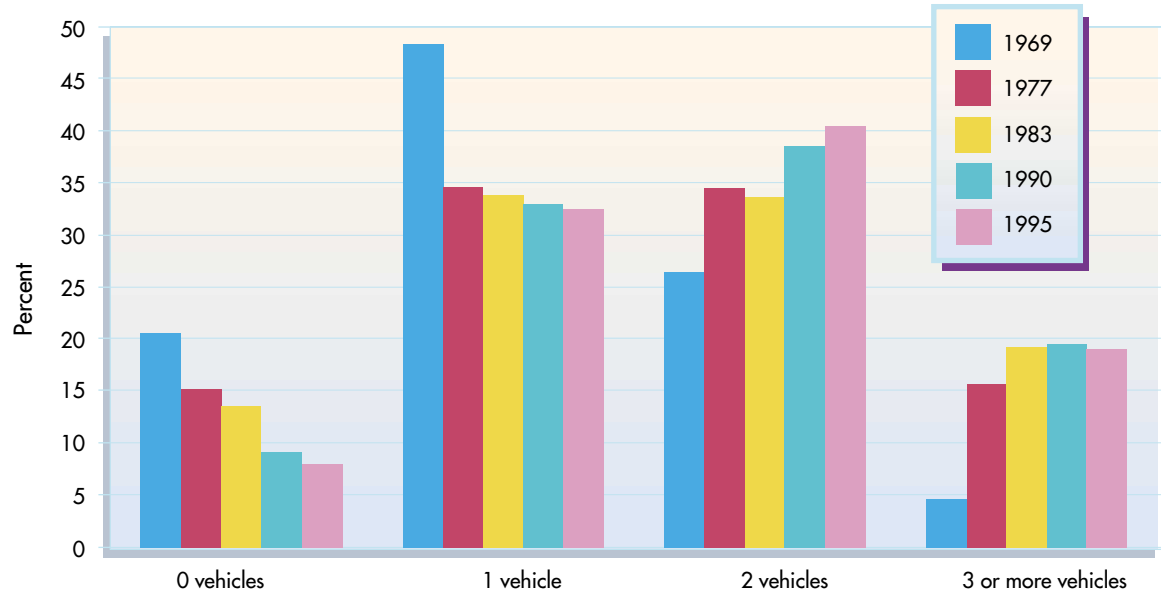
Source: U.S. Department of Transportation, Federal Highway Administration, 1995 Nationwide Personal Transportation Survey data (Washington, DC: 2000), available at www-cta.ornl.gov/npts, as of October 2000.

gap in licensed minorities is most pronounced among those over age 60, but even among young adults, there are significant differences (figure 5-4). The most notable are the youngest groups of African-Americans, among whom only one-half have licenses. Given that a drivers license often is a passport to job opportunities, this has broad significance.

In 1977, the household vehicle fleet of America numbered about 120 million vehicles. But, after a decade in which the nation added more vehicles than people—23 million vehicles and 22 million people between 1980 and 1990—Americas' household vehicle fleet surpassed 175 million vehicles in 1995 as more than 50 million vehicles were added in less than 20 years [USDOT FHWA Various years]. Vehicles per household rose from 1.59 in 1977 to 1.78 in 1995, despite declining household sizes in this period. More significantly, vehicles per household surpassed licensed drivers per household by 1990, essentially producing saturation. In addition, most households have more vehicles per household than workers per household, indicating that almost all American workers have access to a vehicle for work travel. However, while the proportion of households with no vehicle has dropped sharply in the past 25 years, there were still about 8 million American households without vehicles in 1995 (figure 5-5).

Figure 5-5

Household Vehicle Ownership: 1969, 1977, 1983, 1990, and 1995

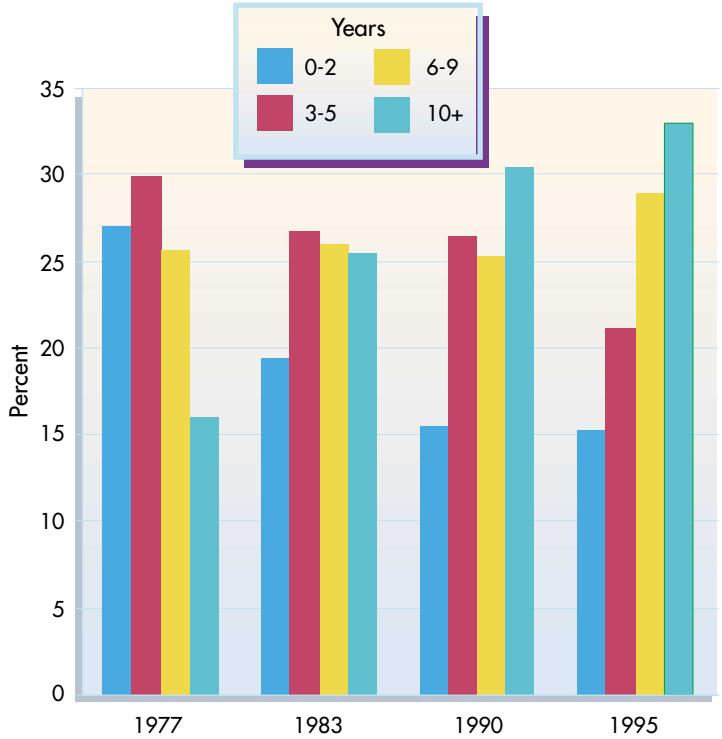


Source: U.S. Department of Transportation, Federal Highway Administration, *Summary of Travel Trends: 1995 Nationwide Personal Transportation Survey* (Washington, DC: 1999).

As a direct result of improvements in vehicle quality and longevity, affordable and effective older vehicles were available to purchasers who may not have been able to afford a vehicle otherwise. In effect, increased vehicle longevity lowered the threshold costs of owning and operating a vehicle. Since the 1970s, the fleet of private vehicles six or more years old has grown substantially (figure 5-6). In 1977, the average age of the private vehicle fleet was 6 years—in 1995, it was 8 years [USDOT FHWA Various Years]. Older vehicles are being used at increasing levels. New vehicles, or those less than three years old, cover about the same distance annually as they did in the past, approximately 16,000 miles per year. But, there have been significant increases in annual miles of travel for vehicles 10 years or older, from roughly 6,800 miles per year in 1977 to 8,800 miles in 1995 [USDOT FHWA Various years].

Figure 5-6

Distribution of the Private Vehicle Fleet by Age of Vehicle: 1977, 1983, 1990, and 1995



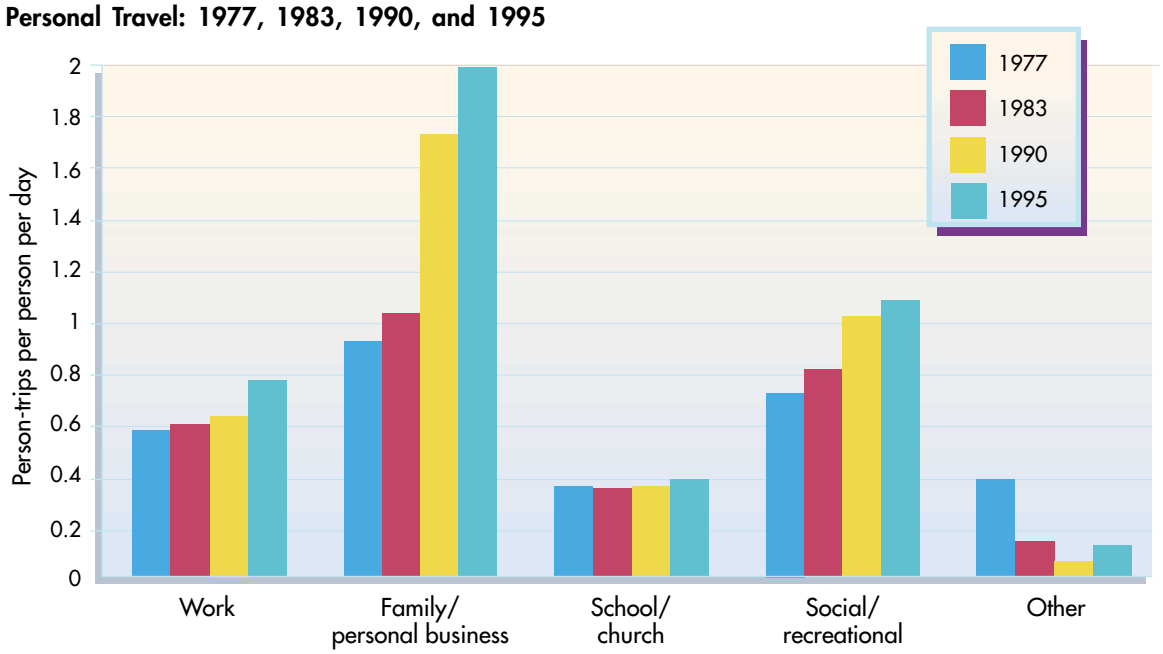
Source: U.S. Department of Transportation, Federal Highway Administration, *Nationwide Personal Transportation Survey* data (Washington, DC: Various years).

The improved longevity of vehicles combined with lower relative costs of owning and operating a vehicle has resulted in their pervasive use for all travel purposes. One of the effects of this increasing availability of vehicles was a marked decline in carpooling for work travel and declining auto occupancy rates for other trip purposes. Average vehicle occupancies for work travel declined from about 1.3 per vehicle in 1977 to about 1.1 by 1995. Occupancies for all purposes dropped from 1.9 to 1.6 in the same period [USDOT FHWA NPTS Various years].

Changing Trip Purposes and Patterns: One important change over the past 25 years has been the purpose of travel. In the early 1970s, work was the major factor influencing travel. However, since then, while commuting has grown rapidly, trips for household chores and personal business have grown even faster (figure 5-7) [USDOT FHWA Various years].

Figure 5-7

Personal Travel: 1977, 1983, 1990, and 1995

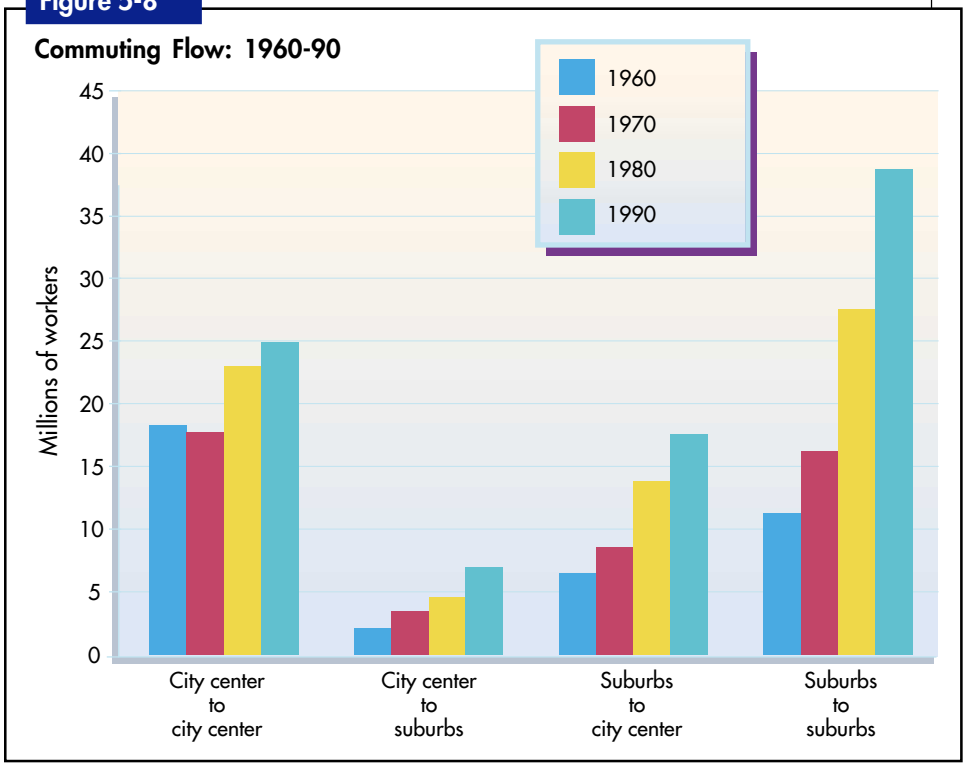


Note: The Nationwide Personal Transportation Survey (NPTS) was first conducted in 1969, and then again in 1977, 1983, 1990, and 1995. Numerous methodological improvements in the NPTS make exact comparisons across time difficult, but travel behavior for these two points in time are adequately reflected in the survey data.
Source: U.S. Department of Transportation, Federal Highway Administration, *Nationwide Personal Transportation Survey* (Washington, DC: Various years).

As households and jobs have shifted to the suburbs, commuting, as well as other trip purposes, have increasingly taken on a circumferential rather than a radial pattern. Contemporary commuting flows are dominated by suburb-to-suburb flows (figure 5-8), which accounted for half of all commuting growth between 1980 and 1990. The dominance of the suburb-to-suburb pattern tends to increase with the size of metropolitan area and has been strongest in areas where population exceeds two million. In contrast, smaller metropolitan areas tend to retain the importance of their center [Pisarski 1996].

Another flow pattern that has increased is "reverse-commuting," as city residents commute outward to suburban jobs. This is a critical commuting concern because of the difficulties in serving the growing transportation needs of this population, particularly those with low income (box 5-1). As metropolitan areas grow closer together, there also has been a small, but rapidly growing, flow pattern from rural areas into suburbs and from suburbs of one metropolitan area into the suburbs of another as edges of metropolitan areas grow closer together. The net result is a complex commuting pattern comprised of many cross-directional flows.

Figure 5-8



Source: A. Pisarski, *Commuting in America II* (Lansdowne, VA: Eno Transportation Foundation, Inc., 1996).

Box 5-1

Access to Jobs

Changes in the nation's welfare system in 1996 have promoted aggressive public- and private-sector actions to provide employment opportunities for welfare recipients. More than 5.6 million Americans left the welfare rolls between August 1996, when President Clinton signed a sweeping welfare overhaul into law, and September 1999. There were 46 percent fewer individuals and 44 percent fewer families on welfare in September 1999 than in August 1996. Welfare rolls dropped in every state during this period, in some cases, by as much as 90 percent [USDHHS 2000].

With these changes, communities are becoming increasingly aware that one of the keys to moving people from welfare to work and helping them keep a job is providing adequate and reliable transportation. Obtaining reliable transportation to and from work, and often to and from childcare facilities, is a challenge that employees and employers struggle to meet. Transportation is the "to" in welfare to work. We have strived to make our transportation system inclusive in service, leaving no one behind.

According to a 1998 survey conducted by Wirthlin Worldwide [Welfare to Work Partnership, 1998], more than half of businesses participating in the Welfare to Work Partnership, a public-private initiative to help workers make the transition, found that employee transportation is a problem. The most common problems reported were deficiencies in public transportation. Thirty-three percent of employers surveyed said that there are no public transportation routes near their businesses, and 18 percent said that public transportation does not operate during the hours necessary to transport workers to and from work.

Many entry-level jobs, especially in the service and retail sectors, require employees to work late hours and weekends. People in these jobs may find that their needs are not met by transit service geared to the standard "9-to-5" workday. Additionally, job growth has increasingly occurred in

(continued on next page)

Box 5-1 *continued*

suburbs, forcing many central-city residents to rely on "reverse commute" transit services and vanpools that go to suburban office parks, shopping malls, and other sites. In rural areas, transit service is a lifeline for millions of residents.

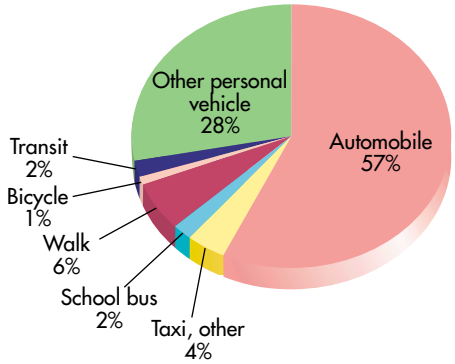
Access to Jobs

One response to the problem has been the federal Job Access and Reverse Commute grant program. A part of the Transportation Equity Act for the 21st Century (TEA-21), the program assists states and localities in developing new or expanded transportation services that connect welfare recipients and other low-income persons to jobs and other employment-related services. Job Access projects are targeted at developing new or expanded transportation services such as shuttles, vanpools, new bus routes, connector services to mass transit, and guaranteed-ride-home programs for welfare recipients and low-income persons. Reverse Commute projects provide transportation services to suburban employment centers from urban, rural, and other suburban locations for all populations.

Changing Modal Choice: Automobiles and other private vehicles are used for most local trips (figure 5-9). This share has increased since 1977. Moreover, when people drive they now are more likely to have fewer passengers with them. For example, car-pooling to work has declined from about 15 percent of commuters in 1977 to 10 percent in 1995. Additionally, average per-vehicle occupancy for work travel declined by 15 percent per vehicle in 1977 to about 1.1 in 1995. Occupancies for all purposes dropped from 16 percent during this same period [USDOT FHWA Various years]. Trends in the annual number of trips taken by each house hold and their choice of transportation are shown in figure 5-10.

Figure 5-9

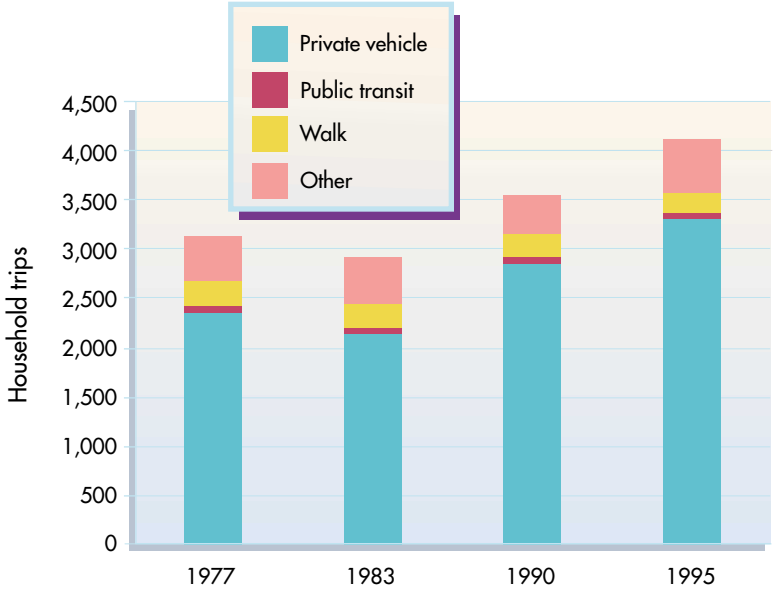
Transportation Choice for Trips Under 50 Miles: 1995



Source: U.S. Department of Transportation, Federal Highway Administration, 1995 Nationwide Personal Transportation Survey data (Washington, DC: 2000), available at www-cta.ornl.gov/npts, as of October 2000.

Figure 5-10

Annual Household Trips by Mode: 1977, 1983, 1990, and 1995



Note: The Nationwide Personal Transportation Survey (NPTS) was first conducted in 1969, and then again in 1977, 1983, 1990, and 1995. Numerous methodological improvements in the NPTS make exact comparisons across time difficult, but travel behavior for these two points in time are adequately (if not perfectly) reflected in the survey data.

Source: U.S. Department of Transportation, Federal Highway Administration, 1995 Nationwide Personal Transportation Survey data (Washington, DC: 2000), available at www-cta.ornl.gov/npts, as of October 2000.

Box 5-2

Access to Transportation for Americans with Disabilities

Many people have disabilities that make it difficult or impossible for them to operate a motor vehicle or to use public transportation without special equipment or assistance. Such disabilities can include problems with walking or other motor functions, hearing or sight impairments, and/or various cognitive and mental difficulties. People who are unable to fully use the transportation system may experience reduced access to opportunities for employment, health care, education, shopping, social and cultural events, and recreation. But our transportation system must be inclusive in service, providing access to opportunities for all Americans.

In 1990, Congress passed the Americans with Disabilities Act (ADA), which protects persons with disabilities from discrimination in employment, provision of public services and accommodations, and transportation. The ADA defines a disability as a physical or mental impairment that substantially limits one or more of an individual's major life activities. The Census Bureau estimates that, at the end of 1994, about 1 in 5 people in the United States, including both adults and children, had some form of disability (54 million), while 1 in 10 had a severe disability (26 million) [McNeil 1997].

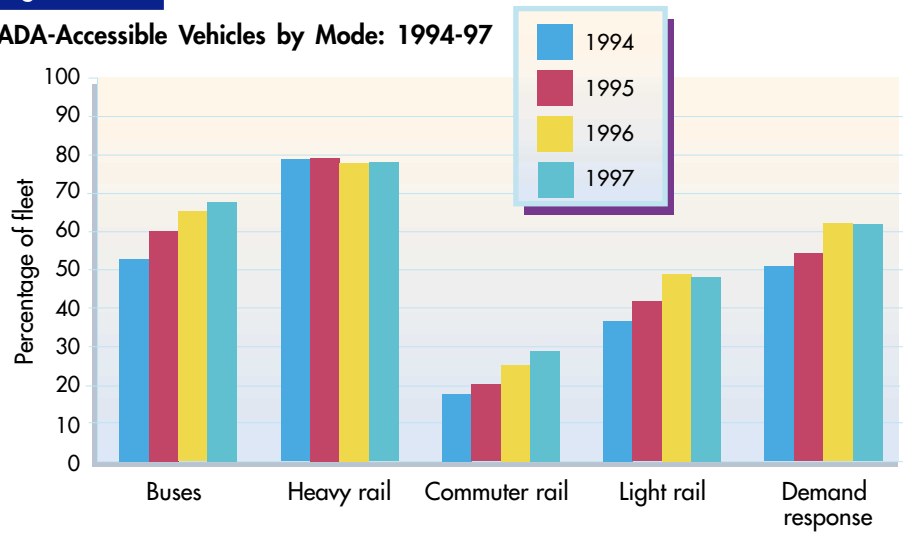
Under the ADA, it is a violation of civil rights law to discriminate against people with disabilities in providing public transportation. When federal funds are involved, accessibility guidelines are also governed by Section 504 of the Rehabilitation Act of 1973. Although the ADA applies nationwide, about 600 public transportation agencies and 700 key railroad stations have been the focal point for most transportation compliance activities. Figure 5-11 shows the general improvement in accessible transit vehicles. Today, 83 percent of transit buses are ADA accessible, an increase of nearly 30 percent since 1994. It is expected that 100 percent of transit buses will be accessible by 2002. (Additional ADA requirements apply to intercity bus lines, Amtrak, and other public and private carriers. A separate law, the Air Carriers Access Act of 1986, makes it illegal for air carriers to discriminate against people with physical or mental impairments.)

One of the main effects of the ADA is that paratransit (e.g., alternative transportation arrangements for the disabled) is no longer to be used as a substitute for fixed-route service. Under the ADA, fixed-route service must be made available to the disabled; paratransit is to be provided only when fixed-route transit does not meet a customer's needs or is inappropriate to the situation. Moreover, paratransit eligibility is no longer based on a person's disability, but on whether or not the person has the ability to use the fixed-route system.

In 1998, the U.S. Department of Transportation (USDOT) amended its ADA regulations to require accessibility for new over-the-road buses (OTRBs). The new rule applies both to intercity and other fixed-route bus operators and to charter- and tour-bus operators. The rules require operators to ensure that passengers with disabilities can use OTRBs.

Figure 5-11

ADA-Accessible Vehicles by Mode: 1994-97



Source: U.S. Department of Transportation, Federal Transit Administration, *Federal Transit Summaries and Trends* (Washington, DC: 1998), p.25.

Long-Distance Travel: Initiated for a variety of purposes, long-distance travel—both intercity and international—has increased dramatically in the past 25 years. Long-distance travel has become more international in reach, linking us to destinations around the world. Long-distance travel trips—over 100 miles one-way from home—include more frequent, shorter duration trips and more travel around weekends than did long-distance travel trips of two decades ago. In addition, as female labor-force participation rates have increased, women are traveling more.

On average, each American makes about 4 long-distance trips per year averaging about 830 miles each, up from the 1977 average of about 2.4 trips per year. In 1995, Americans generated about a billion long-distance roundtrips per year within the United States (table 5-1). Long-distance travel accounts for only a small fraction of trips, but nearly 25 percent of total national travel in terms of miles traveled. The transportation system also is used by approximately 50 million foreign visitors who come to the United States by air each year, and millions more who arrive by land and sea [USDOT BTS 1999].

"Transportation is only a means to an end: getting people, products, and information where they need to go. We need to encourage forms of transportation that fulfill this mission without harming the environment, including public transit, carpooling, bicycles, walking, and telecommuting."

Mortimer Downey
Deputy Secretary of Transportation
Fifth Conference on U.S.–Japan Cooperation In Transportation
June 2, 1998, Washington, D.C.

Some of the same factors that have spurred local travel have also led to an increase in long-distance travel over the past 25 years, including population and household growth, higher median income, and greater vehicle availability. Other factors, such as increasing regional interdependencies (including globalization) of economic production and consumption, and lower airfares (adjusted for inflation), have also caused this growth. The critical attributes of long-distance trips are purpose of the trip and length of the trip. These two factors determine the trip's time and cost sensitivities, and, thereby, affect the mode of transportation chosen. Traveler characteristics are also important, partly because of the substantial variation in long-distance trips. Characteristics of significance include gender, age, income, race and ethnicity, and family composition.

Long-distance travel can have multiple purposes, such as a work trip that includes a vacation and even a visit to local friends and relatives. The broad-purpose categories used in the American Travel Survey are business, which accounts for about 23 percent of domestic long-distance travel; pleasure travel, accounting for about 63 percent of the trips; and personal business trips, with about 15 percent of the trips [USDOT BTS 1997a].

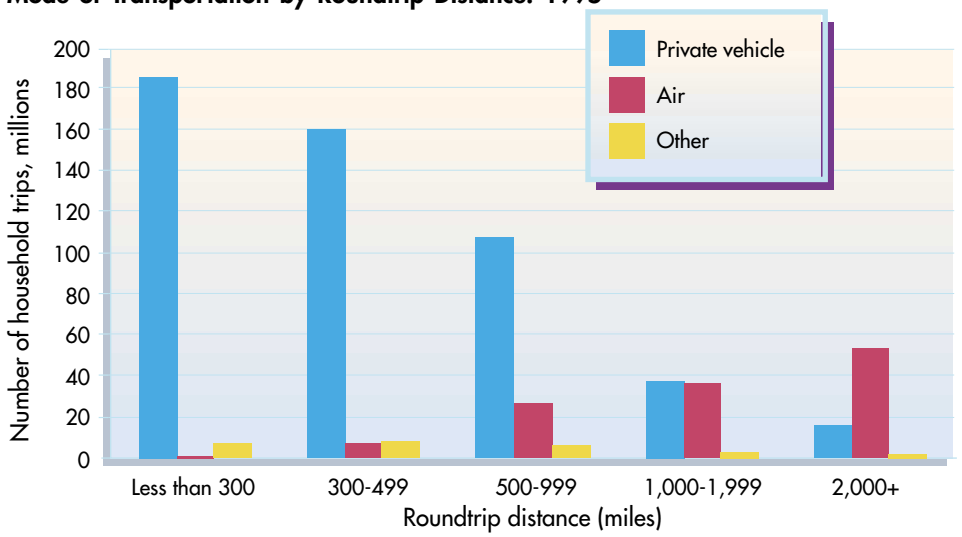
Modal choice is greatly influenced by the distance of the trip (figure 5-12). For roundtrips up to 1,000 miles, the automobile dominates; thereafter, air travel gains an increasing share. The other modes—scheduled intercity bus, charter bus, and Amtrak passenger rail service—have short- to intermediate-distance roles, but their combined share of all trips is less than 5 percent.

Travel by personal vehicle accounts for more than 80 percent of all domestic trips, but only about 55 percent of miles; air travel accounts for only 16 percent of all trips, but 43 percent of miles traveled. Intercity bus travel, including charter trips, is 2 percent of all trips and 1.6 percent of the miles. Amtrak's share is about one-half of one percent for both number of trips and miles traveled. Ships have a negligible share [USDOT BTS 1997a].

Intercity transportation modes serve very different trip purposes (figure 5-13). For example, business travel is a major factor in air travel services, but less so in other modes. The "visit friends and relatives market" is critical to the scheduled bus industry, and leisure travel is critical to the charter bus market. The personal-use vehicle has significant roles in all travel purposes.

Figure 5-12

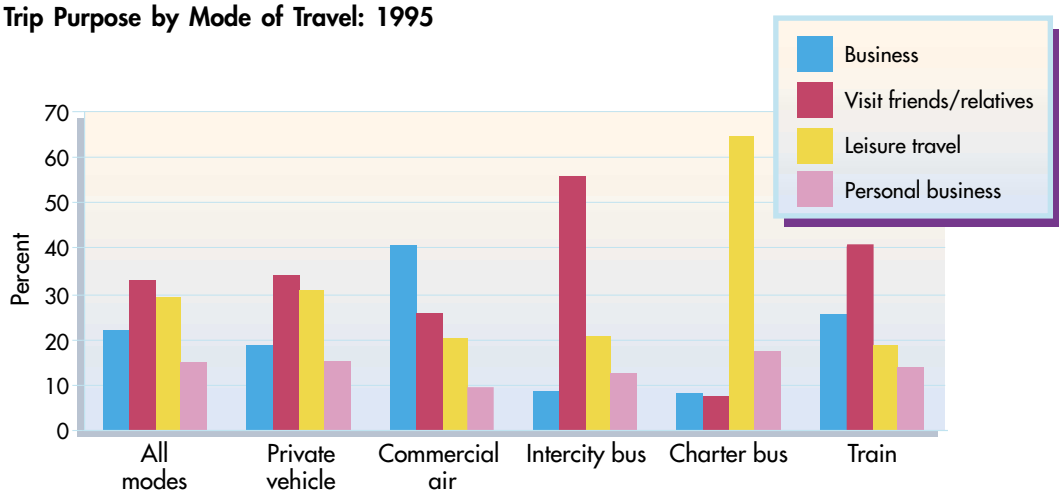
Mode of Transportation by Roundtrip Distance: 1995



Source: U.S. Department of Transportation, Bureau of Transportation Statistics, 1995 *American Travel Survey: U.S. Profile* (Washington, DC: 1997).

Figure 5-13

Trip Purpose by Mode of Travel: 1995



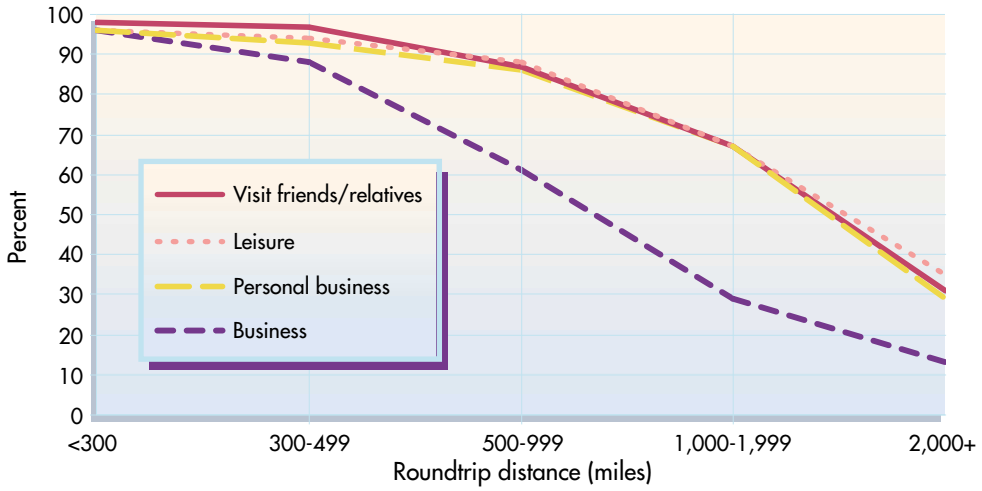
Source: U.S. Department of Transportation, Bureau of Transportation Statistics, *1995 American Travel Survey: U.S. Profile* (Washington, DC: 1997).

In travel for all purposes, the use of the private vehicle declines as the distance of the trip increases. However, it declines much more quickly and sharply in business travel (figure 5-14). This is undoubtedly due to the time sensitivities of business travel.

There is substantial variation in trip making among men and women. Although there has been substantial growth in women's long-distance travel in some areas, their travel still lags behind men's. Both men and women have increased their long-distance trip making rates by about 60 percent over 1977 rates. But overall, women make only 80 percent as many long-distance trips as men, unchanged from 1977 (figure 5-15). This is most notable in two areas: women still make only 40 percent as many long-distance business trips as men; and they make only about 85 percent as many long-distance leisure trips as men, primarily because women take fewer outdoor recreational trips for activities such as camping and fishing. Women do, however, make more trips to visit friends and relatives [USDOC 1979; USDOT BTS 1997b].

Figure 5-14

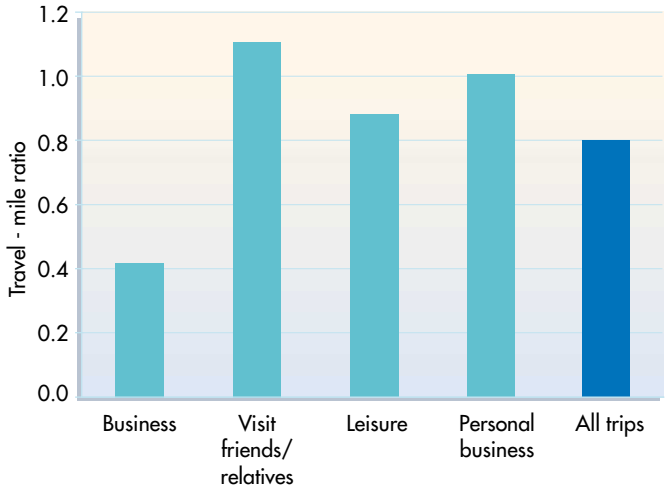
Vehicle Use by Distance and Trip Purpose: 1995



Source: U.S. Department of Transportation, Bureau of Transportation Statistics, 1995 American Travel Survey data (Washington, DC: 2000), available at http://www.bts.gov/ats, as of October 2000.

Figure 5-15

Female-to-Male Ratios of Long-Distance Travel-Miles by Purpose: 1995



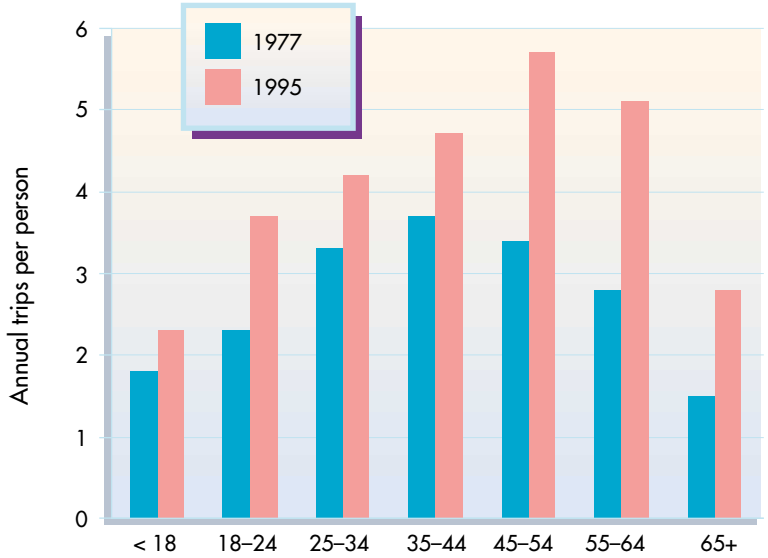
Source: U.S. Department of Transportation, Bureau of Transportation Statistics, 1995 American Travel Survey data (Washington, DC: 2000), available at http://www.bts.gov/ats, as of October 2000.

Age is, and will continue to be, a significant factor in long-distance travel. But the age distribution of travelers has shifted significantly since 1977 (figure 5-16). The peak travel age has shifted from the 35-to-44 age group in 1977 to the 45-to-54 age group (the age group into which the baby boomers are moving) in 1995. Those above age 55 also had a noticeable increase in travel, compared to 1977 figures [USDOC 1979; USDOT BTS 1997b].

Travel by African-Americans increased more than for whites and Hispanics between 1977 and 1995. African-Americans made about 80 percent more long-distance trips in 1995 than in 1977, compared with about a 60 percent increase for both whites and Hispanics (figure 5-17). But travel activity for whites is still double that of Hispanics and African-Americans [USDOC 1979; USDOT BTS 1997b].

Figure 5-16

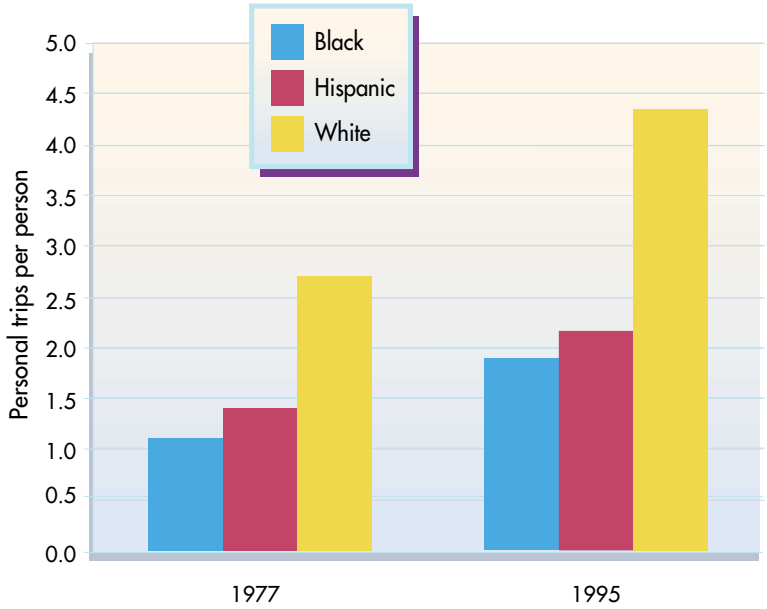
Long-Distance Trip Making Rates by Age Group: 1977 and 1995



Source: U.S. Department of Transportation, Bureau of Transportation Statistics, 1995 American Travel Survey data (Washington, DC: 2000), available at http://www.bts.gov/ats, as of October 2000.

Figure 5-17

Annual Long-Distance Trip Rates: 1977 and 1995



Source: U.S. Department of Transportation, Bureau of Transportation Statistics, 1995 American Travel Survey data (Washington, DC: 2000), available at http://www.bts.gov/ats, as of October 2000.

Income also has a major impact on the propensity to travel long distances. Those with incomes greater than $50,000 per year in 1995 made 5.6 long-distance trips per year, compared with 2.2 long-distance trips per year for those earning under $25,000 and 3.8 long-distance trips for those in the middle income group [USDOT BTS 1997b]. Most of the growth in long-distance travel between 1977 and 1995 occurred in higher income groups [USDOC 1979; USDOT BTS 1997b].

Keys to the Future

The future of passenger transportation over the next 25 years will depend on a wide range of factors: demographics, immigration, social equity, affluence, and urban decentralization.

The changing age profile in America will facilitate growth in both local and intercity passenger travel in the near term, but reduce growth over the long term (figure 5-18). As the baby boom generation passes through the ages when people travel most (in their 40s and 50s), passenger travel will increase. However, beginning in 2011, the eldest of this group reaches the traditional retirement age of 65. After retirement, personal travel tends to remain the same, while work travel is reduced substantially. As people become increasingly physically and mentally frail in their 70s and 80s, all travel declines.

Counteracting the aging population will be the number of new immigrants entering the country. Future population growth will result largely from immigration. Because most immigrants are adults, they have an immediate impact on the transportation system. These individuals tend to use the transit system more than other sectors of the population because of lower income and because they tend to locate in urban areas. Transit use tends to decline the longer an immigrant is in the country, and subsequent generations tend to adopt the same transit profile as the rest of the population.

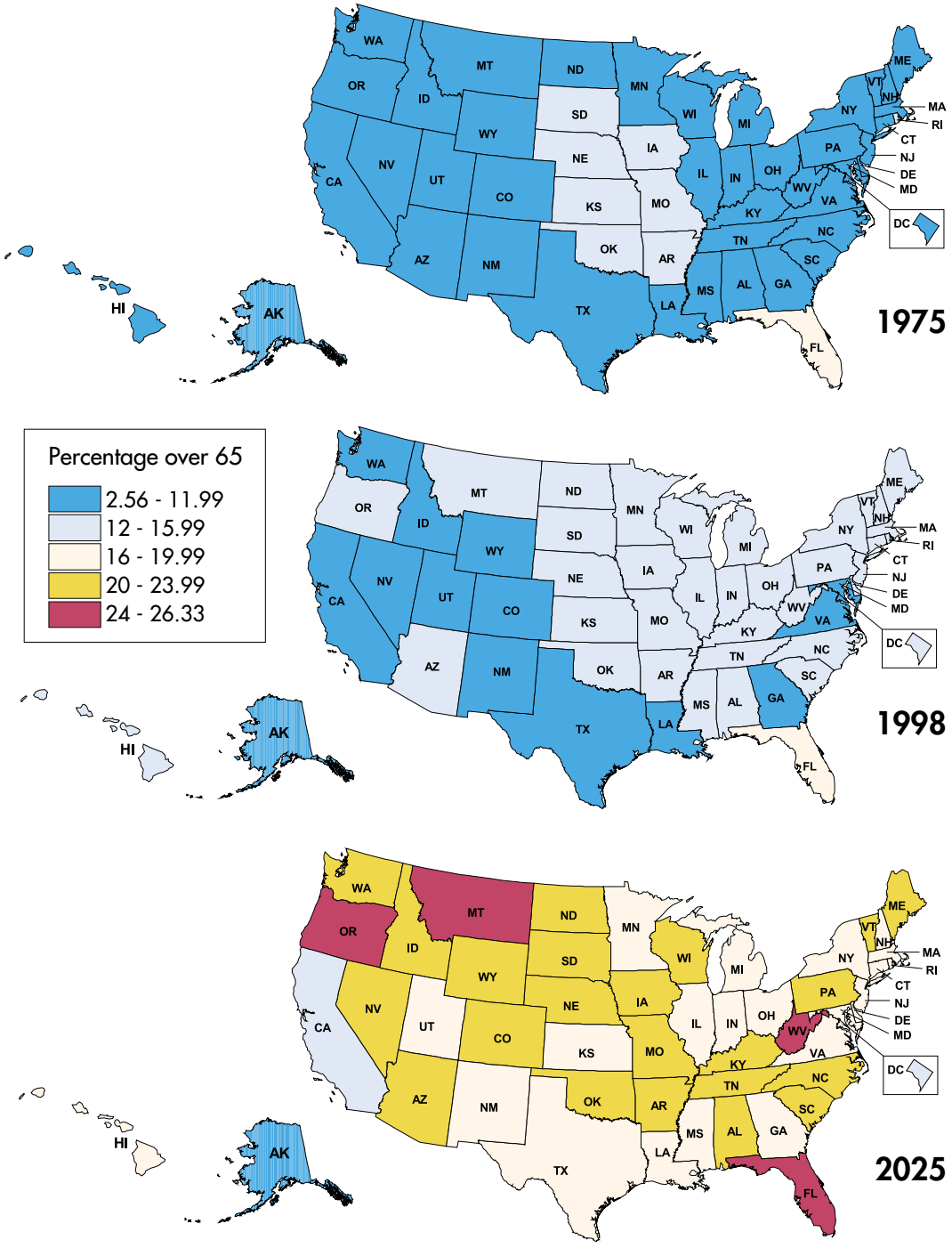
Another possible source of travel growth is social equity, particularly growth in vehicle ownership and, therefore, vehicle travel among racial and ethnic minorities. About 95 percent of white households have at least one vehicle, compared with about 88 percent of Hispanic households and about 75 percent of African-American households. Increases in vehicle use among these groups will be a function of vehicle cost, income, and geographic location.

Cyclical and long-term changes in economic activity have a strong impact on the level of local and long-distance travel. Income growth generally increases the propensity to make more frequent and longer trips. But increased affluence also tends to increase the value people place on time, generally pushing them to faster means of transportation, such as the single-occupant vehicle and (on longer trips) aircraft. The interaction of an aging population, smaller households, and time pressures may, in some places, influence people to live in smaller, higher density neighborhoods that have more potential for transit use and walking.

On the whole, the dominant trend will still be urban decentralization, spurred by technology that allows people to set up home-based businesses in order to work at home, or to have multiple places of work—which will include private vehicles. Technology also will increasingly allow employers to locate facilities near skilled employees and in places with spare road and airport capacity. Increases in the share of workers who telecommute part or full-time imply that the location and type of transportation necessary to support a given level of economic activity will change. Increasing use of the Internet for the purchase of goods and services will affect the nature and location of shopping travel, with increased freight deliveries to residences.

Figure 5-18

Estimated Percentage of Total State Population Over the Age of 65: 1975, 1998, and 2025



Sources: U.S. Department of Commerce, Census Bureau, *Statistical Abstract of the United States* (Washington, DC: 1999).

The USDOT's mobility goals are directed toward improving the physical condition of the infrastructure, reducing transportation time from origin to destination, increasing accessibility, reducing costs, and increasing reliability. To achieve these goals, the USDOT will address the efficient use of transportation resources; anticipate the needs of low-income, minority, and older Americans; address transportation needs in key geographic areas; ensure mobility in response to emergencies and disruptions; address feedback from customers; and improve information collection.

All mobility outcomes present complex measurement issues. Accordingly, the USDOT will:

- develop a means of measuring user transportation cost, time, and reliability with time-series data;
- develop better approaches for measuring access;
- develop a straightforward measure of congestion and its costs;
- produce more timely and comprehensive data on the condition and use of the transportation system; and
- develop a more complete understanding of variables influencing travel behavior.

Energy

Transportation cannot occur without energy, which is a major concern for the transportation industry because of the environmental consequences of using energy and because the world's resources of petroleum, on which most modern transportation systems rely, are limited. This section focuses on the nature of transportation energy use, the industry's dependence on petroleum and the consequences thereof, and the sustainability of energy supplies for future transportation needs.

Transportation is a major energy-using sector of the U.S. economy. Transportation used 26 quadrillion Btu (British thermal unit) (quads) of energy in 1999, 27 percent of the 97 quads used by the entire U.S. economy [USDOE EIA 1999a]. This approximate energy use by transportation has not varied by more than three or four percentage points since 1950. Total transportation energy use, however, has nearly tripled since 1950 (figure 5-19). From 1950 until the first oil price shock in 1973, transportation energy use increased steadily, at an average annual rate of 3.5 percent. Since then, the average rate of growth has slowed to 1.2 percent, partly due to improved energy efficiency [USDOE EIA 1999a].

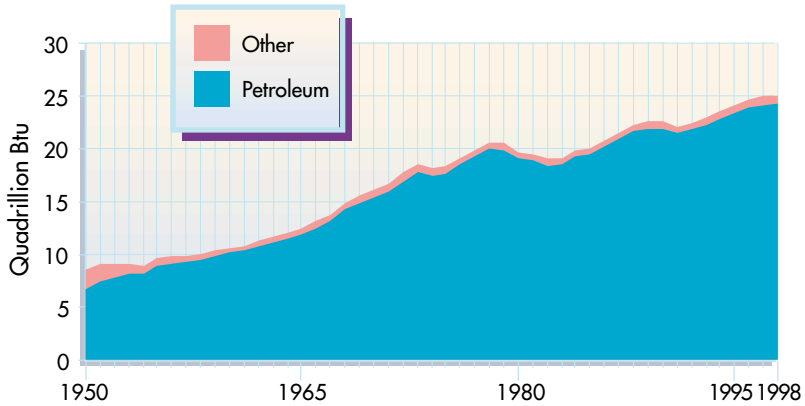
Petroleum supplies more than 95 percent of the energy used in transportation and has done so for the past 40 years (figure 5-19). The largest nonpetroleum energy uses in transportation are natural gas and electricity for pipelines and natural gas-derived liquids blended with gasoline. While other sectors of the economy reduced their petroleum dependence after the oil supply upheavals of the 1970s and 1980s, transportation has remained nearly totally dependent on petroleum, despite significant efforts to promote alternative fuels. The Alternative Motor Fuels Act of 1988 and the Energy Policy Act of 1992 provide a combination of tax incentives, fuel economy credits, and fleet mandates that have helped increase the numbers of alternative-fuel vehicles on U.S. roads from an estimated 251,000 in 1992 to 430,000 in 2000 [USDOE EIA 1999b]. Over the same period, use of alternative fuels grew by 49 percent, to 341 million gallons in 1999. Still, this number is slight, less than 1 percent, compared with the 155 billion gallons of fuel consumed by 215 million motor vehicles on U.S. highways in 1998 [USDOT FWWA 1999a]. As a result of its continuing dependence on petroleum,

transportation's share of U.S. petroleum use has risen from 51 percent in 1973 to 66 percent in 1998 [Davis 1999]. Moreover, the transportation sector demands a disproportionate share of the lighter, higher value petroleum products that drive the market.

Within transportation, the highway mode dominates energy use, with an 82 percent share in 1997 (figure 5-20). Energy use by aircraft, the fastest growing component of transportation energy use, comes next with an 8 percent share [USDOT BTS 1999].

Figure 5-19

U.S. Transportation Energy Use: 1950-98 (Annual totals)



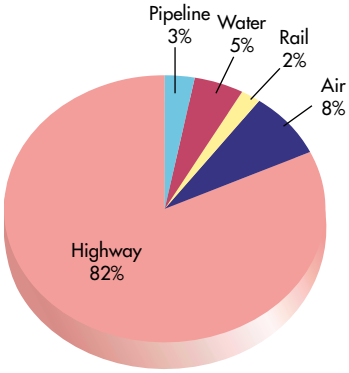
Source: U.S. Department of Energy, Energy Information Administration, *Annual Energy Review 1999* (Washington, DC: 2000).

Water transport accounts for five percent of transportation energy use, one percent of which is attributable to recreational boating. Pipelines require four percent of transportation energy, but nearly four-fifths of that is natural gas used by natural gas pipeline pumps. The remainder is electricity used by crude oil and petroleum product pipeline pumps, but their 0.2 quads of electricity consumption makes them the largest electricity-using mode. Finally, rail accounts for 2 percent, of which more than 85 percent is for freight movement [Davis 1999].

Energy-Efficiency Trends: The energy market upheavals from 1973 to 1985 greatly slowed the growth of transportation energy use in the highway, air, and pipeline modes (table 5-4). As a consequence of the oil embargo of 1973 to 1974 and related events, oil prices more than doubled from $11.76 per barrel in 1973 to $23.56 in 1974. Oil supply shortages associated with the Iran-Iraq War and subsequent OPEC supply restrictions caused oil prices to jump again, from $24.48 in 1978 to $53.39 in 1981 (in 1992 dollars). Both oil-price shocks slowed the growth of transportation activity and led to major energy-efficiency improvements across all modes.

Figure 5-20

Transportation Energy Use by Mode: 1997



Source: U.S. Department of Transportation, Bureau of Transportation Statistics, *National Transportation Statistics 1999*, BTS99-04 (Washington, DC: 1999), pp. 289-90.

Table 5-4

Transportation Energy Use by Mode: 1960-97
(Trillions of Btu)

	1960	1970	1980	1990	1997
Air	293	1,155	1,394	1,811	1,965
		14.7%	1.9%	2.6%	0.7%
Rail	480	492	551	445	507
		0.2%	1.2%	−2.1%	1.9%
Water	701	753	1,677	1,396	1,230
		0.7%	**	−1.8%	− 0.9%
Pipeline*	358	745	654	680	775
		7.6%	−1.3%	0.4%	1.3%
Transit	55	70	111	117	122
		−1.3%	2.4%	4.8%	0.9%
Highway	5,261	11,707	14,657	16,692	19,215
		8.3%	2.3%	1.3%	2.0%

**Pipelines include natural gas only. Crude oil pipeline energy use not shown here.*
***The source of water data changed between 1980 and 1990, making these estimates non comparable.*

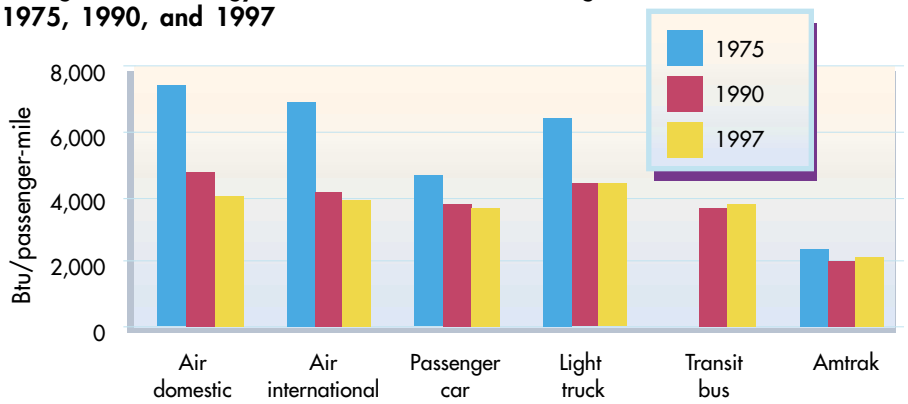
Source: U.S. Department of Transportation, Bureau of Transportation Statistics, *National Transportation Statistics 1999,* BTS99-04 (Washington, DC: 1999), pp. 291-292.

Most transportation modes responded to higher fuel prices and the conservation policies they spawned by reducing the amount of energy required to carry a passenger or a ton of freight (called energy intensity). From 1975 to 1997, the energy required for a passenger-mile of travel by car fell more than 20 percent, from 4,700 to 3,700 Btu [USDOT BTS 1999]. During the same period, the energy needed to transport a passenger one mile by commercial aircraft domestically decreased by more than 40 percent, from 7,500 to 4,100 Btu [USDOT BTS 1999]. The energy intensity of Amtrak intercity rail travel also declined, from 2,380 Btu per passenger-mile in 1975 to 2,070 in 1990 [USDOT BTS 1999]. Energy intensities of urban bus transit actually increased. The somewhat remarkable result was a convergence in the energy intensity of travel by most modes (figure 5-21). Intermodal comparisons are generally misleading, however, because the modes perform different functions and serve different travel markets. Since 1990, improvements in energy efficiencies have generally slowed or stopped, due to falling energy prices and constant fuel economy standards.

Less is known about the energy intensiveness of freight transport. Rail freight energy use per ton-mile has been declining consistently over the past 30 years, from roughly 840 Btu per ton-mile in 1960 to about 370 Btu per ton-mile today [USDOT BTS 1999]. The data for domestic waterborne commerce are more volatile for reasons that are not well understood, and it is difficult to draw conclusions from them. Reliable data on heavy truck ton-miles do not exist, but it is clear that energy use per vehicle-mile has decreased, albeit more slowly than for other modes. Between 1970 and 1997, energy use per tractor-trailer truck-mile decreased at an average annual rate of 0.8 percent [USDOT BTS 1999; USDOT FHWA 1999a]. This, combined with a general increase in truck size and weight limits, suggests that truck energy use per ton-mile has probably also decreased.

Figure 5-21

Changes in the Energy Intensiveness of U.S. Passenger Travel: 1975, 1990, and 1997



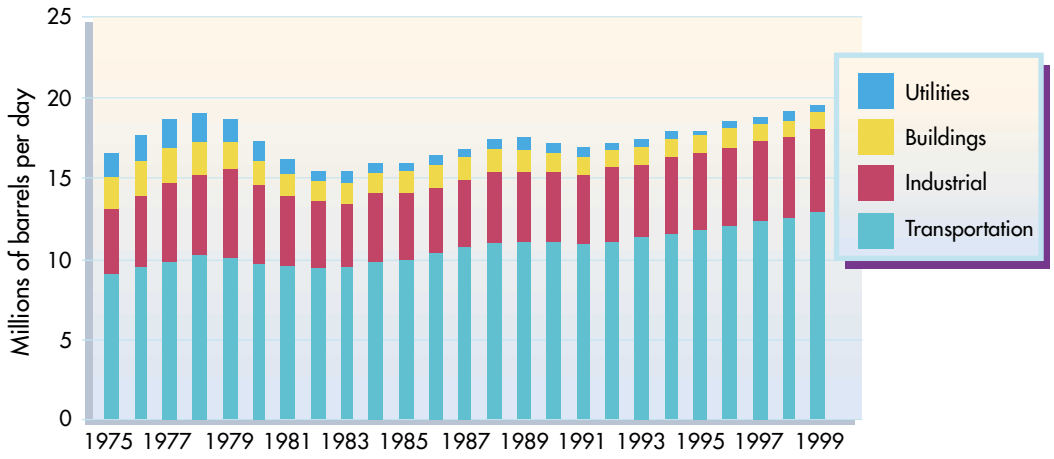
Note: 1975 Passenger bus data are not available.
Source: U.S. Department of Transportation, Bureau of Transportation Statistics, *National Transportation Statistics 1999*, BTS99-04 (Washington, DC: 1999), p. 309.

Oil Dependence: The U.S. economy's dependence on petroleum is driven principally by the transportation sector's dependence on it. The risks of oil dependence was a major theme of the 1977 *National Transportation Trends and Choices* report [USDOT 1977]. Not only is transportation nearly totally dependent on petroleum as an energy source, but it also is the largest and fastest growing consumer of petroleum products. According to the Department of Energy, transportation derives 97 percent of its energy from petroleum (figure 5-19), although this includes a small percentage of nonpetroleum gasoline blending stocks such as ethanol [USDOE EIA 1999a].

Transportation consumes 66 percent of the petroleum products supplied to the U.S. economy, up from 55 percent in 1975. As a result of the oil price shocks of the 1970s and 1980s and the deregulation of U.S. natural gas markets, oil use in residential and commercial buildings and by utilities to generate electricity has fallen to about half of its 1975 level (figure 5-22). Industrial use of petroleum is up by 26 percent over 1975 consumption, but transportation oil use is up 93 percent over the same period [USDOE EIA 1999a].

Figure 5-22

Petroleum Use in the U.S. Economy: 1975-99 (Annual totals)



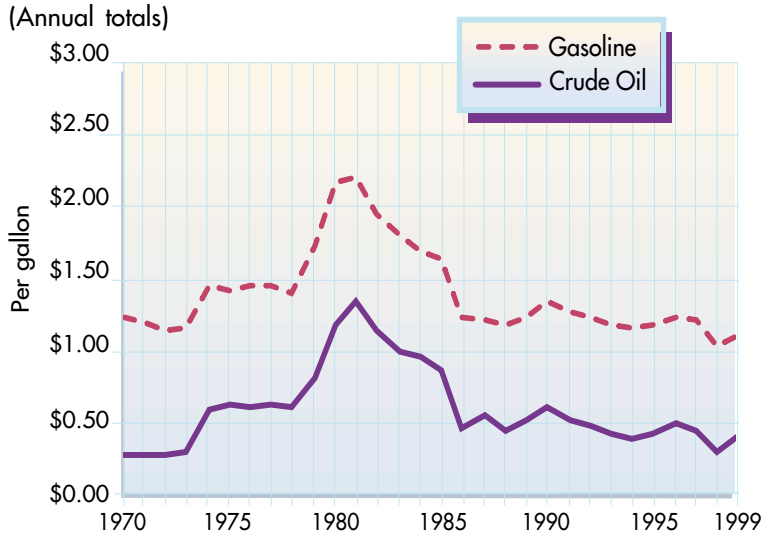
Source: U.S. Department of Energy, Energy Information Administration, *Annual Energy Review 1999*, table 5.12, available at www.eia.doe.gov/emeu/aer/petrol.html, as of June 23, 2000.

The continuing growth of petroleum use by transportation, combined with declining domestic oil production, has resulted in increasing U.S. dependence on imported petroleum. In 1998, for the first time in U.S. history, net imports exceeded 50 percent of U.S. petroleum supply [USDOE EIA 2000]. In 1973, the year of the first OPEC-driven oil price shock, net imports to the United States totaled 6 million barrels of oil per day (mmbd), while the United States produced 11 mmbd. In 1999, domestic production was down to 7.8 mmbd, while net imports were 9.6 mmbd [USDOE EIA 2000]. Still, today there is much less public concern over the issue of petroleum imports than there was at the time of the 1977 *Trends and Choices* report.

More than a decade of lower oil prices, as low as $10 a barrel (bbl) during the winter of 1998-1999, and abundant supplies during most of the 1990s may explain the apparent lack of concern by U.S. citizens (figure 5-23). The realization that oil prices are unlikely to rise forever, that what went up could also come down, and a strong economy also helps explain our relative complacency in the face of the highest levels of oil imports on record, even in the face of recent gasoline price increases. But, higher prices for petroleum products in 2000 have raised the issue of oil dependency in the public consciousness, once again.

Figure 5-23

Crude Oil and Gasoline Prices: 1970-99 (Chained 1996 U.S. dollars)
(Annual totals)



Note: Gasoline prices are for regular leaded (1970-75) and for regular unleaded (1976-99).
Source: U.S. Department of Energy, Energy Information Administration, available at http://www.eia.doe.gov/emeu/aer/petro.html, tables 5.19 and 5.22, as of June 23, 2000.

The costs of past oil dependence were real and substantial, and the doubling of world oil prices between January 1999 and January 2000 as a result of production cutbacks by Organization of Petroleum Exporting Countries (OPEC), with the cooperation of Mexico, Norway, and Russia, suggest that oil dependence may reemerge as a serious concern for transportation and the economy in the not-too-distant future. Estimates of the economic costs of past oil price shocks and the anticompetitive influence of OPEC on world oil markets are numbered in the trillions of dollars, and prospective analyses indicate that a single future shock could cost hundreds of billions of dollars [Greene, Jones, & Leiby 1998]. When oil prices are suddenly increased by the exercise of market power, oil consumers suffer three kinds of economic costs [Greene 1997]. First, an energy price increase, whether due to geologic scarcity or cartel-created scarcity, signals to the economy that less can be produced with the same amount of capital, labor, and materials. The increased economic scarcity of a basic resource reduces the Gross Domestic Product (GDP) the economy is able to produce when all resources are fully employed. Second, when prices increase suddenly, the economy is unable to respond immediately to the changed price regime. As a result, there is less than full employment of productive resources and a further, temporary loss of GDP. The size of these economic losses will depend on the importance of oil in the economy and its ability to substitute other energy sources for oil. The transportation sector has so far shown little capacity to replace oil with alternative energy sources.

Finally, a cost to the U.S. economy (but not to the world economy) is the transfer of wealth from oil consumers to oil producers, which is caused by the noncompetitive price increase. The

loss to the U.S. economy is equal to the price increase times the amount of oil imported. For example, the recent OPEC-orchestrated price increase from approximately $10/bbl in the winter of 1998/1999 to $25/bbl in the fall of 1999 increased U.S. wealth transfer by approximately $15/bbl. With imports exceeding 9.5 mmbd, the daily loss of wealth amounted to $142 million or over $50 billion on an annual basis. For comparison, total expenditures on the nation's highways by all levels of government are approximately $100 billion per year [USDOT FHWA].

There are military, strategic, and geopolitical costs of oil dependence as well. Though these components are less readily measured, their importance should not be underestimated. In addition, inappropriate responses to oil price shocks can increase their cost. For example, tightening money supply to curb the inflation caused by an oil price increase, rather than accommodating it, can unnecessarily slow economic growth.

Global Trends: Around the world, the rates of growth of motorized transport and its energy use exceed those in the United States. From 1973 to 1996, world transportation energy use (of which petroleum comprises 96 percent) increased by 66 percent, from 950 million metric tons (Mtoe) to 1,580 Mtoe [IEA 1999]. Over the same period, U.S. transportation energy use grew by only 32 percent. Petroleum's share of world transportation energy use also increased slightly, from 94.7 percent to 96.0 percent. Globally, road transport accounts for more than 70 percent of transportation energy use, and light duty vehicles are responsible for about 50 percent, very similar to the U.S. statistics [IEA 1999].

The growth of world transportation energy use and its petroleum dependence is driven by the long-term trend of increasing motorization of the world's transportation system and the ever-growing demand for mobility. Just after World War II, the world's motor vehicle fleet numbered 46 million vehicles, of which 75 percent were in the United States. In 1996, there were 671 million motor vehicles in the world, and the U.S. share was only 30 percent. Whereas the U.S. motor vehicle population has been growing at 2.5 percent per year since 1970, the rest of the world's stock has been growing at nearly twice that rate to 4.8 percent per year [MVMA 1998].

Keys to the Future

Future Energy Requirements: Projections of future transportation energy requirements foresee continually expanding energy needs. The U.S. Energy Information Administration anticipates a 77 percent increase in total world transportation energy use over 1996 levels by 2020, an average annual rate of growth of 2.4 percent [USDOE EIA 1999d]. Continued petroleum dependence is expected as world motor vehicle stocks surpass 1.1 billion in 2020.

Vice President Al Gore has been instrumental in new initiatives to meet key energy challenges. With his leadership through the Partnership for a New Generation of Vehicles and the 21st Century Truck Initiative, businesses are developing innovative technologies that promise dramatic increases in automotive fuel economy – reducing our reliance on imported oil while saving consumers money. Pursuing the strategies of promoting clean energy alternatives and reducing fuel use in the federal government vehicle fleet by 20 percent by 2005 will help ease reliance on imported oil.

The World Energy Council has produced a series of scenario projections for future world transportation energy use, with annual growth rates ranging from 0.9 percent to 2.2 percent, implying 26 percent and 92 percent increases, respectively, in 2020 over 1990 [WEC 1993]. Passenger travel and associated energy use have been projected over a much longer period, to 2050, using the concepts of constant travel time and money budgets [Schafer & Victor 1999]. Their analysis foresees global passenger travel growing from 23 trillion passenger-kilometers

in 1990 to 105 trillion in 2050. Increasingly wealthy travelers are expected to shift to faster modes of transportation.

All of these forecasts foresee ever increasing demands for energy by the world's transportation systems—systems that, today, are all but totally dependent on petroleum for energy. Experts disagree over whether there will be adequate sources of low-cost, environmentally acceptable energy for transportation well into the 21st century. But, few would disagree that continued advances in the technologies of energy supply and transportation energy efficiency must be achieved.

Available Energy Resources: Running out of energy is not a problem for transportation as it enters the 21st century. The world's hydrocarbon resources appear to be sufficient to last for a century, but at a potentially high cost to environmental damage, potential climate change, and vulnerability to the costs of oil market manipulation. Conventional oil reserves total about 1 trillion barrels, but reserves measure known amounts ready to be produced at prevailing prices and are more a measure of the oil industry's inventory than an estimate of the total geologic resources.

The U.S. Geological Survey (USGS) [Masters et al. 1994] puts the world's ultimate resources of conventional petroleum at 1.7 trillion barrels, enough to last 46 years at current consumption rates, 33 years if oil consumption continues to grow at 2 percent per year (table 5-5). Some geologists point out that it is unreasonable to expect a smooth drawdown of resources to the last drop [Campbell & Laherrère 1998]. These analysts predict that when cumulative oil production exceeds 50 percent of the world's ultimate resources, oil production will decline. There is general agreement that the 50 percent point will be passed during the first two decades of the 21st century. If production does begin to decline, higher prices and greater market power for OPEC producers can be anticipated.

Oil industry analysts point out that, presently, only an average of 34 percent of the oil in the ground is recovered and that technological advances have and likely will continue to increase recovery rates, perhaps to 50 percent [Porter 1995]. This would expand ultimate resources of conventional oil to 2.8 trillion barrels, enough to last 117 years at current consumption rates, but only 60 years if consumption continues growing at 2 percent per year (table 5-5). But conventional oil is not the only resource from which transportation fuels can be made.

Table 5-5

World Petroleum Resources

Resource	Cumulative quantity (Trillion barrels)	Years remaining: Current consumption	Years remaining: Consumption growing 2% annually
Proven reserves	1	42	30
USGS identified reserves	1.1	46	33
Ultimate resources	1.7	71	44
Enhanced recovery 34% to 50%	2.8	117	60
Unconventional oil resources	3.4	142	67
Oil shale and tar sands	17.4	725	137

Current consumption rate of 0.024 trillion barrels per year.

Source: C.D. Masters, E.D. Attanasi, and D.H. Root. "World Petroleum Assessment and Analysis," *Proceedings of the 14th World Petroleum Congress* (New York, NY: John Wiley and Sons, 1994).

Venezuelan heavy oils are already beginning to be produced and processed into fuels as are Canadian oil sands. The United States contains vast deposits of oil shale that, at a higher cost and with greater environmental damage, can be made into gasoline or distillate fuel. If these resources are considered usable, 137 years of growing world petroleum demand could be accommodated. Moreover, natural gas can be converted into clean, low-emission distillate fuel and even gasoline, but growing demand for natural gas by other users will have to be outbid, or ways will have to be found to make use of the vast methane deposits in coal seams and in the form of methane hydrates [USDOE 1998]. The USGS estimates that the United

States' gas hydrate resources alone range from 100 to 700 quadrillion cubic feet with a mean estimate of 200 quadrillion, 20 times the optimistic estimate of remaining world reserves of conventional gas, roughly equivalent in energy content to conventional petroleum reserves.

Technology and Policy Options: Transportation can improve its energy sustainability by increasing the energy efficiency of transportation vehicles, developing the ability to use cleaner alternative energy sources, reformulating existing fuels and developing improved emissions control technologies for existing power plants, and increasing system efficiency.

The future holds enormous potential for both energy-efficiency improvements and alternative fuels. As a result of industry and governmental research and development, transportation technology has progressed substantially, especially for light-duty highway vehicles [Greene DeCicco 2000]. The U.S. Partnership for a New Generation of Vehicles (PNGV) has made considerable progress toward its goal of tripling fuel economy while reducing pollutant emissions and maintaining safety and all consumer amenities [NRC 1999].

Similar research and development efforts are underway in Europe and Japan. Japanese manufacturers have introduced lean-burn gasoline, direct-injection engines capable of improving fuel economy on the order of 20 percent. In Europe, direct-injection, light-duty diesel engines, which improve fuel economy 40 percent over modern gasoline engines, have captured nearly half of the passenger car market. One European manufacturer offers such engines in the United States. And, for the first time, an ultra-low emission hybrid vehicle is being offered for sale in the United States in model year 2000, following the success of a hybrid passenger car introduced in 1997 in Japan. The U.S. hybrid achieves 65 miles per gallon, making it the most efficient passenger car in the United States. Pollution-free fuel cell vehicles seemed a remote possibility just a decade ago. But rapid advances in power density, cost, and systems improvements have led to fully functional prototype fuel cell cars being demonstrated by major manufacturers around the globe and promises of commercial models by 2005. The successes of light-duty vehicle technology research and development suggest that other modes might achieve similar advances. At present, promising technologies have been identified for heavy trucks, aircraft, rail, and marine transport, but these receive far less attention, even though their combined energy use accounts for 40 percent of transportation's total.

Public policy will play a critical role in creating a sustainable transportation energy future; technological progress may need policies to speed implementation in the short term. At present, all of the advanced technologies mentioned above face one or more barriers to success in the marketplace. In the case of direct-injection gasoline and diesel engines, the hurdle is meeting ever tighter emissions standards. In the case of hybrid vehicles, cost reduction is the key issue, and fuel cells still face a number of technical and economic challenges. In an environment of relatively low fuel prices, even with recent price increases and abundant supplies, consumers are, generally, more interested in acceleration and size of their vehicles and less sensitive to fuel efficiency. If hydrogen fuel cell vehicles are to succeed, considerable effort will be needed to create an efficient and safe transition to such a radically different energy source. History suggests that different policies will work best for different modes and circumstances. Moreover, history also suggests technological and institutional evolution work best in concert with market forces and when they reinforce other important societal goals.

Transportation will always require energy. Achieving sustainable energy for transportation will require that pollutant emissions fall faster than traffic grows, that greenhouse gas emissions are controlled to acceptable levels, that dependence on oil is reduced, and that energy resources for transportation expand faster than they are consumed.

Environment

The effects of transportation on the environment are complex and widespread. Air, water, land use, and animal habitats, are just a few of the areas affected by transportation. Often,

these impacts are not fairly distributed—a fact that is taken into consideration in many planning processes today (see box 5-4 on environmental justice). But, we have come a long way in recognizing and dealing with environmental impacts over the past 25 years, in large part reflecting environmental laws enacted in the late 1960s and early 1970s. These include the National Environmental Policy Act (NEPA) of 1969—the basic charter for environmental protection—requiring an environmental impact statement for every major federal government project; the creation of the U.S. Environmental Protection Agency (EPA) in 1970 to oversee the nation's efforts to clean up the air and water; the Clean Air Act and the Resource Recovery Act, both enacted in 1970; the Clean Water Act and the Ocean Dumping Act, both of 1972; the Endangered Species Act of 1973; and the Safe Drinking Water Act of 1974.

"In the new century, innovations in science and technology will be the key not only to the health of the environment, but to miraculous improvements in the quality of our lives and advantages in the economy"

President William J. Clinton
State of the Union Address
Jan. 27, 2000

This section outlines several problem areas with which we grappled over the past 25 years, including air quality, global climate change, water quality, noise, solid waste, and land-use and habitat.

Box 5-3

Sustainability

As we enter the 21st century, it is apparent that we must not only consider the ramifications of transportation for relatively short-term problems such as air and water quality; we must also consider the relationships between our transportation systems and the degree to which natural ecosystems and livable communities can be nurtured and sustained in the long term.

The most frequently cited definition of sustainability was adopted by the World Commission on Environment and Development (known as the "Brundtland Commission"): "A sustainable condition for this planet is one in which there is stability for both social and physical systems, achieved through meeting the needs of the present without compromising the ability of future generations to meet their own needs." This definition acknowledges that sustainability has social and community, as well as physical dimensions, and is the most broadly accepted definition of "sustainability."

Transportation systems produce environmental, economic, and social equity effects, characterized as the "Three Es." Transportation systems can be considered sustainable to the extent that they contribute, in the short- and long-term, to national goals, including reduced greenhouse gas emissions, healthy ecosystems, enhanced biodiversity, reduced air and water pollution, reduced dependence on finite fossil fuel supplies, and affordable access to economic and social opportunity. Transportation decisions can be considered more or less sustainable in terms of how they produce and balance these effects. The challenge for decisionmakers is to achieve an appropriate balance.

The USDOT is laying the foundation for this broad-based approach to sustainability as related to transportation. The Department has formed a Center for Climate Change and Environmental Forecasting, which is conducting research and development solutions that can address long-term environmental problems while accomplishing other national transportation goals. The Center is the USDOT's focal point for technical expertise on transportation and climate change. One of its primary goals is to develop compliance and multimodal approaches to reduce transportation-related greenhouse gases. The USDOT also has launched Smart Growth initiatives focused on the interaction between transportation investments and land use. These, and related initiatives, will address both current and future challenges in enhancing and preserving communities and the natural environment.

Box 5-4

Environmental Justice

Community groups have raised concerns and challenges about the disparate impacts from and inequities in transportation services, including environmental quality effects on minority populations and low-income populations.

In 1994, President Clinton issued an executive order to address environmental justice. The order directs each federal agency to "make achieving environmental justice part of its mission by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority populations and low-income populations." The executive order and accompanying presidential memorandum emphasize that agencies should use existing laws to achieve this goal.

The USDOT issued an order in 1997 that incorporates environmental justice principles throughout its programs, policies, and activities. The order also sought to integrate the executive order's goals with the existing requirements of such laws as NEPA, Title VI of the Civil Rights Act of 1964, and the Uniform Relocation Assistance and Real Properties Acquisition Policies Act.

Environmental justice principles must be considered during the transportation planning process. Proposed new planning and environmental regulations will provide guidance on how states can demonstrate consistency in environmental justice principles.

Air Quality

Over the past 25 years, the United States has made significant progress in reducing air pollution. For highway vehicles, this success resulted primarily from improvements in vehicle fuel systems, the use of catalytic converters to treat combustion products, and the development of cleaner burning fuels. These changes have occurred because of a combination of scientific and engineering innovations and regulations. Aircraft emissions also have been reduced, largely through international standards.

Federal standards for light-duty vehicle emissions were put in place in the 1960s and have become increasingly stringent over time, covering not only tailpipe emissions but also fuel evaporation. Standards for heavy-duty highway vehicles were adopted in the 1970s; they, too, have become more stringent over time. The EPA has proposed new emission standards for heavy-duty vehicles to take effect in 2001 and diesel fuel requirements, lowering sulfur levels from the current 500 parts per million (ppm) to 15 ppm by 2006. In the 1990 Clean Air Act Amendments, the EPA's responsibility for mobile source regulation was expanded to cover "nonroad engines and vehicles," including ships and locomotives.

Box 5-5

Cold Starts

Motor vehicle exhaust emissions are controlled by catalytic converters. The catalyst requires heat to reach the temperature at which it functions most efficiently; thus, there is a delay before it reaches operating temperature. Since emissions during normal operation have been dramatically reduced, now about 70 to 80 percent of the nonmethane hydrocarbons that escape conversion by the catalysts are emitted during the first two minutes after a cold start. Several engineering techniques are being developed to warm catalysts up more quickly so they can better control emissions. In the absence of such technologies, many transportation specialists recommend strategies such as reducing the number of trips or chaining trips to reduce cold starts. In 1998, eligibility under the Congestion Mitigation and Air Quality Improvement Program was expanded to allow funding for projects intended to reduce emissions from extreme cold-start conditions.

For the first time, the EPA published regulations this year in February 2000 covering both vehicles and fuels as an integrated system under the "Tier II" standards. These standards require a reduction in tailpipe emissions and lower sulfur content. The regulations specify

acceptable ranges for some fuel qualities (e.g., volatility, sulfur content). And in areas of the country with severe ozone problems, the EPA requires the use of reformulated gasoline to reduce emissions.

For the six air contaminants known as criteria pollutants, EPA establishes air quality standards based on maximum acceptable atmospheric concentrations. The six contaminants are:

1. carbon monoxide (CO),
2. sulfur dioxide (SO_2),
3. lead (Pb),
4. nitrogen dioxide (NO_2),
5. ozone (O_3), and
6. particulate matter less than 10 microns (PM_{10}).

States that fail to meet the standards must develop State Implementation Plans (SIPs) specifying how they will reach these standards. These SIPs must also contain enforceable requirements to keep emissions within necessary levels.

Since 1990, regulatory developments have been complemented by significant changes in transportation planning. These changes have occurred because of provisions in the 1990 Clean Air Act Amendments and the 1991 Intermodal Surface Transportation Efficiency Act

Box 5-6

Air Quality and Transportation Planning

In many areas, transportation planning is subjected to the conformity process. Transportation emissions must remain within levels projected by State Implementation Plans (SIPs) that, when implemented, will lead to attainment of air quality standards. Transportation plans and programs, therefore, must "conform" with air quality goals. This process is the result of more than three decades of legal and regulatory evolution. The current Transportation Conformity regulation was adopted in 1993 and amended in 1997.

The enaction of the National Environmental Policy Act (NEPA) in 1969 established a framework for collaboration between federal agencies and those who will bear the environmental, social, and economic impacts of agency decisions. NEPA further established a requirement that decisions about development projects, such as highway and airport construction, be informed by analyses of environmental impacts. Although this law established procedures for such analyses, it provided little guidance about how project decisions should be made. It also had a project-specific focus that did not necessarily lead to consideration of the integrated impact of multiple projects in a region.

Amendments to the Clean Air Act in 1977 added a requirement prohibiting metropolitan planning organizations from adopting plans that did not conform to an approved SIP and authorized the USDOT to withhold federal highway funding in cases of nonconformity. Guidance from the USDOT and the EPA required the timely implementation of any transportation control measures included in a SIP. Clean Air Act Amendments in 1990 provided more specific requirements for conformity determination. The Intermodal Surface Transportation Efficiency Act of 1991 solidified the connection between conforming requirements and the use of transportation funding.

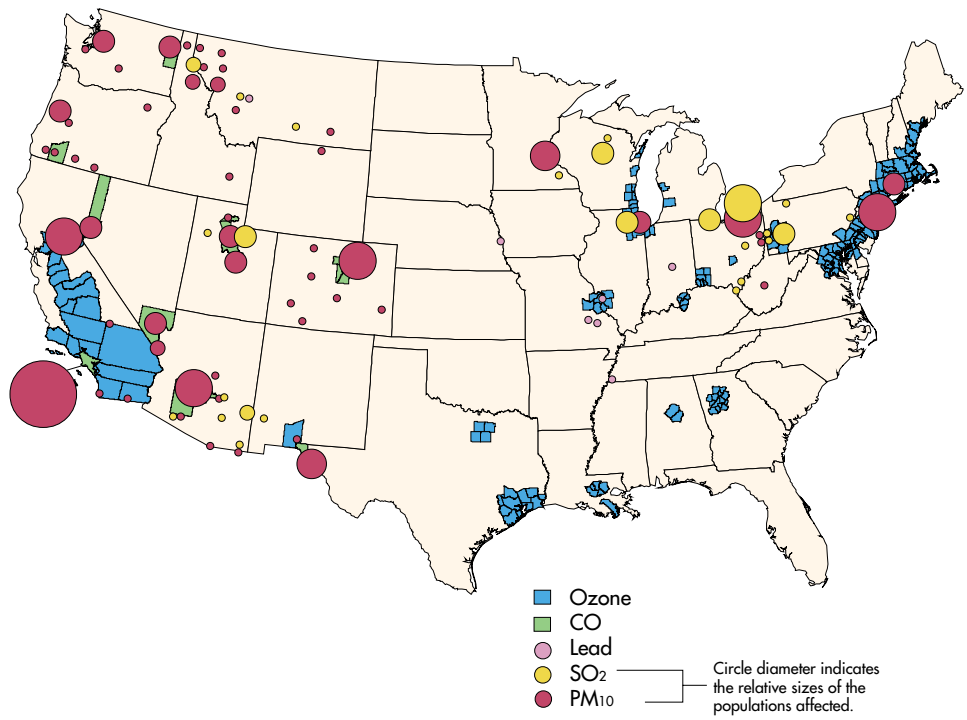
Subsequent regulations and legislation have further defined these requirements and made them more flexible. However, the underlying philosophy that transportation plans and programs must conform to air quality plans has not changed.

(ISTEA), which was subsequently updated by the Transportation Equity Act for the 21st century (TEA-21) in 1998. ISTEA and TEA-21 also allow a portion of fuel tax revenues to be used to fund public transit systems and other specific projects to reduce congestion and improve air quality.

Despite dramatic reductions in air emissions by mobile sources and measurable improvements in the nation's air quality, some areas do not meet the standards set by the EPA for the six criteria pollutants. These nonattainment areas, as of 1998, are shown in figure 5-24. At that time, 113 million people were affected by the air quality in these areas.
Historical trends vary for criteria air pollutants emitted by transportation. For example, lead has been virtually eliminated since the late 1980s, while nitrogen oxide (NO_x) has generally increased since the late 1980s.

Figure 5-24

Nonattainment Areas for Criteria Pollutants: 1998



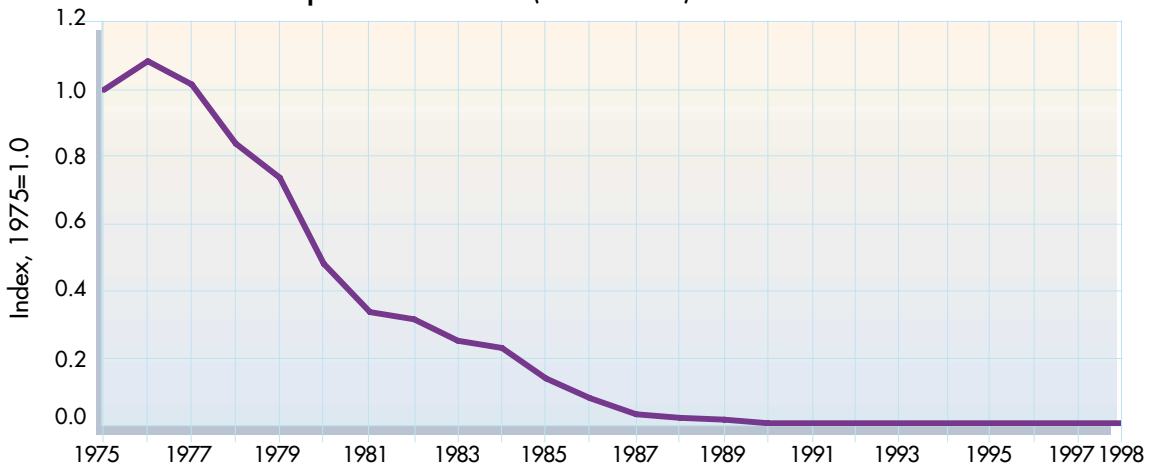
Source: U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, *National Air Quality and Emissions Trends Report, 1998* (Washington, DC: 1999).

By banning the use of lead in gasoline, the United States has virtually eliminated transportation sector emissions of lead (see figure 5-25) [USEPA 1998]. As a result of this ban and other lead control measures, such as restrictions on the use of lead in paint, lead levels in children's blood are down more than 80 percent from levels experienced in the late 1970s [Jacobs 1999].

In a period during which vehicle-miles traveled (VMT) rose considerably, emissions of volatile organic compounds (VOCs) and carbon monoxide (CO) have declined since the mid-1970s. However, emissions of NO_x have not declined (see figure 5-26). NO_x and VOCs contribute to the formation of ground-level ozone (i.e., smog), which causes pulmonary health problems. Ozone and NO_x also damage aquatic ecosystems, forests, and agricultural crops. CO contributes to cardiac health problems. These data reflect national emissions. Emissions in many areas of the country have fallen further and faster in response to the implementation of regional strategies such as vehicle inspection and maintenance and clean fuel programs. Emissions of particulate matter smaller than 10 microns (PM_{10}) can contribute to pulmonary health problems (figure 5-27). Much of the improvement over the years is attributable to improvements in diesel engine technology and diesel fuel quality.

Figure 5-25

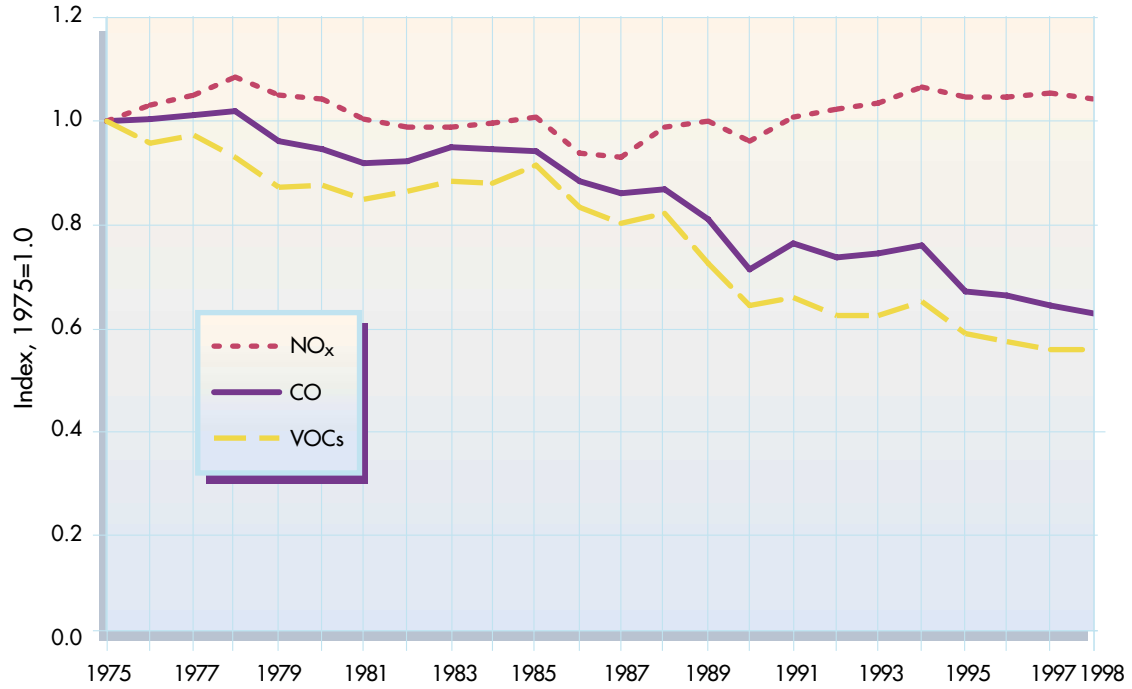
Lead Emissions from Transportation: 1975-98 (Annual totals)



Source: U.S. Environmental Protection Agency, Office of Air and Radiation, Air Quality Planning and Standards, *National Air Pollution Emission Trends, 1900-1998*, EPA 454/R-00-002 (Washington, DC: 2000), available at http://www.epa.gov/ttn/chief/trends98/trends98.pdf, as of June 28, 2000.

Figure 5-26

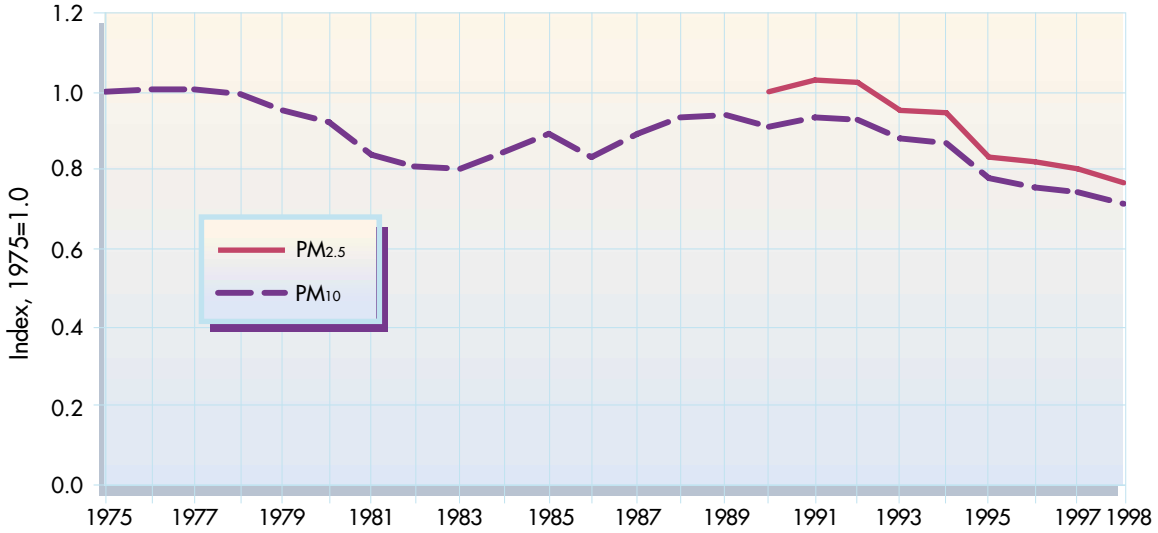
VOCs, NO_x, and CO Emissions from Transportation: 1975-98
(Annual totals)



Source: U.S. Environmental Protection Agency, Office of Air and Radiation, Air Quality Planning and Standards, *National Air Pollution Emission Trends, 1900-1998*, EPA 454/R-00-002 (Washington, DC: 2000), available at http://www.epa.gov/ttn/chief/trends98/trends98.pdf, as of June 28, 2000.

Figure 5-27

Particulate Emissions: 1975-98
(Annual totals)



Source: U.S. Environmental Protection Agency, Office of Air and Radiation, Air Quality Planning and Standards, *National Air Pollution Emission Trends, 1900-1998*, EPA 454/R-00-002 (Washington, DC: 2000), available at http://www.epa.gov/ttn/chief/trends98/trends98.pdf, as of June 28, 2000

Reductions in emissions from the transportation sector, as well as from other sectors (in particular, electric utilities), have resulted in improvements in measured urban air quality from 1988 to 1997. Although directly comparable air quality measurements from the 1970s are scarce, emissions trends suggest that improvements from the late 1980s to the late 1990s represent a continuation of air quality improvements [USEPA 2000b].

In 1997, EPA tightened the standards for ozone and particulate matter. A court decision has prevented EPA from implementing the tighter ozone standard; however, the agency has appealed the decision. The Supreme Court has agreed to hear the case in the 2000-2001 timeframe.

Box 5-7

Transportation Demand Management and Air Quality

Transportation Demand Management (TDM) is a strategy used to reduce travel on the nation's roadway system in large urban areas that have both high levels of traffic congestion and poor air quality. The strategies typically include carpooling, transit use, pedestrian, and cyclist programs. TDM is not a new concept, having been first used during World War II to reduce civilian fuel consumption and, again, during the energy crisis of the 1970s.

The Clean Air Act Amendments of 1970 included a reduction of auto emissions through the promotion of ridesharing and public transit. Large metropolitan areas submitted transportation control plans that included regulatory measures, including driving reductions.

Box 5-7 *continued*

Transportation Demand Management and Air Quality

The 1974 Emergency Highway Energy Conservation Act authorized the creation of regional rideshare programs, high occupancy vehicle (HOV) lanes, and park-and-ride lots. The Federal Energy Act, also passed in 1974, provided corporate tax incentives for the purchase of ride-sharing vans. The 1992 Comprehensive Energy Policy Act added more incentives through the Commuter Choice incentive program. This program was expanded in 1999 to include a pretax option that employers could offer as an incentive to transit and ridesharing employees. The federal government as an employer has spearheaded attempts to encourage telecommuting, transit use, and alternative work schedule arrangements. For instance, on October 1, 2000, by executive order, all federal employees in the National Capital region became eligible for up to $65 per month in transit benefits.

Mandatory programs requiring businesses to reduce their employees' commuting trips began to spring up in the mid-1980s. These programs were included in the 1990 Clean Air Act Amendments as a mandated measure for areas with the worst pollution and as an optional measure for those with less serious problems. These mandates were changed to voluntary options under legislation passed in 1995. Some metropolitan areas, such as Washington, D.C., now include voluntary trip reduction programs in their transportation and air quality planning processes. Trip reduction has been part of the debate surrounding urban sprawl; sustainability; and, lately, the push for "livable communities."

Box 5-8

Bicycle and Pedestrian Alternatives

Although bicycling and walking are two of the oldest forms of transportation, their role in the U.S. transportation system has changed significantly over the last 25 years. In the late 1970s, both were recognized as energy-efficient modes that could be used for shorter trips or in combination with other modes, such as mass transit, for longer trips. Given that a large part of harmful emissions are released within the first two minutes of starting cars, walking and bicycling on short trips were increasingly recognized as good for air quality. However, these transportation modes were sometimes overlooked when projects and programs were planned and implemented.

This began to change in the 1990s as a result of federal legislation such as ISTEA and TEA-21. Pedestrian and bicycle projects and programs must now be part of the planning process at the state and Metropolitan Planning Organization (MPO) levels. Increasingly, states have allocated additional funding for such projects.

The USDOT is supporting these forms of transportation by expanding funding and setting goals to increase their use and to make them safer. Goals call for doubling the percentage of trips made by bicycling and walking and for reducing the number of injuries and fatalities attributed to these activities by 10 percent.

Keys to the Future

Nitrogen oxide and unburned hydrocarbon emissions are projected to continue declining in response to more stringent regulations related to fuel quality and vehicle emissions, although an upturn, in response to increased travel, is still possible over the longer term.

Beyond 2010, further reductions in particulate matter might be available through more stringent emission standards and/or more stringent fuel-quality requirements. The groundwork has been laid so in the future, emissions of some hazardous air pollutants should decline significantly as fuel quality improves. The same types of changes that have enabled air-quality improvements, cleaner vehicles and fuels, and

"There's no doubt that clean-fuel vehicles are coming to the mass market. The billion dollar question is which one or ones will get there first and when?"

Mortimer Downey
Deputy Secretary of Transportation
Natural Gas Vehicle Coalition
Minneapolis, Minnesota
Oct. 5, 1999

cleaner industrial and electrical generation facilities likely will continue in response to technological improvements and ongoing regulation.

Through the Partnership for a New Generation of Vehicles (PNGV), government and industry are collaborating on developing prototype passenger vehicles that would achieve up to a tripling in fuel economy without increasing life-cycle cost and without compromising safety, performance, or convenience. Lightweight structural materials, hybrid electric power trains, and hydrogen fuel cells show promise toward meeting this goal. Such technologies also can significantly improve the efficiency of medium- and heavy-duty vehicles, a goal the federal government is pursuing through the Advanced Vehicle Technologies Program (AVP) and other incentives. AVP goals include tripling the fuel economy of transit buses and doubling that of freight trucks (see discussion in Chapter 6 Technology). If manufacturers are ultimately successful in marketing vehicles that meet AVP and PNGV goals, the long-term growth of emissions could be reduced significantly.

"The key (to reducing green-house gases) will be reducing the carbon intensity of our transportation sector, which can be done in three ways: by encouraging more efficient travel practices, by making transportation more fuel efficient, and by adopting fuels that will emit less carbon."

Mortimer Downey
Deputy Secretary of Transportation
Washington, D.C.
Dec. 9, 1998

Air quality in the year 2025 will almost certainly be better than it is today. These improvements will probably be achieved in all sectors, but perhaps most significantly from mobile sources where the benefits of some regulations like those on heavy duty trucks and small engines are just starting to be realized. The improvements will be driven by the continuing importance the American people place on a healthy environment, which will result in increasingly stringent governmental and private sector attention to air quality. New technologies and fuels will be the mechanisms by which air quality gains are made. Electric hybrid vehicles, fuel cell engines, and new fuels—from reformulated petroleum products and entirely new sources like biomass—will be commonplace through widespread commercialization and "green marketing." Interestingly, these improvements will come despite ever increasing demand for travel. All travel modes will experience this increased demand as wealth, leisure time, and market globalization expand, but none so much as aviation. Yet despite these increases, extremely low and even zero-emitting engine-fuel combinations will represent a large part of what is now the complete set of internal combustion engines. Americans will have cost- and convenience-competitive choices in every class of engine. Such innovations will continue to be developed and introduced into the marketplace, completely offsetting any increases in emissions due to the volume of travel.

In the coming decades, the Marine Transportation System will provide environmentally sound transportation of people and goods, which can relieve congestion in other transportation modes, thereby reducing some unintended environmental impacts, including air pollution. Ferries increasingly will provide an environmentally sound alternative. The ferry system in New York and Washington State, for example, will continue to provide significant commuter links. The Puget Sound ferries, which today carry 23 million passengers per year, and the Alaska ferries will remain vital transportation links to homes and businesses.

Global Climate Change

In the last quarter century, the scientific evidence of human impacts on global climate patterns has mounted. It is now commonly recognized that the buildup of greenhouse gases in the atmosphere could cause increased average global temperatures; higher average sea levels that inundate some wetlands and low-lying coastal areas; more intense droughts, storms, and floods; extended growing seasons; and an expansion in the geographic range of insect-borne

diseases such as malaria. Moreover, the emissions that contribute to the greenhouse effect remain in the atmosphere for much longer periods than do emissions affecting air quality. Most of the CO_2 released in 2000 through fossil fuel combustion will still be in the atmosphere at the beginning of the 22nd century.

Carbon dioxide is the dominant greenhouse gas emitted by transportation. It is produced in approximate proportion to the amount of petroleum used, and its production can only be reduced by burning less fossil fuel (i.e., through energy efficiency or use of alternative fuels). Transportation sources account for about 26 percent of greenhouse gas emissions, and transportation sector greenhouse gas emis-sions have increased by nearly 40 percent since 1975, in parallel with increases in transportation sector energy consumption (figure 5-28) [USDOE EIA 1999e]. Contributing factors include growth in travel; a significant market shift away from automobiles and toward trucks and sport utility vehicles (SUVs); and petroleum prices during the 1990s that, adjusted for inflation, were much lower than past levels.

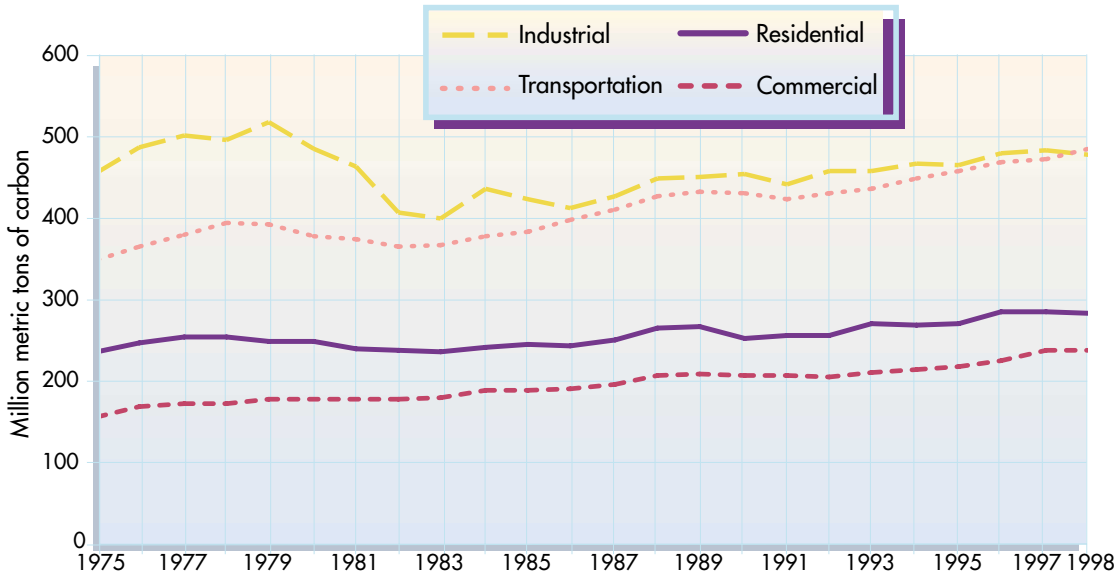
"Just last week, automakers unveiled cars that get 70 to 80 miles a gallon, the fruits of a unique research partnership between government and industry. And, before you know it, efficient production of biofuels will give us the equivalent of hundreds of miles from a gallon of gasoline."

President William J. Clinton
State of the Union Address
Jan. 27, 2000

Greenhouse gas emissions from private vehicles (cars and light trucks) increased by about 12 percent from 1990 to 1997 and accounted for about 70 percent of that period's overall growth in transportation greenhouse gas emissions. Emissions from other trucks and buses grew much faster—21 percent over the same period—accounting for most of the remaining overall growth. About 95 percent of these emissions were from medium- and heavy-duty trucks.

Figure 5-28

Carbon Dioxide Emissions by End-Use Sector: 1975-98
(Annual totals)

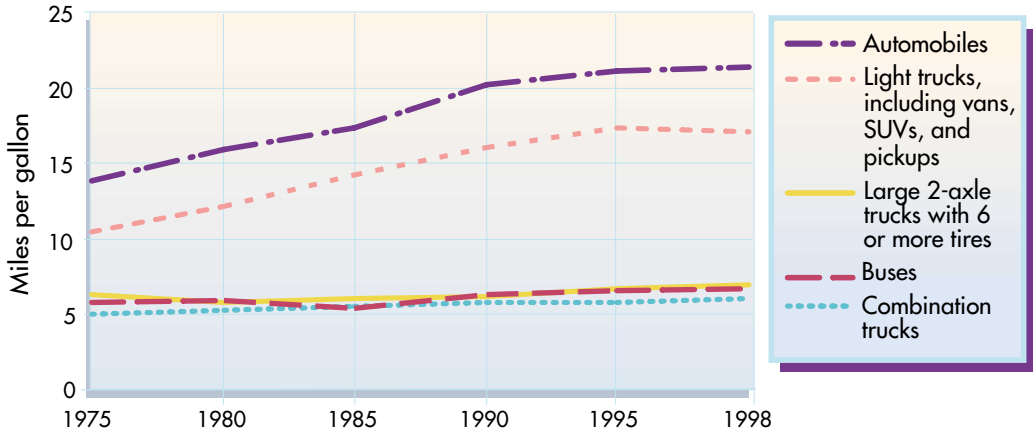


Source: U.S. Department of Energy, Energy Information Administration, *Emissions of Greenhouse Gases in the United States, 1998* (Washington, DC: 1999).

Because transportation greenhouse gas emissions are the direct result of fuel combustion, the nation's transportation-related energy trends and policies have had a major impact on the direction of levels of greenhouse gas emissions. A key energy policy step was passage of the Energy Policy and Conservation Act of 1975, which mandated Corporate Average Fuel Economy (CAFE) standards for each new car fleet. As a result, the average fuel economy of automobiles and light trucks increased by 54 percent and 63 percent, respectively, between 1975 and 1998 (figure 5-29). These measures were not adopted in response to climate change, but they have reduced the growth rate of CO_2 emissions. However, in the last few years, the growth in energy efficiency of automobiles and light trucks has slowed.

Figure 5-29

Average Fuel Economy of Highway Vehicles: 1975-98



Note: This figure shows results for the entire fleet of operating vehicles, not just new ones. It is derived from estimates of vehicle travel and total fuel consumed.
Source: U.S. Department of Transportation, Federal Highway Administration, *Highway Statistics* (Washington, DC: Annual issues).

As scientific recognition of the climate change problem grew in the 1980s, the public in the United States and elsewhere became increasingly interested in finding solutions. In 1992, the United Nations Framework Convention on Climate Change (UNFCCC) was negotiated in Rio de Janeiro to establish a framework for a global response to this problem. The ultimate pur-pose of the Convention is to stabilize atmospheric greenhouse gas concentrations "at a level that would prevent dangerous anthropogenic interference with the climate system." A prominent feature was the nonbinding aim of returning to 1990 greenhouse gas emission levels by the year 2000 in developed countries. The United States was one of 184 (as of May 2000) countries that ratified the Rio accords; we did this in 1992.

The overall growth in transportation greenhouse gas emissions is indicative of the significant difficulties the United States, like many other developed countries, has experienced in making progress toward the voluntary goal under the Rio accords. Instead, transportation sector greenhouse gas emissions have grown since 1992 and are projected to grow significantly over the next 20 years.

In October 1997, President Clinton set out his goals for both international negotiations and domestic actions and proposed a shift from nonbinding aims to binding targets. He identified the nation's six climate change principles:

"The Kyoto Agreement is based on the simple idea that it will not be government bureaucrats or regulators, but free markets and free minds that will be our best bet to win the battle against global warming, while lifting the lives and the hopes of citizens around the world … I believe the American people can meet the challenge of global warming and end up with a better and stronger economy in the process."

Vice President Al Gore
Dec. 11, 1997

1. policies should be guided by science;
2. policies should rely on market-based, common-sense tools;
3. win-win solutions should be sought;
4. global participation is essential;
5. the United States will not adopt binding obligations without developing country participation; and
6. policies should be informed by common-sense economic reviews conducted every 5 years.

In December 1997, the third Conference of the Parties under the UNFCCC adopted the Kyoto Protocol, which has as its central feature a set of binding emission targets for developed nations. The specific limits vary from country to country, although those for the key industrial countries of the European Union, Japan, and the United States are similar: eight percent below 1990 levels for the European Union, seven percent for the United States, and six percent for Japan.

Box 5-9

Greenhouse Gases Governed by the Kyoto Protocol

Carbon dioxide (CO_2)
Methane (CH_4)
Nitrous oxide (N_2O)
Hydrofluorocarbons (HFCs)
Perfluorocarbons (PFCs)
Sulfur hexafluoride (SF_6)

The Protocol allows nations with targets to save money by meeting those targets as blocs, rather than on a country-by-country basis. The emissions targets are to be reached over five-year budget periods, the first of which will be 2008 to 2012. The emissions targets include six major greenhouse gases, and they may be offset through activities that absorb carbon, such as forestation.

Because climate change is a global problem, the Protocol provides flexibility in meeting emission reduction targets. It allows for emission trading so countries can purchase less expensive emission permits from countries that might reduce their emissions more easily. The Protocol addresses greenhouse gases from international aviation and marine transportation by requiring nations to work through the International Civil Aviation Organization and the International Maritime Organization.

In the United States, the Protocol becomes binding only with a two-thirds majority vote of the Senate. In addition, it will not enter into force until it is ratified by at least 55 countries, collectively accounting for 55 percent of developed countries' 1990 emissions. The Clinton-Gore Administration's proposed strategy for complying with a binding cap on domestic emissions in the Kyoto Protocol emphasizes reliance on domestic and international emissions trading. The United States signed the Kyoto Protocol, but the Clinton Administration stated it will not submit the Protocol to the U.S. Senate for its advice and consent until there is meaningful participation by developing countries.

"We have a chance to completely rewrite the transportation future of America, to dramatically reduce the one-third of our greenhouse gases that come out of transportation, and do it without some crippling regulation or some astronomical tax."

President William J. Clinton
U.S. Conference Of Mayors
Breakfast Reception
Jan. 28, 2000

Keys to the Future

An important way to limit future transportation greenhouse gas emissions is to increase reliance on fuels made from renewable resources. For example, Argonne National Laboratory has estimated that it is possible to achieve emission reductions of up to 25 percent by switching to corn-based ethanol fuels now; and, with wider use, a reduction of about 30 percent might be possible by 2005 [Wang et al. 1999]. However, because of issues such as cost and land availability, ethanol appears unlikely to displace more than 10 percent of gasoline consumption in the near future.

Other fuels show less promise at this time. Natural gas may provide modest greenhouse gas benefits, relative to gasoline, but can actually increase overall greenhouse gas emissions, relative to diesel fuel. When produced from renewable resources, hydrogen and electricity have the potential to virtually eliminate greenhouse gas emissions when they can be substituted for gasoline. However, the infrastructure does not exist to produce, distribute, or deliver hydrogen fuel on a widespread basis. Electric vehicles also are limited by infrastructure; and without breakthroughs in battery performance and cost, pure electric vehicles appear unlikely to significantly penetrate the market.

Although policies, such as purchasing requirements and tax incentives, have successfully increased the number of alternatively fueled vehicles and the use of alternative fuels, the transportation sector is still 95 percent dependent on petroleum. Moreover, despite the promise of these technologies and fuels, the cost and the pace of fleet turnover could limit their impact in the next 20 years. Five national energy laboratories recently projected that under favorable conditions, the combined effect of advanced vehicle technologies and alternative fuels could reduce transportation sector greenhouse gas emissions in 2015 by 25 percent relative to "business as usual" [ORNL et al. 1997]. This same analysis also projected that growth during that time could offset much of these reductions so that net emissions could remain at 1997 levels.

In the 1990s, domestic electric utilities gained considerable experience with emissions trading through the Clean Air Act sulfur dioxide permit-trading program. It is not yet clear whether or how the transportation sector might participate in an emissions trading program, although general concepts have been outlined; the USDOT's Center for Climate Changes and Environmental Forecasting is researching this issue.

Under one option, with *energy-source-based* emissions trading, refiners and refined product importers could be required to hold permits covering the projected emissions of transportation fuels sold by them for domestic use. Alternatively, under a *manufacturer-based* approach, transportation vehicle manufacturers and importers could be required to hold permits covering the projected future emissions of vehicles offered for sale. There are important policy, administrative, and technical differences among these and other potential approaches. Since reducing the transportation sector greenhouse gas emissions may be difficult, emissions trading among sectors and across countries might provide needed flexibility if a binding cap on overall domestic emissions is adopted.

Water Quality

The major direct source of water contamination from the transportation sector comes from oil and fuel leaks and spills, particularly from tankers, motor vehicles, and above- and below-ground fuel storage tanks. Oil spills from tankers can have major impacts on nearby ecosystems, aquatic species, wildlife, and birds, but the extent and severity of environmental contamination vary greatly with the location and size of the spill. Even a small amount of petroleum in the groundwater system can contaminate large quantities of water.

Runoff from roads, infrastructure construction, and the deterioration of discarded vehicles also have an impact on surface and groundwater quality. The amount and magnitude of highway runoff depend on traffic characteristics, maintenance activities, and climatic conditions, as well as the location of the road itself. For example, runoff from roads and parking lots has a higher than normal concentration of toxic metals, suspended solids, and hydrocarbons, which alter the composition of surface and groundwater. In northern regions, the application of road salts in winter is another concern. Increased sodium levels in water and surrounding soils can damage vegetation.

Moreover, transportation infrastructure may cause changes in the local water table and drainage patterns by increasing the share of rainwater that becomes runoff. This affects the soil moisture content of the area, which, in turn, may alter vegetation and wildlife. The construction of transportation facilities also may result in the destruction of wetlands. Wetlands are areas that are neither fully terrestrial nor fully aquatic. They range from the vast cypress swamps of the southern United States to shallow holes that retain water only a few weeks of the year. Wetlands can provide critical habitat for migratory waterfowl, control flooding, act as natural filters for drinking water, and provide recreation.

The largest threat to U.S. waterways remains petroleum in transport; of the 198 billion gallons spilled since 1975, 75 percent of it spilled during transportation. Nevertheless, oil spilled into U.S. waters in the 1990s has been much less than in the late 1970s and 1980s. From 1990 through 1998, the average annual amount of oil spilled was 2.6 million gallons, compared with 9.5 million in the 1980s, and 16.0 million from 1975 through 1979 [USDOT BTS 1999]. The improper disposal of used motor oil is a widespread source of groundwater and surface water contamination. According to EPA estimates, of the 714 million gallons of used motor oil collected annually in the early 1990s, 161 million gallons (23 percent) were disposed improperly [USEPA 1994].

Groundwater contamination often is caused by leaks from underground storage tanks, such as those found at local gasoline service stations, which have a history of leaking due to corrosion, overflows, and spills. Most underground storage tanks are used by the transportation sector. In response to legislation, EPA set up the Underground Storage Tank (UST) Program in the mid-1980s to remediate leaking tanks and establish regulations on leak detection and tank standards. Data reported to EPA by states, as of September 1998, show that the country has almost 900,000 active tanks, and that 1.2 million tanks have been closed and more than 300,000 cleanups initiated since 1990. There are 168,000 known releases not yet cleaned up [USEPA 1998].

Spills from aboveground storage tanks (ASTs) also are a source of groundwater contamination. ASTs at transportation facilities serve two primary functions: 1) to provide breakout storage or overflow relief at small pumping stations, and/or 2) to provide short-term storage at tank farms/distribution facilities. Spills from these facilities are often due to overfill, failure of tank bottoms, improper disposal of tank-bottom contaminants, and leakage from piping associated with tanks. A 1994 American Petroleum Institute (API) survey found improved spill prevention and reduced incidents of environmentally unsound disposal practices at refining, service station, and transportation facilities operated by API member companies [API 1994]. The survey did not yield information regarding incident frequencies or accidental release volumes.

Runoff from streets, parking lots, and airports is another source of water and groundwater contaminants. Motor vehicles are the primary source of pollutants, except during periods of snow and ice when deicing chemicals and abrasives predominate. Pollutants derive from, among others, tire and brake lining residue, gasoline, oil, grease, and hydraulic fluids. The nature and extent of damage nationally from highway runoff is still being studied. Aircraft deicing and ethylene or propylene glycol-based chemicals at airports are other sources of runoff contaminants. The total amount of aircraft deicing fluid (ADF) released by U.S. airports is uncertain and varies from year to year with weather, number of aircraft departures, and size and type of aircraft. EPA estimates that the United States released a total of about 28 million gallons of ADF per year to surface waters prior to 1990, when new practices for managing stormwater were implemented. Current discharges to surface waters are estimated to be 21 million gallons of ADF, with another 2 million gallons being discharged to publicly owned treatment works [USEPA 2000c].

The advent of increased environmental awareness and legislative action in the early 1970s paved the way for the preservation of wetlands and water quality. The Federal Water Pollution Control Act of 1972 and The Clean Water Act of 1977 significantly strengthened federal requirements. These laws clarified the intent of wetlands protection, strengthened the control of pollutant discharges from point sources, and eventually led to a national program to protect waters from pollutants introduced by stormwater runoff.

Additional Clean Water Act amendments in 1987 strengthened the stormwater program and instituted new measures, giving rise to greater areawide or watershed-based management approaches. Subsequent regulations were issued controlling the discharge of runoff from temporary construction sites and, in larger municipal areas, stormwater in general.

Mitigation for water quality impacts has always been an eligible activity on newly proposed transportation projects as part of the project development and the environmental review process established with NEPA. ISTEA and TEA-21 provided for and expanded funding for wetlands banking, environmental restoration, and pollution abatement. Environmental restoration returns the habitat, ecosystem, or landscape to a state as close as possible to its predisturbance condition and function. Since natural systems are diverse and dynamic, the process of recreating or duplicating their natural, or presettlement, state is virtually impossible. Therefore, the goal of the restoration is to reestablish the basic structure and function associated with recent predisturbance conditions. Pollution abatement includes the retrofit or reconstruction of stormwater treatment systems. In essence, a proposed restoration project will include analysis of the water quality impact from a previous highway project, in relation to a watershed plan for the area, and correct any past deficiencies in a stormwater treatment plan. These costs can be funded with federal highway dollars.

Since 1968, successive Presidents and Congresses have responded to the health and environmental threats posed by inadvertent releases of oil and hazardous substances by passing several major pieces of legislation. The Federal Water Pollution Control Act of 1972 is the principal federal statute protecting navigable waters and adjoining shorelines from pollution caused by oil and hazardous substance releases. Regulations based on this act detail specific requirements for pollution prevention and response measures. The EPA and U.S. Coast Guard (USCG) implement these provisions. EPA implements the legislation through a variety of regulations and programs, including the National Contingency Plan (NCP). The NCP (more properly known as the National Oil and Hazardous Substances Pollution Contingency Plan) was first developed in 1968 in response to 37 million gallons of oil spilled off the coast of England in 1967 from the Torrey Canyon oil tanker. To avoid the kinds of problems faced in this incident, officials developed a coordinated approach to cope with future incidents in U.S. waters. The 1968 plan provided the first comprehensive system of accident reporting and spill containment and cleanup. The NCP also established a response headquarters, a national reaction team, and regional reaction teams, which were precursors to the current National Response Team and Regional Response Teams.

Over the years, Congress has broadened the scope of the NCP. The Plan was revised in 1973 to include a framework for responding to hazardous substance spills, as well as oil discharges. Following the passage of Superfund legislation in 1980, the NCP was again broadened to cover emergency removal actions at hazardous waste sites on land. The latest revisions to the NCP were passed in 1994 to reflect the oil spill provisions of the Oil Pollution Act of 1990 (OPA-90), which was enacted largely in response to rising public concern following the Exxon Valdez spill in Alaska. OPA-90 required vessels and facilities that store and transport oil in bulk to develop response plans that ensure they have the equipment and manpower to respond to and mitigate a worst-case discharge. Additionally, it required the EPA and the USCG to develop stronger Regional and Area Contingency Plans concentrating on their area's unique hazards and risks, including the planning for the potential use of

alternate response technologies including dispersants and in-situ burning. As the beginning of a strong prevention initiative, OPA-90 enabled the USCG to initiate sweeping improvements to prevention, preparedness, and response. Using risk analysis and partnerships throughout the maritime community, over 42 regulatory projects were enacted. These changes have substantially reduced the risk of a pollution incident and have ensured increased vigilance by those transporting oil in our waterways.The Oil Pollution Act of 1990 also created the national Oil Spill Liability Trust Fund, providing up to $1 billion per incident for compensation if the spiller of the oil cannot be found or refuses to pay. In the latter case, the issue is settled in the courts.

The USCG's Port State Control (PSC) program ensures that foreign-flagged vessels calling at U.S. ports comply with the comprehensive safety standards of the International Maritime Organization. All foreign flag vessels have been subject to PSC exams to ensure that substandard vessels are identified and detained until safety deficiencies are corrected, thus reducing the risk of vessel casualties that may result in oil spills. This successful program resulted in a reduction of over 50 percent in the rate of such vessels discovered in U.S. ports between 1995 and 1999, and the downward trend is expected to continue as the quality of ships calling at U.S. ports continues to improve.

Hazardous liquid pipelines incurred an average of 200 incidents per year between 1988 and 1997 resulting in an average of 2 deaths, 16 injuries, $34 million in damages, and a net loss of 85,000 barrels of liquid per year. Outside damage and external corrosion were the primary cause of hazardous liquid pipeline incidents in 1997 [USDOT OPS 1998]. Natural gas transmission and distribution operators reported a 1988 to 1997 average of 215 incidents per year, resulting in 18 fatalities, 91 injuries, and $32 million in property damage. In 1997, the primary cause of natural gas pipeline incidents was the same as for hazardous liquid pipelines—damage from outside forces. For transmission pipelines alone, internal corrosion ranked second. At the conclusion of a 1996 liquid pipeline accident investigation, the National Transportation Safety Board recommended in late 1998 that the USDOT Office of Pipeline Safety make several changes to federal regulations to improve the pipeline industry's ability to prevent accidental releases caused by corrosion [USDOT OPS 1998]. In November 2000, the USDOT issued strong new requirements for large hazardous liquid pipeline operators to regularly inspect and promptly repair pipelines in populated and environmentally sensitive areas and to take systematic steps to detect and prevent leaks. Also the USDOT is taking steps to implement stronger pipeline safety standards, including improved enforcement, enhanced federal-state partnerships, increased public access to information, and more innovative technology. Together, these actions will help ensure that our oil and gas pipeline system is sound, our communities safe, and our environment protected.

Keys to the Future

Over the past 25 years, most water quality control efforts relied on broadly applied national programs that reduced pollution from individual sources, such as discharges from sewage treatment plants, industrial sites, and from polluted runoff. The result has been dramatic improvements in water quality throughout the nation. Today, there is a growing recognition that clean water strategies built on this foundation, but applied on a watershed scale, are the keys to the future. By 2025, universal application of consolidated and coordinated water resource management programs, coupled with dramatic advances in technology, will spell the end of water pollution as we know it today. The watershed approach in managing water resources and most other land-use issues will be applied uniformly throughout the nation. Such management will be commonplace in federal, state, tribal, and local governments and in private programs. There will be new collaborative efforts to restore watersheds that will involve all stakeholders, including transportation entities. Nonpoint source pollutant

reduction programs will be highly successful in defining and treating water quality problems originating from diffuse sources.

Technology will match these management programs. Treatment facilities will be commonplace on highway facilities, such that no untreated roadway runoff having the potential to impact water quality will enter receiving waters. An abundance of inexpensive, yet highly effective, Best Management Practices will be available to highway designers to incorporate into road drainage system reconstruction and retrofit projects. Sources of pollution from roadways will also be controlled. The potential for water pollutant emissions will be a factor in the design of new vehicle propulsion systems, tires, lubricants, and structural components. Closed system lubrication will largely eliminate the oil and grease now common on roadway surfaces. Finally, the effectiveness of response to transportation-related water quality problems will dramatically improve. Spill response, crash clean-up, and other emergency actions will move from its infancy today to become a highly perfected, routine practice on future highways.

By 2025, many of today's challenges facing the nation's coastal-ocean interface will be a thing of the past. A strong risk-based network of regulations and partnerships to prevent spills from all sources coupled with an integrated planning and response capability from the local to the national level is a key to the future.

Noise Pollution

The transportation industry generates considerable noise pollution, which is defined as an intrusive, unwanted sound. Aircraft, trains, buses, automobiles, and other forms of transportation produce noise pollution that can lower the quality of life. Noise can be irritating or distracting and can disrupt sleep, all of which can be harmful to health. At extreme levels, or at high levels over a long period, noise can permanently harm hearing.

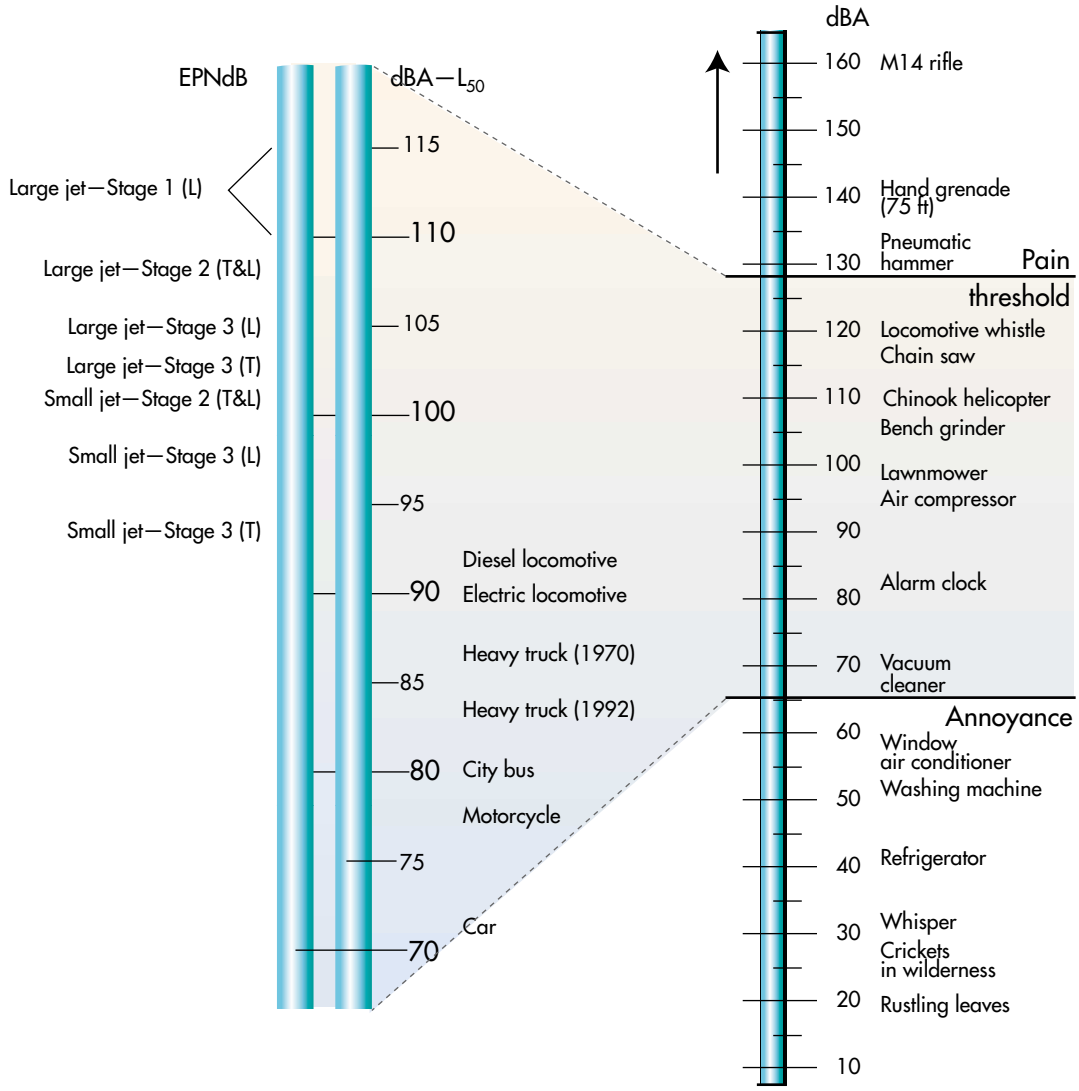
Sound is usually measured in decibels. The A-weighted scale, measuring the sound frequencies that humans can most easily hear, is the common reference point. As with the Richter Scale, which measures earthquakes, the measurements of decibels are nonlinear; a 10-decibel increase in sound on a scale of A-weighted decibels (dBA) represents a perceived doubling of sound. A vacuum cleaner operating 10 feet away is audible at 70 to 75 dBA. Noise becomes annoying at 65 dBA and painful at 128 dBA.

Noise is a purely local phenomenon, and its transmission is affected by both manmade structures and natural terrain. Therefore, because national or even regional measurements are nearly impossible, regulations are based on limiting the sources of noise pollution to safe levels. The federal Noise Control Act of 1972 authorizes the EPA to regulate transportation and other major sources of noise.

Selected vehicles are required to generate no more than certain levels of noise at prescribed distances. For example, trucks manufactured after 1988 are supposed to generate no more than 80 dBA. The limit for motorcycles varies from 70 to 80 dBA, depending on such factors as the year of manufacture. Locomotives built after 1979 must meet standards ranging from 70 to 90 dBA, depending on whether they are moving or stationary. Railcars moving at speeds above 45 miles per hour have a 93-dBA limit. Measurements are made 50 feet from the centerline of travel (figure 5-30) [USDOT FHWA 1994].

Figure 5-30

Transportation Noise Levels



Key: EPNdB = Effective Perceived Noise Level used to measure aircraft flyover noise during a specified 10-second interval. Included maximum audible sound level. Measurement is not comparable to A-weighted decibel scale.
dBA = A-weighted decibels (see text definition).
dBA—L_{50} = The sound level (measured in A-weighted decibels) exceeded by no more than 50 percent of the sample readings in the measurement time period. Peak sound level is not necessarily measured. Noise measured at a point 7.5 meters from highway vehicles and locomotives. Unless noted, highway vehicles are 1992 European models.
L = Landing noise over reference point 2,000 meters from runway threshold.
T = Takeoff noise over reference point 6,500 meters from start of takeoff roll.
Small jet = Commercial aircraft up to 100,000 lbs maximum takeoff weight.
Large jet = Up to 1,000,000 lbs maximum takeoff weight.
Stage 1 = Aircraft certified prior to 1969, before Federal Aviation Administration (FAA) noise regulations.
Stage 2 = Aircraft sound level needed to meet FAA 1969 noise regulations; now being phased out.
Stage 3 = Aircraft sound level needed to meet FAA's more stringent 1975 noise regulations.

Sources: Aircraft noise. adapted from 14 *Code of Federal Regulations*, Part 36, appendix C; Highway and railroad noise: P.M. Nelson, ed., *Transportation Noise Reference Book* (London, England: Butterworths, 1987) and T. Berge, Vehicle-Noise Emission Limits: Influence on Traffic Noise Levels Past and Future, *Noise Control Engineering Journal*, vol. 42, no. 2, March–April 1994; All other information adapted from Ann Arbor Science Publishers, Inc., *Environmental Impact Data Book* (Ann Arbor, MI: 1979).

A 1980s study estimated that 37 percent of Americans were exposed to noise levels exceeding 55 dBA from all sources; 10 percent were exposed to noise above 60 dBA; 7 percent were exposed to noise above 65 dBA; 2 percent were above 70 dBA; and 0.4 percent were above 75 dBA [OECD 1988].

Highway Noise: Highway noise is the most common form of transportation-related sound. The noise is produced by a combination of tires moving on pavement and the operation of engines, exhaust, and other vehicle systems. Traffic volume, vehicle speed, and vehicle mix are factors affecting the level of noise generated.

Highway noise can be mitigated through a variety of strategies, ranging from vehicle controls to highway design and land-use planning. Vehicle controls include quieter engines, engine sound enclosures, and improved mufflers. Proper vehicle maintenance, alone, can produce sound reductions in the 5 to 10 dBA range, and many localities enforce requirements restricting vehicle operating sounds to acceptable levels. Local agencies also sometimes employ various measures to prevent noise from affecting people, including limits on new development near roads, mandatory soundproofing, and the erection of noise barriers.

Highway design also is an effective countermeasure. Studies can determine a new roadway's potential impact on nearby communities. If the projected noise exceeds acceptable levels, alternative routes can be selected or other measures can be taken to construct the roadway in a manner that minimizes noise.

Finally, noise barriers—solid obstructions that separate roads from residences and other structures—can further reduce noise; reductions of 10 to 15 dBA are possible. Noise barriers also screen the view of roadways and can serve as a safety measure. For these reasons, their popularity as a solution to noise pollution has grown (table 5-6).

Table 5-6

Highway Noise Barrier Construction: 1970-98

	1970-79	1980-89	1990-98
Linear length (km)	281	925	1,397
Cost (millions $1998)	134	656	1,141

Source: U.S. Department of Transportation, Federal Highway Administration, *Highway Traffic Noise Barrier Construction Trends* (Washington, DC: 2000).

Aviation Noise: Aircraft noise was a minor problem during aviation's first half-century, but the advent of commercial jetliners in the 1960s made it a much more serious issue. Although the noise from aircraft is not dangerous except in unusual or extreme circumstances, it can be disruptive to sleep and conversations.

Amendments in 1968 to the Federal Aviation Act mandated standards and regulations for aircraft noise. The Federal Aviation Administration (FAA) adopted its first regulations the following year, establishing "Stage 2" standards for new turbojet and transport category aircraft. However, even in 1974, it was estimated that about seven million people were severely affected by aviation noise pollution. In 1976, the FAA required that existing planes be retrofitted to meet the Stage 2 standard.

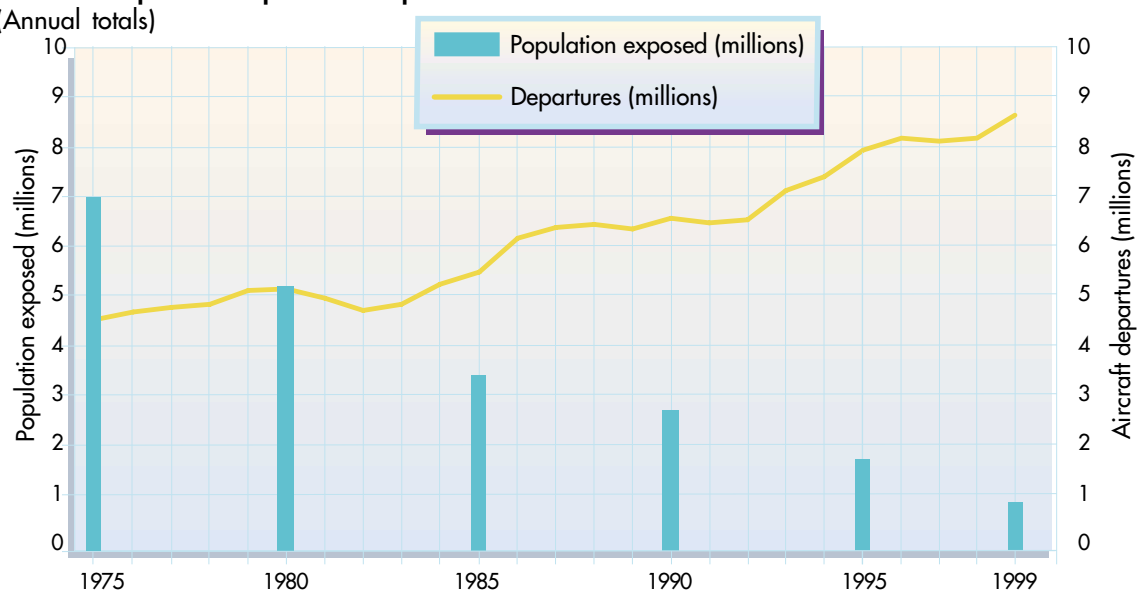
Ensuing regulations have evolved to cover virtually all aircraft. These regulations have resulted in substantially lower noise levels for aircraft operating in the United States, as well as for the affected population (figure 5-31). Today, the average aircraft generates perceived loudness of about 25 dBA less than in the 1950s (a drop of about 80 percent in perceived loudness). Perceived loudness is a scale developed in the 1950s to measure the loudness of a jet aircraft by observers on the ground. The majority of these improvements resulted from the introduction of high-bypass-ratio engine designs.

Stage 3 aircraft were made mandatory by the 1990 Aircraft Noise and Capacity Act, which restricted noise levels to between 95 and 105 dBA (at a distance of 2,000 meters on landing

approach and 6,500 meters on takeoff). All large aircraft operating within the United States had to meet Stage 3 requirements by the end of December 1999. This was accomplished, giving the United States the quietest aviation fleet in the history of the country. Many older, Stage 2 aircraft have been retrofitted with so called "hush kits" to bring them into regulatory compliance.

Figure 5-31

Estimated Population Exposed to Airport Noise Levels of DNL 65 dB or More: 1975-99
(Annual totals)



Sources: Exposure estimates: U.S. Department of Transportation (USDOT), Federal Aviation Administration (FAA), Office of Environment and Energy; Departures 1975-93: USDOT, FAA, *Statistical Handbook of Aviation (Washington, DC: Annual issues);* Departures 1994-95: USDOT, Bureau of Transportation Statistics, *Airport Activity Statistics of Certificated Air Carriers: Twelve Months Ending December 31, 1995* (Washington, DC: 1996).

In January 2001, the International Civil Aviation Organization (ICAO) will meet to set international noise standards for the next several decades. This meeting will set the stage for future FAA actions. The Clinton-Gore Administration believes that the best way to achieve such noise reduction levels is to work through ICAO to establish a new Stage 4 standard and then implement that standard.

Keys to the Future

Highway traffic noise reduction is a shared responsibility. Thus, the Federal Highway Administration encourages state and local governments to practice compatible land-use planning and control in the vicinity of highways. Source control or control of noise emissions from the vehicles themselves is a joint responsibility of private industry and of federal, state, and local governments and will be an ongoing activity in the future. Noise abatement measures also will be considered and implemented if determined to be both reasonable and feasible. The construction of noise barriers will likely continue to be the most commonly used method. Future research efforts will strive to produce more cost-effective solutions and efficient allocation of resources to deal with the problems of highway traffic noise. Emphasis is anticipated in the areas of traffic noise prediction and abatement analysis.

The Federal Railroad Administration regulates noise based on standards developed by the Environmental Protection Agency. Operations in yards, particularly switching, is the primary source of railroad noise. By 2025, railroad traffic is expected to increase by nearly 75 percent;

and if we remain vigilant, we could stem the growth in railroad noise. As rail traffic increases and more people are exposed to railroad noise, pressure may grow to impose a more stringent train noise standard.

Because of the international nature of aviation, aircraft noise standards are established by the International Civil Aviation Organization (ICAO), a specialized agency of the United Nations. In 1991, ICAO's Committee on Aviation Environmental Protection, while retaining noise reduction at the source as the preferred option, agreed to pursue a "balanced approach" to noise. This approach would consist of reducing aircraft noise, developing procedures to make operations quieter, and land-use planning to minimize the number of homes and other incompatible uses near airports. Currently, airspace redesigns and remediation measures, such as land buyouts and residential insulation, play an important role in managing aircraft noise in the United States. Moreover, the U.S. Department of Transportation is currently working with NASA on developing even quieter airplanes, and is also working through the ICAO to establish and implement a new standard—Stage 4.

Solid Waste

Transportation generates a good deal of solid waste that is either recycled or ends up in landfills. Discarded vehicles and vehicle parts and abandoned infrastructure, such as pavement from highways or rail line materials, are the major elements of transportation-related solid waste. The maintenance of transportation infrastructure can also generate solid waste, the most notable of which is disposal of silt and other material dredged from ports and harbors.

Significant improvements have been made in dealing with these elements. Much of the material generated by scrapping automobiles is currently recycled. In 1994, nearly three-quarters of the 12.8 million tons of material generated from retired automobiles was recycled. The remainder (3.5 million tons) was placed in landfills [USDOT BTS 1999]. Between 1990 and 1998, the number of scrap tires stockpiled, landfilled, and dumped annually declined appreciably, while the annual number of scrap tires generated each year increased 10 percent. The number of tires used as fuel increased nearly fivefold, reaching more than 110 million. Nonfuel markets for processed and whole tires consumed 49 million scrap tires in 1998, three times the 1990 level. Export of scrap tires has increased more modestly since 1990, from 12 million tires in 1990 to 15 million in 1998 [USEPA 1991; Scrap Tire Management Council 1999].

The railroad industry also reuses and recycles much of its old infrastructure. Almost all rails removed from mainlines are reused on secondary lines, branch lines, or yard tracks. Other track materials such as fasteners, tie plates, spikes, and anchors are reused when possible, and components such as switch stands, joint bars, and switch plates are repaired and used or sold to short lines that need lower cost products. Materials that are not reusable are sold to brokers or directly to steel mills for recycling. Wooden ties are often repaired with a chemical plugging agent to fill holes, and are then reused. Those that cannot be reused are sold as landscape materials, parking bumpers, fence posts, and retaining walls or are sold to powerplants. Only the worst ties are placed in landfills. Like wooden ties, treated timber from bridges and other structures is either reused or disposed. Used concrete ties and most plastic rail-tie components are placed in landfills. Fine materials removed from ship ballasts that have been cleaned are occasionally reused on roads [Thompson & Morehead 1996].

Approximately 14 to 28 million cubic yards of contaminated material is dredged each year. This is estimated to be about 5 to 10 percent of all dredged material [NRC 1997]. Uncontaminated dredged material can be used for beach nourishment, wetland creation, and as caps for

landfills, or it can be dumped in certain disposal sites in open waters. Contaminated material, on the other hand, may have to be treated to reduce its toxicity and managed using unique methods, increasing the costs of navigational dredging. Contaminants include heavy metals and other pollutants, such as dioxins and polychlorinated biphenyl (PCBs), that have been discharged into water and air. Contributing sources are industrial facilities within ports and upstream and nonpoint sources, such as transportation and agriculture. Contaminants reduce or injure fish and wildlife populations. Improper disposal of contaminated material can present costly environmental and human health risks.

Keys to the Future

Continued vigilance will be vital to reducing and reusing the many and varied types of solid waste generated by the transportation sector. Pressure to reduce and reuse solid waste will emanate from landfill capacity problems and NIMBY ("not in my back yard") sentiments, but also will be spurred on by technological innovations that reduce the amount of waste produced and which make recycling solid waste easier and more cost effective.

Land-Use and Habitat Effects of Transportation

The effects of transportation on land use and habitat include the impact of transportation on wetlands, the introduction of invasive species into ecosystems by transportation, and transportation and land-use interactions.

Wetlands: Since the early 1800s, the United States has lost or converted more than half of the wetlands that existed prior to European settlement. About 100 million acres of wetlands remain in the contiguous 48 states. Some states, such as California, Indiana, and Iowa, have lost more than 90 percent of their original wetlands. Much of this loss resulted from agriculture, urbanization, and infrastructure construction. In the 1960s and early 1970s, wetland loss was estimated at approximately 450,000 acres per year, primarily due to agricultural activities [USEPA 1996]. According to the U.S. Department of Agriculture resource inventories, the wetlands' rate of loss has, subsequently, declined to approximately 100,000 acres per year, not including those created or preserved through wetland restoration activities and programs, and now amounts to less than 50,000 acres per year. ISTEA and TEA-21 provided expanded funding for wetlands banking, which allows the mitigation of several or many projects at one location by combining funds to establish and manage larger wetlands complexes. This enhances wetlands functions and improves management while controlling costs.

Data on annual wetlands losses due to all transportation projects are not available, but those caused by federally funded highway construction have been available since 1996. Between 1,100 and 2,400 acres have been converted or lost annually since then (table 5-7). This represents less than 10 percent of the estimated total national loss or conversion and has been compensated at a rate of about 2.3 to 1, exceeding USDOT's performance standard of 1.5 to 1 [USDOT 1999]. In other words, wetlands are being replaced at more than twice the rate of loss in the federal-aid highway program.

Table 5-7

Wetlands Loss and Replacement for Federal-Aid Highways: 1996-99

	Acres impacted	Acres replaced	Recovery ratio	Target
1996	1,568	3,554	2.3:1	1.0:1
1997	1,699	4,484	2.6:1	1.0:1
1998	1,167	2,557	2.2:1	1.5:1
1999	2,354	5,409	2.3:1	1.5:1

Source: U.S. Department of Transportation, Federal Highway Administration, *Connecting America: 1999 Report to the Nation*, available at http://www.fhwa.dot.gov/reports/1999annual/, as of Sept. 25, 2000.

Invasive Species: Transportation influences water resources not only as a result of physical infrastructure, but also as a means by which species can be transferred between distinct ecosystems. One example of this type of problem is the zebra mussel. Zebra mussels are part of an environmental threat of invasions by non-indigenous species brought on, in part, by the increasing level of global commerce. Zebra mussels are thumbnail-sized freshwater mollusks that arrived in the United States through ship ballast water in 1986 and are projected to cause $5 billion in economic disruption to the Great Lakes region by the end of the year 2000. Since their discovery in Lake St. Clair in 1988, zebra mussels have spread throughout the Great Lakes; the Arkansas, Hudson, Illinois, Mississippi, Mohawk, Ohio, St. Lawrence, and Tennessee rivers; and other waters of southern Canada and the eastern United States. They also have been intercepted on boat trailers at four points in California.

"In its path, sprawl consumes thousands of acres of forests and farmland, woodlands and wetlands. It requires government to spend millions extra to build new schools, streets, and water and sewer lines. In its wake, sprawl leaves boarded up houses; vacant storefronts; closed businesses; abandoned, and often contaminated, industrial sites; and traffic congestion, stretching miles from urban centers."

Maryland Governor
Parris N. Glendening
A New Smart Growth Culture for Maryland

The mussels attach themselves to various surfaces, such as rocks, aquatic weeds, and industrial and residential water intake pipes. They rapidly form large reefs, reducing or blocking water flow through pipes used for municipal drinking water facilities, electric power generation, and industrial plants. By competing for the food and habitat of native species, the mussels can alter local aquatic ecosystems. They have also affected navigation, fishing, and the recreational use of beaches.

Earlier invaders, such as the lamprey and alewife, continue to affect Great Lakes fisheries. New England waters, such as Long Island Sound, are being invaded by new species on the average of one species every 36 months. The most common method of transport is via ballast water in oceangoing ships; although the organisms also can travel between lakes and rivers on boat hulls, on aquatic weeds caught in propellers, on boat trailers, and invisibly in bait buckets in their larval form. Other aquatic examples of species that have invaded U.S. ecosystems include:

- Asian clams, which filter the equivalent of the entire volume of northern San Francisco Bay more than once per day, severely disrupting the food chain;
- hydrilla, an aquatic plant that clogs waterways in 40 states and costs Florida $14 million per year to control; and
- purple loosestrife, another aquatic plant that has invaded 40 states, where it displaces native vegetation and disrupts ecosystems.

Urban Sprawl: Urban sprawl is a response to individual preferences and market signals. However, it also is the primary cause of numerous social and environmental problems, including the loss of farmland, forests, wetlands, and other natural habitats. Sprawl also is costly for government because the resulting development usually is served by new roads and single-occupant vehicles rather than more efficient transportation modes, such as mass transit, bicycling, or walking.

Sprawl is a complex, multidimensional phenomenon, with no easy solutions. There is no consensus about the severity and breadth of the problem because many of the contributing factors, such as single-family homes on large lots, low industrial and commercial structures, and abundant parking availability, are considered desirable.

Moreover, the role of transportation is not always clear. Partly this is a "chicken and the egg" question: does an extensive highway system lead to sprawl or do new highways handle the congestion created by growth? Some metropolitan areas, such as Phoenix and Milwaukee, have sprawled extensively without major highway systems. Others, such as Los Angeles, have extensive highway networks but have experienced little additional sprawl in recent years. Regardless, sprawl is inconsistent and does not occur across all metropolitan areas at the same rate.

Box 5-10

Characteristics of Sprawl

- Unlimited outward extension
- Low-density residential and commercial settlements
- Leapfrog development
- Fragmentation of powers over land use among many small localities
- Dominance of transportation by private automotive vehicles
- No centralized planning or control of land use
- Widespread strip commercial development
- Great fiscal disparities among localities
- Segregation of types of land use in different zones
- Primary reliance on the trickle-down or filtering process to provide housing to low-income households.

Source: Adapted from remarks by Anthony Downs at the University of Minnesota, Center for Transportation Studies, Transportation Research Conference, May 19, 1998, Minneapolis, MN.

The decentralization characteristic of urban sprawl is a phenomenon well entrenched in the American landscape. It was recognized as long ago as the 1920s. Researchers, at that time, identified causes of sprawl that are still applicable today: high urban property values, traffic congestion, inability to secure ample space, lack of choice locations, legal restrictions, and the desire to avoid urban problems.

"Investing in important mass transit projects...is key to rebuilding our cities and creating livable communities..." For hardworking Americans, who live in our metropolitan areas, the payoff is in a better quality of life."

Vice President Al Gore
Livable Communities Initiative
Press Release
Feb. 4, 2000

Keys to the Future

Wetlands: As the demand for wetlands mitigation increases, the costs of mitigation are expected to increase, even allowing for the increased efficiency of wetlands banking. Average mitigation costs for wetlands are expected to exceed the $20,000 per acre of mitigation provided in the immediate future and continue to increase as land values, performance demands, and technology costs increase.

The federal government also expects demands for compensatory mitigation to increase as regulatory agencies perceive continued threats and risks to existing wetlands and landscapes. This, combined with increases in the federal-aid highway program under TEA-21, is expected to result in slightly greater losses of wetlands due to additional construction, with even greater compensatory mitigation costs. The cost of compensatory mitigation in the federal-aid program is expected to exceed $100 million annually by 2010 if funding levels and construction programs continue at their current rate.

Invasive Species: The 1996 National Invasive Species Act is expected to help prevent contaminated ship ballast water from entering U.S. ports in the Great Lakes and across the country. As of July 1999, ships operating outside of U.S. waters must report their ballast water management practices to the USCG, which will enter the information into the National Ballast Water Information Clearinghouse database. The database will aid the USCG in identifying the patterns of ballast water management and delivery in U.S. waters. The USCG's ballast water program regulates discharges of ballast water in U.S. waters, while fostering the research and development of new technologies and management procedures that will greatly

Box 5-11

Clinton-Gore Livable Communities Initiative

Haphazard development patterns, disinvestment in older communities, and a deteriorating quality of life have led to concern about the livability of communities. Problems such as these, resulting from existing development patterns, have led many states and localities to adopt growth management laws over the past few decades.

Recently, these concerns have led to the "smart growth" or "livable communities" movement and the Clinton-Gore Administration's Livable Communities Initiative. The Livable Communities Initiative is aimed at broadening choices available to communities and empowering them to sustain prosperity and expand economic opportunity by strengthening local and regional economies, reclaiming brownfields, achieving a more favorable jobs-housing balance, and encouraging smart growth.

The initiative also seeks to enhance the quality of life by preserving open space; easing traffic congestion; securing safe streets; enhancing air and water quality; and ensuring that families have places and more time to walk, play, and relax with neighbors and friends. The initiative also hopes to build a stronger sense of community by creating community-centered schools, preserving local cultural heritage, and empowering individuals and communities with the information and tools they need to create the communities they desire. A whole range of initiatives has been developed in a variety of areas to accomplish this, including the Redevelopment of Abandoned Buildings Initiative, Regional Crime-Data Sharing, Community Transportation Choices, Land Acquisition Grants, and the Farmland Protection Program.

One way in which the U.S. Department of Transportation is supporting Livable Communities is by encouraging participation in transportation projects that include the use and redevelopment of contaminated "brownfield" sites when appropriate.

reduce the risks posed by shipping. Since invasive species are broadly recognized as a global problem requiring a global solution, there is a sense of optimism that the concerted efforts underway today to find technological solutions will be rewarded with significant breakthroughs soon. If we remain vigilant, by 2025, we will have developed environmentally sound methods to completely minimize the impacts of invasive species.

Urban Sprawl: Although urban sprawl is attributable to a series of factors, many have little relationship to transportation. Moreover, many of the factors contributing to sprawl are viewed as desirable by the public and, therefore, cannot be readily altered. However, factors such as home ownership and decreasing household size will change naturally over time, and their effects on sprawl will wane. It is likely that in the near future urban sprawl will be more a function of population growth; it is even conceivable that lower labor force participation rates, increasing household size, lower home ownership rates, and smaller lot sizes will contribute to more compact cities in the future. These offer promise toward declining rates of sprawl and need to be coordinated with new transportation initiatives to produce livable cities.

Box 5-12

Environmental Streamlining

Environmental streamlining refers to a new way of doing business to achieve both the timely completion of transportation projects and environmental protection. Enacted into law for highway and transit projects with the passage of TEA-21, environmental streamlining consists of cooperatively establishing and adhering to realistic project development schedules among government transportation and environmental agencies.

Because major transportation projects are affected by dozens of federal, state, and local environmental requirements administered by a multitude of agencies, such cooperation ensures that projects meet environmental standards without delay. Strategies include pilot efforts, process reinvention, alternative dispute resolution, and a focus on performance evaluation. Experience in implementing environmental streamlining may point to the need for revisions to transportation or environmental laws or regulations.

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