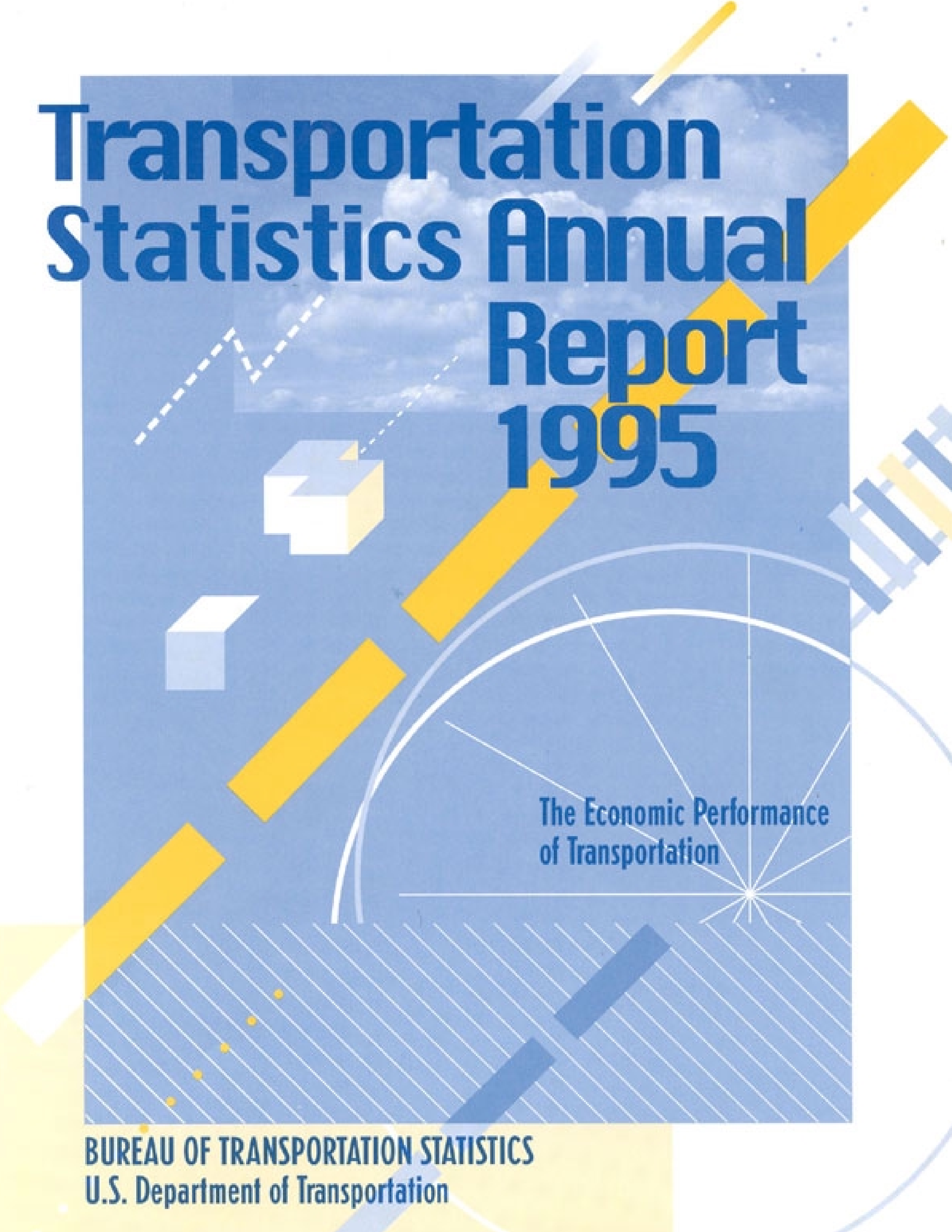

# Transportation Statistics Annual Report 1995

## The Economic Performance of Transportation

BUREAU OF TRANSPORTATION STATISTICS
U.S. Department of Transportation

# TRANSPORTATION STATISTICS

# *Annual Report*

# 1995

**Bureau of Transportation Statistics**

**U.S. DEPARTMENT OF TRANSPORTATION**

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# STATEMENT *of the* DIRECTOR

The Bureau of Transportation Statistics (BTS) of the U.S. Department of Transportation has prepared the 1995 *Transportation Statistics Annual Report,* as required by the Congress in Section 6006 of the Intermodal Surface Transportation Efficiency Act of 1991, to provide a comprehensive assessment of the state of the nation's transportation systems and the state of transportation statistics.

*The Transportation Statistics Annual Report* is an evolving document. Last year's inaugural edition followed an encyclopedic approach, providing a baseline of information on various aspects of the extent, condition, use, performance, and consequences of transportation. This second edition adds a thematic section to provide greater depth on major topics. This year's theme, "Transportation and Economic Performance," includes: the trends in and factors governing *productivity* of transportation service providers, the *contribution* that public investments in transportation make to the overall economy, and the impacts of economic growth and change on *the use and costs* of highways, aviation, water transportation, and public transit.

## The State of the Transportation System

### The U.S. Transportation System

The U.S. transportation system carries over 4 trillion passenger miles of travel and 3 trillion ton miles of domestic freight generated by more than 258 million people, 6 million business establishments, and 86 thousand units of government. The system includes 3.9 million miles (6.3 million km) of public roads, 1.4 million miles (2.3 million km) of oil and natural gas pipelines, 123 thousand miles (198 thousand km) of railroads, over 25 thousand miles (41 thousand kilometers) of commercially navigable waterways, over 5 thousand public-use airports, 503 public transit operators in 314 urbanized areas, and 145 major ports on the coasts and inland waterways. In 1992 the system carried 2.3 trillion miles (3.7 trillion km) of travel by cars and trucks, 8.4 billion trips on public transit, 442 million passenger boarding on airplanes, and 22.1 million trips on Amtrak. School buses alone carried more than 9 percent of the U.S. population during a typical school day.

Sustained growth in personal transportation activity in the last half century shows signs of leveling off as growth in population and the labor force declines, the U.S. approaches saturation of vehicle ownership and driver's licenses, and the amount of migration among regions of the country declines. However, the growth in personal transportation activity may receive new impetus from immigration, continued development of travel patterns by women, and increased travel by the younger and older populations and by low income groups.

Long-term trends in freight transportation activity are characterized by continued growth, partly due to the initial impacts of the North American Free Trade Agreement (NAFTA). Trade among the three NAFTA partners has increased, generally following the geographic patterns and commodity composition that existed in the years just prior to the Agreement. Land transportation modes have increased their dominance of trans-border freight movements, carrying nearly 90 percent of commodities in terms of value moving across the U.S. borders with Canada and Mexico.

The condition and performance of the transportation system are a mixed picture. For highway transportation, pavement conditions have been improving, congestion has been worsening slightly, and bridge conditions have stabilized. Public transit performance has been improving in terms of speed. But some problems remain: more than one-fourth of transit riders cannot find a seat, half must endure transfers, and one-fifth waited more than 10 minutes for their ride. On-time performance of major air carriers was down slightly in 1993 to 82 percent of flights, while Amtrak's short-distance trains declined slightly to 79 percent on time that year. On-time performance of Amtrak's long-distance trains plunged to only 47 percent partly as a consequence of the Midwest floods. The disruptions to transportation in 1993 caused by floods were followed in 1994 by the disruptions of the Northridge Earthquake. The earthquake demonstrated the surprising resilience of the transportation system in Los Angeles; the loss of major freeway segments was accommodated through creative traffic operations on parallel surface streets, through the rapid implementation of new commuter rail and bus services, and through temporary adjustments in ridesharing and other behavior of commuters.

## Expenditures on Transportation

The U.S. spends over one trillion dollars on transportation in a year. When intermediate expenditures (such as fuel purchases by for-hire carriers that are then paid for by shippers) are removed, gross domestic product (GDP) attributable to transportation demand was $687.7 billion in 1993, accounting for 11 percent of GDP. This proportion has held fairly steady at least four years. Households in 1993 on average spent $5,453 for transportation, representing nearly 18 percent of household expenditures. Households in higher income groups spend a larger proportion of their income on transportation than lower income groups, mainly because they purchase more vehicles per household, purchase more expensive vehicles, and travel farther. Purchased transportation is a small percentage of household transportation spending, and rises slowly with income.

In the public sector, governments spent over $113 billion on transportation in 1992. Less than one-third of transportation expenditures were by the federal government. Transportation accounts for 1.0 percent of all expenditures by the federal government, 9.3 percent of all expenditures by state governments, and 8.3 percent of all expenditures by local governments. Over 70 percent of government transportation expenditures were off-set by $80 billion in gasoline taxes and other transportation revenues collected at all levels of government.

## Unintended Consequences of Transportation

While transportation is part of every good and service in the economy and provides highly valued mobility for daily life in the U.S., it also creates a variety of undesired consequences. These consequences are large, which is not surprising given the enormous size of the U.S. transportation system. In 1993, transportation accounted for 43,179 deaths and 3,159,000 injuries. Transportation-related energy use reached its highest-ever level at 22.9 quadrillion Btu, leading to the highest degree of oil import dependence since 1977. Carbon dioxide ($CO_2$) emissions from transportation continued a steady increase, reaching 408 million metric tons of carbon in 1992.

Public and private actions taken over the last two decades to mitigate such problems created by transportation appear to have been beneficial. For example, during the two decades of considerable growth in vehicle travel ending in 1992, total transportation fatalities and injuries, *rates* of transportation fatalities and injuries, transportation energy use intensities, and emissions of air pollutants (“criteria pollutants”) have all been slowly declining. Had transportation fatality rates remained at 1972 levels, *twice* as many lives would have been lost in transportation accidents in 1992. At 1972 rates, the transport sector in 1992 would have used 3.8 quads more energy than it actually did, would have produced several times as much pollution, and would have generated 15 percent more $CO_2$ emissions.

Based on an analysis by BTS, the decline in nonhighway traffic fatality rates between 1972 and 1992 can be attributed almost equally to the shifting of traffic to modes with lower fatalities (largely an increase in commercial air travel), and to general decreases in accident rates per passenger mile. Fatalities per accident remained essentially unchanged. In the case of nonhighway injuries, which declined more steeply than fatalities, reductions in accident rates and changes in modal structure are nearly equally responsible for the improvement. In contrast to other modes, reductions in the number of highway fatalities and injuries per accident played a major role in improving safety per passenger mile.

BTS has set U.S. experience with transportation-related $CO_2$ emissions in an international perspective with a comparative analysis of similar trends in seven major industrialized countries, the so called G-7 countries. $CO_2$ emissions from transportation grew faster than total $CO_2$ emissions of the overall economy in the U.S. and other G-7 countries, and per capita $CO_2$ emissions continued to increase as well. The factors which have driven the shifts in transportation energy use and $CO_2$ emissions in these countries include the growth in the scale and evolving modal composition of passenger and freight flows, changing energy intensity of different modes of transportation, increasing personal propensity to travel, and changing vehicle occupancy rates and load factors.

## The State of Transportation Statistics

A variety of research projects have been initiated in recent years to improve the scope and detail of information on transportation and its consequences. Surveys of commodity and passenger flows are underway or being processed for the first time in 15 years. New data collections and analyses related to the role of transportation in the economy are planned. Data on the locations and interrelationships of transportation facilities, services, flows, sources of demand, and impacts are being compiled and integrated through geographic information systems technology into a National Transportation Atlas Database. BTS is disseminating data and analyses widely through printed reports, CD-ROMs, the Internet, and other formats at no cost to the customers. Continued progress is planned toward developing and disseminating widely an increasingly complete picture of the transportation system, its costs, and its benefits.

Potential future disruptions, highlighted in last year’s *Transportation Statistics Annual Report,* continue to threaten the quantity and quality of statistics. The content of the decennial census and methods used by the Bureau of the Census to create invaluable small-area transportation data nationwide are extremely vulnerable for the year 2000. The Standard Industrial Classification system is also faced with changes that may undermine the ability to collect, tabulate, and analyze data for understanding the role of freight and passenger transportation in the economy.

New challenges include international transportation and performance measurement. With respect to the former, the transportation community depends heavily on foreign trade and tourism data to identify the growing demands of international activity on the domestic transportation system. Customs modernization and related initiatives provide opportunities for improvements to the utility of these data, but could also result in significant data loss. With respect to performance measurement, greater emphasis is being placed on the transportation community in general and the Department in particular to understand the economic, social, environmental, safety and other outcomes of transportation, and not just transportation's inputs (such as fuel and expenditures) and outputs (such as quantity of travel). The challenge remains to define measures that identify in understandable terms whether conditions are getting better or worse, and why those conditions are changing.

## Transportation and Economic Performance

The thematic section of the 1995 *Transportation Statistics Annual Report* addresses three salient features of economic performance:

—*Productivity:* How efficiently do for-hire transportation providers move people and goods? Does the value of these transportation services grow more rapidly than the costs of inputs used to produce these services?

—*Economic impact of transportation investment:* What contribution does public investment in transportation facilities make to overall economic performance? Do these investments reduce the costs of moving people and goods, and by how much? What gains in national economic output derive from public investment in transportation?

—*Impact of economic growth on infrastructure use and costs:* How do changes in regional and national economies affect industry and household patterns of use of transportation? How do these patterns of costs and infrastructure use vary as the economy grows and undergoes technical and structural change?

### Transportation Productivity: Trends and Prospects

The Bureau of Labor Statistics (BLS) publishes annual measures of labor productivity for five for-hire transportation industries, which cover 39 percent of employment in the transportation sector. Between 1958 and 1992, the labor productivity of railroads has grown 5.9 percent per year; that of air transportation has grown 4.4 percent per year; labor productivity of petroleum pipelines and trucking have grown respectively by 4.1 percent and 2.9 percent per year; and the productivity of intercity buses has not grown.

While the BLS estimates of productivity have the advantage of being organized around the Standard Industrial Classification system, they do not apply to transport activity carried out in many manufacturing and retail firms. The value of this in-house transportation activity (unrecorded in official statistics because it involves no transactions between firms) was estimated at 65 billion dollars in 1987.

The BLS productivity estimates are based on a consistent framework, which has been refined over the years by applying economic theory, new data sets, and index numbers. However, recent social, economic, and political changes have raised issues that these conventional methods are less suited to address. These involve

—*Compositional changes* in the American economy, especially the growing importance of service industries;

—*Institutional changes,* such as evolving forms of economic regulation and environmental controls;

—*Technological changes*, which affect both transportation service providers and the needs of their customers; and

—Increasing pressures on *highways, airports, and other public transportation infrastructure.*

Productivity analysts, including those at BLS, are enhancing their methods to better address these changes—but analytical frameworks may be needed that will allow the changing economic environment to be more fully taken into account when evaluating transportation performance. BTS identifies different ways it can, through data collection and research efforts, contribute to productivity analyses by BLS, other government agencies, and academia.

### Transportation Investment and Economic Performance

The relationship between the growth of regional or national economies and transport infrastructure is reciprocal. Over the last two centuries, transportation has clearly played a part in determining the regional structure and spatial character of the U.S. economy; transportation continues to exert its influence today. There is evidence that public investment in transportation capital reduces costs of transportation and production, and contributes to economic growth and productivity. At the same time, changes in the economy affect the use of transportation facilities and services by households and businesses.

The nature and magnitude of these reciprocal relationships between transport public capital and the overall economy have great policy relevance. Indeed, in recent years a good deal of empirical research has been directed at the issue of the contribution that public investments in transportation make to economic growth and productivity in the U.S. Some studies conclude that decreasing public investments in infrastructure played a large role in the country's recent productivity slowdown, while other studies suggest that highways and other forms of public capital make no marginal contribution to private production in the U.S. (i.e. that the country is saturated with highways). *A clear majority of these studies conclude that highway capital makes a positive contribution to total economic output, although small relative to private labor and capital inputs.* Studies in Europe and Asia also find positive contributions of transportation infrastructure to national economies. The findings are, however, sufficiently varied to suggest that the ways in which transportation affects overall productivity are not fully understood, and warrant further inquiry.

During the period of substantial growth and structural change in the U.S. economy between 1977 and 1987, the use of highways, public transit, commercial aviation, and water transportation increased significantly. This increase was greater among industries (22.4 percent) than households (10.5 percent), and exceeded the 2.4 percent annual growth of the economy. Industry use of trucking grew in particular, driven in part by greater use of just-in-time logistics systems which required smaller, more frequent shipments. During that period of growth in highway use, highway net capital stock *declined* $6.7 billion in 1977 dollars, or 2.4 percent of its value in 1977. Further work is needed to update and understand these figures.

Much of the increased use of transportation by economic sectors derives from growth in high value-added industries such as services and durable goods manufacturing. These industries also increased their proportional share of air transport. While the material intensity in the overall economy may have declined—indicating less material transport per unit output—the rise in new logistics systems may signify more use of highways and air transportation facilities.

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The summary of transportation statistics programs and many of the tables and graphs pioneered in last year's *Transportation Statistics Annual Report* have been incorporated into the companion volume, *National Transportation Statistics.* The 1995 edition of *National Transportation Statistics* contains modal profiles, transportation trends, data on transportation and the economy, and energy aspects of transportation. Most data series in the 136 tables and 57 graphs cover 1960 through 1992. These tables are also available as spreadsheets on the Internet and on disk.

The second edition of *Transportation Statistics Annual Report* and the twenty-third edition of *National Transportation Statistics* represent a continuing evolution of the BTS effort to make the nation aware of its transportation resources. BTS encourages the reader to provide comments on these volumes so that future products respond to the needs of decisionmakers and the transportation community.

T. R. Lakshmanan

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# Abbreviations

| | |
|---|---|
| AAR | Association of American Railroads |
| AFV | Alternative-fuel vehicles |
| ATA | American Trucking Association |
| ATS | American Travel Survey |
| BAC | Blood alcohol concentration |
| BEA | Bureau of Economic Analysis |
| BLS | Bureau of Labor Statistics |
| BN | Burlington Northern |
| BTS | Bureau of Transportation Statistics |
| CAAA | 1990 Clean Air Act Amendments |
| CAFE | Corporate Average Fuel Economy |
| Caltrans | California Department of Transportation |
| CD-ROM | Compact Disk, Read Only Memory |
| CFS | Commodity Flow Survey |
| CNG | Compressed natural gas |
| CO | Carbon monoxide |
| $CO_2$ | Carbon dioxide |
| DLGs | Digital Line Graphs |
| DOE | Department of Energy |
| DOT | Department of Transportation |
| EPA | Environmental Protection Agency |
| FAA | Federal Aviation Administration |
| FGDC | Federal Geographic Data Committee |
| FHWA | Federal Highway Administration |
| FRA | Federal Railroad Administration |
| FTA | Federal Transit Administration |
| G-7 | Group of 7 nations |
| GATT | General Agreement on Tariffs and Trade |
| GDP | Gross Domestic Product |
| GIS | Geographic information systems |
| GM | General Motors Corporation |
| HOV | High occupancy vehicle |
| HPMS | Highway Performance Monitoring System |
| HS | Harmonized System |
| ICC | Interstate Commerce Commission |
| INS | Immigration and Naturalization Service |
| ISTEA | Intermodal Surface Transportation Efficiency Act |
| JIT | Just-in-time |
| km | Kilometer |
| LPGs | Liquefied petroleum gases |
| LTL | Less-than-truckload |
| MFP | Multifactor productivity |
| mmt | Million metric tons |
| mpg | Miles per gallon |
| $N_2O$ | Nitrous oxide |
| NAFTA | North American Free Trade Agreement |
| NAICS | North American Industry Classification System |
| NBTA | National Bus Traffic Association |
| NHS | National Highway System |
| NHTSA | National Highway Traffic Safety Administration |
| NIPA | National Income and Product Accounts |
| $NO_x$ | Nitrogen oxide |
| NPTS | Nationwide Personal Transportation Survey |
| NRC | National Research Council |
| NSDI | National Spatial Data Infrastructure |
| NTS | National Transportation Statistics |
| $O_3$ | Ozone |
| OECD | Organisation for Economic Cooperation and Development |
| OMB | Office of Management and Budget |
| OPEC | Organization of Petroleum Exporting Countries |
| ORNL | Oak Ridge National Laboratory |
| Pb | Lead |
| PM-10 | Particulate matters of 10 microns in diameter or smaller |
| PPI | Producer Price Index |
| ppmv | Parts per million volume |

| | |
|---|---|
| PPPs | Purchasing Power Parities |
| RCI | Roadway Congestion Index |
| RPMs | Revenue passenger miles |
| RR | Railroad |
| SIC | Standard Industrial Classification |
| $SO_2$ | Sulfur dioxide |
| STCC | Standard Transportation Commodity Classification |
| STRAHNET | Strategic Highway Corridor Network |
| TFP | Total factor productivity |
| TIUS | Truck Inventory and Use Survey |
| TL | Truckload |
| TMIP | Travel Model Improvement Program |
| TOFC | Trailer on flat car |
| TPER | Total primary energy requirement |
| TSAR | Transportation Statistics Annual Report |
| UK | United Kingdom |
| US | United States |
| VMT | Vehicle-miles travelled |
| VOCs | Volatile organic compounds |
| ZEV | California Zero Emission Vehicles |

Note: A more complete list of abbreviations is contained in *Transportation Acronym Guide*, published by the Bureau of Transportation Statistics.

# PART I:

# *The*
# STATE *of the*
# TRANSPORTATION
# SYSTEM

# *The* TRANSPORTATION SYSTEM

The U.S. transportation system blends infrastructure, services and activity to produce over four trillion passenger miles of travel and almost four trillion ton miles of domestic freight, serving more than 258 million people, six million business establishments, and 86 thousand units of government. The use, extent, conditions and physical performance of this system are highlighted in this chapter. General trends in passenger and freight activity are described, followed by mode-by-mode summaries of system extent and use, and condition and performance. Events of 1994 that caused momentary or lasting departures from long-standing trends in transportation activity are also described.

The physical transportation system and its use can be described by using a variety of measures. (See Table 1–1.) While the system has expanded relatively little in recent years, its use continues to grow significantly. Passenger transportation is dominated by motor vehicles, while freight transportation is divided more evenly among the modes. (See Figures 1–1 and 1–2.) More detailed information about the physical transportation system and its use is to be found in the *National Transportation Statistics* (NTS), which is another publication of the Bureau of Transportation Statistics and a companion volume to this Report.

## Trends in Personal Transportation Activity

Sustained growth in personal transportation activity in the last half century shows signs of leveling off. However, forces of change could stimulate new growth in future travel demand.

### Elements of Stability

Several factors contribute to stability in demand for personal travel, including:

- Declining population growth as well as lower growth in the labor force;
- Saturation of vehicle ownership and drivers' licenses; and
- Slowing internal migration.

## TABLE 1–1

### The Transportation System in Summary: 1993

**Highways**
- 3,904,721 miles of public roads (6,282,696 km of public roads)
- 2.3 trillion miles of vehicle travel (3.7 trillion km of vehicle travel)
- 331 million intercity bus riders
- 871 billion ton-miles of freight (1.3 trillion tonne-km of freight)
- 5.8 million employees in highway

**Railroads**
- 122,843 miles or railroad routes (197,654 km of railroad routes)
- 22.1 million trips on Amtrak
- 1.1 trillion ton-miles of freight (1.61 trillion tonne-km of freight)
- 217 thousand employees in Class I RR & Amtrak

**Air**
- 5,538 public-use airports
- 442 million passenger boardings
- 10.5 billion ton-miles of freight (15.3 billion tonne-km of freight)
- 323,000 airline & airport employees

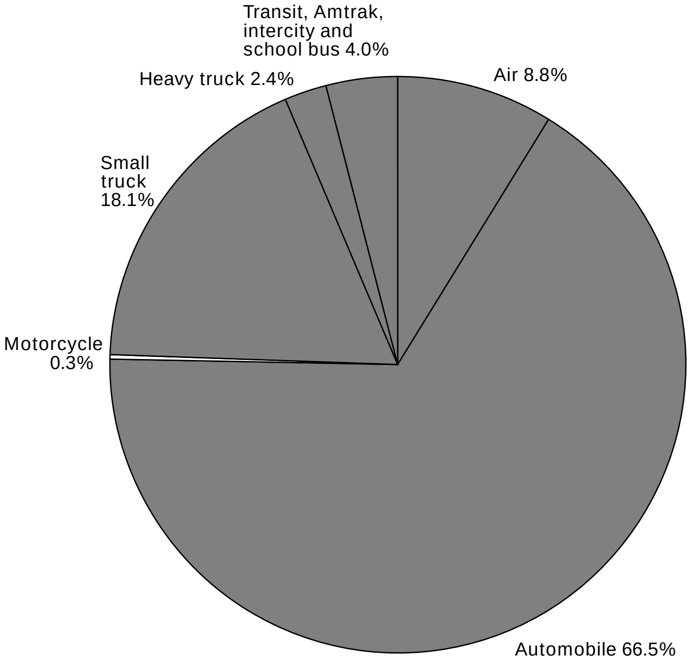
**Water Transport**
- over 25,000 miles of commercially navigable waterways.
- 196 commercial ports (ports receiving commerce over 1,000,000 tons)
- 946 billion ton-miles of freight (1.4 trillion tonne-km of freight)
- 343,000 employees

**Transit**
- 8.4 billion passenger trips
- 503 operators in 314 urbanized areas
- 292,000 employees

**Pipelines**
- 575 billion ton-miles of freight (840 billion tonne-km of freight)
- 1.5 million miles of oil & natural gas pipelines (1992) (2.3 million km of oil & natural gas pipelines (1992))
- 201,800 employees of oil & natural gas pipelines

## FIGURE 1–1

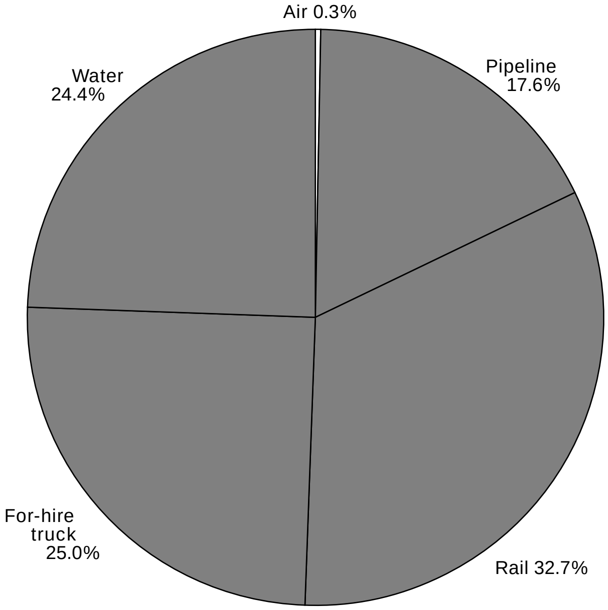
### Passenger Miles: 1992



Source: NTS 1995, Table 6.

## FIGURE 1–2

### Ton-Miles of Intercity Freight: 1992



Note: Private trucking is excluded for lack of available data.

Source: NTS 1995, Table 7.

*Population*. The growth of the U.S. population between 1980 and 1990 was measured at 9.8 percent. That period was the only time in the nation's history, other than the decade of the Great Depression of the 1930s, when population growth dropped below 10 percent. Had there been no immigration, the natural increase in population would have been closer to six percent.

Population growth by itself is no longer a major factor in rising transport demand for the United States. Importantly, the number of persons coming of driving age in the next two decades will be well below historic levels. The number of 18-year-olds peaked at 17.4 million in 1980, will fall to 14 million in 1995, and is not projected to exceed the 1980 figure again until around 2010. Relative to figures in other developed countries, U.S. population increase (at about 1 percent annually—the same as China) is high; European countries such as France, Germany, Italy, and Spain have annual growth rates ranging from 0.1 to 0.4 percent. Japan's rate of increase is also low, at 0.4 percent. Immigrants to the United States are a major component of the expected growth, and immigrants have a far more immediate impact on travel activity than does growth through births, because most immigrants are in their twenties and thirties.[1]

*The labor force.* In the 1980s America had an extraordinary increase in labor-force participation and employment—registering a 19 percent increase in employed workers, nearly double the rate of population growth. It appears that the last surge of the two forces impelling a boom in workers has now spent its course. Those forces were the coming of working age of the post-World War II baby boom and the addition of women to the work force in far greater numbers than in the past. Although the labor force will not grow at the high rates of the last decade for the foreseeable future, the absolute numbers of new participants in the labor force will still be substantial.

*Drivers' licenses.* The greater number of persons with drivers' licenses has been a major factor in more travel by the average person, particularly among women. The number of trips and the distances traveled have both risen. Over 90 percent of all males and females in every age group after teenagers are licensed drivers (except for the oldest groups of women). As younger females with high percentages of licenses move into the over-65 age groups, the oldest groups can be expected to have the great majority of their members licensed to drive. Since most of those able and willing to drive are licensed, growth in the proportion of licensed drivers in the population ceases to support growth in the proportion of licensed drivers in vehicle use.

*Vehicles owned or available for use.* There is clear evidence of stability in U.S. vehicle ownership. The number of vehicles per worker actually declined slightly between 1980 and 1990—from 1.34 to 1.32 vehicles on the average. The share of households with three or more vehicles actually declined slightly (by about a 1 percent decrease in share). The overall pattern of auto ownership seems to have stabilized. (See Figures 1–3 and 1–4.)

*Domestic migration patterns.* For at least the past 50 years the United States has experienced major changes in internal migration patterns. There was, for example, the shift away from the "rust belt," those states located from the East Coast to the Great Lakes, where major employment was found in older industrial activities. Population growth took place in the "Sunbelt," the warmer areas in the South, stretching from Florida to California. During the 1970s and early 1980s more than 90 percent of national growth went to the South and West of the United States—more than half of it in Texas, Florida and California. These trends have moderated. California, which had historically grown at twice the national rate, had a growth rate of less than the national average from July 1992 to July 1993.

As workers age, the tendency to move long distances for job-related reasons declines. With the aging of the U.S. population, the explosive growth of many metropolitan areas of the Southwest—along with accompanying transportation demands—can be expected to moderate.

## Forces for Travel Change

While many components of travel demand are no longer growing as in the past, several continue to be important:

- Increasing rates of immigration;
- Continuing evolution in women's travel;
- Travel growth by both younger and older populations; and
- Increasing travel by persons with lower income.

*Immigration.* Almost 40 percent of the U.S. population increase during the 1980s came from immigration, largely from Central and South America and Asia. There have been extraordinary levels of immigration in recent decades. (See Figure 1–5.) The impact on transportation demand comes from young immigrants.

FIGURE 1–3

Auto Ownership—Registered Vehicles by State: 1992

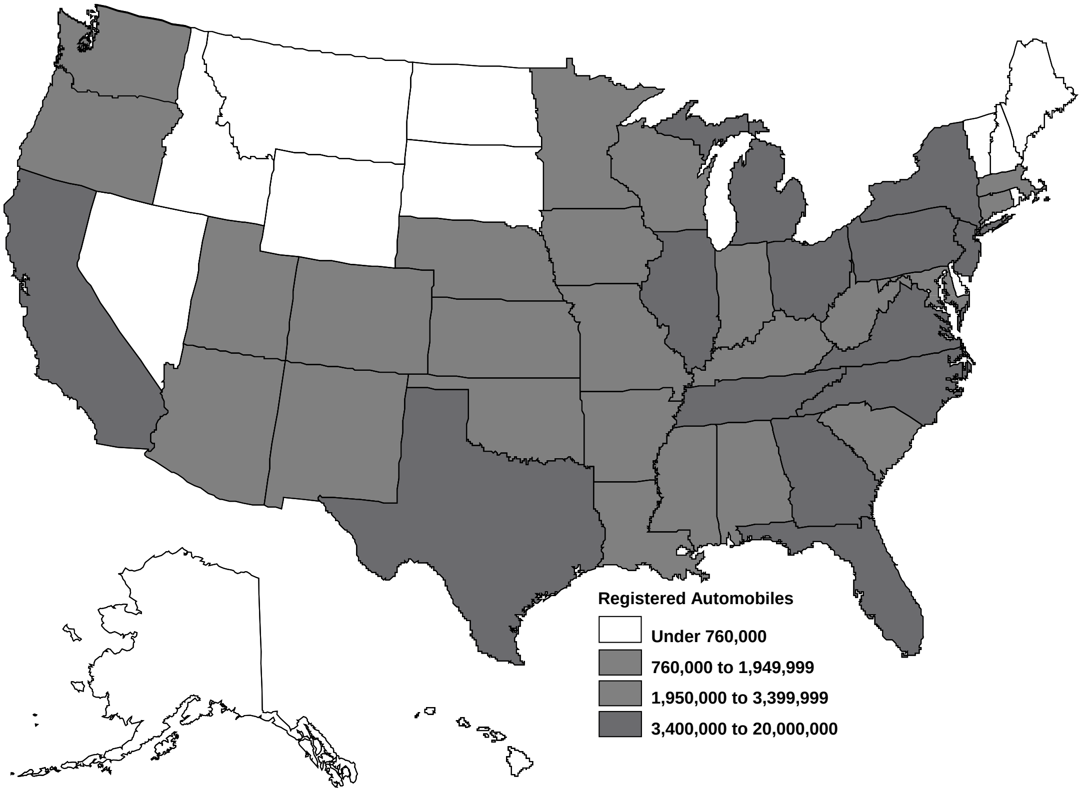


FIGURE 1–4

Auto Ownership—Per Capita Registration of Vehicles by State: 1992

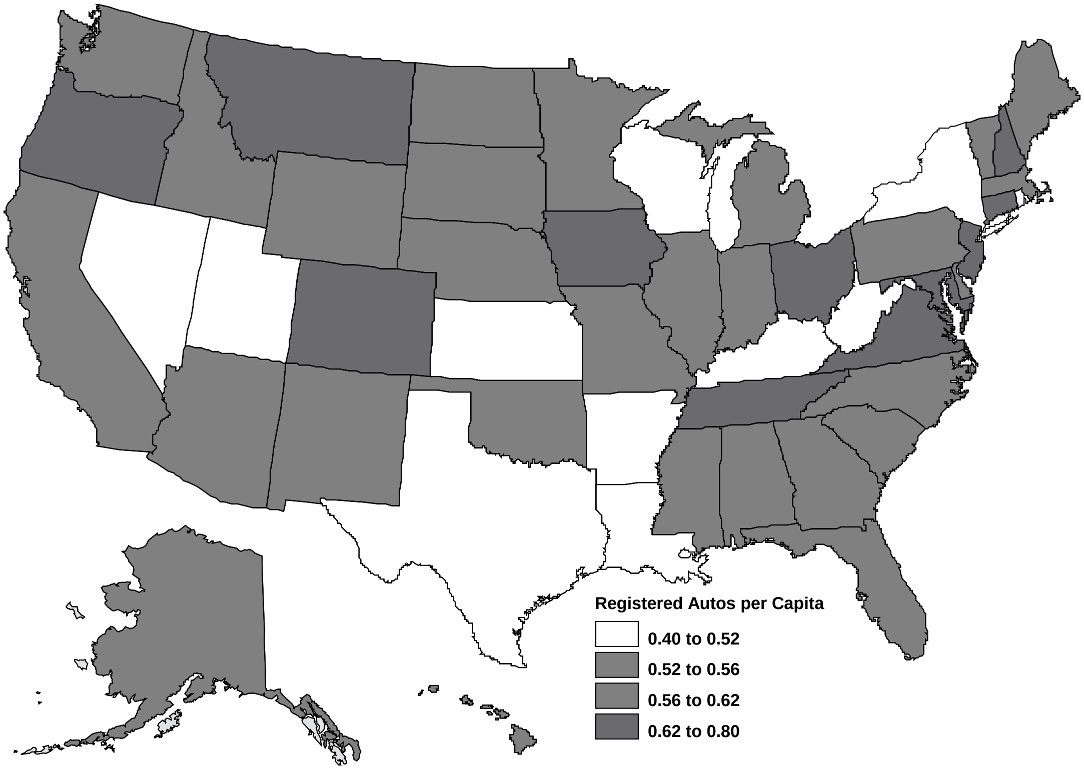
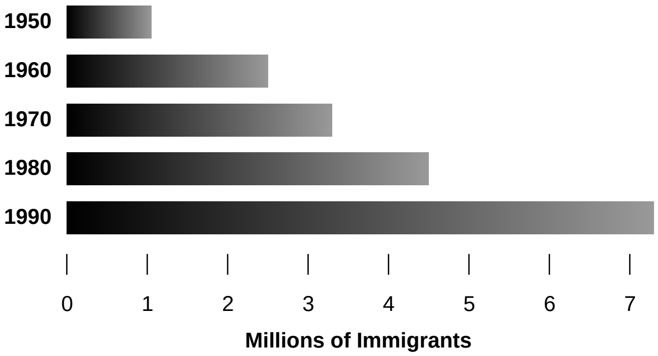


**FIGURE 1–5**

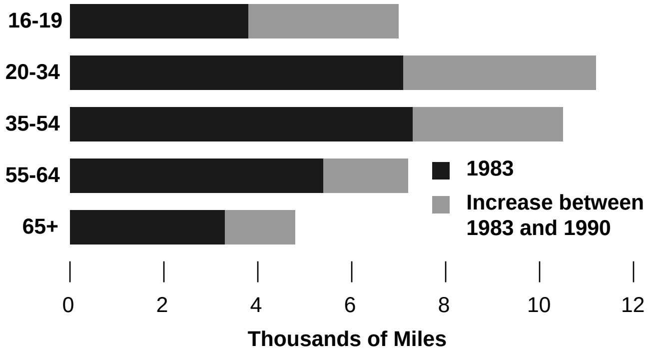
Foreign Immigration: 1950-1990



About 80 percent of immigrants are of labor-force age, and most immigrants locate in metropolitan areas. Continued immigration growth at recent rates will have a major influence on increasing urban travel demand.

**FIGURE 1–6**

Distance Driven Annually by Females by Age Group: 1983 and 1990



*Highway travel by women.* Many factors increasing travel by women have matured over the past decade, such as a higher proportion of licensed women drivers and a greater percentage of women in the work force. There are recent increases in travel by women. (See Figure 1–6.) In 1990 women's daily numbers of trips exceeded those of men, although the overall travel volume of men remained greater because of the longer average lengths of men's trips.

**TABLE 1–2**

Female/Male Travel Ratios for Selected Countries

(1.0 indicates equal travel for both groups)

| Country | Ratio for All Travel | Ratio for Vehicular Travel |
|---|---|---|
| U.S. | 0.82 | 0.63 |
| Great Britain | 0.64 | 0.54 |
| The Netherlands | 0.64 | 0.44 |
| Denmark | 0.67 | 0.30 |

The ratio of female travel to male travel is a measure of mobility in a society. (See Table 1–2.) There are few countries for which such information is available. Household travel data collection is underway in national surveys in France and Sweden this year; when those surveys are complete, additional comparative calculations will be possible.

**TABLE 1–3**

Percentage of Licensed Drivers, by Gender (of the Adult Population)

| Country | Percent Male Drivers Licensed | Percent Female Drivers Licensed |
|---|---|---|
| U.S. | 0.93 | 0.86 |
| Great Britain | 0.80 | 0.49 |
| The Netherlands | 0.85 | 0.65 |

The availability of vehicle operator licenses to women and to men can be compared between a few countries. (See Table 1–3.) Far more persons, male and female, are licensed to drive in the United States than in Britain or the Netherlands. It should be noted that these figures are influenced by labor force participation; working males and females are more likely to have licenses, and U.S. labor force participation is greater than in Europe.

*Growth in travel by the young and old.* The growth of travel by the youngest and oldest age groups in the United States has been great. More change may occur, but the rate of change has slowed. Travel demand nationally continues to rise because today's 20-year olds make more trips than those of past generation (and young females have increased their trip-making to equal that of males), while those of 65 and older likewise make more trips (and today's older females, unlike those of the past, are making nearly as many trips as older males).

*Travel by persons of low income.* Those with lower incomes typically travel less and own fewer vehicles. But as vehicles have become more ubiquitous, used vehicles have become increasingly available; with average vehicle ages going up, used vehicles can be more affordable. While the number of those who are poor may not be falling, the proportion of the U.S. population with access to a vehicle has been growing, and more travel by car is likely. As greater proportions of the lower-income populace come to own cars, there is likely to be some decline in carpool use, in transit patronage, and in pedestrian travel. Overall, though, as car ownership by those with lower incomes rise, the result will be greater demand for travel.

### Summary Effects on Travel Patterns

While some social and economic changes are having less effect on travel demand, other influences still apply. Rising levels of travel are to be expected. The rate of increase may not continue growing, and past patterns of explosive demand in Sunbelt metro areas may not be repeated, but the average person in future years is likely to travel more, unless constrained by environmental problems, finances, or road capacity, or attracted by transportation substitutes such as telecommuting.[2]

## Trends in Freight Activity and Initial Impacts of NAFTA

The long-term trends in freight transportation activity are characterized by continued growth. Part of the growth is due to general economic liberalization within Mexico as a result of its joining The General Agreement on Tarrifs and Trade (GATT), passage of the U.S.–Canadian Free Trade Agreement, and implementation of the North American Free Trade Agreement (NAFTA). NAFTA is the most recent, and has particularly significant potential impacts on the U.S. domestic transportation. Some elements of the NAFTA treaty took effect the first day of 1994, while other aspects will be phased in during 1995. Any transportation consequences of NAFTA are therefore quite preliminary, but certain effects were discernible during 1994. The overall effects of NAFTA can be grouped into three classes: (1) those that result from changes in the rules and regulations applying to trade; (2) those that are a result of changes in access to the territory of other countries; and (3) those that result from changes in rules and regulations applied to vehicles and operators when transporting within one of the countries.

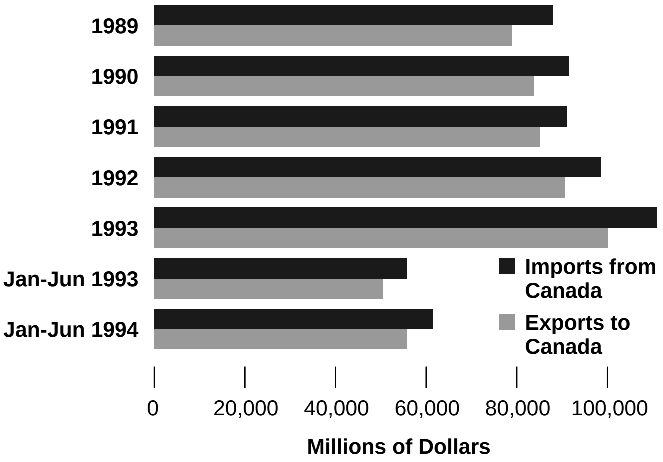
It is the first class of impacts, occurring from changed rules and regulations, which began to affect trade and transportation among the three trading partners on January 1, 1994, the beginning date for NAFTA. Reductions in tariffs applied to goods traded between Canada, Mexico, and the United States started to phase in on that date. In December, 1995, effects of the second sort will apply, as U.S. carriers are given access to Mexican border states and Mexican carriers are given similar access for international shipments to U.S. border states. Eventually, all of the U.S. and Mexico will be open to international movements by carriers of both nations.

As to impacts of the third class, foreign operators and vehicles operating in another nation must adhere to the rules and regulations of that nation (such as truck size and weight laws). The three trading partners retain their sovereign rights over licensing, operating, and safety laws to protect their citizens. However, NAFTA does establish mechanisms to harmonize rules and regulations among the three nations. Harmonization discussions are proceeding, and as agreements are reached and implemented, transportation consequences may occur depending on the results of ongoing negotiations.

In NAFTA's initial months, only effects of the first class could be expected, and given the short period of time since passage, few of these have taken place. Trends and changes from past relationships are only suggestive of what is likely to occur

FIGURE 1–7

United States Trade with Canada: 1989–1994



over the next few years, but it is informative to compare the first few months after NAFTA to pre-NAFTA conditions.

### Growth in North American Trade

Two-way trade between Canada and the U.S. grew moderately from 1989 to 1992, rising from $166.5 billion to $176.2 billion. (See Figure 1–7.) The moderate rate of growth was due in part to general economic sluggishness through 1992. Growth in 1993 showed a strong advance of 11.9 percent. This rate of growth continued into the first six months of 1994, during which imports increased 10.1 percent over the comparable period in 1993 and exports increased 10.5 percent. Throughout the total period, there was a relatively steady negative U.S. balance of trade. Based upon these data, trade with Canada, post-NAFTA, appears to be very similar to pre-NAFTA.

Mexican trade demonstrated a higher growth rate in the pre-NAFTA years than did Canadian, largely as a result of changes in the terms of trade brought about by Mexican acceptance of GATT and from the economic liberalization policies of the Salinas administration. The United States had been running a trade deficit with Mexico, but in 1991 the balance of trade shifted in favor of the United States. The post-NAFTA trade figures for Mexico show substantially higher rates of growth than for Canadian trade. U.S. exports to Mexico rose 16.4 percent in the first six months of 1994, compared to the same period in 1993, and imports rose 20.5 percent. (See Figure 1-8.)

### Modal Shares

For both Canadian and Mexican trade, the land modes have been, and remain, the dominant means of transporting freight.

Trade with Canada shows a recent, post-NAFTA increase in the share of traffic moved by the land modes. Although the land modes were dominant over the entire period, the share of trade using land modes fell from 91.1 percent in 1989 to 88.1 percent in 1993. Air and water, meanwhile, both increased their traffic shares. However, in the last six months, the land modes gained market share at the expense of water. (See Figure 1–9.)

Trade with Mexico depends on the land modes, which had risen from 85.3 percent to 87.7 percent of the total by 1993, and rose further to 88.3 percent for the first half of 1994 (again, measured in value terms). The results mean the land transport share of Mexican trade is just about the same as the Canadian land share (which was 89.4 percent for the first six months of 1994). Air has also gained a larger share of trade in Mexico, rising from 2.6 percent to 3.8 percent by 1993, and continuing its increase in market

FIGURE 1–8

United States Trade with Mexico: 1989–1994

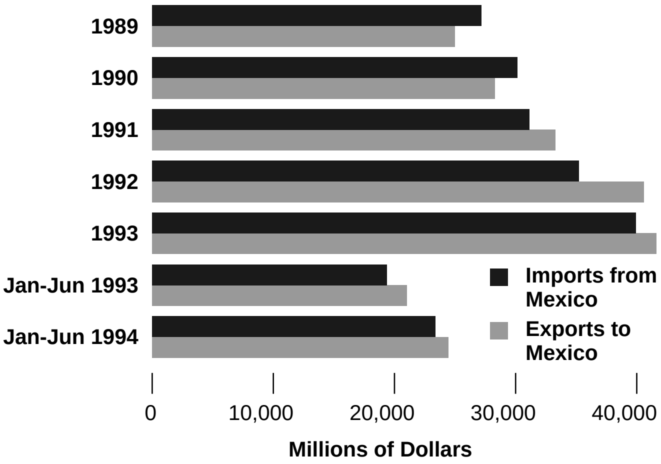


**FIGURE 1–9**

Modes of Transportation Used by Canadian International Shippers

share during the first six months of 1994. The water modes had fallen from 12 percent to 8.5 percent by 1993, and fell even further in 1994. These post-NAFTA impacts appear likely to increase demands on the land border crossings with Mexico. (See Figure 1-10.)

### Composition of Trade

Export and import trade by commodity between the U.S. and Canada remained relatively stable over a three-year period prior to 1992–93. Such stability is to be expected given that the terms of trade between these nations also remained quite constant. (See Figures 1–11 and 1-12.)

The composition of trade with Mexico has also remained relatively stable. The major trend has been the increasing importance of manufactured imports to the U.S. Given that many of the manufactured commodities are likely to be produced by maquilla industries, most of which are located near the U.S.-Mexican border, and that these commodities use land transport predominantly, most transportation demands and problems associated with NAFTA implementation in Mexico are apt to be border related. (See Figures 1-13 and 1-14.)

### Regional Patterns of Trade

Information on origins or destinations of U.S. trade is subject to errors in reporting and interpretation, necessitating that care be taken when discussing the data. Nonetheless, one can provide a general characterization of the geographic patterns of exports and imports to help in visualizing the domestic transportation implications of the trade.

### Land Trade by Border Crossing

Many of the transportation issues arising from trade with Canada or Mexico are associated with congestion and delays at critical land border crossings. The reasons for this are evident, since the land modes continue to carry the bulk of the trade. To the extent that trade composition is changing, it seems to be shifting further toward goods that generally move by truck or rail. Further, the trade origins and destinations continue to focus the flows through several major gateways. Few states dominate trade between the U.S. and Canada. This trade is concentrated in the industrialized Northeast and Midwest, California, Washington, and Texas. To date, NAFTA has had little impact on the geographic patterns of trade.

**FIGURE 1–10**

Modes of Transportation Used by Mexican International Shippers

**FIGURE 1 – 11**

Canadian Exports by Commodity

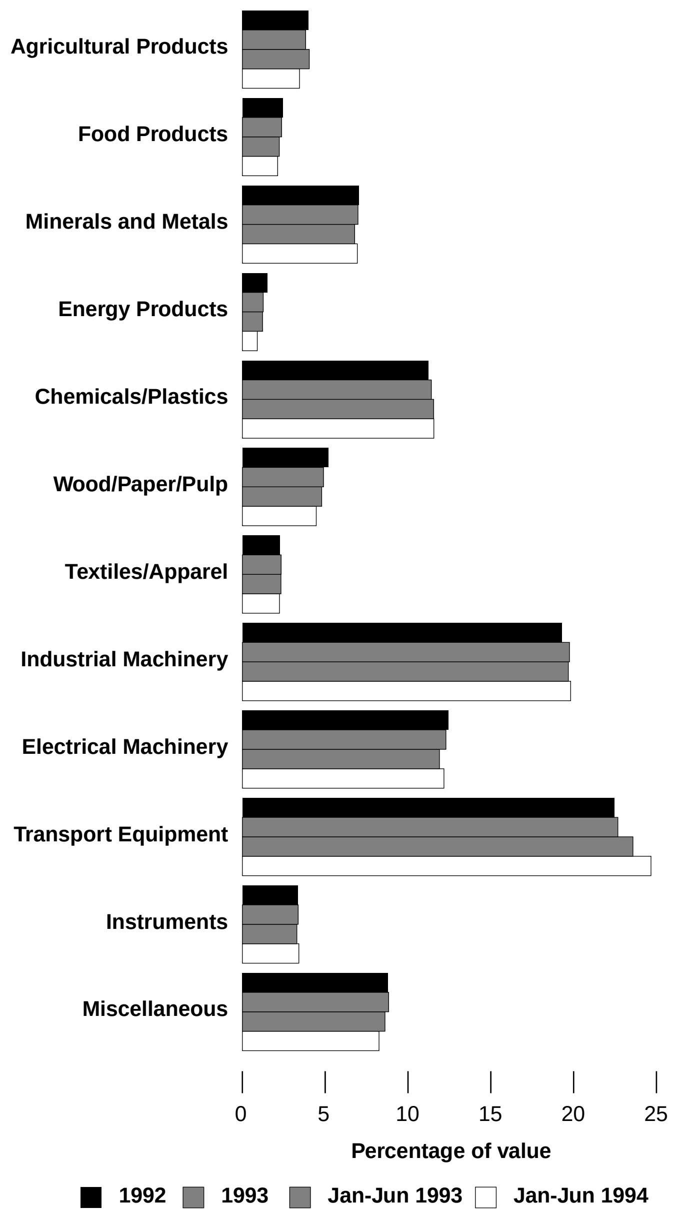
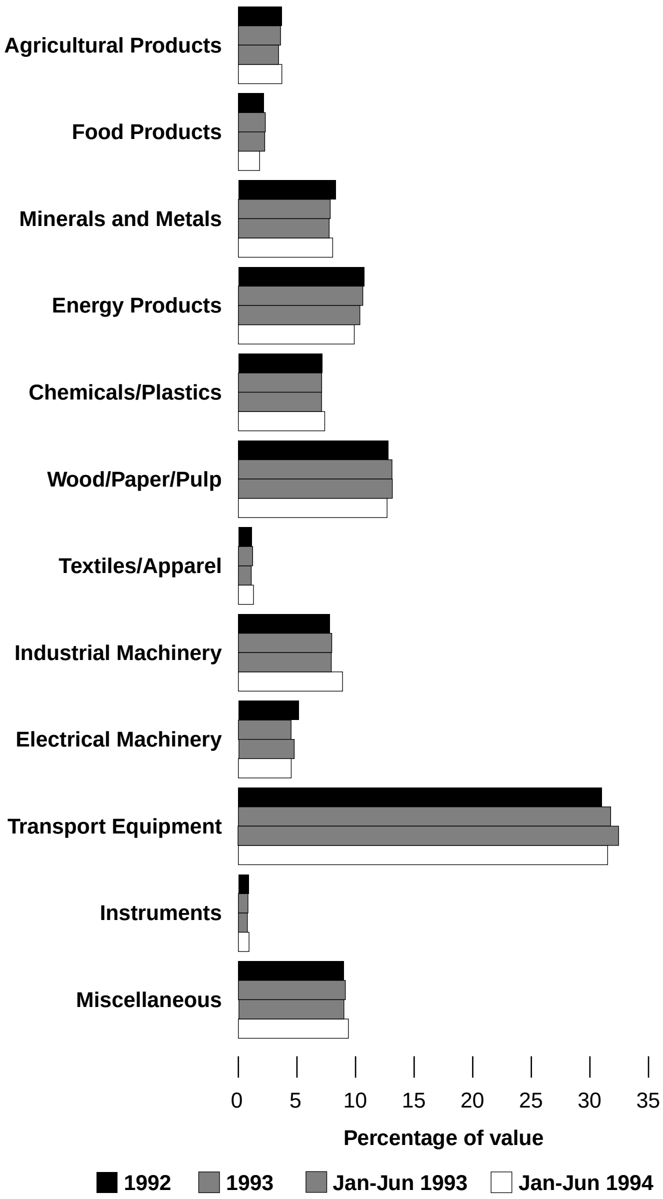


**FIGURE 1 – 12**

Canadian Imports by Commodity



U.S.-Mexico trade is also concentrated among a small number of states, notably Texas and adjacent southwestern states. The degree of concentration is even greater with Mexican trade than with Canadian.

The northern border is interesting in that it shows increasing proportions of trade through the Michigan crossings (already the busiest land crossings). Along the southern border, Laredo continues to be the major gateway for exports to Mexico, while imports are distributed more evenly across the major gateways. However, no changes in border-crossing trends, such as switching from one gateway to another, are obvious from the limited post-NAFTA data available.

## Summary Effects

It is too early to make definitive comparisons of the pre- and post-NAFTA trade situation, or to draw strong conclusions

FIGURE 1–13

Mexican Exports by Commodity

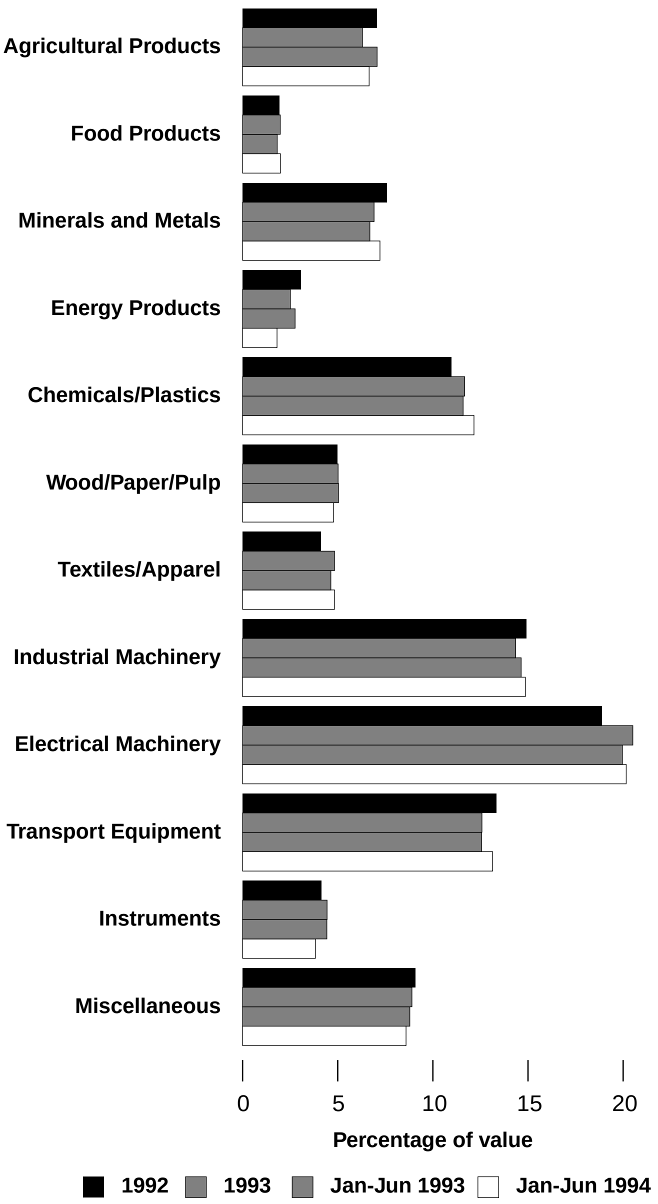
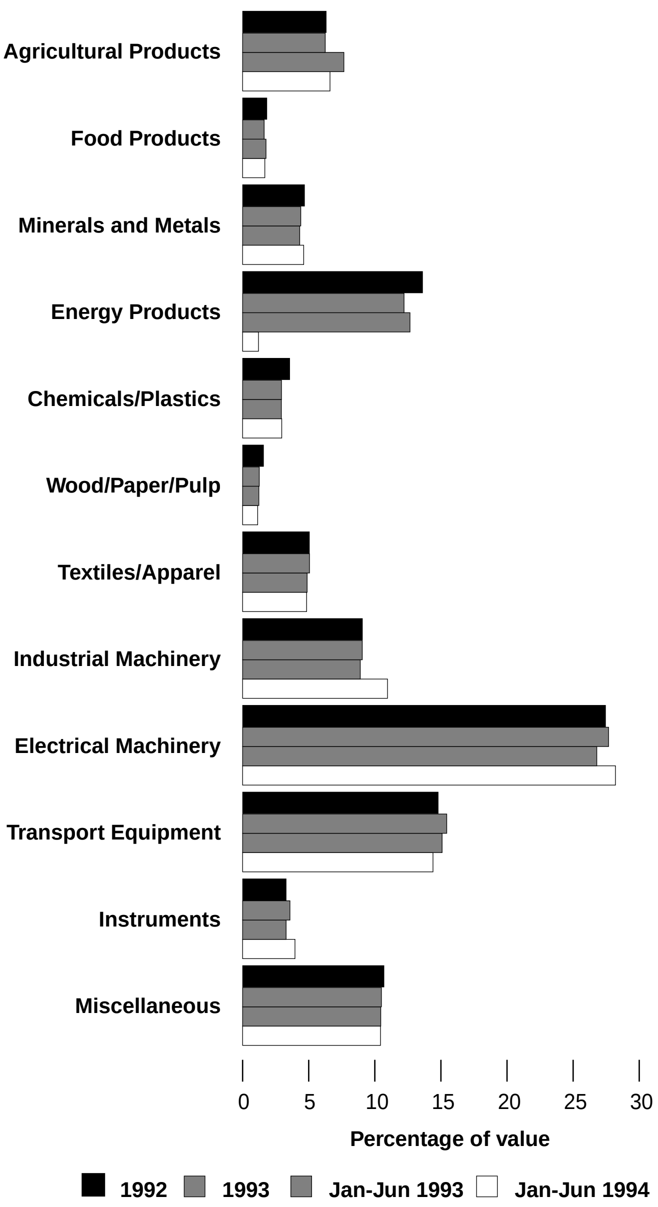


FIGURE 1–14

Mexican Imports by Commodity



about the transport impacts. However, the available data should be reassuring to those planning for future impacts. As expected, trade among the three North American partners has increased, but the geographic patterns and commodity compositions of the trade are still similar enough to those of the recent past that near-term transport needs can be anticipated. These transportation needs are likely to result from the continuing growth in *total* trade through today's major ports and from the opening of U.S. and Mexican border states to international traffic that will occur in December, 1995. As these gains in trade are anticipated, the transportation industry is preparing to serve the new traffic.

# The Extent and Use of Highway Transportation

The most pervasive form of transportation in the United States is the highway. It includes: (1) the highway infrastructure, composed of roads, streets and highways, together with associated bridges, traffic control devices and additional facilities; (2) vehicles, such as automobiles, motorcycles, trucks, truck-tractors and trailers, and buses; and (3) drivers, as well as other highway-related workers. *National Transportation Statistics* (NTS) includes a three-page statistical profile of all of these elements of highways, followed by profiles of autos, buses, trucks and transit. The data begin with 1960, ending in coverage of 1992. The following section draws on NTS and its sources, adding 1993 and 1994 findings when available.

## The Highway Inventory

The highway infrastructure contains a network of 3.9 million miles (6.28 million km) of public facilities. These roads and streets are operated primarily by state and local governments. The United States also has a substantial private road mileage, especially in new suburban development, but data to describe its extent and variety are lacking.

Most of the nation's highways—3.1 million miles (5.0 million km), or about 80 percent—are in rural areas. However, the 20 percent of the network located in urban places carries the majority of road traffic. Use of the system is commonly measured in vehicle-miles of travel. Those urban vehicle miles of travel were estimated to be 60.6 percent of total highway activity in 1992. Total vehicle miles of 2.3 billion in 1993 rose 2.2 percent from 1992.

The size of the U.S. highway system has been relatively static for many years, but the proportion of the system consisting of roads with higher service levels (that is, paved as opposed to gravel or nonsurfaced) has increased to over 90 percent of the total.[3]

*Highway Functions.* Highways and roads are classified according to the traffic functions they are intended to serve. There are three key functional systems: arterials, collectors, and local roads. Each road is placed in a functional system according to the traffic that it is primarily designed to serve, such as local land access traffic for local roads and streets, and higher-speed, higher-volume traffic for arterials. Traffic on arterial facilities also often makes longer trips than do vehicles on local or collector roads. Overall, some 13 percent of the annual vehicle-miles of traffic (VMT) in the United States are found on local facilities; 16 percent of this traffic occurs on collectors; and 71 percent of the VMT takes place on arterials—23 percent on the Interstate Highway System alone. (The Interstate System was authorized by Congress in 1956 to serve as a high-function facility connecting major population centers throughout the United States.)

*The National Highway System.* In December 1993, as directed by the Intermodal Surface Transportation Efficiency Act (ISTEA), Secretary of Transportation Federico Peña recommended to Congress a National Highway System (NHS) of arterial facilities totaling some 159,000 miles (255,831 km). The purpose of the NHS "...is to provide an interconnected system of principal arterial routes which will serve major population centers, international border crossings, ports, airports, public transportation facilities, and other intermodal transportation facilities and major travel destinations; meet defense requirements; and serve interstate and interregional travel."[4] To achieve its purpose, the NHS includes a highway system identified by the Department of Defense known as the Strategic Highway Corridor Network (STRAHNET), which encompasses the Interstate Highway System plus other routes such as those needed for emergency evacuation in the event of natural disasters.

*Highway Jurisdiction.* While the federal government plays important roles in funding and managing U.S. highways, state and local governments control almost all the roads and bridges in the United States. Local governments have jurisdiction over about 74 percent of the system; the states own and maintain 21 percent. Just 6 percent is under the direct jurisdiction of the federal government (consisting of facilities open to public use on federal lands, such as national parks, forest lands, and monuments).

## The Highway Vehicle Inventory

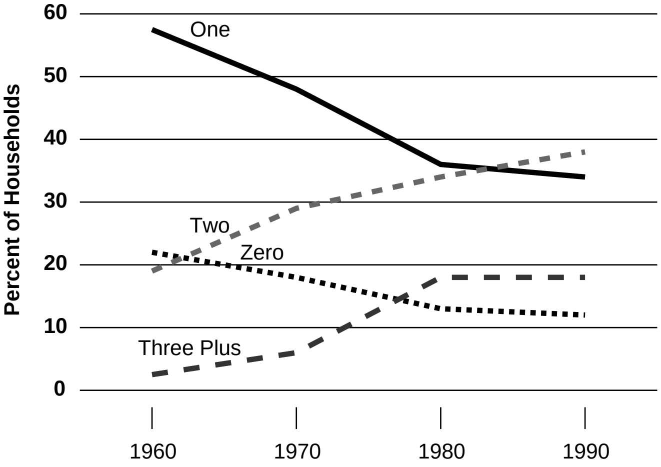
There were estimated to be 198.0 million registered motor vehicles of all types in the United States during 1993, operating over the 3.9 million miles (6.28 million km) of highways, streets, and roads—or about 57 automobiles, light trucks, or vans, and 77 total vehicles (large trucks, buses and motorcycles included) for every 100 people. (See Figure 1-15.)

The ever-increasing number of vehicles comes about at the same time that the vehicle fleet is aging: "Clearly the U.S. population has increased their ownership of vehicles not so much by adding new vehicles, but by not throwing the old ones away."[5] Small trucks and vans are becoming increasingly popular, making up an ever larger share of the "automobile" market. Nevertheless, 1994 has been a stronger year than most in the recent past for auto production, with sales of domestic and imported vehicles expected to top 15 million (compared with last year's 13.9 million).[6]

There are relatively more of the heavier trucks in the vehicle mix, too; truck-tractors (which pull single or multiple trailers transporting the heaviest loads) had increased 3.5 percent to 1.3 million from 1.2 million in 1991.[7] The stock of buses (most of which are school buses) has been growing as well. There were estimated to be 645,000 buses in 1992, compared with 397,000 in 1971 and 544,000 in 1981.

**FIGURE 1–15**

Vehicles Available to U.S. Households: 1960-1990



## Inventory of Motor Carrier Services

Motorists use highways, but so do operators of many other vehicles: trucks (long- and short-haul truckers, including local cartage), buses (transit, school, charter and intercity), public service and utility vehicles (ambulances, police and fire vehicles, sanitation trucks, etc.), taxicabs, bicycles, and vans. Some of these operators serve passengers, others serve freight demands, and a few provide joint services (for example, intercity buses jointly produce package freight and passenger services; taxicabs occasionally carry packages, as well as passengers and their parcels or luggage). Overall, it is calculated that more than 75 percent of the value of all goods and services produced in the United States is carried by truck, and most passenger traffic moves over the highways. (It has been estimated that 80.8 percent of intercity passenger travel in 1993 was auto transport, with 1.1 percent made by intercity bus, and that 92 percent of journey-to-work trips have been taken by auto and truck combined. Altogether, 87 percent of all trips were made by personal vehicle).

The Interstate Commerce Commission reports that there are over 50,000 motor carriers of property operating in the United States (although most are small, Class III carriers). Bus carriers total 4,573, although only 30 are Class I carriers (with $5 million or more in annual revenue), and the largest carrier by far is Greyhound Lines, Inc., the sole bus company to offer nationwide service. The industrial structure of freight motor carriage is generally considered highly competitive, while the structure of passenger bus carriage is concentrated. However, events in 1994 suggest potential changes in both industries. State regulation of motor carriage is ending (through passage of the Trucking Industry Regulatory Reform Act of 1994) and some observers anticipate a number of small interstate freight carriers will cease operations, slightly concentrating trucking. Greyhound has suffered declining traffic and financial difficulties, suggesting a declining relative importance of Greyhound in the bus market and reduced industrial concentration in intercity bus.

## School Buses

Information about school buses has been sparse. While such a key federal statistical source as *Highway Statistics* contains a bus registration figure for private and commercial "school and other" buses, plus a second figure for the number of publicly owned "state, county, and municipal" buses, little information beyond this is to be found in government records. Due to differences in definitions, state laws, and practices, the statistics we do have are of questionable accuracy.

In order to increase our knowledge of school bus activity and improve reliability, the Bureau of Transportation Statistics sponsored a research project in 1994 to generate new data about this extensive, and quite important, element of highway transportation. The findings are to be published in a research monograph in 1995, but:

- For the 1991–92 school year, 24.9 million one-way trips were made for the purpose of transporting pupils to schools. Less than one percent of these trips were for pupils in private schools. Ridership of school buses has generally risen about one percent annually in recent years.
- In 1992 (the base year studied), during a typical school day more than 9 percent of the total U.S. population rode a school bus. (That figure represents almost half of all children enrolled in public and private schools.)
- School buses served some 22 percent of all pupils with disabilities.
- The average distance a pupil rode daily on a school bus was between 10 and 15 miles.
- School bus travel was substantially more extensive than travel by all forms of transit (rail, bus, ferries, and paratransit) and Amtrak. Preliminary findings suggest over 60 billion miles of pupil-miles traveled annually on school buses, versus some 40 billion passenger-miles of transit travel and 6 billion miles traveled on Amtrak.
- If parked end-to-end, the country's estimated 418,000 school buses would stretch nearly coast-to-coast (about 2,400 miles).
- The per-mile cost of school bus operation was relatively low (with an average cost of about 15 cents per pupil-mile, compared with some 48 cents per passenger-mile on a transit bus).
- Travel by school bus has been quite safe; only 15 bus occupants died in accidents in 1992.

Additional information will be forthcoming from the study about school bus employment, energy efficiency of bus use, and related school bus expenditures. The study will recommend ways to collect better statistics from private sources, and to revise the Nationwide Personal Transportation Survey.

### Highway Use

Year by year, highway travel has risen and trucks have been moving more and more commodities. The vehicle miles of travel reported by the Federal Highway Administration on the total rural and urban highway system of the United States were 2.297 trillion in 1993, rising some 2.2 percent from 2.247 trillion in 1992. The vehicle miles of all trucks taken separately went up from 631 to 656.6 billion over the same period, with an increase rate 86 percent higher than that of all highway vehicles; travel by the largest combination truck-tractor vehicles increased from 99.1 to 102.7 billion, a rate that was 64 percent higher than the overall gain. One result of increased highway use is greater congestion in urban areas. Although highway traffic goes up, little new highway capacity has been added in recent years through construction, with most increases in highway capacity coming from improved transportation-systems management or transportation-demand management (such as better traffic signalization, the provision and promotion of high occupancy vehicle [HOV] facilities and practices, and the use of transportation ordinances by local government).

## Bicycles

Data about the use of bicycles as a transportation mode have been sparse on a national level. As noted in last year's *Transportation Statistics Annual Report:* "Bicycle inventory information is not kept by federal or state authorities. The condition of the bikeway inventory is not even defined."[8] Only bicycle production and imports are measured; 7.2 million were produced and 4.4 million imported in 1991. Yet the use of bicycles is strongly considered concomitant to establishing more environmentally sensitive urban communities.

During 1994 a major federal review of bicycles as transportation took place, concluding with publication of the Federal Highway Administration's *National Bicycling and Walking Study Final Report.* This report was required by the U.S. Department of Transportation's 1991 Appropriations Act, which directed the Secretary to conduct a national study to determine current levels of bicycling and walking, determine why they are not better used as transport means, develop a plan for increased use and enhanced safety of these modes, and identify the resources to implement the plan. While the study establishes goals and action plans to work towards greater use of bicycles and improve bicycle safety, no enhanced bicycle data was produced. Information from such existing sources as the 1990 Nationwide Personal Transportation Survey, the Census Bureau's "Journey to Work" survey, and public opinion polls was utilized.

Nevertheless, efforts are underway throughout the country to plan for bicycles, and many of the state and Metropolitan Planning Organization transportation plans that are required by the Intermodal Surface Transportation Efficiency Act at the start of 1995 are likely to contain bicycle elements. A number of recent urban reports and efforts, such as the Livable Communities Initiatives Program, point toward increased reliance on the bicycle. We do produce data about bicycle production (7.4 million domestic shipments and 4.3 million imports in 1992) and bicycles are registered in some communities, providing an added information source. As new plans are put forward, implemented, and extended, we are likely to begin seeing more data on bicycle use and can expect to have the widespread opportunity for comparative review of bicycle programs.

## The Extent and Use of Rail Transportation

The physical elements of the U.S. rail system consist of trackage, operating equipment, and the additional capital and human resources necessary to produce rail freight and passenger services. For-hire rail freight transport is provided by a number of freight rail lines, and passenger service is the responsibility primarily of Amtrak (the National Railroad Passenger Corporation), which operates over its own right-of-way in the Northeast Corridor of the country, as well as over the tracks of 24 freight rail carriers.[9] NTS provides a rail profile with data about these industry elements and contains a second profile for Amtrak. The U.S. transportation facilities map supplement to this TSAR illustrates the national rail network.

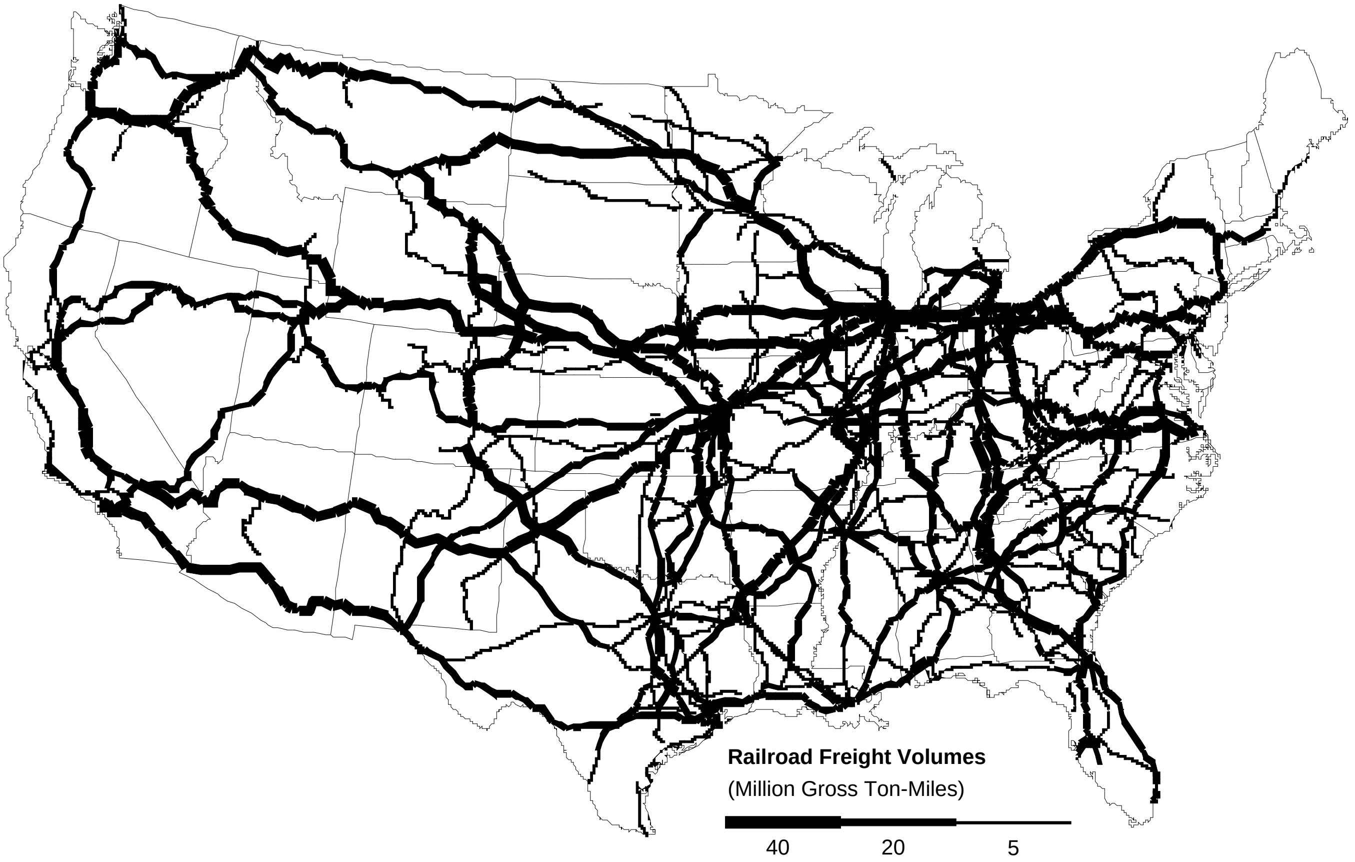
### Rail Track Inventory

The density of the rail track network in the U.S. has been declining for decades, falling to 110,425 miles of Class I line in 1993.[10] Reduced geographic coverage has led to some major origin and destination points having one rail line instead of several; direct rail service to minor markets and service to some agricultural production regions has been dropped, requiring truck interconnections to railroads. On the other hand, with the improved financial condition of the railroads and substantial demand for intermodal traffic and certain commodities such as low-sulfur coal, spot trackage expansions have occurred, such as the Chicago & North Western's budgeting of $45 million for new tracks to serve the Power River Basin.[11] (See Figure 1–16.)

*Intercity passenger rail.* Route miles operated by Amtrak in intercity service during FY 1994 were unchanged from the FY 1993 level of 25,000. The number of stations served increased by 5 from 535 to 540. Intercity ridership was down 300,000 from 22.1 million to 21.8 million, while ridership on commuter trains operated by Amtrak under contract to state and regional authorities increased from 29.3 million

FIGURE 1–16

Railroad Network Showing Volume of Freight: 1992



to 33.3 million. FY 1995 will see route and service reductions as Amtrak takes necessary actions to cut costs in order to bring its operating deficit under control.

At the end of FY 1994 Amtrak's equipment inventory included 370 owned or leased electric and diesel locomotives and 2016 owned and leased passenger cars. Both figures are slightly higher than 1993 inventories, but are expected to fall in FY 1995 and beyond as Amtrak retires its oldest equipment when service reductions are made. Year-end FY 1994 employment stood at 25,056, split approximately 11 percent management and 89 percent agreement or labor. A ten percent reduction in total employment is planned for FY 1995.

*Railroad classification.* Rail lines are not classified functionally as are highways, in the categories of arterials, collectors, and local facilities, but an approximate equivalent is found in the terms main line, secondary main, and branch line. However, these rail terms are not precisely defined and no time-series figures report changes in the extent of facilities for each category. Moreover, while the Interstate Commerce Commission (ICC) categorizes railroad firms as it does motor carriers, in size categories Class I, Class II, and Class III, the biggest Class I railroad will operate light-traffic-density branch lines as well as main lines. Similarly, a Class II carrier may have a high-volume main line.[12]

Another way of classifying freight railroads has been established by the Association of American Railroads, which uses the ICC revenue-related definition for Class I carriers (12 carriers meeting the Class I revenue threshold of $253.7 million in 1993), but redefines smaller railroads as either regional or local. In 1993 there were 34 regional railroads and 463 local ones. While the number of Class I carriers has been shrinking because of mergers and some carriers not achieving the necessary revenue threshold, the number of local and regional roads has grown, as new carriers have been established to operate lines transferred from the Class I carriers.

Yet another classification can be made, but of rail lines instead of carriers. Lines can be measured by weight of rail (in pounds per yard), with heavier rail generally signifying the ability to carry heavier, more frequent traffic. The weight category with the largest number of Class I miles is 130–139 pound rail (65,412 miles, or 52.5 percent of the total). By the end of 1993, the miles of line with weight of rail under 100 pound—a weight not suitable for mainline operations—had fallen to only about 13,000 miles (10.4 percent of the total). A potential means of line classification might be in terms of lines requiring positive train control (automated train separation systems) as opposed to those where control would not be necessary. Positive Train Control is under development and testing in the Pacific Northwest with the assistance of the Federal Railroad Administration.

### Rail Equipment Inventory

The number of rail cars in operation in 1993 was about 1.17 million. Most of these—587,000—were owned by Class I carriers, but increasingly the rail car fleet is owned by car companies and shippers (their ownership totaled 498,000 units in 1993). Regional and local railroads owned 88,600 cars. There were 18,161 diesel electric locomotives in service, a slight increase from 18,003 the year before.

The number of rail cars operated in 1993 was virtually the same as in 1992, but the 43,000 new and rebuilt rail cars brought into the fleet was the greatest in at least a decade. Capital expenditures for equipment were higher at $1.4 billion (compared with $874 million in 1992) than in any year during the past decade. The number of carloads of traffic originated for the year was also a record for the decade, at 21.7 million, compared with 21.2 million in 1992, for an increase of 2.2 percent—despite a decline in loads of coal, the railroads' top commodity. Intermodal traffic of trailers and containers rose 7.9 percent to 7.2 million units.

### Rail Carrier Services and Traffic

The Class I railroads provided 1.067 billion ton-miles of revenue service in 1992, manifesting a 3.2 percent increase from 1.034 billion ton-miles in 1991. As recently as 1980, rail output was 919 billion ton-miles. These figures do not include the output of regional or short-line rail carriers.

## The Extent and Use of Air Transportation

The elements of the air transportation system are: airports; air traffic control and air navigation aids; aircraft; pilots and other personnel; and the suppliers of air passenger and freight services. NTS contains profiles of air carriers and general aviation.

### Inventory of Airports

There are more airports in the United States than in the rest of the world combined. In all, the United States had some 17,800 airport facilities in 1992, up from 15,200 as recently as 1980. Of course, these are not all large or sophisticated facilities; only 4,654 had paved runways in 1992. In 1993 only 401 had Federal Aviation Administration (FAA) traffic control towers. Another 28 towers were operated by contractors. Major airports are shown on the U.S. transportation facilities map supplement.

*Airport classification.* Airports, like highways, are classified in various ways. Scheduled air passenger service is provided at about 800 airports, and some 570 of those (airports with 2,500 or more enplanements annually) are classified as commercial service airports. Commercial service airports that enplane 0.01 percent or more of total U.S. air passengers are classified as primary airports. Primary airports—numbering about 400—account for more than 99 percent of air passenger enplanements on certified air carriers, and at least 95 percent of air passenger enplanements on all scheduled domestic air carriers, including commuter airlines.

*Hub airports.* The country contains 26 large air traffic hubs, defined as facilities in a geographic area that handle 1 percent or more of the total national enplanement of air passengers. These large hubs handled 289.7 million passenger enplanements in 1992, 71.4 percent of total passenger enplanements in that year. There are also 31 medium and 69 small hubs, which handled 18 percent and 8 percent of total passenger enplanements in 1992, respectively. Hubs are geographic areas, and may contain more than a single airport facility (for example, there are 49 airports operating in the 26 large hub areas). During 1992, nearly 98 percent of all passenger enplanements were recorded at those 126 hubs (437 million of the 448 million enplanements). (See Figure 1–17.)

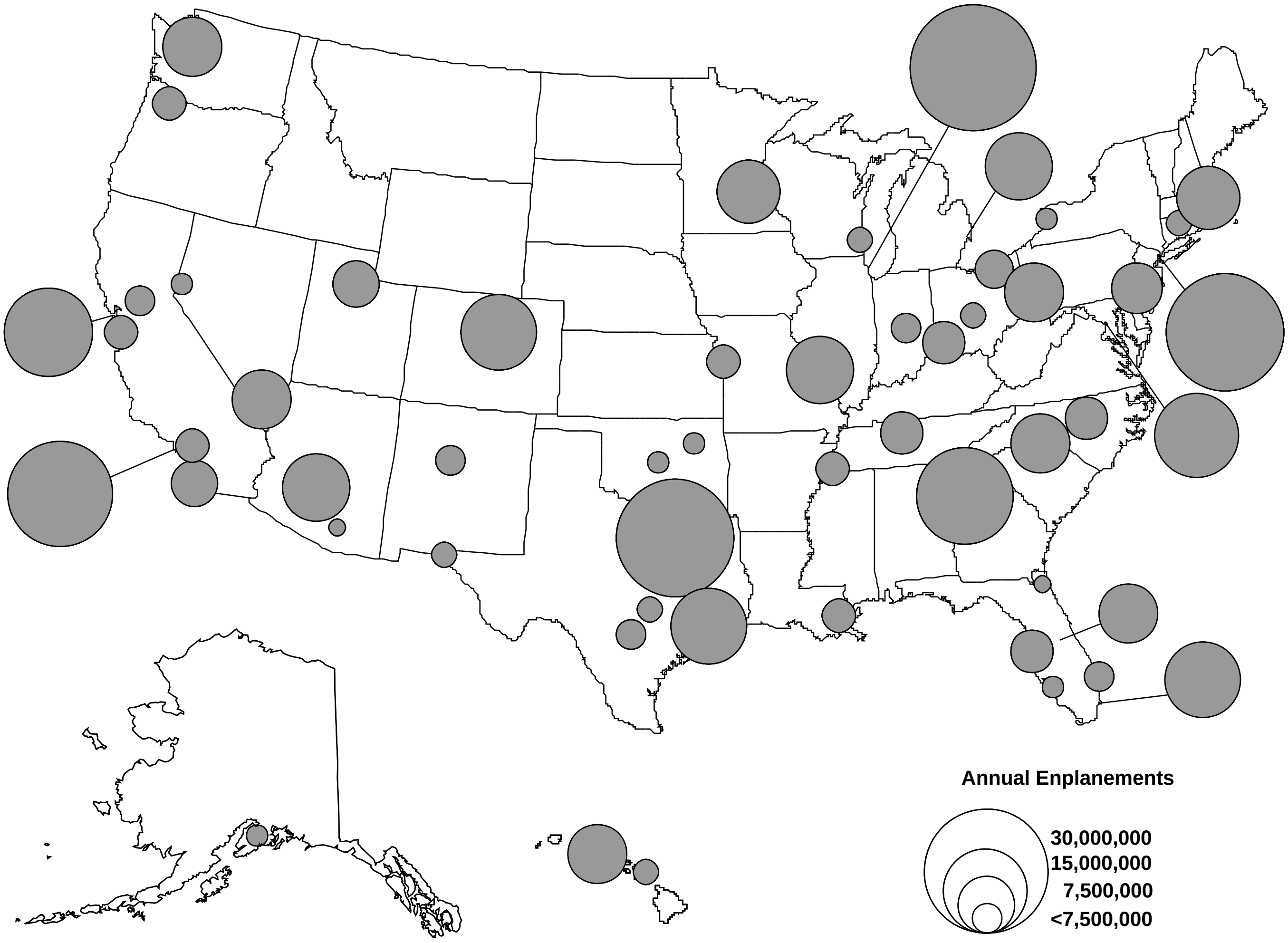
### Inventory of Aircraft and Pilots

The U.S. aircraft fleet consisted of some 184,000 active general aviation aircraft in 1992 (down from 199,000 in 1991), and 18,000 air carrier aircraft in 1993 (up from 16,100 in 1992). In 1993 there were 6,452 fixed-wing turbine aircraft reported in operation by air carriers; a portion of these were available for air-passenger-carrier service (estimated at 3,782 in 1991).

The number of active air pilot certificates held was 665,000 in 1993, down from 683,000 in 1992. The downward trend is marked by the decline in number of student pilots. Student certificates numbered 104,000 in 1993, but equaled 150,000 as recently as 1986.

**FIGURE 1 – 17**

Total Enplanements at Large and Medium Size Hubs: 1992



### Air Carrier Services

There are some 200 U.S.-certified and commuter air carriers in operation today. Of these, the 11 major carriers account for about 80 percent of all passenger enplanements. Another 13 percent of enplanements take place on smaller, national carriers (18 firms), while commuter carriers account for 5 percent of enplanements, and regional carriers (41 firms) provide 2 percent.

### Air Transportation Operation and Use

Certificated carrier revenue passenger miles in 1992 were calculated at 493.7 billion, up 4.5 percent from 472.6 billion the year before. Recent information for the October to June FY 1994 period show 377 billion revenue passenger miles, up from the same period in 1993 by 0.9 percent. Available seat miles were also up 0.9 percent, but load factors had improved to 64.4 percent in 1994 from 61.8 percent the preceding year.

Air freight ton-miles were 63 billion in calendar year 1993, up 4.8 percent over the 61.05 billion provided in 1992, which in turn exceeded 1991's output by 7.3 percent. Air cargo seems likely to continue as a growth item.

## The Extent and Use of Transit

Public transit services were provided in 314 urbanized areas by 503 public transit operators in 1992, while an additional 5,010 local and regional organizations served rural and small urban areas.[13] NTS contains a transit profile with information about transit equipment and services by bus, heavy rail, light rail, and a variety of other means.

### Inventory of Transit Vehicles and Operations

The most common transit vehicle is the motor bus, but transit operators use other highway vehicles and a variety of forms of fixed-guideway transit equipment. (See Table 1–4.) In comparison with similar figures for 1990, by 1992 the total number of transit vehicles in the country had increased by just over 24,000—with about half that large increase in vans, and most of the rest consisting of special-service vehicles, with slight increases occurring in both rural-service vehicles and buses.

Transit usage in terms of passenger miles was estimated to equal 37 billion in 1992, down 0.4 percent from 1991's figure of 37.5 billion. Passenger use has been split about equally between rail and nonrail systems (18.5 billion passenger miles on rail systems in 1991 and 18.9 billion on nonrail; 18.8 billion rail in 1992, with 18.2 billion nonrail). (See Figure 1–18.)

### Transit Classification

Public transit services have no equivalent to highway's rating systems of present serviceability or level of service. Providers operate different frequencies of service over the routes they decide to serve (with headways varying according to anticipated ridership, hour of the day and day of the week). Providers also supply different equipment based on their estimates of demand. Transit can be functionally classified, however, in terms of the purposes served by individual trips. There are three functions recognized by the DOT that transit serves: low-cost basic mobility; congestion management; and supporting livable metropolitan areas. In the future the Federal Transit Administration intends to develop data to describe and analyze these functions.

**TABLE 1–4**

Active Transit Fleet: 1992

| Vehicle | Number |
|---|---|
| Buses | 56,316 |
| Rapid rail | 10,161 |
| Light rail | 1,006 |
| All commuter rail | 5,285 |
| Vans | 12,047 |
| Other (including ferryboats) | 153 |
| Rural service vehicles (primarily vans) | 12,450 |
| Special service vehicles (mainly vans, used by senior citizens and persons with disabilities) | 29,331 |
| **Total** | **126,751** |

Source: *Condition and Performance Report*, 26

## The Extent and Use of Water Transportation

Water transportation is a broad category that includes domestic movements on the inland waterways, the Great Lakes and along the coast, as well as between the contiguous 48 states and Alaska, Hawaii, Guam, Puerto Rico, and the Virgin Islands. Water transport also encompasses international ocean shipments. The inventory of facilities for this mode is extensive, including harbors and ports, channels, navigation aids, piers, wharves, cargo handling equipment, locks and dams, and storage facilities, as well as ships, barges, tugboats and smaller vessels. The U.S. transportation facilities map supplement illustrates the inland waterway system, and a water transport profile is to be found in NTS.

### Vessels

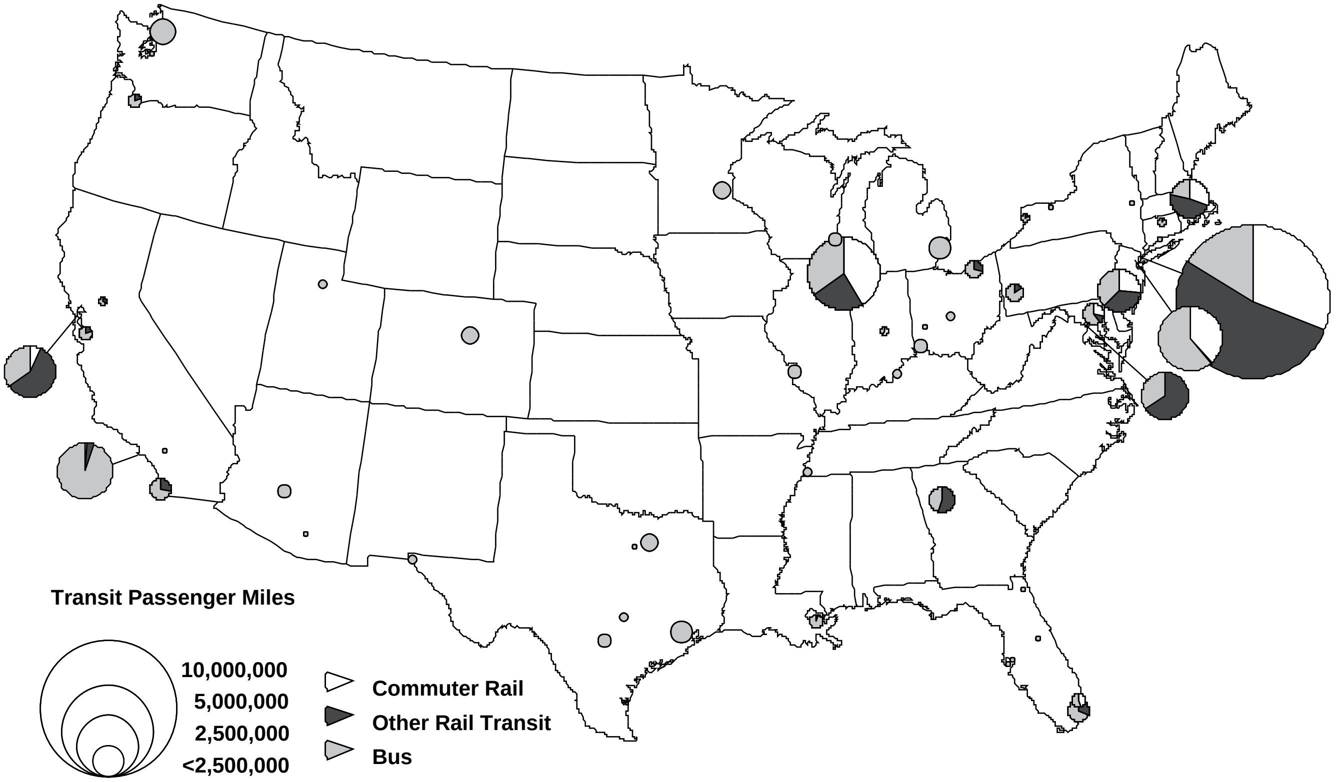
*Great Lakes fleet.* The U.S. Great Lakes fleet of self-propelled vessels of 1,000 gross tons and over contained 77 vessels in 1993, almost all of which were self-unloading or bulk carriers. Additional services on the lakes are provided by the Canadian Laker fleet and by ocean vessels representing perhaps 40 foreign flags of registry that operate among all the Great Lakes and through the St. Lawrence Seaway, serving U.S., Canadian and overseas markets.

*Inland waterways.* The inland waterways fleet is composed of towboats-tugboats, dry cargo barges, and tank or liquid cargo barges. In 1993 there were 26,980 dry cargo barges, 3,864 tank barges and 5,203 towboats-tugs.

*Deep sea shipping.* Three main types of ocean trade exist: general cargo carriage undertaken by scheduled freighters —liner vessels and container ships—both

**FIGURE 1 – 18**

Rail and Bus System Passenger-Miles of Travel (millions): 1992



operating as common carriers; dry-bulk movements in specialized ships moving coal, grains, minerals, and fertilizer under contract; and liquid-bulk shipping using tankers and tank-barges.

The U.S.-flag fleet of commercial size (1,000 gross tons and over) contained 367 privately-owned ships in 1994, consisting of 183 tankers, 21 bulk carriers, 161 freighters and two combination passenger-cargo vessels. There were also some 190 government-owned merchant ships (mainly freighters, mostly inactive at national defense reserve fleet sites).

The private fleet contained 11.8 million gross tons (17.3 million deadweight tons), or about 3 percent of the world's 404.3 million gross tons in 1994. While the U.S. fleet's rank of 10th in the world may not suggest a major influence in international commerce, many of the ships that are registered in countries with larger fleets, such as Panama (first in the world with 54.3 million gross tons), Liberia (second in the world), Cyprus, the Bahamas, and British Dependent Territories are believed to be owned by U.S. nationals or U.S.-owned firms. Several U.S. companies have begun to transfer or register new vessels under foreign flags. In November 1994, American President Lines, Ltd. was granted permission to operate six new foreign-built ships under foreign registry. Since then, Sea-Land Service, Inc. has been given permission to transfer five containerships to Marshall Islands registry; Lykes Bros. Steamship Co. received permission to time charter four new foreign-built containerships under foreign registry. Marine Transport Lines was given permission to reflag a car carrier to foreign registry; and ten tankers (nine of which had been under charter to the Military Sealift Command) and two ore-bulk-oil ships have been authorized to transfer to foreign registry.

### Ports, Waterways and Navigation Facilities

The water transport facilities of the United States include harbors on the Great Lakes and the connecting channels from the Lakes to the Atlantic Ocean, inland and intracostal waterways, a variety of navigation facilities operated by the U.S. Coast Guard, and both inland and coastal ports and harbors. (See Figure 1–19.)

### Water Transportation Operations and Use

Water carriage is provided by inland and ocean-going barge operators, Great Lakes carriage, and U.S.- and foreign-flag maritime operators. The country's total waterborne commerce in 1992, the latest year for which published data are available, was estimated at 2.1 billion short tons, up about 2 percent from 1991. This tonnage was divided just about equally between domestic transport (1.095 billion tons) and foreign trade movement (1.037 billion tons). Domestic commerce involved 857 billion ton-miles of carriage, mainly coastwise traffic (502 billion ton-miles).

Reports from the 1994 navigation season suggest a strong increase in St. Lawrence Seaway traffic in 1994. Commercial tonnage was up as much as 20 percent over 1993, and vessel transits through Seaway locks rose 24 percent. The tonnage figure was the highest since 1988.[14]

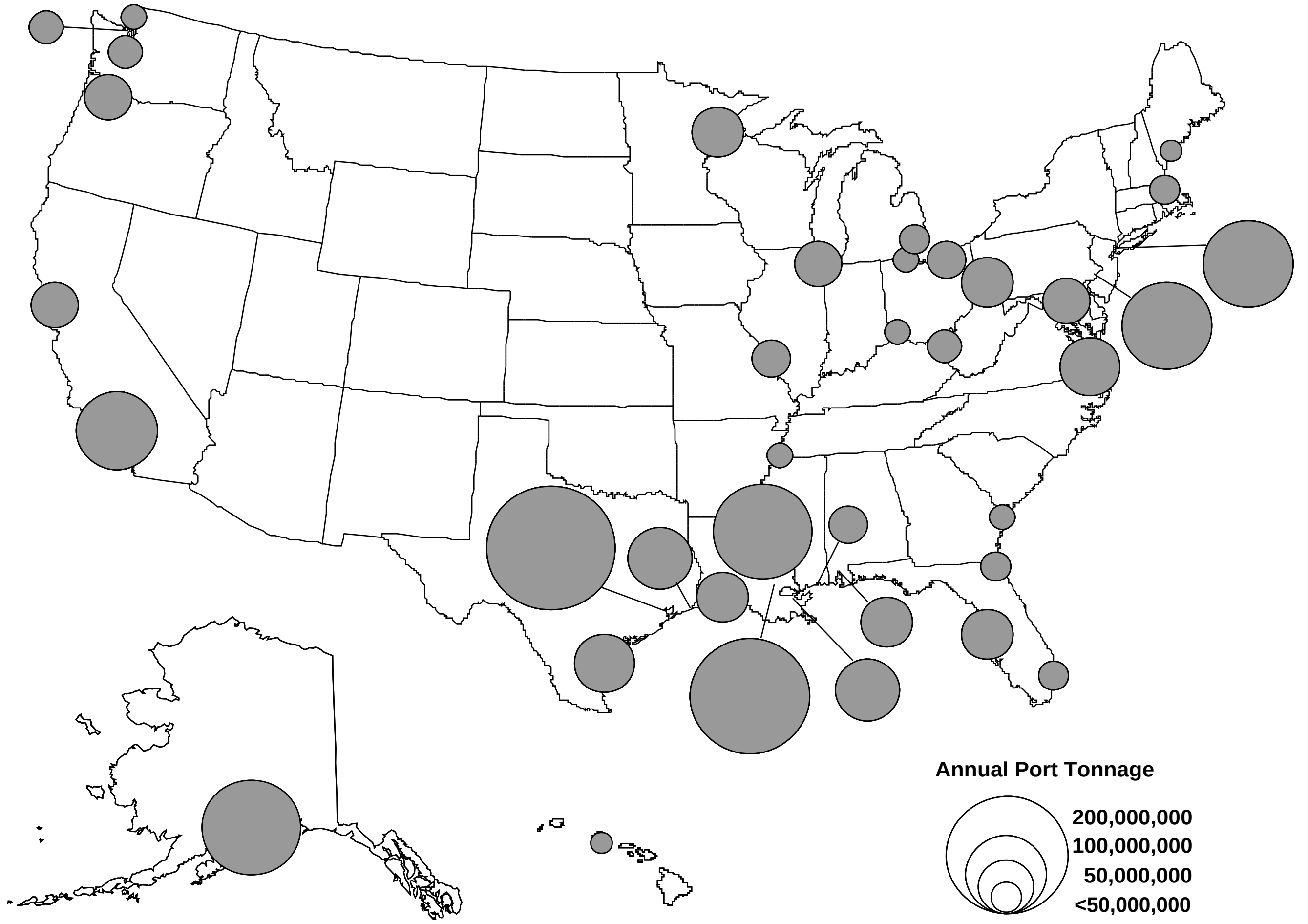
*Passenger services and operations.* According to the Cruise Lines Industry Association, the North American cruise market's annual growth averaged 9.2 percent from 1980 to 1993. Some 4.8 million passengers are expected to have sailed overnight from U.S. and Canadian ports in 1994, with 85 percent of those being U.S. citizens.

Numerous other water passenger services exist, but the data are scattered and incomplete. The Coast Guard inspects about 5,200 small passenger vessels, and a University of Massachusetts data base counts 324 ferries operated by 152 companies throughout the United States. Deep-sea passenger transportation (except ferry) contained 124 establishments in 1992, employing 7,100 persons; ferries had 103 commercial establishments with 1,700 persons; and water passenger transport n.e.c. had 586 establishments with 9,500 employees. There were 26 urban ferryboat systems with 98 vessels and 314 million passenger trips in 1992. Other state and local government-operated ferry services also exist.

Finally, private recreational boating, which has elements of passenger service, is very important, with 20.3 million boats owned in the United States and $10.3 billion spent annually on boating in 1992.

**FIGURE 1–19**

Ports with Total Tonnage Greater than 10 million tons: 1993



Note: Several ports have been combined (such as Los Angeles and Long Beach)

## The Extent and Use of Pipeline Transportation

There are two primary types of pipeline—oil and gas. Profiles for both oil and gas pipelines are provided in the NTS. Oil pipelines transport crude petroleum and various petroleum products, while gas pipelines move natural gases and liquefied petroleum gases. The extent of the oil pipeline has been declining slightly in recent years, from some 209,000 miles in 1990 to 199,000 miles in 1992. In contrast, the mileage of gas pipelines rose a bit from 1,225,000 in 1990 to 1,254,000 in 1992.

The pipeline industry's industrial organization is relatively concentrated, with 126 interstate natural gas pipeline companies in 1992 (compared with 132 in 1990 and 91 in 1980). However, most of these are smaller operators; there were just 44 major gas pipeline companies in 1991. The number of oil pipeline companies regulated by the Federal Energy Regulatory Commission was 145 in 1992 (nearly the same as the 150 for 1990).

### Pipeline Traffic

The pipelines are very important to the carriage of a limited number of commodities. The gas pipelines delivered 17.8 million cubic feet of product to consumers in 1992, up from 16.8 million in 1990 (although somewhat less than 19.0 million delivered in 1970). The oil pipelines produced 571 million ton-miles of service in 1992, split between crude petroleum movement of 324 million and petroleum products movement of 247 million. This volume of production has been very similar over the past several years, between 573 and 584 million ton-miles each year from 1990 to 1993.

## Intermodal Transportation

Terminal facilities, such as airports and waterports, among others, are intermodal—transporting both passengers and freight and transferring both between modes. A good portion of the stock of all transportation equipment has intermodal use, such as truck-trailers, while other parts of transportation fleets, like double-stacked railcars, are specifically dedicated to intermodal operation. Transportation employees work with intermodal shipments (which are usually the higher-valued shipments), sometimes interchangeably with shipments that utilize a single mode. Intermodal activity in transportation is becoming increasingly pervasive.

The most commonly associated aspect of intermodal freight is the container. According to the Maritime Administration's Inventory of American Intermodal Equipment for January 1992, we have:

- More than 2.1 million containers, a 14 percent increase from 1991;
- A container fleet comprised primarily of 20-foot containers (50 percent of the total) and 40-foot containers (48 percent); and
- Intermodal leasing companies own most of the containers (84 percent), while the rest are owned by U.S.-flag shipping companies (16 percent, increased from 13 percent in 1990).

In 1994, the National Commission on Intermodal Transportation, as required by Section 5005 of the Intermodal Surface Transportation Efficiency Act of 1991, made "a complete investigation and study of intermodal transportation in the United States." According to the Commission's final report that September:

> *Intermodalism describes an approach to planning, building, and operating the transportation system that emphasizes optimal utilization of transportation resources and connections between modes. From the perspective of the user—the traveler or shipper of goods—the mode is irrelevant; what matters is the quality, cost, timeliness, and safety of the trip.*

The Commission's report points out that intermodal "growth has been explosive" but that physical bottlenecks and a lack of institutional coordination have prevented further progress.[15] However, the Commission's report did not contain data about intermodal activity; rather, the report supported the conclusions of the BTS first annual report on the lack of intermodal data. The testimony the Commission received from local and state planners highlighted the difficulty of planning and project analysis in the absence of relevant intermodal information.

## The Condition and Performance of Highway Transportation and Transit

The condition of highways and of transit has been studied for many years, with congressionally-mandated reports regularly published to describe the findings. Starting in 1993, the Department of Transportation's Federal Highway and Federal Transit Administrations began producing a combined report on the condition of both modes. With its second combined report in 1994, the Department introduced an integrated framework for addressing condition and performance in the two modes.

To maintain current highway condition and performance, FHWA estimates that over 100,000 miles of highway and 11,000 bridges require some degree of capital investment. In recent years, pavement conditions have been improving, congestion has been worsening slightly, while bridge conditions have stabilized.

Highway performance has been further measured in terms of vehicle speed, number of trips made, accident and fatality rates, and miles traveled. Another measure of highway condition is the level of capital stock in highway transportation: that is, the remaining life expectancy or the present value of the system. Capital stock information is available for only some highway transportation.

Congestion is another aspect of highway performance. Congestion levels have been quantified for 50 urban areas throughout the country. Vehicle-miles of travel and lane-mile data have been combined to develop values for a Roadway Congestion Index (RCI). According to this RCI, the highest levels of congestion are found in Los Angeles, Washington, D.C., San Francisco/Oakland, Miami, and Chicago. Congestion exceeded desirable levels in 24 of 50 areas in 1990, up from 11 areas in 1982. Travel delay, added fuel consumption, and necessary facility lane-mile additions have been estimated as urban mobility measures. Annual congestion costs estimated from these measures can be determined, both per registered vehicle (highest in Washington, D.C. at $1,420 per vehicle, followed by San Bernardino/Riverside at $1,320 and New York at $1,090) as well as per capita (San Bernardino/Riverside tops the list with $880). These figures are all for 1990, as reported in 1993 by researchers at the Texas Transportation Institute.[16] (See Figure 1-20.)

Others have recently attempted to measure urban traffic problems. A 1993 survey of road congestion in 32 metropolitan areas conducted by Metro Traffic Control, a traffic-reporting service for radio and television stations, found that, for the third year in a row, New York was the city with the worst traffic in America. Close behind were Chicago and Los Angeles, determined by the following measures (with the worst offenders shown in brackets):[17]

- Longest drive from major airport to downtown (Chicago);
- Miles of highways under construction (Chicago, New York, Pittsburgh);
- Slowest highway during commute (New York);
- Longest daily rush hour (Atlanta, Denver, Los Angeles, San Francisco/San Jose, Seattle);
- Total miles of congested traffic during peak rush hour (Los Angeles, New York);
- Highest percentage of "drive alone" commuters (Columbus, Detroit, Indianapolis, Kansas City); and
- Fewest mass transit/carpooling programs/high occupancy lanes, etc. offered (Buffalo, Indianapolis, Norfolk, Portland, Tampa/St. Petersburg).

Environmental consequences, such as air pollution, noise, loss of open space, impact on endangered species, water quality and wetlands change, community impacts, and energy use are further condition measures related to highway and transit use. No overall urban indices of these externalities, or of social-cost impacts in general, appear to have been established at this time.

The latest information on transit suggests the following:

- Passenger-mile-weighted speed of transit systems increased 12 percent between 1983 and 1992, due to increases in operating speeds and because of a larger share of transit activity taking place on rail systems.
- Some 27 percent of transit riders were not seated for some or all of their trip; 51 percent of riders transferred during their trip; 20 percent of riders waited more than 10 minutes. The quality of transit service, as described by these measures, varied between the functions of transit. The data are for 1990. More recent information on transit comfort and convenience is unavailable.
- Transit rolling stock, infrastructure and stations continue to have unmet investment needs. In 1991, some 57 percent of bus facilities remained in conditions requiring improvement; rail facilities in maintenance yards which were in poor, bad, or fair conditions were 36 percent of the cases; and 73 percent of elevated structures were in undesirable condition. The average age of the transit bus fleet has been stable (8.13 years in 1986 and 8.29 years in 1992); the age of rapid rail cars was 17.1 years in 1985, 15.2 years in 1988, and 17.7 years in 1992. Some 18 percent of standard-size buses had exceeded their normal replacement lives in 1992, as had 30 percent of the rapid-rail vehicles and 19 percent of commuter-rail vehicles.[18] The number of new rail transit cars fell from a recent high of 1,003 in 1986 to an all-time low of 23 in 1991, but rose again to 198 in 1992.

# The Condition and Performance of Rail Transportation

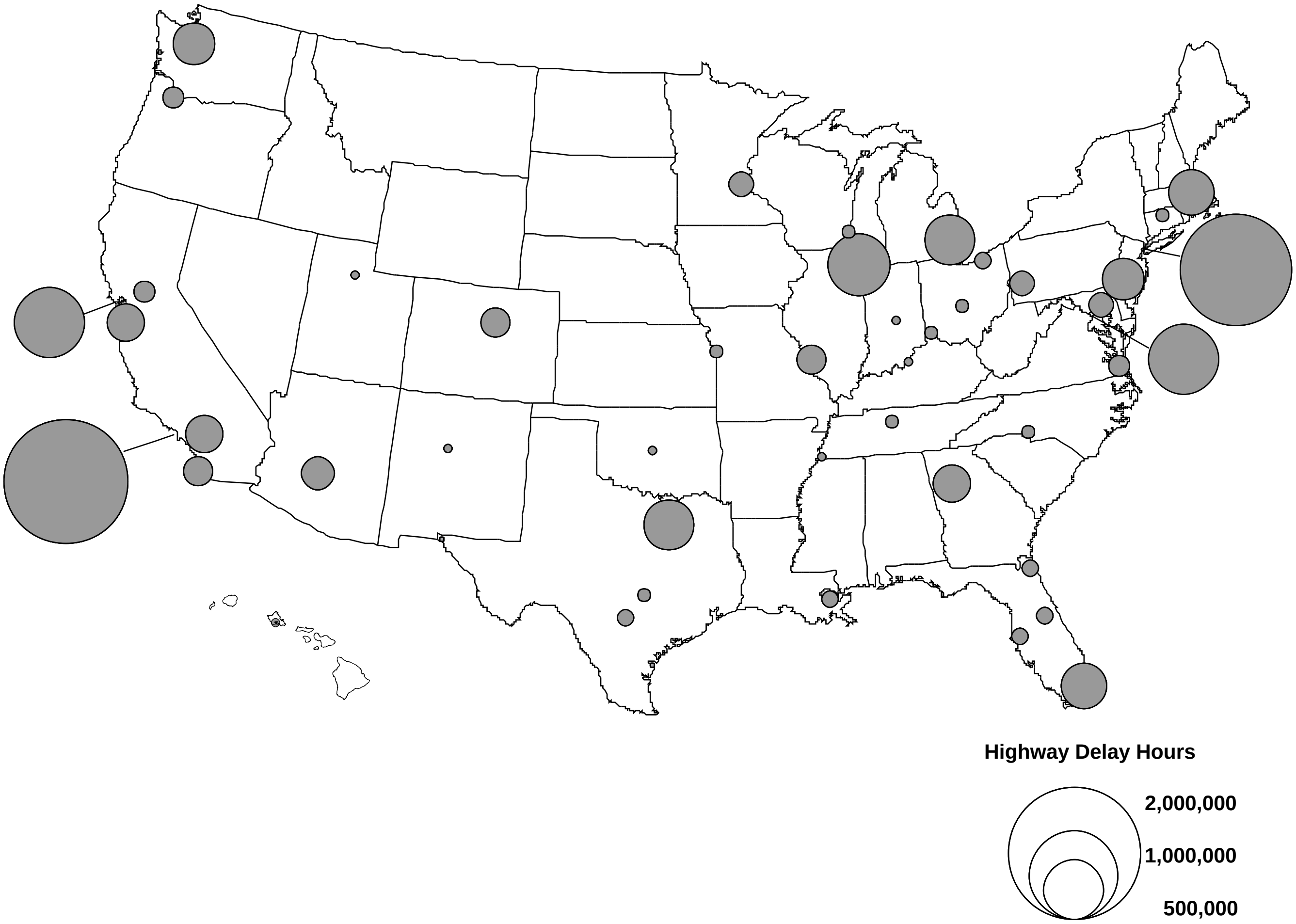
No broad-based, readily available information can be found to indicate the physical condition of the railroads. Track inspections are performed by the Federal Railroad Administration and state inspectors, and speed limits are placed indicating safe operations for the various lines. However, these data do not appear to be compiled and reported in a manner similar to the highway condition reports on present serviceability or levels of service ratings.[19] Yet, selected information is to be found about equipment condition, financial condition and performance quality.

## Passenger Service

On-time performance for Amtrak's short-distance trains fell slightly in 1993 to 79 percent, compared with 82 percent every year from 1990 through 1992. Long-distance trains had a major decline in on-time performance from 60 percent in 1992 to 47 percent in 1993, partly attributable to the extensive floods of that year. Weather conditions during the snowy winter of 1993–94 in the eastern states also negatively affected train service. In mid-1994 Amtrak did request DOT assistance under the Rail Passenger Service Act (which gives priority to passenger trains over freight) to ask Conrail, the Burlington-Northern and other rail-

FIGURE 1–20

Highway Delay Hours for 50 Cities (in thousands): 1990



roads to help Amtrak improve on-time performance (especially on the NY–Chicago and St. Paul–Seattle routes).

Amtrak's passenger cars were older on average in 1993 than in 1992 (22.6 years versus 21.5 years, and 17.5 years as recently as 1989), but deliveries of 140 new bilevel Superliner cars began with 20 cars in July 1993 and will continue through 1995. An order was placed for 50 new Viewliner sleeping cars for delivery in 1996 to replace 40-year-old Heritage cars with higher capacity equipment. Late in 1994 new passenger cars financed by California are to be delivered. Some 26 of 54 new locomotives ordered were delivered during 1993, however, the average age of Amtrak's locomotives still rose slightly to 13.2 years from 13.0.

Amtrak's performance is affected by the condition of its repair facilities and its track, in addition to its equipment. The Northeast corridor and the maintenance facilities at Beach Grove, Indiana, have unfunded needs. According to the General Accounting Office, "For Amtrak to continue nationwide operations at the present level, enhance service quality and reliability, and improve its overall financial condition, requires substantial operating and capital funding (in excess of Amtrak's proposed FY95 budget of $987.6 million)."

### Freight Service

The major rail carriers have enjoyed sharply higher earnings through most of 1994, reflecting strong freight traffic, efficiency gains, and recovery from the 1993 Midwest floods. In reporting record third-quarter results, John Snow, the Chair and Chief Executive of CSX, said, "We look forward to a continuation of these trends through the remainder of 1994 and well into 1995."[20]

According to one observer: "The comeback for an old smoke-stack-era industry, much of which was wallowing in bankruptcy and under threat of nationalization just 20 years ago, has surprised many railroaders. For the first time in their working lives, they are laboring for a growth industry." Traffic is up. There are track extensions and equipment shortages. On half the trackage of 50 years ago, the railroads haul 30 percent more tonnage than at the height of World War II. Intermodal traffic is very strong; the Santa Fe estimates that more than 90 percent of long-distance trucking between California and the Midwest moves by rail.

It should also be noted that technological change in rail equipment and operation has accelerated, due in part to the better financial condition of the railroads, and supported by new entries into equipment supply. According to one observer, we have underway "...the most intense technology push the industry has seen in more than 30 years." Carriers plan major investment in equipment—$600 million in the next four years by the Union Pacific for 240 of the new locomotives.

Computer technology is finding broad application in rail, with an industrywide initiative underway to have Automatic Equipment Identification tags installed on 1.5 million locomotives and freight cars by 1995, supported by a national network of three to five thousand trackside tag scanners. Shipments will be tracked, and arrival time and other information can be adjusted as needed. Railroads will then be able to monitor their service performance.

A further computer application is the joint Burlington Northern/Union Pacific project announced in 1994 to test alternative satellite and radio technologies to detect trains and provide automatic stopping for collision prevention. The testing is taking place on 750 miles of line in the Northwest. According to the Association of American Railroads the nationwide cost of installing positive train control systems has fallen from $3 billion five years ago to $860 million in 1994.

## The Condition and Performance of Air Transportation: The Traveler's Perspective

From the standpoint of the air traveler, one important element in the condition of commercial air service is on-time performance. In 1993, the proportion of flight operations performed on-time for major air carriers was 81.6 percent, down slightly from 82.3 percent in 1992. The trend of the past half-dozen years has been towards better performance, with the last two years being improved compared with the average over the 1988–1993 period of 80.4 percent on-time service.

From the standpoint of system operations, the Federal Aviation Administration, in keeping track of National Airspace System delays, finds that delays of 15 minutes or longer have been falling in the past several years from 393,000 in 1990 to 298,000 in 1991, 281,000 in 1992, and 276,000 in 1993. Delays were also down the first eight months of 1994 from 190,000 in 1993 to 177,000 in 1994.

Passengers are also interested in the extent to which airlines are unable to accommodate them, either denying boarding to passengers who are confirmed (termed involuntary denied boarding) or requesting volunteers to let others occupy their seats. The recent record on involuntary denied boardings is one of improvement, to a recent plateau of 51,000 denials in 1993; the average number for major and national U.S. airlines during the 1986 through 1993 period was 98,000 annually, nearly double that of the latest year. The number of voluntary denied boardings was 632,000 in 1993 against 718,000 in 1992, and an average of 630,000 annually over the past eight years. The apparent trend for both on-time effort and for certainty that a seat will be guaranteed is for improved passenger service.

## Water Transportation Condition and Performance

System and vessel condition in water transport have often been described as a function of age, although elements of water transportation have broad-based methods of measuring other factors that affect throughput, such as the Performance Monitoring System for the inland waterways. That system ranks locks based on average delay, total delay time, average processing time, total down time, total stall events, and lock traffic. Not all water systems produce condition information on a regular basis. Ocean port delay and congestion, for example, is not found on the national level. Some investment estimates are produced on an occasional basis. Expenditure surveys by the American Association of Port Authorities, for example, suggest that anticipated capital expenditures reported from a survey of 55 deep-draft and Great Lakes ports total $5.5 billion for the period 1993 through 1997.

It should be noted that automated techniques are being applied in water transportation, just as in the other modes discussed above. The St. Lawrence Seaway Development Corporation held a demonstration in August 1994 of the Vessel Tracking Services System that it will apply by 1997. The System will use Global Positioning System technology to track vessels as they sail between Montreal and Lake Ontario, displaying ship position, speed and course, plus background information on cargo, dimensions, and ownership. Each ship will take a portable surveillance unit to transmit the information as it enters the Seaway and return the unit upon departure. Tracking will be within 100 meters, helping traffic control operations and improving safety.

## Pipeline Condition and Performance

An aging pipeline system suggests concern over the effects of corrosion and erosion of the pipe over time, reducing its ability to support stress and higher pressures.[21] Some 19 percent of natural gas pipelines were built before 1950, while most of the liquid product lines were built after 1950. Preventive efforts such as frequent monitoring, corrosion control programs, and selective rehabilitation or replacement can offset the effects of aging. The number pipeline failures appears to have exhibited a minor upward trend over the past several years, at 216 for gas pipelines in 1993 and 228 for liquid pipelines that year, compared with four-year averages of 210 in both cases. Pipeline failures are far lower than in past decades such as the 1,996 failures recorded for gas pipelines in 1980 and the 351 liquid pipeline failures that took place in 1970. A major products pipeline failure in Houston during the flood of 1994 affected gasoline availability and price throughout much of the East Coast.

# Transport Trends and Special Events in 1994

## Harbingers of the Future: Trends in Transportation Equipment Manufacture

The year has seen an upturn in the production of transportation equipment in several modes. Overall, expenditures for transportation and related equipment are said to be up 4.3 percent in 1994, although aircraft outlays are down. 1994 is being labeled the best car market in years. Sales for U.S. manufacturers are being led by minivans and light trucks (now nearly half the production). As a result of strong sales, U.S. producers are attempting to increase North American production next year by an estimated 600,000 vehicles more than this year's output of an estimated 12 million cars and light trucks. (Domestic producers account for roughly 76.5 percent of U.S. sales.) Sales of heavy trucks are similarly high with an estimate of 200,000 in 1994 against 96,000 in 1991.

Late in 1994 the sales estimates for new registrations of motor homes suggested almost a 17 percent rise over 1993, which in turn had a 3 percent increase compared to 1992.

U.S. commercial shipbuilding and the U.S.-flag fleet have been in long decline, but a turning point may have been reached in 1993 and 1994. On October 1, 1993, a plan for shipyard conversion from the construction of naval vessels was released by the White House. Subsequently, the 1993 Department of Defense Authorization Act for Fiscal Year 1994 was implemented, containing a $147 million National Shipbuilding Initiative. Loan guarantee programs have been extended (through Title XI of the Merchant Marine Act of 1936, as amended, including guarantees for foreign purchasers for the first time). A new maritime technology program—Maritech—authorized $50 million during fiscal 1994 in cooperative research agreements.[22] Since the enactment of the National Shipbuilding and Shipyard Conversion Act of 1993, U.S. shipyards have been aggressively competing for reentry into the domestic and foreign commercial shipbuilding markets. The newly expanded federal mortgage guarantee program has been a major impetus to the shipyards, and during 1994 seven companies received loan guarantees to construct a total of 52 ships and barges in U.S. shipyards, including the first export order since 1957. Through August of 1995, guarantees were approved for additional 32 ships, tugs and barges, which has catapulted the U.S. from 30th place among the world's shipbuilders at mid-year 1994 to 23rd place at mid-year 1995. Other possible orders are for barges from the Ghana National Petroleum Corporation and for tankers from Mexico's Pemex. Clearly, a resurgence in U.S. vessel production is underway.

With the improved profitability of rail carriers, and the strong second-half financial performance of air carriers during 1994, makers of rail and air equipment should be seeing strong orders. However, equipment manufacture is cyclical, and there are often lags between higher carrier profits and equipment orders. For example, although the latest published data show the inventory of commercial for-hire aircraft in operation (turbojet, turboprop and piston) reported by all U.S. carriers increased from 4,695 in 1991 to 5,319 in calendar 1993, the inventory of total U.S. registered civil aircraft has been nearly the same size for the past decade.[23] The year has seen new orders for U.S. aircraft producers. Boeing, for example, received 40 committed orders in 1994 for its newly designed 737-800 aircraft.[24] Yet, Boeing's orders lag the upturn during 1994 in air carrier profits because carriers have been reducing capacity or maintaining steady capacity in number of aircraft operated. Boeing delivered 214 new planes in the first nine months of 1994, compared to 269 in that period during 1993. The firm's order backlogs were at $67.5 billion on September 30, down from $73.5 billion at the end of 1993.

However, U.S. manufacture of light general aviation aircraft, which has been decreasing for decades, has greatly improved prospects since the General Aviation Revitalization Act became law on August 17, 1994. This tort-reform legislation changes the manufacturer's unlimited liability for every plane ever built. Industry observers see a major turn-around; Beech

Aircraft, for example, produced only 120 single-piston-engine planes in 1993 versus 712 in 1979. Cessna Aircraft Company, which produced almost 8,000 small aircraft at its peak in 1978, has not manufactured a small piston-engine plane since 1990 but expects to begin building around 2,000 a year with the first to be delivered in 1996. This output will add at least $300 million a year in sales and 1,500 jobs. Other new production could come from Commander Aircraft Company, France's Aerospatiale group, and Toyota. The long-term outlook is greatly improved.

## Bumps in the Trends from Earthquakes and Floods

During 1994 a number of natural disasters took place that affected transportation, such as floods in Georgia and Houston. The July floods in Georgia closed roads and bridges, doing over $100 million in damage. The October downpour in Houston resulted in over 20 inches of rain—and lead to 20 deaths, $700 million in damage and 14,000 people forced from their homes in 35 counties. The disaster shut down the Port of Houston for several days because port employees were unable to reach their worksites. Strong currents caused by surge runoff resulted in barges breaking away from moorings. Finally, a major river pipeline broke, spreading oil into the bay and affecting fuel supplies as far away as the Northeast.

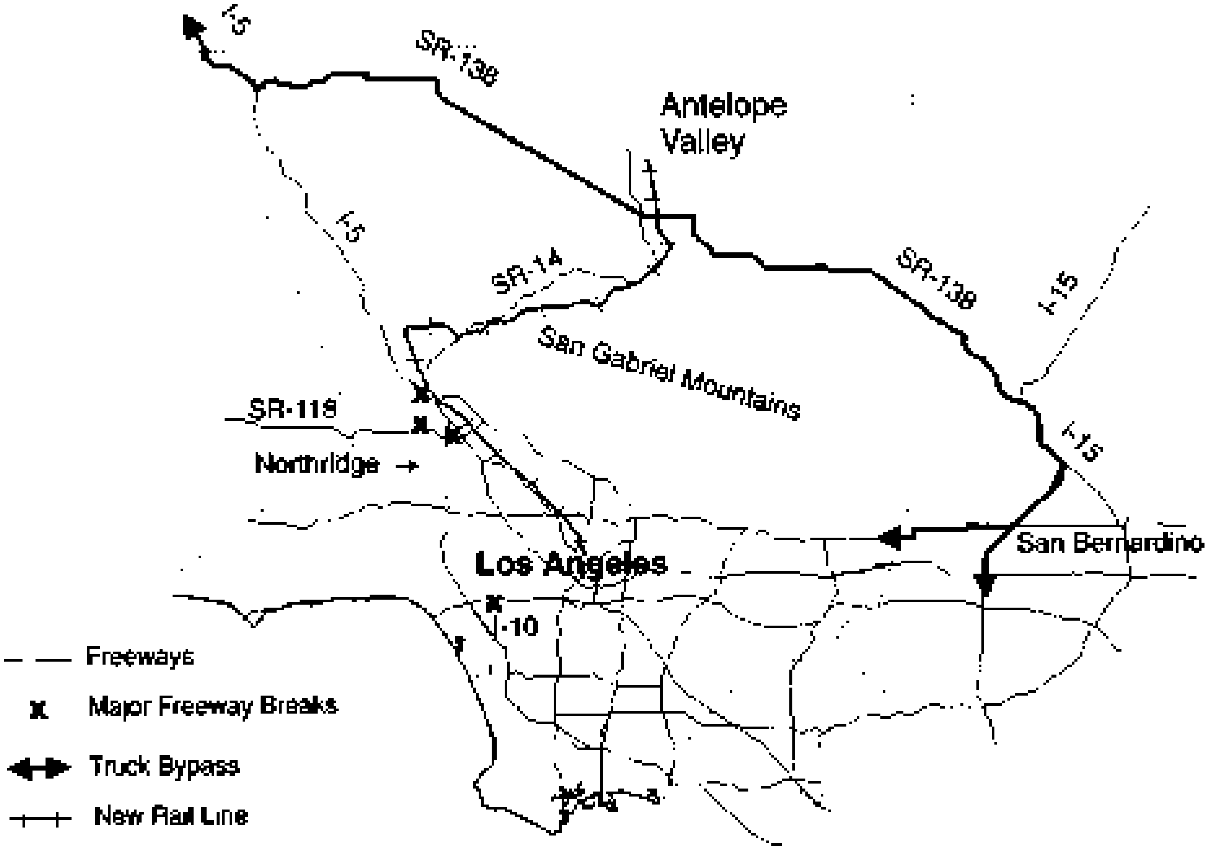
While all these floods combined did not have impacts equal to 1993's catastrophic rains in the Midwest (and discussed extensively in the context of transportation vulnerability in TSAR 94), yet another natural disaster struck the nation this past year. The nations second largest metropolis and principal gateway to the Pacific was rocked by an earthquake of 6.8 magnitude in January. Centered on the Northridge community in the San Fernando Valley, the earthquake knocked out four freeways, caused the collapse of parking structures, and ruptured numerous natural gas distribution lines. (See Figure 1–21.) The interchange between Interstate 5 and State Route 14 collapsed (as it had once before in the 1971 Sylmar Earthquake), severing California's main north-south artery and cutting off the rapidly growing suburbs north of the San Gabriel Mountains. State Route 118, a principal connector between the heavily suburbanized Simi Valley and the rest of Los Angeles, collapsed in two places. The Santa Monica Freeway portion of Interstate 10, which normally carries 330,000 vehicles per day, was also severed.

After the Northridge Earthquake, a BTS team visited the area and found that:

- The transportation system in Los Angeles had enormous resiliency. Most nonhighway transportation was operational within two days. Alternatives were found within a week for the key highway links that had been destroyed by the earthquake. Alternatives included rerouting of traffic over parallel streets, institution of High Occupancy Vehicle (HOV) lanes on parts of the reroutes, and rapid expansion of commuter railroad service. For example, commuter service on the railroad that paralleled State Route 14 jumped from 950 riders per day to 22,000.
- Traffic was often diverted from broken links on the proposed National Highway System (NHS) to local arteries not on the proposed NHS.
- A significant number of parking structures failed, with consequences for both transportation and public safety.
- Post-earthquake shifts to telecommuting and other changes in travel behavior took place but were not due entirely to congestion avoidance. Many people stayed home for the entire week following the earthquake to clean up and arrange for repairs to personal property.
- Caltrans (the state department of transportation) and the California Highway Patrol were concerned about commerce as well as commuters. While Interstate 10 is not a major truck route, Interstate 5 is the major north-south corridor for trucking between the Pacific Rim states, and was effectively severed for several days. Traffic between the Los Angeles–San Diego area and Northern California could use U.S. 101 without too much added circuity. Traffic between the Los Angeles–San Diego area and the southern San Joaquin Valley (e.g., Bakersfield) was diverted via San Luis Obispo or San Bernardino and suffered from relatively much greater circuity.

**FIGURE 1 – 21**

Transportation Disruptions of the 1994 Northridge Earthquake



- The combined response of Caltrans, the California Highway Patrol, the Los Angeles Department of Transportation, the Los Angeles Metropolitan Transportation Authority and others was exemplary for its timeliness and effectiveness. Local officials consistently attributed their ability to perform to the practice with the 1984 Olympics, with recent fires and riots, and with recurrent events throughout the year (such as the Academy Awards) that affect traffic.
- Transportation officials appeared to depend on up-to-date local knowledge and a willingness to experiment rather than on pre-set solutions and simulation models to guide their decision-making.
- The damage and loss of life could have been far worse if the earthquake had been slightly stronger, centered in other nearby locations, or later in the day.

Subsequent studies by Commuter Transportation Services, a not-for-profit organization that promotes ridesharing and transit use, found that half of all commuters in Los Angeles and 80 percent of commuters in the earthquake zone made some adjustment in their travel, but most changes were temporary. Most were to routes and time of departure. Some commuters have stuck with the alternate routes on arteries paralleling the freeways that they “discovered” following the earthquake. One-fourth of the new riders on the commuter rail service have stayed on the trains.

BTS recognizes that the Northridge Earthquake of 1994 and its aftermath provide a natural laboratory to examine travel behavior, the reliability of the transportation system, and the impact of transportation disruptions on businesses and regional economies. BTS is utilizing this natural laboratory through research projects at the University of California at Los Angeles, the University of California–Irvine, the University of Southern California, and California Polytechnic University, Pomona. Results of the BTS sponsored research are expected to be published in the Spring of 1996.

## Endnotes

1 Rates of change calculated by Alan Pisarski from the 1980 and 1990 U.S. censuses. Population trends from *Current Population Reports, Population Projections of the United States, by Age, Sex, Race and Hispanic Origin: 1993 to 2050.* European population trends from OECD in Figures, 1993 Edition—Statistics of the Member Countries.

2 For a recent discussion of telecommuting see the "Section 352 Study," U.S. Department of Transportation, *Transportation Implications of Telecommuting* (Washington, D.C.: U.S. Government Printing Office, 1993).

3 The 60.6 is calculated from NTS, Highway Profile, page 20. Not until 1943 did the proportion of surfaced mileage—including gravel and stone—reach 50 percent, and it was not until 1972 that the proportion reached 80 percent. *Transportation Statistics Annual Report,* 1994, p. 39, footnote 6.

4 *Report to Congress on the Proposed National Highway System Required by Section 1006(a) of the Intermodal Surface Transportation Efficiency Act of 1991, Public Law 102–240* (Washington, D.C.: U.S. Department of Transportation, 1993). Also, Federal Highway Administration, *The National Highway System, The Backbone of America's Intermodal Transportation Network* (Washington, D.C.: U.S. Department of Transportation, 1994). For a description of administrative efforts to bridge between the National Highway System and former highway system classifications, see *The Status of the Nation's Highways, Bridges, and Traffic Conditions and Performance,* Report of the Secretary of Transportation to the United States Congress pursuant to Section 307(h) of Title 23. United States Code, and Section 308(e) of Title 49, United States Code (Washington, D.C.: U.S. Government Printing Office, 1994) 30. Herinafter referred to as Conditions and Performance Report.

5 Stephen C. Fehr, *Auto Fleet Is Aging, Signaling Hazards Ahead, The Washington Post* (August 29, 1994), A1, A9, at A9. Note, however, that cars (and trucks as well) are more durable than in the past so that older vehicles have greater, more reliable performance than was once the case. The average age of a passenger car in use in the U.S. in 1993 was 8.3 years (for the mean) versus 8.1 years in 1992—the highest since 8.8 years in 1946. (The median was 7.3 years, up from 7.0 in 1992.) See *AAMA Motor Vehicle Facts and Figures* (Detroit, MI: American Automobile Manufacturers Association, 1994), 39. Data derived from R.L. Polk & Company.

6 Robert L. Simison, *U.S. Vehicle Sales Rose 9% in October Despite Slow Start-Up of Some New Cars, The Wall Street Journal* (November 4, 1994), A2.

7 The comparison is 1,236,148 versus 1,278,811; see *Highway Statistics, 1992,* op.cit., 19 and *Highway Statistics, 1991* (Washington, D.C.: U.S. Government Printing Office, 1992), 19.

8 U.S. Department of Commerce, *Statistical Abstract of the United States: 1993* (Washington, D.C.: U.S. Government Printing Office, 1993), 253.

9 For information about Amtrak see *National Railway Passenger Corporation 1993 Annual Report* (Washington, D.C.: National Railroad Passenger Corporation [1994]).

10 Association of American Railroads, *op.cit.,* 44.

11 *C & NW to expand Wyoming coal line, Traffic World,* Vol. 238, No. 12 (June 20, 1994), 34. Further prospects of new track investment and increases in track mileage are being discussed in rail circles.

12 Class size (from Class I, the largest, to the smallest Class III) is measured in terms of operating revenue of the firms in the industry.

13 *Condition and Performance Report,* p. 25. This is a 7 percent increase from 1990's figure of 293 urbanized areas with service as reported in last year's TSAR report, *The Status of the Nation's Highway, Bridges, and Transit: Conditions and Performance, Report of the Secretary of Transportation to the United States Congress, Pursuant to Section 307(h) of Title 23, United States Code, and Section 308(e) of Title 49, United States Code* (Washington, D.C.: U.S. Government Printing Office, 1993), 43. A somewhat different total for transit operators in 1992 is provided by the American Public Transit Association: 5,086—including 32 heavy- or light-rail operations, 1,174 fixed-route bus operators in urbanized areas, and 3,894

demand response providers. See *1993 Transit Fact Book* (Washington, D.C.: American Public Transit Association [1994]), 26.

14 *Seaway Tonnage Rises During 1994 Navigation Season, DOT Today*, Vol. IV, No. 2 (November 1994), 7.

15 *Toward a National Intermodal Transportation System*, op. cit., 9.

16 For a description of the 6-year Texas Transportation Institute study that has developed these index measures see David L. Schrank, Shawn M. Turner and Timothy J. Lomax, *Estimates of Urban Roadway Congestion–1990* (Washington, D.C.: U.S. Government Printing Office, 1993).

17 Scorecard, Worst Driving Bottlenecks, *Consumer Report Travel Letter*, Vol. 10, No. 8 (August 1994), 184.

18 *Condition and Performance Report,* 12, 13.

19 U.S. Department of Transportation, *National Transportation Strategic Planning Study.* Washington, D.C.: U.S. Government Printing Office, 1990, 13–6.

20 Daniel Machalara, "Southern Pacific CSX Third-period Net Jumped on Gains in Traffic, Efficiency" *The Wall Street Journal*, Oct. 26, 1994, B4.

21 "Aging pipelines are of concern because there is a higher risk that they will result in pipeline incidents. The Reston pipeline incident [March, 1993 in Reston, VA] points out that even relatively newer pipelines are subject to failure." Allen Li, *Pipeline Safety, Use of Instrumented Technology to Inspect Pipelines* (Washington, D.C.: U.S. General Accounting Office, 1993), 2.

22 Maritime Administration, *103rd Congress, Maritime-Related Legislation, as of October 27, 1994*, processed. The Title XI program will continue, with slight modification, under the OECD multilateral shipbuilding agreement announced July 18, 1994, going into effect upon ratification January 1, 1996. U.S. Department of Transportation, *Transportation Facts* (October 28, 1994).

23 The total number of aircraft was 271 thousand in 1984 and 279 thousand in 1993. U.S. Department of Transportation, *Census U.S. Civil Aircraft, Calendar Year 1993, op. cit*., 1–3.

24 Southwest Airlines, Danish carrier Maersk Air and German tour carrier Hapag-Lloyd have placed orders for the 737-800, with delivers to take place starting in 1998. See *Boeing Co. Receives German Plane Order Valued at $700 Million, The Wall Street Journal* (November 21, 1994), A6.

## Sources

Due to the extensive resources used to prepare this chapter, a complete bibliography is available through BTS. Below is a listing of sources used to compile information contained in this chapter.

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National Commission on Intermodal Transportation
National Research Council
*Newsweek*
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*Planning*
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# EXPENDITURES *for* TRANSPORTATION

The United States makes enormous expenditures in transportation to support commercial and industrial activities and meet the mobility requirements of its citizens. This chapter quantifies transportation expenditures as a share of the total economy and of consumer spending. The chapter also examines the transportation expenditures and revenues of local, state, and federal government. Social costs of transportation, such as safety, are examined in Chapter 3, and the economic consequences of transportation expenditures are explored in Part Two of this book.

## Transportation Expenditures

### Transportation Expenditures as a Percentage of GDP

What does transportation cost the country? One way to answer this question is to estimate the proportion of the gross domestic product (GDP) represented by the production of transportation services in the United States. In 1993—the most recent year for which data are available—GDP was about $6.3 trillion, and the portion of GDP attributed to transportation was about $680 billion in current dollars. Thus, transportation's share of GDP was slightly under 11 percent—a proportion that has held fairly steady over the last four years. (See Tables 2–1 and 2–2.)

GDP-based data may undervalue transportation output, however. For one thing, some categories of transportation-related activity—notably, spending by businesses on in-house transportation (such as private trucking) and military purchases of transportation equipment—are not allocated to transportation in the GDP figures. Additional research is needed to identify these components of transportation spending so that the role of transportation in the economy is no longer understated.[1]

There is a larger sense in which GDP-based figures fail to indicate transportation's extensive role in the U.S. economy and society. The mobility provided by transportation affects the life circumstances of every citizen. Transportation is an intermediate good that is consumed at every stage of production in order to create final products. It is a key element in workforce productivity, because labor markets depend upon employees' access to the workplace. Also, the distribution of goods and retail sales are dependent both on transportation of items to market and on consumer access to the marketplace. Clearly, inefficiencies or inadequacies in these intermediate transportation linkages can affect the economy's total productivity, as well as individuals' personal opportunities.

## The Transportation Bill

Another way of estimating what transportation costs the United States is to calculate a *transportation bill*. This bill takes into account all expenditures made throughout the economy for transportation at various stages of production and consumption. For example, the transportation bill includes both shipper spending on for-hire trucking and spending by motor carriers on fuel. This accounting method is very different from that of GDP calculation and cannot be compared directly. GDP accounts only for expenditures that contribute directly to the final output of the nation. To avoid double counting, the GDP calculation includes shipper purchases of motor carrier services, but excludes amounts spent for fuel because fuel is an intermediate input to final motor carrier

### TABLE 2–1

Gross Domestic Product Attributable to Transportation Demand
(in billions of current dollars)

| | 1989 | 1990 | 1991 | 1992 | 1993 |
|---|---|---|---|---|---|
| Personal Consumption of Transportation | 437.3 | 453.9 | 433.6 | 466.3 | 504.2 |
| User-operated transportation | 399.6 | 414.0 | 394.5 | 426.9 | 461.9 |
| Purchased local transportation | 8.1 | 8.9 | 9.0 | 9.1 | 9.3 |
| Purchased intercity transportation | 29.5 | 30.9 | 30.1 | 30.3 | 33.0 |
| Gross Private Domestic Investment in Transportation | 79.6 | 88.3 | 88.1 | 95.2 | 108.8 |
| Purchases of structures by transportation-related organizations | 3.0 | 3.0 | 3.2 | 3.7 | 4.6 |
| Private purchases of producers' transportation equipment | 76.6 | 85.3 | 84.9 | 91.5 | 104.2 |
| Net Exports of Goods and Services | –33.1 | –25.5 | –14.9 | –13.2 | –23.4 |
| Exports | 72.1 | 84.0 | 92.5 | 102.1 | 101.7 |
| Civilian aircraft, engines and parts | 26.6 | 32.2 | 36.6 | 37.7 | 32.7 |
| Automotive vehicles, engines and parts | 34.9 | 36.5 | 40.0 | 47.0 | 52.4 |
| Passenger fares | 10.6 | 15.3 | 15.9 | 17.4 | 16.6 |
| Imports | 105.2 | 109.5 | 107.4 | 115.3 | 125.1 |
| Civilian aircraft, engines and parts | 9.6 | 10.5 | 11.7 | 12.6 | 11.3 |
| Automotive vehicles, engines and parts | 87.4 | 88.5 | 85.7 | 91.8 | 102.4 |
| Passenger fares | 8.2 | 10.5 | 10.0 | 10.9 | 11.4 |
| Government Purchases | 81.4 | 87.7 | 98.7 | 94.7 | 98.1 |
| Federal government transportation-related purchases | 9.6 | 10.4 | 11.8 | 12.6 | 13.1 |
| State and local government transportation-related purchases | 63.8 | 68.4 | 70.9 | 72.5 | 76.0 |
| Defense related transportation purchases* | 8.0 | 8.9 | 16.0 | 9.6 | 9.0 |
| Gross Domestic Product Attributable to Transportation Activity | 565.2 | 604.4 | 605.5 | 643.0 | 687.7 |
| Gross Domestic Product | 5250.8 | 5546.1 | 5724.8 | 6020.2 | 6343.3 |
| Transportation Share of Gross Domestic Product | 10.8% | 10.9% | 10.6% | 10.7% | 10.8% |

*Includes defense-related transportation of material and travel of persons

**TABLE 2–2**

Gross Domestic Product Attributable to Transportation Demand
(in billions of 1987 dollars)

| | 1989 | 1990 | 1991 | 1992 | 1993 |
|---|---|---|---|---|---|
| Personal Consumption of Transportation | 407.5 | 403.1 | 372.3 | 390.3 | 410.5 |
| User-operated transportation | 373.8 | 369.1 | 339.2 | 357.5 | 377.0 |
| Purchased local transportation | 7.6 | 7.9 | 7.6 | 7.2 | 7.2 |
| Purchased intercity transportation | 26.0 | 26.2 | 25.6 | 25.6 | 26.2 |
| Gross Private Domestic Investment in Transportation | 75.4 | 81.3 | 77.5 | 81.6 | 91.6 |
| Purchases of structures by transportation-related organizations | 2.8 | 2.8 | 2.8 | 3.3 | 3.8 |
| Private purchases of producers’ transportation equipment | 72.6 | 78.5 | 74.7 | 78.3 | 87.8 |
| Net Exports of Goods and Services | –29.1 | –23.4 | –13.1 | –11.5 | –19.6 |
| Exports | 68.2 | 76.7 | 81.8 | 88.4 | 87.4 |
| Civilian aircraft, engines and parts | 25.0 | 28.6 | 31.1 | 30.7 | 25.9 |
| Automotive vehicles, engines and parts | 33.4 | 34.1 | 36.3 | 41.9 | 46.3 |
| Passenger fares | 9.7 | 13.4 | 12.7 | 13.2 | 12.6 |
| Imports | 97.5 | 99.9 | 93.6 | 98.0 | 105.1 |
| Civilian aircraft, engines and parts | 9.0 | 9.3 | 10.0 | 10.2 | 8.9 |
| Automotive vehicles, engines and parts | 80.7 | 81.4 | 75.8 | 79.7 | 87.4 |
| Passenger fares | 7.8 | 9.2 | 7.8 | 8.1 | 8.8 |
| Government Purchases | 75.8 | 78.7 | 86.6 | 80.4 | 81.0 |
| Federal government transportation-related purchases | 8.9 | 9.3 | 10.1 | 10.5 | 10.5 |
| State and local government transportation-related purchases | 58.8 | 60.4 | 60.6 | 60.4 | 61.8 |
| Defense related transportation purchases* | 8.1 | 9.0 | 15.9 | 9.6 | 8.7 |
| Gross Domestic Product Attributable to Transportation Activity | 529.3 | 539.3 | 522.9 | 540.1 | 562.8 |
| Gross Domestic Product | 4838.0 | 4897.3 | 4867.6 | 4979.3 | 5134.5 |
| Transportation Share of Gross Domestic Product | 10.9% | 11.0% | 10.7% | 10.8% | 11.0% |

*Includes defense-related transportation of material and travel of persons

services. The larger amount of transport expenditure measured by the transportation bill—$1 trillion—vs. the GDP figure of less than $700 billion points up the difference in definition. Because the transportation bill and GDP are based on different accounting methods, the former *cannot* be divided by the latter to measure transportation’s role in the economy.

## Consumer Expenditures for Transportation

In 1993, the most recent year for which data are available, total spending on transportation was on average $5,453 for American households.[2] This figure covers all spending for transportation by a household for vehicle purchases, gasoline and oil, other vehicle expenditures, and for-hire transportation; it does not include business travel if paid for by others. In all, these expenses represent on average about 17.8 percent of total household expenditures—or just over $1 of every $6 spent by reporting households. Transportation’s share of total consumer spending is second only to housing (at 31.4 percent); it ranks higher than such other consumer expenditure categories as food, insurance and pensions, health care, and apparel. (See Figure 2–1.)

The largest portion of consumer transport expenditures is on personal vehicle operation, upkeep, and purchase. (See Figure 2–2.) Vehicle purchase in fact accounted for the lion’s share of all personal transport expenditures —averaging $2,319 in 1993, or 42.5 percent of total transportation expenditures.[3] For-hire transportation (by air, bus, transit, taxi, intercity train, ship, and school bus), on the other hand, averaged a surprisingly low $314 per household, or about 6 percent of total personal transport expenditures. (See Table 2–3.)

The Consumer Expenditure Survey shows variability from year to year in the percentages of expenditure made for transportation and its various subelements. In general, transportation's share of total personal expenditures seems to have declined slightly in recent years when compared to the previous decade. Much of this decline can be traced to relatively lower expenditures on gasoline and oil in the early 1990s versus the early 1980s. (See Table 2-4.) These costs have declined because fuel prices (including the user-fee component of those prices) have dropped relative to other consumer prices,[4] and because vehicle fuel economy has improved, despite more overall travel as measured in vehicle-miles of travel.

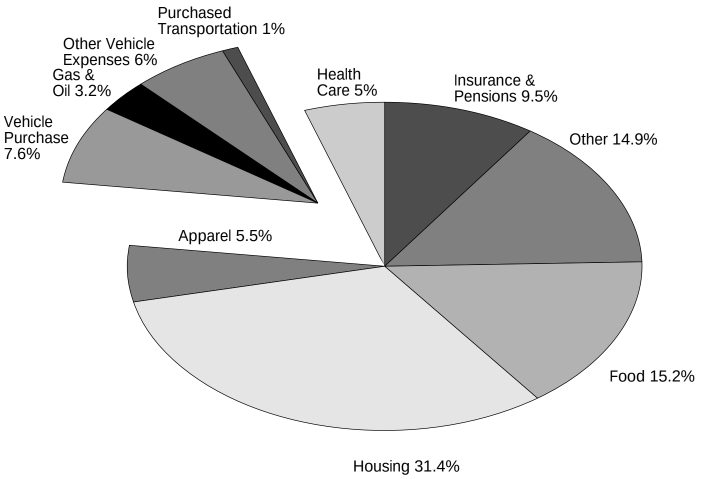
### Consumer Expenditures by Region

Household expenditures for transportation differ greatly by region. (See Figure 2–3.)

- In the Northeast, spending for vehicles and vehicle operations is lower than elsewhere, while spending for purchased transport services—particularly transit—is higher. Average purchased transportation expenditures in the Northeast easily topped the national household average—$449 versus $314—primarily because of high transit, taxi, and train expenditures. Transit spending, which is about $127 per year in the Northwest, is nearly five times that of the Midwest and over six times that of the South. The Northeast has the lowest vehicle ownership rate of any region.
- The Midwest has the highest level of vehicle expenditures ($2,504), particularly of used cars and trucks (almost double that of the Northeast). Insurance spending is lowest in the Midwest.
- Fuel purchases are highest in the West, and fuel purchased for out-of-town trips in this region is twice that of the East. Western spending for vehicle maintenance and repairs (such as for tires and parts) is higher than in other regions for almost all subcategories of this type of expenditure. Western households purchase more transport services than does the U.S. households on average, particularly in the category of air travel.

**FIGURE 2–1**

Total Consumer Spending Shares by Major Category: 1993

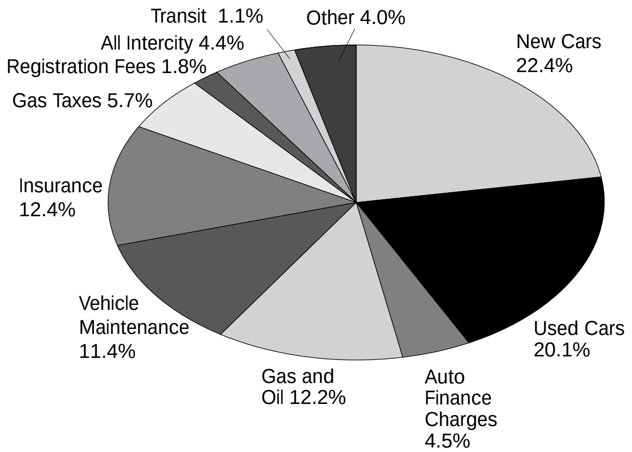


### Consumer Expenditures by Household Size

The amount of money spent for transportation does not increase at a steady per person rate as the size of the household unit increases. (See Table 2–5.) For example, the amount of money spent on transportation in two-person households is more than twice that spent in one-person households: $5,720 versus $2,727 in 1993. For three- and four-person households, however, the amount spent per person on transportation is substantially less than for

**FIGURE 2–2**

Detailed Consumer Spending for Transportation: 1993



## TABLE 2–3

### Average Household Expenditures for Transportation: 1993

| | | |
|---|---|---|
| **VEHICLE PURCHASES** | | $2,319 |
| Including: | | |
| Cars and Trucks, New | 1,216 | |
| Cars and Trucks, Used | 1,079 | |
| **GASOLINE AND OIL** | | 977 |
| **OTHER VEHICLE EXPENDITURES** | | 1,843 |
| Including: | | |
| Finance | 244 | |
| Maintenance and Repair | 620 | |
| Vehicle Insurance | 678 | |
| Vehicle Rental and Leasing | 154 | |
| Vehicle Registration, Licenses, Fees | 146 | |
| Parking | 22 | |
| **FOR-HIRE TRANSPORTATION** | | 314 |
| Including: | | |
| Airline Fares | 203 | |
| Intercity Bus | 10 | |
| Transit and School Bus | 60 | |
| Taxi | 13 | |
| Intercity Rail | 16 | |
| Ship | 11 | |
| Total | | $5,453 |

## TABLE 2–4

### Share of Consumer Expenditures Related to Transportation and Fuel Costs

| | Transportation | Gas and Oil |
|---|---|---|
| 1980 | 21.07% ($3,409) | 7.43% ($1,202) |
| 1990 | 18.05% ($5,122) | 3.69% ($1,047) |
| 1991 | 17.39% ($5,151) | 3.35% ($ 995) |
| 1992 | 17.51% ($5,228) | 3.26% ($ 973) |
| 1993 | 17.77% ($5,453) | 3.18% ($ 977) |

each person in a two-person household. Moreover, in five-person households, spending is actually less than for households of four persons.[5] These data suggest that factors such as age, life cycle stage, and disposable income have more impact on transportation spending than does household size.

## FIGURE 2–3

### Transportation Spending by Type and Region: 1993

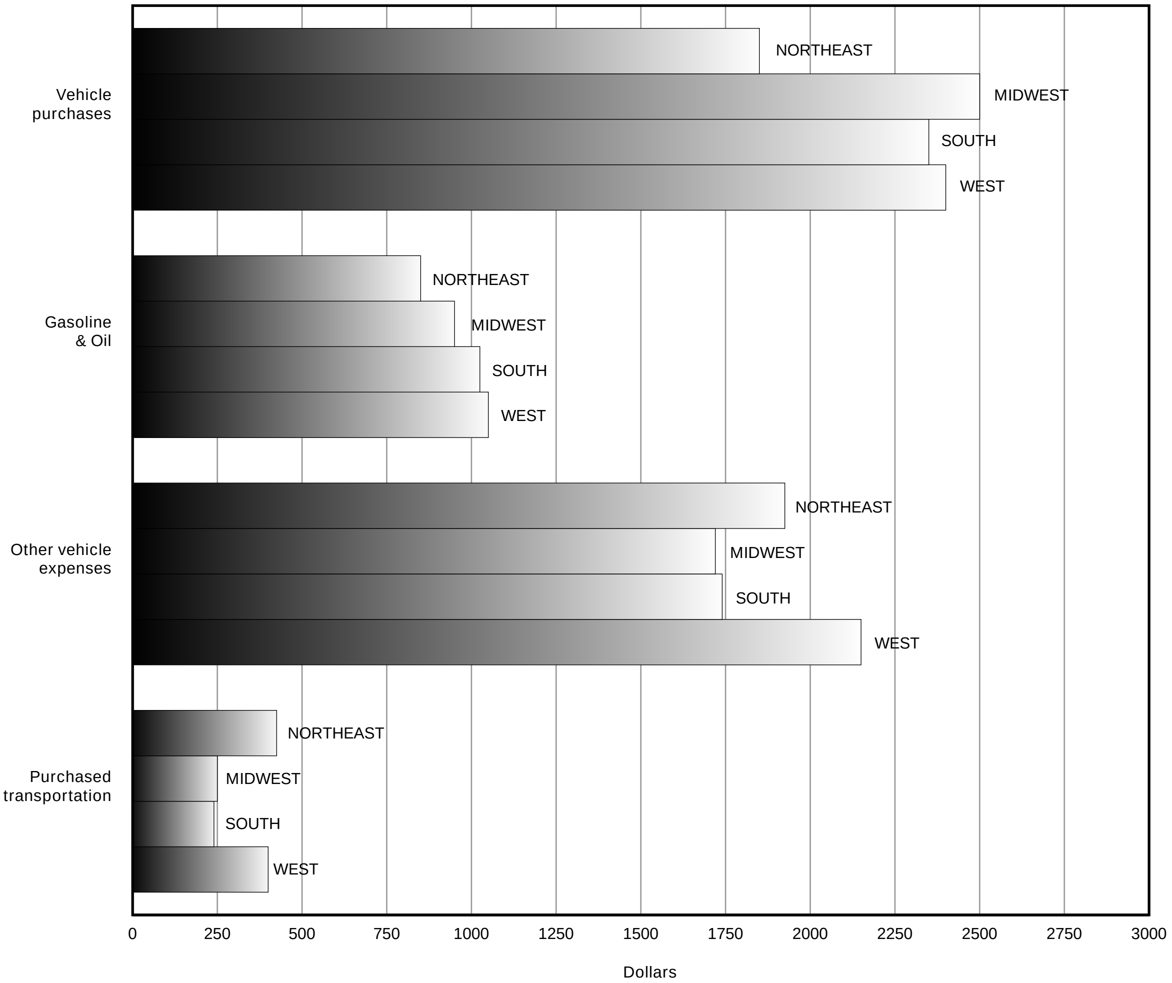


TABLE 2–5

Spending by Size of Consuming Unit: 1993

| | Total Spending | Transportation Spending | Transportation Share of Spending |
|---|---|---|---|
| 1 Person Unit | $17,999 | $2,727 | 15% |
| 2 Person Unit | $31,603 | $5,720 | 18% |
| 3 Person Unit | $35,416 | $6,696 | 19% |
| 4 Person Unit | $42,397 | $7,671 | 18% |
| 5 or more Person Unit | $39,981 | $7,265 | 18% |

TABLE 2–6

Spending by Age Group: 1993

| | Total Spending | Transportation Spending | Transportation Share of Spending |
|---|---|---|---|
| Less than 25 years | $17,468 | $3,948 | 23% |
| 25–34 years | $28,594 | $5,099 | 18% |
| 35–44 years | $37,429 | $6,651 | 18% |
| 45–54 years | $41,020 | $7,479 | 18% |
| 55–64 years | $32,973 | $6,340 | 19% |
| 65 years and over | $21,322 | $3,081 | 14% |

### Consumer Expenditures by Age

Younger people spend less for transportation than do older people. (See Table 2-6.) Spending on transportation rises with age up to the 45–54 age bracket, falls slightly for the 55–64 age bracket, and then drops substantially with the retirement years.[6] Those 65 and over spend much less on vehicle purchases than any other age group, but their public transport expenditure is half again as high as for households under 25 (the group spending the second lowest amount on transportation). The age group with the greatest per capita spending on transportation, ages 45 to 54, is also the group that spends the most overall on transportation.

### Consumer Expenditures by Income Group

Higher income groups spend a larger proportion of their income on transportation than do lower income groups. When households are divided into five income groups, the transport share of their expenditures increases slightly with income through the first four quintiles.[7] (See Figures 2–4 and 2–5.)

The main reason for the higher levels of expenditure at higher levels of income is the propensity to spend more on vehicles as income rises. One reason to spend more is the increased household size at higher income quintiles: The two lowest quintiles have about two people per household, while the two highest quintiles have about three. Larger households tend to have more drivers and own or lease more vehicles than do two-person households. The expense of vehicle operation, such as gasoline and oil purchases, rises less rapidly when income increases. This suggests that more capital expense for vehicles, rather than more travel, is the reason for the increase with income in total transportation expenditure. The very highest income quintile spends dramatically more on *new* vehicles—50 percent more than does the next highest income quintile.

Purchased transportation rises slowly with income, as steady amounts of transit and intercity bus expenditures are replaced by air travel in the higher income groups. The highest income quintile spends more than twice as much on air travel as does the next highest income group.

## Transportation Expenditures: the Public Sector

Government agencies at all levels (federal, state, and local) play a significant role in providing transportation infrastructure and selected transportation services. Government agencies are also significant purchasers of transportation equipment and services. The financing of these transportation expenditures involves user charges, general tax revenues, and transfers of funds from the federal to the state and local levels. This section describes trends in both public spending on transportation and revenues collected for transportation.

**FIGURE 2–4**

Transportation Spending by Income Quintile: 1993

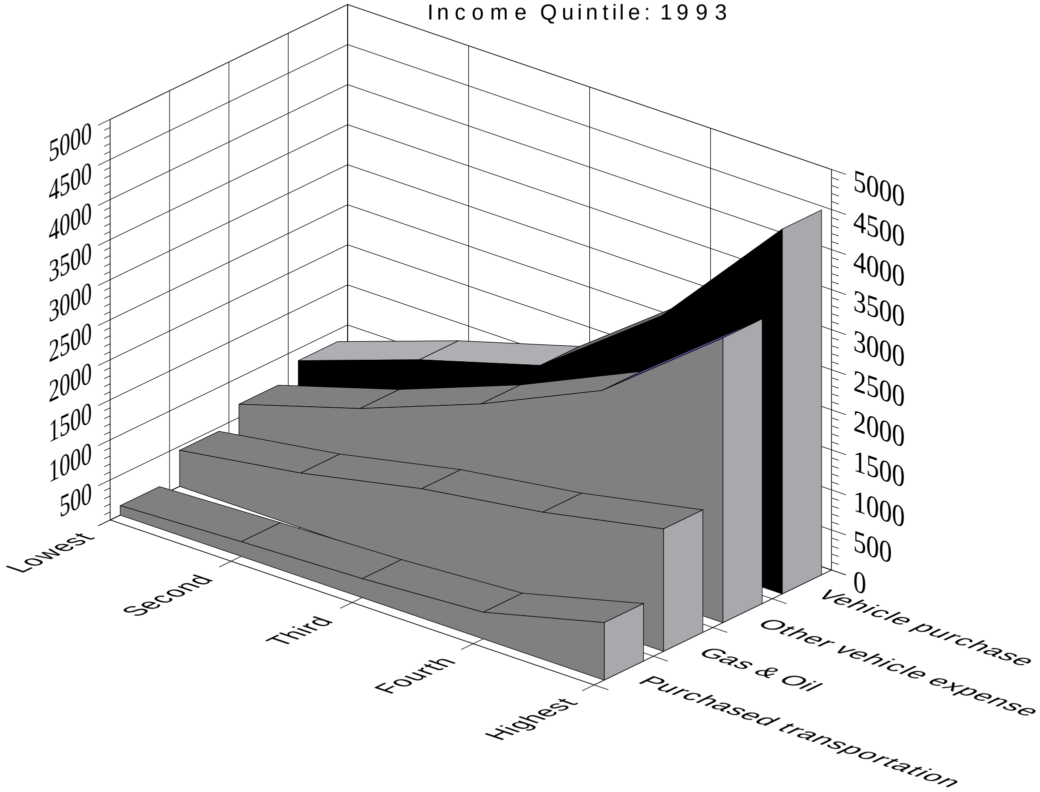
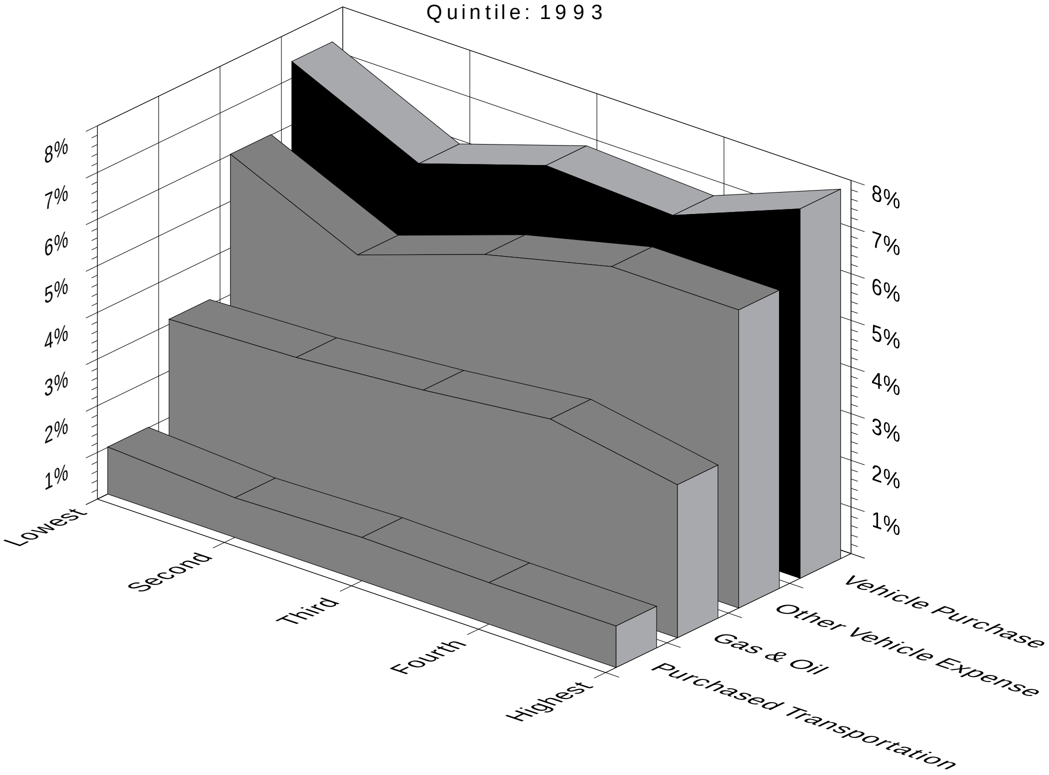


**FIGURE 2–5**

Share of Transportation Spending in Total Expenditure by Income Quintile: 1993



## Government Transportation Expenditures

All governments spent $113.3 billion on transportation in fiscal year 1992, or 4.6 percent of total government expenditures. (See Table 2–7.) Some 60 percent of that expenditure was on highways. (See Table 2–8.) Transport as a proportion of all government expenditure was 1.0 percent for the federal government, 9.3 percent for the states, and 8.3 percent for all local governments.

Figure 2–6 shows trends in total expenditures by level of government in current and constant dollars. Direct federal transport expenditures measured in current dollars rose at a low rate for the period, while federal grants-in-aid grew slightly faster. In contrast, state and local transport expenditure (excluding federal intergovernmental transfers) expanded greatly. The findings in constant (1982) dollars show direct federal spending static, while federal grant expenditure grew $1.7 billion in 11 years. Much greater growth occurred, however, in the state and local category, with a $17 billion rise in expenditures solely from local and state sources of funds.

Most *federal* funds spent for transportation purposes are intergovernmental trans-

**TABLE 2–7**

Government Transportation Expenditures (billions of current dollars)

| | Including Federal Grants | | Excluding Federal Grants | |
|---|---|---|---|---|
| | 1982 | 1992 | 1982 | 1992 |
| Federal | $23.6 | 34.8 | $9.8 | $13.4 |
| State and Local | 36.8 | 78.5 | | |
| State | | | 23.1 | 46.5 |
| Local | | | 27.5 | 53.4 |
| Total | $60.4 | $113.3 | $60.4 | $113.3 |

**TABLE 2–8**

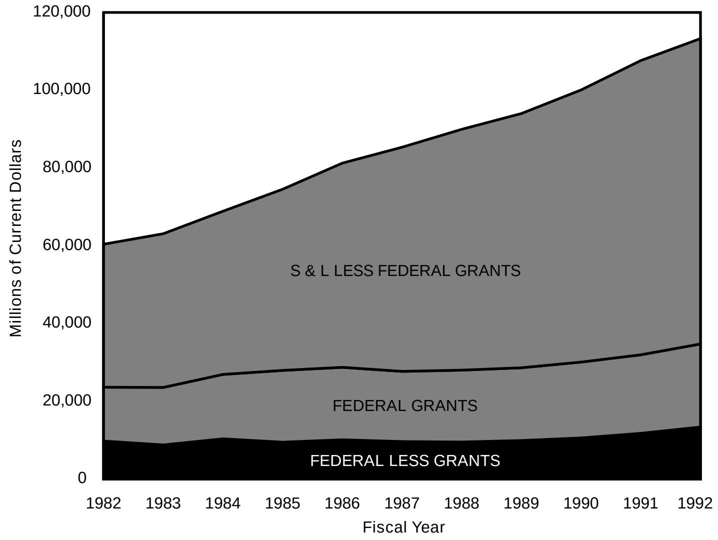
Federal, State, and Local Transportation Expenditures by Mode: FY 1982–1992 (In millions of current dollars)

| | 1982 | 1992 | Annual change in current $ | Annual change in constant $ |
|---|---|---|---|---|
| Highway | 35,731 | 67,417 | 6.55% | 2.85% |
| Air | 6,043 | 15,753 | 10.06% | 6.23% |
| Transit | 11,401 | 22,350 | 6.96% | 3.24% |
| Water | 4,412 | 5,653 | 2.51% | –1.06% |
| Rail | 2,250 | 905 | –8.71% | –11.89% |
| Parking | 395 | 898 | 8.56% | 4.79% |
| Unallocated | 155 | 289 | 6.44% | 2.73% |
| Pipeline | 9 | 32 | 13.07% | 9.85% |
| Totals | 60,396 | 113,297 | 6.49% | 2.79% |

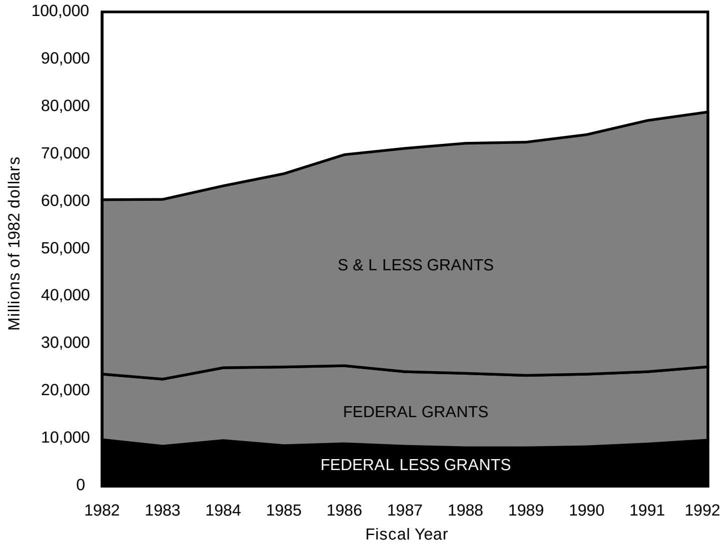
Note: Annual change is compound annual growth rate in current or constant 1982 dollars. Highway expenditures exclude administrative, debt-reduction, and other overhead expenses.
Source: BTS (1995), *Federal, State and Local Transportation Financial Statistics,* Table 10A, p. 32.

**FIGURE 2–6**

Government Expenditures for Transportation: 1982–1992 (in current dollars)



Government Expenditures for Transportation: 1982–1992 (in constant 1982 dollars)



fers to state and local governments. The federal government's direct expenditures of $9.8 billion in 1982 and $13.4 billion in 1992 were 16.2 and 11.8 percent of all government transport expenditures in those two years. Federal expenditures plus grants to other governments were $23.6 billion and $34.8 billion in those same two years, for 39.1 and 30.7 percent of all sums spent by government on transportation. In both cases the federal role is declining, and direct federal expenditures are not going up at the same pace as intergovernmental transfers. The dollars transferred to state and local government ($14.1 billion in the initial year and $21.4 billion in 1992) rose in constant dollars at a 4.7 percent average annual rate over the period from 1982 to 1992. The dollars spent directly by federal agencies were up at a slower 3.3 percent average annual rate.

## Government Transportation Revenues

### Revenue Trends

Government's transportation revenues consist of

- Receipts from special user taxes, often placed in transportation trust funds (rather than in general funds with other tax receipts);
- Payments (such as road and bridge tolls) made by transportation consumers; and
- General tax receipts from sales, income, and property taxes applied to transportation purposes.

All in all, receipts from general taxes support about 30 percent of all governmental transportation expenditures, while transport-related revenues provide the majority of support.

In 1992, total U.S. government (local, state, and federal) transportation revenues were $80.2 billion—or about 3.6 percent of all government revenues. (See Table 2–9.) By sector, transportation revenues represented 6.8 percent ($39.1 billion) of all tax and other revenues for state governments, 3.6 percent ($15.31 billion) for local governments, and 2.1 percent ($25.8 billion) for the federal government. However, since 1982, federal revenues have increased the most: 6 percent per year compounded. By contrast, state revenues for transportation rose over the 1982–92 decade at a 3.5-percent annual rate; local revenues grew by 3.8 percent annually (in constant 1982 dollars). Thus, while states accounted for over half of all transportation revenues in 1982, they now provide just under half (52.2 percent in 1982, compared to 48.8 percent in 1992). The federal share rose over the decade from 27.6 percent to 32.2 percent.

Table 2–10 shows "coverage ratios," the proportion of total transportation expenditure paid directly by users through transport-related charges. The overall coverage ratio for all levels of government increased between 1982 and 1992 from 60 percent to 71 percent.

### Federal Government Revenues

Federal transportation revenues from user charges are placed in trust funds (except for portions of those revenues—such as part of motor vehicle fuel tax receipts—that are placed in the general treasury for specific purposes such as

**TABLE 2 – 9**

Government Transportation Revenues (in billions of current dollars)

| | 1982 | 1992 | Annual change |
|---|---|---|---|
| Federal | $10.0 | $25.8 | 6.44% |
| State | 18.9 | 39.1 | 3.52% |
| Local | 7.3 | 15.3 | 3.78% |
| Total | $36.2 | $80.2 | 4.45% |

Note: Annual change is compound annual growth rate in constant 1982 dollars

**TABLE 2 – 10**

Transportation Revenues by Mode (in billions of current dollars)

| | Revenues | | Percent Covered by Users | |
|---|---|---|---|---|
| | 1982 | 1992 | 1982 | 1992 |
| Highway | $26.9 | $56.8 | 75.4% | 84.2% |
| Air | 4.0 | 11.8 | 66.3% | 74.8% |
| Transit | 3.4 | 7.6 | 29.7% | 33.8% |
| Water | 1.4 | 3.1 | 32.8% | 54.8% |
| Parking | 0.4 | 1.0 | N/A | N/A |
| Pipeline | N/A | 0.1 | N/A | 70.8% |
| **Total** | $36.2 | $80.2 | 59.9% | 70.8% |

**TABLE 2 – 11**

Federal Transportation Revenues by Mode: FY 1982–1992 (in millions of current dollars)

| | 1982 | 1992 | Annual change current $ | Annual change constant $ |
|---|---|---|---|---|
| Highway Trust Fund Highway Account | 7,822 | 16,572 | 7.80% | 4.37% |
| Highway Trust Fund Transit Account | N/A | 1,816 | 14.93% | 11.42% |
| Airport/Airways Trust Fund | 1,711 | 5,918 | 13.21% | 9.61% |
| Water Receipts | 474 | 1,474 | 12.01% | 8.45% |
| Pipeline Safety Fund | N/A | 14 | 9.23% | 5.27% |

Note: Annual change is compound annual growth rate in current or constant 1982 dollars

deficit reduction). There are five transportation-related federal trust funds. The revenues placed in these funds over the past decade are shown in Table 2–11.

The Federal Highway Trust Fund is funded by user fees on highway fuels and its receipts are earmarked for highway and transit purposes. On October 1, 1993, the gasoline tax began to be levied at a rate of 18.4 cents per gallon, with 6.8 cents of that amount earmarked for federal budget deficit reduction. On October 1, 1995, 2.0 cents of the 6.8 cents is scheduled to be dedicated for highway purposes and 0.5 cents for transit.

In April 1983, 1 cent of the federal gasoline tax was set aside for transit purposes in the Mass Transit Account of the Highway Trust Fund. This increased to 1.5 cents per gallon in 1990 and to 2.0 cents in 1995.

The Airport and Airways Trust Fund receipts come from a 10-percent tax on passenger tickets, a 7 percent tax on the value of air freight waybills, and other fees paid by airport and airway users. Most of the fund is devoted to airport grants and capital improvements, such as new radar and traffic control towers. Within limits set by Congress, some of the remaining money can be used to support the Federal Aviation Administration's expenses for airway operations and maintenance. Any FAA operating and maintenance expense not paid for by trust fund revenues is supported by general U.S. Treasury funds.

# Endnotes

1 This discussion follows the conventional description of gross domestic product as the sum of final demand (net of intermediate goods) by personal consumption, business, and government, plus net foreign trade. Transportation must be estimated as a share of total consumption and investment demand by each final demand category of the economy in order to express it as a portion of gross domestic product. Tables 2–1 and 2–2 include military purchases of transportation services, but not equipment. Available data do not distinguish military purchases of transportation equipment, such as trucks, from purchases of weapons systems, such as tanks.

2 These statistics are based on unpublished data from Bureau of Labor Statistics (BLS), *Consumer Expenditures Survey* 1993. (Hereinafter BLS unpublished tables).

3 This figure does not include expenditures on other vehicles used for personal transportation, such as bicycles and motorcycles.

4 The price of unleaded regular gasoline fell from $1.15 per gallon in 1990 on average to $1.11 in 1993. See Table 104 of *National Transportation Statistics*, 1995. During this period, while the motor fuel price index declined by 3.1 percent, the retail price index of all items in the consumer's market basket rose 10.6 percent.

5 BLS unpublished tables.

6 BLS unpublished tables.

7 BLS unpublished tables.

# *The* UNINTENDED CONSEQUENCES *of* TRANSPORTATION

Transportation is a part of every good and service produced in the economy, and the mobility it provides is an essential ingredient of daily life. These benefits, however, come at a cost measured not only in dollars but in accidents, oil dependence, and collateral damage to the environment. Because of the enormous scale of transportation in the United States, the toll of transportation fatalities and injuries, oil consumption and imports, and air and water pollution is proportionally—and unacceptably—high. In all of these areas, actions have been and are being taken to mitigate the problems created by transportation. The second section of this chapter assesses the effectiveness of these actions. It uses a rigorous method to analyze trends over the last two decades in key indicators of safety, environmental impacts, and energy efficiency to measure the benefits of improvements and better understand how they occurred. This analysis shows that the benefits of mitigative actions have been enormous. Had transportation fatality rates remained at 1972 levels, *twice* as many lives would have been lost in transportation accidents in 1992. Also, transportation would have produced several times as much air pollution, and generated 15 percent more carbon dioxide ($CO_2$) in using 15 percent more fossil fuel.

The most recent statistics, however, caution against complacency.

- Motor vehicle traffic fatalities *increased* in 1993 over 1992, rising from 39,250 to 40,115, as fatality rates remained constant and vehicle travel increased. And 237 lives were lost in three commercial air crashes in 1994, up from one fatality in 1993.
- Energy use by transportation has increased to the highest level ever. Transportation is 97-percent dependent on petroleum and accounts for two-thirds of the country's total petroleum use. In 1993, U.S. dependence on petroleum imports climbed to 44 percent—the highest level since 1977 and the second highest level on record. Concurrently, the in-use fuel economy of highway vehicles *decreased* for the second year in a row.
- In 1993, the Environmental Protection Agency (EPA) revised its annual estimates of transportation emissions

upward by about 10 to 80 percent over previous estimates. Although the new estimates still show significant declines in all criteria pollutants from 1991 to 1992, they represent an acknowledgment that under actual operating conditions, emissions controls have not been working as effectively as had been thought.

Despite these negative points, the overall picture remains one of continued improvement, as the following section details. But the bad news warns that reducing the unintended consequences of a growing transportation system takes sustained effort, and a balancing of the continuing need for both improved abatement and greater efficiency and productivity.

The last section of this chapter examines trends in transportation emissions of $CO_2$—the principal man-made "greenhouse" gas. The potential for global climate change caused by a build-up of greenhouse gases in the atmosphere poses a serious threat—albeit one of uncertain dimensions—to the global environment. Transportation is a critical sector in this regard, not only because it produces about one-fourth of anthropogenic greenhouse gas emissions, but also because its $CO_2$ emissions are growing faster than those of any other sector. The section looks at trends not only in the United States, but in other industrialized and developing nations—nations whose transportation sectors produce proportionately fewer $CO_2$ emissions than does the United States, but whose rate of growth is higher.

## The State of Transportation Safety, Energy Use, and Environmental Impacts

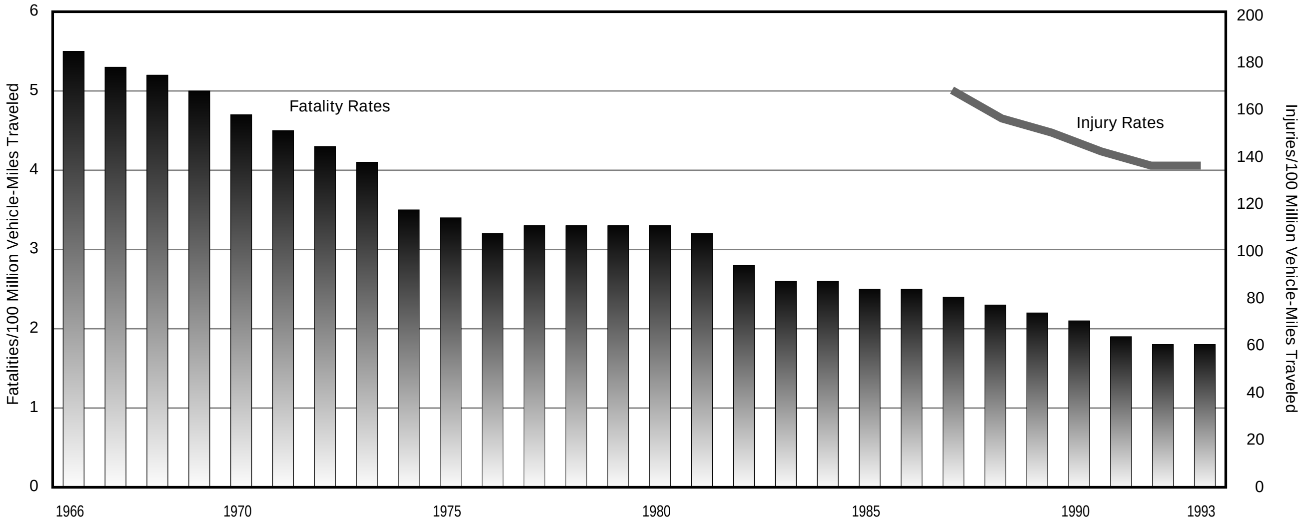
### Safety

Overall Fatalities and Injuries. Transportation fatalities in all modes increased by 1.7 percent between 1992 and 1993, rising from 42,453 to 43,179. Although the increase is on a par with the rate of growth of transportation activity, it represents a disturbing development, because highway fatality rates had steadily dropped in recent years. (See Figure 3–1.)

An increase in motor vehicle traffic fatalities of 865—from 39,250 to 40,115—is largely responsible for the overall transportation fatality increase. (See Table 3-1.) By far the predominant transportation mode, highway travel accounted for 90 percent of all passenger miles traveled in 1993; air travel was a distant second with almost 9 percent of all passenger miles. Highway's share of transportation fatalities in 1993 was 93 percent—94 percent if the 626 deaths caused by accidents at rail-highway grade crossings are included.

**FIGURE 3–1**

Highway Fatality and Injury Rates: 1966–1993



## TABLE 3–1

### Fatalities and Injuries by Transportation Mode: 1960–1993

| Year | U.S. Air Carrier | Commuter Air Carrier | On-Demand Air Taxi | General Aviation | Motor Vehicle Traffic | Railroad | Rail-Highway Grade Crossing | Rail Rapid Transit | Water-borne Transport | Recre-ational Boating | Gas Pipeline | Liquid Pipeline | Haz-ardous Materials | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | FATALITIES | | | | | | | |
| 1960 | 499 | — | — | 787 | 36,399 | 924 | 1,421 | — | — | 819 | — | — | — | 40,849 |
| 1965 | 261 | — | — | 1,029 | 47,089 | 923 | 1,610 | — | — | 1,360 | — | — | — | 52,272 |
| 1970 | 146 | 100 | — | 1,310 | 54,180 | 785 | 1,440 | — | 178 | 1,418 | 22 | 4 | — | 59,583 |
| 1975 | 122 | 28 | 69 | 1,252 | 44,525 | 575 | 966 | — | 243 | 1,466 | 14 | 7 | 27 | 49,294 |
| 1980 | 1 | 37 | 105 | 1,239 | 51,091 | 584 | 833 | 83 | 206 | 1,360 | 11 | 3 | 19 | 55,572 |
| 1985 | 526 | 37 | 76 | 955 | 43,825 | 454 | 582 | 17 | 131 | 1,116 | 26 | 5 | 8 | 47,758 |
| 1990 | 39 | 6 | 49 | 766 | 44,599 | 599 | 698 | 117 | 85 | 865 | 5 | 3 | 8 | 47,839 |
| 1991 | 50 | 77 | 73 | 781 | 41,508 | 586 | 608 | 103 | 30 | 924 | 14 | 0 | 10 | 44,764 |
| 1992 | 33 | 21 | 70 | 862 | 39,250 | 591 | 579 | 91 | 105 | 816 | 15 | 5 | 15 | 42,453 |
| 1993 | 1 | 24 | 42 | 715 | 40,115 | 653 | 626 | 70 | 104 | 800 | 14 | 0 | 15 | 43,179 |
| | | | | | | | INJURIES | | | | | | | |
| 1960 | — | — | — | — | — | 16,113 | 3,367 | — | — | 929 | — | — | — | — |
| 1965 | — | — | — | — | — | 21,930 | 3,725 | — | — | 927 | — | — | — | — |
| 1970 | — | — | — | — | — | 17,934 | 3,272 | — | 105 | 780 | — | — | — | — |
| 1975 | 71 | — | — | 728 | — | 50,138 | 4,168 | — | 97 | 2,136 | — | — | 648 | — |
| 1980 | 17 | 14 | 43 | 675 | 2,848,000 | 58,356 | 3,890 | 6,801 | 176 | 2,650 | 45 | 3 | 626 | 2,921,296 |
| 1985 | 30 | 16 | 43 | 517 | 3,363,000 | 31,617 | 2,687 | 1,039 | 172 | 2,757 | 106 | 18 | 253 | 3,402,255 |
| 1990 | 39 | 11 | 36 | 391 | 3,231,000 | 22,736 | 2,407 | 10,036 | 175 | 3,822 | 67 | 7 | 425 | 3,271,152 |
| 1991 | 26 | 30 | 27 | 420 | 3,097,000 | 21,374 | 2,094 | 9,285 | 110 | 3,967 | 89 | 8 | 439 | 3,134,869 |
| 1992 | 13 | 5 | 19 | 418 | 3,070,000 | 19,408 | 1,975 | 10,446 | 172 | 3,683 | 87 | 38 | 604 | 3,106,868 |
| 1993 | 18 | 2 | 24 | 383 | 3,125,000 | 17,284 | 1,837 | 9,792 | 146 | 3,559 | 97 | 10 | 626 | 3,158,778 |

Note: Injury data in this table are estimates of the National Highway Traffic Safety Administration, which differ substantially from estimates of the National Safety Council. Injury estimates of the National Safety Council are used in the analyses of injury trends below.

The commercial air carrier mode's overall safety record is generally far better than that of any other passenger mode, but fluctuates substantially from one year to the next. While deaths associated with railroad operations were also up in 1993, recreational boating, which tends to be either the second or third largest cause of fatal accidents, actually saw a small decline in fatalities.

While fatalities generally grab the headlines, transportation injuries are no less serious a problem. There were 3,159,000 transportation injuries reported in 1993; this was nearly 75 times the number of fatalities. Once again, this represents an increase of approximately 1.7 percent, or 52,000, over 1992. Nearly all of this increase involved motor vehicles; most non-highway modes actually declined. Like fatality rates, injury rates have not increased but total injuries have. Highway traffic injuries, which account for 3,125,000 of the total, include incapacitating injuries, visible but not incapacitating injuries, possible but not visible injuries, and injuries of unknown severity. Obviously, the accuracy of injury estimates, which are rounded to the nearest 1,000 for motor vehicle accidents, is also less precise than the fatality statistics. The modal distribution of transportation injuries is also quite similar to that of fatalities. (Table 3–1.)

Drunk Driving. Reducing deaths caused by motor vehicle accidents involving alcohol has been a focal point of federal, state, local, and private efforts. A greater awareness of the problems caused by drinking and driving, the 21-year-old minimum drinking age, stronger laws against drunk driving, and stricter enforcement have all helped to significantly reduce deaths in alcohol-related traffic accidents. Yet there are still more than 17,000 per year, accounting for over 40 percent of all traffic deaths.

In 1993, alcohol-related fatalities declined significantly for the fifth consecutive year. (See Figure 3–2). Involvement of intoxicated drivers—those with blood alcohol concentration (BAC) of greater than 0.10 grams/deciliter, in fatal crashes declined to 35 percent. Alcohol-related fatal crashes also reached a new low: 44 percent of total fatal crashes. Finally, despite the growth of vehicle and passenger miles of travel, fatalities in alcohol-related crashes were 6,165 lower in 1993 than in 1988. (See Drunk Driving box.)

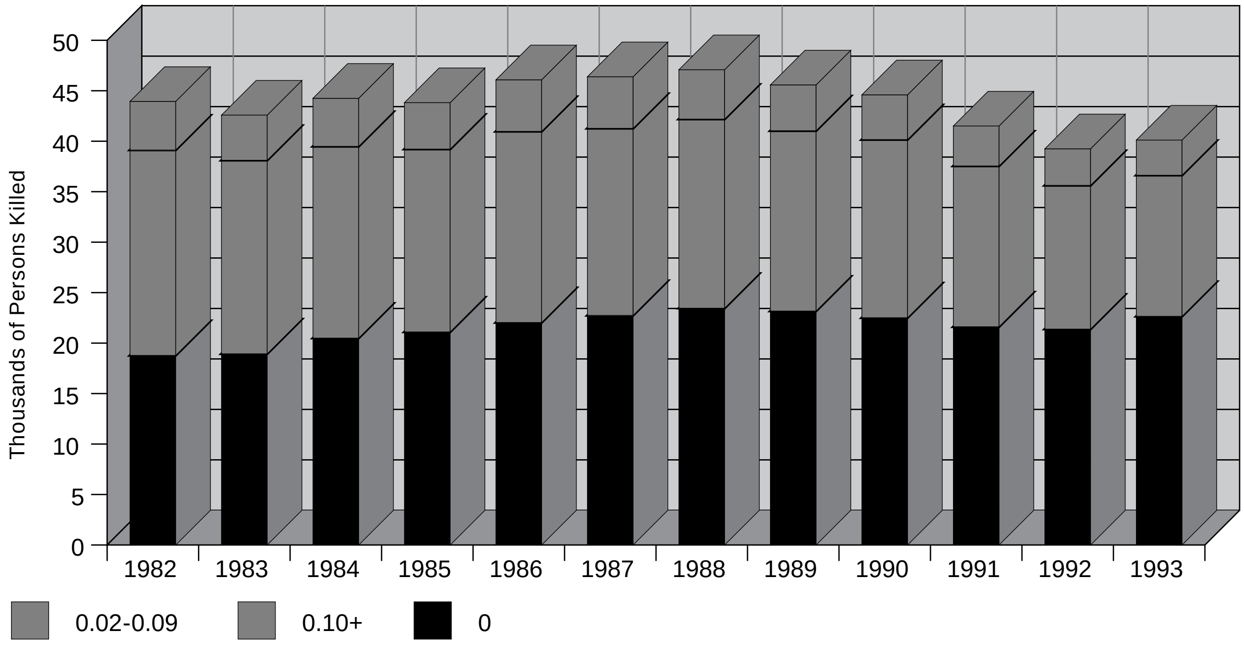
## A Decade of Progress in Battling Drunk Driving

In 1982, drivers with measurable BACs were involved in accidents responsible for more than half (57 percent) of the 43,945 highway fatalities that year. Specifically, drunk drivers were involved in 20,356 fatal highway crashes. Since then, meaningful steps have been taken at all levels of government, and by private individuals and organizations, to eliminate the threat alcohol-impaired drivers pose to themselves and society. Perhaps the most far-reaching action to date has been the passage of 21-year-old minimum drinking age laws in all states and the District of Columbia. The National Highway Traffic Safety Administration (NHTSA) estimates that these laws have reduced fatalities involving drivers 18 to 20 years old by 13 percent, and cumulatively saved an estimated 13,968 lives since 1975.[1] Even so, 17,461 people lost their lives in alcohol-related crashes in 1993: much obviously remains to be done.

FIGURE 3–2

Highway Traffic Fatalities,

by Highest Blood Alcohol Concentration in the Crash: 1982–1993



Drunk drivers make driving in the early morning hours far more dangerous than at other times of the day. NHTSA statistics show that fatality rates per 100,000 vehicle-miles traveled between the hours of midnight and 3:00 a.m. on Saturday are nearly 40 times the overall rate. More than 50 percent of the crashes at this time involve drivers with high blood alcohol levels. Fatality rates per vehicle-mile at all times increase with the percentage of drivers with high BAC levels, but at those times of the day when the proportion of drivers involved in traffic accidents having high BAC levels exceeds 40 percent, fatality rates skyrocket. The times of ultra-high traffic fatality rates are all between the hours of midnight and 6 a.m. Every day of the week between midnight and 3 a.m. is an ultra-high traffic fatality period, plus Saturday and Sunday mornings between 3 a.m. and 6 a.m. These times, plus Saturday evenings between 9 p.m. and midnight, account for only 3 percent of all vehicle-miles but 20 percent of traffic fatalities.

*Air Safety.* One of the best years on record for commercial airline safety was 1993; 1994, however, was among the poorer years. Three major crashes caused commercial air carrier fatalities to jump from one in 1993 to 237 in 1994. On October 31, 1994, American Eagle Flight 4184 from Indianapolis bound for Chicago's O'Hare Airport crashed in a cornfield near Roselawn, Indiana. All 64 passengers and four crew members on the fully loaded plane perished. Earlier in the year, two crashes involving jets operated by USAir killed 169. Various factors, from equipment failure to local weather conditions are suspected to be responsible for the three disastrous accidents.

*Rail-Highway Crossing Safety.* Fatalities at rail-highway grade crossings numbered 626 in 1993; almost all of these fatalities were occupants of motor vehicles. This places rail-highway crossing accidents in the second tier (after highway traffic accidents) among types of transportation safety risks. In June 1994, the U.S. Department of Transportation published a Rail-Highway Safety Action Plan, a multimodal effort to improve safety at highway-rail crossings and prevent trespassing on railroads' rights-of-way.

Rail-highway fatalities occur under nearly all conditions at crossings with nearly every type of control device. Almost 60 percent of fatal rail crossing crashes occur during daylight, as opposed to less than 45 percent of all fatal crashes.[2] Fatal rail crossing crashes occur nearly uniformly throughout the day—again unlike all highway traffic fatalities. The age and gender profiles of drivers involved in fatal rail-crossing crashes, however, generally match those of drivers in fatal highway crashes. And about the same fraction of crashes involve alcohol. Crash frequencies by type of control device are biased toward automated devices:[3]

- Motor vehicle fatalities at crossings with signs only comprise 57 percent of the total, while 61 percent of all crossings have such devices.
- Crossings with flashing lights account for 20 percent of fatalities; 18 percent of all crossings have flashing lights.
- Fatalities at crossings with gates and stop signs also exceed in frequency the prevalence of those devices.

These statistics indicate that the factors underlying rail-highway crossing accidents include driver understanding, driver compliance, and traffic law enforcement. Secretary Peña's Action Plan describes initiatives addressing these factors.

## Energy

Transportation energy use reached 22.9 quadrillion Btu (quads) in 1993, its highest level ever. Preliminary data show 1994 running about 0.5 quad higher than 1993.[4] Moreover, U.S. dependence on imported petroleum reached 44 percent in 1993, the second highest year on record (1977 was the highest at 46.5 percent); dependence will average close to 46 percent for 1994. The transportation sector's share of U.S. petroleum use increased to 66 percent in 1993 from 53 percent in 1973. Of the high-value, light petroleum products that drive the petroleum market, transportation consumes four-fifths. The nation's dependence on oil is growing, and transportation energy demand is the primary reason.

Of all the unintended consequences of transportation covered in this chapter, the pressure on energy resources has shown the least improvement over the past two decades. Transportation energy use in 1992 was about 15 percent less than it would have been had no efficiency improvements or changes in modal structure been made over that period. These trends and changes are analyzed in greater detail in the following section. Moreover, the gains in automobile and light truck energy efficiency achieved during the 1970s and 1980s are now ended: New light-duty vehicle fuel efficiency has not changed appreciably since 1982, and on-road vehicle fuel economy is now in decline. (See Figure 3–3.) In 1982, the average miles per gallon (mpg) of new passenger cars and light trucks sold was 24.7. In 1993, the average new light-duty vehicle mpg was 25.0.[5] The Federal Highway Administration reported a decline in average highway vehicle mpg in 1993 for the second year in a row.[6] With no gains in new vehicle mpg to drive improvements to the total fleet, adverse traffic conditions and increasing urbanization appear to have reversed the trend of improving highway vehicle mpg.

These trends are disturbing, in view of the fact that the share of the world oil market supplied by Organization of Petroleum Exporting Countries (OPEC) nations continues to increase. In 1993 OPEC supplied 47 percent of world oil demand—down from a high of 53 percent in 1973[7]—but the U.S. Department of Energy (DOE) projects that by 2005 that share will grow to 59 percent, and by 2010 will exceed 60 percent.[8] As OPEC's market share grows, so will its ability to influence world oil prices.

### The Environment

Air quality statistics show steady improvement and continued reductions in emissions by transportation sources. Despite considerable uncertainty about the accuracy of estimates of total emissions (discussed below), the fact that estimated declines in emissions are matched by improvements in measured air quality indicates that emission control efforts are having the desired effect. The Environmental Protection Agency (EPA) tracks airborne toxic substances plus six major "criteria pollutants": carbon monoxide (CO), lead (Pb), nitrogen oxides ($NO_x$), ozone ($O_3$), small particulate matter (PM-10), and sulfur dioxide.[9] (See Figure 3-4.) Ozone is formed in the atmosphere by precursor emissions, largely $NO_x$ and volatile organic compounds (VOCs); these are sometimes referred to as hydrocarbons.

**FIGURE 3–3**

Transportation Energy Use: 1970–1993
and Light Duty Vehicle Fuel Economy: 1975–1993

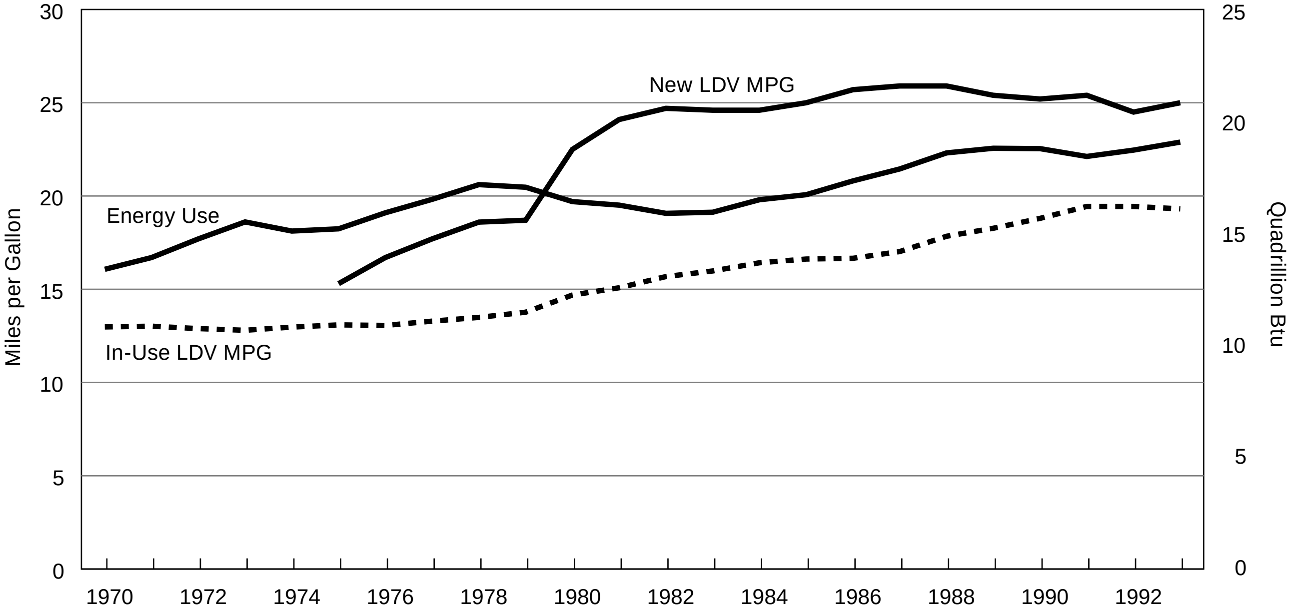
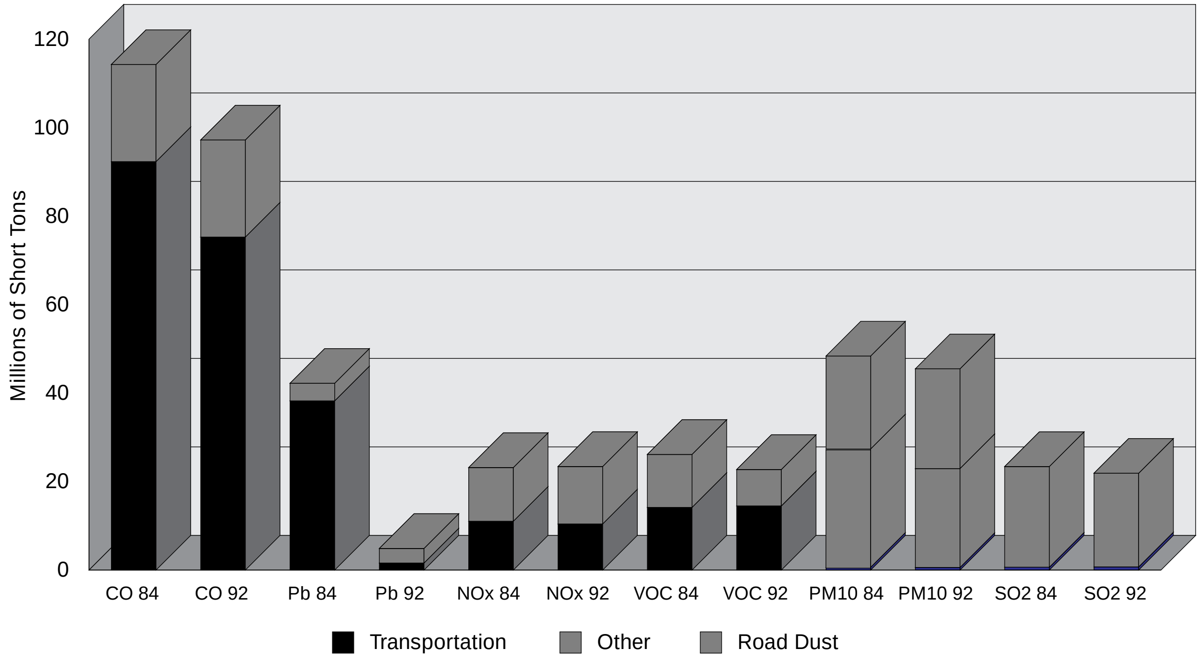


**FIGURE 3–4**

Transportation as a Share of Total Emissions of Pollutants: 1984 and 1992



*Carbon Monoxide Emissions.* Air quality improved 37 percent with respect to CO between 1984 and 1993, and by 5 percent from 1992 to 1993.[10] CO emissions declined over the same periods by 15 percent and 1 percent, respectively. Unlike most pollutants, CO is predominantly emitted by transportation vehicles. An estimated 77 percent of CO produced in 1993 came from transportation vehicles, with 62 percent from highway motor vehicles alone. The reductions in CO emissions were achieved despite a 33-percent increase in vehicle-miles of travel between 1984 and 1993.

*Lead Emissions.* Reduction of lead in the environment is perhaps the clearest environmental success story. Dramatic reductions in transportation emissions are largely responsible. Air concentrations of lead decreased by 89 percent over the past decade and 11 percent from 1992 to 1993. Emissions of lead decreased by 88 percent from 1984 to 1993, but emissions from transportation sources decreased by 96 percent. In 1984, an estimated 42,217 tons of lead were emitted in the United States: 91 percent were from transportation sources. In 1993, lead emissions were estimated to be 4,885 tons: less than one-third came from transportation sources. These decreases were largely achieved by removing lead from all gasoline; consequently, motor vehicles are no longer considered a source of nonattainment problems.

*Nitrogen Oxide Emissions.* Nitrogen oxides are both a respiratory irritant and one of two precursor agents to ozone formation and acidic precipitation. Concentrations of nitrous oxide ($N_2O$) in the atmosphere have fallen by 12 percent since 1984; in 1993, they decreased by 2 percent over 1992 levels. Emissions of all oxides of nitrogen, however, were virtually the same in 1993 as they were in 1984, and are estimated to have increased in 1993 by 2 percent over 1992. More than any other criteria pollutant, emissions of $NO_x$ have proven to be difficult to reduce.

*Volatile Organic Compounds.* Volatile organic compounds are the other principal ozone precursor. Emissions of VOCs have declined by 9 percent since 1984, but are estimated to have increased in 1993 over 1992 by 1 percent. Ozone—the primary constituent of smog—damages lung tissue, reduces lung function, and sensitizes the lungs to other irritants. Although air concentrations of ozone have been reduced by 12 percent over the past decade, 1993 concentrations were 2 percent higher than in 1992. The introduction of reformulated gasoline (RFG), discussed below, is expected to help reduce emissions of ozone precursors by motor vehicles.

*Fine Particulate Matter Emissions.* Fine particulate matter—both manmade and natural source—is the subject of intense study in the United States today. It has already been established that PM-10 (particulate matter of 10 microns in diameter or smaller) affects the respiratory system, can aggravate existing respiratory and cardiovascular diseases, and can be carcinogenic. What is not clearly understood is whether all small particles or particular substances are the chief cause of these problems. Transportation vehicles are a relatively minor source of manmade PM-10, accounting for 22 percent of this matter.

Concern about PM-10 is growing despite the fact that its concentrations declined by 20 percent from 1988 to 1993 and 3 percent in 1993 over 1992. Emissions are also down by 10 percent and 2 percent over the same periods. An area of great uncertainty at the present time is the role of road dust versus vehicle emissions in the quantity and adverse effects of PM-10. Dust from roads accounts for 53 percent of EPA's natural source particulate matter estimates, and 50 percent of EPA's total particulate emissions estimates.

*Sulfur Dioxide Emissions.* Transportation is a very minor source of sulfur dioxide emissions, accounting for only 3 percent of total emissions of this pollutant, which are primarily created by fuel combustion at electricity generation plants. Transportation's sulfur dioxide emissions have been fairly steady over the past decade; they should decline with the introduction of low sulfur reformulated gasolines and diesel fuels.

*Accuracy of Emissions Estimates.* In recent years the accuracy of basic transportation emissions estimates has been seriously questioned. Emissions measured by EPA in actual traffic indicated that the best available methods were significantly underestimating emissions of key pollutants. The National Research Council (NRC) subsequently reported that previous estimates of VOCs and $NO_x$ emissions probably underestimated actual emissions by motor vehicles by a factor of two to four times.[11] In light of this, NRC noted, any analysis of trends in transportation pollutant emissions must be used cautiously.

In October 1993, EPA published updated national emissions statistics reflecting a significant change in both methods and results.[12] In so doing, the agency noted that its previous emissions estimates were useful in describing trends and changes from year to year, but did not accurately reflect absolute emissions levels for any given year.[13] For the transportation sector, current and historical emissions estimates for nearly every major pollutant were revised upward from previously published estimates. The 1990 emissions of $NO_x$ and VOCs, the principal causes of ozone pollution in cities, are 30 percent higher in the newly published statistics than in preceding EPA volumes. (See Table 3–2.) CO emissions are nearly 80 percent higher. (See Figure 3–5.) The original and revised estimates of PM-10 emissions are not com-

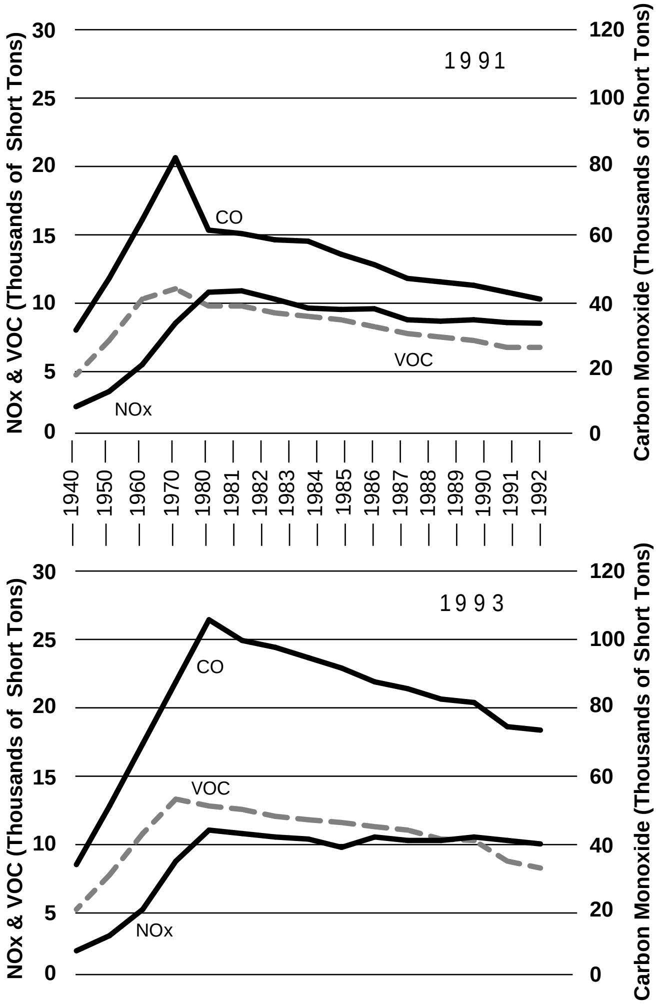
**TABLE 3–2**

## Comparison of Transportation Emission Estimates Between 1991 and 1993 EPA Publications

| | CO | VOC | $NO_x$ | Pb | $SO_2$ | PM–10 |
|---|---|---|---|---|---|---|
| | Teragrams per Year (Percent of National Total) | | | | | |
| 1990 Original (1991 pub.) | 37.611<br>(63%) | 6.410<br>(34%) | 7.494<br>(38%) | .0022<br>(31%) | 0.949<br>(4%) | 1.464<br>(23%) |
| 1990 Revised (1993 pub.) | 67.534<br>(81%) | 8.253<br>(38%) | 9.670<br>(45%) | .0017<br>(34%) | .915<br>(4%) | 24.938<br>(49%) |
| 1992 (1993 pub.) | 63.474<br>(80%) | 7.463<br>(36%) | 9.370<br>(45%) | .0014<br>(31%) | .957<br>(5%) | 24.898<br>(48%) |

**FIGURE 3-5**

Transportation Emissions Estimates: 1991 publication Versus 1993 publication



parable. The 1990 original estimates did not include road dusts, which composed well over 90 percent of transportation PM-10 emissions.

Gaps between the new and old estimates for the three most significant transportation pollutants (CO, $NO_x$, and VOCs) range from 30 percent to 80 percent. Nevertheless, the trends of the emissions of these pollutants shown by the new and old estimates appear quite similar. The new statistics indicate that transportation emits a greater fraction of national air pollutants than was previously believed. Estimates of transportation's share of CO emissions in 1990 increased from 63 percent to 81 percent, while the shares of national $NO_x$ and VOC emissions went up from 38 percent to 45 percent and from 34 percent to 38 percent, respectively. The accuracy of even these revised estimates is still in question, however, so these data may also be too low. It is virtually certain that future statistics will be further revised.

*Cleaner Fuels.* On January 1, 1995, motorists in designated areas around the United States began using a new gasoline blend, formulated in accordance with the 1990 Clean Air Act Amendments (CAAA), to reduce air pollution by motor vehicles. The new blend is a result of a joint effort by the petroleum and motor vehicle industries to develop a petroleum-based fuel for conventional motor vehicles capable of meeting the emissions performance requirements of the 1990 CAAA for clean alternative fuels. In the nine most severe ozone-nonattainment areas, home to 60 million people, the low-polluting reformulated gasoline is the only gasoline sold. Other states—as of this writing accounting for about 30 million inhabitants—have voluntarily decided to require RFG.

The RFG program constitutes one of the most sweeping efforts ever to achieve ambient air quality standards in areas that have had persistent air quality problems. By simultaneously addressing the fuel and vehicle systems, the RFG solution also represents a significant break from past strategies that have concentrated on vehicle-based emissions control measures only.

Interest in alternative-fuel vehicles (AFVs) and alternative fuels derives from growing concern about the nation's increasing dependence on imported petroleum and the environmental consequences of fossil fuel combustion. Policies to promote alternative fuels and vehicles were written into the Energy Policy Act of 1992, the 1990 CAAA, and the Alternative Motor Fuels Act of 1988. Each of these acts provides for tax subsidies and incentives, as well as mandates to promote purchase and use of AFVs by governments, private fleets, and—in the case of the California Zero Emission Vehicles (ZEV) program—the public at large. The most ambitious of all the new programs, the California ZEV program calls for 10 percent of new vehicles sold by manufacturers in California to be zero-emissions vehicles by year 2003. Currently, only battery-powered electric vehicles qualify as ZEVs.

In 1992, there were at least 251,000 AFVs in use in the United States. The estimated number for 1995 is 418,000—an increase of two-thirds, but still only 0.2 percent of all registered motor vehicles. (See Table 3–3.) Most of these vehicles (about 71 percent) are fueled by liquefied petroleum gases (LPGs), primarily propane gas. The second most common alternative-fuel technology is compressed natural gas (CNG); 22 percent of AFVs use CNG. Both vehicle types are predominantly bi-fuel, that is, they can use either gasoline or the alternative fuel. Five percent of all other AFVs use methanol M85 (a blend of 85-percent methanol, 15-percent unleaded gasoline); the remainder are fueled by either electricity, liquefied natural gas, neat methanol, or ethanol E85 or E95. Nearly all (81 percent) AFVs are owned by the private sector. The inventory of government-owned AFVs should increase rapidly as the provisions of recent legislation are carried out.

DOE tracks both alternative fuel and replacement fuel use. Replacement fuels, which are most often blended with conventional gasoline, are defined by the Energy Policy Act of 1992 to include alcohols, natural gas, LPGs, hydrogen, coal-derived liquids, electricity, ethers, and other fuels designated by the Secretary of Energy as substantially nonpetroleum and yielding substantial energy security and environmental benefits.

Oxygenates (mostly alcohols and ethers) blended with gasoline are expected to comprise 92 percent of the alternative and replacement fuels market in 1995. Together, alternative and replacement fuels should account for 3.3 percent of total motor fuel use in 1995.[14]

## Historical Trends in Transportation Safety, Energy, and the Environment

As a society, we have taken significant steps to lessen the unintended consequences of transportation. The Clean Air Act Amendments of 1990 renewed the nation's commitment to achieving air quality standards in all U.S. cities by setting stringent standards for vehicles and fuels. New safety standards, optional safety equipment offered by manufacturers, and nationwide campaigns in the public and private sectors are all aimed at decreasing the unacceptable number of deaths and injuries in trans-

TABLE 3–3

Alternative Fuel Vehicles and Alternative Fuel Use: 1992 and 1995

| Technology/Fuel | Vehicles 1992 | Vehicles 1995 | Thousands of Gasoline Equivalent Gallons 1992 | Thousands of Gasoline Equivalent Gallons 1995 |
|---|---|---|---|---|
| **Alternative Fuels** | | | | |
| LPG | 221,000 | 299,000 | 208,142 | 293,773 |
| CNG | 23,191 | 93,186 | 16,823 | 66,783 |
| LNG | 90 | 447 | 585 | 2,734 |
| M85 | 4,850 | 20,040 | 1,069 | 3,411 |
| M100 | 404 | 413 | 2,547 | 3,160 |
| E85 | 172 | 828 | 21 | 89 |
| E95 | 38 | 33 | 85 | 104 |
| Electricity | 1,725 | 2,250 | 374 | 525 |
| **Subtotal** | 251,470 | 416,197 | 229,646 | 370,579 |
| **Replacement Fuels** | 0 | 2,429 | 1,876,000 | 4,200,830 |
| **Total** | 251,470 | 418,626 | 2,105,646 | 4,571,410 |

portation. The federal automotive fuel economy standards and alternative-fuels initiatives of the Energy Policy Act of 1992 and other legislation are designed to reduce transportation's dependence on petroleum and diminish the environmental impacts of the sector's energy use.

But to gain insight into how well such actions have worked in the past, we must analyze trends in key indicators over a sufficient period of time. Meaningful indicators of the unintended consequences of the transportation system are total fatalities and total injuries (safety indicators), barrels of petroleum and other fuels consumed (energy indicators), and tons of principal air pollutants emitted (environmental indicators). *Decomposition analysis*—specifically, Divisia analysis—offers a consistent and rigorous technique for going beyond aggregate statistics in order to analyze trends in these key indicators and identify the basic factors responsible for these trends. These causal factors are associated with the building blocks of the transportation system—infrastructure, vehicles, modal structure, and human behavior.

In this section, two decades of trends for key transportation indicators are analyzed using the Divisia method. (See Divisia Method box.) The goal is to obtain a deeper understanding of why the changes observed in key indicators are taking place and how we can use this understanding to chart a course for future improvements.

## Overview of Trends: 1972–92

Over the past two decades, the U.S. transportation system has been able—in most cases—to sustain the same levels of

## The Divisia Method

The mathematical technique known as Divisia analysis is used here to identify the proportions of changes in total transportation fatalities, injuries, energy consumption, and emissions that are due to:

- Growth in transportation activity (e.g. passenger-miles, ton-miles, and vehicle-miles of travel)
- Changes in rates of transportation fatalities, injuries, energy consumption, and emissions per unit of transportation activity
- Changes in the structure of transportation activity (e.g. the relative share of activity by mode)

The results of Divisia analysis are shown in figures throughout this section. Each figure has two lines: the "actual" line shows total transportation deaths, injuries, energy consumed, or emissions, and the "trended" line shows what the total would have been had the rates and modal structure of the base year not changed over time. The difference between the "actual" and "trended" lines is the net effect of changes over time in rates and modal structure. The bars in each figure show how much changes in rates and modal structure contributed to the difference between the "actual" and "trended" lines. Bars above the horizontal axis push the "actual line" upwards by an amount equal to the length of the bar, while bars below the axis push the "actual" line down by an amount equal to the length of the bar. Figure 3-6 shows, for example, that declining rates of deaths per accident and accidents per passenger-mile traveled reduced fatalities by roughly 7,000 lives in 1992, while changing mode structure pushed fatalities up slightly.

The present analysis is limited to accident rates and other factors that have been measured reliably over time. Other factors, such as the role of car size in traffic injuries, would be valuable additions to the analysis if adequate data were available. For the included factors, Divisia analysis shows only how much the factor contributes to the transportation trend and not what causes the factor itself. We do not know from the Divisa analysis, for example, what is causing the declining rates of deaths per accident and accidents per passenger-mile. We do know that 7,000 lives were saved. The Divisia method is a precise tool for dissecting key transportation trends over time and suggesting areas for further study.

safety, emissions, and energy consequences, or improve upon them, despite a near doubling of transportation activity levels. Divisia analysis demonstrates that the passenger and freight movements of 1992 would have required 3.8 quads (about 15 percent) more energy at 1972 energy intensities and modal shares. Reductions in intensity alone would have saved 4.9 quads if traffic had not shifted to more energy-intensive modes. And if motor-vehicle fatality rates (per vehicle-mile) had remained constant at 1972 levels, traffic fatalities in 1992 would have been twice what they were. Only a small reduction in fatality rates per vehicle-mile can be attributed to changes in the composition of traffic; about 10 percent is due to reduced vehicle occupancy. The rest of the improvement is derived from a reduction in fatalities per passenger-mile of travel for all vehicle types. Finally, at 1970 emissions rates, the transportation activity that occurred in 1992 would have generated several times as much pollution as it did.

Transportation's benefits of mobility and economic development come at a cost in accidents, energy consumption, and collateral damage to the environment. Basic trends reported in the previous *Transportation Statistics Annual Report* and documented in Table 26 of *National Transportation Statistics 1995* remain stable. The rates of transportation-related fatalities and injuries have declined fairly consistently for a decade, although 1993 totals increased slightly to 43,179 fatalities and 3,158,778 injuries and rates remained essentially constant. Improvements in fuel economy over the past decade are leveling off or declining for most forms of transportation and show little potential for significant improvement in the near future. As a result, we can expect petroleum use by transportation to increase in step with passenger travel and goods movement. Impacts on air quality, global warming, and other environmental issues are more difficult to monitor but show past improvement and potential for further gains with the continuing implementation of the Clean Air Act Amendments of 1990.

## Trends in Transportation Safety

Transportation fatalities and injuries have been slowly, if not steadily, declining for two decades. Further, death and injury *rates*, whether measured per vehicle-mile or per passenger-mile, have been consistently on the decline as well. Numerous factors have contributed to these trends. For example:

- Human factors such as increased legal drinking ages for young drivers and campaigns to reduce drunk driving have proven their effectiveness. In 1985, alcohol was a factor in 52 percent of all highway fatalities. This number has been reduced to 44 percent in 1993 through efforts to keep drunk drivers from getting behind the wheel.
- Seat belts require both vehicle hardware and human cooperation to be effective. Increasing availability of three-point harnesses for all passengers, the adoption of seatbelt laws in nearly all states, and the growing recognition by motorists that seatbelts save lives have demonstrably contributed to reducing fatalities and injuries on the highway.
- Infrastructure has also made a contribution. Breakaway roadside hardware, "friendly" buffers for bridge abutments and other fixed objects, as well as improved warning devices and restraints at railroad crossings have produced notable benefits.

The Divisia analysis that follows is not able to distinguish the effects of individual programs and measures such as those just mentioned. What it *can* do is disentangle the effects of the growth of travel, the accident rate per mile, fatalities or injuries per accident, and the distribution of travel among modes. By measuring the relative importance of each factor, the Divisia method can provide insight into the factors causing changes in transportation safety.

*Understanding the Analysis.* Highway travel accounted for 85 percent of passenger travel in 1992. It follows, therefore, that the highway mode dominates transportation safety statistics. In fact, 93 percent of transportation fatalities and 98 percent of transportation injuries occurred on the nation's highways. Indeed, the highway mode is so predominant, analysis of all transportation safety trends simply reflects highway trends. For this reason, highway and nonhighway modes are separated in this section.

Safety trends are analyzed here in two ways. First, transportation fatalities or injuries are expressed as the product of accident severity (fatalities or injuries per accident), accident rate (accidents per vehicle-mile), vehicle occupancy (vehicle-miles per passenger-mile), and activity level (passenger-miles traveled). This decomposition is, as noted above, carried out separately for the nonhighway and highway modes.

The second analysis concentrates on highway fatalities, in which the factors are deaths per passenger-mile, vehicle occupancy, and the distribution of travel by vehicle type. For this analysis, activity is measured in vehicle-miles.

*Nonhighway Fatality and Injury Rates.* The nonhighway modes investigated are commercial air; general aviation; both freight and intercity passenger railroad; rail transit, including commuter rail; and recreational boating. Passenger-miles for recreational boating have been crudely estimated by multiplying the number of recreational boats times 2,175 passenger-miles per boat-year.

Fatality and injury rates for modes other than highway remained nearly constant from 1975 to 1979, but have since declined dramatically. (See Figures 3–6 and 3–7.) At 1975 fatality rates per passenger-mile, the passenger-miles traveled by air, rail, and in recreational boats in 1992 would have produced almost four times as many fatalities (8,848 rather than 2,340). The decline in fatality rates can be attributed almost equally to the shifting of traffic to modes with lower fatality rates (largely an increase in commercial air travel), and to general decreases in accident rates per passenger-mile. Fatalities per accident remained essentially unchanged.

Nonhighway injuries declined even more conspicuously. At 1975 injury rates, passenger-miles in 1992 would have resulted in six times the number of injuries

**FIGURE 3–6**

Nonhighway Transportation Traffic Fatality Trends: 1975–1992

**Analysis of Rate per Passenger-Mile Traveled**

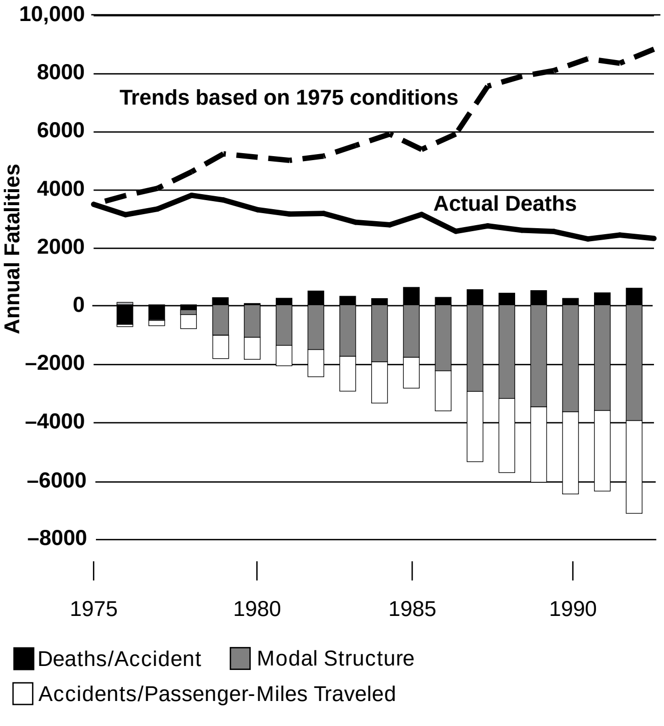
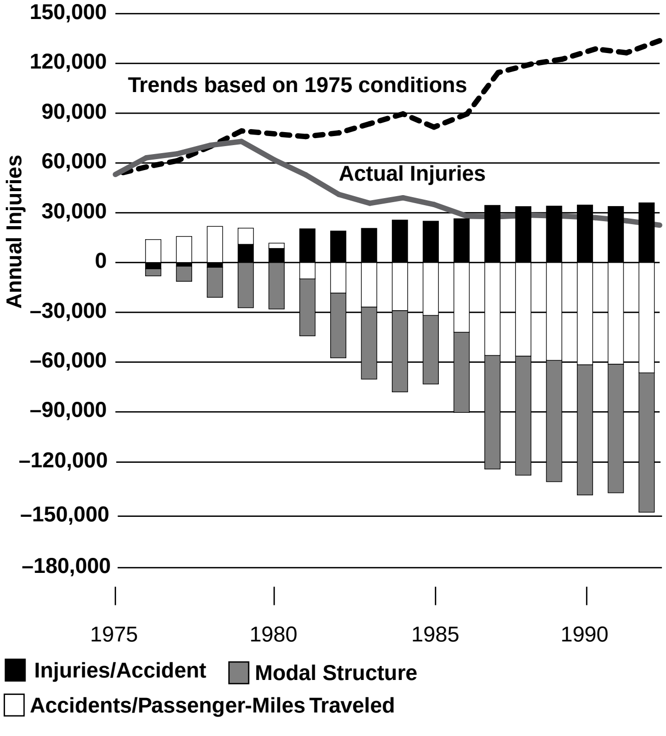


**FIGURE 3–7**

Nonhighway Transportation Traffic Injury Trends: 1975-1992

**Analysis of Rate per Passenger-Mile Traveled**



reported for that year (133,700 versus 22,500). Once again, reductions in accident rates and modal structure are nearly equally responsible for the improvement. Injuries per accident, however, increased somewhat during the 1980s, offsetting some of the gains from other factors.

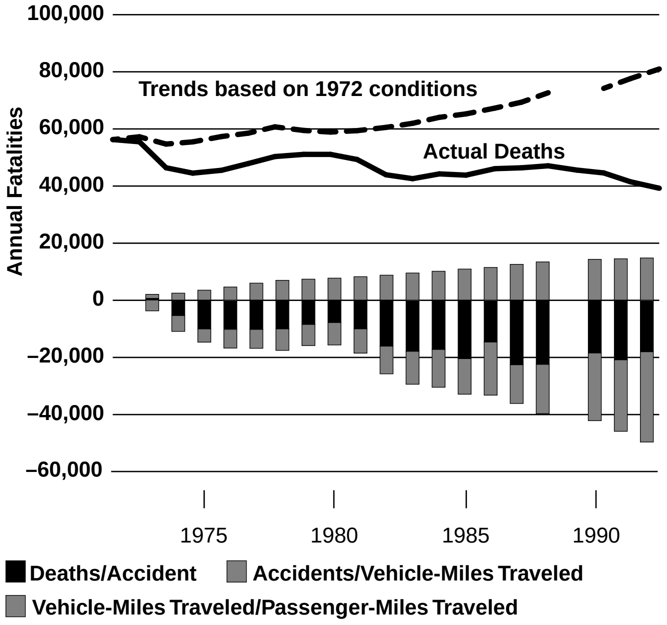
*Highway Fatality and Injury Rates.* Fatality and injury rates for highway travel have also improved significantly in the past 20 years. Had this not been the case, there would have been at least 40,000 more traffic fatalities and 1 million additional injuries in 1992. The factors responsible are different, however, and the analysis is made more difficult by the nature of available accident data. Highway accident counts are less precise than those for other modes. In addition, the methods for estimating the number of highway accidents were changed in 1989, making the subsequent data incompatible with previous years. This forced us to divide the analysis into two subperiods, pre-1989 and post-1988, with the change from 1988 to 1989 "falling between the cracks in the data." There also appears to be an anomaly in the highway accident counts in 1986; a sudden drop in accidents leads to a greater contribution from reduced accident rates and a greatly lessened benefit from the accident "severity" factor (deaths per accident).

In contrast to the other modes, reductions in the numbers of fatalities and injuries per accident played a major role in improving safety per passenger-mile traveled through 1988. (See Figures 3–8 and 3–9.) In fact, a decrease in fatalities per accident was the largest single factor in this improvement. A large part of this, however, is clearly due to fewer occupants per vehicle. The fact that it took more vehicle-miles to produce the same number of passenger-miles, on the other hand, increased the rates of both fatalities and injuries per passenger-mile. Even when this effect is considered, however, the net fatalities per accident show a significant improvement. Thus, it appears that both accidents per vehicle-mile and the consequences of accidents, in terms of injuries and fatalities, contributed to improving highway safety through 1988. From 1989 to 1992, only accident rates improved; the other factors had small, negative effects. The results of our analysis by highway

FIGURE 3–8

Highway Traffic Fatality Trends: 1972-1992

**Analysis of Rate per Passenger-Mile Traveled**

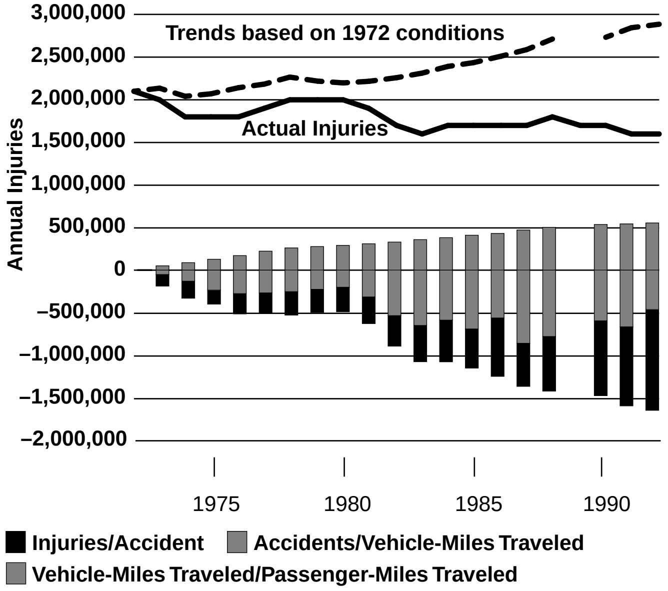


There is a discontinuity in 1989 due to the incompatibility of traffic accident estimates for prior years.

FIGURE 3–9

Highway Traffic Injury Trends: 1972-1992

**Analysis of Rate per Passenger-Mile Traveled**



There is a discontinuity in 1989 due to the incompatibility of traffic accident estimates for prior years.

vehicle type indicates that shifts in passenger-miles among vehicle types have not had any appreciable effect on highway fatality rates.

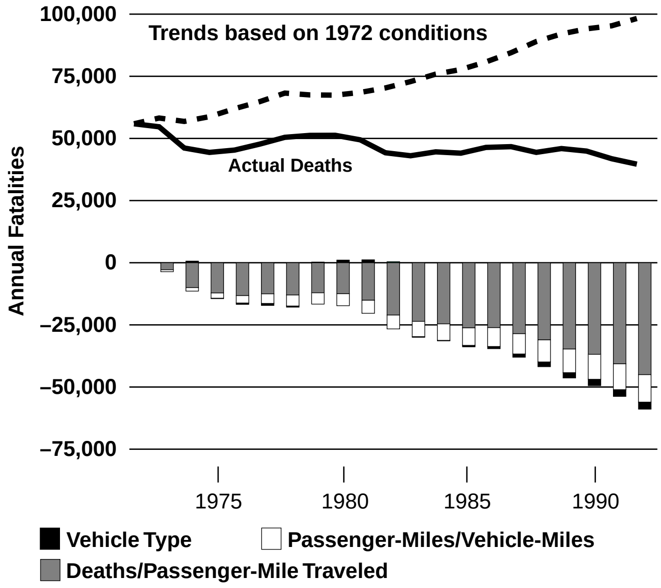
*Highway Fatalities.* The second safety analysis divides highway fatalities by vehicle type (passenger cars, light trucks, motorcycles, heavy vehicles, pedestrians, and bicycles) but does not use accident data since it is not available by vehicle type. Thus, fatality rates are expressed per vehicle-mile rather than per passenger-mile. Injury statistics are not available by vehicle type, so only fatality rates can be analyzed in this way. In this analysis, each pedestrian or bicycle is treated as a vehicle. Vehicle-miles and passenger-miles for pedestrians and cyclists have been crudely estimated based on statistics from the 1990 Nationwide Personal Transportation Survey.[15] *Bicycle miles* are the estimated number of bicycles times 164 trips per bike per year, times 1.99 miles per trip. *Pedestrian miles* equal the U.S. population times an average of 81 trips per person per year, times 0.64 miles per trip. Occupancy rates for both are assumed to be one. It is likely that these estimates understate the exposure of pedestrians and cyclists. This underestimation tends to inflate the rates for these modes, but has little effect on the attribution of changes to the different factors.

Highway traffic fatality rates per vehicle-mile show an impressive decline over the past 20 years. If rates had not improved, more than twice as many fatalities would have resulted from the vehicle-miles traveled in 1992. (See Figure 3–10.) Decreased fatalities per passenger-mile for all vehicle types were by far the largest factor. Passenger-mile fatality rates improve each year through 1976, remain stagnant through 1980, and then improve steadily through 1992. Decreased vehicle occupancy also reduced fatality rates per vehicle-mile. If there are fewer persons per car, with all other factors remaining constant, there will be fewer fatalities per crash. However, this finding does not mean we should abandon car pools, because more persons per car means fewer vehicle-miles.

**FIGURE 3 – 10**

Highway Traffic Fatality Trends: 1972-1992

**Analysis of Rate per Vehicle-Mile Traveled**



## Trends in Transportation Energy Use and Efficiency

The energy crises of 1973–74 and 1979–80 and the ensuing changes in transportation technology might lead to an inference that major improvements in transportation energy efficiency had been achieved over the past 20 years. In fact, efficiency improvements have varied greatly across modes, and the overall gains—though meaningful—have not been dramatic. Spurred by fuel-economy standards and fuel-price shocks, new passenger car fuel economy nearly doubled and light-truck mpg improved by more than 50 percent. Larger, more advanced commercial jets penetrated the airline fleets; railroad operations were overhauled for greater competitiveness; and long-haul trucks sprouted aerodynamic devices, grew longer and heavier, and added an extra trailer for improved ton-mile capacity. Despite these conspicuous changes, Divisia analysis shows that efficiency gains have been fairly recent and much more modest than those improvements made in highway safety. Modal successes in improving energy efficiency have been mixed; for certain modes, declining load factors and lower vehicle occupancy rates have partially or fully offset technical gains in vehicle efficiency.

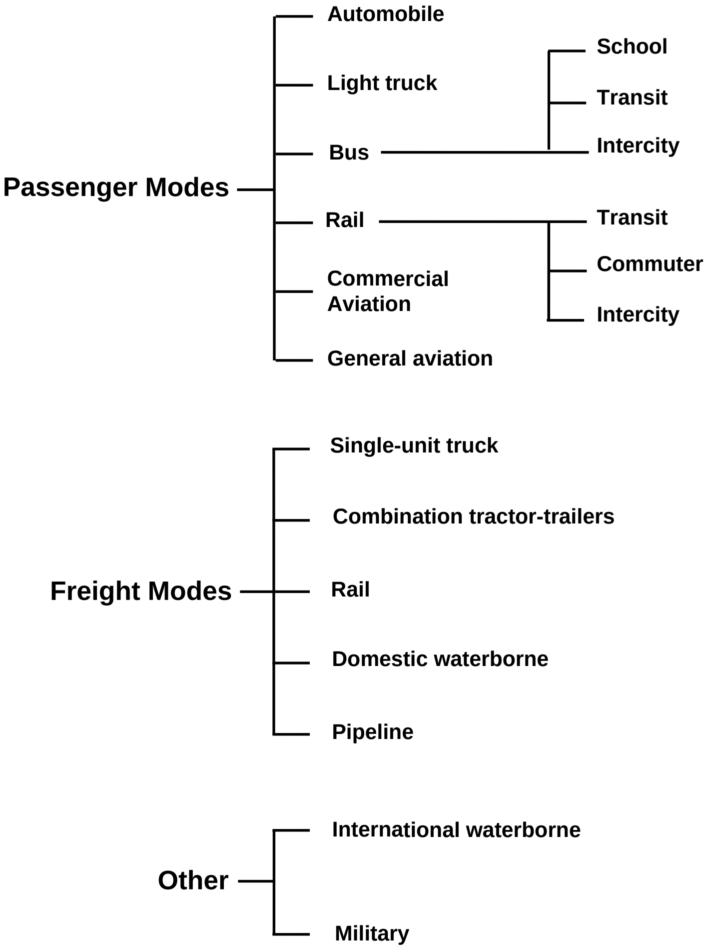
The result of energy efficiency improvement has been dramatic gains for some modes, most notably air passenger and rail freight; more modest gains by others such as highway passenger vehicles; and no apparent gains for other modes. Perhaps of greatest concern is the fact that fuel-economy gains for highway vehicles have reversed, declining for the second year in a row in 1993.

*Understanding the Analysis.* For this analysis, all transportation activity is divided into three parts: passenger, freight, and other. (See Figure 3–11.) Reasonable estimates of passenger-miles can be constructed for all passenger modes. Ton-mile estimates can be derived for all freight modes except international waterborne commerce, where activity levels are measured in terms of ton-miles on U.S. territorial waters only. Air freight has not been included in this analysis for several reasons: the bulk of this freight is carried by commercial passenger flights, a complete and consistent time series for all cargo flights is not readily available, and all cargo flights account for only a small fraction of transport energy use.

For the overall analysis of transportation energy trends, activity is measured in dollars. While reasonable estimates of freight revenues are available, most passenger travel is produced by households. Thus, comparable revenue estimates are not available. Instead, we have substituted estimates of dollar costs of personal vehicle travel, based

FIGURE 3–11

Structure of Transportation Sector Decomposition



on vehicle operating costs per mile. (The value of the driver's time is not included.) The values of modal activities are computed using 1987 as an index year, in much the same way price indices are constructed. For example, 1987 commercial air carrier revenues are divided by 1987 revenue passenger-miles (RPMs) to obtain a dollar yield per RPM for 1987. This value is then multiplied by RPMs in all years to obtain a series of dollar activity estimates indexed to 1987. Using this indexing method means that productivity effects, defined as changes in physical output per dollar (e.g., ton-miles per dollar), cannot be quantified since they will be zero by construction.

For separate analyses of the freight and passenger modes, ton-miles and passenger-miles, respectively, are used as activity measures. These may seem to be uniform measures for the respective modes but in fact, a passenger-mile by air is qualitatively different from a passenger-mile by car, the most obvious but not only difference being speed. The same holds for freight: tons of overnight mail do not equate to tons of coal shipped by rail or tons of oil by tanker. Thus, while some of the changes that appear in a Divisia analysis of trends will be due to the changing nature of the phenomena being studied, others will be artifacts of definitions that equate ton-miles of potato chips to ton-miles of crushed rock.

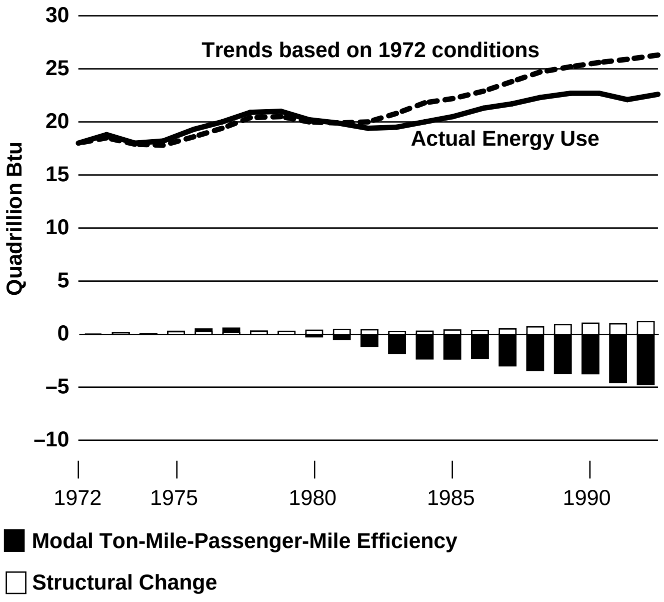
Available data on transportation activities are deficient in many areas, a flaw that hinders the assessment of energy trends. In the freight sector, for example, estimates of ton-miles are weak for all types of trucks but especially for single-unit trucks; also, ton-miles transported by pipelines, especially natural gas pipelines, are not reported on an annual basis. Estimated energy efficiencies for domestic waterborne transport fluctuate widely for reasons that are not well understood. On the passenger side, reasonable estimates of highway vehicle-miles are available, but consistent estimates of vehicle occupancy rates (and thus passenger-miles) are available only from infrequent surveys. Intervening years must be interpolated. Broad trends are likely to be meaningful, but numerical results involving suspect data, such as truck ton-miles, must be interpreted with caution.

Overview of Findings. The transportation sector would have used 3.8 quads more energy in 1992 if passenger and freight movements had taken place at 1972 energy intensities per dollar and relative modal activity levels. (See Figure 3–12.) Energy use would have been 4.9 quads higher if there had been no changes in the energy intensities.

These trends are somewhat different from those reported by DOE for 1972–86;[16] they also differ from calculations by M. Ross for the 1972-85 period.[17] The DOE analysis shows slightly increasing energy intensity up to 1975, with growing efficiency, or "conservation savings," thereafter. The DOE study reports an almost 4-quad savings by 1986 as a result of efficiency improvements; nearly all of these savings are from light-duty vehicles and commercial aircraft. Ross's findings are similar, with annual average growth rates in passenger- and ton-miles of traffic of 3.6 percent and 1.7 percent. He reports an overall growth rate of energy use of only 1 percent, because of an average 2.4 percent per year decrease in energy intensity for pas-

FIGURE 3 – 12

Transportation Energy Use: 1972–1992
Efficiency and Modal Structure Effects



senger travel and a 1.1 percent per year decrease for freight. In contrast, our analysis finds no net energy savings until after 1980 and no net savings for the freight modes collectively.

Previous studies have found earlier and larger energy efficiency savings because they measured energy intensities for passenger cars, light trucks, and heavy trucks on a per vehicle-mile basis. Here, passenger car and light truck activity is measured in passenger-miles; heavy truck activity is measured in ton-miles. Because the best available data indicate significant declines in vehicle occupancy rates and in truck load factors, particularly during the 1970s, this analysis indicates less reduction in energy intensities.

*Passenger Travel Energy Efficiency Trends.* Significant improvements in the efficient use of transportation energy have been made in passenger travel. Had there been no changes in vehicle efficiencies, vehicle occupancies, and the modal shares of passenger travel, 19.4 quads would have been required for the more than 4 trillion passenger-miles traveled in 1992—23 percent more than the actual energy used that year. In fact, vehicle occupancy rates have declined significantly, and modal shifts have favored less energy-efficient modes. If these factors had remained constant at 1972 levels, but highway vehicle and aircraft fuel economy had improved as they did, passenger travel would have required only 11.5 quads of energy in 1992. This figure is almost 30 percent less than actual energy use and 40 percent less than if there had been no changes in vehicle occupancy, modal share, or fuel economy since 1972. (See Figure 3–13.)

The energy intensiveness of passenger travel was slowly increasing in the early 1970s. By 1978, this trend began to reverse and efficiency improvements added continually to energy savings through 1992. Structural shifts and vehicle occupancy rates seem to have added gradually and continuously to energy use in passenger transport. Since load factors on commercial aircraft had been improving over this period, the increase in energy use from structural change must be entirely attributable to shifts to more energy-intensive vehicle types and/or the general decline in automobile and light truck occupancy rates. (See Table 3–4.) The rapid growth of air travel increased its share of passenger-miles from 5.6 percent in 1972 to 12.3 percent in 1992. The increasing popularity of light trucks for passenger travel boosted their share of passenger-miles from 11.6 percent in 1972 to 20.4 percent by 1992. Declines in the shares of rail and bus had a relatively minor impact on total transportation energy use.

By far the most dramatic energy efficiency gains have been achieved in commercial air travel. Energy use for air travel would have been more than twice its level in 1992 had there been no reductions in energy use per seat-mile. (See Figure 3–14.) Almost three-fourths of the gain in passenger-mpg can be attributed to delivering more seat-mpg; the remaining one-fourth was due to an increase in load factors (the average number of passenger-miles per seat-mile). Unlike the trend for highway travel, aircraft load factors improved through 1979 and then worsened suddenly in 1980, perhaps as a transitory impact of airline deregulation. In subsequent years, aircraft occupancy regained lost ground, and by 1989 contributed half a quad to air travel energy savings.

The more than 3 trillion passenger-miles traveled by highway in 1992 would

FIGURE 3 – 13

Passenger Transportation Energy Use: 1972–1992
Efficiency and Modal Structure Effects

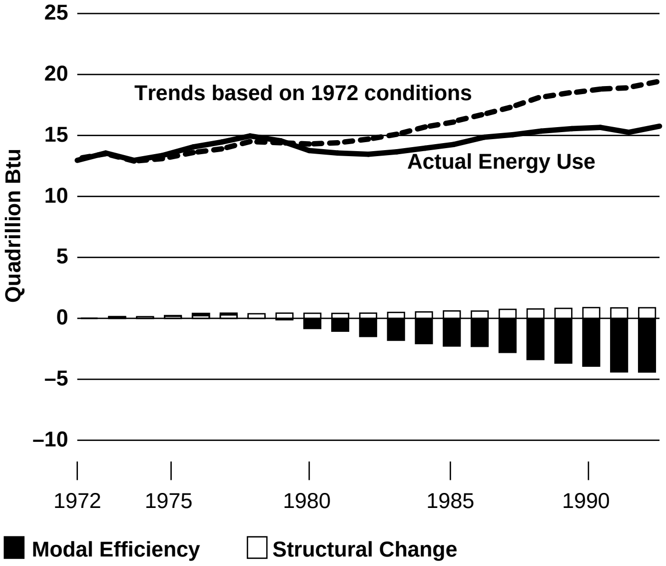
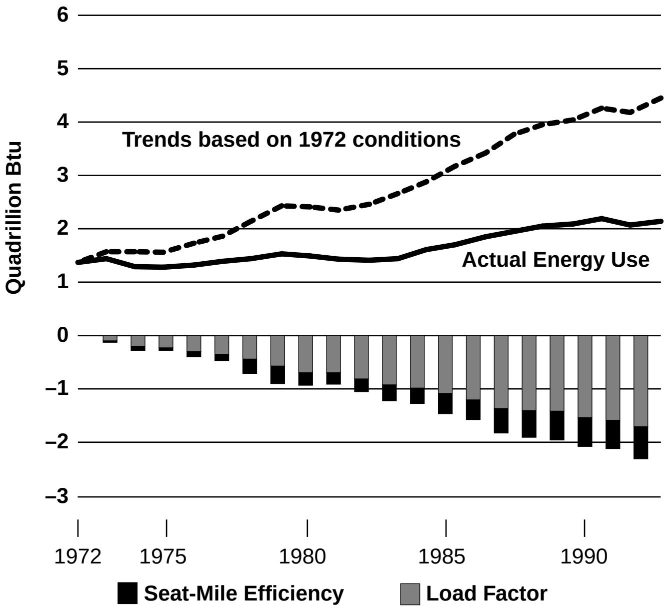


**FIGURE 3–14**

Air Passenger Energy Use: 1972–1992
Seat-Mile Efficiency and Load Factor



have required an additional 6.6 quads of energy had vehicle fuel economy remained constant at 1972 levels. Vehicle-mile energy efficiency decreased in 1973 and then began continuous improvement. The replacement of older low-fuel-economy vehicles with newer, more efficient ones caused this gradual improvement. However, new light-duty-vehicle fuel economy has not improved appreciably since 1982. Since average vehicle life expectancy is now about 12 years, fleet efficiency improvements should be slowing to a halt. This appears to have begun, since average energy use per mile of highway vehicle travel increased in 1992. The apparent increases in cumulative savings in 1992 and 1993 were the result of the growth in vehicle travel magnifying the past cumulative efficiency gain, which outweighed the small decline in efficiency per vehicle-mile in those years. (See Figure 3–15.)

Energy savings due to vehicle efficiency improvement since 1972 were more than cut in half by falling vehicle occupancy rates. Decreases in the number of passengers per vehicle-mile added 3.5 quads to total energy use, while vehicle-type shifts added 0.5 quads. The effect of the increasing light-truck market on efficiency is small, but evident at the very beginning of the period; this negative effect on efficiency persists in spite of the fuel price shocks of 1973–74 and 1979–80. The observation that declining vehicle occupancy rates have significantly eroded the benefits of vehicle efficiency improvements must be interpreted cautiously, since data on highway vehicle occupancy rates are somewhat weak. The best data come from surveys such as the Nationwide Personal Transportation Survey, rather than from direct observation of highway vehicles.

*Freight Energy Efficiency Trends.* The picture for the freight sector is quite different from that for the passenger sector.

**TABLE 3–4**

Vehicle Occupancy Rates and Load Factors: 1972–1991

| | 1972 | 1975 | 1977 | 1980 | 1983 | 1985 | 1990 | 1991 |
|---|---|---|---|---|---|---|---|---|
| **Passenger** | Passenger-Miles/Vehicle-Miles | | | | | | | |
| Passenger Car | 2.07 | | 1.86 | | 1.76 | | 1.62 | 1.61 |
| Light Truck | 2.02 | | 1.81 | | 1.71 | | 1.72 | 1.72 |
| Air | 65.20 | | 85.20 | | 101.00 | | 100.00 | 99.50 |
| Bus | 18.30 | | 18.60 | | 15.90 | | 15.30 | 15.40 |
| Rail | 26.70 | | 26.90 | | 25.50 | | 23.40 | 22.90 |
| **Freight** | Ton-Miles/Vehicle-Miles | | | | | | | |
| Combination Trucks | 11.50 | 9.70 | | 8.10 | | 7.70 | 7.60 | 7.80 |
| Rail | 25.90 | 27.40 | | 31.80 | | 35.90 | 40.90 | 42.10 |

FIGURE 3–15

Highway Passenger Energy Use: 1972–1992
Occupancy, Efficiency, and Vehicle Type Effects

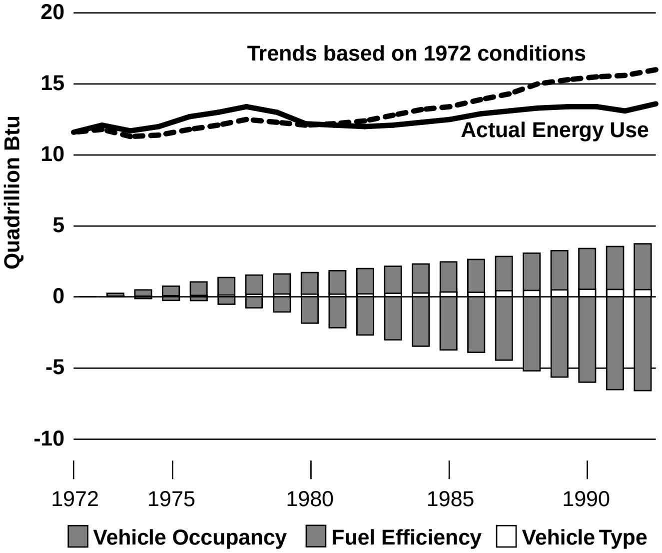
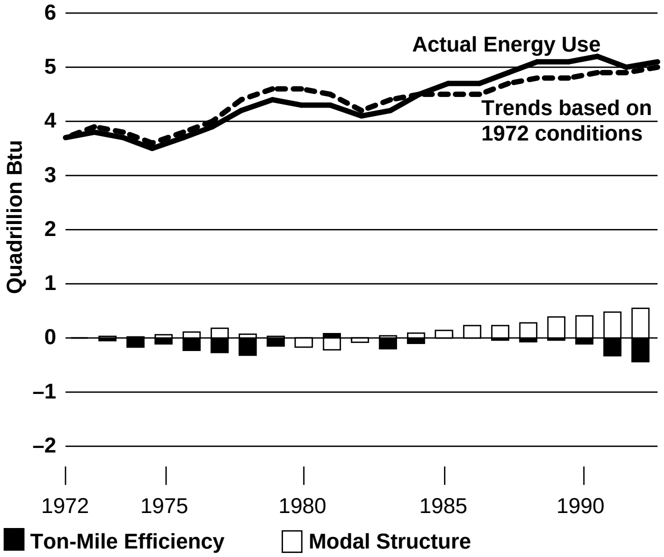


FIGURE 3–16

Freight Energy Use: 1972–1992
Efficiency and Modal Structure Effects



However, the quality of data on freight activities is poor and could be misleading. Data quality notwithstanding, Divisia analysis suggests that, had ton-mile energy efficiencies and the distribution of traffic by mode remained at their 1972 levels, freight transport in the United States in 1992 would have required just slightly *less* energy than was actually used. (See Figure 3–16.)

The minor impact of changes in the modal structure of freight transport is not surprising, given that the modal shares of ton-miles in 1992 were very close to those in 1972. Rail carried an estimated 28 percent of ton-miles in 1972 and 29 percent in 1991. Combination trucks increased their share from 17 percent to 20 percent. Changes in the energy intensity of ton-mile movements tended to increase energy use slightly as impressive gains by rail were offset by apparent increases in the energy use per ton-mile by intercity trucks. Rail freight Btu per ton-mile has declined from 706 in 1972 to just over 399 in 1992. The energy intensiveness of domestic waterborne commerce shows a more erratic, but downward, trend.

The factor most responsible for the apparent decline in freight energy efficiency is a decrease in tons carried per truck. Data on truck load factors (i.e. tons carried per truck) are rough estimates and could be subject to substantial error. Other evidence on truck load factors, however scarce, does tend to corroborate decreasing heavy-truck load factors. The Truck Inventory and Use Survey (TIUS) indicates that the average load carried by combination trucks declined from 17.7 tons in 1982 to 15.9 tons in 1987—a surprising finding, because the Surface Transportation Assistance Act of 1982 permitted larger and heavier trucks to operate nationwide over a specified network. This opportunity should have increased the average tons carried per truck. TIUS data also suggest a decline in tons carried per heavy single-unit truck.

It may be, however, that other factors, such as the changing composition and delivery requirements of freight and the greater movement of partial loads or empty back-hauls, more than offset the potential for larger trucks to increase truck load factors. Because trucks are on average far more energy intensive per ton-mile than the other modes, these apparent changes in truck ton-mile efficiencies offset changes in the other modes.

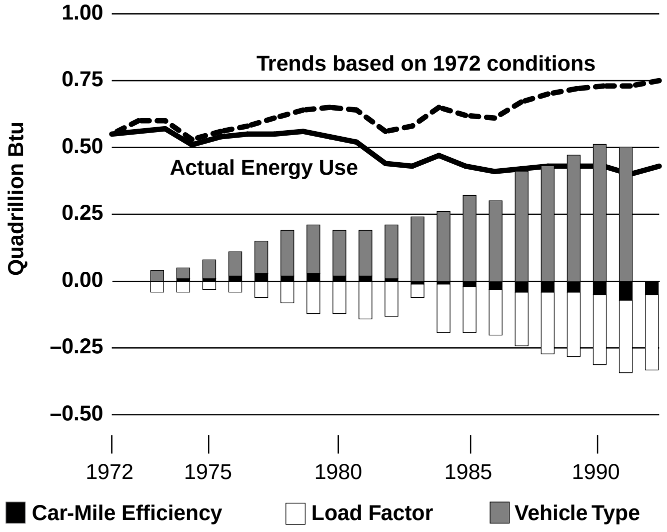
The Divisia analysis of rail freight movements, in contrast, shows enormous efficiency gains—gains almost entirely due to increased carloads (ton-miles per railroad car-mile). If the 1992 rail ton-miles had been moved at 1972 energy intensities, 75 percent more energy would have been required. (See Figure 3–17.) Nearly all (85 percent) of the 0.33 quad savings was achieved by increasing railroad car load factors from about 25 tons per car in 1972 to about 40 in 1992. Although the Divisia analysis does not show it, vehicular efficiencies did improve with locomotives, operating policies, and other advances. Otherwise, moving more tons per car would have produced an increase in energy use per car-mile. More than any other mode, rail has succeeded in reducing energy intensity by improving the efficiency of its operations.

## Transportation Air Pollutant Emissions Trends

Transportation's impacts on the environment are manifold. Transportation facilities require land: in fact, perhaps one-fifth of the land in a typical metropolitan area is given over to transportation use. Transportation facilities crossing wetlands and other sensitive habitats remove portions of these habitats from their natural state and can act as disruptive barriers to wildlife. Similar barriers can be created in human communities. Transportation facilities also generate considerable noise pollution for nearby neighborhoods. Runoff from roads and other facilities, spills of transportation fuels and cargoes, and leaks from underground fuel storage tanks all contribute to ground and surface water pollution. This analysis does not attempt to deal fully with the environmental impacts of transportation activities, but instead focuses on air pollution. Not only is this the most prominent environmental impact of transportation, but comprehensive and consistent data series are available for every major air pollutant. An objective of the 1996 volume of the *Transportation Statistics Annual Report* is to treat environmental impacts comprehensively, devoting appropriate attention to those important areas neglected here such as land use impacts, noise, and water pollution.

**FIGURE 3 – 17**

Rail Freight Energy Use: 1972–1992
Efficiency, Load Effects, and Vehicle Type



Over the past two decades, enormous strides have been made in reducing air pollution rates for transportation activities. In federal emissions tests, new gasoline-powered passenger cars and light trucks today produce only about 10 percent of the emissions per mile as vehicles did 30 years ago, prior to vehicular emissions regulations.

As the Divisia analysis shows, emissions of major pollutants would be 50 to 100 percent higher than they now are without these improvements. The fact that the difference is not greater is evidence that the performance of emissions control systems in actual use falls short of their performance in federal tests. And, concurrently, highway vehicle travel has increased at an average annual rate of 3 percent per year, erasing much of the potential gains. Not surprisingly, a debate has arisen over whether air quality improvement can long continue in the face of the seemingly inexorable growth of transportation activity.

*Air Quality.* Some experts argue that ways must be found to curb highway vehicle travel if all metropolitan areas are to fully attain air quality standards. Others argue that the answer lies in continued technological improvements: ever cleaner vehicles and fuels. Whether the vehicle and fuel standards required by the Clean Air

Act Amendments of 1990 will produce dramatic gains or only modest ones will depend to a large extent on how fast travel demand grows. Divisia analysis of past trends shows that technological improvements have substantially reduced pollutant emissions.

Based on EPA estimates, air pollution from transportation activities appears to have peaked during the decade from 1970 to 1980, and declined thereafter. Emissions of CO and VOCs seem to have been steadily declining since 1980. (See Figures 3–18 and 3–19.) Passenger cars have accounted for most of this reduction, since they are the single largest source of these pollutants in the transportation sector. Every major pollutant source, except off-highway mobile equipment, has also contributed to these reductions. On the other hand, $NO_x$ emissions by transportation appear to have remained essentially constant over the past decade. (See Figure 3–20.) The near elimination of lead emissions is a great environmental success story for transportation and for the nation as a whole. Drastic reductions in lead emissions began with the lead-phasedown requirements for gasoline in the 1970s; these efforts culminated in the federally mandated requirement to use unleaded gasoline in all new passenger cars and light trucks. (See Figure 3–21.)

The results of the decomposition analysis indicate that at 1970 emissions rates per vehicle-mile, the vehicle travel that took place in 1992 would have generated several times as much pollution as it did. Reductions in pollution per vehicle-mile by all modes appear to have been enormously successful in allowing transportation activity to grow with no apparent increase in air pollution. Shifts in modal activity toward trucking have generally tended to increase pollution, but their overall effect has been negligible. It is important to remember that this analysis is based entirely on estimated emissions, and is therefore no more accurate than the estimates on which it is based.

The cumulative effect of reduced emissions per mile, which is the gap between the air pollution that transportation actually produced and what it would have produced at 1970 emissions rates, continues to expand over time. (Figure 3–22.) Cumulative emissions reductions are expanding both because emissions per mile continue

FIGURE 3 – 18

Emissions of CO by Transportation: 1940–1992

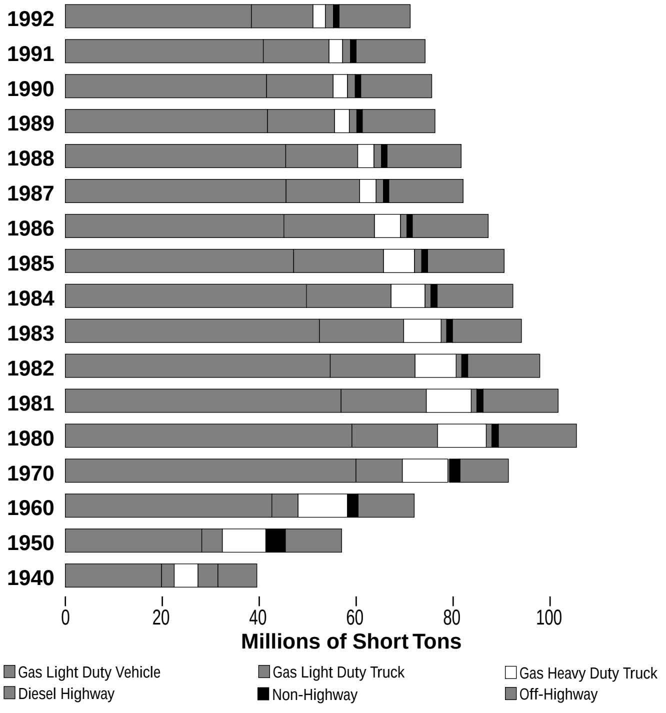


FIGURE 3 – 19

Emissions of VOCs by Transportation: 1940–1992

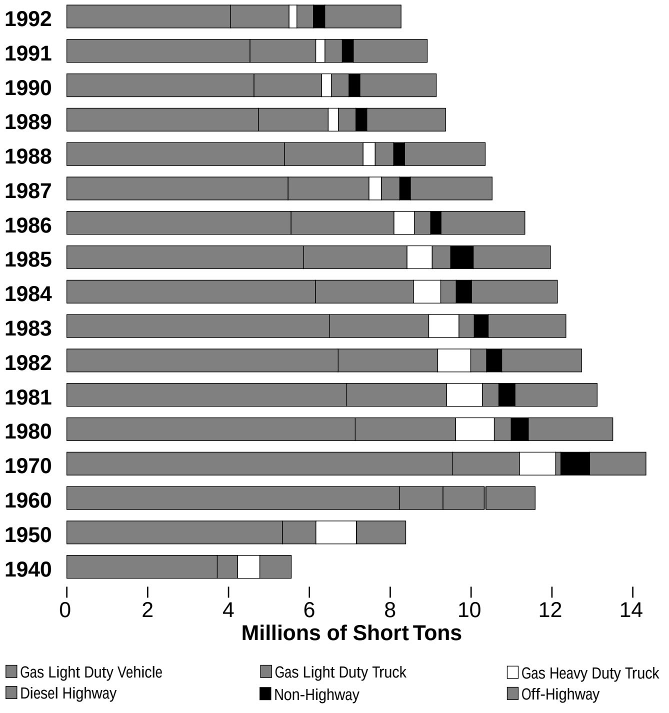


FIGURE 3–20

Emissions of $NO_x$ by Transportation: 1940–1992

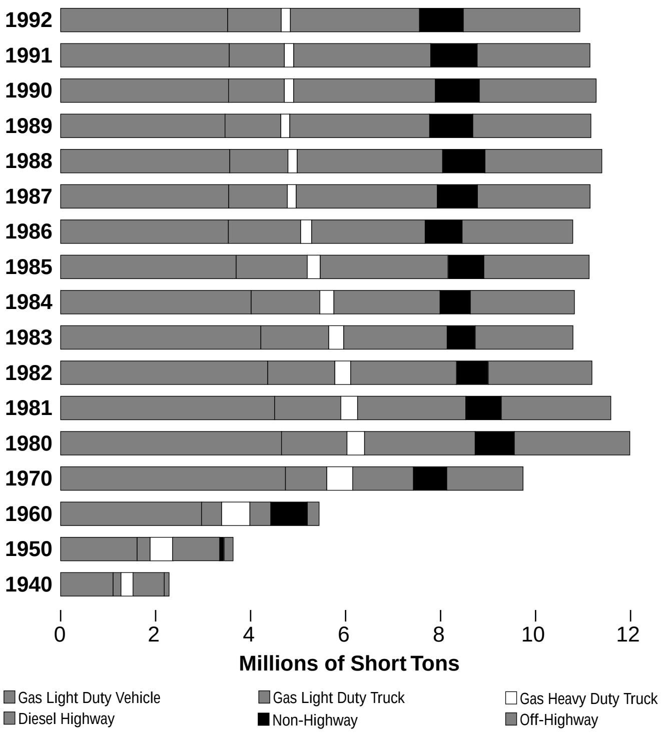
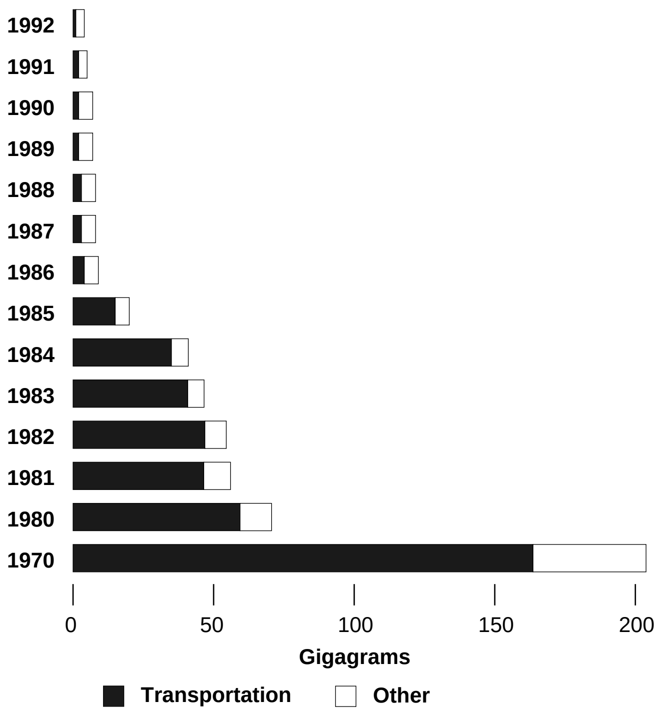


FIGURE 3–21

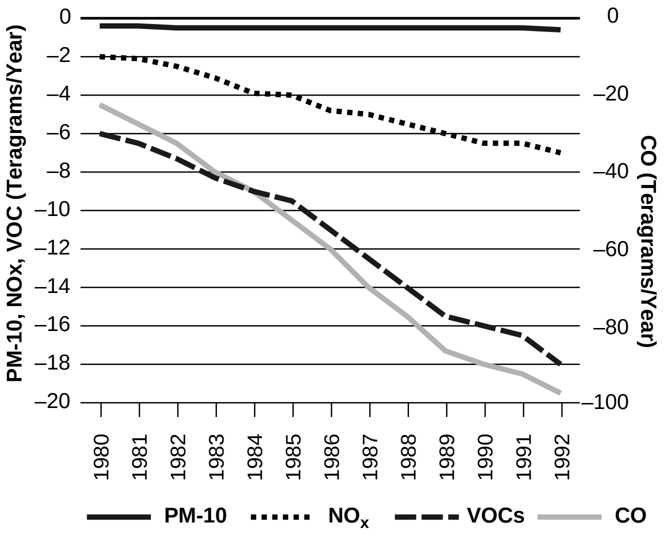
National Emissions of Lead: 1970–1992



to fall and because transportation activity is growing. According to EPA data, emissions rates have fallen every year since 1970 for each of the three major pollutants (CO, $NO_x$, and VOCs), with one exception: in 1985, $NO_x$ emissions showed a negligible increase.

FIGURE 3–22

Cumulative Emissions Rate Reductions Since 1970



## $CO_2$ Emissions from Transportation

### Overview: An International Perspective

The earth's atmosphere is largely transparent to solar radiation, which is concentrated in the short-wavelength, visible light spectrum. Much incoming solar radiation is reflected back to space by clouds or the earth's surface itself. The rest is absorbed by oceans and land and reradiated to the atmosphere in the longer wavelength, infrared spectrum. *Greenhouse gases* are those that are especially effective at absorbing this longer wavelength radiation and trapping it in the atmosphere, thus raising the temperature of the atmosphere. Were it not for greenhouse gases, temperatures on the earth's surface would be far too cold for life as we know it. More than 40 greenhouse gases have been identified, but the most potent ones in terms of warming effect are $CO_2$, water vapor, and methane. Of these, $CO_2$ is far and away the most significant greenhouse gas simply because its large quantity. Over the past decade or so, there has been a growing concern that increasing anthropogenic (i.e., caused by human activities) emissions of $CO_2$ and other greenhouse gases are contributing to a general warming of the global climate. Anthropogenic emissions of $CO_2$—two-thirds of which derive from the combustion of fossil fuels, with the remainder primarily caused by deforestation—have increased its concentration in the atmosphere by 25 percent since the beginning of the Industrial Revolution.

A recent report by the Intergovernmental Panel on Climate Change suggests that even if $CO_2$ emissions were maintained at today's levels, there would be a nearly constant rate of increase (about 0.4 percent per year) in atmospheric concentrations of $CO_2$ for at least two centuries.[18] What appears to be troubling is not so much the *level* of $CO_2$ concentrations (which has been exceeded in geological history) but the *pace* of growth, which may strain the adaptive capability of biological and human systems. Atmospheric concentrations of $CO_2$ can be stabilized in the range between today's level (350 parts per million volume (ppmv)) and two times today's level only if global anthropogenic emissions could be reduced below 1990 levels. Although there is considerable uncertainty about how far the earth's temperature will rise and what the specific climatic impacts will be in different regions of the globe, the fact that anthropogenic greenhouse gas emissions will cause some global warming is generally accepted.

In the United States, $CO_2$ emissions from the use of fossil fuels have steadily increased over the last quarter century by 51 percent, specifically, from 1,003 million metric tons (mmt) of carbon in 1965 to 1,551 mmt by 1992. The key emitters of $CO_2$ in the American economy are electricity generation, transportation, industrial production, and commercial and residential use of energy. (See Figure 3–23.)

Among these sources of $CO_2$ emissions, transportation has grown in both absolute and relative terms. In the 1965–92 period, the $CO_2$ emissions deriving from transportation in the United States rose 79 percent from 229 mmt of carbon to 408 mmt —easily outpacing the increase in overall $CO_2$ emissions. (See Table 3–5.) A similar trend of transportation $CO_2$ emissions outpacing overall $CO_2$ emissions is evident in all the advanced industrial economies. For example, the Organisation for Economic Cooperation and Development (OECD) as a whole, which consists of a set of affluent industrialized countries, experienced a 115-percent increase in transportation $CO_2$ emissions; in comparison, total $CO_2$ emissions increased 62 percent in the 1965–92 period. A major factor underlying the growing role of transportation in the generation of $CO_2$ and other greenhouse gases in the United States and other OECD countries is the steady increase in transportation demand over the last quarter century.

The objective of this section is to track trends in $CO_2$ emissions in the United States over the last quarter century or so, and to interpret these trends in terms of their underlying factors. To set the U.S. experience in an international perspective, a comparative analysis of similar trends in the seven major OECD countries, the so called G-7 countries, is also provided. The section begins with a parallel discussion of trends in $CO_2$ emissions and energy use—particularly transportation energy use. It proceeds to a survey of several factors that have driven the shifts in the patterns of transportation energy use in the G-7 countries. These factors include the increasing magnitudes and evolving modal composition of passenger and freight flows, the

**FIGURE 3–23**

Distribution of U.S. $CO_2$ Emissions by Sector: 1992

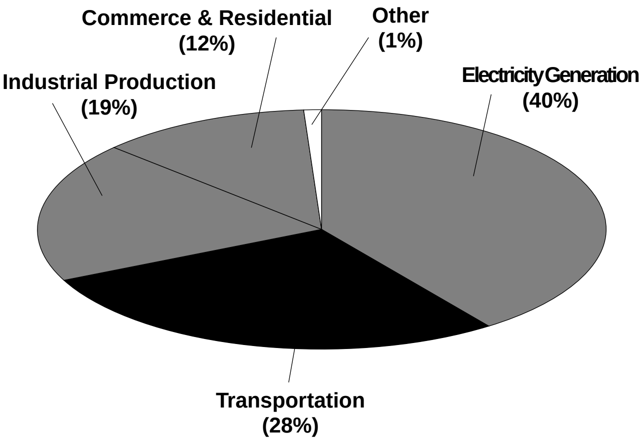


**TABLE 3–5**

$CO_2$ Emissions from Transportation in the G–7 Countries: 1965–1992

| Country/Year | 1965 | 1970 | 1975 | 1980 | 1985 | 1990 | 1992 |
|---|---|---|---|---|---|---|---|
| | Millions of Metric Tons of Carbon | | | | | | |
| **United States** | **229** | **291** | **337** | **351** | **368** | **407** | **408** |
| Canada | 19 | 24 | 31 | 36 | 32 | 35 | 36 |
| France | 14 | 17 | 24 | 28 | 29 | 34 | 36 |
| Germany | 19 | 24 | 28 | 34 | 35 | 49 | 50 |
| Italy | 10 | 14 | 16 | 21 | 23 | 28 | 30 |
| Japan | 16 | 27 | 35 | 44 | 47 | 63 | 71 |
| United Kingdom | 19 | 22 | 25 | 28 | 31 | 39 | 39 |
| OECD | 363 | 470 | 560 | 618 | 646 | 746 | 778 |

changing energy intensity of different transportation modes, the shifting vehicle mix in road transportation, the increasing personal propensity for travel, and changing vehicle occupancy rates and load factors. (See Emissions in Non-OECD Countries box.)

### Trends in Transportation Energy Use and $CO_2$

The quarter century under review in this section, 1965–92, comprises two distinct periods of energy use. The years 1965–72 were the last part of the remarkable postwar era of economic growth based on material and energy intensive industries. The first part of the 1973–92 era was a discontinuity, characterized by high energy prices and insecure energy supplies. The oil crises led to a period of slower growth, energy conservation, and the production of more energy efficient capital stock—as promoted, for example, by the Corporate Average Fuel Economy (CAFE) standards in the production of more fuel efficient cars in the United States. However, two developments in the last decade appear to be altering the energy scene again:

- Energy prices first stabilized and then fell in real terms between 1980 and 1987, slowing the momentum for energy conservation.
- In the G-7 economies, industrial structures are evolving away from material- and energy-intensive sectors toward knowledge-intensive sectors, thereby reducing overall energy demand.

The trends in transportation energy use and $CO_2$ emissions described below occurred—and must be understood—against this backdrop of energy price changes and structural evolution in the larger economy.

*Total Energy Use and Total $CO_2$ Emissions.* The total primary energy requirement (TPER) of the American economy increased 62.5 percent from 1,220 mmt of oil equivalent in 1965 to 1,984 mmt in 1992. (See Table 3–6.) By comparison, the OECD as a whole and all the other G-7 countries except the United Kingdom experienced higher rates of TPER growth in the same period. In 1965, the United States had a much higher level of per capita energy use, reflecting its higher real income; since then, the levels of energy use in the OECD countries have moved sharply upward as their per capita incomes have caught up with that of the United States. (See Figure 3–24.)

Predictably, the growth of $CO_2$ emissions from energy use between 1965 and 1992 parallels the patterns observed above, but at a slower pace. While $CO_2$ emissions in the United States increased by 51 per-

## Emissions in Non-OECD Countries

Although they are not considered in detail in this section because adequate data on transportation energy use are not available, $CO_2$ emissions by non-OECD countries have become an important and rapidly growing part of world emissions. By 1992, non-OECD countries, including the former Soviet Union and China, accounted for just over half (51 percent) of world energy consumption and carbon emissions. Furthermore, energy consumption and emissions have been growing far more rapidly in non-OECD countries than in OECD countries. From 1970 to 1992, the energy use of OECD countries grew by 36 percent and carbon emissions increased by 24 percent as the percentage of total energy attributed to non-fossil energy grew. In the non-OECD countries, energy use and carbon emissions increased by 121 percent and 99 percent, respectively. This phenomenally higher rate of growth in energy use can be attributed to a population growing at twice the rate of OECD countries, and the fact that non-OECD economies use twice as much energy per dollar of gross domestic product (GDP) as do OECD economies. Still, the OECD economies accounted for 48 percent of carbon emissions in 1992, although they comprised only 16 percent of the world's population.[19]

Transportation's role in the growth of $CO_2$ emissions in non-OECD countries is more difficult to discern due to the lack of consistent data on end-use energy consumption. However, use by non-OECD countries of petroleum—the principal energy source for transportation fuels—has increased much more slowly in recent years. From 51.6 quads in 1983, non-OECD energy use increased to 58.2 quads in 1992: an average annual growth rate of just 1.4 percent. At the same time, OECD petroleum use increased at almost exactly the same average annual rate. Its energy use in non-OECD countries continues to grow as rapidly as it has in the past two decades, its energy use and carbon emissions of these countries will soon come to dominate world totals.

**TABLE 3–6**

Total Primary Energy Requirement (TPER) in the G–7 Countries: 1965–1992

| Country/Year | 1965 | 1970 | 1975 | 1980 | 1985 | 1990 | 1992 |
|---|---|---|---|---|---|---|---|
| | Millions of Metric Tons of Oil Equivalent | | | | | | |
| **United States** | **1,220** | **1,546** | **1,647** | **1,801** | **1,772** | **1,920** | **1,984** |
| Canada | 99 | 132 | 161 | 192 | 193 | 211 | 216 |
| France | 106 | 147 | 162 | 191 | 201 | 221 | 231 |
| Germany | 182 | 234 | 239 | 273 | 270 | 355 | 340 |
| Italy | 71 | 111 | 124 | 139 | 137 | 155 | 159 |
| Japan | 137 | 256 | 307 | 346 | 359 | 428 | 451 |
| United Kingdom | 184 | 208 | 202 | 201 | 203 | 212 | 216 |
| OECD | 2,243 | 2,983 | 3,262 | 3,622 | 3,640 | 3,989 | 4,195 |

FIGURE 3–24

Per Capita Energy Use
In G-7 Countries: 1965–1992

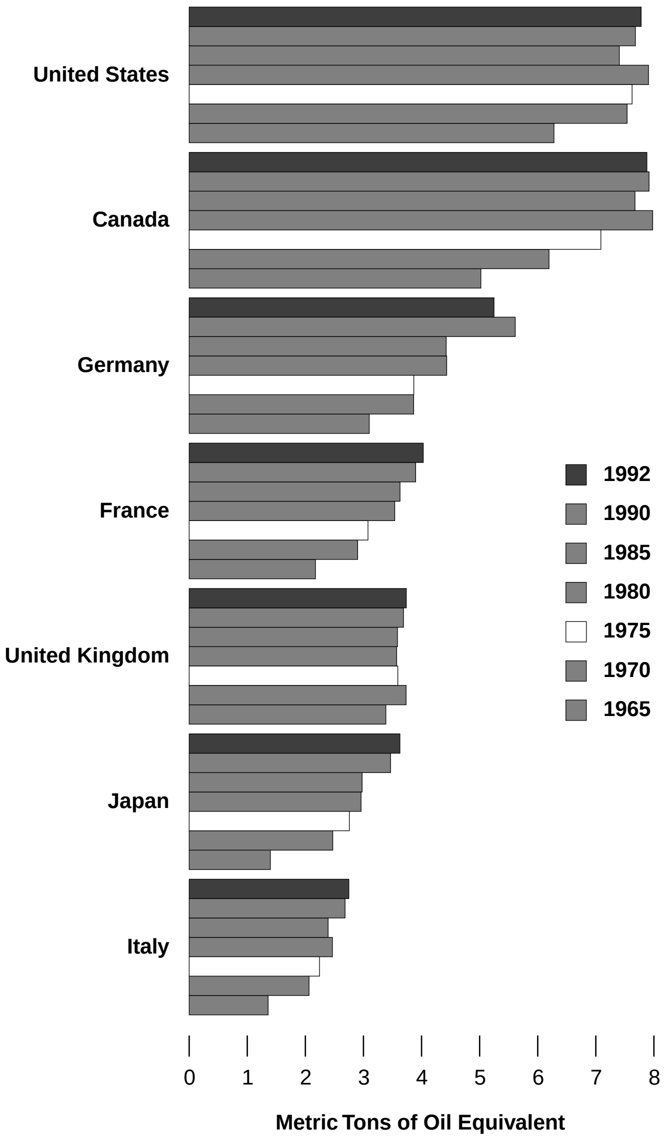
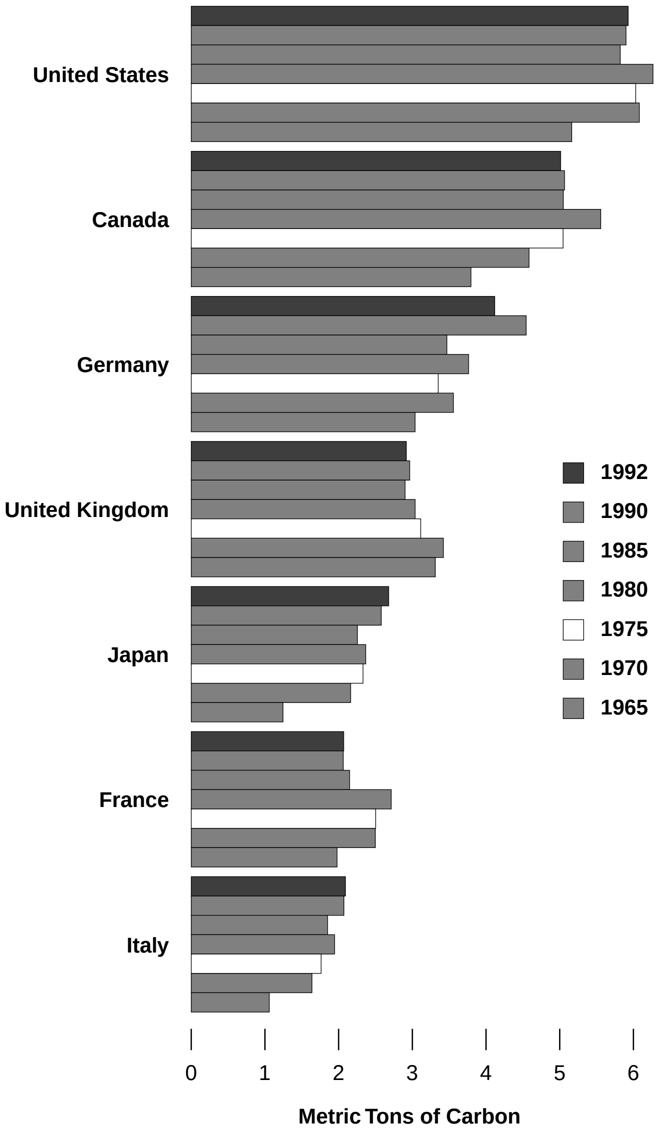


FIGURE 3–25

Per Capita Total $CO_2$ Emissions
in G-7 Countries: 1965–1992



cent between 1965 and 1992, those from OECD as a whole, Japan, Italy, and Canada grew even faster. Like the growth of energy demand, the growth of $CO_2$ emissions in the selected OECD countries was mainly caused by the population growth and GDP growth in these countries. On a per capita basis, however, $CO_2$ emissions even declined in some of these countries. (See Figure 3–25.) Per capita $CO_2$ emissions in the United States peaked in 1979. By 1985, they had dropped to below their 1970 level and have since stabilized. A similar pattern of changes in per capita $CO_2$ emissions is observed in Canada, France, and the United Kingdom. But per capita $CO_2$ emissions in Germany, Japan, and Italy posted a consistent increasing trend in the same period.

The differences between the energy use and $CO_2$ emissions patterns derive from fuel substitution and the resulting changes in the fuel mix of energy consumption in these countries. The increasing share of nonfossil energy, such as nuclear and hydropower in TPER in these countries, is one major reason why $CO_2$ emissions are

**TABLE 3–7**

Shares of Non-fossil Fuel Electricity in Total Electricity Production: 1970–1992

| Country / Year | 1970 | 1975 | 1980 | 1985 | 1992 |
|---|---|---|---|---|---|
| | Percent | | | | |
| **United States** | **16.9** | **24.4** | **22.7** | **26.8** | **28.5** |
| France | 42.8 | 42.6 | 51.1 | 83.8 | 88.8 |
| Germany | 9.8 | 12.8 | 16.9 | 35.1 | 33.1 |
| Japan | 24.6 | 23.3 | 30.5 | 37.7 | 34.6 |
| United Kingdom | 12.7 | 13.0 | 14.8 | 22.9 | 26.1 |

growing more slowly than total energy use. (See Table 3–7.) Other aspects of fuel shifts relate to the increasing share of natural gas and decreasing share of coal. France experienced the sharpest change in fuel mix; correspondingly, its rate of growth in $CO_2$ emissions was only half that of the United States in the 1965–92 period.

*Transportation Energy Use and Related $CO_2$ Emissions.* Transportation's energy use and $CO_2$ emissions grew faster than total energy use and total $CO_2$ emissions in the United States in the 1965–92 period—79 percent versus 63 percent for energy and 78 percent versus 51 percent for $CO_2$ emissions. A similar pattern is evident in all the G-7 countries, except that their rates of growth are two to four times greater than those of the United States.

The relatively faster growth of transportation energy use and $CO_2$ emissions is also apparent on a per capita basis. Per capita growth in transportation versus total energy use has been particularly sharp in Japan and Europe. In the United States, the disproportionate growth of per capita transportation energy use versus total energy use is even more apparent: after peaking in 1980, per capita total energy consumption in the United States had fallen back to its pre-1975 level by 1985. Although it had been climbing up since then, it was still lower than its 1980 level in 1992. But per capita transportation energy consumption experienced only a slight decrease between 1975 and 1985 (partly reflecting the effect of higher oil prices), after which it increased rapidly, reaching a record high in 1990. The absolute level of per capita transportation energy consumption in the United States is about twice as high as in other major OECD countries. This fact reflects not only the higher personal mobility in the United States, but also the much bigger size of the United States and the spatial distribution pattern of its economic activities.

The difference between per capita total $CO_2$ emissions and per capita transportation $CO_2$ emissions in the seven major OECD countries over the 1965–92 period is even greater than the difference between total and transportation energy use. In the United States, France, and the United Kingdom, per capita total $CO_2$ emissions decreased after 1980 (Figure 3–25), but per capita transportation $CO_2$ emissions continued to increase. (See Figure 3–26.) Even on a per capita basis, the transportation $CO_2$ emissions level in the United States is much higher than those in the other major OECD countries. But the big gap between the United States and the other countries has been narrowing, particularly since 1985.

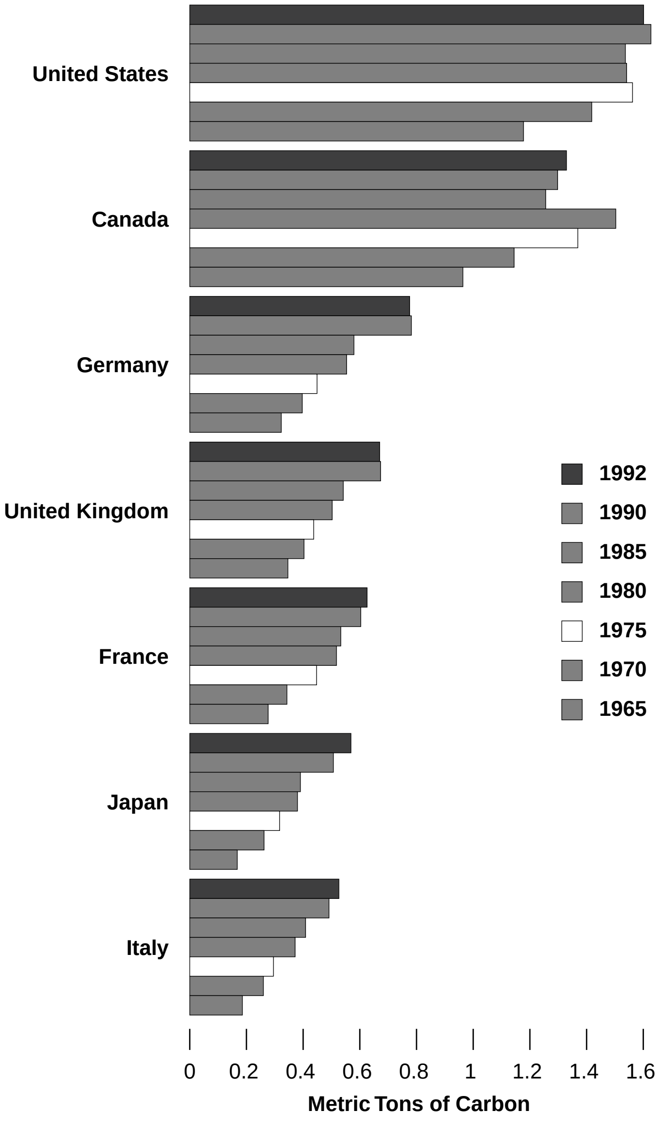
As a result of the relatively faster growth of transportation energy use and $CO_2$ emissions, the share of transportation in total energy use and $CO_2$ emissions increased in the United States and other major OECD countries by 1992. (See Figure 3–27.) The limited, if any, ability to shift away from fossil fuels in transportation energy use is one factor behind this situation.

*Increases in Transportation as a Product of Economic Expansion.* The demand for transportation energy is a derived demand. It results from the need expressed in the market for the movement of goods and persons in support of production and consumption activities. The energy consumed by the transportation capital stock used in these production and consumption activities (e.g., trucks, cars, airplanes, railroads, ships, transit vehicles, etc.) represents the transportation energy demand. Thus, the explosive growth in transportation reflects the remarkable economic expansion of the United States and other major OECD countries in the last two decades or more.

Per capita GDP increased in real terms in the United States by $6,000, or 50 percent, between 1965 and 1992.[20] (See Figure 3–28.) Other major OECD countries have experienced much steeper rates of income growth as they move toward convergence with the United States. As incomes have

FIGURE 3–26

Per Capita Transportation $CO_2$ Emissions In G-7 Countries: 1965–1992



increased, car ownership has also surged: the disparities in car ownership narrow between the United States and other countries over time (See Figure 3–29.)

Concurrently, propensities for travel have increased. (See Figure 3–30.) The annual average domestic kilometers traveled per person by road, for example, increased in the United States from 14,900 km in 1965 to 23,700 km in 1992. The major European OECD countries have also sharply increased their travel propensities in this period. However, their mean annual per capita travel moved from about a third of the U.S. levels (5,000 km) in 1965 to

FIGURE 3–27

Share of Transportation in Total $CO_2$ Emissions: 1965 and 1992

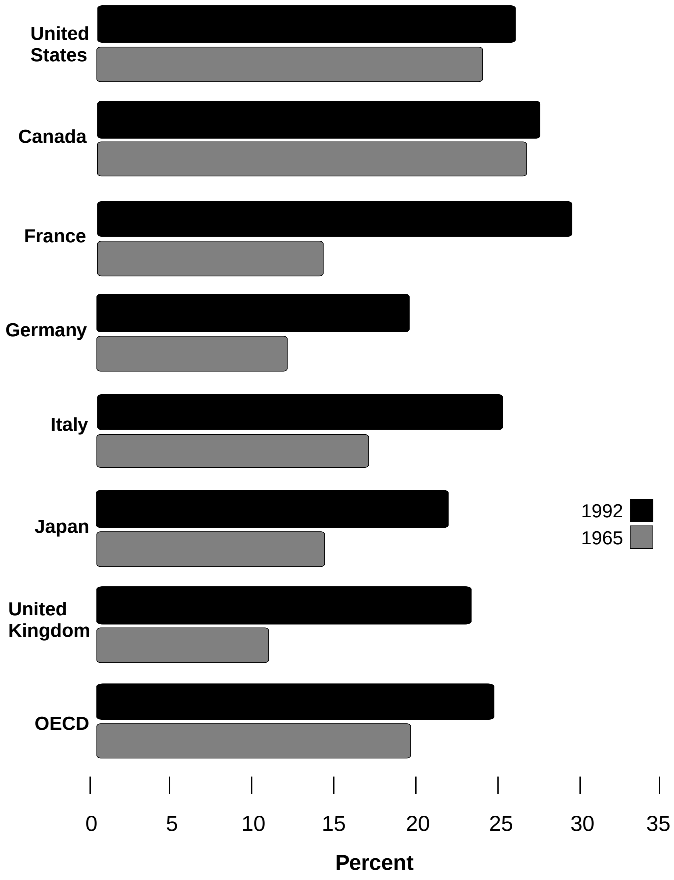


FIGURE 3–28

Per Capita GDP (at PPPs) in the G-7 countries: 1965–1992

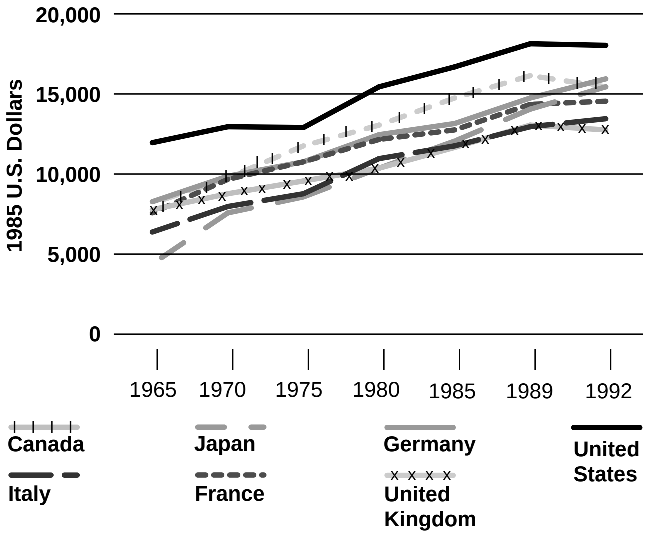
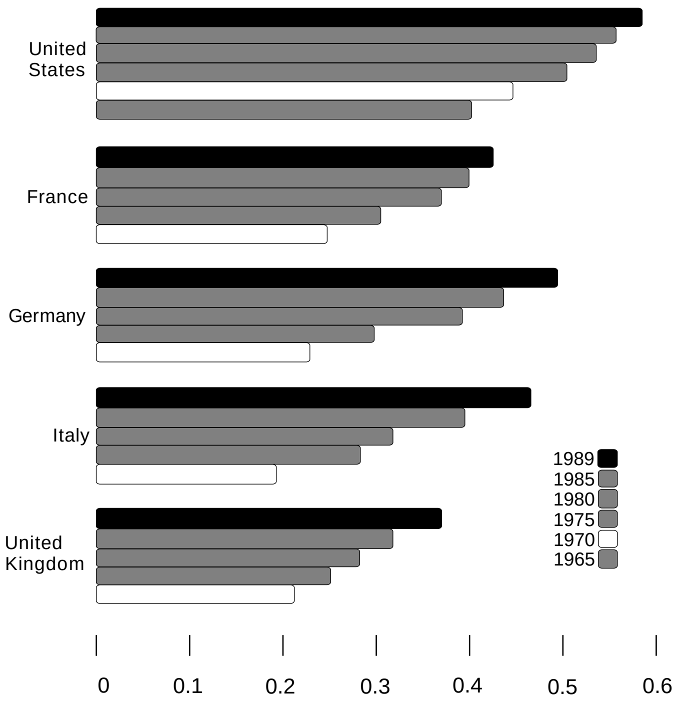


**FIGURE 3–29**

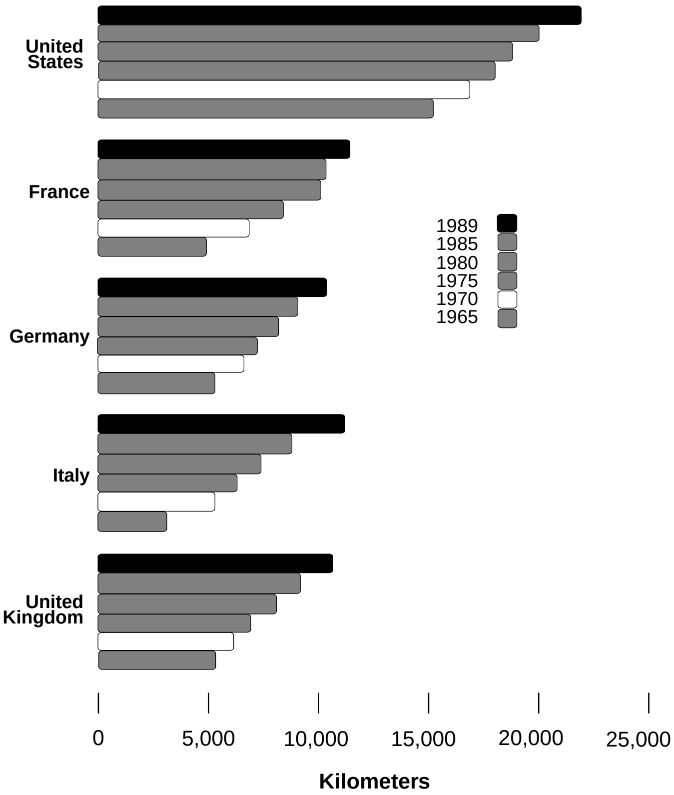
Cars per Person: 1965–1989



Note: Data for European countries in 1965 are not available.

**FIGURE 3–30**

Average Domestic Kilometers Traveled by Road, per Person, per Year: 1965–1992



only about a half of the U.S. levels by 1992. Clearly, as contrasted with per capita income and car ownership, the gap in personal travel propensities between the United States and other countries is quite large. Thus, of the three factors influencing transportation energy use considered so far—income, car ownership, and travel propensities—the United States registers higher values on all variables (particularly the last) than the other countries. This disparity provides part of the explanation for the much higher per capita transportation energy consumption—and corresponding $CO_2$ emissions—in the United States as compared to other countries.

*Energy Use Efficiency.* Another factor affecting $CO_2$ emissions and energy use in transportation is energy use efficiency. In passenger transport, the fuel efficiency of the U.S. auto population rose by 52 percent between 1973 and 1991, rising from 12.6 mpg to 19.1 mpg. This remarkable efficiency improvement derives from the legally mandated CAFE standards, which led to an approximate doubling of new car fuel efficiency in the United States. If it had not been for this surge in fuel efficiency, energy use and $CO_2$ emissions of road transportation would have risen significantly in the United States. In Japan and European countries, car fuel efficiency was much higher in 1973. (See Tables 3–8 and 3–9.) However, efficiency in these countries improved much less dramatically than in the United States in the last decade and a half, reflecting increases in body size and engine power of new cars in these countries. Consequently, the gap in mean car fuel efficiency between the United States and other countries narrowed by 1991.

In addition to vehicle fuel efficiency, another factor affecting transportation's contribution to the total $CO_2$ emissions of an economy is the transportation intensity of the economy in terms of ton-kilometers (ton/km) per dollar of GDP. In the last decade or so, there has been a declining trend in ton-km per dollar of GDP in the United States—about a 16-percent drop from a 1.39 ton-km per dollar of GDP in 1980 to 1.17 in 1989. (See Figure 3–31.) This trend reflects the changes in industrial structure underway in all advanced economies, as low value-added sectors (e.g., primary sectors such as agriculture, mining, and certain manufacturing sectors such as

## TABLE 3–8

### Fuel Efficiency of the Gasoline Automobile Population for Selected Countries: 1970–1991

| Year/Country | United States | France | Germany | Italy | Japan | United Kingdom |
|---|---|---|---|---|---|---|
| | Miles per Gallon | | | | | |
| 1970 | 12.6 | 27.8 | 23.1 | N/A | 21.7 | 23.5 |
| 1971 | 12.6 | 27.8 | 22.1 | N/A | 20.7 | 23.4 |
| 1972 | 12.5 | 27.8 | 21.5 | N/A | 21.9 | 22.0 |
| 1973 | 12.4 | 27.0 | 22.0 | 27.9 | 21.3 | 21.8 |
| 1974 | 12.6 | 27.8 | 22.3 | N/A | 21.0 | 21.9 |
| 1975 | 12.7 | 27.4 | 22.0 | N/A | 21.4 | 22.6 |
| 1976 | 12.7 | 26.4 | 21.9 | N/A | 21.2 | 22.7 |
| 1977 | 12.9 | 26.6 | 21.7 | N/A | 21.0 | 22.5 |
| 1978 | 13.1 | 26.2 | 21.5 | N/A | 20.8 | 22.1 |
| 1979 | 13.4 | 26.6 | 21.8 | 27.9 | 20.4 | 21.6 |
| 1980 | 14.3 | 25.8 | 21.6 | 27.9 | 20.4 | 22.7 |
| 1981 | 14.7 | 25.6 | 21.7 | 28.1 | 20.8 | 23.6 |
| 1982 | 15.3 | 25.4 | 21.7 | 28.1 | 21.1 | 23.8 |
| 1983 | 15.7 | 25.4 | 21.7 | 28.4 | 21.1 | 23.8 |
| 1984 | 16.2 | 25.7 | 21.7 | 28.9 | 21.5 | 23.8 |
| 1985 | 16.5 | 25.9 | 21.7 | 29.1 | 21.9 | 24.2 |
| 1986 | 16.5 | 26.0 | 21.7 | 29.6 | 22.0 | 24.2 |
| 1987 | 17.1 | 26.3 | 21.9 | 30.0 | 22.4 | 24.5 |
| 1988 | 17.8 | 26.2 | 22.1 | 30.3 | 22.5 | 25.0 |
| 1989 | 18.2 | 26.6 | 22.5 | 30.1 | 22.5 | 25.8 |
| 1990 | 18.6 | 26.7 | 22.7 | 30.1 | 2.3 | 25.6 |
| 1991 | 19.1 | 26.7 | 23.0 | 29.9 | 21.8 | 25.8 |

Note: All data for Germany before 1990 are for West Germany.

## TABLE 3–9

### New Gasoline Car Fuel Efficiency for Selected Countries: 1973–1991

| Year/Country | United States | France | Germany | Italy | Japan |
|---|---|---|---|---|---|
| | Miles per Gallon | | | | |
| 1973 | 13.1 | N/A | 23.0 | N/A | 22.6 |
| 1974 | 13.9 | N/A | N/A | N/A | 22.1 |
| 1975 | 15.4 | 27.7 | N/A | N/A | 21.2 |
| 1976 | 16.8 | 28.2 | N/A | N/A | 22.6 |
| 1977 | 17.8 | 28.5 | N/A | N/A | 24.9 |
| 1978 | 18.7 | 28.7 | 25.1 | N/A | 26.6 |
| 1979 | 18.8 | 29.1 | 25.4 | N/A | 27.3 |
| 1980 | 22.6 | 30.4 | 26.7 | 28.4 | 28.2 |
| 1981 | 24.2 | 31.9 | 28.2 | 28.8 | 28.9 |
| 1982 | 24.8 | 33.1 | 29.1 | 29.6 | 30.6 |
| 1983 | 24.7 | 33.7 | 29.3 | 31.9 | 30.1 |
| 1984 | 24.7 | 34.5 | 31.4 | 32.9 | 30.1 |
| 1985 | 25.1 | 35.1 | 32.0 | 32.9 | 29.2 |
| 1986 | 25.8 | 35.3 | 32.8 | 33.8 | 28.2 |
| 1987 | 26.0 | 35.7 | 31.8 | 34.3 | 27.8 |
| 1988 | 25.9 | 36.1 | 30.5 | 34.3 | 27.3 |
| 1989 | 25.6 | 36.3 | 30.0 | N/A | 26.8 |
| 1990 | 25.3 | 36.3 | 30.0 | N/A | 27.1 |
| 1991 | N/A | 36.3 | N/A | N/A | N/A |

Note: All data for Germany before 1990 are for West Germany.

FIGURE 3–31

Ton-Kilometers per Dollar of GDP: 1965–1989

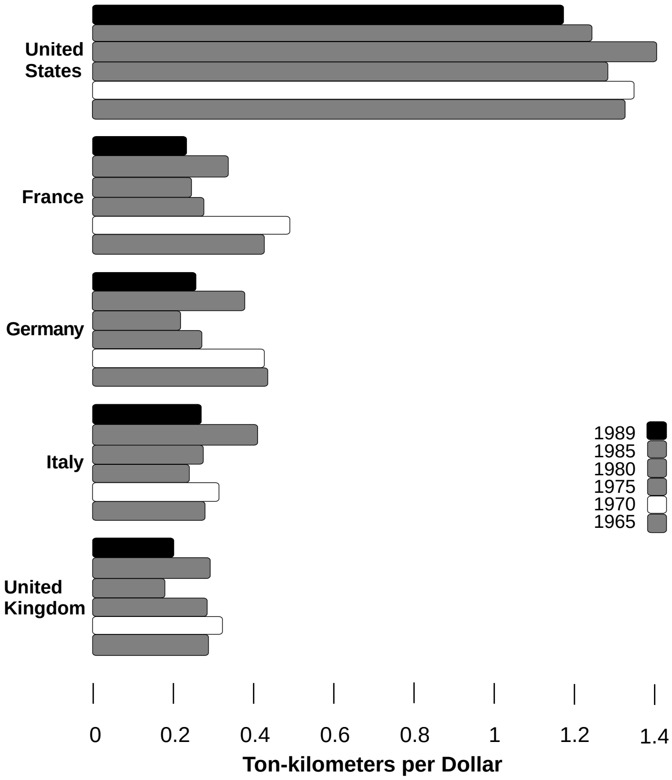
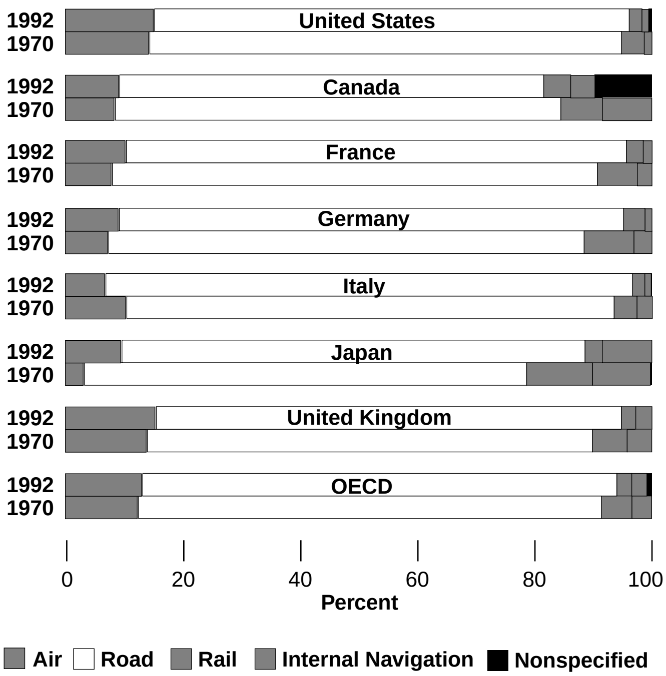


FIGURE 3–32

Shares of Individual Modes in Total Transportation Energy Demand: 1970 and 1992



the iron and steel industry) decline, while high value-added manufacturing sectors and services rise. The growth sectors are less material and energy intensive, hence, the drop in ton-km per dollar of GDP.

While this pattern is replicated in European countries, the absolute ton-km per dollar values are much lower than in the United States—between 20 percent to 40 percent of U.S. values. This large difference is primarily attributable to the difference in size of territory and the geographic patterns of production.

## Modal Composition of Energy Use and $CO_2$ Emissions in Transportation

Changes in the fuel mix of transportation energy consumption between 1965 and 1992 in the G-7 countries stemmed more from changes in the modal composition of transportation than from changes in the fuel mix within each mode of transportation. (See Figure 3–32 and Table 3–10.) The similar pattern of these changes across the G-7 countries suggests an increasing share of road and air transportation, and a decreasing share of water and rail transportation.

Over the 1965–92 period, coal use in transportation was confined to the rail and water modes. Decreases in the importance of these two modes contributed to the decreases in the share of coal in transportation energy consumption in the G-7 countries. On the other hand, rising shares of road and air in total transportation increased the share of oil in total transportation energy demand, thereby increasing oil import dependency and balance of payment problems in some developed countries. While the shares of oil in industrial and residential energy demand in the United States decreased respectively from 38 percent and 27.5 percent in 1965 to 28 percent and 11 percent in 1992, the share of oil in transportation energy demand increased from 95.7 percent to 96.8 percent over the same period.

The pattern of changes in the transportation modal composition of $CO_2$ emissions parallels that of transportation energy consumption. (See Figure 3–33 and Table 3–11.) The dominance of road transportation in total $CO_2$ emissions from

## TABLE 3 – 10

## Transportation Energy Demand by Mode in the G–7 Countries: 1965–1992

| **United States** | **1965** | **1970** | **1975** | **1980** | **1985** | **1990** | **1992** |
|---|---|---|---|---|---|---|---|
| **Transport Sector** | Millions of Metric Tons of Oil Equivalent | | | | | | |
| Total | 272.59 | 346.57 | 401.95 | 418.19 | 438.12 | 484.41 | 486.46 |
| Air | 34.36 | 49.20 | 51.23 | 55.90 | 63.25 | 76.60 | 73.07 |
| Road | 200.94 | 279.40 | 334.29 | 346.64 | 359.43 | 391.14 | 394.46 |
| Rail | N/A | 13.39 | 13.90 | 14.46 | 10.77 | 10.48 | 10.63 |
| Internal Navigation | 9.74 | 4.57 | 2.53 | 1.19 | 4.67 | 3.69 | 5.49 |
| Nonspecified Transport | 25.88 | 0.00 | 0.00 | 0.00 | 0.00 | 2.50 | 2.82 |
| **Canada** | **1965** | **1970** | **1975** | **1980** | **1985** | **1990** | **1992** |
| Total | 22.51 | 29.03 | 37.06 | 43.12 | 37.72 | 41.20 | 44.71 |
| Air | 1.37 | 2.41 | 3.43 | 3.97 | 3.79 | 4.39 | 4.05 |
| Road | 16.68 | 22.10 | 29.28 | 35.03 | 30.57 | 32.89 | 32.39 |
| Rail | 2.08 | 2.06 | 2.28 | 2.22 | 2.04 | 2.13 | 2.06 |
| Internal Navigation | 2.38 | 2.45 | 2.08 | 1.87 | 1.29 | 1.78 | 1.85 |
| Nonspecified Transport | N/A | 0.00 | 0.00 | 0.03 | 0.03 | 0.01 | 4.36 |
| **France** | **1965** | **1970** | **1975** | **1980** | **1985** | **1990** | **1992** |
| Total | 16.08 | 21.14 | 28.59 | 33.8 | 35.71 | 41.51 | 43.54 |
| Air | 0.98 | 1.65 | 2.92 | 3.59 | 3.89 | 4.01 | 4.44 |
| Road | 11.79 | 17.52 | 23.70 | 28.16 | 29.98 | 35.60 | 37.20 |
| Rail | 2.75 | 1.44 | 1.26 | 1.22 | 1.14 | 1.16 | 1.25 |
| Internal Navigation | 0.56 | 0.53 | 0.71 | 0.37 | 0.30 | 0.73 | 0.66 |
| Nonspecified Transport | N/A | 0.00 | 0.00 | 0.45 | 0.40 | 0.00 | N/A |
| **Germany** | **1965** | **1970** | **1975** | **1980** | **1985** | **1990** | **1992** |
| Total | 22.04 | 28.98 | 33.74 | 41.47 | 43.04 | 60.05 | 61.17 |
| Air | 0.98 | 2.08 | 2.45 | 3.04 | 3.73 | 5.80 | 5.51 |
| Road | 16.30 | 23.54 | 28.72 | 35.86 | 37.14 | 51.43 | 52.70 |
| Rail | 3.97 | 2.47 | 1.65 | 1.69 | 1.45 | 2.15 | 2.24 |
| Internal Navigation | 0.79 | 0.89 | 0.92 | 0.88 | 0.72 | 0.67 | 0.72 |
| Nonspecified Transport | N/A | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | N/A |
| **Italy** | **1965** | **1970** | **1975** | **1980** | **1985** | **1990** | **1992** |
| Total | 11.69 | 16.86 | 19.89 | 25.44 | 28.31 | 34.30 | 36.94 |
| Air | 0.89 | 1.73 | 1.87 | 1.96 | 2.04 | 2.11 | 2.47 |
| Road | 9.49 | 14.04 | 16.87 | 22.30 | 25.03 | 31.05 | 33.25 |
| Rail | 0.73 | 0.66 | 0.57 | 0.59 | 0.68 | 0.74 | 0.77 |
| Internal Navigation | 0.59 | 0.44 | 0.57 | 0.60 | 0.56 | 0.40 | 0.40 |
| Nonspecified Transport | N/A | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.05 |

**TABLE 3–10**

## Transportation Energy Demand by Mode in the G–7 Countries: 1965–1992 *(continued)*

| **Japan** | **1965** | **1970** | **1975** | **1980** | **1985** | **1990** | **1992** |
|---|---|---|---|---|---|---|---|
| **Transport Sector** | Millions of Metric Tons of Oil Equivalent | | | | | | |
| Total | 19.33 | 32.92 | 43.29 | 54.16 | 57.52 | 76.23 | 85.96 |
| Air | 0.53 | 1.00 | 1.74 | 2.51 | 2.49 | 3.04 | 8.11 |
| Road | 11.48 | 24.87 | 33.58 | 43.57 | 48.45 | 63.06 | 68.02 |
| Rail | 4.16 | 3.71 | 2.38 | 2.58 | 2.33 | 2.47 | 2.53 |
| Internal Navigation | 3.15 | 3.25 | 5.50 | 5.44 | 4.20 | 7.63 | 7.28 |
| Nonspecified Transport | | 0.09 | 0.09 | 0.07 | 0.05 | 0.03 | 0.03 |
| **United Kingdom** | **1965** | **1970** | **1975** | **1980** | **1985** | **1990** | **1992** |
| Total | 22.13 | 26.88 | 29.51 | 33.95 | 36.76 | 46.47 | 46.61 |
| Air | 2.58 | 3.71 | 4.17 | 5.04 | 5.36 | 7.05 | 7.13 |
| Road | 15.72 | 20.44 | 22.86 | 26.54 | 29.19 | 37.04 | 37.05 |
| Rail | 2.55 | 1.59 | 1.24 | 1.16 | 1.02 | 1.09 | 1.14 |
| Internal Navigation | 1.28 | 1.13 | 1.25 | 1.20 | 1.19 | 1.30 | 1.29 |
| Nonspecified Transport | N/A | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | N/A |
| **OECD** | **1965** | **1970** | **1975** | **1980** | **1985** | **1990** | **1992** |
| Total | 431.32 | 562.70 | 670.94 | 741.05 | 774.87 | 894.96 | 934.94 |
| Air | N/A | 69.04 | 77.46 | 86.99 | 96.32 | 118.24 | 121.44 |
| Road | N/A | 444.96 | 545.39 | 607.36 | 636.61 | 732.68 | 757.31 |
| Rail | N/A | 29.44 | 26.83 | 26.99 | 22.58 | 22.85 | 23.91 |
| Internal Navigation | N/A | 18.94 | 20.82 | 18.78 | 18.36 | 17.95 | 24.13 |
| Nonspecified Transport | N/A | 0.31 | 0.44 | 0.94 | 0.99 | 3.23 | 8.16 |

transportation has increased further as a result of its increasing share in transportation between 1965 and 1992. In the United States, it grew from 73.8 percent to 81.1 percent during the period. In the selected four European countries and Japan, steeper increases were observed. For OECD as a whole, the share of road transportation in total $CO_2$ emissions from transportation increased from 79 percent in 1970 to 82 percent in 1992.

### Energy Use and $CO_2$ Emissions in Road Transportation

Rapid growth of road transportation was the dominant force behind the increase in transportation energy demand and $CO_2$ emissions in the OECD countries. If road transportation had grown at the average rate of other modes in the last two and a half decades, increases in energy efficiency would have stabilized—or even reduced—total transportation energy demand and $CO_2$ emissions in many of the developed countries.

In terms of vehicle-kilometers, road transportation more than doubled in the United States, France, Germany, Italy, and the United Kingdom between 1965 and 1989. On average, road transportation grew faster in the 1965–80 period than in the 1980–89 period, and faster in the European countries than in the United States. (See Figure 3–34.)

Between 1965 and 1989, travel by car increased 108 percent in the United States, rising from 1,141.3 to 2,377.7 trillion car-kilometers (c-km). The growth was even steeper in the European countries, with a whopping 183 percent in France, 169 percent in Germany (Note: data are for West

**FIGURE 3–33**

Shares of Individual Modes in Total Transportation $CO_2$ Emissions: 1970 and 1992

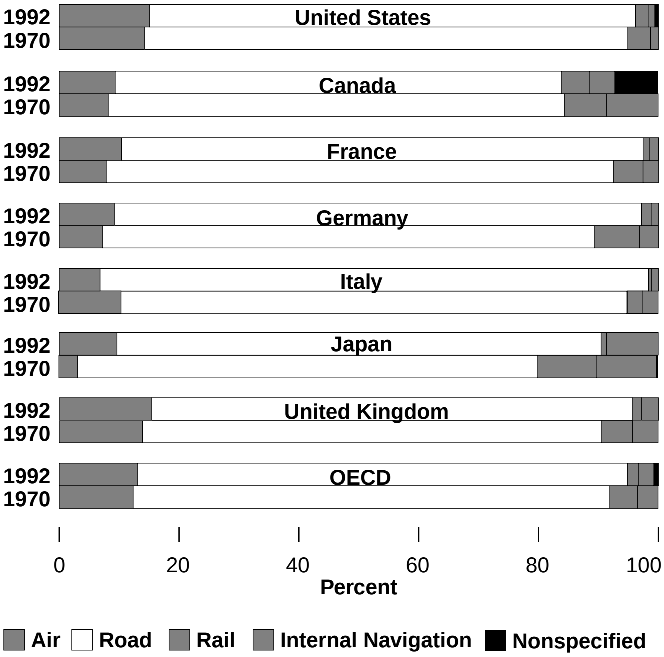
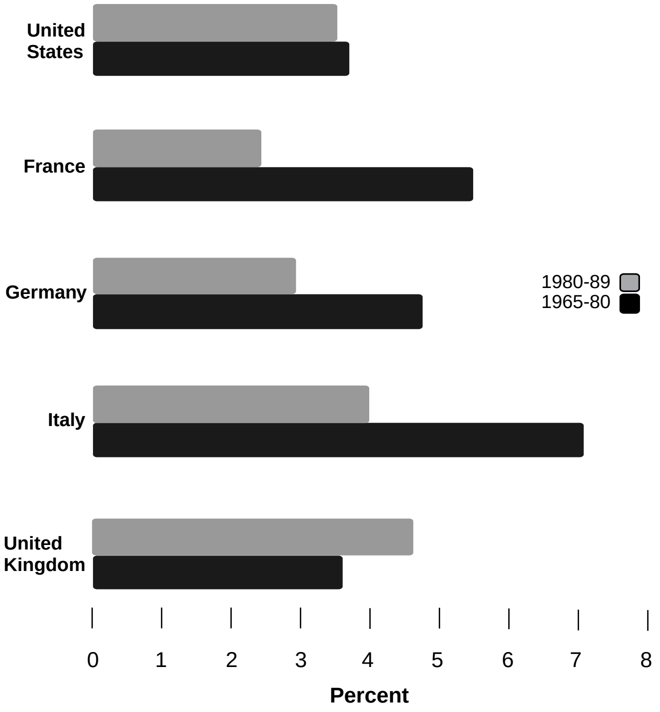


**FIGURE 3–34**

Average Annual Growth Rates of Road Vehicle-Kilometers: 1965–1980 and 1980–1989



Germany only for years before 1990), 476 percent in Italy, and 184 percent in the United Kingdom. All other modes of road transportation grew slower than travel by car in four of the five countries. The United States was the only country in which truck traffic grew faster (247 percent—from 279.4 to 969.7 trillion vehicle-kilometers) than car traffic, reflecting the increasing use of light trucks for passenger transportation.

Factors affecting the energy intensity of road transportation include vehicle mix of road transportation, occupancy rates, and load factors; these are discussed below.

*Changes in the Vehicle Mix of Road Transportation.* The vehicle mix of road transportation, in terms of shares of different types of vehicles in total vehicle-kilometers traveled, varies from country to country. The vehicle mix of road transportation in the United States distinguishes itself from those of other major OECD countries by both the larger share of trucks and the continued rise in this share over the past two and a half decades—reflecting the increasing use of light trucks for passenger transportation and the greater freight ton-kilometers per dollar of GDP in the United States. (See Figure 3–35.)

Changes in the vehicle mix in France, Germany, and the United Kingdom over the 1965–89 period can be characterized as increased share of cars and taxis, and decreased shares of other vehicles, including two-wheeled motor vehicles, buses and coaches, and trucks. In Italy, the share of cars and taxis increased sharply in the 1965–80 period, whereas the shares of two-wheeled motor vehicles and of trucks shrank. But in the 1980–89 period, two-wheeled motor vehicles gained as cars and taxis dropped. The relatively large share of two-wheeled motor vehicles in Italy reflects in some degree the effect of income on mode choice. The income level of Italy in terms of per capita GDP was the lowest among the advanced European countries in 1965. As income has increased, there was a shift in mode choice for personal travel from motorcycle to private cars.

The share of buses and coaches in the total road fleet has declined since 1965 among all the countries compared; this reflects the growing role of automobiles in personal travel and the relative decline in public transit.

## TABLE 3 – 11

## $CO_2$ Emissions from Transportation by Mode in the G–7 Countries: 1965–1992

| **United States** | **1965** | **1970** | **1975** | **1980** | **1985** | **1990** | **1992** |
|---|---|---|---|---|---|---|---|
| **Transport Sector** | Millions of Metric Tons of Carbon | | | | | | |
| Total | 228.78 | 290.82 | 337.35 | 351.05 | 367.74 | 406.61 | 408.33 |
| Air | 28.86 | 41.33 | 43.03 | 46.96 | 53.13 | 64.34 | 61.38 |
| Road | 168.79 | 234.70 | 280.80 | 291.18 | 301.92 | 328.56 | 331.34 |
| Rail | N/A | 10.95 | 11.39 | 11.92 | 8.76 | 8.51 | 8.64 |
| Internal Navigation | 8.18 | 3.84 | 2.13 | 1.00 | 3.92 | 3.10 | 4.61 |
| Nonspecified Transport | 21.74 | 0.00 | 0.00 | 0.00 | 0.00 | 2.10 | 2.37 |
| **Canada** | **1965** | **1970** | **1975** | **1980** | **1985** | **1990** | **1992** |
| Total | 18.96 | 24.40 | 31.11 | 36.18 | 31.62 | 34.54 | 36.48 |
| Air | 1.15 | 2.02 | 2.88 | 3.33 | 3.18 | 3.69 | 3.40 |
| Road | 14.01 | 18.56 | 24.60 | 29.43 | 25.68 | 27.62 | 27.20 |
| Rail | 1.76 | 1.71 | 1.89 | 1.82 | 1.65 | 1.73 | 1.67 |
| Internal Navigation | 2.05 | 2.09 | 1.76 | 1.57 | 1.08 | 1.50 | 1.55 |
| Nonspecified Transport | 0.00 | 0.00 | 0.00 | 0.03 | 0.03 | 0.01 | 2.65 |
| **France** | **1965** | **1970** | **1975** | **1980** | **1985** | **1990** | **1992** |
| Total | 13.50 | 17.41 | 23.58 | 27.89 | 29.46 | 34.23 | 35.89 |
| Air | 0.82 | 1.39 | 2.45 | 3.02 | 3.27 | 3.37 | 3.73 |
| Road | 9.90 | 14.71 | 19.91 | 23.65 | 25.18 | 29.90 | 31.25 |
| Rail | 2.31 | 0.86 | 0.63 | 0.53 | 0.42 | 0.34 | 0.37 |
| Internal Navigation | 0.47 | 0.45 | 0.60 | 0.31 | 0.25 | 0.61 | 0.55 |
| Nonspecified Transport | 0.00 | 0.00 | 0.00 | 0.38 | 0.34 | 0.00 | 0.00 |
| **Germany** | **1965** | **1970** | **1975** | **1980** | **1985** | **1990** | **1992** |
| Total | 18.93 | 24.07 | 27.77 | 34.08 | 35.35 | 49.46 | 50.31 |
| Air | 0.82 | 1.75 | 2.06 | 2.55 | 3.13 | 4.87 | 4.63 |
| Road | 13.69 | 19.77 | 24.12 | 30.12 | 31.20 | 43.20 | 44.27 |
| Rail | 3.73 | 1.80 | 0.81 | 0.66 | 0.41 | 0.82 | 0.81 |
| Internal Navigation | 0.67 | 0.75 | 0.77 | 0.74 | 0.60 | 0.56 | 0.60 |
| Nonspecified Transport | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Italy** | **1965** | **1970** | **1975** | **1980** | **1985** | **1990** | **1992** |
| Total | 9.65 | 13.94 | 16.37 | 20.97 | 23.35 | 28.32 | 30.47 |
| Air | 0.75 | 1.45 | 1.57 | 1.65 | 1.71 | 1.77 | 2.07 |
| Road | 7.95 | 11.78 | 14.12 | 18.68 | 20.98 | 26.04 | 27.89 |
| Rail | 0.46 | 0.35 | 0.19 | 0.15 | 0.18 | 0.17 | 0.17 |
| Internal Navigation | 0.50 | 0.37 | 0.48 | 0.50 | 0.47 | 0.34 | 0.34 |
| Nonspecified Transport | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

TABLE 3 – 11

$CO_2$ Emissions from Transportation by Mode in the G–7 Countries: 1965–1992 *(continued)*

| **Japan** | **1965** | **1970** | **1975** | **1980** | **1985** | **1990** | **1992** |
|---|---|---|---|---|---|---|---|
| **Transport Sector** | Millions of Metric Tons of Carbon | | | | | | |
| Total | 16.42 | 27.18 | 35.36 | 44.39 | 47.14 | 62.60 | 70.71 |
| Air | 0.45 | 0.84 | 1.46 | 2.11 | 2.09 | 2.55 | 6.81 |
| Road | 9.64 | 20.89 | 28.21 | 36.60 | 40.70 | 52.97 | 57.14 |
| Rail | 3.66 | 2.65 | 1.00 | 1.07 | 0.78 | 0.64 | 0.63 |
| Internal Navigation | 2.66 | 2.73 | 4.62 | 4.57 | 3.53 | 6.41 | 6.12 |
| Nonspecified Transport | 0.00 | 0.08 | 0.08 | 0.06 | 0.04 | 0.03 | 0.03 |
| **United Kingdom** | **1965** | **1970** | **1975** | **1980** | **1985** | **1990** | **1992** |
| Total | 18.82 | 22.43 | 24.59 | 28.31 | 30.67 | 38.66 | 38.77 |
| Air | 2.17 | 3.12 | 3.50 | 4.23 | 4.50 | 5.92 | 5.99 |
| Road | 13.20 | 17.17 | 19.20 | 22.29 | 24.52 | 31.11 | 31.12 |
| Rail | 2.35 | 1.18 | 0.84 | 0.76 | 0.65 | 0.54 | 0.57 |
| Internal Navigation | 1.11 | 0.95 | 1.05 | 1.01 | 1.00 | 1.09 | 1.08 |
| Nonspecified Transport | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **OECD** | **1965** | **1970** | **1975** | **1980** | **1985** | **1990** | **1992** |
| Total | 362.92 | 470.41 | 560.09 | 618.37 | 646.31 | 746.28 | 778.33 |
| Air | N/A | 57.99 | 65.07 | 73.07 | 80.91 | 99.32 | 102.01 |
| Road | N/A | 373.75 | 458.08 | 510.13 | 534.68 | 615.39 | 636.07 |
| Rail | N/A | 22.43 | 19.06 | 18.61 | 14.45 | 13.77 | 14.20 |
| Internal Navigation | N/A | 15.97 | 17.52 | 15.78 | 15.44 | 15.10 | 20.28 |
| Nonspecified Transport | N/A | 0.26 | 0.37 | 0.78 | 0.83 | 2.71 | 5.77 |

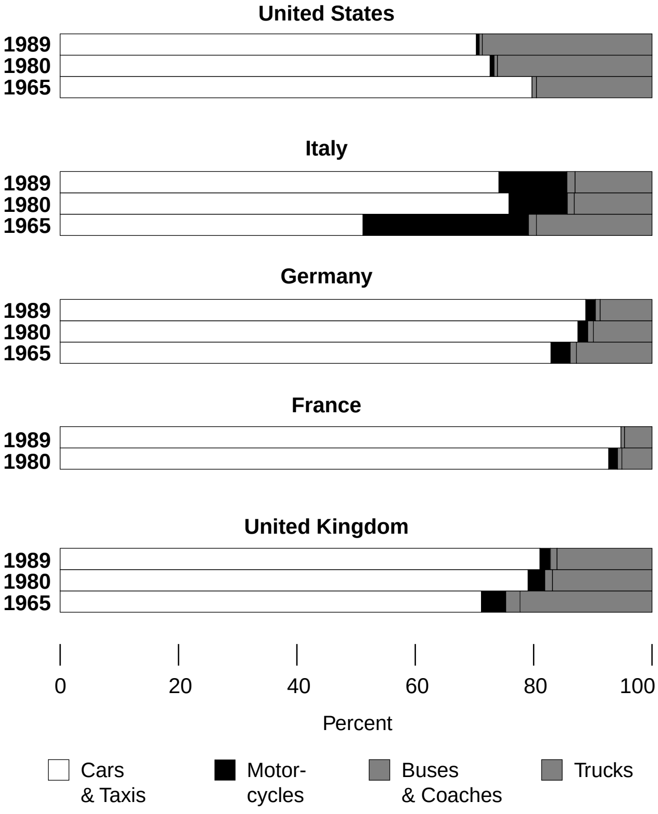
*Changes in Occupancy Rates and Load Factors.* Occupancy rates and load factors affect the energy intensity of road transportation. Other things being equal, increases in occupancy rates in passenger transportation and increases in load factor in freight transportation would reduce the energy intensity of road transportation as measured by passenger-kilometers and ton-kilometers, but would *increase* the energy intensity of road transportation as measured by vehicle-kilometers.

In 1965, the average occupancy rate of cars and taxis was much higher in the United States than in the four European countries examined. (See Figure 3–36.) However, by 1980 the average occupancy rate of cars and taxis in the United States had decreased to the level of the European countries or lower. By 1989, it had become the second lowest among the five countries, just above the level in Germany. The average occupancy rate of cars and taxis in Germany and the United Kingdom also showed a declining trend in the 1965–89 period. On the other hand, the average occupancy rate of cars and taxis fluctuated in France and Italy between 1965 and 1980, and picked up after 1980. The decline in car occupancy rates in the United States and other countries over time reflects factors such as increasing car ownership, changing household characteristics, and increasing number of wage-earning members per household.

In the United States, the occupancy rate of buses and coaches increased between 1965 and 1975, dropped sharply in 1985, then increased again in 1989. Before 1975, Italy had the highest occu-

**FIGURE 3–35**

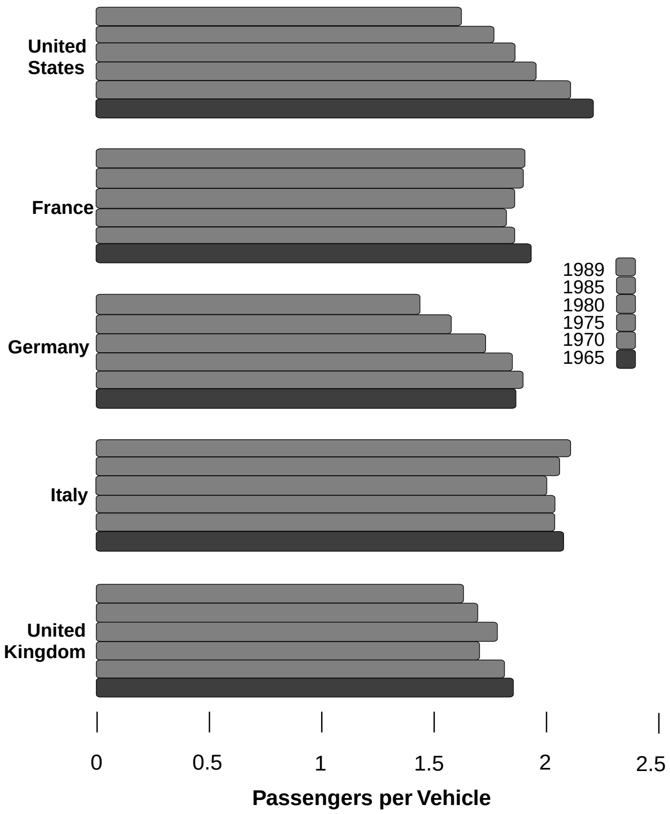
Vehicle Mix of Road Traffic (based on vehicle-kilometers): 1965–1989



Note: Truck and bus data are not available for France in 1965.

**FIGURE 3–36**

Trip Distance Weighted Average Occupancy Rate of Cars and Taxis: 1965–1989



pancy rate of buses and coaches, while the United States had the lowest among the five countries. (See Figure 3–37.) After 1975, the average occupancy rate of buses and coaches showed a declining trend in Germany, Italy, and the United Kingdom. By 1989, the occupancy rate in the United Kingdom had become the lowest among the five countries.

The load factor of trucks in the United States increased between 1965 and 1970. But, it decreased consistently over time in the 1970–89 period. By 1989, the load factor of trucks in the United States had become the lowest among the five countries. The load factor increased slowly over time in Germany. In Italy, it stayed at about the same level between 1965 and 1975, and jumped to a new plateau between 1975 and 1980, and then stabilized again between 1980 and 1989. The load factor of trucks in the United Kingdom was the lowest among the five countries before 1975. In the 1965-89 period, it fluctuated slightly and stayed at a level much lower than those in the other three European countries. (See Figure 3–38.)

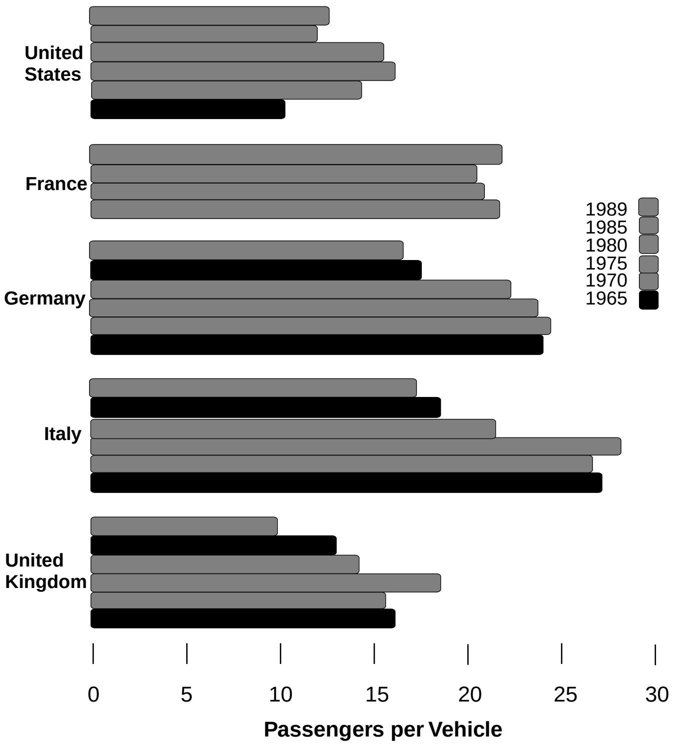
The decline in the load factor of trucks in the United States mirrors from another angle the structural changes in the economy. A more service-oriented economy and the just-in-time practice in production may necessitate smaller size shipments but more frequent and reliable deliveries. High-value commodities, such as computers and household electronic equipment, require special packing and handling. This kind of packing further reduces the weight/volume ratio of the finished products, which in turn contributes to reducing the load factor of freight vehicles.

## Energy Use and $CO_2$ Emissions in Rail Transportation

Although rail's share in total transportation decreased, the absolute volume

**FIGURE 3 – 37**

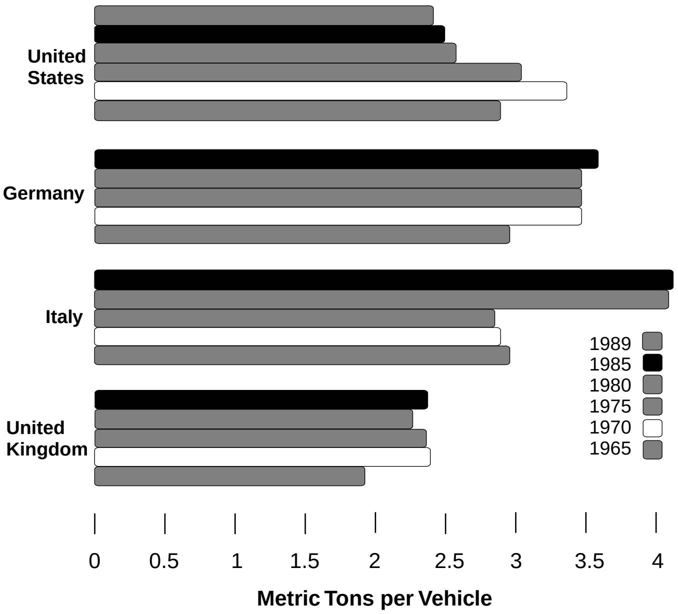
Trip Distance Weighted Average Occupancy Rate of Buses and Coaches: 1965–1989



Note: Data for France in 1965 and 1970 are not available.

**FIGURE 3 – 38**

Haulage Distance Weighted Average Load Factor of Trucks: 1965–1989



of rail passenger transportation increased in the developed countries between 1965 and 1989. Rail freight transportation increased in the United States and Italy, and decreased in France, Germany, and the United Kingdom.

The main passenger markets for railways are intercity and commuter travel. With the explosive growth of road travel, rail services for rural areas and small towns have declined or been discontinued. However, for goods with low value per unit of weight or volume—such as minerals, construction materials, and heavy manufactured goods—rail is still the preferred mode of transportation. Rail is also increasingly used for long-haul, large volumes of high-value, intermodal freight. Rail freight transport remains highly significant in the developed countries, particularly in the United States.

The energy intensity of rail transportation has improved for some applications and worsened for others. Between 1965 and 1980, energy consumption, passenger-kilometers, and ton-kilometers all increased in the United States, with the growth of energy consumption lagging behind transportation output. However, the growth of passenger-kilometers and ton-kilometers by rail were accompanied by a drop in energy consumption in France, Germany, and Italy in the same period. In the United Kingdom, passenger-kilometers increased slightly, ton-kilometers decreased at an annual rate of 2.4 percent, but rail energy consumption decreased at an annual rate of 5.2 percent. These differences in growth rates suggest that the energy intensity of rail transportation decreased considerably in all five countries over the 1965–80 period.

In the 1980–89 period, the momentum of energy intensity reduction in rail transportation increased sharply in the United States, United Kingdom, and Germany, but less so in France. In Italy, the energy intensity of rail transportation increased.

Rail transport's energy intensity is affected by the interplay of several factors, such as occupancy and load factor, tractive unit efficiency, aerodynamic design, and train weight. *Occupancy* is one of the main determinants of energy consumption per passenger-kilometer, and varies widely between types of service and between regions. In general, the highest occupancy is achieved by intercity service. In the United States, for example, trip-distance-weighted occupancy of commuter rail was 36.4 passengers per train-car in 1980, declining slightly over time to 34 passengers per train-car in 1991. On the other hand, trip-distance-weighted occupancy of intercity rail increased over time in terms of passengers per train-car from 9 in 1970 to 19 in 1980, and then to 20 in 1991. *Load factor* of rail freight transportation in the United States also increased over time. In terms of tons per train-car, it was 25.5 short tons in 1970, 31.4 short tons in 1980, and 40.5 short tons in 1991.

Traction units have continued to make improvements in efficiency over the last two decades. Energy savings have been achieved in diesel locomotives by using more advanced engines and transmission.

The aerodynamic design of trains—the main determinant of energy efficiency at constant speed—is also improving, with intercity passenger trains designed in the 1960s having drag coefficients of about 3.5 and the more recently developed high-speed trains having drag coefficients below 2.0. However, when frequent acceleration and deceleration are required, train weight becomes a much more significant factor affecting energy efficiency. In intercity service, train weight has risen as comfort and safety levels rise in the developed countries. In the United Kingdom, for example, railway carriages built in 1950s weighed about 30 to 33 metric tons, while those built in 1990 weighed about 40 metric tons. (The increase in train weight is due mainly to the addition of air conditioning , automatic doors, and sealed toilet systems, and higher finishing standards.)

Another factor affecting the energy intensity and $CO_2$ emissions of rail transportation is the fuel mix of its energy consumption. Accompanying the progress in locomotive engine technologies, the fuel mix of rail transportation changed significantly in the last two decades. In OECD, for example, the fuel mix of rail transportation was 15 percent coal, 71 percent oil (diesel), and 14 percent electricity in 1970. Between 1970 and 1980, oil was increasingly substituted for coal. Coal's share thus fell to 1 percent in 1980, while the shares of oil and electricity increased to 81 percent and 18 percent, respectively. By 1991, the share of electricity in rail energy demand had reached 29.9 percent, while the shares of oil and coal decreased to 70 percent and 0.1 percent.

## Information Needs

Transportation affects every aspect of life in the United States in a multiplicity of ways. From a societal perspective, its performance cannot simply be measured by its contribution to the economy, although that is certainly of critical importance. Among its more important effects are those unintended consequences that we, as individuals, do not buy nor can we pay to fully avoid: risks to person and property, pollution of the environment, and energy dependence. Some of these are what economists term *externalities*, situations in which the actions of an individual or firm affect the environment of another other than by affecting prices. When we drive cars, buses, or fly airplanes, the exhaust pollutes the air for others, the petroleum consumed exacerbates dependence on imports that may increase the chance of future oil market disruptions, and we create at least some risk of collision with pedestrians and other vehicles.

Not all of the unintended consequences of transportation fit the definition of externalities, however. The safety risk we take upon ourselves when traveling primarily affects us alone, and therefore does not fit the economist's definition of an externality. In nearly all cases, we have taken actions as a society to mitigate the unintended consequences of transportation, although as a general rule we have not found acceptable ways to impose prices directly on those externalities—situations in which the actions of an individual or firm affect the environment of another in some way other than economically.

We pay part of the cost of pollution control when we buy vehicles (and now also when motorists in nonattainment areas buy reformulated gasoline), but we do not pay when we actually spew exhaust gases into the air. We pay a portion of the safety risks we impose on others when we buy liability insurance for our vehicles, but we do not pay each time we get behind the wheel and drive, or pay more when we drive inattentively. And we pay to improve our energy security in taxes that support the Strategic Petroleum Reserve or fund research and development of new fuels and propulsion technologies, or when we pay higher prices for cars and trucks with higher fuel economy, not when we buy gasoline.

Some argue that because individuals and firms do not pay for the unintended consequences of transportation directly as they are produced, activities that generate the most undesirable consequences are implicitly subsidized. But estimating the full impacts—both benefits and costs—of transportation on society is a relatively new, complex, and evolving research area. There are numerous as yet unresolved issues concerning how to account for costs that are indirectly paid, or paid in the form of fixed costs or nonfinancial costs that are perceived by transportation users, but for which no explicit payment is made.

It is also critical to distinguish between what economists call *marginal costs*—costs generated by the next unit of transportation activity (i.e., the next vehicle-mile traveled)—and total costs, the sum of the impacts of all transportation activity. The Bureau of Transportation Statistics has an important role to fill in this area by advancing research and improving data. In July of 1995, BTS held a workshop on Measuring the Full Benefits and Costs of Transportation, which brought together U.S. and international experts to advance the theory, methodology, and data required to describe the full environmental and societal costs of the transportation system so that meaningful indicators can be developed and reported. The results of this conference will be reported in the *1996 Transportation Statistics Annual Report.* BTS also plans to focus next year's *Transportation Statistics Annual Report* on the environmental impacts of transportation, and report on the state of the art and progress in fully accounting for the unintended consequences of transportation.

# Endnotes

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2 National Highway Traffic Safety Administration, *Rail-Highway Crossing Safety: Fatal Crash and Demographic Descriptors,* DOT HS 808 196 (Washington, DC: U.S. Department of Transportation, 1994).

3 U.S. DOT, Federal Rail Road Administration, Office of Safety, "Highway–Rail Crossing Accident/Incident and Inventory Bulletin," No. 17, 1994, (Issued July 1995).

4 *Monthly Energy Review*, DOE/EIA-0035(95/01) (Washington, DC: U.S. Department of Energy/Energy Information Administration, January 1995).

5 J.D. Murrell, K.H. Hellman, and R.M. Heavenrich, *Light-Duty Automotive Technology and Fuel Economy Trends Through 1993,* EPA/AA/TDG/93-01 (Ann Arbor, MI: U.S. Environmental Protection Agency, 1993).

6 *Highway Statistics 1993*, FHWA-PL-94-023 (Washington, DC: U.S. Federal Highway Administration, 1994), Table VM-1. A portion of the decline calculated by FHWA is due to significantly higher level consumption figures from improved fuel tax compliance. MPG in past years was overstated by FHWA.

7 *Annual Energy Review 1993,* DOE/Energy Information Administration-0384(93) (Washington, DC: U.S. Department of Energy/EIA, 1994), Tables 11.5 and 11.6.

8 *Annual Energy Outlook 1995,* DOE/ EIA-0383(95) (Washington, DC: U.S. Department of Energy/Energy Information Administration 1995), Table C20. The DOE/EIA projections on which these numbers are based include only exports from Eurasia (China and the Former Soviet countries). It would be more correct to include these countries' production for domestic consumption, as well. The DOE definitions are consistent with historical statistics., however.

9 The data in this section are from *National Air Quality and Emissions Trends Report 1993*, EPA 454/R-94-026 (Research Triangle Park, NC: U.S. Environmental Protection Agency, 1994), Chapter 6.

10 The Environmental Protection Agency measures air quality in various ways, but most often as the number of times that established ambient air quality standards are violated or exceeded.

11 Ozone formation is strongly influenced by meteorological conditions. National Research Council, Committee on Tropospheric Ozone Formation and Measurement, 1991.

12 Washington, D.C. National Academy Press, *Rethinking the Ozone Problem in Urban and Regional Air Pollution.*

13 The agency used three different methodologies to develop the new estimates. Data through 1984 are based on methods used in previous studies, revised somewhat to make a smooth transition to the new methods. Data for 1985 are based on estimates developed for the National Acid Precipitation Assessment Program Emission Inventory. Finally, a new interim methodology has been used to develop data for 1986 to 1992. U.S. EPA, Office of Air Quality Planning and Standards "National Air Pollutant Emission Trends, 1900–1992." EPA-454/R-93-032. Research Triangle Park, NC., October 1993.

14 *Alternatives to Traditional Transportation Fuels 1993,* DOE/Energy Information Administration-0585(93) (Washington, DC: U.S. Department of Energy/EIA, 1995).

15 National Personal Transportation Survey for 1969, 1977, 1983, and 1990, conducted by the Federal Highway Administration, U.S. Department of Transportation.

16 U.S. Department of Energy, Office of Policy, Planning and Analysis, and the Office of Conservation and Renewable Energy, 1989. "Energy Conservation Trends: Understanding the Factors that Affect Conservation Gains in the U.S. Economy." DOE/PE-0092, Washington, DC.

17 M. Ross, "Energy and Transportation in the United States," *Annual Reviews of Energy,* Vol. 14 (1989), pp. 131–71.

18 Intergovernmental Panel on Climate *Change, Draft Summary for Policymakers of the 1994 Working Group One Report on Radiative Forcing of Climate Change,* November 1994.

19 *Energy Use and Carbon Emissions: Some International Comparisons,* DOE/Energy Information Administration-0579 (Washington, DC: U.S. Department of Energy/ Energy Information Administration, 1994).

20 Per capita GDP (expressed here in constant 1985 U.S. dollars) is based on purchasing power parities (PPPs), which are rates of currency conversion that equalize the purchasing power of different currencies. In other words, GDP data from all countries were converted into U.S. dollars not at exchange rates, but using PPPs. A given sum of money, if converted into different currencies at PPP rates, will acquire the same market basket of goods and services in all countries, thereby eliminating the effects of price levels between countries.

## Sources

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U.S. Department of Transportation, Volpe National Transportation Systems Center
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CHAPTER **FOUR**

# *The* STATE *of* TRANSPORTATION STATISTICS

Congress requires BTS to report annually on the state of the transportation system, documentation of the methods used to obtain and ensure the quality of the statistics presented in the report, and recommendations for improving transportation statistical information.[1] This chapter presents the state of statistics needed to answer the fundamental questions: are transportation and the world it affects getting better or worse, and what do we mean by better or worse?

Effective answers to the fundamental questions depend on both raw data and analytical tools to turn that data into effective information. BTS is pursuing parallel strategies to improve our understanding of the somewhat distinct worlds of freight and passenger transportation. The Bureau integrates these worlds through its emphases on the geography, finance, and performance of transportation.

## Freight Transportation Activity and Services

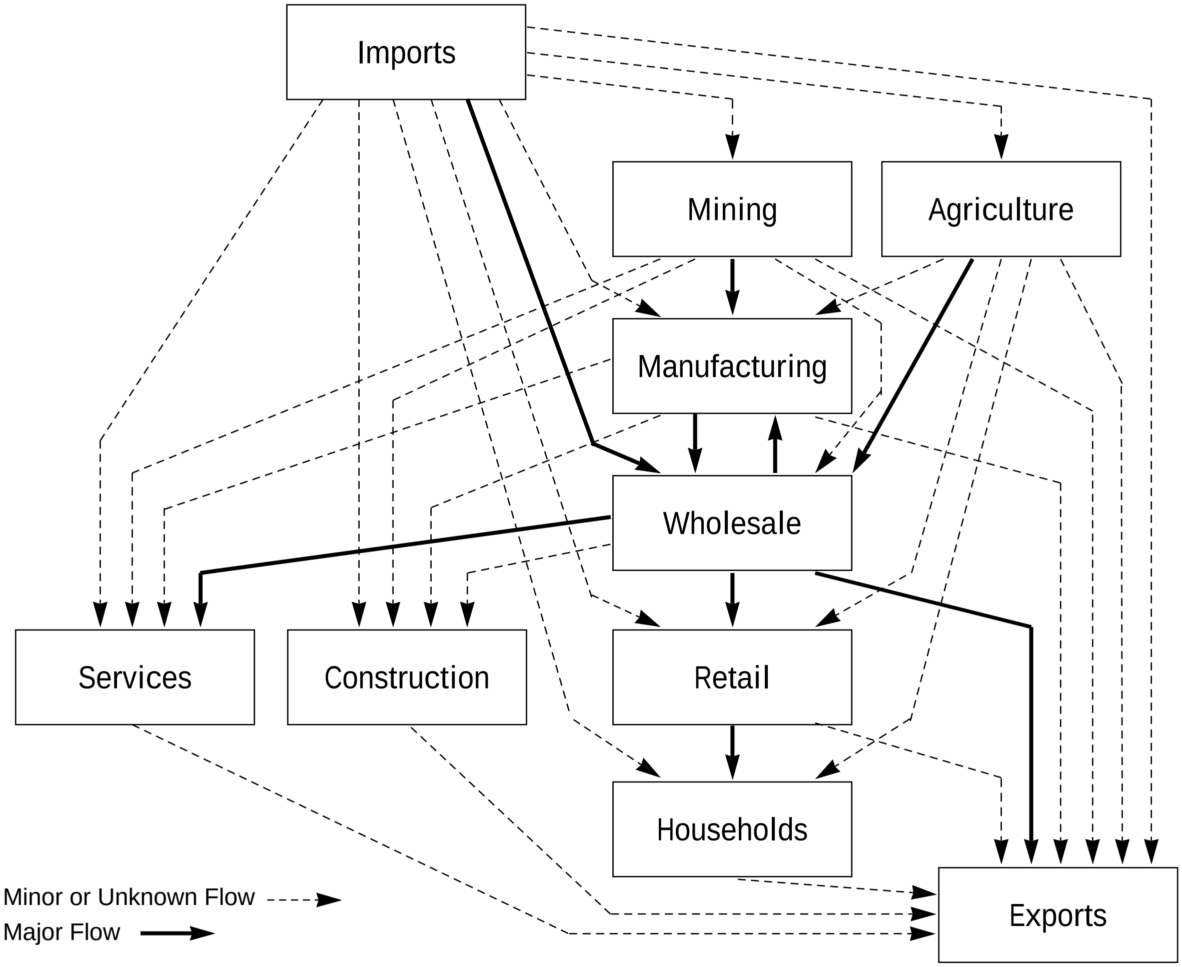
Any comprehensive effort to monitor commodity movements and multimdal freight transportation activity throughout the United States is an enormous undertaking. The shippers, arrangers, carriers, recipients, and disposers of shipments include nearly six million business establishments and over 90 million households. There are also more than 83 thousand governmental units that can ship, transport, or receive goods.

The complexity of the freight transportation universe is illustrated in Figure 4–1. Each of the flows in the figure can be subdivided as shown in Figure 4–2. The shipper may handle the shipment in the shipper's own vehicles, or turn the shipment over to a for-hire carrier or a transportation broker, freight forwarder, or other "third party." Third parties and many long-distance carriers work with other for-hire carriers to get the shipment to its final destination. The frequent result is that no one party knows all of the players and modes that were involved in moving the shipment from the shipper to its ultimate destination. Except for hazardous cargo, there are no standard documents that accompany or track shipments across all modes of transportation.

The size of the nation's transportation system and the variety of establishments and individuals involved in transporting

**FIGURE 4–1**

Commodity Flows Through the Economy



goods precludes the use of a single method, model, or survey to capture the universe of freight transportation activity. This universe must be viewed from a variety of vantage points: measuring the shipments, carriers, shippers, and the vehicles that comprise freight transportation activity.

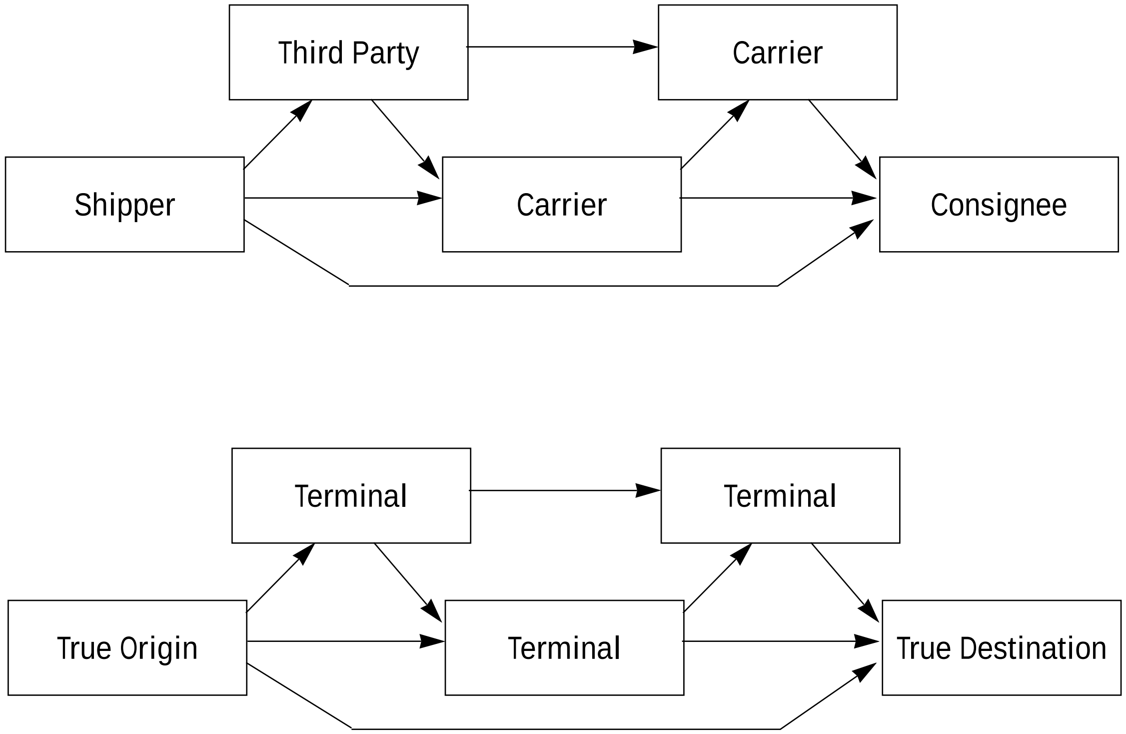
### Shipment Data

Shipment data includes basic information on what commodities move, where they move, and how they get there. These data can be collected from the carrier, arranger, or shipper. As suggested by Figures 4–1 and 4–2, carriers know much about the shipment's specific route and handling while it is in their care, but that is often only part of the trip. The carrier is also unlikely to know much about the economic activity of many shippers and consignees. Carriers may not even know what they are moving if the commodities are containerized and moving under a general rather than commodity-specific rate, both of which are increasingly common. In contrast, the shipper usually knows the shipment's characteristics, ultimate origin, and ultimate destination, as well as the characteristics of both shipper and consignee. The shipper knows little, however, about the modes and routes used by the carriers, especially when the shipper's volume or individual shipment size are small and when multimodal parcel delivery services or third parties are involved.

Most ongoing data on commodity movements are collected from carriers.

**FIGURE 4–2**

Components of a Commodity Flow Between Two Sectors of the Economy



The Interstate Commerce Commission, the Federal Energy Regulatory Commission, and the U.S. Army Corps of Engineers obtain shipment records from railroads, pipeline operators, and inland waterway operators respectively. These records include the size of shipments by origin and destination. These data generally do not indicate the true origin and destination for shipments that are handled by more than one carrier or mode, and commodity movements by truck are completely absent.

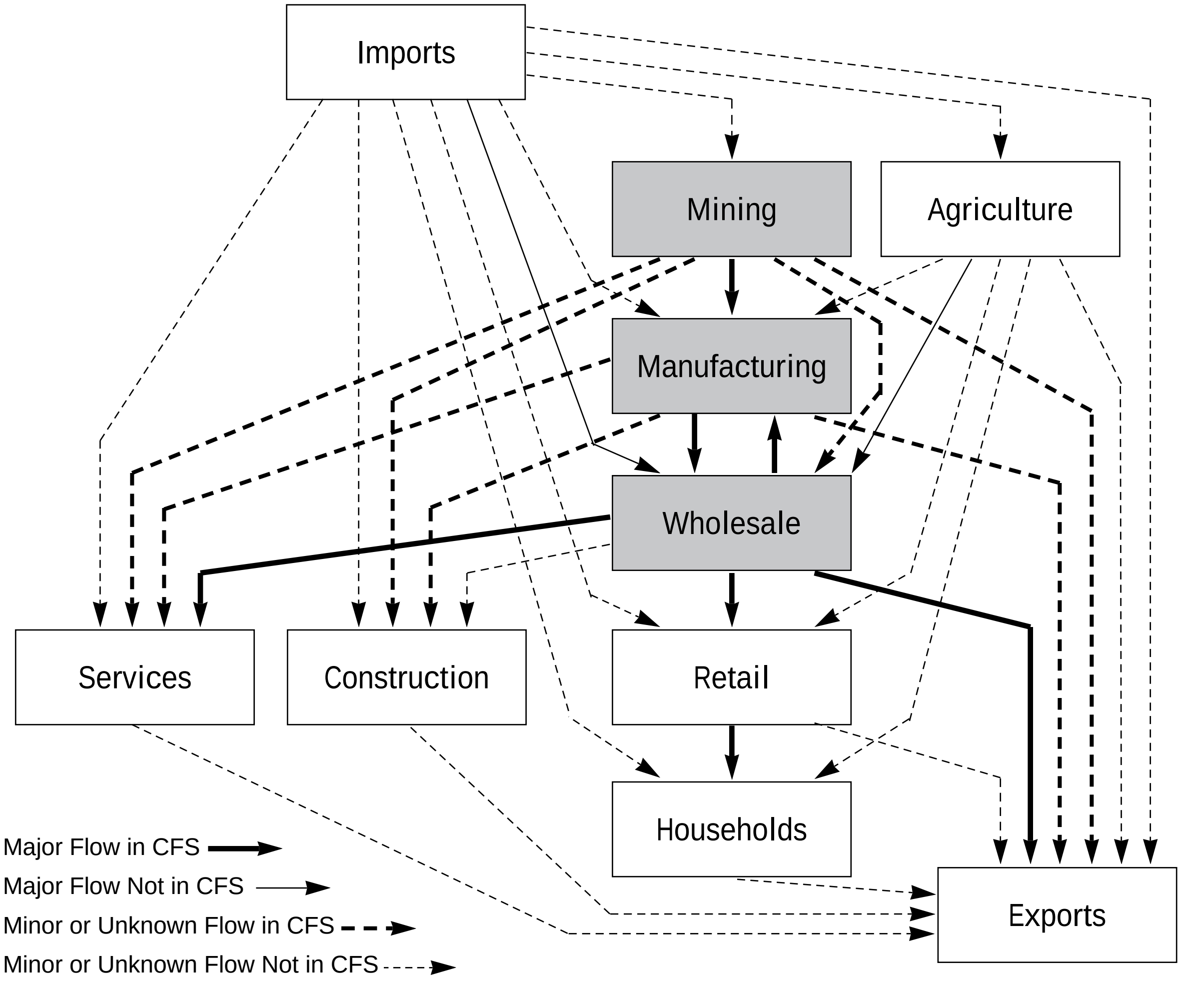
*The Commodity Flow Survey.* Until recently, the only shipment data for commodity movements by all modes of transportation were from the Commodity Transportation Survey. This quinquennial survey was conducted by the U.S. Bureau of the Census between 1963 and 1977, and was limited to shipments by domestic manufacturers. The 1977 survey encountered technical problems that could not be resolved with the limited funds for data collection in the 1980s.

These data are finally being updated and significantly expanded by the Commodity Flow Survey (CFS), which was conducted by the Census Bureau throughout calendar year 1993 as a regular part of its quinquennial economic censuses. The Department of Transportation funded those portions of the CFS dealing with the commodity and geographic detail. CFS data products will be available for distribution starting in the second half of 1995.

CFS coverage is indicated by the filled boxes and heavy outlines in Figure 4-3. Approximately 12 million shipments were sampled from 200,000 establishments selected from the 800,000 establishments in manufacturing, mining, wholesaling, warehousing auxiliaries of multi-establishment companies, and selected other industries. This large sample is needed to support statistically reliable tabulations of tons, ton-miles, and value by commodity type, mode of transportation (including intermodal combinations), shipment dis-

FIGURE 4–3

Universe of the Commodity Flow Survey



tance, shipment size, and combinations of origins and destinations.

The largest anticipated missing pieces of freight transportation activity include:

- Shipments from over three million farms to agricultural assemblers, virtually all of which are by truck, and much of which moves over relatively short distances;
- Imports from the port of entry to the manufacturer's or wholesaler's facility;
- Landbridge movements, in which shipments from foreign origins cross the United States and depart for foreign destinations;
- Shipments by governments, such as municipal garbage and transfers of munitions among military bases;
- Waste shipments by manufacturers, some of which are hazardous; and
- Household goods movements.

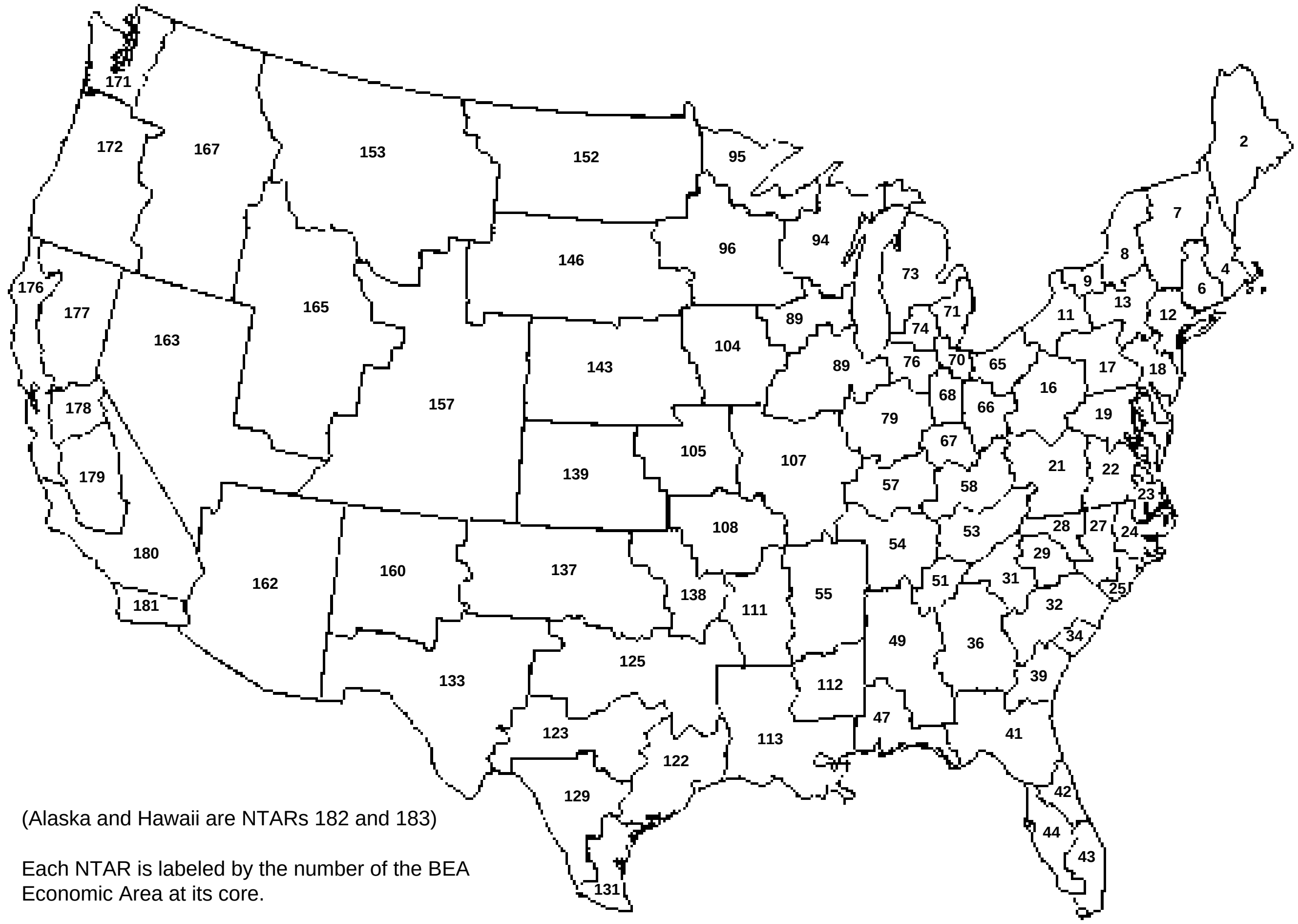
Methods for estimating the magnitude and geography of these missing pieces are being investigated.

Origins and destinations are summarized in the CFS by State and National Transportation Analysis Region. As shown in Figure 4–4, NTARs are aggregations of Bureau of Economic Analysis's Economic Areas and reflect the functional geography of markets and economic spheres of influence.

*International Shipment Data.* Shipment data on imports and exports are collected by the Customs Service and processed by the Bureau of the Census into foreign trade statistics. These trade data have traditionally suffered from several major problems, including the lack of

FIGURE 4–4

National Transportation Analysis Regions (NTARs)



(Alaska and Hawaii are NTARs 182 and 183)

Each NTAR is labeled by the number of the BEA Economic Area at its core.

reliable information on the domestic leg of the international movement. (See Needs for Data box.)

The Bureau of the Census is continuing its efforts to improve its identification of domestic inland origins and destinations of foreign trade, and BTS is working with Census to better identify the mode of transport used at international crossings. The Census Bureau began in April 1993, to distinguish surface modes (truck, rail, and pipeline) used for transborder shipments between the U.S. and Canada and the U.S. and Mexico under an interagency agreement with the BTS.

Information on the mode of transport used for the inland movement of foreign trade was last collected in 1975 by a DOT-funded Census program. The mode of transport used for the inland movement of exports has been captured by the CFS, although the ability to publish quality data is presently unknown since the CFS is not designed specifically to measure export shipments. Additional data collections are needed to capture the domestic movements of imports and landbridge traffic, as well as corroborate the export data from the CFS. BTS proposes to resurrect and expand the 1975 survey in which the Census Bureau drew a sample of export and import declarations and asked the filing establishment for information on the domestic leg of the shipment. A new survey would also be designed to collect data from carriers on through-shipments such as the landbridge traffic. In all cases, BTS would ask for the type, value, weight,

## Needs of the Transportation Community for Foreign Trade and Tourism Data

Transportation facilities, services, and the flows of people and goods do not stop at the international border. The ports of Montreal and Halifax vie with New York to link Europe with markets in the Midwest and Ontario. U.S. airlines compete with foreign flag carriers for passengers at home and abroad. Asian products that formerly reached the eastern U.S. via the Panama Canal now pass through West Coast ports and travel by rail across the continent. Miami is a major hub for passenger flows between Europe and South America, and a point of departure for the nascent cruise ship industry. Growing trade between Canada and Mexico is blazing new north-south corridors through the U.S.

Transportation statistics—like transportation activity—should not be constrained by the border. Informed decisionmaking requires an understanding of how international activity places demands on the domestic transportation system, and how the domestic transportation helps bring foreign business and tourism to the U.S.

The advantage of transborder transportation activity is that movements of people, goods, vessels, and craft are recorded for purposes of tariff collection, immigration control, countermeasures against smuggling, and the calculation of trade balances. The problem is that data collected for these purposes overlap—but do not match—the needs of the transportation community:

- The trade community is concerned with goods and people who enter and exit the U.S. economy, which is not necessarily the same as U.S. territory. For example, “landbridge” traffic between Canada and Mexico does not enter the economy, even though it consumes hundreds of miles of U.S. highways and railroads. Customs is interested only in making sure that everything that entered subsequently left, while the transportation community is vitally interested in how and where the goods passed through the domestic transportation system.
- The trade community is primarily interested in the value and ownership of commodities traversing the border, while the transportation community is concerned with the weight and other physical attributes of the commodity that affect its transportability.
- The trade community is interested in who moved the goods for purposes of recordkeeping and enforcement, while the transportation community is more interested in how the goods are moved.

While the data interests of the trade and transportation communities do not correspond exactly, they are closely enough aligned to be served by one-stop reporting and extensive use of administrative records rather than interviews at the border.

Several efforts are underway to minimize barriers to movement across the border, to improve the effectiveness of contraband interdiction, and to provide an effective trade data base for economic development planners at all levels of government. These efforts can provide an effective data base for transportation planners as well, or they can undermine the utility of trade data for transportation if critical data elements are jettisoned.

For trade data to meet the needs of the transportation community, data elements involving both commodity and passenger flows should include:

- the true geographic origins and destinations of shipments and trips (and not just locations of intervening terminals);
- the frequency and distance of shipments and travel;
- the transportation services consumed and the conveyances and facilities used;
- the port of embarkation or arrival for international movements; and
- the transportation costs to the shipper or traveler, including accidents and damage.

Additional data elements involving commodity flows include:

- volume by commodity type and hazard class, measured by shipment weight and value;
- containerization and other packaging characteristics; and
- characteristics of the shipper and receiver that generate—or are affected by—commodity flows.

Additional data elements involving passenger flows include:

- the purposes and duration of the trip; and
- the demographic and economic characteristics of the traveler and the traveler’s origins and destinations that generate—or are affected by—passenger flows.

These and other data elements are combined to forecast future passenger and commodity flows, determine how well the current transportation system serves current and future flows, and to evaluate the consequences of those flows for economic, social, and environmental goals.

While country of origin for imports and country of destination for exports is adequate for understanding intercontinental transportation, greater geographic specificity is needed for shipments to and from either Canada or Mexico to identify, understand, and forecast:

- competition between ports of the three nations for inland traffic;
- competition and complementary activity between parallel transportation services near the borders; and
- north-south corridors between Canada and Mexico.

The U.S. Department of Transportation must ultimately have the same detailed understanding of Canadian and Mexican traffic as U.S. domestic transportation since the systems of the three countries complement and compete with one another. Ultimately, the content and specificity of these data items are essential to estimate the impacts of domestic policies on the ability of the U.S. transportation system to serve the needs of North America and to connect the U.S. with the world.

domestic modes, and geography of each sampled shipment.

### Carrier Data

Carrier data includes information on service availability and performance, which have a significant influence on the modes chosen to serve individual freight flows. Most railroad, waterway, pipeline, aviation, and intermodal facilities are listed in public reports or private guides. DOT monitors and publishes on-time performance by the airlines, and similar information is available from Amtrak. Guides to trucking are less comprehensive, largely because the industry is large, ubiquitous, and has a high turn-over rate.

Most carrier performance data are limited to economic performance. Revenue, expenditure, and related data are collected by regulatory agencies, trade associations, and financial rating services. Much of the financial data formerly collected by federal regulatory agencies are now being obtained by the Bureau of the Census, which is expanding its annual surveys and quinquennial Economic Census to include establishments primarily engaged in for-hire transportation or in services related to transportation.

The longest time-series provided by Census on carriers is the Annual Survey of Motor Freight Transportation and Public Warehousing, which covers companies that have payrolls and that are primarily engaged in for-hire trucking and warehousing.[2] This survey includes questions on employment, revenue, expenses, and truck fleet size. A smaller set of questions focusing on kinds of business activity and expenditures is used for the complete census of motor carriers in the quinquennial Economic Census.

As of 1992, the Economic Census provides revenue, payroll, and other limited economic data on establishments primarily engaged in for-hire trucking and warehousing, water transportation, nonscheduled air carriers, and transportation services. Similar data on scheduled airlines are reported to the BTS Office of Airline Information, and data on large railroads are reported to the Interstate Commerce Commission.[3] Data on short line railroads are not collected, leaving a significant gap in our understanding of local freight transportation service.

Neither the Economic Census nor related annual surveys provide data on private trucking and other transportation activity of establishments that are not primarily engaged in for-hire transportation. Limited data on all bus- and truck-operating establishments are collected by the Office of Motor Carriers of the Federal Highway Administration to monitor carrier fitness and safety.

### Shipper Data

The Census Bureau collects data on revenues, expenditures, employment, resource consumption, and product output for establishments throughout the economy in its annual surveys and quinquennial Economic Census, Census of Agriculture, and Census of Governments. These data collection programs provide information on sources of demand for freight transportation, and provide the sample frames for surveys of shipments.

Roughly one-half of all commodity movements by truck and intermodal combinations including trucks are made in vehicles operated by manufacturing, agricultural, retail, and other establishments that are not for-hire motor carriers. Of the remaining share, a significant but unmeasured percentage of activity is served by independent owner-operators who do not have payrolls. To capture the relationships of commodity transportation to economic condition for the full range of this activity, the scope of existing surveys would have to be expanded to cover trucking auxiliaries, private trucking, and independent owner-operators who do not have payrolls. This expansion will be practical only if requisite screening questions are included in the other parts of the Economic Census (such as the Census of Manufacturing and the Census of Agriculture) to obtain a cost-effective sample frame.

### Vehicle Data

The large percentage of commodity movements that are served by not-for-hire motor vehicles can be measured directly by surveys based on vehicle registrations or by roadside observations. This sampling strategy has many of the strengths and weaknesses of data collections on shipments from carriers, but can be applied to both motor carriers and others that are not primarily in for-hire truck transportation.

Surveys based on motor vehicles can provide a powerful supplement to the CFS because highways carry the largest and least-known portion of trips and shipments. Vehicle registration files provide a sample frame that is generally not limited by the economic activity of establishments or the household status of individuals; the only limitation involves vehicles owned by governments.

The power of this sample frame is illustrated by the Truck Inventory and Use Survey (TIUS), which remains the only direct source of nationwide payload ton miles by type of truck. The TIUS has been conducted by the Bureau of the Census as part of the quinquennial Economic Census since the 1960s, and is based on a sample of registered trucks in each state. Extensive information is collected on the characteristics of each vehicle and its annual use, but lacks effective information on the location of truck travel.

States estimate aggregate vehicle activity by highway and vehicle class for FHWA based on roadside counts as part of the Highway Performance Monitoring System (HPMS). Counts by vehicle type on sampled sections of major highways provide useful "screen line" data to check the magnitude of commodity flows; however, the HPMS provides no information on the content of those flows.[4] The HPMS cannot link vehicle activity to commodities carried because it depends increasingly on automatic vehicle identification and weigh-in-motion equipment that measures the vehicle's exterior characteristics only. Together, though, the HPMS and TIUS can be used to link commodity movements and highway type through models described in the following section.

### Beyond National Surveys

National surveys alone cannot provide a complete, integrated picture of freight transportation activity and services. Such surveys are precluded by cost and confidentiality issues from providing adequate information for local transportation planning. Even for understanding at the national scale, no single strategy can provide complete coverage of all modes, establishments engaged in freight transportation activity, and other players who affect—or are affected by—freight transportation activity. Models and special analyses are needed to integrate diverse data sources and obtain the needed national picture. Additional data collection is also needed at the local level, since no existing model of freight demand is adequate to estimate county-to-county or more localized freight transportation activity from national data sets. (See Role of Models box.)

At national or local levels, the volumes of goods shipped and people moved can be translated with modest assumptions into volumes of vehicle and carrier activity; however, the consequences of those volumes for economic productivity, energy consumption, and environmental problems cannot be calculated without additional information. The most contentious added data elements are the in-use fuel economy of motor vehicles and railroad equipment, and transportation costs to the shipper or traveler. The former is measured by rough estimates from survey respondents and by controlled tests under artificial conditions. The latter is measured by a shrinking number of regulatory reports, by aggregate cost data from carriers, by private and government surveys of limited ranges of establishments, and by anecdotal evidence.

Special studies are needed to develop better estimates of in-use fuel economy and to estimate transportation costs by mode, carrier type, and distance-based market. Data from simulations and laboratory tests are inadequate substitutes for field tests under normal conditions.

Finally, the freight transportation data community must begin to shift its focus from the national scale to the local scale. Efforts to identify and improve methods of local data collection are relatively recent, and should be encouraged. More than a decade has passed since the last major round of urban goods movement studies. The old methods and findings should be revisited in light of more recent issues such as intermodal planning requirements and international competition for local industries. The long tradition of urban

## The Role of Models

Virtually all efforts to monitor transportation activity involve one or more models. Models of primary interest to BTS are used to expand samples to a universe, measure a characteristic at the intersection of data sets, and integrate separate data sets into a total picture. Models of primary interest to policy offices are used to forecast future conditions, particularly when the condition may be affected by a proposed policy or other action.

Samples of transportation activity are expanded into a universe by two basic approaches. *Statistical models* are commonly used to expand samples to a universe, particularly when the sample size is large or the geographical distribution of the activity being measured is relatively uniform. For example, individual shipments reported for the Commodity Flow Survey (CFS) are turned into estimates of interregional flows based on the output of the shipper, the way in which the shipper was sampled from all establishments in the shipper's industry, and the total output of that industry. Simple extrapolation or more sophisticated statistical models can then be used to estimate transportation activity in between years in which the survey is conducted. Network simulation models are more appropriate when the activity being measured is geographically diverse and sample sizes are too small to support statistical models. *Network simulation models* are based on the assumptions of how individual firms and households respond to local geography and to available transportation resources. Shipment distances in the CFS are estimated by simulating the routing decision of shippers given the costs of using available parts of the transportation network.

Models are often used to obtain information that cannot be measured directly. In some cases, the requisite information can be obtained by linking separate data bases-such as the results of different surveys of the same shippers-through common variables in a relational data base. Unfortunately, desired cross-tabulations in transportation are typically too complex for either a relational data base or for direct measurement. For example, informed policies on truck size and weight issues require estimates of ton miles by some combination of commodity type, industry of the shipper (manufacturing, wholesale, government, household, etc.), modes of transport, carrier type (for-hire company, owner-operator, business other than transport, personal), State, and multi-state corridor. We know from the CFS where commodities are carried by truck, and from the Truck Inventory and Use Survey what kinds of commodities are carried by what kind of truck. We need a very sophisticated network simulation model to combine the results of those surveys to integrate disparate data sources and provide cross-tabulations that cannot be estimated directly.

Unfortunately, the longest tradition of network simulation models in transportation is limited to local urban passenger travel. This tradition is based on the tendency of households to travel in geographic patterns that are relatively easy to summarize by a few key variables. The number of trips taken and distance traveled are functions of household size, income, and other attributes that apply to large segments of the population over long periods of time. In contrast, the transportation activity of business establishments varies radically by the type of commodity or service produced, by the market served, and by other factors which are industry-specific and not always correlated to easily measured attributes such as size of establishment. The transportation activity of a nearly ubiquitous service such as grocery stores may be as spatially and temporally stable as the travel behavior of households, but the quantity and direction of transportation activity for establishments such as construction companies will shift radically from project to project over a wide geographic area in the course of a year. Effective models of non-passenger transportation activity at the county-to-county level or greater geographic detail must be built on new approaches and significant local data collection.

transportation models has little to offer the freight side for the reasons given in the box on the role of models.

## Passenger Transportation Activity and Services

Separate strategies are required for measuring freight and passenger transportation because boxes can't talk but usually leave a trail of shipping documents, while people can describe their travel but don't always have records to jog their memories. Freight activity is generated mostly by businesses and is primarily sensitive to economic conditions; passenger activity is dominated by households and affected primarily by demographic conditions. Data collection and model development have emphasized intercity transportation to the near exclusion of urban concerns on the freight side, while data and models have a strong urban tradition and a weaker intercity tradition on the passenger side.

The measurement of freight and passenger transportation also share many similarities. Recent data on intercity movements exist only for terminal-to-terminal flows by non-highway modes, and intermodal surveys for door-to-door intercity travel are just now underway after a 17 year hiatus. Current programs measure outbound transportation by shippers and travelers while missing the domestic transportation of foreign goods and non-residents. Business establishment data are limited to for-hire carriers, missing a large segment of transportation service (such as private trucking for freight and school buses for passengers). Models to integrate and forecast activity must be rethought in light of new societal conditions and planning requirements.

Within the topic of passenger transportation activity, data collection programs and problems divide readily among local travel, long distance domestic travel, and travel to other countries. (See Table 4–1). Passenger movements are measured mainly by household surveys, ticket collections, and roadside vehicle counts, but the specific approach varies between daily, repetitive local travel and less frequent and more geographically diverse long distance travel.

### Local Travel

Existing knowledge of local passenger transportation activity is a trade-off between trip/traveler characteristics and geographic detail. One national survey provides details on all types of trips with virtually no geographic specificity, the decennial census provides great detail for only one trip purpose, and local data generally include geographic detail for all trip purposes without distinguishing among the purposes.

The importance of understanding both geography and trip purpose is suggested by Figures 4–5 and 4–6. Figure 4–5 shows significant variation in travel by trip purpose and time of day, while Figure 4–6 suggests significant geographical variation for just one of the trip types: the journey to work. Better understanding of the interaction of those characteristics is key to identifying the stress points on local transportation systems and the areas where environmentally driven travel reduction or modal diversion programs may collide with human desires.

TABLE 4–1

Principal Sources of Passenger Travel Data

| | Local Travel of Local Residents | Local travel of Out-of-Town Visitors | Long Distance Domestic Travel | Travel Overseas |
|---|---|---|---|---|
| U.S. Residents | Nationwide Personal Transportation Survey | Local tourism studies in some locations | American Travel Survey, Airline and Amtrak tickets | American Travel Survey, U.S. Customs |
| Foreign Visitors | Not Applicable | Local tourism studies | U.S. Customs | U.S. Customs (in transit) |

FIGURE 4–5

Person-Trips by Purpose by Time of Day: 1990

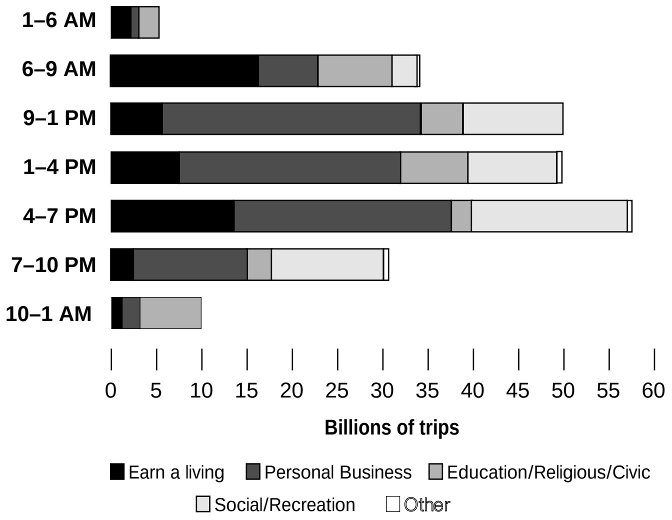
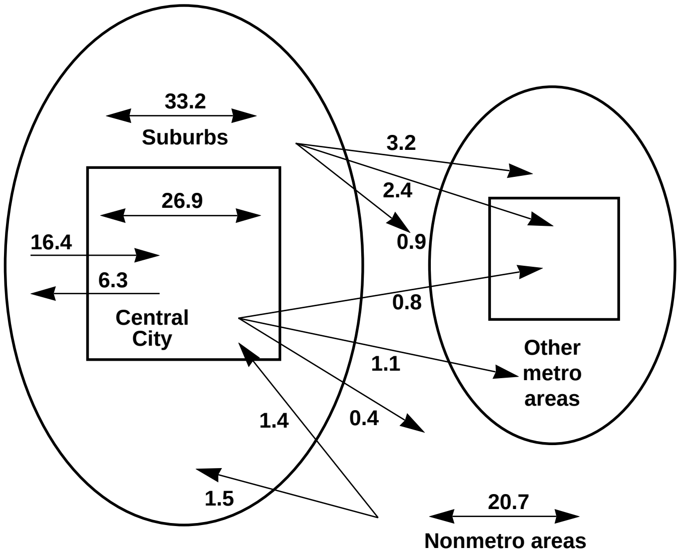


FIGURE 4–6

National Commuting Flow Patterns (Millions of Daily Trips)



### *The Nationwide Personal Transportation Survey*

Figure 4–5 is based on the Nationwide Personal Transportation Survey, which is conducted approximately every 5 years by DOT. The NPTS provides a wealth of information on the trip purposes, modes and vehicles used, demographics of the traveler, and other characteristics of travel. While the NPTS includes all travel, its small sample size (25,000 households) and limited recall period (one telephone interview covering a sample day) are not designed for capturing infrequent, nonrepetitive, long distance trips. The NPTS is most effective in measuring typical local travel.

### *The Decennial Census*

Figure 4–6 is based on the workhorse of urban transportation data, the decennial census. The decennial census is the only national source of data on commuting patterns by small areas, and is an essential component of the urban transportation planning process.

The potential crisis with the Year 2000 Census, described by BTS in its *Transportation Statistics Annual Report: 1994*, has not yet been averted. Congress continues to question the need for and cost of the data, including the transportation data, that have historically been collected in the census for use in implementing federal programs. Options currently being discussed by the House appropriations subcommittee that controls the Census Bureau's budget include (1) limiting the number of questions in the census that collect data for federal programs, (2) requiring federal agencies to reimburse the Census Bureau for the cost of collecting and processing the data, or (3) dropping from the census altogether the questions that collect data needed for federal programs and forcing agencies to find or develop alternative sources for the information. The Census Bureau continues to promote the collection of data in smaller monthly surveys conducted throughout the decade in a "continuous measurement" system.

At the same time Congress is looking at ways to reduce the information collected in the census, the DOT and state and metropolitan transportation planning organizations are increasingly reliant on the nationally consistent, cost-effective data collected in the decennial census to implement the requirements of ISTEA and the Clean Air Act Amendments of 1990. In its role of coordinating the collection of transportation data with information-gathering activities of other federal departments, the BTS is continuing to work closely with the Bureau of the Census, the

Office of Management and Budget (OMB), and other federal agencies to represent the interests of the transportation community in decisions about the types of data that will be collected in the 2000 census and the method in which the census will be conducted.

### *The Prospect for Continued Collection of Transportation Data in the 2000 Census*

After the 1990 census, the Census Bureau received a great deal of criticism from members of Congress who felt the census was too costly and inaccurate. The Congress expressed through the budget process its view that questions included in the census to collect data to meet federal program needs contributed significantly to the increase in the cost of the census and to the undercount of the population. In its report on the Census Bureau's fiscal year 1994 budget request, the House appropriations subcommittee directed OMB to ensure that only data required by law would be collected in the census at taxpayer expense.

Many federal agencies, including the DOT, expressed strong objections to restricting the data collected in the census (most federal programmatic data collected in the census are not specifically required by law). In response to these objections, Congress eased its position in subsequent budget guidance and directed the Commerce Department and OMB to ensure that the absolute data requirements of federal departments and agencies and state and local government data needs were considered in the 2000 census planning effort. But the guidance also included the stipulation that Congress expected other federal departments and agencies with significant data requirements, for which the decennial census is determined to be the most effective means of collection, would reimburse the Census Bureau for a portion of the costs of planning for and conducting the Year 2000 Census.

OMB requested federal agencies to formally submit their requirements for data from the 2000 census. In response to OMB's request, BTS provided on behalf of the DOT documentation describing the transportation data needed, the uses of the data for federal, state, and local transportation planning, and the legislation that requires the planning activities which depend so heavily on the decennial census data. Following the Congressional guidance that it ensure that only the absolute data requirements of federal agencies be considered in planning for the 2000 census, the OMB grouped all federal requests for decennial census data into three categories: (1) Decennial census data specifically *mandated* by legislation; (2) Data specifically required by legislation, for which the census is the only or historical source; and (3) Data used for *program* planning, implementation, or evaluation or to provide legal evidence.

Questions that collect decennial census data specifically mandated by legislation stand the best chance of being included in the 2000 census. Other questions that collect data specifically required by legislation would be second priority, while questions that collect data to fulfill program needs would be the lowest priority. The transportation data collected in the census are required by legislation, but the decennial census is not mandated as the source of the information.

The final decision of the Congress on the issue of 2000 census content remains to be seen. However, continued Congressional questioning of the legitimacy of data needs, perception of the adverse impact of the length and complexity of the census questionnaire on the undercount, and interest in reducing the cost of the census offer the very real possibility that the amount of information collected in the 2000 census may be reduced significantly compared with past censuses. If a "reduced-content" census becomes a reality, the transportation questions will survive in the Decennial census to the degree that their inclusion is made mandatory by law.

### *The Prospect for a Cost-Reimbursable Census*

The conference report on the Census Bureau's fiscal year 1994 budget stated that the conferees expected that other federal agencies with significant data requirements, for which the decennial census is determined to be the most effective means of collection, would reimburse the Census Bureau for a portion of the costs of planning for and conducting the Year 2000 Census.

The Federal Agency Policy Committee for the 2000 Census assessed the feasibili-

# The Continuous Measurement Alternative to the Decennial Census

The Bureau of the Census is continuing to promote "continuous measurement" as an alternative to the traditional census. Under a continuous measurement system, the decennial census conducted in 2000 would collect only population and housing unit counts and minimal demographic information such as age, race and Hispanic origin, sex, and household relationship. The transportation characteristics traditionally obtained from a sample of households using the long-form questionnaire, as well as the whole range of social, economic, and housing data collected on the long form, would not be collected. Instead, the long form would be replaced with a monthly Intercensal Long-Form Survey. Data from these continuous monthly surveys would be cumulated to produce averages over various periods of time. Annual estimates for large cities, metropolitan areas, and states could be derived by cumulating 12 months of interviews, but a five-year cumulative average would be required to produce estimates for small areas such as traffic analysis zones that are based on a sample of comparable size to that obtained in the traditional decennial census.

Data users within and outside the transportation community have been unwilling to embrace the continuous measurement system without a comparison between data collected by the proposed system and by the traditional long form. In April, 1994, the Transportation Research Board conducted the third National Conference on Decennial Census Data for Transportation Planning. DOT officials, Census Bureau representatives, and state and local transportation planners met in Irvine, California to review their experiences with using the 1990 census data for transportation planning and to make recommendations for the 2000 census. Census Bureau representatives described their proposal for a continuous measurement alternative to the traditional census.

The conference attendees recommended that a conventional census with appropriate improvements be implemented in the year 2000, along with a parallel test of the continuous measurement process. Then, if the resulting data from a continuous measurement system prove to be valid for transportation uses when compared with data from a conventional census conducted at the same time, a national continuous measurement system could be put in place by 2005.

To address the implications of data from a continuous measurement system for the uses of conventional census data in transportation planning, BTS conducted a formal study during the fall of 1994. A panel of experts representing the broad range of data users was briefed by Census Bureau staff and other statisticians who discussed the methodology, the pros, and the cons of continuous measurement compared with a traditional census.

Afterwards, the panel members carefully assessed the implications of continuous measurement within their particular area of expertise (travel forecasting models, clean air models, land use, transit planning, planning for large and small metropolitan areas, and so forth).

Like the attendees at the National Conference on Decennial Census Data for Transportation Planning, the study panel concluded that only after a parallel test of continuous measurement and a conventional census could continuous measurement data be evaluated sufficiently to determine their utility for the various applications of census data in the transportation planning process.

In the Decennial Census Improvement Act of 1991, Congress mandated that a study of the fundamental requirements for the nation's decennial census be undertaken by the National Academy of Sciences. As specified by the legislation, the Panel on Census Requirements in the Year 2000 and Beyond, under the Committee on National Statistics, was established to study (1) the means by which the government could achieve the most accurate population count possible, and (2) ways for the government to collect other demographic and housing data.

The Panel on Census Requirements conducted a comprehensive evaluation of the pros and cons of different ways of conducting the census, including continuous measurement. In its final report, *Modernizing the U.S. Census*, released in December, 1994, the panel concludes that it will not be possible for the Census Bureau to complete the needed research on continuous measurement in time to make the critical decisions regarding the 2000 census. Therefore, the panel recommends against substituting continuous measurement for the long form questionnaire in the 2000 census.

BTS supports the recommendation of the Panel on Census Requirements, The National Conference on Decennial Census Data for Transportation Planning, and the results of its own formal study: continuous measurement should not be substituted for the long-form questionnaire for the 2000 census. BTS encourages the Bureau of the Census to design and implement a test of continuous measurement to parallel the conventional 2000 census, so that data derived from the two methodologies can be compared and analyzed. If this test demonstrates that transportation data obtained from a continuous measurement system are adequately comparable to the data collected in the conventional census, implementation of a continuous measurement system should be considered prior to the 2010 census.

ty, risks, and benefits of sharing the costs of the census and concluded that there is no practical or feasible way of implementing this concept for the 2000 census. The Policy Committee, including BTS as DOT's representative, reached this conclusion for the following reasons:

1. Diffused funding sources for the census will not be cost effective because of uncertainties about the total cost to be shared and overhead costs to be incurred by each agency for handling the funds. Census costs would actually be higher as a result of each agency having to add overhead costs to census budget allocations.
2. Developing an agreeable cost-sharing formula would be difficult, and without firm obligations to contribute, a given agency's share may increase dramatically if other agencies are unable or unwilling to pay their allocated share.
3. The census is perceived as a national resource to which all citizens can have access. As a "public good" it is difficult to assess the value of the census data and how to charge persons for obtaining the data.
4. Cost sharing would spread responsibility among the agencies and their appropriations committees that place data requirements on the census. Diffused control and accountability may adversely affect the efficient conduct of the 2000 census.

The BTS supports the conclusion of the Policy Committee that it is neither practical nor feasible to implement a cost-sharing concept for the 2000 census. The decennial census is a national resource that benefits both the federal and non-federal sectors. Census data exist, in large part, because of federal legislation which directly or indirectly requires census data to meet the objectives intended by the law. The nation's interest will be served best by centralized funding of decennial planning and implementation costs in the Census Bureau for the 2000 census.

#### *The Prospect for Transportation Data to No Longer Be Collected in the Census*

A Congressional decision to exclude from the 2000 census data needed for federal programs is a very real possibility. If transportation data for states and metropolitan areas are no longer collected in the decennial census, a replacement program of state and local travel surveys must be designed and implemented to provide the data needed for transportation planning. BTS has been directed by the Deputy Secretary to take the lead within the DOT in developing a Decennial Census Transportation Data Replacement Program. In response to the Deputy Secretary's directive, BTS will begin the initial planning for this program in fiscal year 1996.

### The Transit Question

While both the NPTS and the decennial census cover local transit use, neither are completely effective instruments for capturing the share and characteristics of transit use. The other major source of transit data—the Federal Transit Administration's Section 15 program—provides only total ridership and passenger-mile statistics by property.

### The Travel Model Improvement Program

The bulk of data on local passenger transportation activity comes from home interview surveys, on-board transit surveys, and automatic vehicle counters by metropolitan planning organizations and other local agencies. Little has been done since the 1970s to advance the state of the art in data collection and analysis for urban travel, particularly in the area of origin-destination surveys.

One response has been the development of the Travel Model Improvement program (TMIP), a joint effort of FHWA, FTA, the Office of the Secretary of Transportation, and BTS, with financial support from the Department of Energy and the Environmental Protection Agency. TMIP was initially organized into four tracks, each of which reflects a current area of weakness in the state of local transportation data and analysis:

A. Outreach to bring practitioners throughout the states and metropolitan planning organizations up to speed in the current state-of-the-art in travel demand modeling and data collection.
B. Near-term improvements to make existing travel demand models more responsive to transportation management options, land-use concerns, and air quality issues.
C. Long term improvements to develop fundamentally new approaches that make existing travel demand models more responsive to transportation management options, land-use concerns, and air quality issues.
D. Data collection initiatives to provide inputs to existing and new models, to develop indicators of general conditions, and to capitalize on new technologies of data acquisition such as automatic vehicle identification and satellite-based tracking systems.

Initial proposals for the data track emphasize the need for better information on: the relations between travel behavior and vehicle ownership; driver characteristics that affect emissions; impacts of non-investment policy options such as pricing on travel demand; and the relationships of travel demand to demographic and urban development trends. Initial proposals also recognize the importance of understanding the impacts of commercial traffic on commuting and other personal travel, as well as the impacts of congestion on commercial traffic.

### Long Distance Travel

Currently, the principal sources of data on long distance passenger travel are limited to terminal-to-terminal passenger flows for scheduled airlines and Amtrak. These data are based on a published 10-percent sample of airline tickets and a complete but not publicly accessible census of Amtrak tickets. These flow data do not include trips by private vehicles, intercity bus, or general aviation, and provide little information on the traveler, purpose of the trip, and segments of the trip between the airport or train station and the actual trip origin and destination.

*The American Travel Survey.* Our understanding of long distance passenger flows will increase dramatically with the Bureau's American Travel Survey. The ATS is the first nationwide, multimodal survey of passenger movements since the last National Travel Survey was conducted by the Bureau of the Census in 1977. The sample size of the ATS is four times greater than its predecessor, and will include numerous other improvements. The ATS is being conducted for BTS by the Bureau of the Census as a part of the quinquennial economic censuses.

Members of over 80,000 households are surveyed once each quarter throughout calendar year 1995. The sample is large so that statistically reliable estimates of passenger flows among states and among major metropolitan areas can be made. Sampled households received a packet of materials, including a map and a calendar with which they track their trips over 75 miles from home, and an introductory phone call before the four interviews are conducted. Households that do not answer or that do not have telephones are visited by an interviewer. Special interviews are conducted to test for potential biases in the responses and assure high quality statistics.

Information is being collected on the trip destinations, intermediate stops, modes of transportation used, trip purpose, size of travel party, trip duration, and types of accommodations used. Basic information on the demographic and economic characteristics of the household is also being collected. Trip distances will be calculated by Oak Ridge National Laboratory based on the origin, destination, and most likely path though the computer representation of the transportation network.

ATS will provide essential data for both the transportation community and the tourism industry. The results will provide the only national estimates of passenger travel by all modes of transportation and origin-destination patterns of personal vehicle travel. Results will be published in 1996.

*Other surveys.* There are other useful but limited sources of long distance passenger travel information developed in both the private and public sectors. These surveys cannot substitute for a comprehensive ATS; in fact, often they are dependent on a comprehensive national survey to provide the measure of the total universe of passenger travel on which to base their more limited survey approaches.

The private sector's National Travel Survey is produced annually by the U.S. Travel Data Center of the Tourism Industry Association. This survey provides a very effective tool for monitoring trends in overall travel patterns, but its small sample size does not permit significant geographic identification. Historically, the industry has strongly supported the concept of a national passenger flow survey as a benchmark and guide to the industry's continuing survey activity.

Another source of information on long distance passenger travel is the Consumer Expenditure Survey of the U.S. Bureau of Labor Statistics. This survey is a very rich source of data on expenditures and activity related to travel paid by households. Business travel, about 15 percent of intercity passenger travel activity and a larger share of travel spending, is not within the survey's scope. This exclusion seriously limits the utility of the data for transportation applications, but the data can provide a useful adjunct to any DOT survey design.

## International Activity

The international travel sector has always been an area of substantial statistical importance out of proportion to its share of travel activity, in large part because of its effect on the national balance of payments, but also because international relations, prestige, and competitiveness enter into the subject as well. From a transportation perspective, foreign travel is an increasingly significant segment of all travel. International travel has shown annual levels of growth far greater than that of domestic travel.

Foreign travel can be divided into several market segments that have different consequences for transportation:

- Travel abroad by U.S. citizens (which affects U.S. and competing carriers abroad and U.S. points of arrival and departure);
- Foreign visitor arrivals (which affect U.S. and competing carriers abroad and U.S. points of arrival and departure);
- Internal U.S. travel by foreign visitors (which affects intercity and local transportation systems, particularly with regard to information and other special needs of foreign visitors); and
- Transiting travelers (which is not historically significant in the U.S., but which could become increasingly important with the growth of land travel between Canada and Mexico, and air travel between South America and Europe via Miami and other U.S. facilities).

As with freight statistics, the measurement of these activities is linked historically with documents related to customs and immigration. The balance of payments implications of travel abroad by U.S. citizens and travel to and within the U.S. by foreign residents are other factors that have determined the nature of statistical programs treating these phenomena. Transportation statistics are in fact a byproduct of these other purposes.

The primary source of information on international travel activity is the International Air Data Base, derived from form I-92 of the Immigration and Naturalization Service (INS). Form I-92 is a document that must be completed for every vessel and aircraft arriving or departing the U.S., describing the number of U.S. citizens and noncitizens carried, the port of arrival and departure, and the national registry of the carrier.

The Travel and Tourism Administration of the U.S. Department of Commerce conducts the In-Flight Survey on board aircraft departing the United States. This survey obtains information on foreign travel by U.S. citizens and travel just completed within the U.S. by foreign visitors. The survey also obtains some information regarding internal U.S. travel by visitors, including different modes of travel used while staying in the U.S. Detailed internal trip-making is not obtained.

Given the disparate set of interests in developing international travel statistics, it is not surprising that not everyone can be satisfied by the same set of information. Balance of payments calculations, immigration management, tourism, and transportation planning require somewhat different data. For instance, the I-92 system, defined by Immigration and Naturalization Service needs, makes a distinction only between citizens and aliens; it also describes the flows by port of departure and nationality of carrier. For other purposes, tourism and balance of payments, the apt distinction is based on residence rather than citizenship. Similarly, a German flying from Switzerland would be statistically indistinguishable from a Swiss national given the methods used. As in freight statistics, the present INS data identify ports of entry or departure but do not identify inland origins or destinations.

The future of these international data are in doubt, particularly in light of proposals to disband the Travel and Tourism Administration and the Department of Commerce. BTS is reviewing options to maintain these data should reorganization proposals be enacted.

### Passenger Vehicles and Service Providers

HPMS and local traffic studies provide vehicle counts for automobiles, vans, and pick-ups, and data on the characteristics of trucks and vans for passenger travel are available from the TIUS; however, inventory and use data on automobiles and buses, and information on the geography of all personal-use vehicle activity, are nonexistent. We know next to nothing about the use of automobiles and other vehicles for business purposes, including the activity of taxicabs, rental cars, and company vehicle fleets. Information on buses and vans is generally limited to those used by federally funded public transit, missing an enormous number of school buses. church buses, vans used by hotels and airport shuttle services, and vehicles used by social service agencies. The federal Department of Health and Human Services subsidizes a significant quantity of transportation that is not captured in federal transportation statistics.

The quickest and most effective fix for this data gap at the national scale is expansion of the TIUS to include automobiles and buses. The distinctions between trucks, vans, automobiles, and buses has blurred into a continuum with the popularity of minivans and small pick-ups for personal use and the large but unmeasured use of automobiles for service delivery and other businesses.

While FTA’s Section 15 and Section 18 programs provide some information on public providers of passenger transportation service, very little information is available on private providers or on the extensive amount of passenger transportation provided by schools, churches, and social service agencies. The first step in filling this gap would be to initiate the Charter, Rural, and Intercity Bus Survey proposed by the Bureau of the Census.

## Geography of the Transportation System

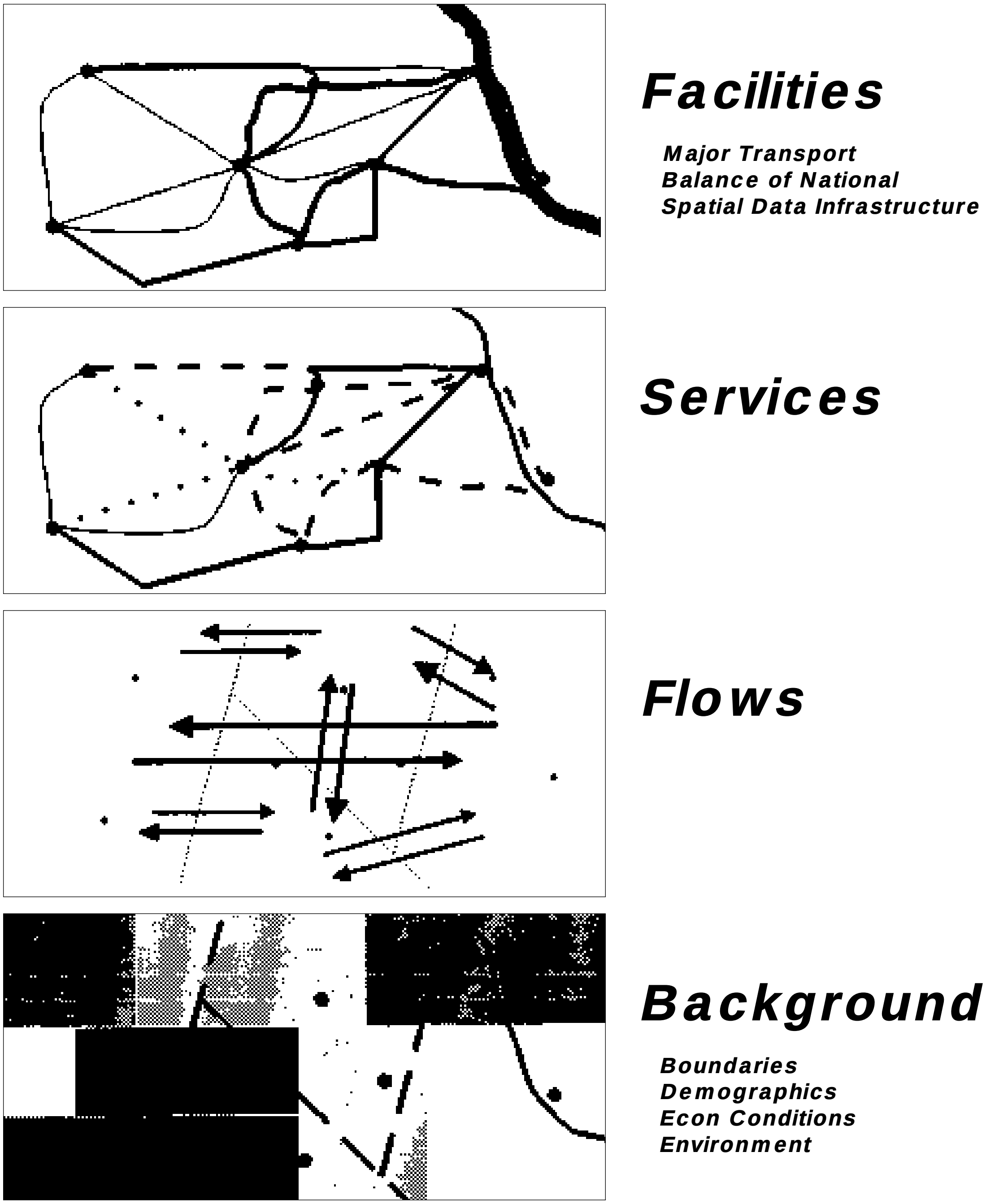
Freight and passenger transportation meet on the infrastructure. Transportation activity, services, and facilities must be combined in a geographic context to understand how well the transportation system meets its basic goals: to get people and things where they want to go, when they want to get there, at a minimum cost to the transportation user and the innocent bystander.

For the first time since 1977, DOT is developing extensive, integrated geographic data on transportation facilities and networks, the activities they serve, and the surroundings they affect. The emphasis on geographic data and analyses reflects the central purpose of transportation: to connect separate locations and accommodate the flow of people and goods. This emphasis requires refinement and application of analytical methods based on geographic information systems (GIS) technology.

BTS is organizing DOT’s geographic data into four layers of information, shown in Figure 4–7. The *facilities layer* represents the location, physical characteristics, and connectivity of highways, railroads, waterways, fixed guideway transit, airports, pipelines, terminals, bridges, locks, and other structures. The *service layer* represents transportation services on and across the transportation facilities, such as bus lines and railroad trackage rights. The *flows layer* represents interactions between areas, such as commodity movements and donor/recipient financial relationships, which can be assigned to specific transportation facilities and ser-

FIGURE 4-7

Layers of BTS Geographic Data



vices primarily with analytical models. Much of the flow data will come from the CFS, ATS, and the decennial census. Finally, the *background layer* includes data of use to the transportation community that are published and maintained by others. Examples include political boundaries, geographic names, population distributions, economic activity, and environmental conditions. Boundary and name files that help define locations for the facility, service, and flow layers will be published by BTS. BTS also plans to publish its estimates of daytime population by place, based on the 1990 Census Transportation Planning Package. The remainder of the background layer is used by BTS for creating thematic maps and preparing analyses, but is left to other agencies for dissemination.

The Bureau's efforts are parallel to a national attempt to modernize the Nation's mapping programs through interagency and intergovernmental cooperation under Executive Order 12906, *Coordination of Geographic Data Acquisition and Access: the National Spatial Data Infrastructure* (NSDI). This order assigns overall responsibility for NSDI to the Federal Geographic Data Committee (FGDC), chaired by the Secretary of the Interior. The order assigns DOT responsibility for the transportation layer of the NSDI. NSDI provides basic location (but not necessarily connectivity) data for the facilities layer through the Census Bureau's TIGER files and the Digital Line Graphs (DLGs) of the U.S. Geological Survey. NSDI is also supposed to provide a framework through which the mapping and geographic data activities of all government agencies can be brought together for efficiency, synergy, and serendipity. The need for NSDI is in part a reflection of the increasing number of government agencies involved in mapping and geographic data development, the potential analytical power of integrating electronic maps and geographic data, and the inability of federal mapping agencies to keep up with changes in the American landscape.

Table 4–2 summarizes the status of the major geographic databases for transportation. The highway network database consists of approximately 400,000 miles of highways, or 10 percent of the total roads in the United States. The rail network contains the entire mainline and secondary rail systems while the waterway network includes all navigable waters. All rail transit systems are covered.

These databases have been developed from paper maps of varying scales and associated levels of accuracy. Table 4-3 summarizes these scales and lists examples of recommended uses at each scale. As shown in the table, the 1:2,000,000 scale networks are used for national level planning and analysis functions, while the 1:100,000 scale networks are used for more localized activities at the state, regional and metropolitan level. The primary reason for this distinction is the increased size and detail required for the 1:100,000 scale networks, which directly affects the time and resources required to perform planning tasks.

The transportation databases are built on three often conflicting sources: DLGs that were originally created from maps at the 1:2,000,000 scale, DLGs that were originally created from maps at the 1:100,000 scale, and the Census TIGER/Line files that are also based on maps at the 1:100,000 scale. Differences among the sources is illustrated in Figure 4-8, which contains railroad networks from each source for central Chicago. The 1:100,000 DLGs provide the best geographic detail for older facilities, particularly with respect to shape points along network links. TIGER is more current, particularly for the street network, but often at the expense of locational precision and shape points. (Curves often show up as a straight line.) The railroad network based on the 1:2,000,000 DLGs has much less locational precision, but contains far more attribute information such as ownership and traffic carried. Differences between the 1:100,000 sources must be reconciled and information snapped from the 1:2,000,000 source to capture the best of each source.

Most transportation network data bases have been subjected to planimetric quality checks so that the maps look good, but have not been subjected to quality checks for topological accuracy. Planimetric accuracy is the traditional concern of cartographers, and topological accuracy is the concern of analysts. Planimetric accuracy means that the bridge, intersec-

TABLE 4–2

Major Geographic Databases for Transportation

| Database | Scale of source maps | Source Agency | Status |
|---|---|---|---|
| National Highway Planning Network, version 1 | 1:2,000,000 | FHWA/ORNL | Used for CFS; to be retired |
| National Highway Planning Network, version 2 | 1:100,000 | FHWA | Initial release in 1994 |
| Railways (to which waybill data can be attached) | 1:2,000,000 | FRA | Initial release in 1992 |
| Railways | 1:100,000 | FRA | Initial release in 1995 |
| Waterways | 1:100,000 | Interagency Consortium | Initial release in 1995 |
| Pipelines | State-to-state network | Nat'l Petroleum Council | Used for CFS; to be retired |
| Pipelines | 1:100,000 | Office of Pipeline Safety | Planned for 1997 |
| Fixed-guideway Transit | 1:100,000 | FTA | Initial release in 1995 |
| Air Network: Freight (connectivity between airports) | | BTS | Initial release in 1995 |
| Air Network: Passenger (connectivity between airports) | | BTS | Initial release in 1995 |
| Rail Double-Stack route attribute | | FRA | Initial release in 1996 |
| Passenger / Commuter Rail route attribute | | FTA | Initial release in 1995 |
| Urban Bus Routes | | FTA | Planned completion in 1996 |
| Intercity Bus Routes | | Volpe Center | Initial release in 1995 |
| Airports | | FAA / Volpe Center | Initial release in 1993 |
| Water Ports | | Corps of Engineers | Planned for 1996 |
| Docks | | Corps of Engineers | Initial release in 1995 |
| TOFC/COFC and other Terminals | | FRA | Planned for 1995 |
| Transit Stations | | FTA | Initial release in 1995 |
| Rail-Highway Grade Crossings | 1:100,000 | FRA and BTS | Planned for 1996 |

tion, or other facility is in the right place. Topological accuracy means that bridges are distinguished from intersections, and that connections in the real world are reflected in the computer representation. Planimetric accuracy is important for visual credibility, and for linking data on transportation facilities with environmental, economic, and social information about the surrounding area. Topological accuracy is essential for most forms of transportation analysis, in which the computer must determine whether you can really get there from here.

GIS tools are generally available to edit and analyze geographic data related to transportation. Many of these tools remain complex for the user. Even if geographers and vendors begin to make GIS as easy to use a spreadsheets, additional tools are still needed. Examples of these tools include: geographic data visualization tools for multi-dimensional tabulations, chloropleth maps, and flow maps; network simplification tools for link chaining (i.e. end-on link collapsing), network spur removal (i.e. removing dead-ends), and network aggregation (i.e. merging of two or more parallel routes); and network matching tools to resolve problems such as those illustrated in Figure 4–8.

## Transportation Finance

Much of the data for "information on public and private investment in intermodal transportation facilities and ser-

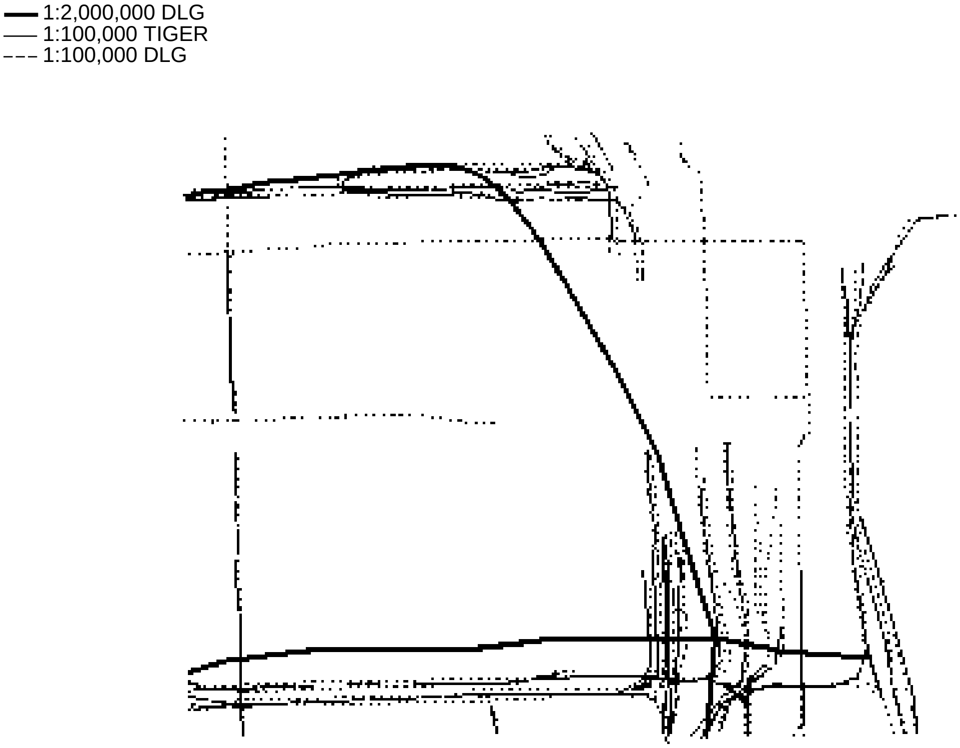
**TABLE 4–3**

Scales of Source Material for Geographic Data

| | 1:2,000,000 | 1:1,000,000 | 1:100,000 | 1:24,000 | 1:10,000 |
|---|---|---|---|---|---|
| Sources | USGS National Atlas, DLG's (1:2M) | Digital Chart of the World (DCW) | USGS DLG's, Census TIGER/Line | USGS Quad Maps | Property maps, engineering drawings |
| Root mean square positional accuracy | 1,200 m (0.75 mi) | | 80 m (260 ft) | 15 m (40 ft) | |
| Smallest Typical Feature Portrayed | Major highways | Major highways | City streets | Alleys | Curblines |
| Representative Size | 51,000 links for National Highway Planning Network | | 110,000 links for National Highway Planning Network | | |
| Typical Applications | National or statewide policy studies; market analyses | North American planning studies | Metropolitan travel demand studies; route planning | Route planning; IVHS applications | Facility planning, safety planning |

**FIGURE 4–8**

Different Representations of Chicago's Railroads



vices" required by title 5 of the ISTEA[5] is aspatial, or at least not the level of geographic detail as described above. This is particularly true for financial, employment, and other institution-based information that applies to a company or service, and that is typically not measured (or even possible to measure) below the county or state level.

BTS provided relatively few statistics on public finance of transportation in the first *Transportation Statistics Annual Report*; yet those statistics resulted in many favorable responses from readers who want more information.

BTS recognizes that much of the interest in public finance involves quests to uncover subsidies. Valid statistics on subsidies are very difficult to develop, especially when shared costs and indirect subsidies are included. For example, what percentage of highway patrol budgets should be considered a transportation expenditure and how much should be general public safety? The issue of subsidies within modes is at least as difficult and controversial as the issue of subsidies between modes. FHWA has made the most extensive effort to identify who is paying for what within the highway program through a series of highway cost allocation studies. A new highway cost allocation study is just getting underway, and will undoubtedly provide key information for public debates on ISTEA reauthorization.

Statistics on private finance of transportation are surprisingly limited given the extensive ownership of transportation equipment by banks and other financial institutions. Most existing financial data come through the ICC and the BTS Office of Airline Information. BTS is beginning an extensive review of its newly acquired airline statistics program to determine which data are valuable, what can be improved internally or replaced by alternatives, and what the relationships should be between the public and private sectors in the provision of the data. (See Economic Classification box.)

## The Bottom Line: Performance Measurement

The study that guided the creation of BTS also called for establishment of a national transportation performance monitoring system.[6] The measures which comprise this system are the summary form of the statistics discussed throughout this chapter. These performance measures provide the basic understanding of whether transportation and the world it affects are getting better or worse; the definition of performance measures identifies what we mean by better or worse. In the intergovernmental system, where strategic transportation decisions are made by several levels of government, the relevant indicators will be specified in performance partnership.

Performance measures in transportation are typically composites of variables based on direct observation (such as traffic counts and lane miles) and variables based on estimates (such as vehicle miles of travel). For a performance measure to be effective:

- The observations underlying the variables must be accurate, reliable, and have adequate coverage.
- The estimation methods must be demonstrably unbiased.
- The composite measure must be relevant, transparent, and devoid of spurious accuracy.

Many performance measures in transportation do not pass the relevance test, either because the measure is not readily linked to the real world experience or because the measure fails to capture the desired concept. The commonly used measure of ton miles illustrates the former; very few decisionmakers can visualize a ton mile and relate it to an understood quantity. The ratio of the "transportation bill" to gross domestic product as a measure of transportation's share of the economy illustrates the latter; the numerator and the denominator are based on entirely different forms of accounting and should not be combined.

"Level of service" in highway planning is one of the more effective performance measures devised in transportation. Six levels of service are defined to represent traffic conditions from A (when vehicles can move at the posted speed and change lanes whenever you want) to F (when traffic comes to a complete standstill). The implications of each level of service for the traveler are readily understood from common experience. Level of service can be accurately established by casual observa-

## Economic Classification: Industries and Commodities

The Standard Industrial Classification (SIC) system is the key to most financial and institutional data, since it provides the basic framework by which establishment-based data are collected and tabulated. The SIC affects data collection and analysis at all levels of government and in many private corporations.

As noted last year, revisions to the SIC are needed.[7] Since that time, the Economic Classification Policy Committee convened by the Office of Management and Budget has proposed a trilateral effort to replace completely the SIC with a North American Industry Classification System (NAICS).[8] NAICS is proposed to reflect changes in the economy, improve the consistency of the SIC's hierarchical structure, and improve the comparability of statistics among nations. BTS supports these goals as long as data availability and analytical integrity are not compromised. BTS is particularly concerned with the cost and philosophical basis of proposed classification system.

### Cost

Any change to an economic classification system incurs costs to the programs that use that system. Forms and sample frames must be redesigned to collect data by the new classification of establishments, and statistical bridges must be built between new and old ways of tabulating the data. Some time-series data will be disrupted beyond repair. These costs must be balanced against improvements to data quality and utility before a change is accepted.

Work to date by subcommittees of the Economic Classification Policy Committee indicates that significant and numerous changes to the SIC are required to achieve comparability with the less detailed industrial classification systems in Canada and Mexico. U.S. detail would be maintained primarily by establishing a supplemental fifth digit to the proposed 4-digit NAICS codes.

The magnitude of potential changes could be costly to implement, and result in considerable loss of detail in economic data. If adopted under an international agreement, conversion to NAICS would be mandatory at a time when government budgets are declining. U.S. statistical agencies would be sorely tempted to cover conversion costs by collecting less detailed data under the reduced number of industry categories in NAICS. The supplemental fifth digit could easily become a footnote rather than a framework for data collection and tabulation.

BTS strongly recommends that the potential loss of economic data and other consequences be considered in a formal benefit-cost analysis before the U.S. agrees to adopt NAICS.

### Philosophical basis

Industries can be classified by the goods and services they produce, how they produce those goods and services, or for whom they produce those goods and services. All three approaches—product based, production process based, and market based—are used with other factors in the current SIC. The Economic Classification Policy Committee proposes to use production process as the sole philosophical basis for classifying industries.

BTS believes that the production process is a very appropriate basis for classifying establishments in manufacturing, but not in other sectors of the economy. The service offered and the market served are generally more effective distinguishing characteristics of establishments outside of manufacturing. Indeed, the basic distinction between wholesale and retail trade is based on markets: whether establishments sell to businesses or households. Markets are especially important to transportation, particularly in the distinction between local and long distance carriers.

BTS recommends the use of production process for classifying establishments in manufacturing, and demand-based markets for classifying nonmanufacturing establishments. Ideally, the proposed classification can be justified by both philosophical bases. In the end, usefulness of data to a broad spectrum of analysts and decisionmakers should be more important than rigorous adherence to a single classification principle.

### Commodity classification

BTS recognizes that the classification of products—including commodities and tradable services—is a valuable supplement to the classification of both manufacturing and nonmanufacturing establishments. BTS is particularly interested in a commodity classification system that:

- classifies commodities in a hierarchical structure that is relevant to transportation;
- represents commodities carried by all modes of transportation;
- is relatively easy to use by respondents to the Commodity Flow Survey;
- is compatible with the Harmonized System (HS) now used world wide; and
- can be linked to the Standard Transportation Commodity Classification (STCC) codes.

In response to problems with the use of STCC codes for the 1993 CFS, BTS has initiated research at the Volpe National Transportation Systems Center to devise a more effective classification for the 1997 survey. Should the resulting classification system prove its worth in the 1997 CFS, BTS will propose the system's adoption as a statistical standard.

tion from an aircraft or surveillance camera, and does not require detailed traffic counts or other calculations. Level of service can also be predicted by comparing traffic counts to capacity using relationships that have been established from an extensive and widely accepted empirical record.

Four sources of variables for performance measures include:

1. Observations and estimates of current conditions and recent trends for transportation planning and policy.
2. Forecasts of future conditions for transportation planning and policy, such as to determine whether the probable impacts of proposed transportation projects will conform with air quality goals.
3. Real time or daily observations to support daily transit operations, commercial vehicle dispatching, intelligent vehicle highway systems (IVHS) and other intelligent transportation systems (ITS), and other forms of transportation operations.
4. The congestion, intermodal, and other management systems mandated by the ISTEA, which in theory can link the data and analysis activities of transportation operations with those for transportation planning and policy.

DOT has undertaken a departmentwide effort in 1995 to identify key performance measures as part of Secretary Peña's National Transportation System initiative. BTS is participating in this effort to assure that the Bureau's statistics are policy relevant as well as policy neutral.

BTS views the development of performance measures as an evolutionary process, documented each year by the contents of the *Transportation Statistics Annual Report* and its companion volume, *National Transportation Statistics*. The Bureau's success in developing effective performance measures will depend in large part on continuing feedback from users of both volumes. BTS encourages that feedback through the many communication channels identified at the beginning of this report.

## Endnotes

1. 49 USC 111 (f).
2. Independent owner-operators who do not have payrolls and trucking provided by the shipper for its own account are the missing pieces.
3. DOT has proposed transfer of ICC reporting authority to the Department if sunset legislation is passed.
4. Screen lines are locations which divide a region for purposes of measuring intraregional activity.
5. 105 Stat. 2158.
6. Transportation Research Board, *Data for Decisions*, Special Report 234, National Research Council, Washington, D.C., 1992.
7. *Transportation Statistics Annual Report*, 1994, pp. 194–198.
8. *Federal Register*, July 26, 1994, pp. 38092–38096.

# PART II:

# *The* ECONOMIC PERFORMANCE *of* TRANSPORTATION

***The only permanent condition is change.***
***—Heraclitus, c. 500 B.C.***

Part II of this *Transportation Statistics Annual Report 1995* provides a thematic treatment of the economic performance of transportation. In contrast to the earlier section, which provides a statistical overview of the nature and performance of various aspects of the U.S. transportation system, this part offers an in-depth treatment of one major aspect: specifically, what we know about the economic performance of transportation in the United States.

This section focuses on *three* critical aspects of economic performance of transportation.

- Productivity. How efficiently do the industries that move people and goods provide these services? Does the value of these transportation services grow more rapidly than the cost of the inputs used to produce these services? In other words, how *productive* are the transportation service industries?
- Economic impact of transportation investment. What contribution do public investments in transportation make to overall economic performance? Do these investments reduce the costs of moving people and goods? What economic gains in national output derive from public investment in highways and other forms of transport?
- Impact of economic growth on infrastructure use and costs. How do changes in regional and national economies affect industry and household patterns and costs of use of water and air transport, highways, and transit? How do these patterns and costs of infrastructure use vary as the economy grows and undergoes technical and structural change?

Over the years, these broad and complex questions have been the subject of extensive analyses by universities and government agencies. The following three chapters provide a synthesis of the findings of this research on the productivity of the transport services sector, and the magnitude of the reciprocal relationships between transportation infrastructure and economic growth. It seeks to convey the salient aspects of the economic performance of transportation. They identify what is known, what remains to be known, and—where there is debate—the terms of debate and the contingent inferences possible.

Chapter 5. “Transportation and Economic Performance: An Introduction,” describes the interdependence of transportation and the economy. It also clarifies the basic concepts and terms underlying an understanding of trends in transport productivity and the economic role of transport infrastructure.

Chapter 6. “Transportation Productivity: Trends and Prospects,” focuses on the productivity of the transport sector. The first part, prepared by the U.S. Bureau of Labor Statistics, presents and interprets productivity trends over the last three and a half decades for railroads, bus carriers, intercity trucking, air transportation, and petroleum pipelines. The second part explores the effects of various ongoing changes in the sector and in the economy on the measurement of transport sector productivity. These changes include *compositional* changes in the American economy (especially the growing importance of service industries); *institutional changes*, which include economic deregulation and environmental regulation; *technological changes* which are leading to qualitative changes in the demand for transportation; and *quantitative* changes, which involve increasing pressures on public transport. Finally, the chapter discusses gaps in available data and what is needed to develop a more comprehensive understanding of the sector's economic performance.

Chapter 7. Transportation Infrastructure and Economic Growth: Reciprocal Relationships, focuses on transportation and overall economic performance. Over the last two centuries, the transportation infrastructure of the United States has determined not only the regional structure of the country, but also the spatial structure of society within each region and continues to exert its effects as the 20th century draws to a close. In the United States, large elements of infrastructure are supplied publicly and researchers have recently debated the contribution of public capital, particularly highway capital, to current U. S. economic growth and productivity. Some analysts have concluded that public infrastructure investment plays a large role in the country's economic productivity slowdown in the recent past, while others suggest that public capital, including highway capital stock, makes no marginal contribution to private production in the United States—that the country is saturated effectively with highway capital. However, most conclude that highway capital makes *a significant contribution* to private production—although it is small relative to that of private labor and capital inputs. Similar findings on the role of transportation infrastructure—as reducing costs of production and offering positive contributions to national production—come from similar studies in Europe and Asia. Still, the varied results suggest that the ways transportation infrastructure affects the productivity of the overall economy are not fully understood, and further conceptual and data development are warranted.

The last part of the chapter reports on the use—and costs of use—of transportation services and capital stock by various industries and households in the United States. More specifically, the chapter covers use and costs of use of highways, air transport, water transport, and urban transit. These data are based on requirements—that is, actual use of transport per unit of output by industry—rather than needs, thereby shedding valuable light on the size and mix of infrastructure services and capital used by various sectors in the economy. The data also show changes in use and costs over time, illustrating how economic growth, technical changes, and compositional changes in the American economy have affected the demand for highways and other types of transport infrastructure.

CHAPTER **FIVE**

# TRANSPORTATION *and* ECONOMIC PERFORMANCE: AN INTRODUCTION

Transport plays a multifaceted role in a highly industrialized society such as the United States. As it moves goods and people between and within production and consumption centers, it is seldom desired for its own sake. Instead, some of its functions are clearly economic, such as providing low-cost reliable mobility, facilitating production, raising agricultural productivity, exploiting natural resources, supporting participation in a global economy and expanding per capita income. Others are noneconomic, such as strengthening the country's defense, promoting political cohesion, providing greater personal safety in transportation, improving the quality of the environment, and assuring choice and access of the transportation system to all groups in society.

## Transportation and the Economy

The United States has pioneered and invested heavily in the development of transport infrastructure (such as roads, rail, transit, waterways, air and space facilities), in the production of a range of vehicles, as well as in human and organizational capital to support the transport system. Such investments have helped expand agricultural and resource industries, industrial complexes and urban centers across the country, and highly interconnected regional economies, over time.

The story of how the canals and railroads opened up the West in the last century is well known: They contributed to the westward migration, quickening its pace, and determining its path, and also affecting the rates of change of economic development opportunities—thus defining the country's spatial character.[1] In addition, technologies in other sectors complemented transport. For example, railways, which reduced transport costs, were aided by the telegraph, and the two made it possible to direct business enterprises from afar. This gave rise to the large modern corporation in the United States and a robust world-class economy.[2]

Similarly, the interstate highway system (often called the largest public works project to date), was introduced in the middle of this century and rapidly

**FIGURE 5-1**

Federal Capital Spending for Highway Infrastructure: 1956-1987

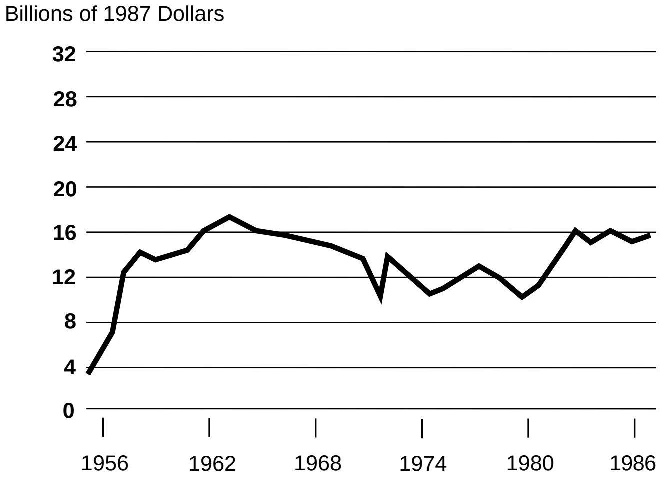
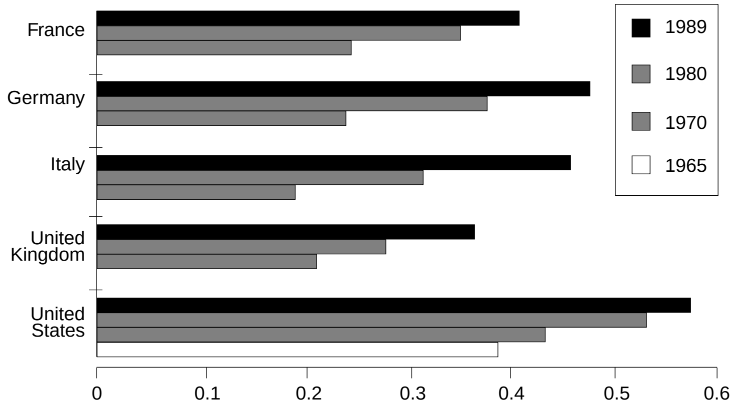


**FIGURE 5-2**

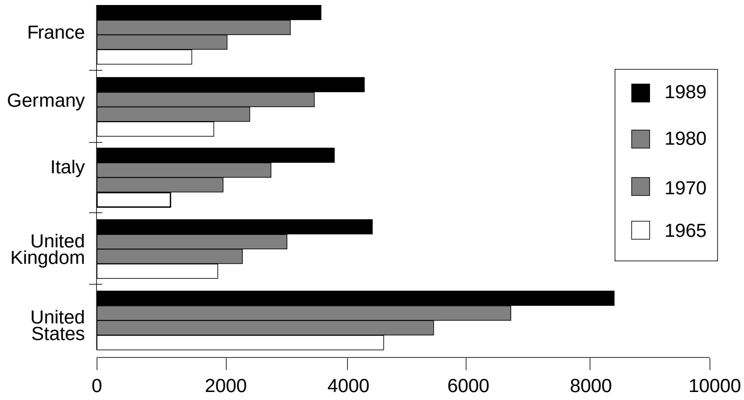
Per Capita Cars and Usage of Highway Transportation for Selected Countries

Cars Per Capita



*1965 data are available for the United States only.

Vehicle-Miles Per Capita



expanded. (See Figure 5–1.) The system greatly enhanced inter- and intra-urban mobility at the same time as it sharply reduced the time and out-of-pocket costs of passenger and freight movements. Along with other factors, such improved transport propelled the postwar American economy and its global ascendance, and was in turn pushed by the breakneck economic expansion.

American use of highway transport as compared with other major industrial countries can be indicated by per capita stock of vehicles and intensity of passenger use of the system. (See Figure 5–2.) Expansion of road transport paralleled the period of sustained American economic growth (before the 1973 energy crisis), and settlement patterns in the U.S. urban landscape were transformed. Much of the growth occurred at the urban periphery, in suburbia and then exurbia, producing a geography of residences and workplaces quite different from that of mid-century America.

Over the last decade, new information technologies (IT) and transport logistics produced major structural changes and, in turn, were influenced by the structural evolution:[3] Not only did these technologies introduce a wide variety of products but they changed the nature of many existing products and services and the functions and interactions among firms. Further, continual interaction and learning across disciplines and industrial sectors lead in these technologies to innovations, often in clusters—with a proliferation of products, a shortening of the products' half life, and a need to rush ideas to market in ever shorter times.

However, such conditions bring a very high level of technological uncertainty and market volatility. To cope with these uncertainties, firms which need to compete flexibly in a global market have reorganized, developing far-reaching networks, which establish links among firms with complementary assets and technological /marketing relations.[4]

The emerging national economy, with firms actively competing in time and space, made possible (and was made possible by) a major logistical revolution in transport networks. The new logistical system has virtually eliminated the inventories and buffers of stocks of production inputs and outputs that have traditionally cushioned against transport delays. Now, "just-in-time" deliveries of customized commodities at the moment they are needed characterize producer-customer relationships. They require flexibility as well as rapid transport, information handling, and prompt decision-making among the networking firms.

The restructuring of the transport sector has underscored the need for efficient connections among different modes of transport, choices among alternate modes, communication, cooperation and competition.[5] In the United States and OECD countries, huge intermodal investments (such as double-stack cars) now allow huge volumes of bulk freight to move rapidly on short notice over long distances at low cost and "seamlessly," cross-mode. Thus, technological progress both induces, and is induced by, improvements in transport.

The transport system is evolving dramatically: It is moving from one serving a material-intensive industrial production system based on economies of scale (where efficiency was gained by concentrating resources in large firms) to one serving an emerging flexible, knowledge-intensive production system with agile firms exploiting economics of scope (where firms offer a broader range of services).

## Evaluating Performance

The performance of a transportation system may be assessed from a variety of perspectives. For example, it can be measured in terms of its safety, for which assessment fatalities per vehicle-mile traveled is an important indicator. Energy efficiency (measured by energy intensity) is another important yardstick, given the role of fossil fuel imports in the balance of payments and the impact of fuel combustion on the environment. A third performance indicator is per capita emissions of $CO_2$ (a major "greenhouse" gas), which provide a measure of the sector's performance in terms of its impact on climatic change.

We are here concerned, however, with the transportation sector's *economic* performance, which involves its contribution to the economy through efficient and effective services. From this perspective, the ability to move goods and people is critical. Thus, aggregate throughput measurements, such as ton-miles and passenger-miles, are useful gross indicators. The system's capacity to accommodate economic growth is another key indicator; this can be measured, for example, by lane-miles of highway. Neither of these measures, however, provides a *comprehensive* indication of economic performance, because each only reveals something about the *quantity* of service provided without discussing its *effectiveness.*

Effectiveness is an important concept. For example, an extravagant program of infrastructure development may have a negative impact on aggregate economic welfare because it diverts resources from more valuable activities. Further, while it may expand the capacity for transport services, it might do so inefficiently. Thus, to assess economic performance more completely, indicators are needed that measure the value of the output of services relative to that of the inputs required to provide them. When the value of services grows more rapidly than the cost of inputs, the sector's contribution to the economy is improving. This is the fundamental logic of *productivity* analysis.

Over the past four decades, economists have developed and refined methods to measure productivity, which is an indicator of the efficiency with which economic inputs are transformed into economic outputs. By measuring the productivity of the transportation sector, we can evaluate how transport industries contribute to overall economic performance.

Since the goal of this report is to summarize the current state of knowledge about economic performance *in and of* transportation, the remainder of this chapter reviews the concepts of economic performance and describes some of the terms frequently used to measure it and its progression over time.

## Performance Concepts

Economic performance in transport can be based on three concepts: *efficiency*, *technological progress,* and *productivity*. Although these terms are commonly used, they have specific meanings when applied to transport productivity analysis.

### Efficiency

Efficiency usually means the minimization of waste. Economic efficiency refers to a situation where the production factors—people, machines, and natural resources—are combined in a way that produces the greatest value of goods and services physically possible, given the best available technology. *Efficiency improvements* can be achieved in two ways. First, firms and institutions organize their resources (called *firm efficiency*) so as to reduce idle capacity, downtime, duplicated efforts, and defects in production: For example, a trucking firm improves scheduling to reduce empty backhauling. Second, resources are transferred among firms and institutions to increase their total contribution to the production of goods and services (called *allocative efficiency*): If an idle vehicle is sold to a firm that needs it, its contribution to output increases, and the economy becomes more efficient overall.

*Economies of scale* represent an important efficiency improvement; these are achieved by concentrating labor, capital, and other resources among a smaller number of larger firms. In the transport sector, economies of scale are achieved when terminal operations, reservation and scheduling systems, and marketing are managed more efficiently on a larger scale. However, there may be a size beyond which no economic advantage is gained, and diseconomies of scale may even occur.

Achieving *economies of scope* by expanding the range of goods and services firms produce is also crucial. For example, if an intercity bus firm decides to offer express parcel service, it can use its existing vehicles and computer reservation system for this purpose, thus producing more with a relatively small commitment of additional resources.

Market forces tend to promote economic efficiency. In fact, these forces are so powerful that some aspects of economic efficiency are treated as givens in theoretical models. In reality, however, there are countervailing forces that slow down or even reverse efficiency improvements. For example, lack of information, cooperation, or effort may prevent firms from achieving their maximum efficiency. Also, market imperfections may hinder allocative efficiency.

### Technological Progress

If economic efficiency means that resources are used up to their maximum productive potential, technological progress means that this maximum productive potential is actually increased. Technological progress occurs as the result of two types of innovations: *process innovations* which allow each unit of output to be produced with fewer units of labor, capital, materials, etc.; and *product innovations* which improve the quality of each unit of output so as to increase its value to the customer. Thus technological progress in transportation may include innovations that make it possible to move goods and people with less labor, capital, and fuel; as well as innovations that make their movement faster or more convenient.

### Productivity

Productivity describes the effectiveness of a person or machine in accomplishing tasks. A productive person is one who can get a lot done in a short period of time. *Productivity analysis* makes the same kind of assessment concerning a firm, a sector, or even an entire national economy. This assessment is expressed by the ratio of the value of the output produced over some period to a measure of the inputs used over the same period. Comparing productivity across sectors, firms, or countries provides an indication of their relative effectiveness in production at any point in time. Since productivity is a ratio of output to input, productivity growth indicates that the level of output in the firm, sector, or economy is increasing faster than the levels of its inputs—thereby constituting a contribution to economic growth.

Since productivity growth is the most general concept related to economic performance, it is the indicator most frequently used in comparisons of performance across sectors, regions, and countries and for assessments of performance changes over time. Furthermore, to the extent that outputs and inputs may be measured accurately, productivity growth is relatively easy to calculate. By contrast, explaining variations in the rate of productivity growth in terms of trends in forces that drive efficiency improvement and technological progress is more challenging.

## Measures of Productivity Growth

Productivity has been measured in the United States since the late 19th century.[6] Until recently, nearly all analyses involved single factor (or input) productivity measurements, which took the ratio of some unit of output to the quantity of a single input (e.g., cars produced per 100 hours of labor). Most often, the input was labor (although in agriculture, land was the crucial input).

This early focus on labor reflects the orientation of classical economists, who identified labor as the key element in the creation of economic value. It was not until the early 20th century that the role of *capital* in the production system was fully appreciated. Also, changes in labor productivity—the ratio of output to labor—has an intuitive appeal, because it represents the change in the economic benefits a society enjoys from the labor it exerts. Finally, compared with capital and some other inputs, labor is relatively easy to measure.

On the other hand, measuring labor productivity has at least one serious drawback. Specifically, changes in the ratio over time may mask the substitution of capital for labor in the production process. For example, a railroad with a fixed pattern of deliveries can use a smaller number of larger trains and thus make the same deliveries with less labor (fewer trains, therefore fewer crews) and more capital (larger trains, therefore more cars). The outcome will show up as an increase in labor productivity. While this type of substitution is an important component of economic dynamics, it does not represent an improvement in performance *per se*, as it does not involve heightened efficiency or the application of new technology or labor skills. As this example proves, changes in labor productivity should not necessarily be interpreted as changes in labor skills or effort. Rather, they often arise from changes in production that are beyond the control of individual workers.

To address such substitutions of inputs, economists developed *multifactor productivity* (MFP) measures in which the labor input is replaced by an index that represents the level of two or more inputs (usually capital and labor).[7] This index is calculated by multiplying the quantity of each input by its share of the production costs and totaling the outcome across all inputs. If the substitution of other inputs for labor does not change the total cost of production, it will have no effect on the MFP value. Although economists generally prefer MFP to labor productivity as a measure of economic performance, the latter is easier to measure and continues to have a broader appeal. Thus, the Bureau of Labor Statistics publishes both types of productivity measures.[8] (See Chapter 6.) Estimates of growth in MFP are almost always lower than estimates of growth in labor productivity. This is because capital stock tends to grow more rapidly than the labor force, and because substituting capital for labor has a positive effect on labor productivity. In many industries the gap between labor productivity and MFP growth is also due to the fact that intermediate inputs (such as component parts, energy, and services) have grown more rapidly than labor inputs.

In the literature, the term *total factor productivity* (TFP) is sometimes used in place of MFP. This implies that the analysis considers all inputs in the production process, including energy and materials (as opposed to early MFP measures, which included only capital and labor). Still missing in nearly all productivity measures are unpriced environmental inputs such as clean air and water.

## Why Productivity Growth Matters

Measures of productivity growth provide a qualitative interpretation to aggregate trends. For example, when the level of labor inputs and outputs increases by 10 percent, growth occurs, but the economic performance does not improve. However, if inputs increase by 10 percent and output by 15 percent, a third of the growth is due to a rise in productivity. Here there is both growth and improved economic performance.

The tendency in developed countries is for growth in the labor force to slow over time. At the same time, the rate of growth in the use of raw materials (timber, minerals, fish); primary energy (petroleum, coal, gas); and land may also diminish as resources are depleted. Only capital has the potential for sustained growth; that growth, however, is restricted by the growth in aggregate savings. Thus, the potential for growth in outputs based solely on a growth in inputs is severely limited.

While estimates differ, most analysts agree that the extraordinary growth in the United States and other developed economies in the quarter century after World War II was due partly to exceptionally high rates of productivity growth in various sectors and in the overall economy.[9] In fact, productivity growth is the most important factor in explaining the growth in these countries in per capita incomes, household incomes, and overall economic welfare in the postwar period. For this reason, policymakers are concerned by the slowdown in the growth rates of productivity and incomes after the mid-1970s.

Productivity growth is also relevant to inflation. “Cost-push” inflation occurs when the prices of inputs (such as wages, profits, interest rates, and fuel costs) rise and, in turn, increase the cost of finished goods. However, this type of inflation can be offset by increases in productivity. Thus, if a wage hike is accompanied by an equal rise in labor productivity, labor costs per unit of output are unchanged, and there is no pressure for firms to increase output prices. The slowdown in productivity growth was therefore implicated in the high inflation rates of the 1970s.

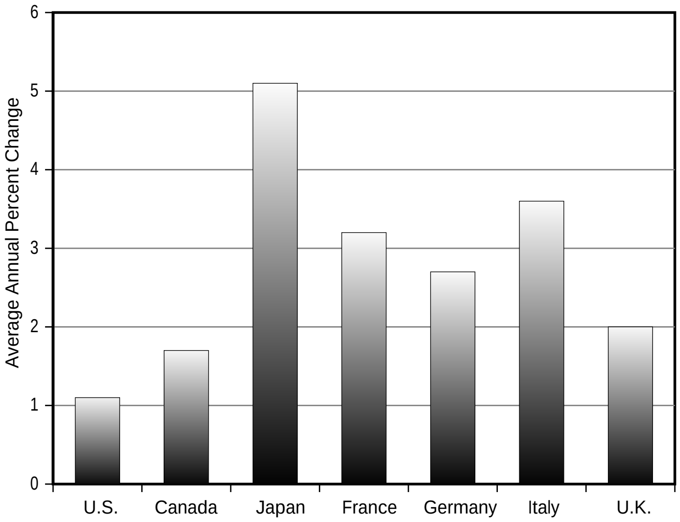
Productivity growth is crucial to a nation’s international competitiveness. If firms in two countries, one with high wages and one with low wages, produce the same product for international markets, and if the price of nonlabor inputs are the same in both countries, then the high-wage country suffers a competitive disadvantage. However, this disadvantage may be offset if the high-wage country has higher labor productivity or higher productivity in some nonlabor input. Over time, a higher than average rate of productivity growth makes it possible for a country’s firms to remain competitive without squeezing wages. (Japan is a prime example of such a country; see Figure 5–3.)[10]

Despite its significance, productivity growth should not be a society’s paramount goal, because it might be achieved —at least in the short term—by harsh or unsafe working conditions, rampant exploitation of nonrenewable resources, or levels of production that far exceed aggregate demand. Rather, productivity growth should be considered as one of many measures—including various welfare, environmental and macroeconomic measures—for assessing the overall state of the economy.

**FIGURE 5-3**

Labor Productivity Growth

**International Comparison: 1960–1991**



Source: Bureau of Labor Statistics

## Productivity Growth in the Transport Sector

To identify the major factors behind transportation sector productivity, this section presents a brief overview of the most recent Bureau of Labor Statistics (BLS) estimates of productivity trends in this sector. More complete findings appear in the next chapter.

BLS does not publish productivity measures for the transport sector as a whole; instead, it estimates labor productivity for five industries: railroads, large bus companies, trucking (large and medium firms), air transport, and petroleum pipelines. While these five provide a useful cross-section, they exclude many important elements, such as smaller trucking firms and transport provided in-house by manufacturing firms. In fact, in 1992, these five industries accounted for only 39 percent of the sector's total employment.[11] Moreover, because it is difficult to calculate MFP measures, BLS only publishes these for railroads.

Since productivity growth is relative (that is, no absolute standard exists), it is useful to compare rates of growth in transportation to those in the broader economy. From 1960 to 1989, in four of the five transport industries (all except buses), the rate of labor productivity growth exceeded that of the entire nonfarm business sector; the rate for bus carriers fell far below this.[12] (From 1973 to 1979, labor productivity growth slowed in all five industries; even so, railroads, trucking, and air all exceeded the nonfarm average growth rate.) Labor productivity for bus carriers actually declined during this period.

BLS labor productivity growth rates for transportation during the 1980s are particularly interesting. During this time, many industries—especially in manufacturing—experienced moderate to robust rebounds in productivity. Such was also the case for railroads, which showed exceptionally high labor productivity rates. However, trucking and air transport rates declined, pipelines maintained the slow growth rate of the 1970s, and bus carriers continued to go backwards, if at a somewhat slower rate.

BLS MFP growth estimates for railroads are calculated based on a combination of labor, capital, and intermediate inputs;[13] they are lower than, but roughly parallel with, the trends in railroad labor productivity growth. This implies that while substitution of other inputs for labor had an important effect on the absolute productivity growth rate, it did not determine its trends over time.[14] Indeed, the growth rate in railroad MFP during the 1980s was one of the highest for any industry measured by BLS. This high growth in railroad MFP coincided with a slow growth in overall railroad output. However, in the same period, capital and labor inputs of the industry declined—with abandonment of some unproductive lines and considerable labor shedding. Thus, rapid productivity growth in a particular sector may occur over a period of massive rationalization of that sector.

Overall, BLS productivity figures for the 1980s paint a mixed picture of economic performance in transport. High productivity growth in rail occurred during a period of decline, while trucking and air transport—which employ more people and account for ever-increasing shares of total transport, failed to rebound to their earlier levels of productivity growth in the way that many manufacturing industries did. Also, as noted above, BLS estimates apply only to a limited subset of the entire transportation sector. In trucking, for example, evidence suggests that productivity growth was slower in those parts of the industry that BLS estimates do not cover.[15]

## Factors that Propel Productivity Growth

Some of the most important factors that determine productivity growth are transport technology, innovations in logistics, regulation and deregulation, and new infrastructure.

### Transportation Technology

Improvements to vehicles and infrastructure are reflected in transport productivity measurements in various ways. In particular, labor productivity growth is affected by technological changes that reduce the labor input per ton-mile or passenger-mile of services delivered. For example, in the postwar period, technology changes in rail transport included the switch from steam to diesel locomotives (which required smaller crews); the move to automated signaling and computerized classification yards (which eliminated certain types of labor); and the introduction of rails in longer, welded sections (which reduced installation and labor requirements).[16] However, changes that conserve inputs other than labor, such as those that increase energy efficiency, are only reflected in MFP measurements. (See box on "Airline Technology.")

The rate at which technology improves depends not only on the innovations themselves but also on rates of growth and decline in transport industries. Most technical changes are embodied in some piece of capital, such as a vehicle, a unit of infrastructure, or a computer. For this reason, changes tend to occur most rapidly during periods of expansion—that is, when large investments in new capital are being made. However, technology may also improve in a declining industry, when capital stock that embodies old, inefficient technology is discarded.

## Airline Technology

Commercial airlines provide an excellent example of how improvements in vehicle technology can promote rapid productivity growth. The most important factor affecting the operating cost per seat-mile is the average distance the craft travels between takeoff and landing. Short hops lead to high operating costs because of the high fuel requirements (in takeoff and landing) and the labor and capital costs incurred while the aircraft is on the ground. Seating capacity also affects operating costs: Significant economies of scale may accrue to large planes, as they help reduce the number of crew and takeoffs per passenger. Naturally, airline routes that cater to short-distance travelers may be compensated by higher fares.

In the early days of commercial aviation, even planes on long-distance routes had to make numerous intermediate stops to refuel. But as fuel stops were reduced and the average seating capacity increased, the industry registered rapid productivity growth. This growth was achieved largely through two advances in technology: increased engine thrust, which made it possible to increase seating capacity; and increased fuel efficiency, which permitted flights to cover longer distances with a given quantity of fuel. (This also had a positive impact on labor productivity.) Airlines switched to planes featuring these improvements because their cost efficiencies exceeded their higher purchase price; thus, they replaced older planes before they reached the end of their useful lives.[17]

### Logistical Innovations

All transport firms deal with logistics—the process of moving goods or people from one place to another. However, each firm combines its resources differently to ensure that shipments and passengers get from their origins to their destinations. For example, an air courier service needs to move packages from a large number of dispersed origins to an equally large number of destinations. The quickest way to do this would be to fly each package directly from the airport nearest its origin to that nearest its destination. This method would, however, be extremely expensive as most planes would thus fly with very small loads. A cheaper alternative would be to truck packages to and from a small number of major airports. But this approach would increase the ratio of truck-miles to air-miles and slow the deliveries. Thus, air couriers have adopted a number of logistical innovations, such as the hub-and-spoke system, whereby all packages are shipped to one or two major centers, sorted, and reshipped to specific destinations. Similar innovations have been adopted in the trucking and rail industries. (See box on "Logistical Management in Railroads.")

Logistical innovations are generally facilitated by technological advances, especially advances involving the application of computers. For the most part, these innovations represent better ways to combine existing resources and lead to productivity growth through gains in efficiency.

### Regulations and Deregulation

The transportation sector's economic performance is highly influenced by government regulations. For example, govern-

## Logistical Management in Railroads

In recent years, rail carriers have adopted several innovations to move freight from origin to destination in an efficient and timely fashion, and thereby increase overall productivity.[18]

*Classification yards* are facilities located at central nodes on the rail network where trains are disassembled and their cars redistributed to new trains according to destination. For example, a train may leave Buffalo hauling cars bound for Minneapolis, St. Louis, and Denver. It enters a classification yard at Chicago, where its cars are transferred to three other trains bound for the three destinations. The efficiency of classification yards has a major impact on railroad productivity, not only because of the labor used in the reassignment of cars, but also because each hour a car or locomotive spends in a classification yard is an hour it is not moving freight. The introduction of computerized classification yards has greatly increased efficiency and boosted productivity.

Another innovation is the *unit train*, which is made up of permanently connected cars devoted to moving a single good over a fixed route. Unit trains are especially useful where there is a continuous flow of freight, such as the regular delivery of coal to an electricity generating station or of auto parts from a components plant to an assembly plant. Similarly, the *run-through train* carries various types of freight exclusively between a single pair of cities, thus eliminating the need to stop at classification yards. To ensure that a large enough number of cars achieve cost effectiveness, run-through trains are frequently operated jointly by two or more carriers.

Just as run-through trains involve cooperation among rail carriers, intermodal rail involves cooperation of rail carriers with road, air, or water carriers. For example, when a rail carrier transports freight, it may be most efficient for it to move the freight part of the way on its own facilities and then subcontract a trucking firm to move it to the final destination. Thus, intermodal transport is facilitated by equipment innovations (such as container or “piggyback” cars and machinery for rapidly transferring freight between modes), combined with complementary institutional changes (for example, in patterns of cooperation among firms)—raising productivity in the process.

ments impose speed and load limits on trucks to reduce the number of accidental deaths and injuries. While the benefits of these regulations are obvious, they also retard productivity growth. Similarly, environmental regulations have increasingly been applied to the sector. Pollution controls divert capital and research and development resources to ends that are “nonproductive”—from the perspective of standard accounting practices—and probably affect productivity growth negatively. Nonetheless, society considers such regulations clearly warranted by the greater good.

Governmental regulations can also limit the flexibility of transport firms by requiring them to provide certain types of services in some locales (while prohibiting them from providing others elsewhere) and by controlling the rates they can charge. Such regulations have long been applied to the rail, truck, and airline sectors. (See box on “Transportation Regulation and Deregulation.” ) In recent years, many of these regulations have been removed. The process of deregulation can positively affect productivity growth: For example, it may be largely responsible for the good performance of the rail sector during the 1980s.

### Public Infrastructure

The transport sector depends highly on infrastructure that is owned, operated, or regulated by various government agencies. Trucking firms absolutely depend on public roads; and airlines on state, county, and municipal governments for terminal facilities and on the federal government for air traffic control services. Inland waterway traffic depends on the system of canals, locks, dredged channels, and ports

## Transportation Regulation and Deregulation

Regulation of the transport sector dates back to the railroad regulations of the late 19th century.[19] Before this time, rail carriers routinely practiced price discrimination, charging higher rates to small shippers or shippers located on routes over which the railroads maintained monopolies. Public outcry over these practices led Congress to pass the Act to Regulate Commerce in 1887, which banned price discrimination and established the Interstate Commerce Commission (ICC), giving it power to control rates. The Hepburn Act of 1906 required oil pipeline owners to act as common carriers, thus prohibiting Standard Oil from denying service to its competitors by controlling pipeline companies.

In 1935, the Motor Carrier Act stated that no new firm could enter interstate trucking as a common carrier without federal permission. Once given approval, firms were subject to ICC regulations that affected their rates and required them to provide service along certain routes. Airlines and water carriers were subjected to similar regulatory structures by 1940. The Reed-Bulwinkle Act of 1948 permitted all land carriers to participate in rate-setting bureaus as long as they conformed to all ICC rules. Thus, the thrust of regulation was to protect transport firms from the rigors of competition. In exchange, they had to conform to regulations on rates and service.

A growing recognition that regulations were retarding efficiency and that some carriers could circumvent regulations led to deregulation of much of the industry in the 1970s. Barriers to entry in the air freight and air passenger industries were removed by legislation in 1977 and 1978, respectively, paving the way for an influx of new airlines. The Motor Carrier Act of 1980 reduced barriers to entry in interstate trucking, ended price regulation, and banned rate-setting bureaus. As a result, the number of carriers increased overall, and rates dropped. The Staggers Rail Act of 1980 liberalized—but did not completely end—price regulation, and made it easier for rail carriers to merge and drop unprofitable lines.

**TABLE 5–1**

Estimated Welfare Gains from Deregulation in the Transport Industries (billions of 1990 dollars)

| Industry | Consumers | Producers | Total |
|---|---|---|---|
| Airlines | 8.8 to 14.8 | 4.9 | 13.7 to 19.7 |
| Railroads | 7.2 to 9.7 | 3.2 | 10.4 to 12.9 |
| Trucking | 15.4 | –4.8 | 10.6 |

The gains to consumers of transport services afforded by these regulatory reforms have apparently far outweighed any corresponding losses to producers.[20] In fact, in the case of airlines and railroads, even producers appear to have benefited from deregulation, primarily due to the removal of controls over activities and prices. (See Table 5–1.)

provided by various levels of government. Even railways and pipelines, which control their own rights-of-way, pass over public land and use public bridges.

The impact of public infrastructure on transport productivity may be profound. For example, the continued expansion of the interstate and other highway systems has made trucking faster and more efficient. Thus, while highway infrastructure is not generally counted as an input to the trucking sector, its expansion helps boost trucking productivity by increasing maximum speeds and reducing congestion. In recent years, however, traffic has grown faster than infrastructure. (See box on "Highway Infrastructure and Use.") Thus, an important question is whether slower growth in infrastructure is partly responsible for slower growth in the overall economy's productivity.

## Highway Infrastructure and Use

To assess the availability of infrastructure for intercity trucking, it is useful to compare the total miles of major arterials in 1980 and 1991, along with information on their use by all vehicles.[21] (See Table 5–2.) The data indicate that the stock of highways has been growing more slowly than highway use.

**TABLE 5–2**

Use of Highway System: 1980 and 1991

| | 1980 | 1991 | % of change |
|---|---|---|---|
| **Total Highway Miles** | | | |
| Interstate | 41,216 | 45,280 | 9.9 |
| All major arterials | 174,999 | 191,072 | 9.2 |
| **Vehicle miles traveled (millions)** | | | |
| Interstate | 293,060 | 490,336 | 67.3 |
| All major arterials | 744,838 | 1,134,990 | 52.4 |
| **Truck ton-miles (millions)** | | | |
| Interstate | 555,000 | 758,000 | 36.5 |

This latter issue of the contribution of transport infrastructure to the overall economy is discussed in some detail in Chapter 7. The next section of this chapter provides some concepts and definitions key to understanding the role of transport infrastructure in economic growth as discussed in Chapter 7.

## Transportation Infrastructure and Economic Growth: Some Definitions

Transportation infrastructure includes streets and highways, bridges, railroad track, seaports, airports, and terminals. It also includes laws, ranging from regulations regarding operators, vehicles, and traffic to common law relating to transport contracts and traffic accidents. Much, but not all, of this infrastructure is publicly provided. Public transportation capital is commonly supplied under conditions in which markets function poorly, failing to give clear and accurate information to guide investments. Consequently, there is a greater chance that highway or other public capital may be either over- or under-supplied, relative to efficient quantity, than there is with private infrastructure capital, for example.

Since highways and other transportation investments tend to be large and have long life spans, the sunk costs can be large and investments risky. To reduce such risks, public investments in transportation are assessed in terms of their economic contributions at *two* levels—at the level of a specific project, or at the level of aggregate transport investments in the economy.

A specific transportation project—e.g., a 20-mile extension of the split-lane section of U.S. Highway 61 north of St. Louis, the segment of the interstate system directly linking Peoria and St. Louis, or the “Chunnel” between England and France—would be subject to a cost-benefit analysis before the decision to invest is made. In such an analysis, estimates of user benefits, based on potential users’ additional demands for transportation, are compared with costs.[22]

For a large transportation investment program that may affect aggregate output or overall productivity, analyses are based on production and cost functions. (See Chapter 7.) For example, what contribution does transportation infrastructure—more specifically, the Interstate Highway System—make to the value of national output? The *production function method* addresses this question. The *cost function method* approaches the same question from the point of view of prices: Would additions to highway infrastructure lower the cost of producing overall national output?

A production function relates physical inputs in a production process to the output of that process. The quantity of output is a function of the traditional inputs or factors of production (private capital, labor, land, and other materials), and infrastructure. Production functions specify how much increase in output should be expected from an increase in the quantity of any one input in a particular period. The statistical estimation of these functions yields results called *output elastici-*

*ties.* An output elasticity—e.g., of capital or of labor—is simply the percentage increase in output generated by a 1-percent increase in the particular input. Several studies suggest that the estimates of output elasticity of highway infrastructure in the United States are in the range of 0.03 to 0.06. The inference is that a 1-percent increase in highway infrastructure would cause U.S. gross domestic product to rise by 0.03 to 0.06 percent.

Cost functions work with input prices and total production costs (which vary with the total quantity of output produced). These say that total production costs are a function of the cost of capital, the wage rate, the prices of other inputs, the total quantity of output produced, and other influences, such as infrastructure. Empirical estimation yields elasticity of cost with respect to particular input prices. The relevant cost elasticity is the percentage by which transportation costs are reduced due to a 1-percent increase in highway infrastructure. As studies suggest a cost elasticity of –0.07, then a 1-percent increase in highway infrastructure stock would reduce highway freight costs by 0.07 percent. When this percentage is projected over a number of years in investment, it can amount to a savings of nearly 2 cents per revenue ton-mile.

## Endnotes

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6 For a brief history, see John W. Kendrick, *Understanding Productivity* (Baltimore: Johns Hopkins University Press, 1977), Chapter 3.

7 The output measure employed in calculating MFP must be appropriate to the set of inputs by which it is divided. If only capital and labor inputs are included in the denominator, the output measure should be value added rather than the full value of output. Otherwise, an increase in the value of some intermediate input might give the erroneous impression of increased productivity.

8 The Bureau of Labor Statistics first published MFP measures in 1983. See Bureau of Labor Statistics, *Trends in Multifactor Productivity*, 1948-81, Bulletin 2178 (Washington, DC: U.S. Government Printing Office, September 1983).

9 Early studies attributed about one-half of this economic growth to productivity growth. See, most notably, Robert M. Solow, “Technical Change and the Aggregate Production Function,” *Review of Economics and Statistics,* Vol. 39, No. 3 (1957): 312–20. More recent studies attribute a considerably smaller proportion to productivity growth. See Dale W. Jorgenson, “Productivity and Postwar U.S. Economic Growth,” *Journal of Economic Perspectives*, Vol. 2, No. 4 (1988): 23–41.

10 All international comparisons of productivity growth rates should be viewed with caution because they are sensitive to differences in accounting practices, the construction of deflators, and the construction of indexes.

11 John Duke, “Productivity Measures for Transportation Industries,” paper presented at the Highway-Related Transportation Industry Productivity Measures Symposium, Arlington, VA, November 20, 1992 (Washington DC: GPO, 1993).

12 The comparison is based on a figure of 1.5 percent which was based on data in Bureau of Labor Statistics, *Productivity and the Economy: A Chartbook,* Bulletin 2431 (Washington, DC: U.S. Government Printing Office, September 1993).

13 Intermediate inputs include materials, fuels, electricity, and purchased business services.

14 Duke, 1992, p. 29.

15 See Robert J. Gordon, "Productivity in the Transportation Sector," in Zvi Griliches, ed., *Output Measurement in the Service Sector*, National Bureau of Economic Research Studies in Income and Wealth, No. 56 (Chicago: University of Chicago Press, 1992).

16 See, for example, Edwin Mansfield, "Innovation and Technical Change in the Railroad Industry," in *Transportation Economics* (New York: NBER, 1965).

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18 This information is adapted from James C. Johnson and Donald F. Wood, *Contemporary Logistics,* fifth edition (New York: Macmillan, 1993), Chapter 4.

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22 R. Willig, "Consumer Surplus without Apology," *American Economic Review*, Vol. 66 (1976): 589–97; and K. Small and H. S. Rosen, "Applied Welfare Economics with Discrete Choice Models," *Econometrica*, Vol. 49 (1981): 105–30.

CHAPTER **SIX**

# PRODUCTIVITY *in the* TRANSPORTATION SECTOR: TRENDS *and* FUTURE DIRECTIONS

The transportation industry measures presented in this chapter form one part of a broad Bureau of Labor Statistics (BLS) program of productivity measurement that encompasses the following: labor and multifactor measures for major sectors of the economy; international comparisons of labor productivity in manufacturing; multifactor productivity measures for selected 3- and 4-digit Standard Industrial Classification (SIC) industries and for all 2-digit manufacturing industries; and labor productivity measures for selected federal government functions. Data sources and methods used for these programs vary. The 3- and 4-digit level industry labor productivity measures cover 178 industries in the mining, manufacturing, transportation, utility, wholesale and retail trade, financial services, and personal and business services sectors. These are annual measures and employ gross output and hours of labor input.

The labor productivity measures for major sectors of the economy (business, nonfarm business, and manufacturing) are quarterly measures based on gross product originating (value added). The multifactor measures for private business and private nonfarm business are annual measures that also use value-added output, BLS hours for labor input, and, for capital input, data obtained largely from the National Income and Product Accounts from the Bureau of Economic Analysis (BEA). The multifactor productivity measures for selected 3- and 4-digit industries and for 2-digit manufacturing industries are based on gross output (adjusted to remove intra-industry transactions), hours for labor input, and capital and intermediate inputs based on data from various sources, including the Bureau of the Census and BEA.

It is important to keep in mind that the BLS productivity measures are developed for industries as defined by the Standard Industrial Classification (SIC) system. These measures show the changes in output, input, and productivity for specific industries as defined by this system. These measures cannot, nor are they meant to, capture the changes in efficiency of the transportation system as a whole. Such changes could result, for example, from ripple effects of changes in highway construction technologies or changes in airway control technologies. The focus of these measures is confined to relations between inputs and outputs in specific industries.

## Methodology of BLS Industry Productivity Measures

BLS publishes two types of productivity measures—labor productivity and multifactor productivity. In a labor productivity measure, output is related to labor input. In a multifactor productivity measure, output is related to labor, capital, and intermediate purchases inputs combined.

The labor productivity index is derived by dividing an index of output by an index of hours. Changes in the labor productivity index reflect not only changes in productive efficiency, but also the substitution of other inputs for labor, economies of scale, and changes in skills and effort of the workforce. The multifactor productivity index reflects many of the same influences as the labor productivity measure, but changes in capital relative to labor and changes in intermediate purchases relative to labor are not reflected in this productivity measure because capital and intermediate purchases are included in the input measure. Multifactor productivity is thus closer to a measure of overall productive efficiency than is the labor productivity measure.

### Industry Output and Input

To ensure an accurate productivity measure, the measures of output and input are developed to embody certain characteristics. BLS industry output and input measures reflect, wherever possible, the following attributes:

- Gross output (or total production) as the basis for measuring output rather than value added. Gross output is preferred because the economic theory of production suggests that utilizing value added requires restrictive assumptions about the specific interactions between capital, labor, and material inputs in the production process.
- Data on outputs and inputs that relate to *all products* or services produced by *establishments classified in the industry* or sector. Using data at the establishment level allows for the development of a measure that relates only to the industry or sector desired and for the inclusion of secondary products. Less desirable company-level data can reflect production over a number of different industries or sectors.
- Output should be measured as production, rather than sales or shipments, for the time period in question (usually a year). This characteristic refers to goods-producing industries since inventories of finished output or work-in-progress are not relevant to service-producing industries.
- Data on outputs and inputs that reflect only transactions occurring between establishments inside and outside the industry or sector—not transactions among or within establishments within the industry or sector. Data sources of revenue or shipments may include intrasectoral transactions and therefore adjustments are made, where possible, to exclude this “double counting” of output. This also applies to purchases of materials inputs when a multifactor measure is being developed.
- Quality increases (decreases) should be reflected as more (less) output or input.
- Data on outputs and inputs should be collected in the finest possible detail so that only those making identical contributions to revenue are directly added together—those making varying contributions must be aggregated with appropriate weights.

In general, a measure of output is derived by aggregating the quantities of each product or service produced with weights that reflect contributions to revenue of each product or service. For this purpose, BLS uses a Tornqvist index. Values of production can be used in place of quantities. In this case, the price change over time must be removed from the value of production by dividing the value of each product by an appropriate price index. Quality change needs to be accounted for where possible. This is accomplished most easily when the price index for a product or service has been adjusted for changes in quality. If that is done, quality changes are appropriately reflected in output when the value of production is divided by its price index.

### Measuring Output

Measuring output in nongoods-producing industries is often very difficult. In many cases, it is difficult even to derive an accurate concept of what services are being produced, let alone determine exactly how to quantify them. However, the transportation sector does not pose the more extreme problems of output definition that some other services do. In transportation industries, the ton-mile provides a good approach to output measurement. That is, the basic unit of output is a ton of goods moved a distance of one mile. (See Rough Measures of Transportation Outputs box.) To be sure, not all ton-miles are alike. Characteristics such as special handling, need for refrigeration, load size, and length of haul affect the cost of service and thus need to be treated as heterogeneous services requiring aggregation with appropriate weights. Unfortunately, data are not collected on all appropriate service characteristics and measures must be based on the best available detail.

As an example, the output indices for the BLS measures of labor productivity and multifactor productivity in railroad transportation take into account the heterogeneity of the loads that are hauled. In particular, the output indices reflect changes over time in the mix of the commodities being transported. Freight revenue by detailed commodity is used to calculate weights. Items which bring in more revenue to the railroads per ton, such as automobiles, are given a relatively larger weight than items which generate less revenue per ton, such as coal, because higher-revenue freight requires more service—in terms of special handling and so forth—than lower-revenue freight does. (See Appendix at the end of this chapter.) The purpose of this type of weighting is to develop a better measure of the service actually produced by the railroad transportation industry, compared to a simple aggregation of ton-miles. Through the weighting process, some important aspects of quality improvement or deterioration should be captured.

### Measuring Input

For industry labor productivity measures, the input measure is an index of labor input. Labor input is represented by the total amount of hours worked. However, often only the hours-paid data, which includes hours that the employee is on vacation or sick leave, are available. Employee hours are treated as homogeneous and additive with no distinction made between hours of different groups of employees. Thus, changes in the qualitative aspects of employment such as skill and experience are not reflected in the employee hours index. For industries for which there are no good data on average hours

## Rough Measures of Transportation Outputs

Transportation involves the movement of goods or people from one physical location to another. The basic unit of measurement for the output of transportation industries is thus the ton-mile (a ton of goods moved one mile) or the passenger-mile. Different service characteristics make ton-miles (or passenger-miles) heterogeneous outputs that should be aggregated with appropriate weights rather than added directly. BLS attempts to incorporate this weighting by service characteristics to the greatest extent feasible, given the raw data available.

The table below shows unweighted total ton-miles and passenger-miles of output in 1991. These are rough indicators of the output levels in the five transportation industries for which BLS publishes productivity measures.

| | **Ton-miles (millions)** | **Passenger-miles (millions)** |
|---|---|---|
| Railroads | 1,038,875 | 6,274 |
| Bus carriers | Not available | 23,500 |
| Intercity trucking | 758,000 | Not applicable |
| Air transportation | 8,858 | 338,085 |
| Petroleum pipelines | 578,000 | Not applicable |

per worker, labor input is represented by an index of the number of employees.

For industry multifactor productivity measures, the input measure includes a weighted aggregate of labor, capital, and intermediate-purchases inputs. A Tornqvist index is used in aggregating these inputs. A broad definition of capital input, including equipment, structures, land, and inventories, is used to measure the flow of services derived from the stock of physical assets. Financial assets are not included.

### Productivity Measurements

For productivity measurement, the appropriate concept of capital is "productive" capital stock, which represents the stock used to produce the capital services employed in current production. To measure the productive stock, it is necessary to take account of the loss of efficiency of each asset as it ages. That is, assets of different vintages have to be aggregated with different weights. In combining the various types of capital stock, the weights applied are based on estimated and implicit rental prices of each type of asset. These prices reflect the implicit rate of return to capital, the rate of depreciation, capital gains, and taxes.

Intermediate purchases include materials, fuels, electricity, and purchased business services. The values of the various intermediate purchases are deflated with appropriate price indices to derive real (constant dollar) costs. Materials measured in real terms refer to items consumed or put into production during the year. Freight charges and other direct charges incurred by the establishment in acquiring these materials are also included. The data from which the intermediate inputs are derived include all purchased materials and fuels regardless of whether they were purchased by the individual establishment from other companies, transferred to it from other establishments of the same company, or withdrawn from inventory during the year.

Annual estimates of the cost of services purchased from other business firms are also required for multifactor productivity measurement in a total output framework. Some examples of services are legal services, communications services, and repair of machinery. An estimate of the real cost of these services is included in the intermediate purchases input.

TABLE 6–1

Labor Productivity Trends in Transportation Industries (Percent per Year)

| Industry | 1958–92 | 1990–92 |
|---|---|---|
| Railroads | 5.9 | 7.0 |
| Bus Carriers* | 0.0 | N/A |
| Intercity Trucking* | 2.9 | N/A |
| Air Transportation | 4.4 | 2.5 |
| Petroleum Pipelines | 4.1 | –2.1 |

* These measures extend only to 1989 N/A= Not Available

## Productivity Trends in Transportation Industries

### Long-term Trends in Labor Productivity

BLS publishes labor productivity measures for five transportation industries: railroad transportation (Class I); bus carriers (Class I and Class II); trucking, except local (Class I and Class II); air transportation, and petroleum pipelines. (See Table 6–1.) These industries comprise 39 percent, in terms of employment, of the total transportation sector. These industries covered over 50 percent of total transportation employment in 1980, but since that time some of the covered industries have had sharp declines in employment. In railroad transportation, for example, employment dropped from 480,000 in 1980 to 225,000 in 1992. At the same time, some of the uncovered industries have had substantial gains in employment. In transportation services, SIC 47, employment rose from 198,000 in 1980 to 348,000 in 1992.

Over the long-term period from 1958 to 1992, labor-productivity growth in the five transportation industries showed a wide dispersion, ranging from no growth, on average, for bus carriers, to a rate of 5.9 percent per year for railroad transportation. (See Figure 6–1.) Trucking, except local, posted productivity gains averaging 2.9 percent per year. (The measures for bus carriers and trucking, except local, extend only through 1989. Problems with the coverage of the output data have led BLS to

**FIGURE 6–1**

Labor Productivity Trends in Transportation Industries: 1958–1992

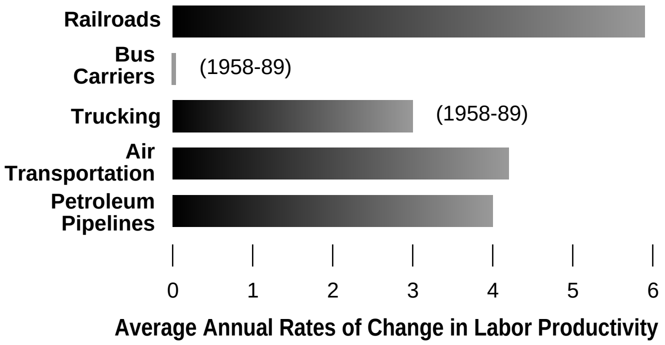


**TABLE 6–2**

Labor Productivity Slowdown in Transportation Industries (Percent per Year)

| Industry | 1960–90 | 1960–73 | 1973–79 | 1979–90 |
|---|---|---|---|---|
| Railroads | 5.9 | 6.0 | 1.4 | 8.3 |
| Bus Carriers * | 0.0 | 0.8 | –1.3 | –0.3 |
| Intercity Trucking * | 2.9 | 2.9 | 3.2 | 2.7 |
| Air Transportation | 4.6 | 7.3 | 4.8 | 1.3 |
| Petroleum Pipelines | 4.1 | 8.8 | 0.6 | 0.6 |

* These measures extend only to 1989

stop publishing results for these two industries since then.)

Air transportation and petroleum pipelines showed increases of 4.4 percent and 4.1 percent per year on average over the 1958–92 period. Of the 145 nonduplicated industries for which BLS publishes labor productivity measures, 79 begin with data in 1958 or earlier. Of these 79 industries, railroad transportation had the second highest average productivity growth since that year. Air transportation had the eighth highest rate and petroleum pipelines had the eleventh highest average annual increase. Trucking growth rate ranked near the middle, at 32. Bus carriers, with its zero average growth, was next to last among the 79 industries. It should be emphasized that the 145 nonduplicated industries for which BLS has developed labor productivity measures (and the 79 cited as beginning on or before 1958) are not necessarily a representative sample of all industries.

## Transportation Industries and the Productivity Slowdown

A slowdown in the growth rate of labor productivity in the private nonfarm business sector began in the early 1970s. From 1948 to 1973, labor productivity growth averaged 2.9 percent. The rate slowed to 1.0 percent per year during the 1973–79 period. From 1979 to 1990, it remained at 1.0 percent. Four of the five transportation industries for which BLS publishes measures also exhibited a post-1973 slowdown. (See Table 6–2.) From 1960 to 1990, productivity growth ranged from an average annual rate of 5.9 percent for railroad transportation to 0.0 percent for bus carriers.

Trucking productivity gained 2.9 percent per year on average over this period, while air transportation productivity rose at a 4.6 percent annual rate. Productivity in petroleum pipelines increased 4.1 percent per year on average. In railroad transportation, productivity growth slowed from an average annual rate of 6.0 percent in the 1960-73 period to 1.4 percent in the 1973–79 period. Bus carriers' productivity fell off from a gain of 0.8 percent per year on average in the earlier period to an average decline of 1.3 percent per year in the 1973–79 period. Productivity growth in intercity trucking actually accelerated slightly from a 2.9 percent per year rise from 1960 to 1973 to a gain of 3.2 percent per year in the 1973-79 period. Air transportation's productivity growth slowed from a robust 7.3 percent in the earlier period to a still strong 4.8 percent in the later time frame. The very strong 8.8 percent average annual productivity growth for petroleum pipelines slowed sharply to only 0.6 percent from the earlier to the later period. The rate for private nonfarm business, by comparison, slowed from 1.9 percent per year in the 1960–73 period to 1.0 percent per year in the 1973–79 period.

During the 1979–90 period, a time when many industries experienced rebounding productivity growth (although the private nonfarm business sector as a whole remained at the same rate as in the

1973–79 period), the record of productivity growth was mixed for transportation industries. In railroad transportation, productivity rebounded sharply, averaging a 8.3 percent annual gain from 1979 to 1990. This performance was aided by efficiencies realized in rail mergers spurred by the Staggers Rail Act of 1980 as well as by technological improvements. (See Railroad Productivity box.) In bus transportation, productivity performance improved in the 1979-89 period from the 1.3 percent decline of the 1973-79 period, but was still negative, at a 0.3 percent average annual decline. Trucking, which had not experienced any slowdown in the 1973–79 period, saw productivity gains slow somewhat after 1979, from the 3.2 percent average annual gain in the 1973–79 period to 2.7 percent per year for the 1979-89 period. Productivity growth in air transportation, which had slowed in the second period, fell off even further after 1979 to an average annual increase of 1.3 percent. Petroleum pipelines showed no change in its growth rate from the 1973–79 period, rising at a rate of 0.6 percent per year in the 1979–90 period as well.

## Railroad Productivity

Productivity growth has been quite rapid in the railroad transportation industry. Over the 1958-91 period, labor productivity grew at an average annual rate of 5.8 percent and multifactor productivity increased by 3.9 percent per year. This growth has come largely from deregulation of the industry and from technological improvements. Prior to deregulation resulting from the Staggers Rail Act of 1980, regulatory practices made it difficult for railroads to abandon uneconomic lines or merge with other railroad companies.

Increased competition from other modes of transportation and a shift of transportation centers from urban to suburban areas made some rail lines unprofitable to operate. The Staggers Act allowed greater flexibility in adjusting shipping rates to meet costs, more freedom for railroads to merge, abandon unprofitable sections of track, and coordinate transportation with other carriers.

Technological improvements have aided productivity in railroads also. Improvements in capital such as the increased use of computers for dispatching and traffic control, larger freight cars, computerized locomotives, and more efficient maintenance-of-way equipment have boosted the capital-labor ratio and increased labor productivity. Improvements such as the emergence of the “cabooseless” train and the double-stacking of containers have increased the overall efficiency of operations.

### Multifactor and Labor Productivity in Railroads

BLS has published multifactor productivity measures for seven industries to date at the 3- and 4-digit SIC level. One of these measures covers the railroad transportation industry. Over the whole 1958 to 1991 period, multifactor productivity in this industry increased at a strong 3.9 percent average annual rate. (See Table 6-3.) This was by far the most rapid long-term growth rate of the seven published 3 or 4-digit industries. The next highest was the tires and inner tubes industry at 2.3 percent. BLS also produces multifactor productivity measures for all 2-digit SIC manufacturing industries. Of these 20 industry groups, the highest multifactor productivity growth rate over the 1958–91 period was recorded by the electrical and electronic equipment industry group (SIC 36) at 2.7 percent, substantially less than the rate for railroads.

Labor productivity grew in the railroad transportation industry by an average rate of 5.8 percent per year over the 1958–91 period. As mentioned above, multifactor productivity grew at an average rate of 3.9 percent over those years. The difference between the growth rates of labor productivity and multifactor productivity are accounted for by the effects of changes in

TABLE 6–3

Multifactor Productivity and Related Measures in Railroad Transportation (Percent per Year)

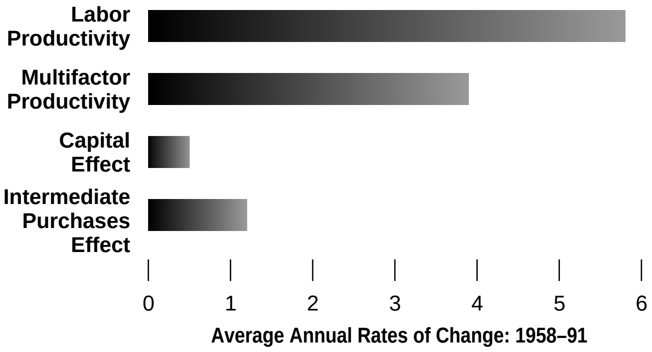
| | 1958–91 | 1990–91 |
|---|---|---|
| Labor Productivity | 5.8 | 7.5 |
| Multifactor Productivity | 3.9 | 3.3 |
| Capital Effect | 0.5 | 1.2 |
| Intermediate Purchases Effect | 1.3 | 2.9 |

capital relative to labor and intermediate purchases relative to labor. (See Figure 6–2.) The capital effect is measured by multiplying the change in the capital-labor ratio by capital's share in the total cost of output. Similarly, the effect of intermediate purchases is measured by multiplying the change in the intermediate purchases-labor ratio by the share of intermediate purchases in total cost. The capital effect grew by 0.5 percent per year on average over the 1958-91 period in railroad transportation. The intermediate purchases effect increased at a 1.3 percent annual rate. Thus, of the 5.8 percent growth rate in labor productivity for railroads, 1.8 percent occurred because capital and intermediate purchases were growing faster than labor input over the period. The rest of the 5.8 percent growth was due to growth in multifactor productivity, which includes changes in overall efficiency as well as other factors such as changes in economies of scale and skill and effort of the workforce.

Multifactor productivity growth averaged 4.8 percent per year during the period from 1979 to 1989 in railroad transportation. Strong gains concentrated in the mid-1980s were spurred by the deregulation brought about by the Staggers Rail Act of 1980. This legislation allowed railroads greater flexibility in adjusting shipping rates to meet costs, greater freedom to arrange mergers, abandon unprofitable sections of track, and coordinate transportation with other carriers such as trucking and barge lines. Technological innovations such as increased use of computers for dispatching and traffic control also helped.

**FIGURE 6–2**

Railroad Transportation



Multifactor productivity gains have moderated somewhat in recent years, at 3.6 percent and 3.3 percent in 1990 and 1991 respectively but are still strong by comparison with other industries.

## Labor Productivity: Buses, Trucking, Air, and Pipelines

For the other four transportation industries for which BLS publishes productivity measures—bus carriers, trucking except local, air transportation, and petroleum pipelines—only labor productivity measures have been developed to date. The measure for bus carriers extends back to 1954. Labor productivity grew at an average annual rate of 2.4 percent from 1954 to 1966, but declined in 15 of the 23 years since then. Since 1966, labor productivity has fallen at an average rate of 1.0 percent per year. During that time, output averaged a decline of 2.8 percent per year while employee hours dropped. However, the average decline in employee hours was only 1.9 percent per year, resulting in the productivity decrease.

Labor productivity in trucking, except local, the measure for which also begins in 1954, has shown substantial growth over the whole period, averaging 2.8 percent from 1954 to 1989. Although there have been cyclical swings in productivity in this industry, with gains as large as 21.4 percent in 1983 and declines as large as 7.6 percent in 1980, the underlying trend rate for most subperiods has remained near the long-term rate. After a decline in 1985 of 3.6 percent, gains ranging from 3.2 to 5.2 percent have been realized from 1986 through 1989.

The labor productivity measure for air transportation, which extends back to 1947, showed a well-above-average growth rate of 5.6 percent for the whole 1947–92 period. Over the first 20 years, from 1947 to 1967, productivity growth was very strong at an average rate of 8.8 percent per year. From 1967 to 1992, growth averaged a much more moderate 3.0 percent per year. Uninterrupted annual gains in productivity were recorded in this industry right up until 1980 and 1981, when the first declines since 1947 were registered (decreases of 6.2 percent and 1.1 percent respectively). Robust gains returned during the 1981–87 period (averaging 5.6 percent annually), followed by three consecutive declines of about 3.5 percent each in 1988, 1989 and 1990. Labor productivity gains returned in 1991 (1.5 percent) and 1992 (3.5 percent).

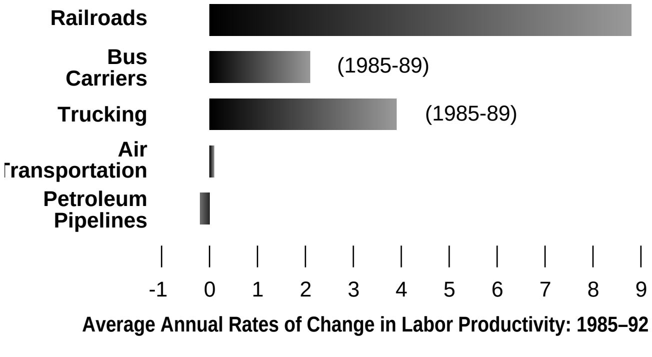
The labor productivity measure for petroleum pipelines begins in 1958 and, as mentioned earlier, showed a growth rate of 4.1 percent on average over the 1958–92 period. Productivity grew at an average annual rate of 9.2 percent from 1958 to 1973. Since 1973, productivity growth slowed sharply to 0.3 percent per year. Steep declines of 8.5 percent and 7.6 percent in 1980 and 1981 significantly influenced this falloff, but the slowdown has been persistent with only one year's gain in the post-1973 period—a 10.8 percent jump in 1984—exceeding the 1958–73 average. Decreases have been recorded in nine of the 19 years from 1973 to 1992.

### Recent Trends in Labor Productivity

Trends in labor productivity since 1985 have shown an even wider dispersion for the transportation industries than the long-term rates discussed earlier. (See Figure 6–3.) Of the 145 nonduplicated industries for which BLS published labor productivity measures, 93 have been updated through 1992. Of these 93, railroad transportation had the highest growth rate during the 1985-92 period at 8.7 percent per year. On the other hand, petroleum pipelines ranked number 81 with an average decline of 0.2 percent in that period. Air transportation, with an average gain of only 0.1 percent, ranked 80th. Trucking and bus carriers had average gains of 3.9 and 2.1 percent, respectively. However, these rates are for the 1985–89 period and are not directly comparable to those of other industries for the period being examined.

**FIGURE 6–3**

Recent Trends in Transportation Industries



## Summary

The Bureau of Labor Statistics publishes annual measures of labor productivity for five transportation industries, which cover 39 percent of employment in the transportation sector. Over the long term, productivity growth has varied widely in the measured industries of the sector, ranging from a high of 5.9 percent per year on average for railroad transportation to a low of 0.0 percent for bus carriers. The remaining industries recorded sizable long-run average annual rates of growth in labor productivity: 2.9 percent in trucking; 4.1 percent in petroleum pipelines; and 4.4 percent in air transportation. (The long-run rates for buses and trucking refer to 1958-89, while the others are for 1958–92.) In recent years, the railroad industry has continued to experience strong productivity growth, while two other industries which have done well in the long run—air transportation and petroleum pipelines—have seen productivity growth hover around zero lately. In addition, a multifactor productivity statistic is published annually for railroad transportation; this measure has increased rapidly over both the long and the short terms.

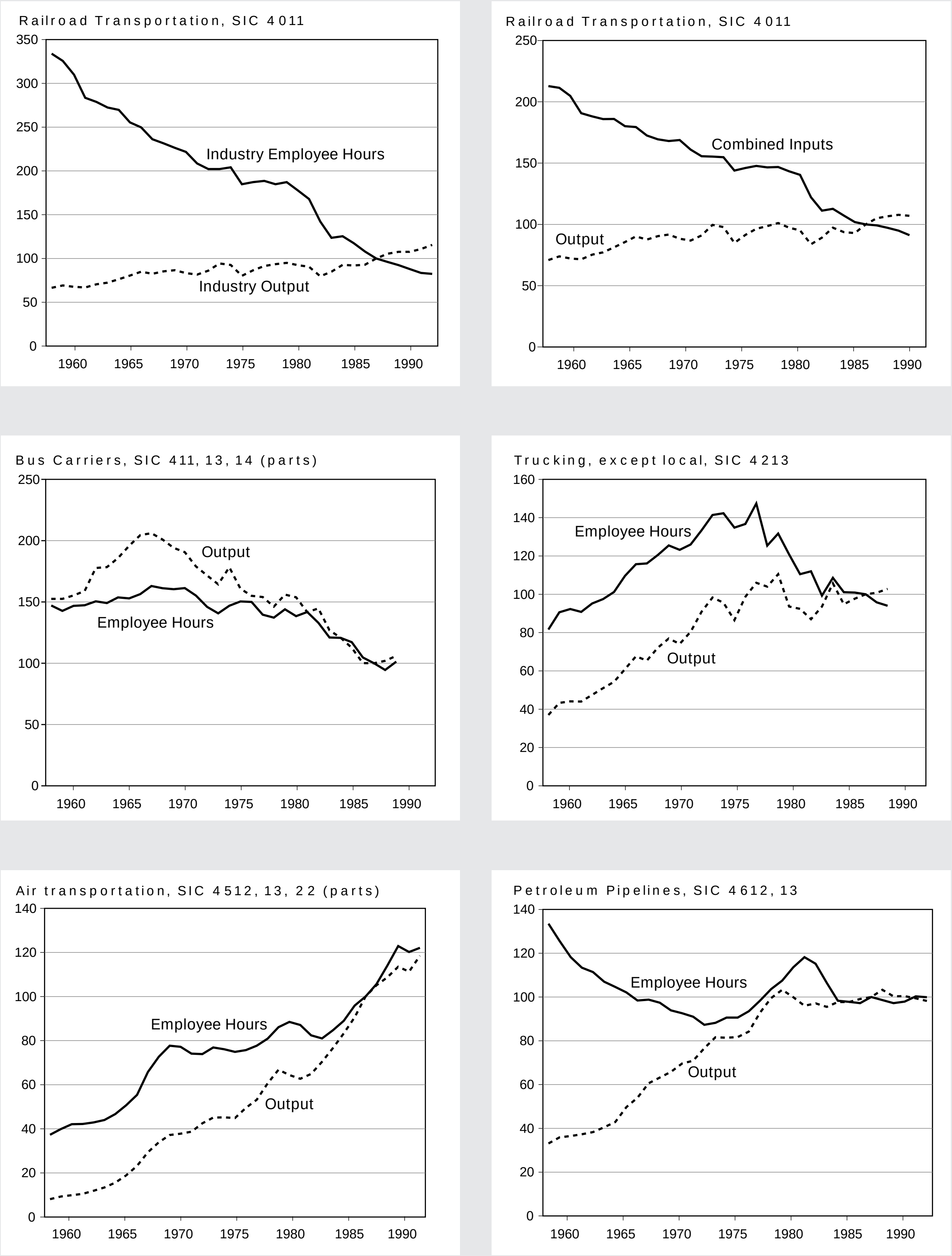
Another way of examining recent trends is to decompose the components of the trends in the productivity index — namely trends in output and labor inputs (Figure 6–4). These trends suggest the following inferences:

- the different transport sectors display a pretty diverse pattern of changes over time in the quantity of inputs and outputs;
- comparable trends among the sectors in the productivity index can result from quite different patterns of change in the labor or capital inputs or outputs.

Air transportation and trucking are growth industries with comparable patterns of both outputs and employment growing over time; On the other hand, in the railroad industry, there has been a modest

**FIGURE 6–4**

Trends of Transportation Productivity by Mode: 1958–1992



growth in output, but a very sharp drop in employment over the last three decades; Bus carriers are a declining industry displaying a persistent decline in output and employment over two decades; Pipelines exhibit a more complex pattern with more or less stagnant output and labor.

These different change patterns provide insights on the varying productivity trends among the sectors. The remarkable growth of railroad productivity appears to derive from a rationalizing industry, which is shedding labor, capital (lines and equipment), and other inputs in the context of slow output growth. Major railroads have reduced unnecessary labor and low density lines. Reductions in the number of carrier-owned freight cars have been largely off-set by increases in shipper-owned cars. Air transportation represents a typical growth situation—outputs and labor growing lock-step. The productivity at any moment is a reflection of whether hiring leads or lags output. Trucking is another growth sector with output and labor use running in parallel (with great sensitivity to the business cycle) to the time of deregulation, after which employment adjusts closely to the output index. Bus carriers are in a spiral of decline in the last two decades, adjusting their labor use to the declining demand for their services.

## Future Directions in Transport Productivity Analysis

Bureau of Labor Statistics estimates of productivity growth offer a consistent historical series of precise measures for several key transport industries. They also have the advantage of being organized around the SIC industrial classification system, which makes them consistent with data collected by other federal agencies. But because they were designed to address specific issues, there are some important areas that these estimates do not cover. For example, estimates apply only to industries in certain segments of the transport sector; but, many manufacturing and retailing firms deliver goods with their own trucks rather than contract with a transport firm. As such, these services are not recorded in official statistics because they do not involve transactions between firms. Thus, economic performance in this kind of trucking has not been included. Also, the absence of data inhibits efforts to adequately adjust for changes in the quality of inputs and outputs in constructing productivity growth series.

Moreover, no single analytical framework can address all the conceptual issues related to economic performance. The framework and methods most frequently used for productivity analysis have evolved over several decades, incorporating refinements in data collection, applying economic theory, and calculating index numbers. As analytical techniques have been standardized, series can be constructed that are consistent and comparable for different industries over different periods, and even for different countries.

Recent social, economic, and political changes have raised issues that these conventional methods are less suited to address. These involve

- *Compositional* changes in the American economy, especially the growing importance of service industries;
- *Institutional* changes, which include reduced economic regulation and environmental controls;
- *Technological* changes, which have affected the demands that goods-producing industries place on transport services; and
- The increasing pressures on *public transport infrastructure.*

Productivity analysts, including those at BLS, have enhanced their methods to better address some of these changes—the application of index numbers has been especially helpful—but new analytical frameworks may be needed that will allow the changing economic environment to be more fully taken into account when evaluating transport performance.

This chapter reviews the current data and methods employed in productivity analyses as they apply to transportation. In this process it identifies various ways in which the Bureau of Transportation Statistics can, through its data collection and research efforts, contribute to the transportation productivity analysis work of BLS and other government agencies and academia.

## Measuring Service Sector Productivity

The increasing role of service industries in the U.S. economy (see Figure 6–5) is a trend that poses interesting challenges for productivity analysis. Both conceptually and operationally, conventional productivity measures (which involve measuring outputs and inputs and combining these measures into indices) are easier to apply to the resource and manufacturing sectors than to the service industries. (See Table 6–4.)

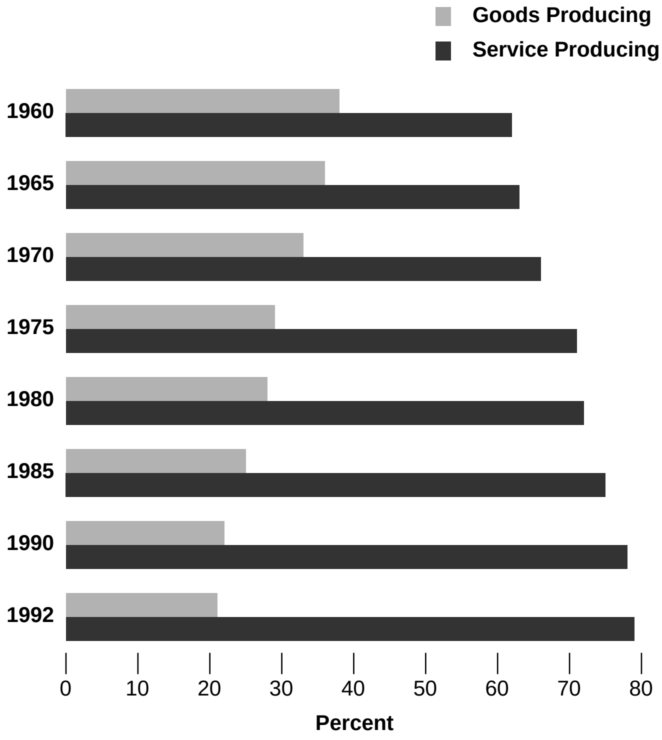
### *Measuring Outputs*

It is generally more difficult to measure the output of firms that produce services than those that produce goods. For example, farm outputs are measured in units of physical commodities—such as bushels of wheat, pounds of pork, or gallons of milk. Measuring the output of an automobile assembly plant may be a bit more complicated, because the unit of output (a car) is less homogeneous, but—with some adjustment for changes in quality—a consistent output series can be constructed.

On the other hand, how should the output of a doctor be measured? Should it be defined in terms of number of patients seen? If so, doctors who give bad advice are as productive as those who give good advice. An alternative might be some measure of patient health. But then doctors who treat young, healthy populations would appear to be more productive than those who treat the elderly or other groups at greater risk.

**FIGURE 6–5**

Percent Distribution of Nonfarm Employment



The example of doctors is extreme, but the problem of defining output pervades productivity analysis throughout the service sector, including banking, insurance, education, producer services, and transportation. The impact of this problem is enormous. Much of the recent slowing in productivity growth is often attributed to

**TABLE 6–4**

Problems of Measuring Outputs and Inputs in the Transportation Sector

| Variable | Problem | Research Direction |
|---|---|---|
| Output | throughput measures (e.g. ton-miles) fail to take account of changes in service quality | • disaggregate output by type of service and calculate index<br>• adopt outcomes rather than transactions based throughput measures<br>• credit transportation industries with some portion of productivity growth in client industries |
| Labor Input | hours worked fail to take account of change in skills levels | • dissagregate labor input data by skills or occupational category |
| Capital Input | book value of assets fails to represent technological progress embodied in capital stock | • disaggregate capital by age and adjust efficiency<br>• deflate investment data by price indices that separate affect of technological improvement from inflation |

shifts in employment from manufacturing to services, which, by available measures, appear to have lower productivity. But if this slowing is instead due to analysts' inability to measure service sector output effectively, much of the productivity slowdown may be more apparent than real.[1]

With respect to transport, throughput (output) indicators such as ton-miles, passenger-miles, and barrel-miles—the indicators on which BLS productivity studies are based—may not adequately measure the level and quality of transport services produced for several reasons, including the following.

*Circuity.* Passenger airlines serve customers by moving them from one point to another. They can be flown directly from the point of origin to destination, or in a circuitous route with one or more stops along the way. Based on a measure of passenger-miles, airlines will produce more apparent output in the latter case, because the passengers covered more distance. However, they received no more real service and, in fact, were inconvenienced by the extra time.[2]

*"Dematerialization" of the American economy.* Earlier in the century, freight transport was dominated by bulky materials such as coal, ores, and grains; and the aggregate number of ton-miles was a good indicator of the output of transport services. However, in recent decades, bulk materials have given way to freight with higher value per unit weight, such as perishables, components, and consumer goods. And, since these materials require very different types of services—defined in terms of speed, terminal activities, and vehicle technologies—using a ton as the unit by which to measure freight has less meaning.

*Time.* Even if number of ton-miles were an adequate output measure, it tells us nothing about the *timeliness* of shipments. In recent years, many trucking firms have invested in computer tracking systems that let them schedule shipments for precise times and immediately locate and expedite shipments that fall behind schedule.[3] These improvements support a shift to "just-in-time" (JIT) inventory systems, which in turn can greatly increase manufacturing productivity. Thus, manufacturers would be willing to pay more for the services of trucking firms that use these systems. This increase in output, however, is not reflected in the ton-miles measure. In fact, since these tracking systems require expenditures of capital and labor, they may actually *decrease* the value of labor productivity and multifactor productivity (MFP) measures of the transport sectors. Thus, product innovations are hard to capture in conventional productivity analysis.

An alternative to throughput measures is taking the deflated value of the transport firm's revenue as a measure of output. However, if a simple deflator based on changes in the cost per ton-mile, passenger-mile, or barrel-mile is used, the outcome is the same—that is, the output measure fails to reflect *qualitative* changes in services. This problem could be corrected by constructing a deflator that would exclude price increases caused by improvements in the quality of output. In theory, such a deflator could be based on *hedonic price regressions*, which break down prices into components due to factors such as distance, time, reliability, etc.[4] In practice, this is difficult. Prices reflect complex factors, such as competitive forces and regulations, that are difficult to disentangle. Further, some quality changes may appear to be "costless" because they occur over a period of declining prices (e.g., the dramatic increase in processing speed of microcomputers over the past decade).

Such problems of output measures based on throughput or revenue arise because of an inability to account for qualitative (as opposed to quantitative) changes in output levels. One solution is to use index numbers that partly alleviate the biases these measures impose.

Another option is to measure *outcomes*. In the literature on measuring output in the service sector, a distinction is made between indicators that measure *transactions* and those that measure *outcomes*.[5] For example, for doctors, the number of patients seen is a transactions measure, while the state of their health is an outcomes measure. An outcome measure for the output of the educational sector can be derived by relating years of schooling to lifetime employment income—thus defining the output of education in terms of increased earnings potential.[6]

Ton-miles, passenger-miles, and barrel-miles are best described as transaction measures of output. But, if the function of passenger transport is *mobility* for individuals, it might be measured better by the number of opportunities a person has to get from one place to another.[7] Thus, the number of *flights*, rather than the number of people who fly on them (which is what is measured in air passenger-miles), is relevant.

For freight services, which give access to raw materials and components *where* and *when* manufacturers need them, an outcome measure might be the ratio of inventory to monthly sales in manufacturing.[8] Since fast and reliable freight service allows firms to reduce inventories, transport service outcome is inversely proportional to this ratio.

While outcomes measures are intuitively appealing, they have a number of practical limitations. Each outcome measure has its problems. In the short run, airline competition might cause an excessive number of flights to be offered on certain routes, which should not be counted as increased productivity. Also, the business cycle could affect inventories for reasons that have nothing to do with the quality of freight services. In general, compared with transactions measures, outcomes measures are vulnerable to the effects of subjectivity on their interpretation—that is, different observers may disagree over what represent desirable outcomes. The economic theory on which productivity, at least as it applies to the goods producing sectors, is based is more consistent with transactions measures, so it is questionable whether methodological advances such as the use of index numbers could be correctly applied to outcomes measures of output. Since transportation is a derived demand, however, the theoretical preference for transaction measures and outcome measures is less clear.

Given the practical limitations of outcomes measures, the BLS has maintained the policy of basing their productivity analysis program on transactions measures of output. Still, some experimentation with outcomes measures may be useful to see whether they can broaden the scope of our assessment of economic performance in service sectors such as transportation.

### *Measuring Inputs*

A key problem when measuring inputs is that variations in quality are difficult to assess. This is especially true of labor, which is normally measured as the number of hours worked. If data are available, hours can be broken down into categories according to workers' skill levels and combined to create an index that adjusts for quality of labor changes over time. However, with the data available for transport industries, there is little breakdown into labor categories.[9]

For example, if a firm dismisses clerks and hires engineers, the latter might be expected to contribute more to output than the former. It would not be economically rational for the firm to pay the higher salaries of engineers if this were not the case. As a result, the firm's labor productivity, defined as output over labor hours, will rise. However, no individual worker will necessarily become more productive as a result of the change. In fact, these engineers might have been transferred from another firm where their productivity might have been even higher. Also, since engineers would normally be hired to work with more sophisticated machinery than clerks, hiring them could be accompanied by substantial capital upgrading. This added expense would not be reflected in the labor productivity measure.

The problem of quality variations in capital is even more onerous because in most sectors, data are insufficient to measure capital directly in terms of physical units. Thus, the only alternative is to measure capital in dollar terms by calculating the real value of investment in the industry over a number of periods to arrive at a measure of net capital stock.[10] The problem here is that the deflated value of capital investments does not necessarily reflect changes in quality over time—$1 million in new machinery may be a qualitatively different input than $1 million of old machinery. The problem, once again, is to separate price changes due to quality changes from those that are simply inflationary—a major analytical undertaking.[11]

An additional problem is that nearly all capital measures indicate the amount of capital *owned* by firms in the industry, rather than that *used* in production. Some part of owned capital is generally idle because of insufficient demand; this is especially true during recessions. Decreases in idle capacity need to be recognized as efficiency improvements that contribute to productivity growth. However, some economists prefer to define productivity in terms of levels of capital-service provision as opposed to capital stock, in which case an adjustment for capacity utilization is needed.[12] This problem is especially difficult in transport industries, because the fact that a vehicle is "in use" is not sufficient information to measure its contribution to capital services. For example, once an airline purchases a plane, its level of capital service can vary through time because of changes in its load factor, seating density, and the number of hours it flies per week.[13] (To address this problem, BLS has adopted an implicit adjustment for capacity utilization. Actual returns to capital, which are affected by capacity utilization, are used as the price of capital in the MFP calculations.)

A conceptual problem arises with changes in the quality of capital stock. If an airplane manufacturer introduces a jet that is faster and more fuel efficient and can operate safely with a smaller crew, and capital input is measured simply in terms of number of planes of various sizes, then the purchase of the jet will increase MFP in the airline industry. The question is whether this should be viewed as an increase in the performance of the airlines or that of airplane manufacturers. If the latter, deflators must be constructed to ensure that the jet's technological improvements are reflected as an increase in the manufacturer's output and the airline's capital input.[14] (This is an effect which can be typically captured in MFP measures but not in labor productivity measures.)

By the same logic, if part of gross productivity growth in transport is to be credited to the vehicle manufacturing sector, part of the growth in sectors that consume transport services should also be credited to the transport sector. For example, if the automotive sector's productivity growth is accelerated by a move to JIT inventories, and if this is made possible by improved service from trucking or rail firms, then part of that productivity growth should be credited to the transport sector.[15] Also, if faster air service allows a firm's sales force to spend less time flying and more time on the ground selling, some part of their increased productivity should be attributed to the airlines. To illustrate the magnitude of this effect, a recent study estimated that an air trip that took almost 5 hours in 1954 only took about 2 hours in 1989. Multiplying the total time saved by all travelers in the United States because of this speedup by an estimate of the value of travelers' time yielded a value for time saved of $51.7 billion, or 116 percent of domestic airline passenger revenue in 1989.[16]

An even more basic problem when measuring capital input in productivity analyses is that it is generally limited to private capital, and transport industries depend greatly on public infrastructure. Thus, an exclusive focus on private capital would lead to inconsistencies in measures of MFP growth across transport industries. In the case of railroads, track, bridges, signals, and rights-of-way are counted as capital for BLS measurements of MFP.[17] A capital estimate for trucking, however, might not include highways, because they are not used exclusively by trucking firms.[18] Thus, the effect of congestion (which depends on the growth in infrastructure relative to the rate of growth in transport activities) would not be controlled for in MFP measures.

Another complication plagues the definition of input levels in all service sectors: The consumption of services usually involves some input of labor by customers. For example, a supermarket provides goods where and when consumers want to purchase them. For these services, it charges a markup on the goods it provides. But it is impossible for consumers to benefit from the services without time spent choosing and collecting the goods and conducting the transaction—which is a kind of labor input to the service provision. If the supermarket decides to devote less labor to placing goods conveniently or to reduce the number of checkers, customers have to spend more time selecting goods, standing in checkout lines, etc. Thus, store labor and customer labor are substitutable in the production of the service. Such changes will be reflected as an increase in labor productivity, although they involve no efficiency improvement or technological progress. From the firm's perspective, the customers' labor is an unpriced input. Thus, firms are tempted to use as much of it as possible, thereby passing production costs on to customers. Competitive pressures, however, may prevent firms from doing this at all or may force them to reduce their output price as compensation.

Customer labor as an unpriced input also exists with regard to transportation. Airlines may economize on inputs by flying more circuitous routes at the expense of travelers' time. Similarly, freight firms may reduce the amount of labor devoted to scheduling and tracking, but at the cost of its customers' labor being idle because of delays in shipments. In this sense, the whole question of *timeliness* can be approached either from the perspective of variations in the quality of output or in the quantity of inputs. That is, for the first example, it can be said that travelers who get more time-consuming trips are given lower quality service, or that travelers must invest more of their own time to get the same service. In the second example, firms that receive slower freight service get a lower quality of service, or must devote more of their own labor and capital inputs to getting the same service. Either approach prevents a reduction in the timeliness of service from being recorded as a pure productivity improvement.

### *Constructing Indices*

Variations in the quality of both outputs and inputs over time may result in misleading measures of labor productivity and MFP. BLS adjusts for such variations—to the extent that it is possible to separate input and output data into a sufficiently detailed set of categories defined in terms of levels of quality—by using *index numbers.*

Index numbers can adjust the measure of labor productivity when output can be classified into two or more discrete types. For example, a trucking firm that offers truckload (TL) and less-than-truckload (LTL) services has only one category of labor, but because of the special handling involved, hours required per ton-mile are greater for LTL. LTL may, however, be defined as a higher quality service because it provides customers with greater flexibility in sizing and scheduling shipments, and therefore usually commands a higher rate per ton-mile. If, over time, the share of LTL in a firm's business increases, a simple ratio of ton-miles to labor hours will indicate a decline in labor productivity. This ratio would be deceptive, however, because the decline does not involve any reduction in efficiency, just a shift of resources to a higher quality service. An index number is needed to capture this change.[19]

BLS recently adopted sophisticated new techniques to adjust for changes in the composition of the labor force in the calculation of MFP growth estimates. The approach is to disaggregate the labor force into categories according to education level and years of experience. Better educated and more experienced workers are weighted more highly in the calculation of the labor input index. This weighting means that a shift to more highly skilled workers will be reflected as an increase in labor input, even if the number of hours worked remains the same.[20] Thus, the impact of changing labor composition on output growth can be separated from pure productivity growth due to efficiency gains and technological progress.

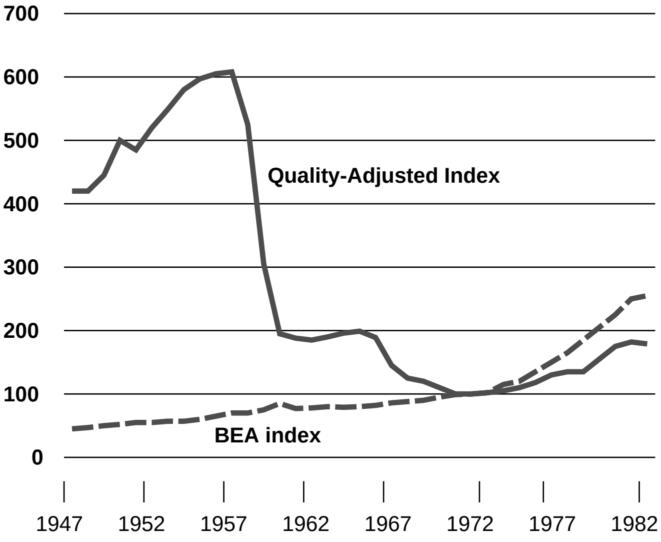
In principal, the judicious application of index numbers makes it possible to resolve many of the problems in measuring productivity growth in service industries. However, the use of index numbers is limited by the data available. If output measures are available for only a few broad categories of service, the benefits are limited because most of the qualitative changes will be occurring *within* those categories, and therefore cannot be represented as a change in their relative weights. Available data provide only a limited breakdown by outputs and inputs for transport industries. For example, in trucking, output can be broken down by three categories of carrier (general freight, specialized carriers, and carriers of household goods); the specialized carrier category can be further broken down into seven freight subcategories, but there is no disaggregation by type of labor input. For air carriers, there are only two categories of output (passenger-miles and freight ton-miles) and no breakdown of labor. This precludes, for example, an adjustment for the increasing role of overnight couriers in the air freight business. (The results of the BTS Commodity Flow Survey should provide some idea of this role.) Clearly, the accuracy of transport productivity measures could be considerably improved *if more detailed labor and output data were collected.*

Creating an index of capital input is especially difficult. Due to the severe shortage of available data, BLS has not attempted to construct such an index for any transport industry except railroads. The conventional approach to estimating a capital index involves deflating a series of annual capital investment figures by a price index so that, ideally, the productive value of $1 worth of 1960 capital is equivalent to $1 worth of 1990 capital. Thus, in addition to adjusting for inflation, the deflator must also adjust for qualitative improvements in capital that increase the productive capacity of particular types of machines or vehicles.

Some recent research on measuring capital inputs to the airline industry dramatically attests to the sensitivity of MFP measures to capital price indices. Based on extensive research on the technical capabilities of planes purchased by the airlines at different times, Robert Gordon estimated a capital price series that showed that, despite inflation, airlines got considerably more productive capital per dollar spent on aircraft in the 1980s than in the 1960s.[21] Because of the series' careful adjustment for qualitative change, it was significantly different from an aircraft price deflator published by the Bureau of Economic Analysis. (See Figure 6–6.) Most important, Gordon estimated MFP growth for airlines using both his and the BEA price deflators: He found that from 1979 to 1987, the estimated average rate of MFP growth was more than 30 percent higher with the BEA deflator than with his own.[22] Given this high level of sensitivity, the need to create price series that fully account for changes in the quality of capital inputs cannot be overstated.

**FIGURE 6–6**

Aircraft Price Indices (1972=100)



Institutional Changes, Trends and Productivity

### *Deregulation and Transport Productivity*

For many years, transportation was one of the most heavily regulated sectors in the American economy. However, over the past two decades, many regulations have been removed and market forces have been allowed to shape the type and price of services. This deregulation constitutes one of the most important institutional changes now acting on the transportation system, and consumers of transport have enjoyed significant welfare gains as a result. These gains are not unambiguous proof, however, that economic performance in transport has improved because of deregulation.

Regulations affect productivity analysis. Perhaps their most important impact is that the economic assumptions that underlie the calculation of MFP growth do not hold in a regulated environment. The fundamental assumption used to combine growth in various inputs into a single index is that firms use inputs to the point where their marginal revenue products are equal to their prices. (This assumption justifies the use of cost shares as appropriate input weights.) When a regulated railroad is required to maintain service along unprofitable lines, it may have to employ more capital to do so. (In economic terms, this means that the price of its capital input is more than its marginal revenue product.) Thus the theoretical basis for the measure is undermined. Further, changes in input and output prices that occur due to deregulation may artificially affect productivity trends due to their effect on the weights employed in various indices. In order to correct for market distortions due to regulation, BLS uses actual returns to capital, rather than capital prices, as weights in the MFP calculation.

Where deregulation allows railroads to abandon unprofitable lines, they reduce their capital stock, labor, and intermediate inputs. Output is reduced because of the loss of revenue from the lines. This reduction, though, will probably be proportionately smaller than the input reductions since the abandoned lines most likely are those with the least business per unit of input. All else held constant, the railroads consequently experience an increase in their rate of productivity growth as inefficient mandated resource inputs are ended.

From a policy perspective, it would be useful to know what proportion of productivity growth can be directly attributed to deregulation. This calculation, however, is difficult to determine. For example, if capital is being discarded on inefficient lines at the same time that new capital is added elsewhere, the changes may offset one another.

Since the effect of deregulation on economic performance is one of the most important policy questions to be addressed by transport productivity analysis, more work in this area is warranted. One approach could be to use case studies rather than aggregate data. This would allow analysts to examine the impact on firm-level productivity of structural changes in the geographical deployments of capital and other inputs.

### Environment and Transport Productivity

Environmental considerations have come to take on increasing significance for transport analysis in recent years. One reason is the growing concern over acid rain and "greenhouse" gases caused by emissions from a broad variety of human activities. This concern is reinforced by the awareness that transport plays a large and growing role in generating these emissions. The relative importance of the smokestack industries, which the public primarily blames for pollution, has declined in the American economy. At the same time, demands for transportation services have grown. Thus, this sector must figure prominently in any comprehensive strategy to mitigate the damages caused by environmental emissions.[23] The perceived need for environmental control constitutes an institutional change whose effects on transport may ultimately prove as profound as those of market deregulation. (See Table 6–5.)

Thus, any assessment of transport's economic performance must address environmental costs and benefits. If not, it will ignore the significant costs of increasing emissions on individuals and firms in

**TABLE 6–5**

Implications of Institutional Change for Transportation Productivity Analysis

| Institutional Change | Implication | Research Direction |
|---|---|---|
| Deregulation | • market imperfections undermine theoretical basis of MFP measures | • adjust series for price distortions |
| | • no current way to measure impacts of deregulation on MFP | • further research to decompose MFP growth into efficiency and technology components |
| Environmental Issues | • environmental damage not included in productivity accounting | • include "clean air" as input in MFP measures |
| | • no basis for weighting environmental inputs in MFP measures | • application of social costs of emissions as input prices |

other sectors. For this reason, analyses should be extended to reflect the expenditure of environmental resources in the production of transport services. One approach could consider clean air as an input used by transport industries because vehicles dispose exhaust wastes into the air. Changes in the level of this input over time should be included in the input index used in calculating MFP growth statistics.

To understand the significance of this approach, consider how actions that reduce pollution from vehicles are reflected in conventional productivity measures. Capital inputs—such as pollution-abatement equipment and more efficient engines—can be used to reduce exhaust wastes, thereby reducing the consumption of clean air. Thus, capital essentially may be substituted for clean air in the production of transport services. Since capital is included in conventional MFP measures and clean air is not, any substitution of capital for clean air shows up as a pure reduction in productivity. It could be argued that environmental regulations, which require substitutions of this type, are thus responsible for a slowdown in productivity growth. But this argument is based on an incomplete specification of inputs, since it ignores the fact that less natural resources are used. If in fact the use of environmental inputs were properly accounted for, the productivity loss due to increased capital input might be offset or even exceeded by the gain in the preservation of clean air.

While such an approach is conceptually attractive, it has certain conceptual difficulties. Transport firms do not account for their emissions as they do for their purchases of labor, capital, and intermediate inputs. Any measurement of emissions from the transport industries must use engineering estimates based on the number of miles traveled and the best information available on the fuel efficiency and emissions characteristics of vehicle fleets.

Another problem with environmental inputs is that there is no market and no cost information. Since the calculation of MFP growth requires the use of cost shares of all inputs as weights, how then can environmental inputs be weighted?

In recent years, a great deal of research has been devoted to estimating the social costs of environmental damage.[24] Pollution costs can be estimated by considering the negative impact pollution has on human health and property values, and the extent to which it retards productive potential. Social costs may be based on public "willingness-to-pay" estimates; these are obtained by surveying affected individuals to see what they might pay to get rid of pollution. These estimates should ultimately help authorities design environmental policy. In fact, some U.S. utility regulatory boards already use cost-per-ton estimates for a variety of pollutants in setting policy for electricity generation.[25] The same information could also be used in designing market-based instruments for environmental control, such as road pricing and emissions fees. While these estimates will always be controversial, they could be used to calculate MFP series that include environmental inputs. At the very least, they could be made under a variety of assumptions concerning the cost of clean air in order to assess the sensitivity of conventional productivity measures to environmental inputs.

## Technological Changes and Transportation Productivity

Changes in the technology of transport firms affect their economic performance in a number of ways (see Chapter 5). However, the firms' productivity may also be affected by changes in the technologies used by their customers. Recently, these changes have led to a demand for higher-quality services. Thus, it is important that these quality improvements are accurately reflected in productivity measures.

A production technology is a mechanism by which inputs are transformed into outputs. Changes in technology can occur through advances in capital equipment; improvements in the skills levels of employees; changes in the organizational structure of the firm; changes in the way the firm marshals its resources to reduce excess capacity in capital, labor, and inventories; and changes in the spatial distribution of the firm's facilities relative to the locations of its suppliers and markets. This section examines two recent technological changes that have had far-reaching impacts on transportation firms' activities: the management of inventories and the spatial configuration of facilities. (See Table 6-6.)

### *Just-in-Time Inventory Systems*

The traditional approach to managing inventories was to stockpile materials and component parts at production sites to ensure that work was not stopped by delays or breakdowns. American firms are increasingly shifting from this approach to the JIT inventory system, which was developed over several decades by Japanese manufacturers. In the JIT system, producers obtain intermediate inputs from their suppliers just when they are needed in the production process. This practice reduces costs of carrying inventories, including working capital costs, as well as the costs of handling, storage space, and spoilage.[26] (See box on "Just-in-Time Trucking.") These savings are achieved through careful coordination of the production systems of the producers and purchasers of intermediate goods, and through the transport firms delivering inputs in a timely fashion. Under the old system, inventory stockpiles allowed some breathing room to cover delays in the delivery of intermediate goods. Under JIT, any significant delay in shipments results in a shutdown of production.

A shift to a JIT inventory system requires an increase in the speed and reliability with which a particular set of intermediate goods is delivered. Thus, transport services must be improved and their output increased to serve a given set of inter-industry transactions. How this shift affects productivity depends upon the efficiency with which this higher level of service is produced. If the increase in the value of the transport service is greater than the increase in the value of the inputs needed to produce it, MFP will grow.

### *The Spatial Configuration of Production*

Over the past 50 years, economic activities in the U.S. have become decentralized. Urban sprawl—which describes the process in which populations shift their residences away from the city center to low-density outlying areas—is well-documented. Production facilities have also spread out: The decline in downtown industrial areas, paralleled by a growth in suburban industrial parks, is a trend familiar to scores of American cities. Some producers have even abandoned existing metropolitan areas to locate in rural areas. With producers becoming more spatially diffused, the average length of trips needed to bring inputs to production sites and goods to markets has increased. This diffusion has also necessitated a shift in freight transport from rail to trucking, because trucks can serve a larger number of points in space than can trains, which rely on a more limited infrastructure network.

The decentralization of production facilities is essentially a technological change. Besides the conventional inputs—labor, capital, energy, and intermediate goods, manufacturing needs land and transport services. If the industries move to a more peripheral location, expenditures on transport may rise, but—because land prices are lower—expenditures on land drop. Thus, accessible land is substituted by the input of transport. Of course, other reasons motivate firms to move to peripheral areas, such as the availability of cheaper labor or an escape from congestion or pollution. Generally, however, all of these reasons entail some cost savings, which is achieved by increasing the total ton-miles of transport services consumed.

As industrial facilities become more dispersed, the average length of a trip required to service an inter-industry transaction, such as a sale of intermediate goods or of finished goods to a retailer, increases. Cost function analyses suggest that transport MFP increases with the average length of haul.[27] This is because the amounts of labor and capital inputs expended on operations such as loading and unloading trucks depend not on the number of miles traveled but on the number of trips made. As the length of trip increases, inputs for these operations decline on a per ton-mile basis. Thus, while the question has not been thoroughly investigated, industrial decentralization should contribute to an increase in the rate of productivity growth as it is normally measured for the trucking industry. On the other hand, because decentralization has required a shift from trains to trucks, and because rail productivity has grown faster than trucking productivity, it may have contributed to a slower rate of transport productivity growth sectorwide.

Measuring truck transport service output on an outcomes basis, as opposed to a transactions basis, might yield very differ-

## Just-In-Time Trucking:
## Case Studies

A recent study commissioned by the Federal Highway Administration includes two examples of well-known U.S. corporations that have made the transition to Just-In-Time (JIT) inventory systems.[28] The first is the Campbell Soup Company. Because most of Campbell's material inputs are perishable agricultural products, the benefits of JIT inventory are especially great. Not only does faster turnover of inventory decrease storage and financing costs, it also reduces spoilage. Further, Campbell believes it is now producing better products by using fresher inputs.

Campbell had to make two fundamental changes in its operating procedures to facilitate the transition to JIT. The first was to shift much of its inbound deliveries from rail to truck, because trucking firms are better able to meet the demanding requirements for timeliness and reliability. (Since most of Campbell's facilities are located outside urbanized areas, highway congestion is not a major impediment to truck transportation.) The second operational change was to prequalify a limited number of "select suppliers." In the past, one of the things that slowed down the turnover of inventory was the need for Campbell to inspect all its perishable inputs before they were used in production. Now it has established relationships whereby suppliers ensure that only produce of acceptable quality will be delivered. By prequalifying its suppliers in this way, Campbell can eliminate most of its inspection procedures and thus speed up the movement of perishables through the production system.

The second company is the General Motors Corporation (GM). In the automobile industry, component parts are manufactured in a large number of specialized plants and then shipped to a smaller number of assembly plants, each of which specializes in the production of a few car or truck models. GM operates 29 assembly plants and 112 parts plants in the United States. Each of the parts plants makes shipments to one or more assembly plants, and each assembly plant ships vehicles to various locations across the continent. The automobile production system thus comprises a complex of spatially dispersed facilities that are highly dependent on transportation services for their linkages. GM estimates that the typical assembly plant receives 120 trucks carrying parts and supplies each day; another 120 trucks, as well as many train cars, deliver finished vehicles to the dealers.

To remain competitive, GM has moved in recent years toward a JIT inventory system. Again, the key operational changes involve increased coordination with the suppliers of inputs (in this case, GM's own parts plants as well as other suppliers) and improved speed and reliability in transportation. GM has shifted much of its inbound deliveries from rail to truck, but since many GM facilities are located in busy metropolitan areas with congestion problems, transportation is a potentially weak link in the JIT system. It is reasonable to infer that highway accessibility will weigh more heavily in decisions that involve allocating production to existing facilities or sitting new facilities. To keep its JIT system running efficiently, GM has reorganized its shipping schedules: truck shipments are now more frequent, but on average smaller, than they were some years ago. The loss of scale economies in transportation are more than compensated by the cost savings realized by the JIT system, though at a cost in congestion, fuel consumption, and air pollution.

ent results. Decentralization translates into more capital, labor, and energy to accomplish the same outcome—to move goods from firm A to firm B—because, on average, firms have moved further apart. From this perspective, the transport system has become less efficient because it takes more resources to service a given set of interindustry transactions, so it could be expected that decentralization would negatively affect productivity. This illustrates how different approaches to measuring service outputs can yield very different assessments of economic performance.

### *New Transportation Services*

A critical question for productivity analysis is whether the careful application of index numbers can sufficiently account for qualitative changes in transport services required by changes in the production technology. In cases such as the shift from short-haul to long-haul services due to industrial dispersion, such an application may be possible. It is not clear if the effects of increased speed and reliability needed for JIT systems can be accurately reflected in transport productivity statistics based on currently available data. Use of disaggregated output data to construct indices that properly adjust for quality change is limited to changes in the distribution of output across *existing* categories of service. In shifting to JIT systems, transport firms must provide what are essentially *new* categories of service.

For example, service with guaranteed delivery within 12 hours of a prearranged time requires sophisticated technologies such as computerized tracking equipment and significant changes in the typical logistical systems and labor requirements of trucking or rail firms. However, it is unlikely that any service offered in the past is sufficiently similar to be designated as comparable for calculating index numbers. Rather, 12-hour guaranteed service should be treated as a new category of output. Alternative methods must be developed to adjust for improvements in the quality of service. Otherwise, the added quantities of capital and labor used to improve quality can only produce measured reductions in productivity growth rates. (See Table 6-6.)

### Transportation Infrastructure and Transport Productivity

The heavy dependence of transport industries—especially trucking, intercity busing, and airlines—on public infrastructure has important implications for measuring productivity growth. Consider the role of interstate and state highways on the production of intercity trucking services. Clearly, these services would be impossible if the highways did not exist. They serve a function similar to that of private capital input—even though they are not directly owned or controlled by the trucking firms. From the perspective of productivity analysis, the relevant question is how the growth of infrastructure affects the growth of MFP in trucking.

An increase in the amount of infrastructure may enhance trucking performance by reducing both circuity and congestion. A simple circuity factor may be calculated as the ratio of the number of highway miles required to make a trip between two cities and the length in miles of a straight line between them. Circuity depends upon the *density* of the highway network. Although a decrease in circuity seems as if it would positively effect productivity, if the output of the trucking industry is measured in ton-miles, decreased circuity could decrease output and inputs by the same proportion and therefore produce no measured effect on productivity.

Also, levels of congestion affect the speed of shipments and therefore the number of labor and truck-hours per ton-mile. Since stop-and-go conditions generally decrease engine performance, congestion also affects fuel consumption per ton-mile. Increasing the density of the highways does not necessarily reduce congestion, since a very dense network may have idle capacity over most routes and a high level of congestion on a few. Congestion depends upon the degree to which the *supply* of infrastructure is compatible with the *demand* for transport. Changes in

**TABLE 6–6**

Implications of Technological Change for Transportation Productivity Analysis

| Technological Change | Implication | Research Direction |
|---|---|---|
| Just-in-time inventory systems | • adequate accounting for increase in transportation service quality | • development of new methods for adjusting for service quality in output indices |
| Spatial Dispersion of Production Facilities | • conceptual difficulties over effect on productivity | • comparative analysis of impacts using transactions and outcomes measures |

congestion levels will always be reflected in productivity measures because they affect the time—and thus the amount of capital and labor—needed to produce a ton-mile.

Attempts to reduce circuity and congestion may, in some cases, conflict. With limited public resources, transport authorities may have to choose between reducing circuity for a large number of cities and towns and reducing congestion along routes connecting a smaller number of large cities with high propensities to generate and attract trips.

Limited evidence suggests that changes in the rate of public infrastructure provision significantly affect trucking industry productivity. Robert Gordon constructed an MFP series for the U.S. trucking industry from 1948 to 1987 that included a crude measure of growth in government capital based on trends in highway expenditures.[29] His results suggest that infrastructure produced measurable increases in MFP growth over some periods and decreases in others. A more direct indication of network effects on productivity is provided by Chiang and Friedlander, who included measures of network congestion and circuity in a cost function analysis applied to a sample of individual truck shipments made in 1976.[30] They found that variations in both network measures had significant effects on trucking costs, and thus on trucking MFP. Case study evidence also suggests that traffic congestion seriously hampers the efficient operation of many types of transport firms. For example, Federal Express recently cited congestion as the major transport problem affecting its productivity: Heavy congestion around some airports actually forced it to use some smaller airports around major metropolitan areas. In another case, a building supply firm in the Los Angeles area was forced to make its deliveries to construction sites at night, resulting in considerably higher labor costs.[31]

These findings warrant further research into the effects of public infrastructure on productivity in the transport sector. This research would not only improve the assessment of economic performance, but would also provide useful information on the economic benefits derived as a result of public investment in highway and other transport facilities. Such research would need to address a number of difficult issues, such as how to measure the level of infrastructure.

Using public expenditures as a measure of infrastructure has its limits, since gross figures will not indicate whether expenditures were made to add new roads, expand or repair existing ones, or develop new management and control systems. A more useful approach would account for changes in a variety of network characteristics and create an input index for roads based on a weighting of those changes. (See Table 6-7 for a summary of the implications of public infrastructure for productivity analysis.)

## Industry Coverage and Productivity Measures

BLS calculates labor productivity only on the components of the transport sector for which appropriate data, including physical output measures such as ton-miles and passenger-miles, are available. In aggregate, these industries comprised only 39 percent of total transport sector

**TABLE 6–7**

Implications of Public Infrastructure for Transportation Productivity Analysis

| Infrastructure effect | Implication | Research Direction |
|---|---|---|
| Circuity effect | • high circuity increases ton-miles | • define output in terms of zone to zone shipments |
| Congestion effect | • high congestion limits speed and reliability | • estimate impact of congestion on increases in the quality of transportation services |

employment in 1992—down from more than 50 percent in 1980. While the absence of appropriate data prevents BLS from expanding its coverage at this time, the issue of what happened in components of the transport sector not covered in the BLS series, must be addressed.

In this regard, a recent study commissioned by the National Bureau of Economic Research is helpful.[32] This study estimates labor productivity growth using deflated output figures from the National Income and Product Accounts (NIPA), which cover a greater proportion of all trucking activity than do the data employed by BLS.[33] (See Table 6-8.) Because estimates based on simple NIPA price deflators do not fully account for qualitative changes in output, the second column in Table 6–5 includes those based on Gordon's own price deflator series, which make extensive qualitative adjustments to the price series and are more in line with the intended purpose of productivity analysis. Differences between the unrevised and revised estimates are quite large, which demonstrates the sensitivity of such measures to variations in data and assumptions.

Comparing Gordon's estimates to those of BLS, the most striking difference is in trucking, where the revised NIPA estimates indicate almost no productivity growth during the 1980s. It must be stressed that neither set of estimates are "correct," since they do not apply to the same range of industries. The difference in the estimates probably occurs because BLS data do not include small carriers, which accounted for a very large part of the growth in trucking activity during this period. This difference demonstrates the sensitivity of productivity growth estimates to the level of sectoral coverage.

### TABLE 6–8

Estimates of Average Labor Productivity Growth Rates: 1977–1987
(Based on Alternative Data Sets)

| Transporation Industry | Unrevised NIPA | Revised NIPA | BLS |
|---|---|---|---|
| Railroad | 1.11 | 8.56 | 7.06 |
| Trucking | –0.97 | 0.11 | 3.28 |
| Airlines | –1.03 | 3.04 | 3.79 |

Source: Robert Gordon, "Productivity in the Transportation Sector," in Zvi Griliches (ed.) *Output Measurement in the Service Sector*, NBER Studies in Income and Wealth, No. 56, Chicago: University of Chicago Press.

The BLS level of coverage of transport activities is actually underestimated in the above discussion because it deals only with data for transport industries. In fact, a considerable amount of transport *activity* is carried on by firms not included in any transport *industry*. This includes "in-house" or "captive" transport services, where firms provide their own transport using a fleet of trucks devoted solely to the delivery of the goods they produce. It is very difficult to estimate the magnitude of these activities directly. Since there is generally no transaction of funds to cover the costs of these services, they are not included as outputs in conventional accounts. Instead, their values are absorbed into the output of the firms that use them.

Paula Cullen Young of the Bureau of Economic Analysis recently observed that the value of these services may be estimated based on the purchases of transport-related inputs, such as gasoline, diesel, tires, motor vehicle insurance, etc., by nontransport firms.[34] She estimates that this value was *at minimum* $65 billion in 1987—a figure larger than total railroad output and more than half as large as total trucking output in the same year. Currently, almost nothing is known about economic performance in this large component of the transport system. (See box on "The Value of In-House and Captive Transportation Services.")

Taking this argument further, a large proportion of transport services are provided by individuals for their own consumption. For example, people who want to travel from Boston to Washington have four options: take a plane, train, or bus, or drive. If they choose to drive, they are substituting a self-provided service for one provided by a transport firm, but no data exist on the labor, capital, and energy inputs consumed or on the value of the trips.

Ultimately, the question of what is an appropriate level of coverage comes down to a tradeoff between the desire to produce comprehensive measures of economic performance in the transport system and the desire to base such measures on high-quality data. It may be that, where individuals provide the transportation themselves, it will never be possible to calculate productivity measures of sufficient quality to be comparable to those produced by BLS. Still, given the currently low level of coverage—especially in trucking—efforts to expand the available data should be a high priority.

### A Research Agenda for the Bureau of Transportation Statistics

The primary role of BTS in the advancement of transportation productivity measurement is to expand and enrich the base of data. In particular, it will help improve the coverage and level of disag-

## The Value of In-House and Captive Transportation Services

U.S. government data collection on the transportation industry is limited to measuring activity levels for establishments whose *primary* line of business is delivery of "for-hire" transportation services. In actual fact, a very large proportion of transportation services are not provided on a for-hire basis. Transportation services that are in-house or captive make up a major proportion of the total ton-miles of freight, but are not generally included in transportation industry statistics. *In-house* transportation refers to goods-producing firms that maintain fleets of trucks to make deliveries rather than contract with for-hire trucking firms. In such cases, the establishment where the trucks are housed is most often a factory, and therefore its primary business is not transportation. *Captive* refers to trucks housed at separate establishments (locations) that provide transportation services exclusively for some nontransportation firm that owns them. In this case, the establishment provides transportation services but not on a for-hire basis. In either case, the establishment from which the services are provided does not meet the criteria for inclusion in the transportation industry. This is not to say that the value of these services are not included in national income statistics. Rather, their value is included as part of the output of the firms that produce the services—that is, in some sector other than transportation.

To estimate the value of these misallocated transportation services, Paula Cullen Young of the Bureau of Economic Analysis recently conducted a study of the transportation-related inputs consumed by nontransportation industries. These inputs include gasoline, diesel, tires, vehicle insurance, and vehicle repairs, all of which could only be used for transportation purposes. The logic of her study was that the value of in-house and captive transportation services must be *at minimum* equal to the value of these transportation inputs purchased by all nontransportation firms, which was $65 billion. In fact, it is almost certainly higher than this because these cost estimates do not include the labor and capital costs incurred in providing transportation services.

Table 6-9 lists the value of output produced by major transportation industries in 1987, along with the estimated minimum value of in-house and captive transportation services.

Clearly, the relative magnitude of the misallocated services is substantial. Even by this highly conservative measure, in-house and captive services were larger than all for-hire rail services in 1987. The greatest component of in-house and captive services is probably trucking, although these services probably also include considerable personal transportation. It would appear from these figures that roughly one-third of total trucking activity is excluded from industry-based statistics.

**TABLE 6–9**

Value of Output in Transportation Industries in 1987

**(billions of 1987 dollars)**

| | |
|---|---|
| Railroad and related services | 43.5 |
| Motor Freight Transportation and Warehousing | 116.1 |
| Water Transportation | 24.1 |
| Air Transportation | 76.2 |
| Pipelines, freight forwarders, and related services | 25.9 |

Estimated Minimum Value of In-House and Captive Transportation in 1987

**(Billions of 1987 Dollars)**

| | |
|---|---|
| Transportation Services by Nontransportation Firms | 65.0 |

Source: Estimates of Bureau of Economic Analysis.

gregation in input and output data. In addition, BTS may play a role in the advancement of analytical methods for productivity measurement.

Any analysis of productivity in transportation must address four types of social and economic changes. These changes are the rise of the service sector, institutional and technological changes, and the changing role of public infrastructure. As Tables 6–4 through 6–7 indicate, various research directions exist that could produce more accurate, comprehensive, and flexible productivity measures. Many of these approaches, such as the disaggregation of outputs and inputs to improve index numbers, are already being actively pursued by BLS and others. The following are some other approaches BTS might address.

- *Developing outcome measures of transport output*. BLS has developed sophisticated transaction-based indices of transport output such as ton-miles and passenger-miles. In some cases, however, data limitations and conceptual issues may justify developing outcomes measures. These measures would not substitute for the current BLS measures, but would complement them by providing different perspectives on economic performance, such as when assessing the impacts of spatial dispersion and circuity on transport productivity. In the first case, an appropriate outcomes measure might be the amount of goods moved between firms in different economic sectors, without regard to the distance they have to be moved: This measure would determine how the efficiency of servicing a set of inter-industry linkages changes as firms become more dispersed over time. In the second case, the measure might be ton-miles calculated along straight lines rather than the network: Increases in network densities should always lead to productivity improvements.
- *Assessing the impact of improved transport quality on productivity in other sectors.* Just as improvements in airplane quality should be credited to the airframe manufacturing industry (instead of to the transport industry), productivity growth due to improved transport that saves costs in the goods-producing sector should be credited to transport industries. This attribution would require a great deal of case study and econometric research, which could be overseen by BTS. One of the key factors in this effort would be the appropriate valuation of productivity growth enjoyed by manufacturing firms due to JIT systems. An equally difficult question is how much of that growth should be credited to transport versus manufacturing. Despite these difficulties, such an accounting might provide a fuller picture of economic performance in transport.
- *Assessing the impacts of deregulation on transport productivity growth.* At present, it is not possible to separate the part of productivity growth directly attributable to deregulation from that due to independent technological progress. This separation might be addressed by applying cost function analysis. Also, case studies could help identify changes experienced by firms after deregulation.
- *Incorporating environmental effects into productivity growth estimates.* Research is needed to account adequately for environmental inputs in calculating productivity growth statistics. This accounting must include estimates of emissions rates from transport over several years, as well as of weights to be applied to environmental resources in input indices.
- *Assessing the impacts of changes in the structure of transport networks on transport productivity.* A careful analysis of how infrastructure affects productivity growth must go beyond a simple accounting of government expenditures. Instead, it must address how public investments affect the structure of the transport network and how structural changes affect productivity. Calculation of network characteristics may be aided by BTS' expertise and facilities in geographic information systems.

In addition to these specific topics, BTS will try to expand the base of data available for productivity analysis in transportation. In particular, it will help improve the coverage and level of disaggregation in input and output data.

# APPENDIX: BLS Methodology for Transportation Industries

## Railroad Transportation: SIC 4011

For railroad transportation, output is measured as the weighted aggregate of freight ton-miles and passenger-miles. Data on revenue freight ton-miles and revenue passenger-miles are collected by the Interstate Commerce Commission and published in *Transport Statistics of the United States, Part I.* Data on labor expenses are also obtained from this source for weights. In recent years passenger-mile data, no longer published by the ICC or by the Association of American Railroads (AAR), are obtained from the National Railroad Passenger Corporation (AMTRAK).

Prior to aggregating freight ton-miles and passenger-miles, an adjustment is made to the data on freight ton-miles in an attempt to reflect underlying service differences among different commodities transported. Revenue and tonnage data are obtained from the *Freight Commodity Statistics* (an AAR publication based on ICC-collected data) for about 175 different commodities. An index of commodity mix is calculated by aggregating tons by commodity with unit revenue weights and dividing this weighted aggregate by unweighted tons. This figure is then indexed and applied to the index of total revenue freight ton-miles.

The indices of passenger-miles and adjusted freight ton-miles are combined in a series of chain-linked, base-year weighted segments, with base years of 1947, 1954, 1958, 1963, 1967, 1972, 1977, 1982, and 1987. The weights are labor expenses derived from detailed expense data in the ICC's Transport Statistics volumes.

The indices of employees and employee hours for railroad transportation are based on data from the ICC and published (until 1988) in the A300 statement.

## Bus Carriers, Class I:
## Parts of SIC 411, 413, 414

The productivity measure published for this industry is an output per employee-hour measure. The output measure for this industry is based on data from the ICC's *Transport Statistics in the United States* and on data from the American Bus Association and the National Bus Traffic Association (NBTA). The ICC divides regulated bus carriers into intercity or local service. For each of these two groups, data for intercity, local, charter, and freight operations are reported. Passenger-miles are reported for intercity operations and the number of passengers are reported for local and charter operations. Revenue is reported for freight operations. An index constructed from express rate data provided by the NBTA is used to convert the freight revenue data to constant dollars. These output data are aggregated in two steps. First, indices of intercity passenger-miles, local passengers, charter passengers, and deflated freight revenue are combined with base year revenue weights (with base years of 1954, 1958, 1963, 1967, 1972, 1977, 1982, and 1987). This aggregation is performed separately for intercity carriers and local carriers. Next, the indices of intercity carrier output and local carrier output are combined with employee-hour weights. Utilizing the same base years as above. The output index segments (1954– 58, 1958–63, 1963–67, etc.) are linked together to form one historical output index.

Data on employment and hours are also derived from ICC's *Transport Statistics.* Hours paid data are available for nonsupervisory workers. Days paid are available for supervisory workers. Supervisory hours are estimated by multiplying the number of days paid by an assumed eight hour work day. Because supervisory workers account for less than ten percent of industry employment, any bias introduced by this assumption on the overall employee-hours series is small.

## Trucking, Except Local: SIC 4213 Part

This measure covers Class I and Class II common and contract carriers. It does not cover any establishments providing storage functions or Class III trucking establishments. The output measure is based on ton-miles by type of service weighted by the labor requirements for each type. The output index is created in a two-step weighting procedure. First, details on ton-miles are aggregated within each of the three major carrier groups—general freight, specialized carriers, and carriers of household goods.

Ton-miles for Class I and Class II carriers of general freight are combined with the base-year employment for each category and ton-miles for specialized carriers are similarly aggregated for the following categories: heavy machinery, liquid petroleum, refrigerated produce, agricultural produce, motor vehicles, building materials, and other commodities. No detail is available within the household-goods-carriers group, so the total number of ton-miles is the basis of the index for this third major component. The second step in output aggregation is to combine the indices of ton-miles for general freight, specialized carriers, and household goods carriers into one total output index, using the employment in each group in the base year as weights.

The labor input measure for trucking is based on the number of employees. Adequate data are not available on the average hours of employees to produce a measure of total employee hours. The number of leased drivers is included in the employment count. These drivers account for about 12 percent of industry employment.

All data for the output and input measures for trucking are derived from data collected by the ICC and published by the American Trucking Associations (ATA).

### Air Transportation:
### SIC 4512, 4513, 4522, Part

The labor productivity measure for the air transportation industry is an output per employee measure. The output measure is based on data collected by the Bureau of Transportation Statistics and published in *Air Carrier Traffic Statistics* and *Air Carrier Financial Statistics.* The output index is formed by weighting passenger-miles and freight ton-miles for domestic and international operations with base-year, unit-revenue weights.

The labor-input measure is based on the number of employees, obtained from the Bureau of Transportation Statistics.

### Petroleum Pipelines: SIC 4612,4613

The labor productivity measure for this industry is output per employee hour. The output measure is an index of trunkline barrel-miles of crude and refined petroleum. Investigation of pipeline industry operations indicated that labor requirements for crude and refined output were similar. Therefore, barrel-miles for the two products are added directly together rather than introducing revenue weights. The barrel-mile data are based on information reported to the U.S. Federal Energy Regulatory Commission. The information on these reports is processed and published by the American Petroleum Institute.

The labor input measure for this industry is based on data published by the Bureau of Labor Statistics. The index of employee hours is derived from the number of employees and the average weekly hours of nonsupervisory workers. The average weekly hours are converted to average annual hours and multiplied by the number of all employees. This procedure assumes that the average annual hours of supervisory workers move in the same way as the average annual hours of nonsupervisory workers.

### Multifactor Productivity Measurement for Railroad Transportation

The output measure for Class I railroads is a Tornqvist aggregation of weighted freight ton-miles and total passenger-miles. For the period 1958–84, freight ton-miles were first adjusted for commodity-mix in the following manner. For each type of commodity, tons were value-share weighted in a Tornqvist aggregation for each year. The index of weighted tons was divided by an index of unweighted tons to form a commodity mix index. Freight ton-miles were then multiplied by the index to obtain the adjusted freight ton-mile series. The commodity mix index is intended to reflect changes in the service composition of output. The sources for these data were the Interstate Commerce Commission and the Association of American Railroads.

From 1984 on, proportions of ton-miles and revenue by length of haul, commodity and shipping mode are computed with waybill sample data from the ICC and applied to total ton-miles and revenue from the *AAR Yearbook.* This procedure yields estimated universe data for 400 categories, grouped by four length-of-haul ranges, 50 commodity types and two shipping modes (trailer on flat car (TOFC) and non-TOFC). The estimated ton-miles are aggregated with revenue shares to generate a Tornqvist index of weighted freight ton-miles.

The employee-hour index measures the change in aggregate employee-hours over time, but contains adjustments to exclude capitalized labor. Employee-hours are treated as homogeneous and additive. Changes in qualitative aspects of employees, such as skill, experience, and age that comprise the aggregate are not accounted for in the indices. The employee-hour data relate to total time expended at work by employees, but exclude paid time for vacations, holidays, or sick leave. Both supervisory and nonsupervisory worker data and their respective hours are derived from data from the ICC and AAR.

As mentioned above, adjustments are made to the employee-hours measure to exclude capitalized labor. Examples of capitalized labor costs are the cost of labor time spent installing ties or rails or the cost for labor time spent testing and preparing a new locomotive prior to use. The exclusion of capitalized labor from the labor measure is necessary to avoid double-counting since the cost of that capitalized labor is included in the investment expenditures on which the capital measure is based. Both capitalized labor compensation and labor hours are estimated using data from the ICC and AAR and then subtracted from the original series of labor compensation and labor hours.

The capital input index is based on the flow of services derived from the stock of physical assets. Capitalized labor costs are included in the capital input because that labor time contributes to the production of output over a period of years, not just the current year. These physical assets are equipment, structures, land, and inventories. Financial capital is excluded. An estimate of the cost of rented assets is included in the measure of intermediate purchases discussed below.

Capital stocks of equipment and structures for this industry are calculated from investment data by the perpetual inventory method. Capital expenditures data for 10 categories of equipment and 13 categories of structures are obtained from the Interstate Commerce Commission. The capital expenditures are deflated to constant dollars using deflators computed from detailed Producer Price Indexes and implicit price deflators from the Bureau of Economic Analysis.

The perpetual inventory method is used to measure stocks at the end of a year equal to a weighted sum of all past investments, where the weights are the asset's efficiency relative to a new asset. Constant-dollar capital stocks are thus calculated for each of the equipment and structures categories. A hyperbolic age-efficiency function is used to calculate the relative efficiency of an asset at different ages. The hyperbolic age-efficiency function can be expressed:

$$S_t = (L-t) / (L-(B)t)$$

where:

$S_t$ = the relative efficiency of a t-year-old asset
L = the service life of the asset
t = the age of the asset
B = the parameter of efficiency decline

The parameter of efficiency decline is assumed to be 0.5 for equipment and 0.75 for structures. These parameters yield a function in which assets lose efficiency slowly at first, then more rapidly later in life. The end-of-year stocks of equipment and structures are averaged at t and t-1 to represent better the value of stocks actually in use during the year.

The real value of inventories is calculated by averaging, at years t and t-1, the end-of-year stocks of materials, supplies, and fuels inventories and deflating these with a composite deflator of materials and fuels purchased by the industry. Land stocks for this industry are estimated using data from the ICC. Data for beginning and end-of-year, nominal-dollar stocks are averaged each year to arrive at an average level for the year. An implicit price deflator for land is calculated as follows: the perpetual inventory calculations are made using ICC nominal-dollar annual land investment to obtain an estimate of gross nominal-dollar stocks, then ICC nominal-dollar investment is deflated using the BEA structures deflator and then the perpetual inventory calculations are performed again to obtain an estimate of constant-dollar gross stocks. The implicit deflator is calculated by dividing nominal-dollar stocks by constant-dollar stocks. The ICC book value of stocks is then deflated by this deflator to arrive at an estimate of constant-dollar land stocks for each year.

The detailed equipment, structure, inventory, and land stocks in constant dollars are aggregated into an overall measure of capital input using cost shares based on estimated rental prices as weights. Rental prices for each asset are calculated as:

Rental price for each asset i = $[(P_i * R) + (P_i * D_i) - (P_i^T - P_i^{T-1})] * (1\text{-}UZ\text{-}K)/(1\text{-}U)$

where:

$P$ = the deflator for asset type i
$R$ = the internal rate of return
$D$ = the depreciation rate for asset type i
$P^T - P^{T-1}$ = the capital gain term for asset type i

$(1\text{-}UZ\text{-}K)/(1\text{-}U)$ reflects the effect of taxation in which:

$U$ = the corporate tax rate
$Z$ = the present value of $1 of depreciation deductions
$K$ = the effective investment tax credit rate

The rental prices are calculated in rates per constant dollar of productive capital stock. Each rental price is multiplied by its constant-dollar capital stock to obtain current-dollar capital costs which are converted to cost shares for Tornqvist aggregation of the capital input index.

The input of intermediate purchases includes the materials, fuels, electricity, and services consumed by Class I railroads. Detailed cost of materials data are available for the years 1958–69 and 1978–forward from the AAR and ICC respectively. Each item is matched as closely as possible to a Producer Price Index (PPI). The detailed values are then deflated and the resulting deflated values are Tornqvist aggregated. For the years 1969-78, only a value for total materials is available from AAR. These data are benchmarked to the 1969 and 1978 values mentioned above. An aggregate base-year weighted materials deflator is calculated using the cost-of-materials detail from AAR in 1969 to weight up the appropriate PPIs. Then, this deflator is used to deflate the total materials aggregate for the 1969–78 period. The three constant dollar material segments are then linked.

As with the materials measure, detailed cost of fuels data are available for the years 1958-69 from AAR. These values are deflated with appropriate PPIs and then Tornqvist aggregated. For the years 1969–forward, detailed quantity and average cost for fuels for motive power are available from AAR. Each segment is Tornqvist aggregated to a measure of total fuels consumed and then linked. Data on the quantity and value of electricity consumed by the industry are obtained from the Edison Electric Institute.

Data on the detailed value of purchased services consumed for freight operations are available from the ICC for the years 1978-forward. Net-rent data (net-rent data exclude intra-industry rental transactions) are also calculated from ICC data. Non-rent purchased services are obtained by subtracting net rent from total purchased services. For 1958–78, non-rent purchased services are estimated by calculating the average ratio of non-rent purchased services to total operating expenses for the years 1978–87 and applying it to total operating expenses from 1958–78. Net-rent data for the same years are taken from AAR. The number of private line freight cars obtained from AAR is used as the quantity series for rent. The aggregate materials deflator is used to deflate non-rent purchased services.

The constant-dollar values or quantities of materials, fuels, electricity and purchased services are Tornqvist aggregated into the index of intermediate purchases input.

The index of combined inputs is calculated as a Tornqvist aggregation of the input indices of labor hours, capital, and intermediate purchases. The cost share weights are calculated by estimating the annual nominal dollar cost of each, summing them and dividing each input's cost by the total.

# Endnotes

1 Extensive discussion of this issue is in Zvi Griliches, ed., *Output Measurement in the Service Sector*, National Bureau of Economic Research Studies in Income and Wealth, No. 56 (Chicago: University of Chicago Press, 1992).

2 For a discussion, see Robert J. Gordon, "Productivity in the Transportation Sector" in Zvi Griliches (ed.) *Output Measurement in the Service Sector* (Chicago: University Chicago Press, 1992), pp. 385–94. Gordon refutes the contention that deregulation has led to increased circuity in air travel.

3 The application of such systems by Roadway Services, Inc., is described in Federal Highway Administration, *An Examination of Transportation Industry Productivity Measures,* (Washington D.C.: U.S. Department of Transportation, July 1993), p. 17.

4 See Zvi Griliches, ed., *Price Indexes and Quality Change: Studies in New Methods of Measurement* (Cambridge, MA: Harvard University Press, 1971).

5 Mark K. Sherwood, "Difficulties in the Measurement of Service Outputs," *Monthly Labor Review,* March 1994: 11–19.

6 Dale W. Jorgenson and Barbara M. Fraumeni, "The Output of the Education Sector," in Griliches, *Output Measurement in the Service Sector*, 303–38.

7 This suggestion was made by Bahar B. Norris, who was a participant in a workshop discussion which is summarized in Federal Highway Administration, *An Examination of Transportation Industry Productivity Measures.*

8 This suggestion was made by Robert V. Delaney, who was a participant in a workshop discussion which is summarized in Federal Highway Administration, *An Examination of Transportation Industry Productivity Measures.*

9 John Duke, "Productivity Measures for Transportation Industries", paper presented at the Highway-Related Transportation Industry Productivity Measures Symposium, Arlington, VA, November 20, 1992, (Washington D.C.: GPO, 1993).

10 See Bureau of Labor Statistics, *Productivity Measures for Selected Industry and Government Services*, Bulletin 2421, Appendix A (Washington, DC: U.S. Government Printing Office, April 1993).

11 In this context, note that BLS uses an age-efficiency function to adjust for the decline of the productive capacity of capital goods over time. For an extensive treatment of this issue, see Robert Gordon, *The Measurement of Durable Goods Prices* (Chicago: University of Chicago Press, 1990).

12 Ernst R. Berndt and Melvyn Fuss, "Productivity Measurement with Adjustments for Variations in Capacity Utilization and Other Forms of Temporary Equilibrium," *Journal of Econometrics*, Vol. 33, No. 1 (1986): 7-29.

13 Gordon, 1992, p. 401.

14 Gordon, 1992, p. 384.

15 Case study evidence of how improved transportation contributes to gross productivity growth in manufacturing and service firms is found in Apogee Research, Inc., *Case Studies of the Link Between Transportation and Economic Productivity*, report prepared for the Federal Highway Administration (Washington, D.C.: January 1991).

16 Gordon, p. 398.

17 John Duke, Diane Litz, and Lisa Usher, "Multifactor Productivity in Railroad Transportation," *Monthly Labor Review*, August 1992: 49–58; see p. 54 for an explanation of capital estimate.

18 Gordon incorporates estimates of government capital in his MFP growth estimates. See Gordon, tables 10.13 and 10.15.

19 An algebraic method is used to correct for this type of situation. The logic may be described as follows: In each period, the aggregate ratio of output to labor is a weighted average of the same ratio for both TL and LTL. This ratio can change from period to period for one of two reasons: Either one or both of the ratios for the two levels of service changes, or the relative weights of the two ratios in determining the aggregate ratio change. Only if the ratio of output to labor for one or both of TL and LTL service changes, is there a true change in labor productivity. Thus, the key function of the index number is to control for changes in the relative weights of the two service levels.

20 The wages of different categories of workers are used as weights in the labor input index. The quantitative impact of differences in education and experience on wages is estimated using econometric wage functions. For complete technical details, see Bureau of Labor Statistics, *Labor Composition and U.S. Productivity Growth, 1948–90*, Bulletin 2426 (Washington, DC: U.S. Government Printing Office, December 1993).

21 Robert Gordon, *The Measurement of Durable Goods Prices,* 1990, Table 4.16. The Bureau of Economic Analysis series was constructed to adjust for year-to-year price changes in identical aircraft models. The quality-adjusted series accounts for differences between the prices of different models as they replace one another over time. It was produced via a method that

takes account of the ability of capital to yield net revenue, defined as the difference between gross revenue and operating costs.

22 Gordon, "Productivity in the Transportation Sector," p. 405, Table 10.13.

23 A compendium of papers on the role of transportation in global warming is found in David L. Greene and Danilo J. Santini, eds., *Transportation and Global Climate Change* (Washington, DC: American Council for an Energy-Efficient Economy, 1993).

24 For general discussions, see Frances Cairncross, Costing the Earth (Boston: Harvard Business School Books, 1992); and David Pearce, Anil Markandya, and Edward Barbier, *Blueprint for a Green Economy* (London: Earthscan, 1989).

25 Regulatory boards in California, Nevada, New York, and Massachusetts have assigned social costs to emissions of carbon monoxide, carbon dioxide, and sulfur oxide to use in making planning decisions. See Paul L. Chernick and Emily J. Caverhill, "Valuation of Environmental Externalities in Energy Conservation Planning," Chapter 11, in Edward Vine, Drury Crawley, and Paul Centolella, eds., *Energy Efficiency and the Environment: Forging the Link* (Washington, DC: American Council for an Energy-Efficient Economy, 1991).

26 See the examples of Campbell Soup Company, General Motors, and Koley's Medical Supplies in Apogee Research, Inc.

27 See Andrew F. Daughty, Forrest D. Nelson, and William R. Vigdor, "An Econometric Analysis of the Cost and Production Structure of the Trucking Industry," in Andrew F. Daughty, ed., *Analytical Studies in Transport Economics* (Cambridge, England: Cambridge University Press, 1985).

28 Apogee Research, Inc.

29 Gordon, "Productivity in the Transportation Sector," p. 418, Table 10.15.

30 S. Judy Wang Chiang and Anne Friedlander, "Output Aggregation, Network Effects, and the Measurement of Trucking Technology," *The Review of Economics and Statistics*, Vol. 66, No. 3 (1984): 267–76.

31 Apogee Research, Inc.

32 Gordon, "Productivity in the Transportation Sector."

33 Gordon points out that BLS data have been carefully adjusted to maintain conceptual consistency over the postwar period, while the NIPA data have not. Thus, with the exception of their low level of coverage for trucking, he concludes that the BLS data are preferable to the NIPA data. Gordon, "Productivity in the Transportation Sector," p. 381.

34 Paula Cullen Young, *Transportation: The Industry and the Activity* (Washington, DC: Bureau of Economic Analysis, August 1994).

CHAPTER **SEVEN**

# TRANSPORTATION INVESTMENTS *and* ECONOMIC PERFORMANCE

The relationship between the growth of regional or national economies and transport infrastructure is reciprocal. Over the last two centuries, transportation infrastructure has clearly played a part in determining the regional structure and spatial character of the U.S. economy; it continues to exert its influence today. There is evidence that investments in highways and other public transport capital reduce the costs of transportation and production, and contribute to economic growth and productivity. At the same time, changes in the economy—such as growth, technical change, and structural change—affect industry and household use of highways, air transportation, water transport, and urban transit.

This chapter discusses the nature and magnitude of these reciprocal relationships. It begins with a survey of the research in the United States, Europe, and Asia on the contribution that transport infrastructure makes to the overall economy. It first covers the role that transport public capital plays in economic development (development implies a transformation in the structural conditions of society well beyond growth, which refers to just an increase in the scale of activities). Illustrations of development abound not only in contemporary developing economies, but also in the experience of the stimulus provided by canals and railroads to agricultural and industrial development of the Midwestern United States in the last century. This first part of the chapter highlights the past and continuing role of transportation systems in these structural transformations in the United States.

The second part of this discussion focuses on the transport infrastructure's contribution to current economic growth and productivity in the United States. Over the last two decades, a good deal of empirical research was carried out on this issue, particularly with respect to highway capital mostly in Europe and Asia, and to some extent with reference to the lagging regions (e.g., Appalachia) of the United States. However, in the last 5 years, this subject has sparked a debate. While some conclude that a decrease in public infrastructure investments in recent decades played a large role in the country's productivity slowdown, others suggest that highways and other forms of public capital make no marginal contribution to private production in the United States—i.e., that the country is effectively saturated with highway capital. But a clear majority of the studies conclude that highway capital makes a positive, although small, contribution, relative to that of private inputs (labor or capital) to aggregate production. Studies in Asia and Europe also find positive contributions of transportation infrastructure. Still, the findings are sufficiently varied to suggest that the ways in which transportation affects overall productivity are not fully understood, and warrant further inquiry.

The final part of this chapter focuses on the reciprocal relationship cited above —specifically, how changes in the U.S. economy affect the demand for different forms of transport infrastructure, the costs of its use by industries and households in 1977 and 1984, and what these changes in infrastructure use imply.

## The Effects of Transportation Infrastructure on U.S. Economic/Spatial Structures

### Transportation and Economic Development in History

Economic development usually refers to the transformation of largely agricultural societies with a limited level of manufacturing and low per capita income growth into newly industrializing nations. However, developmental transformations also continue to occur in advanced industrial countries such as the United States because not all regions within a country develop at the same pace, and personal income lags behind in some regions.

Development transforms the spatial structure of regions and cities. In the United States, first the canals and then the railroads stimulated the agricultural and industrial development of the Midwest. Next, the transcontinental railroad linked the East and West coasts and filled in the middle part of the continent, altering the regional distribution of population and industry by the turn of the century. After this, the automobile and interstate highways transformed the landscape of urban areas, continuing the process begun by the streetcar in the late 19th century. The process continues even now.[1]

Two case studies—one on the Midwest and a second about upstate New York—illustrate the developmental effects of transport infrastructure. The progressive development of this infrastructure, particularly railways, sharply lowered the cost of transportation and brought crops from the Midwest within economic reach of Eastern markets; this, in turn, sparked rapid agricultural expansion and the growth of the food processing industry in the Midwest. With the introduction of steam power, industrial development broadened into other sectors, as these case studies show.

Contemporary developmental effects in the United States derive from the strong influences of transportation on the spatial patterns at the metropolitan and regional levels with their attendant quality of life consequences. Such developmental contributions of transport infrastructure have attracted considerable attention in both the research community and various branches of government. The issues these analysts focus on have included:

- The spatial structure of cities and metropolitan areas, with the problems (such as access to economic opportunities for various segments of the population) these structures produce;
- The relationship between transport and business innovations which frequently support more far-reaching corporate restructuring; and
- The distribution of population and industrial activity among various regions and the environmental impact of such movements.

### Spatial Structure of Cities and Metropolitan Areas

A recurrent concern since the 1960s has been how well metropolitan transport provides access to employment and training opportunities, particularly for inner city residents. In some areas, public transit systems have transported people to jobs quite successfully. In a number of cities, however, rail systems operate in a radial pattern away from the central business district. Because many firms have moved from the center to dispersed areas in the suburbs, these routes no longer effectively link low-income workers with employment. At the same time, congestion on urban freeways is rising, both for personal travel and freight transport—with attendant economic and environmental costs.

### Relationship Between Transportation and Business Innovations

Many U.S. corporations restructured their operations considerably between the 1980s to the present. Some carried out both horizontal and vertical integrations, while others spun off operations that had only a limited relationship to the principal business. Several of these changes rearranged the production process, which had significant effects on transportation. For example, the adoption of just-in-time inventory systems by manufacturers and retailers translated into more small-load traffic for the transportation network and the need for punctual deliveries. In some instances, restructuring (such as in the medical industry, with respect to pharmaceutical producers and distributors) changed the entire system of warehousing and relocated facilities within metropolitan areas.[2] These changes altered transport patterns (in terms of congestion and physical wear on infrastructure) but are understood only marginally. Further, it is thought that just-in-time systems in the retail sector transfer waiting time, and possibly additional transport costs to consumers; but neither such costs nor other transportation effects are accounted for statistically.

The telecommunications revolution (which is critical to corporate restructuring) is likely to affect the demand for both location of economic activity and transport, although it is unclear whether advanced, real-time communications capabilities will substitute for or complement various modes of transportation.

### Distribution of Population and Industrial Activity

Since World War II, and especially since the 1960s, industries have relocated from the Northeast, mid-Atlantic, and upper Midwest to the South and West, taking jobs and population with them. Many of the older cities that lost population severely deteriorated during the 1960s and 1970s. However, a good number of these began to recover their economic and cultural base by the mid-1980s, and some even made significant environmental gains. Within cities on the receiving end of economic activity, transport infrastructure rapidly expanded, usually at much lower densities than existed in the sending regions. The rapid development in the receiving regions in the South and West involved expansion into wetlands, water and air pollution, and—in some areas in the West—serious groundwater depletion.

At the same time this shift occurred, there was the large post-World War migration of southern blacks (searching for better jobs) in Northeast and Midwestern cities; part of this migration occurred just as many of the firms in those cities began moving to suburban locations that were not easily reached by public transport.

The interstate highway system both fostered and adjusted to these regional rearrangements. But while its contribution to productivity has been examined, a precise accounting of its effect has been more elusive. Mills and Carlino found that interstate highways strongly affected the growth of manufacturing jobs and population in U.S. counties from 1970 to 1980.[3] They concluded that "if the density of interstate highways in a county were to double, manufacturing employment could increase by over 50 percent and population density by 17 percent over 10 years." The scope that highway location offers for interregional redistribution of population and industries has predictably directed recent attention to the progress of public highway invest-

# Transport Improvements and Agricultural

Between 1810 and the Civil War, a viable transport system was indispensable for the growth of agriculture in Ohio, Indiana, Michigan, Illinois, and Wisconsin, and of the Eastern markets where agricultural commodities were sold. Before the early 1800s, roads were primitive and often unserviceable, and land transport was expensive. Thus, only those areas adjacent to navigable rivers—and, later, canals—could ship produce economically, since the limits of commercial agriculture were determined by the cost of moving goods. Once transportation was improved, it tremendously reduced costs and enhanced the economic returns to Western farmers. As a result of reduced transport costs and increased demand for their products, farmers increased supply. Also, the reduced costs allowed farmers to obtain a steadily larger share of the selling price of their crops in Eastern cities; consumers also benefited, as they paid less.

**FIGURE 7-2**

Population in the Midwest: 1810–1860

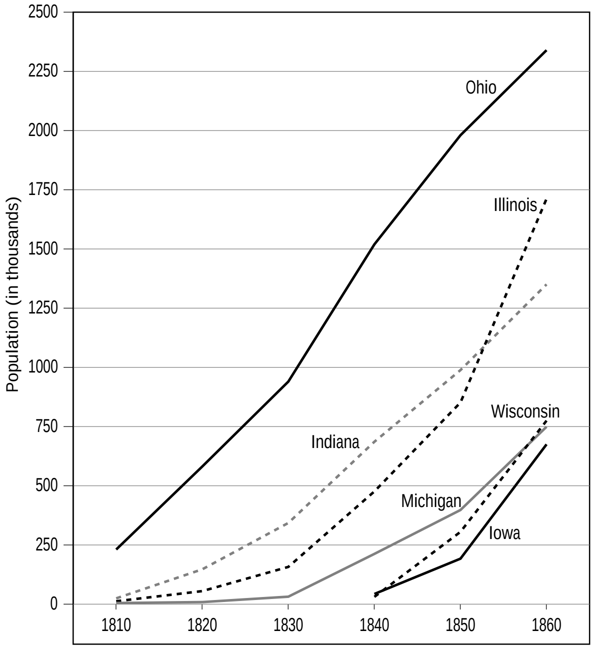
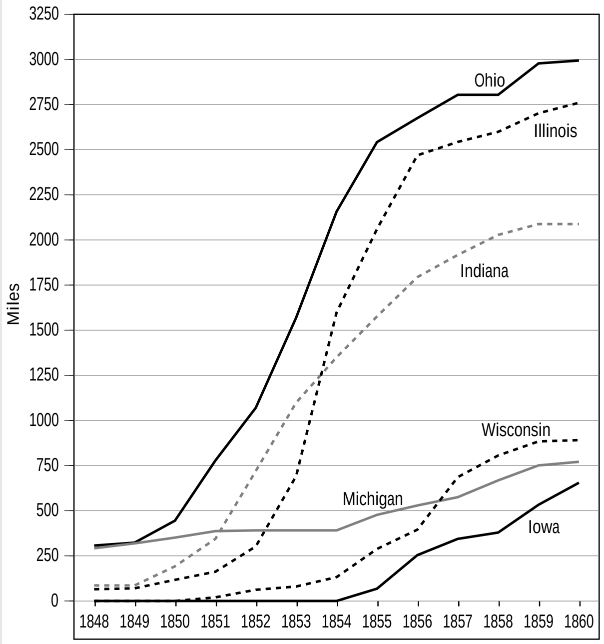


**FIGURE 7-1**

Railroad Mileage in the Midwest: 1848–1860



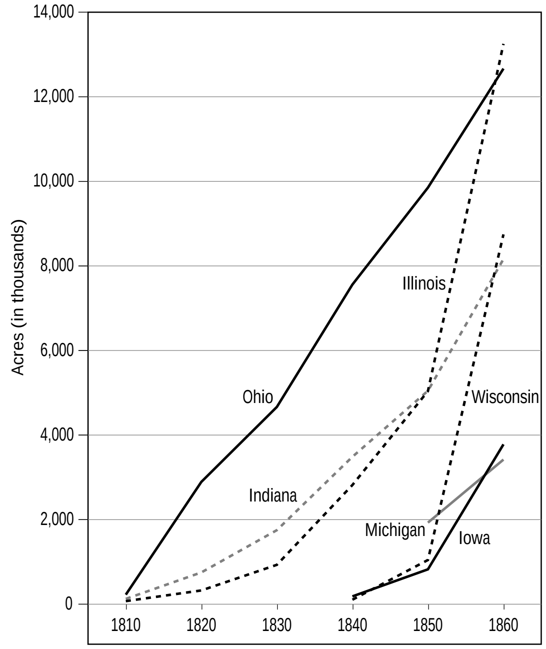
After 1848, rail-miles increased dramatically, as did the population and acreage cleared in the upper Midwest. (See Figures 7-1 through 7-3.) After 1869, the railroads also linked the far West to the Eastern seaboard. As freight costs were reduced, new areas were cleared and cultivated profitably.

Similarly, improved transport was critical in the process by which production became specialized. The expansion of agricultural production had far-reaching consequences. Market links to processing industries such as flour milling, distilling, tanning,

## and Industrial Development in the Midwest[4]

**FIGURE 7-3**

Acres of Improved Land in the Midwest: 1810–1860



and meat packing in the Midwest were particularly important. For example, in 1840, the mid-Atlantic states produced 65 percent of the value of flour, but only 39 percent by 1860. Meat packing experienced a similar shift: Chicago's pork packing tripled between 1852 and 1860, and its beef processing doubled. These processing industries were crucial to American industrialization.

High capital-output ratios (the milling industry ranked fourth in value-added in 1860 and its capital-output ratio was nearly double that of all manufacturing) encouraged the use of industrial steam power, which expanded the demand for products from the American machine tool industry. In turn, the high productivity per worker in agricultural processing industries (productivity per worker was more than double that in manufacturing) led to higher incomes both directly and indirectly, as it encouraged upstream industrialization. Even more important, modern technology was spread across the interior of the country, which eased the transition to more sophisticated industrial structures.

High returns in farming encouraged industrialization and urbanization of such areas as Cincinnati, St. Louis, Minneapolis-St. Paul, Omaha, and Kansas City. The growth of manufactures in the Midwest between 1840 and 1860 led eventually to its inclusion in the Northeast industrial heartland with its concentration of manufacturing. (See Figure 7-4.)

**FIGURE 7-4**

Value of Manufactured Products in the Midwest: 1840–1860

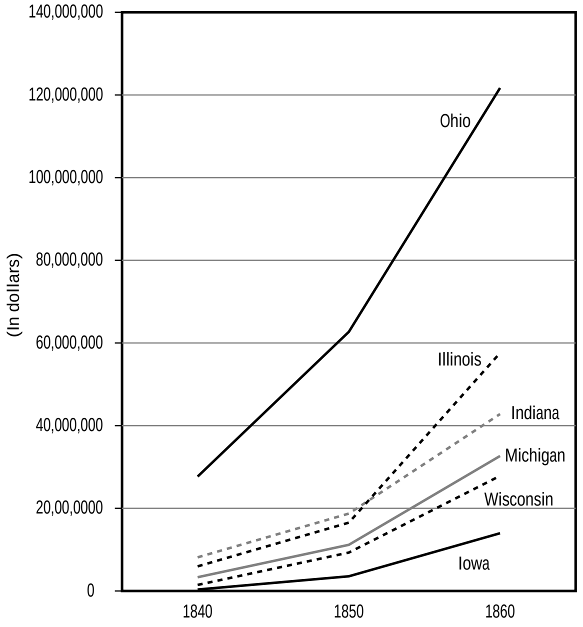
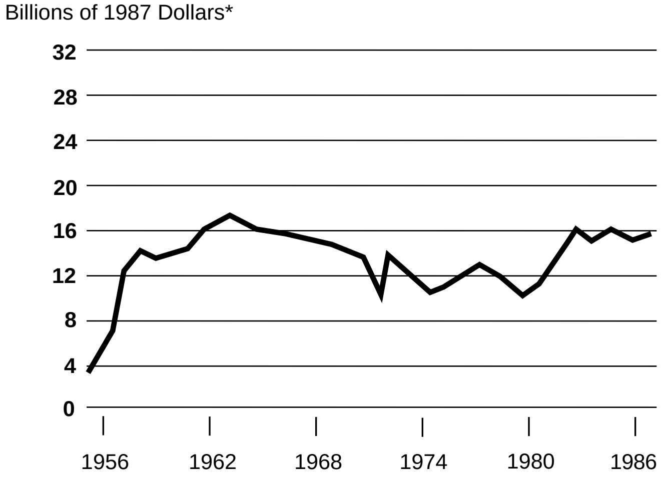


**FIGURE 7-5**

Federal Capital Spending for Highway Infrastructure: 1956-1987

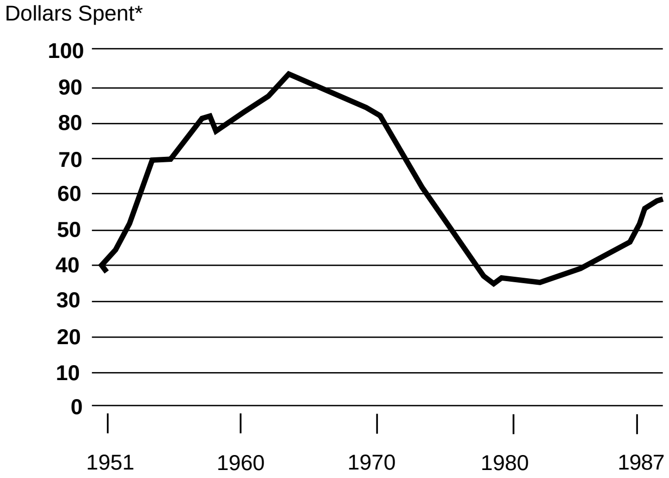


* Current dollars are adjusted to constant dollars based on the construction price index.

Source: Congressional Budget Office using data from the Office of Management and Budget.

**FIGURE 7-6**

Per Capita Highway Construction Expenditures in the U.S.: 1951–1987

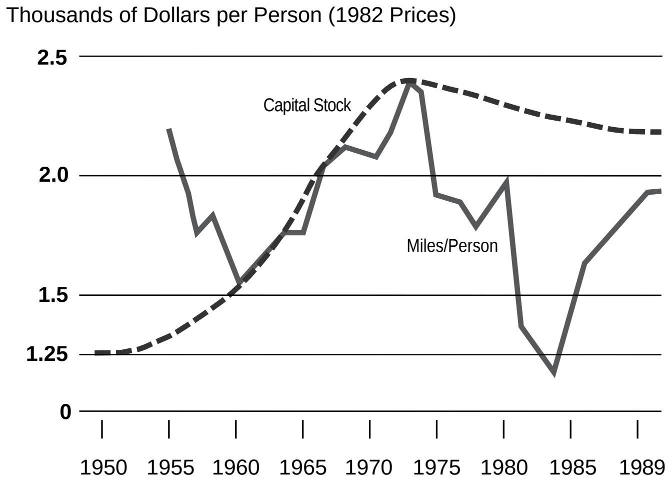


* Constant Dollars (1977=100)

SOURCE: L. Chatterjee and S. A. Hasnath, "Public Construction Expenditures in the United States: Are there Structural Breaks in the 1921-1987 Period?" Economic Geography 67 (1991), Fig 2, p. 48.

**FIGURE 7-7**

Per Capita State & Local Stock of Highways and Streets in Dollars and in Miles: 1950–1989



1 Compounded annual rate for the five-year period ending in each year.
NOTE: Capital stock is end-of-year data.

SOURCE: J.A. Tatom, "Should Government Spending on Capital Goods Be Raised?" *Federal Reserve Bank of St. Louis Review* 73:2 (1991), Fig. 6, p. 12.

ments. (See Figures 7-5 through 7-7.)

These developments and shifting spatial structures were major stories in postwar America. While each left its mark on U.S. productivity growth, the aggregate economic statistics do not reveal them. The above examples demonstrate transportation's spatial developmental effects, but it is far from clear that the construction of transport infrastructure will induce people to locate where they otherwise would not. Better facilities apparently improve the growth potential of areas that are already desirable. The issue then becomes, "How much better (transport facilities) is enough?"

## Transport Infrastructure and Economic Growth

The productive role of public infrastructure has claimed the attention of economists interested in national and regional development since at least the mid-1940s. Paul Rosenstein-Rodan found infrastructure to be a catalyst for the economic development of relatively backward Eastern and Southern European countries toward the end of World War II, and of Third World countries in the decade after the war.[5] Overall, large public projects (such as highways or electric power dams) in Latin American countries increased productivity, but the timing of the sector allocation of public projects affected the pace of overall growth—creating what was termed "unbalanced development."[6]

In the mid-1960s, researchers tried to evaluate the investments in transport and other productive infrastructure as

## Transport and Urbanization in Upstate New York[7]

The development of transportation in the United States contributed to urbanization in several ways. First, towns became centers of agricultural marketing, then manufacturing hubs for transport equipment and related linkages (to markets and suppliers), and later centers for transshipments between various modes.

The growth of Syracuse, New York, is instructive. As the city's transport facilities expanded, its population mushroomed from 6,256 in 1840 to 28,119 in 1860. Consequently, it began to play a more central role in the lives of people in the small, outlying towns; these people who responded to the enhanced transport and commercial activities during the period of railroad expansion. In turn, these customers further stimulated the city's economy and contributed to its growth through their purchases.

One visitor to Syracuse was William B. Harris, who bought a farm in rural Cicero in 1837. According to his diary, Harris went to Syracuse 54 times over the course of two years. Most of the trips were for business or legal reasons, or for making major purchases (such as farm machinery, furniture, or clothing). The city's transport facilities soon provided Harris with other reasons to travel: nearly one in five trips involved meeting friends and relatives arriving by canal or railroad or bringing his guests and visitors to the city to continue their travels.

advanced countries such as the United States and United Kingdom sought to stimulate their own lagging regions (such as Appalachia and the Ozarks in the United States and the Midlands in the United Kingdom). While many concluded that public infrastructure was an attractive instrument of development, the extent of its benefits were less understood than were methods for identifying which investments should be made.[8] Except for cost-benefit analyses of public projects, conceptual thinking about infrastructure was not closely integrated with empirical analysis.[9]

In the early 1970s, Koichi Mera found that public infrastructure—including transport and communications—would contribute to aggregate private production in ways similar to that of privately supplied inputs and that its impact on productivity could be assessed through the use of the production function framework. (See Chapter 6). He divided Japan into eight regions, and concluded that from 1954 to 1963 (a period of intense reconstruction), investments in transport and communication substantially contributed to private production in the secondary (manufacturing) and tertiary (service) sectors.[10] The output elasticities of 0.35 for the manufacturing sector and about 0.40 for the service sector implied that a 1 percent increase in infrastructure stocks led respectively to 0.35 percent and 0.40 percent increases in the outputs of Japanese manufacturing and service sectors.

For some time, there was little research with which to compare these results on the economic contributions of infrastructure. In the past decade, however, there has been an explosion of empirical studies on the productivity of public infrastructure within the framework of production and cost functions.

### The U.S. Experience

In the first such study in the United States, Ratner, relying on aggregate national data from 1949 to 1973, found an output elasticity of nonmilitary public capital of roughly 0.05.[11] This figure raised no controversy: although it was statistically significant, it was small. It also implied that while public capital was productive, the largest contributions were from privately supplied labor and capital.

In the late 1980s, a large number of production or cost function studies of highway productivity were carried out, but the striking findings of David Aschauer, in particular, about the U.S. experience from 1949 to 1985, raised their profile.[12] Before discussing Aschauer's work, however, two earlier studies need to be mentioned. One of these (by Costa, Ellison, and Martin) employed a flexible production function and state-level data to develop output elasticities for the public sector; the values were 0.19 for manufacturing, 0.26 for nonagriculture sector, and 0.2 for all sectors.[13]

The other, by Keeler and Ying, approached the issue of highway productivity from a different perspective—as a retrospective cost-benefit problem.[14] This study raised the issue of whether the interstate highway system lowered production costs for the trucking industry enough to cover a significant part of the investment. However, by focusing on the Class I trucking industry, the researchers knew they would capture only a portion of total benefits to the system, and that benefits to final consumers (such as households and the government) would be excluded. The study found that the reduction in costs due to highways was statistically significant; and that, when calculated annually, benefits to the trucking industry alone would have repaid between one-third and nearly three-quarters of the total highway investment. (See box on "Cost Savings from Investments in U.S. Federal Highways.")

### Aschauer: Findings, Critiques and Reformation

Using aggregate national data, Aschauer obtained an output elasticity for all nonmilitary public capital of 0.39 and for "core" public capital (highways, airports, utilities, mass transit, and water and sewer systems) of 0.24. Since the sum of the output elasticities usually is around 1, the relative contributions of privately supplied labor and capital were correspondingly smaller than those implied by Ratner's study. Alicia Munnell used a similar procedure, but different data, on aggregate private capital stock and extended the time period to 1948–87.[15] Her output elasticities were comparable (0.31 to 0.39 for core public capital) to Aschauer's. These studies were carried out at a time when many observers were claiming that excessive government intervention had lowered productivity; however, Aschauer suggested that his production function findings suggested that much of the productivity decline since the early 1970s was due to under-investment in public infrastructure. His study has acted as a lightening rod, drawing extensive critiques from other U.S. economists, who appeared to have largely neglected previous studies of infrastructure productivity in the United States as well as in Europe and Asia.

Objections to Aschauer's findings take two broad forms. Most of Aschauer's critics point to two types of statistical problems associated with the use of aggregate time series data in the Aschauer/Munnell studies:

The data might create a spurious relationship between inputs to production and output because they both tend to grow over time.

There might be time lags between the construction of public infrastructure and producers' use of it, which could make estimates about productivity obtained from time series data unreliable.

A smaller group of critics suggest that public infrastructure makes little, if any, contribution to the overall economy. Responses to both of these criticisms have led to sophisticated analytical reforms and reinterpretations of earlier findings.

Responding to the first statistical criticism, Lynde and Richmond conducted two additional studies, applying a more sophisticated analysis to the time series data—cointegration analysis or error-correction models.[16] They used aggregate national time series—one annually for the United States from 1958 to 1989, the other quarterly for the United Kingdom from 1966:1 through 1990:2—and found a statistically significant, cost-reducing effect of aggregate public capital on private production. The U.K. study attributed about 17 percent of productivity growth in manufacturing to changes in public capital expenditures per employee; this is about the same contribution made by changes in private capital expenditures.

Other researchers have responded to both of the statistical critiques by using cross-section time series data, which contain data for various U.S. states for several time periods. Aschauer and Munnell focused their analyses on the state level, specifically on highway stock. Aschauer examined the contribution that highway stock (per unit of state land area) and pavement quality made on the average annual growth of state income between 1960 and 1985.[17] The results showed positive, statistically significant, effects of both variables (stock and quality). However, because the analyses did not use a production function framework, the estimated magnitudes of these effects cannot be easily compared to previous production function analyses.

Munnell's study retained the production function framework and obtained statistically significant output elasticities of about 0.15 for core public capital and 0.04 for highway capital stock alone. Using one type of production function, the estimated output elasticities for labor and private capital assumed quite satisfactory values (0.59 for labor and 0.31 for private capital), that were close to the fractions of overall national income going to those two categories of inputs.

This state cross-section time series approach to estimating the productivity of highways has been subject to some technical criticisms, and some useful clarifications.[18] For example, Eisner separated the

## Cost Savings from Investments in U.S. Federal Highways[19]

Between 1950 and 1973, the stock of U.S. federal highways grew from $44.3 billion to $185.8 billion (in 1973 dollars), which, with a 12-percent interest rate and 25-year lifetime, would yield an annual capital cost of $17.8 billion. Keeler and Ying estimated a cost function for the Class I trucking industry over this period that yielded a cost elasticity of –0.07 for highway capital. Then, with simulation techniques, they explored the value of cost savings for the entire trucking industry over this 24-year period.

If alternative assumptions are made about the price elasticity of demand for freight transport and the social discount rate for public investment in highways, the cost elasticity of the infrastructure (–0.07) implies savings in the cost per revenue ton-mile carried by the trucking industry from 0.038 cent in 1950 and to 1.93 cents by 1973. These figures represent an annual saving of 19.3 percent (or $9.73 billion) for transport (at 1973 levels) on 1950 highway infrastructure.

Table 7-1 shows the cost savings for Class I trucking firms alone from the interstate highway system under alternative assumptions about the price elasticity of freight transport and the social discount rate for highway investment. In the more pessimistic case, which assumes a high price elasticity (–2) for freight transport and a high social discount rate (12 percent), one-third of the cost of the interstate system can be counted as a cost savings just to Class I trucking firms. Under the reasonable case of –1 price elasticity and a 6 percent social discount rate, 72 percent of the cost of highways can be counted as savings to the same firms. These estimates do not include the benefits to passengers or those obtained from the improved quality of freight service.

**TABLE 7–1**

Cost Savings from the U.S. Interstate Highway System

| Scenarios | Assumptions | Cost savings for Class I trucking firms only |
|---|---|---|
| I. | "pessimistic" case<br>(a) Price elasticity of freight carriage to be –2<br>(b) High social discount rate (12%) for highway investments | 33% of the total capital cost of the Interstate Highway System ($5.97 billion) |
| II. | (a) Price elasticity of freight carriage to be –1<br>(b) High social discount rate (12%) for highway investments | 44% of the total capital cost of the Interstate Highway System ($7.85 billion) |
| III. | (a) Price elasticity of freight carriage to be –1<br>(b) Social discount rate (6%) for highway investments | 72% of the total capital cost of the Interstate Highway System ($12.84 billion) |

variance in Munnell's state time series data into a variance across states for each year and the variance over time in each state. He found that the variation across states in highway stock per capita was of far greater importance in explaining income growth.[20]

The second broad type of critique noted above, is exemplified by two studies in the past decade by Hulten and Schwab, who suggest that public capital has some limited value in accounting for regional differences in economic performance.[21] One study found that most of the variation in total factor productivity growth among nine U.S. census regions between 1951 and 1976 can be accounted for by regional differences in the private capital-labor ratio, attributing nothing to differences in public infrastructure. However, the study is subject to the criticism that it does not apply any measure of public capital, the variable not included in the analysis but about which conclusions were drawn.

Hulten and Schwab's second analysis of the role of infrastructure in economic growth provides results whose interjection is unclear. They examined two models of the way public capital might contribute to private production and compared their implications for biases in measurements of productivity growth. These models were applied to annual rates of productivity growth in U.S. manufacturing from 1951 to 1986. The studies concluded that public capital made no contributions to productivity growth in manufacturing aside from those already captured in the growth of intermediate inputs, which include transport. The models used in this study imply that the growth rate of private capital should play a statistically significant role in measured productivity growth in manufacturing only when public capital has a direct effect on private production. However, the statistical results from this study were that private capital has an effect when public capital has none, and the interpretation of this result is unclear. In still another study, Moomaw and Williams used U.S. data from the state level and found statistically significant contributions of highway density to total factor productivity growth.[22]

## Productivity Analysis in Other Countries

Many studies about the effects of transportation and other public infrastructure on regional or national economic growth have been carried out in European and Asian countries, some of it preceding the work done in the United States. Cross-section and cross-section time series approaches were used extensively with data from different countries, time periods, and sectoral disaggregations (specific industries, groups of industries, economic sectors, and aggregate production); various types of cost functions and production functions; different types of administrative units, including metropolitan areas as well as states; (in Sweden, United Kingdom, France, Germany, India, Japan, etc.), and various methods of accounting for characteristics of states or other units.[23] These studies invariably found statistically significant output elasticities for aggregate public capital and highway capital, when measured separately. The size of the estimated highway elasticities varied within an acceptable range between 0.03 and 0.08; the ranges of output elasticities for labor and private capital were more varied.

Some of these studies consider certain analytical aspects not explored in American studies. For example, two analyses address the time lag in the private sector in responding to investments in public capital. Elhance and Lakshmanan, in a study of India from 1950 to 1979, found that it took firms a little over 5 years to adjust completely their production activities to changes in public infrastructure.[24] In a Swedish study, the period was found to be 14 to 26 years for complete adjustment to changes in highway infrastructure, depending on the industry.[25] Two other Swedish studies and one in France found that the accessibility of public facilities to the populations they served contributed to their productivity.[26]

The overall thrust of these analyses of the contribution of transport infrastructure to the overall economy in other countries is clear. Using various specifications of production and cost functions over different time periods, in different countries, and with slightly different representations of several variables, researchers have usually found that transport infrastructure makes a contribution to productivity of the aggregate economy. (See Table 7-2.)

### Interpreting the Productivity Studies

Despite a broad agreement among the studies on the contribution of transportation involvement on the overall economy, the wide range of statistical results is due to several factors. Part of the variation can be accounted for theoretically.

The statistical procedures applied to correct for spurious relationships frequently lead to results that fail to satisfy the economic theory of social processes under study. This discrepancy between technically correct statistical methods and the economic behavior being examined raises questions about the theory used to guide statistical investigations.

The production function approach does not satisfactorily represent the characteristics of transport infrastructure—especially its network characteristics—or the outputs of the transport system. The latter may be inadequately represented in some of the analyses by measures of transport output (such as vehicle-miles, ton-miles, and revenue-passenger-miles traveled), rather than by measures of transport outcome.

Thus, the relationship between transport infrastructure and economic growth needs to be conceptualized further to provide a stronger basis for future empirical research, which can in turn support statistical findings and interpretations that may evoke greater confidence.

#### *Variations Explained by Economic Theory*

Some of variations among the studies in the estimated output elasticities can be explained on theoretical grounds. For example, studies using national data yield larger output elasticities for transport infrastructure than those relying on state data.[27] But, it is to be expected that some of the benefits of highways in one state would spill over into another, so this finding of a larger contribution of highways to economic growth at the national level is reasonable.

However, the wide variations in estimated output elasticities of private capital and labor are disturbing. One interpretation is that the structure of production that includes public infrastructure as an input is more complicated than current models can reflect and that the simplifications in the models create quite substantial estimation problems. Overall economic output changes annually, while private production capital turns over in many years; transport infrastructure capital

**TABLE 7–2**

Summary of Output and Cost Elasticities of Highway and Other Public Capital in Various Countries

| Country | Sample | Infrastructure measure | Elasticity range |
|---|---|---|---|
| United States | aggregate (ts)<br>states (xs)<br>states (ts/xs)<br>regions, trucking industry (ts/xs) | public capital<br>public capital<br>highway capital<br>highway capital | output: 0.05 to 0.39<br>output: 0.19 to 0.26<br>output: 0.04 to 0.15<br>cost: –0.07 |
| Japan | regions (ts/xs) | transportation & communication infrastructure | output: 0.35 to 0.42 |
| United Kingdom | aggregate (ts) | public capital | cost: negative, statistically significant |
| France | regions (xs) | public capital | output: positive, statistically significant |
| Germany | industry (ts/xs) | public capital,<br>highway capital | cost: negative, statistically significant |
| India | aggregate (ts), states (xs) | economic infrastructure:<br>roads, rail, electric capacity | cost: –0.01 to –0.47 |

Note: ts=time series; xs=cross section

turns over in a much longer time span. Thus, these production and cost functions (dealing with economic output, private capital, and transport infrastructure) may fail to capture the relationships among economic processes operating at different speeds.

### *Statistical Procedures and Variability in Results)*

The statistical procedures used to correct for spurious interactions among states located near each other eliminate the statistical significance of (public) highway capital's productivity and also conclude that private capital contributes almost nothing to private production.[28] Some efforts to control for state characteristics also eliminate the productivity effect of public infrastructure. At the same time, they blur some immutable characteristics (such as mountainous terrain) with those that can change over time (such as education). As exemplified by these cases, the tension between technically correct statistical methods and the behavior being examined raises questions about the theory used to guide the investigations.

### *Misrepresentations of Transport System and Model Limitations*

The difference in the magnitude of output elasticities for infrastructure estimated from aggregate, national data and from state data reflects transport's spill-over characteristics. However, the size of the difference may point to a more serious technical problem which arises when estimating the productivity effects of transport at the state level. For example, when output, labor, and private capital inputs are reported at the state level, they describe the input quantities deployed by firms within the state and the value of income they produce.[29]

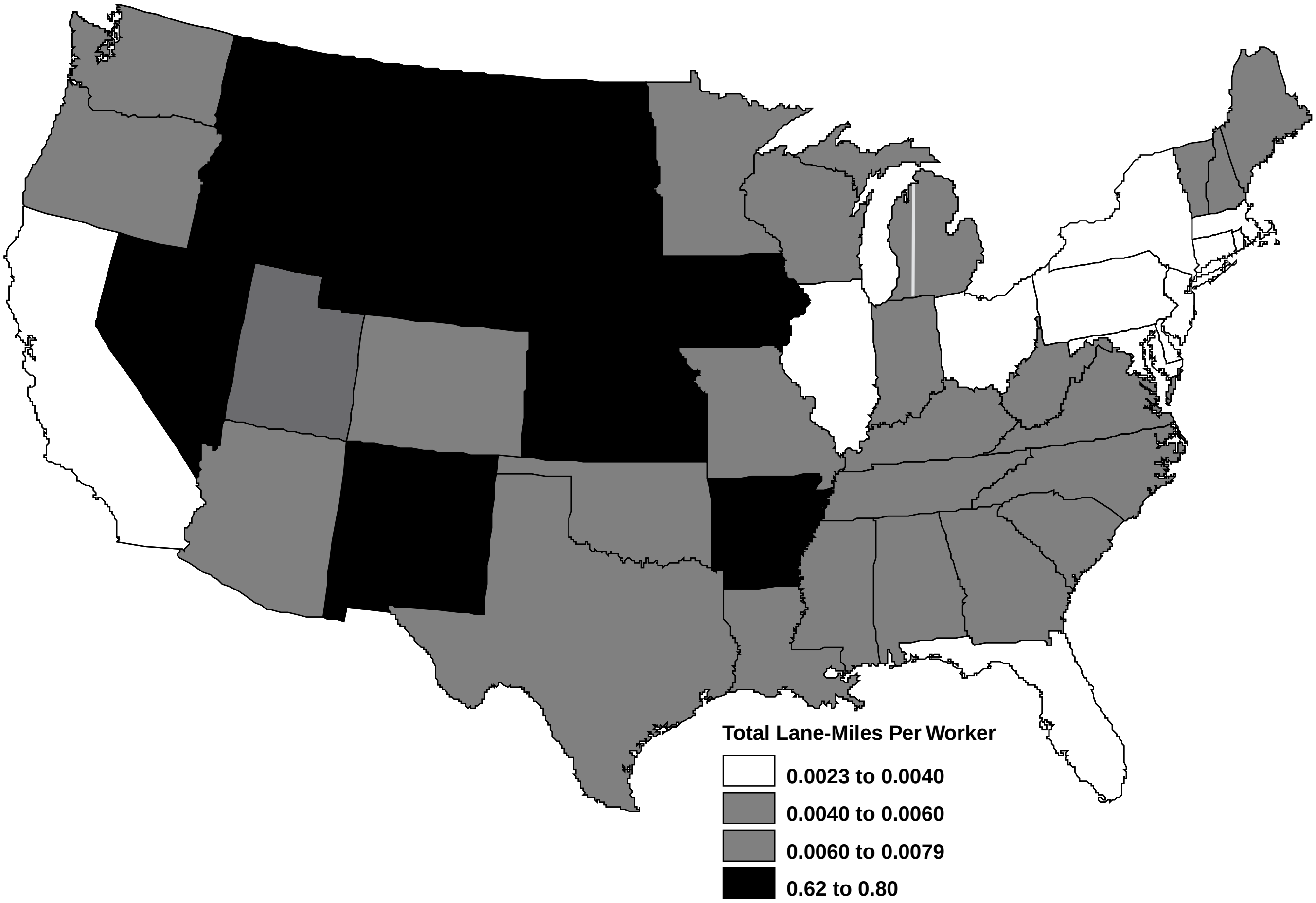
But such reporting does not account for transport's unique characteristics: if a Chicago firm sells goods to one in Seattle, it will truck them there by way of interstate highways across South Dakota, Wyoming, Montana, and Idaho. Although the infrastructure in those states contributes to income reported as produced in Illinois, the method of analyzing state-level transport productivity attributes the interstate mileage (or capital value) in those states against their own production, which does not include the Chicago-based firm's output. Thus, the data present a very high ratio of highway infrastructure to the size of the labor force in the rural states that lie between major manufacturing regions. (See Figures 7–8 and 7–9. Note that the pattern of darkly shaded states in these figures compares quite closely with the pattern of negative output elasticities of public capital calculated by some analysts.) Although truck drivers purchase food and fuel in the states they cross, this is the most revenue those states will get from the Chicago firm's use of the interstate highway mileage accounted to them (aside from some fuel tax revenue). And, while some discrepancies in aggregate data probably cancel each other out, this type of accounting creates a serious discrepancy between the economic theory of the production function and the accounting system that generates highway infrastructure data used in the production function studies reported here.

How serious is this problem? Using state data, studies by Costa *et al.* have produced negative output elasticities of public capital for Arizona, Montana, Nebraska, Nevada, New Mexico, North Dakota, South Dakota, Utah, Wyoming, and Washington; and for rural lane-mileage by Jones et al. using state-level data.[30] In general, these studies eliminate the productivity effects of public capital, and the output elasticities of private inputs take on values that are difficult to believe. Excessive inputs are counted in states that serve as highway corridors for the rest of the nation, and too little is ascribed to infrastructure in major manufacturing states.[31] Using only aggregate, national data eliminates the accounting problem, but also drastically restricts the statistical investigation, and does not account for the lag in the response of private producers to public investments.

It is possible that the production function approach does not satisfactorily represent the characteristics of public inputs in general, of transport infrastructure in particular (especially its spatial network character), or the outputs of the transport system. These latter may be inadequately represented by output measures such as vehicle-miles, ton-miles, or revenue-miles traveled, and might be more appropriately represented by outcome measures such as economic output or income.

**FIGURE 7–8**

Total Lane-Miles Per Worker
(Higher Functional Class)

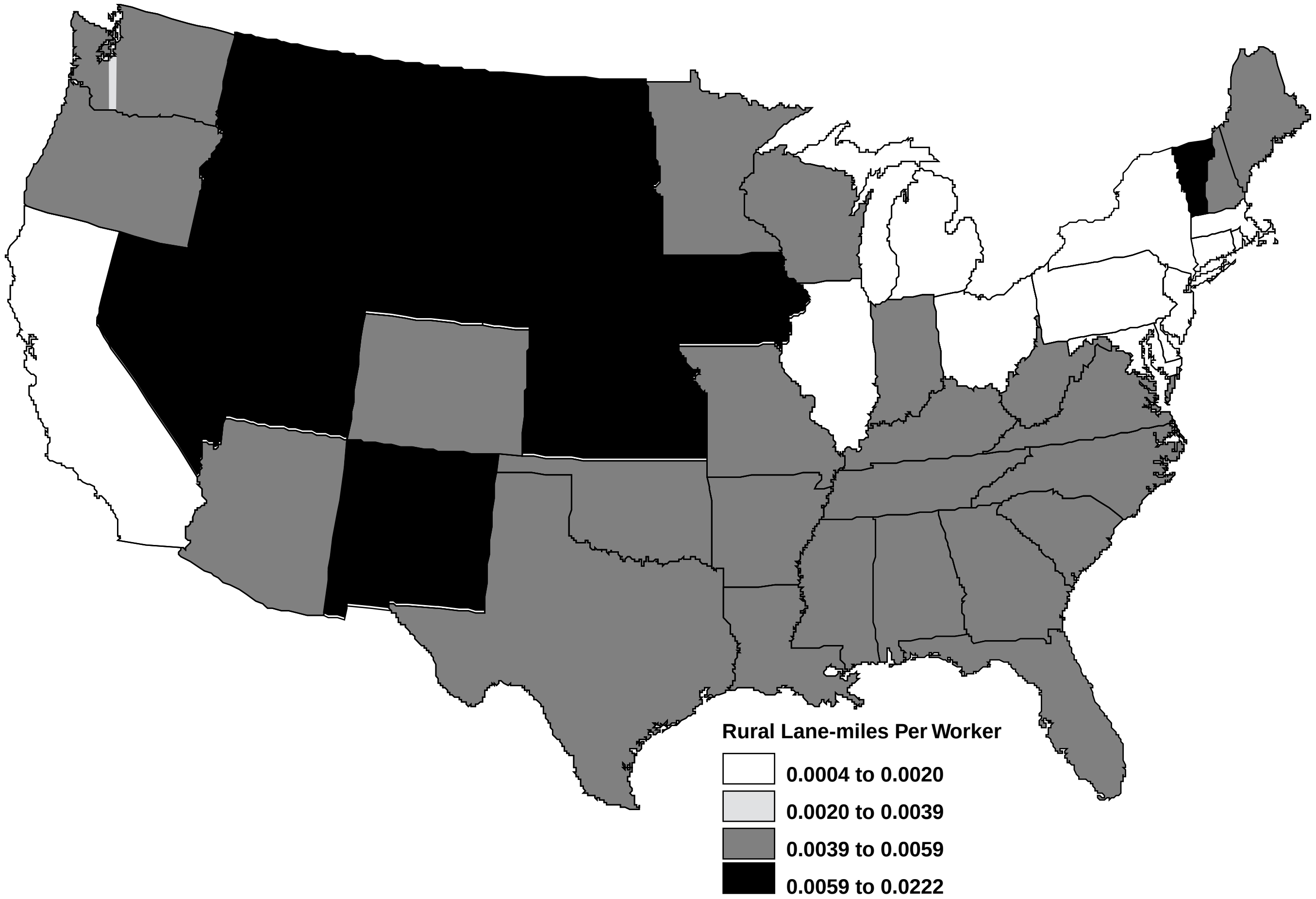


When exploring the productivity of transport, the relationship between economic theory (and its models) and empirical research on transport-economy interactions must be compatible. Any relationship imposed by the statistical investigation involves a model of how the economic phenomena underlying the data interact, and the statistical investigation invariably results in an interpretation (e.g., infrastructure is productive or it is not; there is too much of it or not enough). The model may be developed beforehand or it may evolve, or it may remain only implicit. It may or may not represent the relationships well and may present some errors. But if its limits are understood, the model can be useful and provide a measure of reliability when interpreting statistical results. Conversely, statistical results whose theoretical underpinnings are not understood confer less confidence in the interpretations. For this reason, the correspondence between statistical studies and well-understood theory in the area of transport infrastructure's economic contribution is a subject of some concern.

While some things are known, important, theoretical questions remain open yet: How does a publicly provided input (e.g., highway) affect a firm's production decisions within a production or cost function framework? Does the manufacturing sector derive most of its use of transport infrastructure through its purchased materials and business services materials? If so, does that simply transfer a pricing problem from one set of inputs to another? What proportion of manufacturing firms provide their own transport and why? Does knowledge of how well the transport system functions affect how a

FIGURE 7-9

Rural Lane-Miles Per Worker
(Higher Functional Class)



firm combines its nontransport inputs to produce its products? How does a firm's use of publicly supplied inputs differ from that of privately supplied ones? Further, the problem outlined above, where state transport infrastructure inputs and outputs are accounted for, is just one example of a discrepancy between theory and empirical measurement. Such discrepancies reflect both a data problem (observation and measurement) and a conceptual one (how private consumption of public goods should be modeled in an aggregate production or cost function). The effects of this discrepancy on statistical results are still unknown.

To sum up, due to the variations in results caused by the preceding flaws and weaknesses, further theoretical analysis of the transport infrastructure and economic growth relationship is necessary. To this end, transport data (both infrastructure and behavioral) must be assessed, and the economic processes at work must be theoretically analyzed. Because some important concepts may be difficult to measure directly, indirect measures should be explored and understood.

## Economic Change and the Use of Transport Infrastructure

Technological advances, growth, and the increasing globalization of the U.S. economy have promoted structural change: Some industries have expanded and increased their share of gross domestic product (GDP); and others have declined. Given this reality, it is important to determine how such technical and structural changes affect the nation's use of transport infrastructure.

## The Changing U.S. Economy

One way to assess the changes to the economy, and concomitant changes in the demand for transport, is to identify the attributes of declining and expanding industries over a specific period—in this case, from 1972 to 1984. (See Table 7–3.) For example, declining industries—the "smokestack" industries that dominated the economy for much of the 20th century and which lost their share of GDP over the years in question—use capital, energy, and materials intensively and create high levels of pollution. Conversely, expanding industries use materials and energy less intensively and thus pollute less. Also, they are knowledge-intensive, and include high value-added manufacturing industries such as electrical and electronic equipment, telecommunications instruments, business services, and real estate; they develop in dispersed locations and have a much greater need for transport.

Based on the attributes of these expanding industries, it appears that:

- The American economy will generate fewer ton-miles per dollar of GDP, but will require more frequent, reliable, faster transport service.
- Given the ongoing structural change, the demand for the levels and types of transport services is likely to be volatile.
- Spatial demand for transport infrastructure is becoming less predictable.

While the material weight transported per dollar of GDP may decline, an increase in outsourcing and networking will probably lead to more complex multimodal logistical systems and a rise in transport-related services.

**TABLE 7–3**

Attributes of Expanding and Contracting Industries in the U.S.: 1972–1984

| Industry Attribute | Expanding Industries | Contracting Industries |
|---|---|---|
| Material Intensity | Low | High |
| Pollution Intensity | Low | High |
| Capital Intensity | Low | High |
| Energy Intensity | Low | High |
| Scale of Production | Small | Large |
| Transportability of Products | High | Low |
| Geographical Dispersion of Production | Dispersed | Concentrated |

## The Changing Use and Cost of Transport Infrastructure Services

### *The Changing Cost of Services*

The Office of Economic Affairs in the U.S. Department of Commerce recently analyzed the needs of 95 sectors of the economy with respect to 11 public works services (including four types of transport infrastructure) in 1977 and 1984.[32] This analysis lists the costs and amounts of transport infrastructure and services used by each sector. The costs, estimated by calendar year, are divided into capital consumption allowances and operating expenditures. The former relate to the annual economic depreciation of the stock of public transport and can be viewed as capital costs, or the investment needed to maintain stock and service levels. The latter include all noncapital government outlays connected with transport services.

These costs were estimated by a perpetual inventory method and government investment data from the Bureau of the Census and Bureau of Economic Analysis. Use of the services (in 1977 and 1984) was estimated by industry, households, and government as a percentage of the total. Service costs and percentage of use by each economic sector were then applied to arrive at the costs of various transport services and public facilities used by each sector in 1977 and 1984. Finally, use coefficients (service requirements per $1 million of output) were computed for each industry.

The infrastructure use coefficients were based on actual use per unit of output by industry in 1977 and 1984—not on needs. Thus, this study is theoretically more robust than the typical needs-based transport studies and sheds light on the magnitude and mix of transport services and public capital used by various sectors. It is important to note that transport use levels reflect the production technologies and the industrial structure of the economy, and the investment in transport capital by various levels of government at any given time. To the degree that the transport capital stock in 1977 and 1984 (resulting from the economic and political choices made over a long period) is inadequate to meet the transport demand experienced in those years, congestion will ensue in the transport system.

## TABLE 7–4

### Cost of Transport Services in 1977 and 1984 (in constant 1977 dollars)

| Type of Transport Infrastructure | 1977 Operating Expense | 1977 Capital Consumption Allowance | 1977 Total | 1984 Operating Expense | 1984 Capital Consumption Allowance | 1984 Total |
|---|---|---|---|---|---|---|
| Highways | $11,350 | $10,350 | $21,700 | $11,901 | $13,174 | $25,075 |
| Air Transport Facilities | 2,530 | 488 | 3,018 | 2,776 | 730 | 3,506 |
| Water Transport Facilities | 1,686 | 645 | 2,331 | 1,257 | 739 | 1,996 |
| Urban Transit | 4,322 | 236 | 4,558 | 5,530 | 290 | 5,820 |
| Total Transport Infrastructure | 19,888 | 11,719 | 31,607 | 21,464 | 14,933 | 36,379 |

Source: U.S. Department of Commerce, “Effects of Structural Changes in the U.S. Economy on the Use of Public Works Service, 1987.”

It is worth noting that estimates of capital costs (as well as of net capital stocks and use coefficients) are highly influenced by assumptions about the service lives of highways or airports (this study’s assumptions were drawn from common practice). Thus, if the study had assumed longer service lives for the stock of highways, net highway stocks would have increased and capital consumption allowances (or capital costs) would have been lower.

The cost of providing different services is divided into operating and capital expenses. (See Table 7–4.) Predictably, the cost of providing highways (the most widely used transport infrastructure in 1977), is the highest; this is followed by the costs for urban transit, air transport, and water transport. By 1984, the cost (in constant 1977 dollars) of providing highways and air transport rose by 16 percent each, and that of urban transit by 28 percent. By contrast, 14 percent less was spent on water transport facilities.

Much of the increased cost for highways stems from the 27-percent hike in capital costs during that period, since the growth in operating expenses was modest. The reason for this increase in capital costs is related to the pace of change in highway stock in the period. Capital expenditures on highways, streets, and bridges were the highest of all public works categories in 1977, accounting for 51.2 percent of the value of capital stock in 10 types of public works. (See Table 7–5.) But by 1984, highway stock had declined (in constant 1977 dollars) by $6.7 billion, or 2.4 percent of its 1977 value.[33] It accounted for only 46.4 percent of the value of net capital stock of public works.

This reduction reflects the decreased proportion of total (public capital) construction represented by new highways, and the shift of government investment priorities between 1977 and 1984, in the wake of the energy crisis and the increased importance of environmental considerations. For example, the Clean Water Act of 1977 provided federal dollars to localities to construct sewage treatment and water supply facilities. Similarly, urban transit, whose capital stock increased by over 48 percent, benefited from the Urban Mass Transportation Act of 1964 and its amendments. Electric power structures increased most of all (55.1 percent), reflecting concerns with energy sufficiency. Thus, shifts in national priorities led to an absolute decline of net highway capital and of per capita highway construction, which appears to be recovering in the late 1980s.

Nevertheless, highways maintained their dominant position in the total trans-

## TABLE 7–5

### Transport and Total Infrastructure—Net Capital Stocks (millions of 1977 dollars)

| Infrastructure | 1977 | 1984 |
|---|---|---|
| Highways | $282,956 | $276,300 |
| Air Transport Facilities | 17,285 | 18,950 |
| Water Transport Facilities | 19,251 | 20,621 |
| Urban Transport | 13,577 | 20,127 |
| **Total Transport** | **333,069** | **335,998** |
| Total Public Works (10 Categories) | $553,033 | $594,955 |

port infrastructure. Air and water transport facilities gained in net value of stock by 10 percent and 7 percent, respectively; the figure for urban transit facilities increased sharply by 48 percent. Despite such growth in the capital stock of other modes of transport, the decline in highway capital reduced the proportion of total transport capital in all public transport infrastructure between 1977 and 1984—from 60.2 percent to 56.5 percent.

### Use of Transport Infrastructure Services by Industry, Households, and Government

Determining transport use by industries, households, and government in an economy requires several assumptions. For example, households use highways directly for their consumption (and production) activities and indirectly for the goods and services they purchase from industries and governments. But since the Department of Commerce study focused on industry's use of infrastructure, household or government use was allocated to those users when they used these facilities directly. Where households used a transport facility indirectly—say, by purchasing an industry's goods or services—the use was ascribed to the industry. Thus, if a trucking company delivered bananas or soap to a wholesaler or retailer, the use was allocated to the industry that paid the freight charge. The use of a highway by police cruisers was attributed to government purposes.

Highways and urban transit are mostly used by households directly, reflecting the importance of personal travel on these networks—59 percent and 94 percent, respectively. (See Table 7–6.) Household use of highways dropped from 64 percent to 59 percent between 1977 and 1984, as consumers, responding to higher energy prices, reduced their highway travel over the short term and acquired more energy-efficient cars over the long term.

At the same time, the industry share of highway use climbed from 34.5 percent to 40.2 percent, partly reflecting industries' lower price elasticity, and partly due to new logistical systems such as just-in-time inventories, which require more frequent use of smaller shipments on highways. Industry is also the main consumer of air and water transport.[34] Indeed, the transport service industry is the heaviest user of air and water transport facilities. Conversely, industry accounts only for 4 percent of urban transit use, since those commuting to and from work are allocated to the household sector.

The changing use of highways and air transport, when analyzed at the level of individual industries, provides interesting insights into the growth of relatively higher value goods and their related transport demands. For example, while highway use by all industries rose from 34.5 percent in 1977 to 40.2 percent in 1984 much of this increase is accounted for by the service, wholesale, and retail industries, whose use grew at or above the average rate (16.7 percent) for all industries. (See Table 7–7.)

The remarkable rise in the proportion of highway use among service, wholesale and retail trade, and durable goods manufacturing reflects the growth of relatively higher value traffic and the importance of just-in-time and other logistical systems. While the proportion of total transport use accounted for by air transport does not change much between 1977 and 1984, the same set of industries increased their share of air transport.

Except for water transport, the use of all types of transport infrastructure increased in this period. Industry as a whole used about $12.7 billion of infrastructure services in 1977 and $15.5 billion in 1984 (see Table 7–8), while households accounted for $18.6 billion and $20.6 billion (in constant 1977 dollars). While both sectors registered increases, industry's use outpaced that of households (22.4 percent compared to 10.5 percent). Further, industry's demand for transport infrastructure grew faster than the overall economy; the latter grew at a 2.4 percent average annual rate.

### Transport Infrastructure Use by Specific Industries

The use of highway services by major industries increased significantly in the 1977–84 period—by 15 percent. (See Table 7-9.) The most intensive user of highway services in 1977 was, predictably, the transport services sector which incurred

## TABLE 7–6

### Use of Transport Infrastructure Services: 1977 and 1984 (Percent Distribution)

| Sector | Highways 1977 | Highways 1984 | Water Transport Facilities 1977 | Water Transport Facilities 1984 | Air Transport Facilities 1977 | Air Transport Facilities 1984 | Urban Transport Facilities 1977 | Urban Transport Facilities 1984 |
|---|---|---|---|---|---|---|---|---|
| Total | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| Industry | 34.47 | 40.23 | 88.79 | 88.71 | 97.61 | 97.28 | 3.74 | 4.05 |
| Agriculture, Forestry, and Fisheries | 2.40 | 1.97 | 11.77 | 8.89 | 0.74 | 0.92 | 0.02 | 0.02 |
| Mining | 0.39 | 0.42 | 0.14 | 0.13 | 0.66 | 0.70 | 0.05 | 0.05 |
| Construction | 3.94 | 4.56 | 1.45 | 1.34 | 1.46 | 1.56 | 0.11 | 0.11 |
| Durable Goods Manufacturing | 2.77 | 3.24 | 3.41 | 2.61 | 9.60 | 11.19 | 0.71 | 0.77 |
| Nondurable Goods Manufacturing | 2.36 | 2.65 | 7.08 | 6.08 | 6.54 | 6.35 | 0.74 | 0.70 |
| Transportation Services | 3.59 | 4.18 | 61.85 | 66.00 | 58.04 | 52.25 | 0.25 | 0.22 |
| Electric, Gas, and Sanitary Services | 0.66 | 0.67 | 1.20 | 1.72 | 0.66 | 0.74 | 0.04 | 0.04 |
| Communication | 0.18 | 0.24 | 0.01 | 0.02 | 0.44 | 0.56 | 0.09 | 0.12 |
| Wholesale and Retail Trade | 11.26 | 14.60 | 0.40 | 0.42 | 5.63 | 6.58 | 0.57 | 0.63 |
| Finance, Insurance, and Real Estate | 3.06 | 2.87 | 0.07 | 0.07 | 2.22 | 2.51 | 0.11 | 0.12 |
| Other Services—Private and Public Enterprises | 3.85 | 4.83 | 1.40 | 1.43 | 11.72 | 13.91 | 1.04 | 1.27 |
| Household, Government, and Other* | 65.35 | 59.77 | 11.21 | 11.29 | 2.39 | 2.72 | 96.26 | 95.95 |
| Household | 64.06 | 58.50 | 11.21 | 11.29 | 0.85 | 0.87 | 94.36 | 94.26 |
| Federal Government | 0.20 | 0.17 | 0.00 | 0.00 | 0.73 | 0.77 | 0.06 | 0.08 |
| State and Local Government | 1.27 | 1.10 | 0.00 | 0.00 | 0.81 | 1.09 | 1.84 | 1.51 |
| Other** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

*Since the focus is on industry's use of government provided infrastructure, the household and government sectors only have services allocated to them when they directly use a government provided service, e.g., non-business use of highways with a private passenger vehicle, non-business use of municipal airports with private airplanes, and non-business use of mass transit systems.
**Other includes use for foreign trade and investment purposes.

## TABLE 7–7

### Change in the Share of Highway and Air Transport Use: 1977–1984

| Economic Sector | Highways | Air Transport |
|---|---|---|
| Construction | 16% | 7% |
| Durable Goods Manufacturing | 17% | 17% |
| Service, Wholesale and Retail | 30% | 17% |
| Other Service Provider and Public Enterprises | 26% | 19% |

nearly $6,175 in costs for highway services per $1 million dollars of its output. This level of consumption of highway services increased by 25 percent to $7,742 by 1984. Wholesale and retail trade, along with the construction industry, were the next largest users in 1984, at $7,519 and $3,854 per $1 million of output, respectively.

Interestingly, the use of transport infrastructure by the financial, insurance, and real estate sectors is higher than for both durable and nondurable goods manufacturing and mining. Since the service sector is growing faster than goods manu-

### TABLE 7–8

### Costs of Providing Government Services— Operating Expenditures and Capital Consumption Allowances: 1977 and 1984 (millions of 1977 dollars)

| | Highways | | Water Transport Facilities | | Air Transport Facilities | | Urban Transport Facilities | |
|---|---|---|---|---|---|---|---|---|
| **Sector** | **1977** | **1984** | **1977** | **1984** | **1977** | **1984** | **1977** | **1984** |
| Total | $21,700 | $25,075 | $2,331 | $1.996 | $3,018 | $3,506 | $4,558 | $5,820 |
| Industry | 7,479 | 10,089 | 2,070 | 1,770 | 2,945 | 3,411 | 170 | 236 |
| Agriculture, Forestry, and Fisheries | 521 | 494 | 274 | 177 | 22 | 32 | 1 | 1 |
| Mining | 85 | 106 | 3 | 3 | 20 | 24 | 2 | 3 |
| Construction | 855 | 1,143 | 34 | 27 | 41 | 55 | 5 | 6 |
| Durable Goods Manufacturing | 600 | 813 | 80 | 52 | 290 | 392 | 32 | 45 |
| Nondurable Goods Manufacturing | 513 | 666 | 165 | 121 | 197 | 223 | 34 | 41 |
| Transportation Services | 779 | 1,048 | 1,442 | 1,317 | 1,751 | 1,832 | 12 | 13 |
| Electric, Gas, and Sanitary Services | 144 | 168 | 28 | 34 | 20 | 26 | 2 | 3 |
| Communication | 39 | 59 | 0 | 0 | 13 | 20 | 4 | 7 |
| Wholesale and Retail Trade | 2,443 | 3,660 | 9 | 8 | 170 | 231 | 26 | 37 |
| Finance, Insurance, and Real Estate | 665 | 720 | 2 | 1 | 67 | 88 | 5 | 7 |
| Other Services—Private and Public Enterprises | 835 | 1,212 | 33 | 28 | 354 | 488 | 48 | 74 |
| Household, Government, and Other* | 14,220 | 14,986 | 261 | 225 | 72 | 96 | 4,387 | 5,584 |
| Household | 13,901 | 14,668 | 261 | 225 | 26 | 30 | 4,301 | 5,492 |
| Federal Government | 44 | 43 | 0 | 0 | 22 | 27 | 3 | 4 |
| State and Local Government | 276 | 275 | 0 | 0 | 25 | 38 | 84 | 88 |
| Other** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

*Since the focus is on industry's use of government provided infrastructure, the household and government sectors only have services allocated to them when they directly use a government provided service, e.g., non-business use of highways with a private passenger vehicle, non-business use of municipal airports with private airplanes, and non-business use of mass transit systems.

**Other includes use for foreign trade and investment purposes.

facturing and mining in the economy, the demand for highway services shows an increasing trend. While material intensity may have declined in the economy (implying less material transport), the rise of the just-in-time system and the growth of the service sectors (which involves a good deal of car and light truck travel and less-than-full truckload travel) may signify more rather than less use of highways and bridges.

With regard to water transport, there was a 27-percent drop in use, from $624 per $1 million of industry output in 1977 to $453 in 1984. This drop reflects a decline in operating costs and a rise in output, along with an increase in industry's use per physical unit of output (resulting from the very large fall in the coefficient). The decline in capital stock was slight, despite the shortfall in funding—in view of the longer life of water transport facilities.

Industry's use of air transport services in an expanding economy was stable, while net capital requirements per $1 million of output dropped by 8 percent.

## TABLE 7–9

### Transport Infrastructure Services per Unit of Output—Operating Expenditures and Capital Consumption Allowance for Government Services per Million Dollars of Output: 1977 and 1984 (1977 dollars)

| Sector | Highways | | Water Transport Facilities | | Air Transport Facilities | | Urban Transport Facilities | |
|---|---|---|---|---|---|---|---|---|
| | 1977 | 1984 | 1977 | 1984 | 1977 | 1984 | 1977 | 1984 |
| Total* | $2,255 | $2,582 | $624 | $453 | $888 | $873 | $51 | $60 |
| Agriculture, Forestry, and Fisheries | 4,019 | 3,279 | 2,116 | 1,177 | 172 | 214 | 6 | 7 |
| Mining | 1,087 | 1,276 | 43 | 30 | 257 | 295 | 30 | 32 |
| Construction | 3,236 | 3,854 | 128 | 90 | 155 | 185 | 19 | 22 |
| Durable Goods Manufacturing | 850 | 1,035 | 113 | 66 | 411 | 500 | 46 | 57 |
| Nondurable Goods Manufacturing | 790 | 961 | 254 | 175 | 304 | 321 | 52 | 59 |
| Transportation Services | 6,175 | 7,742 | 11,424 | 9,732 | 13,877 | 13,534 | 92 | 94 |
| Electric, Gas, and Sanitary Services | 1,361 | 1,337 | 265 | 273 | 187 | 206 | 17 | 20 |
| Communication | 641 | 641 | 5 | 4 | 216 | 215 | 70 | 78 |
| Wholesale and Retail Trade | 6,354 | 7,519 | 24 | 17 | 442 | 474 | 67 | 76 |
| Finance, Insurance, and Real Estate | 665 | 720 | 2 | 1 | 67 | 88 | 5 | 7 |
| Other Services—Private and Public Enterprises | 1,548 | 1,701 | 60 | 40 | 656 | 685 | 88 | 104 |

*Average across all industry sectors, using industry output as weights.

(See Table 7–10.) This decline reflects the growth in air traffic, which has outpaced the addition of air transport public capital stock. As with water transport, the transport service sector is the largest user of air transport facilities.

The use and capital coefficients with regard to urban transit are small and experienced little change during the period.

### Implications of Economic Changes on Infrastructure Use: Some Highlights

In summary, between 1977 and 1984—a period of substantial economic growth and structural change—the U.S. economy increased its use of highways, air and water transport, and urban transit. This increase was greater among industries (22.4 percent) than households (10.5 percent). Indeed, industry's use of infrastructure grew faster than the economy (which grew at a average of 2.4 percent annually). Industry's share of highway use climbed from 34.5 percent to 40.2 percent, partly reflecting the effects of new logistical systems, such as just-in-time, that require smaller shipments more frequently. In that period of sharp rise in highway use, highway net capital stock declined by $6.7 billion (in constant 1977 dollars) or 2.4 percent of its 1977 value—reflecting the decreased proportion of new highway construction. The total cost of providing highways and air transport rose (in constant dollars) by 16 percent; the cost of urban transit rose by 28 percent.

Much of the increased use of highways by industries derives from the growth in three groups: service, wholesale, and retail; other services and public enterprises; and durable goods manufacturing. The same sets of industries increased their proportional share of air transport. The changing use of highways and air transport provide insights into the growth of higher value goods.

Among industries, the most intensive user of highways was the transport services sector, followed by wholesale and retail trade, and the construction industry. While the material intensity in the overall

**TABLE 7 – 10**

**Transport Infrastructure Services per Unit of Output**
**Net Infrastructure Capital per Million Dollars of Output: 1977 and 1984**
**(1977 dollars)**

| | Highways | | Water Transport Facilities | | Air Transport Facilities | | Urban Transport Facilities | |
|---|---|---|---|---|---|---|---|---|
| **Sector** | **1977** | **1984** | **1977** | **1984** | **1977** | **1984** | **1977** | **1984** |
| Total* | $29,299 | $28,446 | $5,152 | $4,681 | $5,085 | $4,717 | 4153 | $209 |
| Agriculture, Forestry, and Fisheries | 52,403 | 36,132 | 17,473 | 1,165 | 983 | 1,157 | 19 | 26 |
| Mining | 14,172 | 14,056 | 357 | 315 | 1,471 | 1,593 | 88 | 110 |
| Construction | 42,190 | 42,468 | 1,056 | 930 | 889 | 999 | 58 | 76 |
| Durable Goods Manufacturing | 11,089 | 11,405 | 931 | 686 | 2,352 | 2,700 | 137 | 196 |
| Nondurable Goods Manufacturing | 10,307 | 10,586 | 2,098 | 1,811 | 1,741 | 1,737 | 155 | 204 |
| Transportation Services | 80,515 | 85,309 | 94,336 | 100,551 | 79,486 | 73,148 | 273 | 325 |
| Electric, Gas, and Sanitary Services | 17,742 | 14,731 | 2,189 | 2,823 | 1,073 | 1,115 | 51 | 69 |
| Communication | 8,357 | 7,067 | 41 | 38 | 1,240 | 1,160 | 208 | 268 |
| Wholesale and Retail Trade | 82,859 | 82,857 | 201 | 176 | 2,531 | 2,562 | 200 | 261 |
| Finance, Insurance, and Real Estate | 31,711 | 22,854 | 50 | 44 | 1,402 | 1,371 | 53 | 68 |
| Other Services—Private and Public Enterprises | 20,183 | 18,743 | 500 | 413 | 3,755 | 3,700 | 263 | 359 |

*Average across all industry sectors, using industry output as weights.

economy may have declined—indicating less material transport per unit output—the rise of the new logistical systems may signify more use of highways and bridges.

## Endnotes

1 A. Fishlow, *American Railroads and the Transformation of the Ante-Bellum Economy* (Cambridge, MA: Harvard University Press, 1965), pp. 306–11; and S.F. Leroy and J. Sonstelie, "Paradise Lost and Regained: Transportation Innovation, Income, and Residential Location," *Journal of Urban Economics* Vol. 13 (1983): 67–89. The latter work offers clear insights into the transportation mechanisms involved in the shifting patterns of spatial structure of American urban residence.

2 This case comes from Jack Faucett Associates and A.T. Kearney, Inc., "Industry Studies of the Relationship between Highway Transportation and Productivity," draft final report on Contract No. DTFH61-91-C-00058 with the Federal Highway Administration (Bethesda, MD.: Jack Faucett Associates, August 1993), pp. 31–42.

3 E.S. Mills and G. Carlino, "Dynamics of County Growth," in Å. Anderson, D. F. Batten, B. Johansson, and P. Nijkamp, eds., *Advances in Spatial Theory and Dynamics* (Amsterdam: North-Holland, 1989), pp. 195–205. These authors previously found a lower degree of responsiveness to interstate highway density, although the reasons for the difference are not entirely clear. See Carlino and Mills, "The Determinants of County Growth," *Journal of Regional Science*, Vol. 27 (1987): 39–54.

4 This information was derived from Fishlow, pp. 225–33; J.G. Clark, *The Grain Trade in the Old Northwest* (Urbana, IL: University of Illinois, 1966), pp. 9–13; and E.F. Haines, J. Mak, and G.M. Walton, *Western River Transportation; The Era of Early Internal Development, 1810-1860* (Baltimore: Johns Hopkins University Press, 1975), pp. 111–18.

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6 A.O. Hirschman, *The Strategy of Economic Development* (New Haven: Yale University Press, 1958).

7 R.B. Miller, *City and Hinterland; A Case Study of Urban Growth and Regional Development* (Westport, CT: Greenwood, 1979), pp. 86–87.

8 A.J. Youngson, *Overhead Capital; A Study in Development Economics* (Edinburgh: Edinburgh University Press, 1967). Also see T. R. Lakshmanan, "Infrastructure and Economic Transformation," in Å. Anderson, D.F. Batten, B. Johansson, and P. Nijkamp, eds., *Advances in Spatial Theory and Dynamics* (Amsterdam: North-Holland, 1989), pp. 241–61, for a review of theories about infrastructure's role in development and for suggestions regarding incorporation of infrastructure and movement into some standard, widely used economic models.

9 Although many transportation projects have been subjected to the scrutiny of rigorous cost-benefit analysis, these studies are prospective: they attempt to anticipate, in a controlled way, how profitable a particular project would be if it were to be undertaken and completed at the projected cost. Few public projects, including transportation projects, are undertaken which are projected clearly to be unproductive once they would be completed, but there have indeed been wasteful projects. Individual cost-benefit analyses do not guarantee an efficient, aggregate pattern of public investment, even if they guide project selection and all the projects perform as predicted; an ordering of investments across competing projects according to their marginal social returns is necessary. Few projects have been subjected to such analyses after they have been constructed and used for a number of years. Consequently, despite the plethora of cost-benefit studies, we do not really know much about the productiveness of public projects. Keeler and Ying's retrospective analysis of the U.S. interstate highway system, discussed below, is a useful exception to this; see T.E. Keeler and J.S. Ying, "Measuring the Benefits of a Large Public Investment; The Case of the U.S. Federal-Aid Highway System," *Journal of Public Economics* Vol. 36 (1988): 69–85.

10 K. Mera, "Regional Production Functions and Social Overhead Capital: An Analysis of the Japanese Case," *Regional and Urban Economics* Vol. 3 (1973): 157–86; and K. Mera, *Income Distribution and Regional Development* (Tokyo: University of Tokyo Press, 1975), Chapter IV. Mera did not attempt to estimate the productivity of transportation and communication infrastructure in the primary (agriculture and mining) sector.

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12 D.A. Aschauer, "Is Public Expenditure Productive?" *Journal of Monetary Economics* Vol. 23 (1989): 177–200.

13 J.S. Costa, R.W. Ellison, and R.C. Martin, "Public Capital, Regional Output, and Development: Some Empirical Evidence," *Journal of Regional Science* Vol. 27 (1987): 419–37. The production function they use is the transcendental logarithmic function, known as the translog. It is a quadratic form, so its estimation involves the products of the various inputs as well as their independent values. This feature quickly uses up statistical degrees of freedom; three variables use 10 degrees of freedom, including the constant term in the regression. Larger samples commonly are useful in estimating this functional form.

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15 A.H. Munnell, "Why Has Productivity Growth Declined: Productivity and Public Investment," *New England Economic Review* January/February 1990: 3–22.

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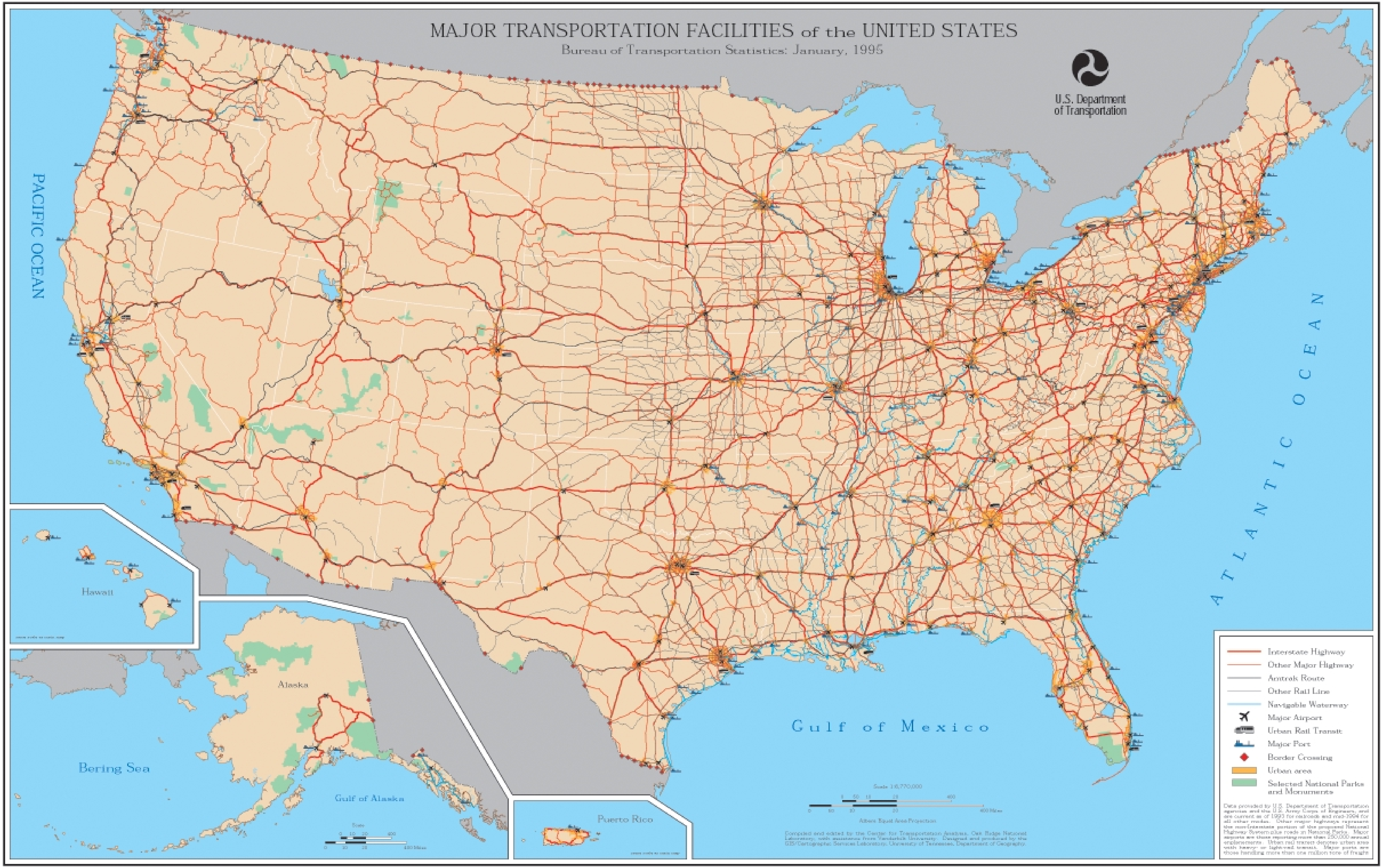

MAJOR TRANSPORTATION FACILITIES of the UNITED STATES

Bureau of Transportation Statistics: January, 1995

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