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

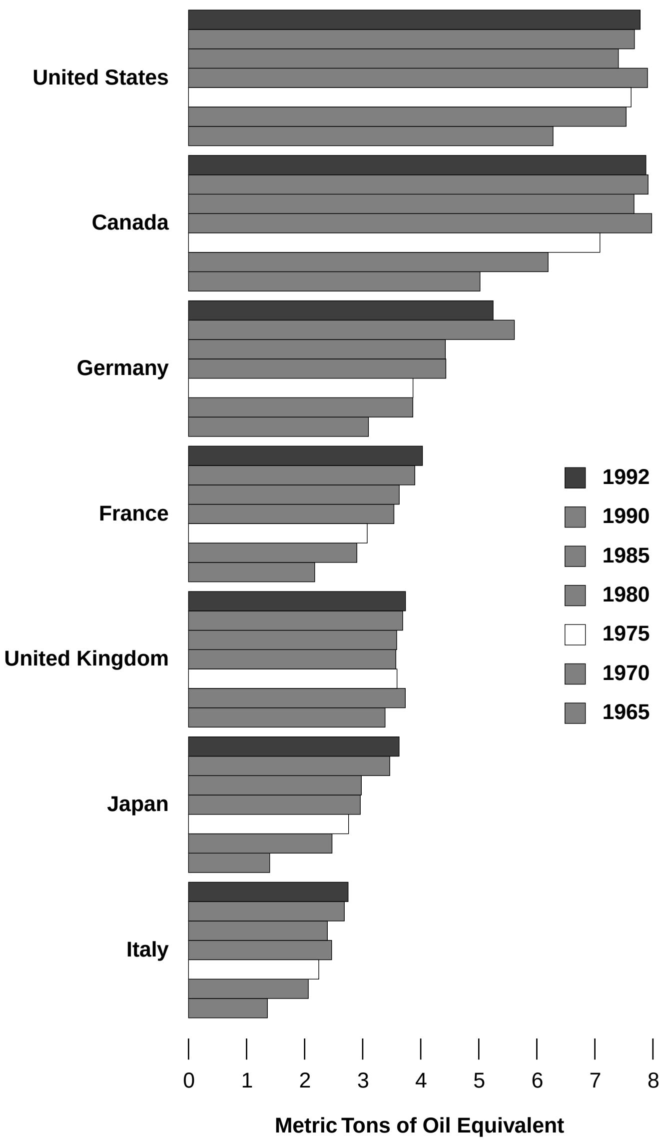
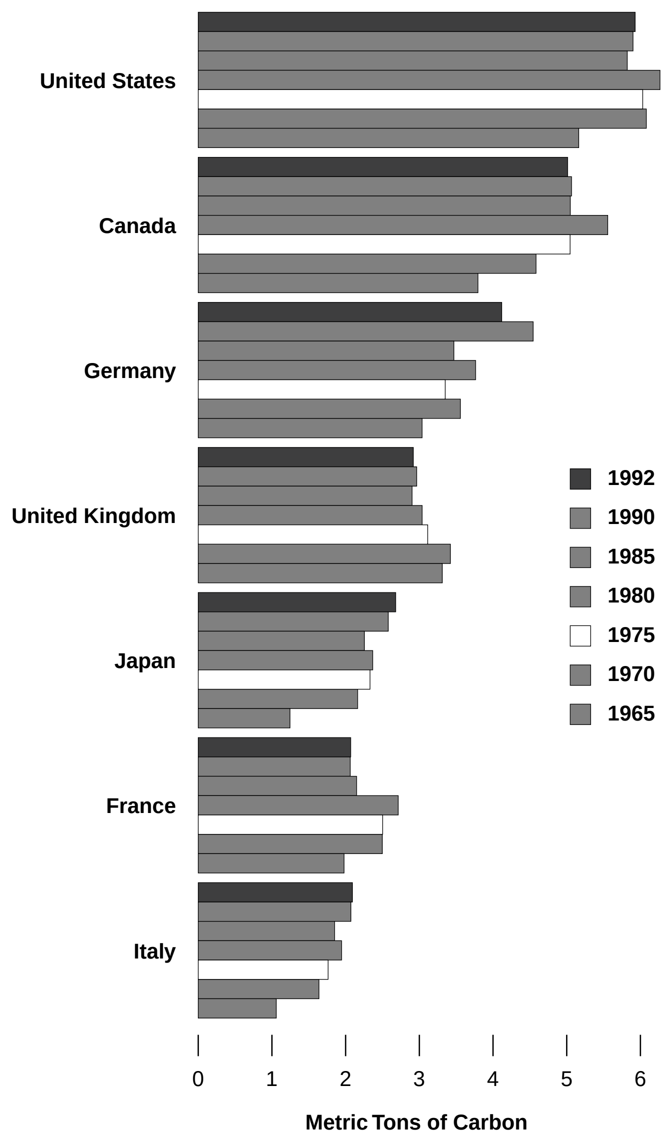


FIGURE 3–25

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

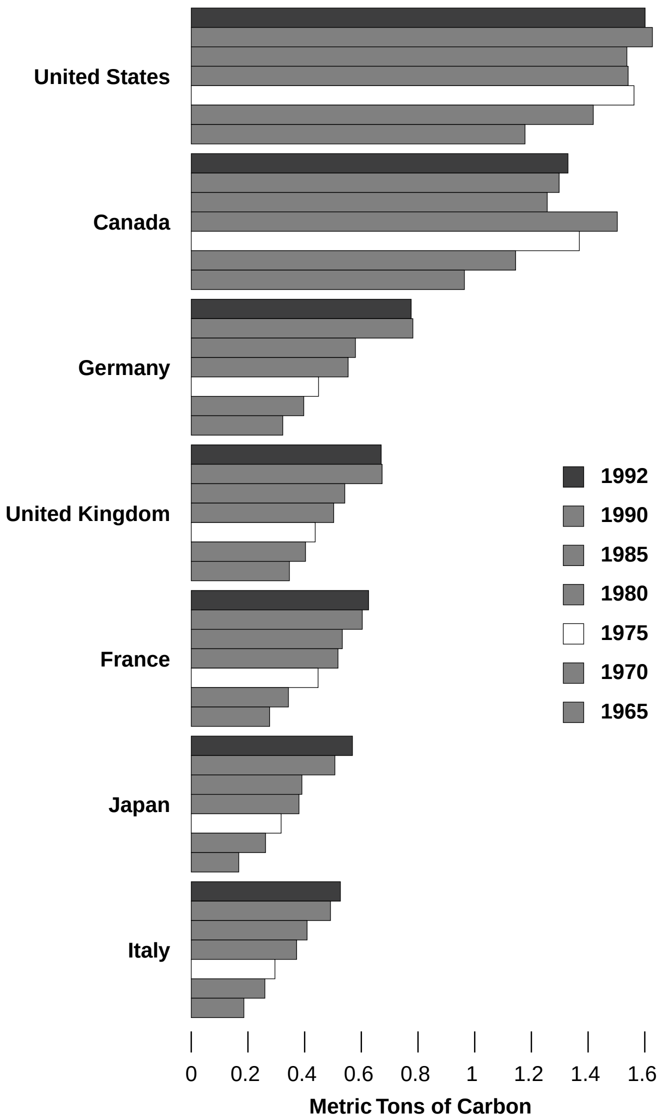


FIGURE 3–27

Share of Transportation in Total CO_2 Emissions: 1965 and 1992

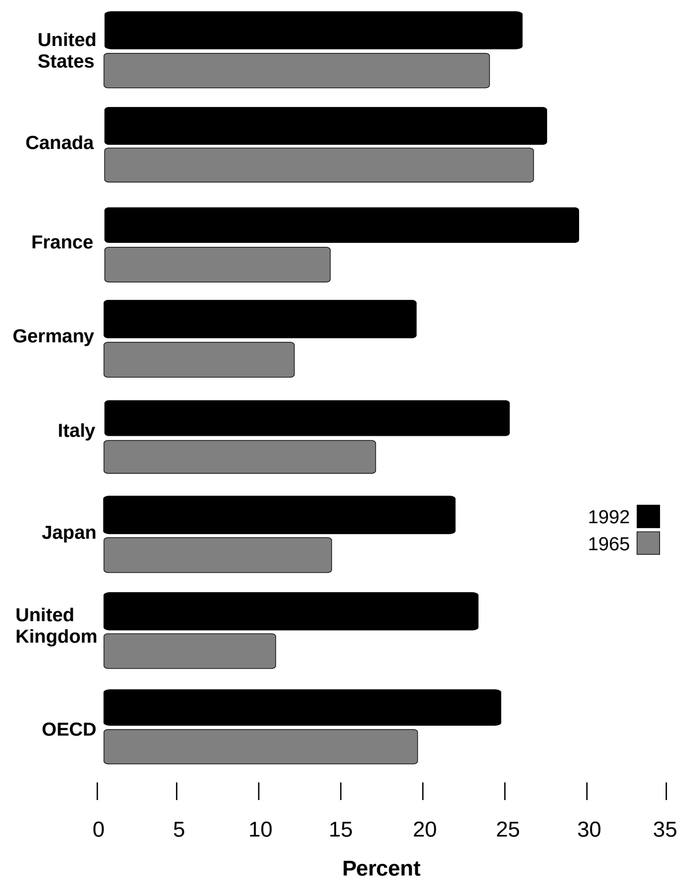
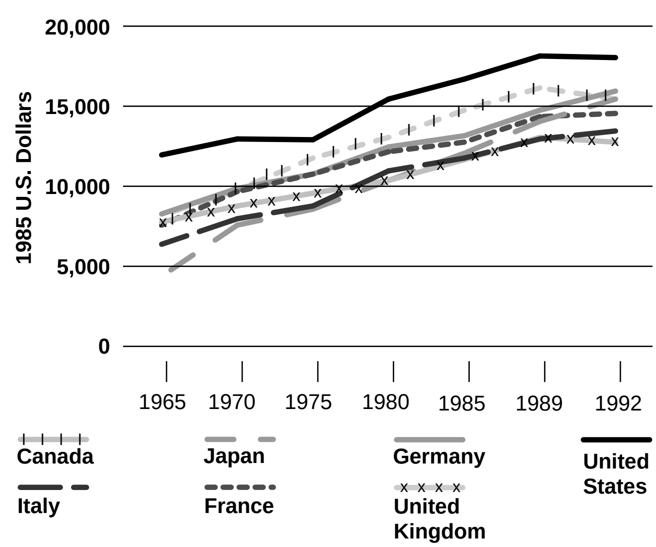


FIGURE 3–28

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

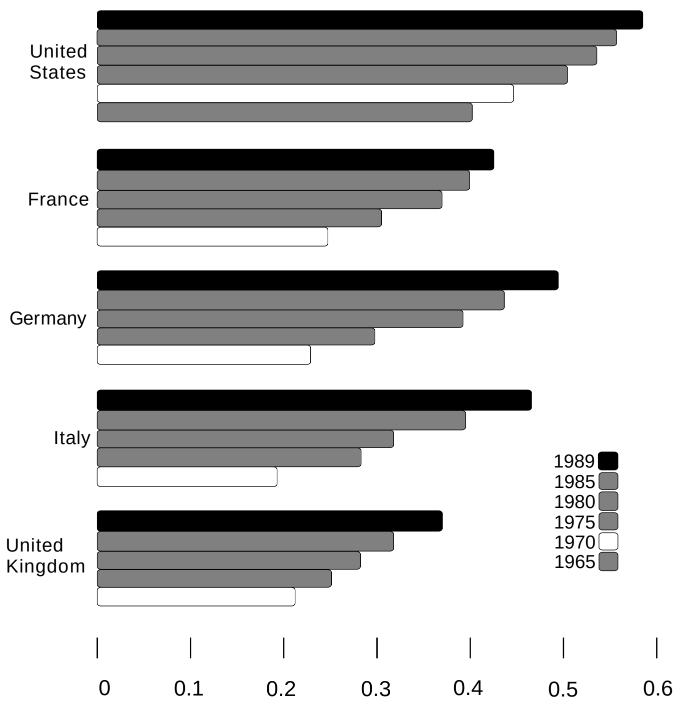


increased, car ownership has also surged: the disparities in car ownership narrow between the United States and other countries over time (See Figure 3–29.)

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 3–29

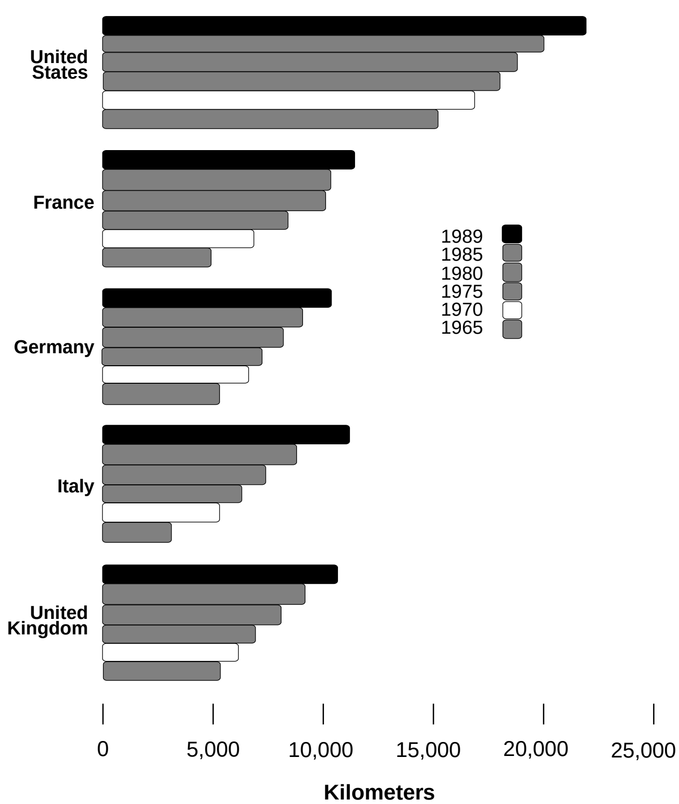
Cars per Person: 1965–1989



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

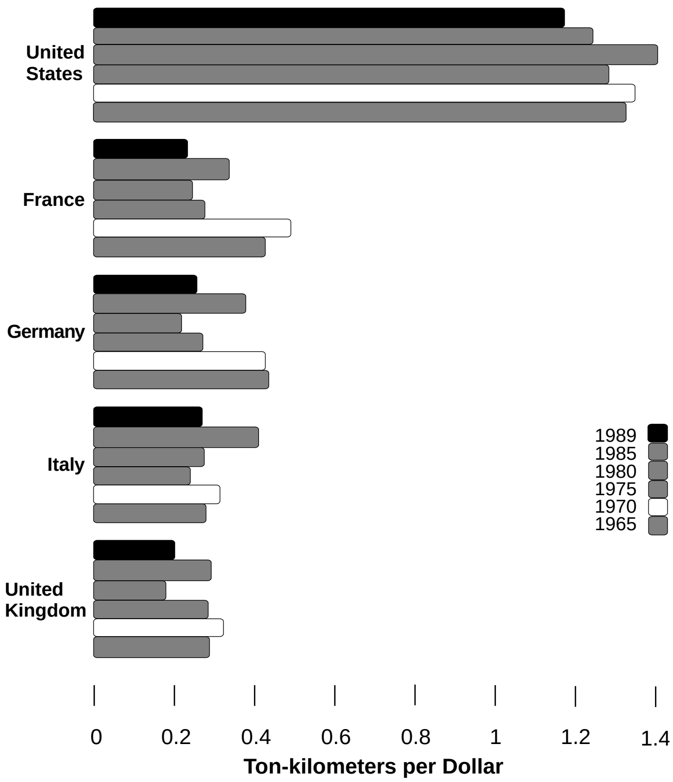
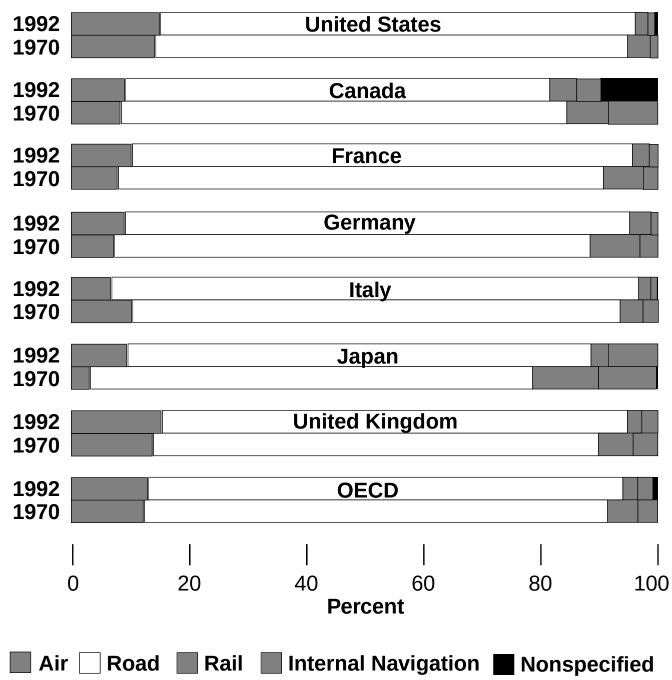


FIGURE 3–32

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

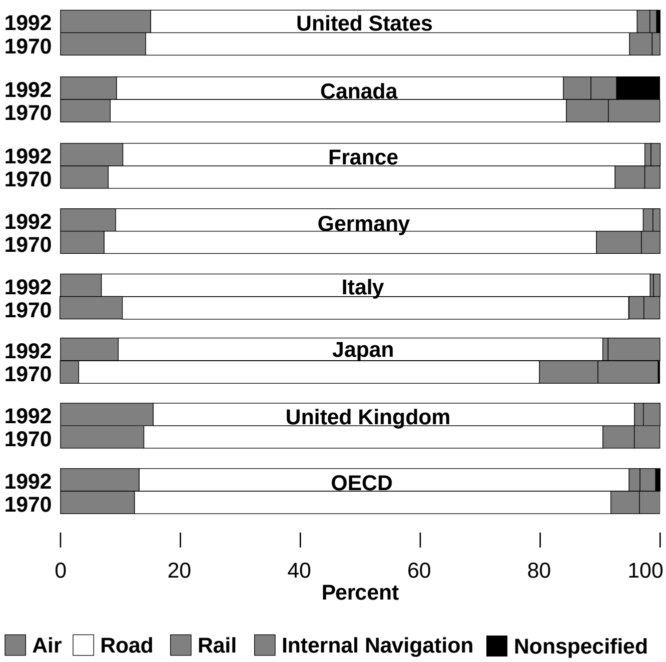
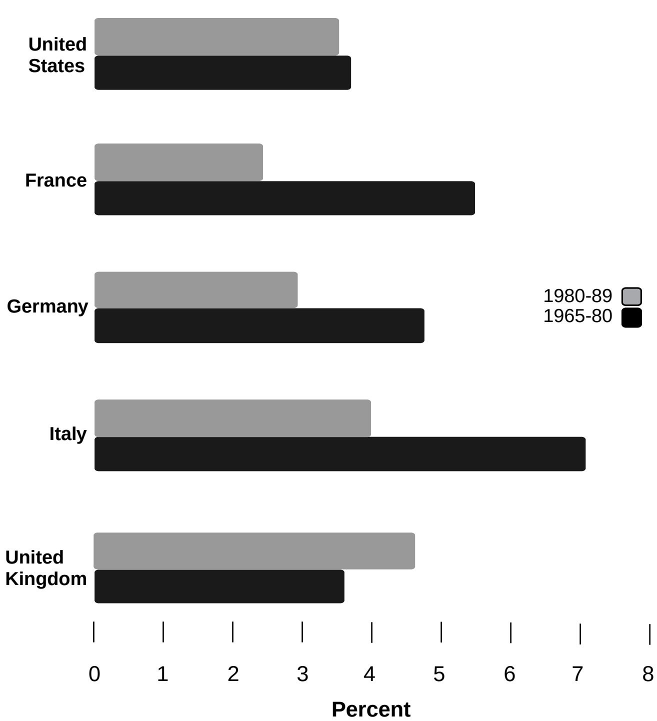


FIGURE 3–34

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

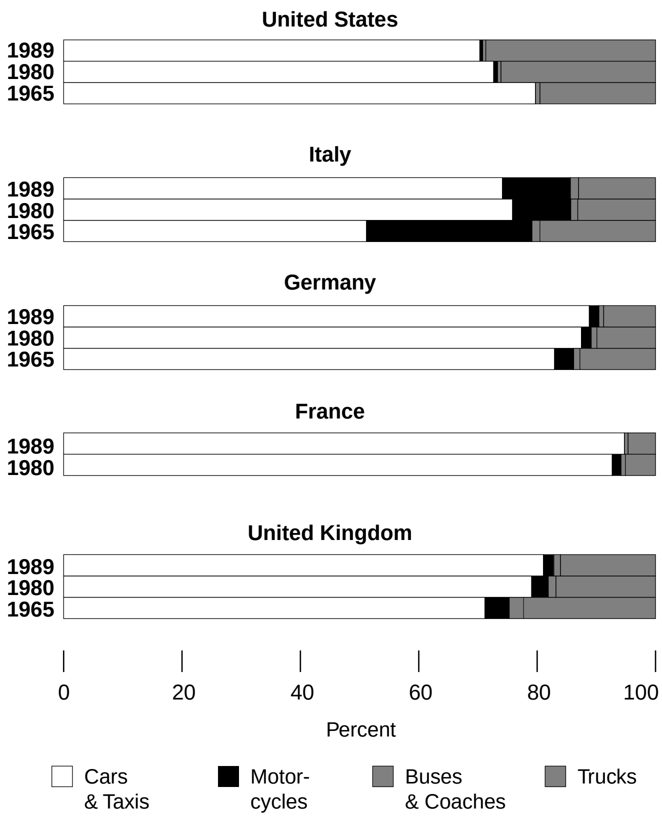
Changes in Occupancy Rates and Load Factors. Occupancy rates and load factors affect the energy intensity of road transportation. Other things being equal, increases in occupancy rates in passenger transportation and increases in load factor in freight transportation would reduce the energy intensity 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

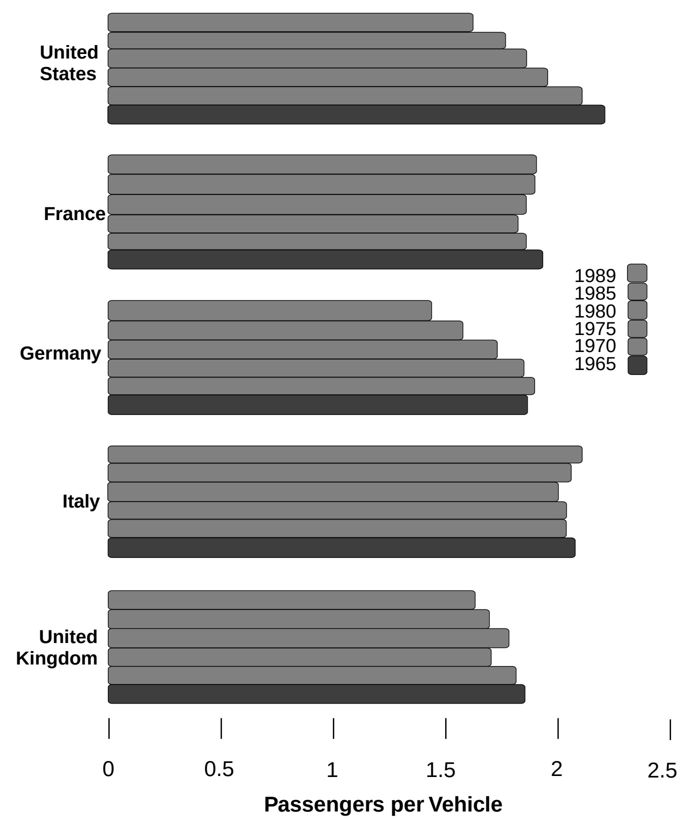
Vehicle Mix of Road Traffic (based on vehicle-kilometers): 1965–1989



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.)

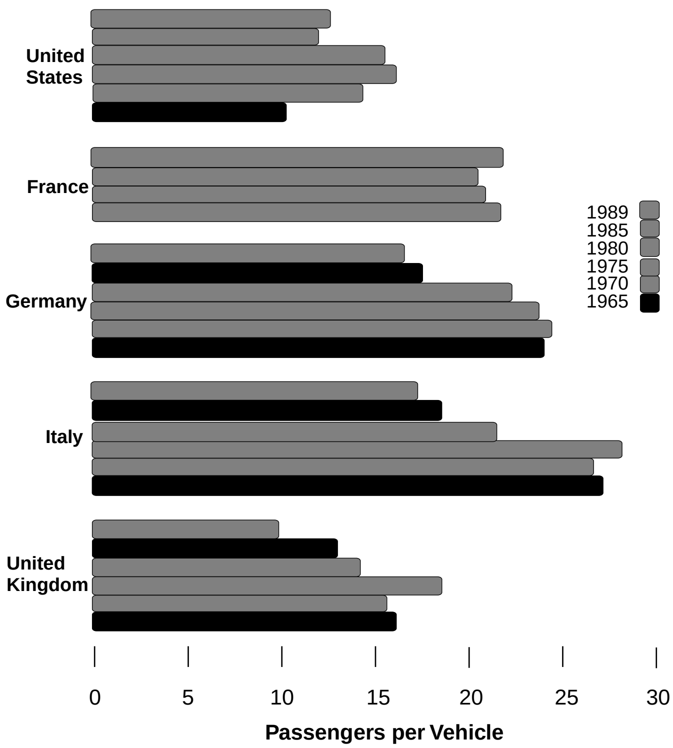
The decline in the load factor of trucks in the United States mirrors from another angle the structural changes in the economy. A more service-oriented economy and the just-in-time practice in production may necessitate smaller size shipments but more frequent and reliable deliveries. High-value commodities, 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

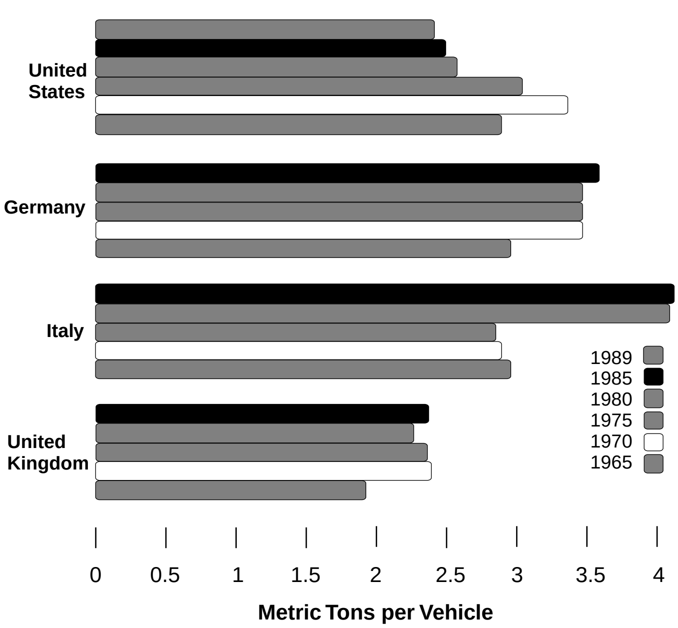
Trip Distance Weighted Average Occupancy Rate of Buses and Coaches: 1965–1989



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 inatten-