Chapter 20

TRANSPORTATION

The National Energy Strategy seeks to reduce the amount of energy we use to move people and goods by improving the efficiency of *all* the vehicles on the road, and by increasing the overall efficiency of the transportation system itself. Specifically, the National Energy Strategy will:
•expand efforts to develop advanced technologies;
•accelerate scrappage of older cars;
•evaluate Corporate Average Fuel Economy (CAFE) program;
•improve consumer information on fuel economy and system efficiency;
•promote mass transit and ride sharing.

(*National Energy Strategy, Executive Summary*, 1991/1992)

[Administration's] policies to improve transportation efficiency and introduce alternatives:
•promote near-term efficiency improvements;
•develop markets for alternative fuels;
•reduce the demand for travel;
•develop technologies for a new generation of vehicles.

(*Sustainable Energy Strategy*, 1995)

We have mentioned previously that history books will probably label the 20th century as the “age of communications.” Much of this progress in communications has been due to the dramatic increase in the use of transportation vehicles. The number of registered vehicles in the U.S. has almost tripled in the last thirty years. Worldwide growth has been even more spectacular: between 1950 and today human population has more than doubled (see Figure 5-4) but the car population has increased tenfold, to some 500 million, according to a recent Worldwatch Institute study (see *World Watch*, January 1996, p. 24). This number is expected to reach one billion in 2020 or so. Similar statistics apply to airline passengers.

There is no question that the benefits derived from this increased mobility of people – and thus of ideas – by far outweigh the problems, both those already created and those that may develop. But the accumulating problems need to be addressed and resolved if the balance is to remain in favor of progress. The number of cars on the roads of developed countries and in cities of underdeveloped nations is reaching saturation levels. Today it is almost impossible to park a car in the streets of New York, Paris, London, Tokyo, Milan, even in Mexico City and Lagos. According to an energy-conservation advertisement by the Mobil Corporation (NYT, 3/21/91), the motorists on U.S. freeways suffered 722 million hours of delay in 1985 and this number could reach 3.9 billion hours by 2005. In 1988, this congestion wasted an estimated 1.4 billion gallons of fuel. The air space around cities like Chicago, Atlanta and Frankfurt is also becoming congested. From the standpoint of energy consumption, the transportation sector of the U.S. economy is almost as important as the entire industrial sector. This is shown in Figure 20-1. The U.S. and the world are simply ‘hooked’ on transportation vehicles. The transportation sector, in turn, is hooked on oil, as shown in Figure 20-2.

FIGURE 20-1. Energy consumption in the United States by economic sector.
[Source: Energy Information Administration.]

In this chapter we analyze the energy consumption patterns in the transportation sector. We know by now that the “energy crises” of the 1970s were really much more focused than was implied by the term used. There is no shortage of energy in the world, as was made clear in Chapter 5. There did exist temporary problems with the supply of fuel for transportation vehicles in 1973 and 1979, because a large portion of imported crude oil was coming then from the politically unstable Middle East. An ever-increasing portion of crude oil will continue to flow to the industrialized world from this region, as was shown in Chapter 5. Consequently, these problems will not go away even if they disappear from TV and newspaper headlines, as they have done – for the most part – after the most recent Persian Gulf crisis. We shall address here the consequences of such problems by first discussing the concept of *mileage* and the issues surrounding it, and then analyzing the possibility of finding (and using) alternative fuels for our vehicles of today and tomorrow.

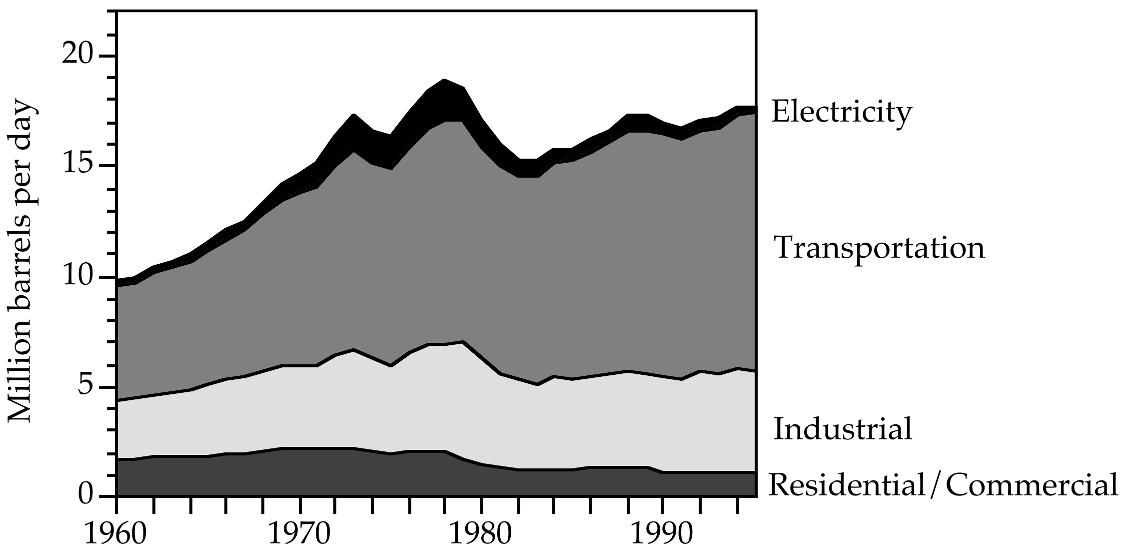

FIGURE 20-2. Illustration of transportation sector's dependence on oil.
[Source: Energy Information Administration.]

Transportation Fuels: Consumption Trends

In Chapters 5, 6 and 8 we discussed the supply of petroleum. Here we analyze its demand. In particular, we analyze the (im)balance between supply and demand of transportation fuels. It all began in 1973 when the OPEC countries agreed to quadruple world petroleum prices. Until then, energy prices in general and petroleum prices in particular were very low. They allowed rapid and energy-intensive industrial development. Since then, the price of a barrel of oil embarked on a roller-coaster ride that has transformed OPEC oil ministers into media stars and has Wall Street analysts permanently guessing if and when OPEC will "get their act together again." Figure 20-3 reproduces what is by now almost a household diagram, the variation of the official price of Saudi Arabian light crude oil (see Chapter 8) over the last twenty five years. The U.S. average prices have followed the same trend. Most daily newspapers include this or some related price (for example, that of West Texas intermediate crude oil) among their key economic indicators. A similar roller-coaster price variation occurred during the most recent Persian Gulf crisis (see Chapter 21).

FIGURE 20-3. Variation in the official price of oil (Saudi Arabian light) in the past 25 years. [Source: Energy Information Administration.]

There is nothing like a high (oil) price to effectively stimulate (oil) conservation. This is illustrated in Figures 20-4 and 20-5, where the consumption of gasoline and the petroleum imports are shown for the same period (1970-1995). Figure 20-5, in conjunction with Figure 20-2, also highlights several additional important facts. In the entire 25-year period, petroleum imports have represented more than 25% of the overall crude oil consumption in the U.S. Furthermore, both in the late seventies and early nineties, foreign supply of crude oil has approached the 50% mark. The economic and political implications of such a situation, together with a more detailed analysis of the imports, are explored in Chapter 21.

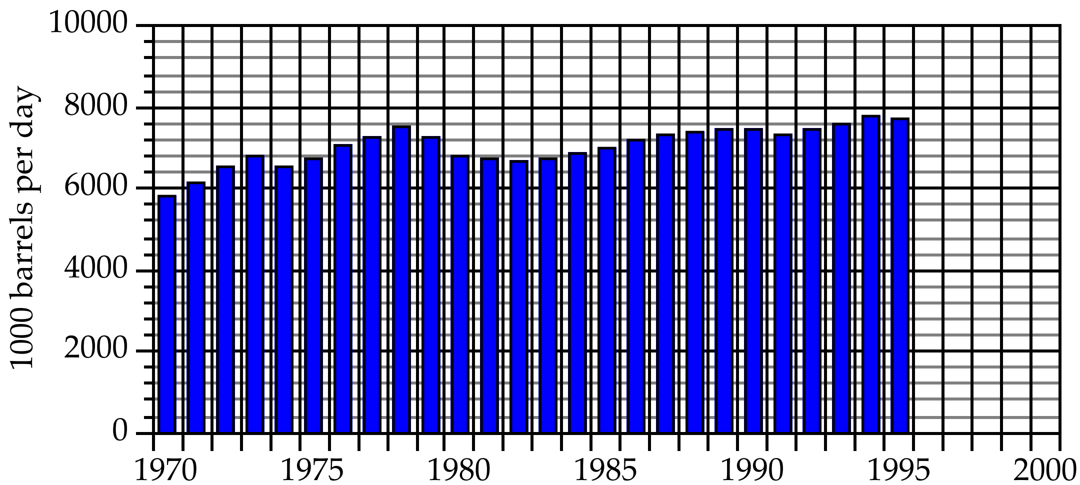

FIGURE 20-4. Consumption of gasoline in the U.S. over the last 25 years. [Source: Energy Information Administration.]

Illustration 20-1. From the information provided in Figures 8-3, 20-3 and 20-5, (a) show that in 1989 oil imports represented approximately 50% of the total crude oil consumption; and (b) estimate the annual cost of oil imports for the year 1989.

Solution.
(a) From Figure 8-3, the total crude oil consumption in 1989 was about 17 million barrels per day. In the same year, the total imports were approximately 8 million barrels per day (Figure 20-5). Therefore,

$$\%\ \text{imports} = \frac{8\text{x}10^6\ \frac{\text{bbl}}{\text{day}}}{17\text{x}10^6\ \frac{\text{bbl}}{\text{day}}} = 0.47\ (= 47\%)$$

(b) Total crude imports were 8 million barrels per day (Figure 20-5). The price of a barrel of Saudi Arabian light crude oil was about \$17.50 in 1989 (Figure 20-3). Therefore,

$$\text{Imported petroleum cost} = 8\text{x}10^6\ \frac{\text{bbl}}{\text{day}}\ \left(\frac{\$17.50}{\text{bbl}}\right)\left(\frac{365\ \text{days}}{1\ \text{year}}\right) = \$51.1\text{x}10^9/\text{year} =$$

$$= \text{about } \$51 \text{ billion}$$

FIGURE 20-5. Imports of oil into the U.S. in the past 25 years.
[Source: Energy Information Administration.]

The greatest portion of the crude oil fed into U.S. refineries is converted into transportation fuels (gasoline and jet fuel). This was illustrated in Figure 8-14. It is interesting to note that despite the relatively large decrease in crude oil input into refineries in the period 1979-1983 (paralleled by the increase in the price of imported crude oil, from about $20 to $35 per barrel), the consumption of gasoline did not decrease at all, confirming that we are hooked on oil in general and on gasoline in particular. Thirty percent of world's oil and forty percent of world's gasoline is consumed by four percent of world's population living in the U.S. Most of it is burned in the engines of our automobiles.

The Automobile

Of all transportation vehicles, it is the automobiles that consume the most fuel. They are responsible for nearly 80% of passenger traffic in the U.S., as illustrated in Figure 20-6. The credit for inventing the automobile – in the late 1880s – goes to two Germans, Karl Benz and Gottlieb Wilhelm Daimler. The first automobiles in the U.S. were built shortly thereafter by Charles and Frank Duryea. In 1896 Frank Duryea perfected the Duryea Motor Wagon and the *Economist* has recently celebrated “the first hundred years of the American automobile industry (1/13/96, p. 28). In 1908 Henry Ford started making affordable cars on the assembly line – the price of the famous model T was only $950 – and the rest, as they say, is history. In the hundred years since this historic invention, man's fascination by the automobile has continuously grown. Not even the “energy crises” of the last two decades were able to change this, as documented in Figures 8-14, 20-4 and 20-7. The average number of people per car decreased from about 50 in 1950 to about 10 today. (In places like California, of course, there are almost as many cars as there are people.) In the same period, world oil consumption increased proportionately from about 600 million tons to some 3 billion tons per year.

FIGURE 20-6. Oil consumption by U.S. transportation vehicles. [Source: Energy Information Administration.]

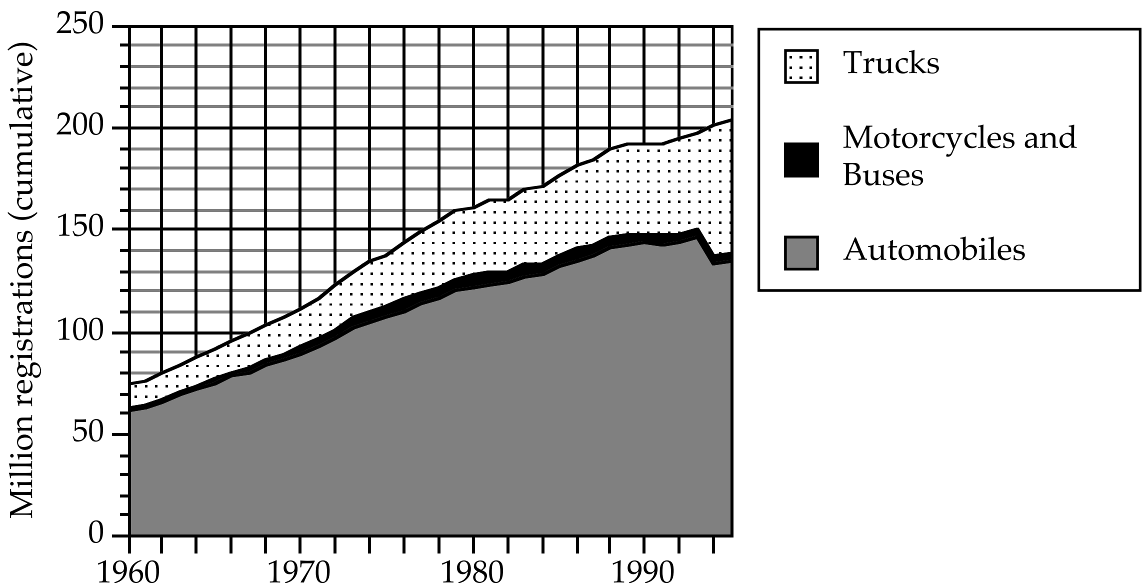

FIGURE 20-7. U.S. vehicle registrations in the past 35 years. [Source: Energy Information Administration.]

The vast majority of cars on the roads of the world, and in the U.S. in particular, use the spark-ignition, or gasoline-powered engine. This is a four-stroke engine. Its operation was discussed briefly in Chapter 8, in connection with the requirements imposed upon the fuel to be used in it. Its principle of operation is illustrated in Figure 20-8.

When the mixture of air and fuel (gasoline) ignites and burns (ignition and power stroke), the pressure of the hot products of combustion (CO_2, H_2O, etc.) rises at the very high combustion temperature. The effect of this rise in pressure is to push the piston down. (The experts say that the engine "turns over.") Chemical energy in the molecules of gasoline, liberated by the combustion process, is converted to kinetic energy of the piston. This kinetic energy is transmitted through the engine to the drive shaft and finally to the wheels, and we are able to drive down the road. The intake and exhaust strokes allow the entrance of the fuel and the exit of the products of combustion, respectively. The compression stroke (see Figure 20-8) is necessary to complete the cycle, as well as to facilitate the ignition of the fuel.

Tables 20-1 and 20-2 and Figures 20-9 and 20-10 summarize the information on the car buying habits of Americans in the last 30 years. It is obvious that the second large oil price increase (1979/1980) had a much greater impact than the first one (1973/1974). It is also clear that the low gasoline prices in the 1990s have brought pickup trucks and minivans to center stage (see also Figure 20-7). Indeed, a new term, "soccer mom," has entered our political and social jargon in the 1996 presidential election. As William Safire writes in his NYT Magazine column of October 1996, "she often drives a sport-utility vehicle or a minivan." Until a few years ago, the changes in the weight, size and engine type of the best-selling cars were all in the direction that helps to increase the mileage (see next section). This is particularly evident for the years 1982 and 1983, when the price of oil reached the (pre-1991) all-time high of $34/barrel (see Figure 20-3), and when Ford Escort was the most popular car in the U.S., with its impressive fuel economy of 31 miles per gallon in the city and 47 miles per gallon on the highway. The Escort remains a popular car in Europe, but recent trends in the U.S. market have reversed some of these gains in efficiency. Much publicity has been given to the fact that "the American love affair with high speed and big cars is back" (see Investigation 20-2).

TABLE 20-1
Best-selling cars in the United States in the period 1965-1990

Year	Model(s)	Weight (tons)	Length (feet)	Base price ($)[a]	Engine type[b]	Miles per gallon (city/hwy)
1965	Full-size Chevrolets	1.7	17.8	2,367	8V	N/A
1966	Full-size Chevrolets	1.7	17.8	2,537	8V	N/A
1967	Full-size Chevrolets	1.7	17.8	2,589	8V	N/A
1968	Full-size Chevrolets	1.7	17.9	2,728	8V	N/A
1969	Full-size Chevrolets	1.9	18.0	3,039	8V	N/A

FIGURE 20-8
Schematic representation of the operation of a four-stroke automobile engine: (1) intake stroke; (2) compression stroke; (3) ignition and power stroke; (4) exhaust stroke.

Year	Model(s)	Weight (tons)	Length (feet)	Base price ($)[a]	Engine type[b]	Miles per gallon (city/hwy)
1970	Full-size Fords	2.1	18.0	2,271	8V	N/A
1971	Full-size Chevrolets	1.9	18.1	3,742	8V	N/A
1972	Full-size Chevrolets	2.0	18.3	3,771	8V	N/A
1973	Full-size Chevrolets	2.1	18.5	3,752	8V	N/A
1974	Full-size Chevrolets	2.1	18.6	4,135	8V	10
1975	Full-size Chevrolets	2.2	18.6	4,891	8V	12
1976	Oldsmobile Cutlass	2.2	18.3	4,965	8V	17/22
1977	Full-size Chevrolets	1.8	17.7	5,237	8V	17/22
1978	Full-size Chevrolets	1.8	17.7	5,628	8V	17/24
1979	Full-size Chevrolets	1.8	17.7	6,271	8V	16/21
1980	Chevrolet Citation	1.2	14.7	5,552	6V	22/27
1981	Chevrolet Chevette	1.0	13.7	5,394	4V	26/33
1982	Ford Escort	1.0	13.8	5,642	4V	31/47
1983	Ford Escort	1.0	13.8	7,745	4V	31/47
1984	Chevrolet Cavalier	1.2	14.5	6,666	4V	24/31
1985	Chevrolet Cavalier	1.3	15.7	6,900	4V	24/31
1986	Chevrolet Celebrity	1.3	15.7	8,931	4V	22/32
1987	Ford Escort/EXP	1.3	14.0	6,586	4V	26/31
1988	Ford Escort/EXP	1.1	14.0	8,024	4V	24/30
1989	Honda Accord	1.4	15.0	14,180	4V	27/34
1990	Honda Accord	1.4	15.4	12,590	4V	24/30

[Source: *The New York Times*, November 18, 1990, p. F6.]
[a]Base price (without options); not adjusted for inflation.
[b]8V = eight cylinders; 6V = six cylinders; 4V = four cylinders.

TABLE 20-2
Comparison of top-selling cars and light trucks in the United States
1995 vs. 1965

Ranking	Model (number of vehicles sold) 1965	1995
1	Chevrolet Impala (1,698,471)	Ford F-series pickups (660,907)
2	Ford Galaxie 500 (981,531)	Chevy C/K pickups (505,464)
3	Ford Mustang (518,252)	Ford Explorer (395,227)
4	Pontiac Catalina (517,953)	Ford Taurus (366,266)
5	Chevrolet pickups (495,719)	Honda Accord (341,384)
6	Ford pickups (389,258)	Toyota Camry (328,595)
7	Chevrolet Chevelle (349,555)	Ford Ranger (309,085)

8	Full-size Buicks (343,065)	Honda Civic (289,435)
9	Oldsmobile 88/98 (324,592)	Saturn (285,674)
10	Volkswagen Beetle (314,625)	Ford Escort (285,570)

[Source: *The New York Times*, 9/26/96, p. D1.]

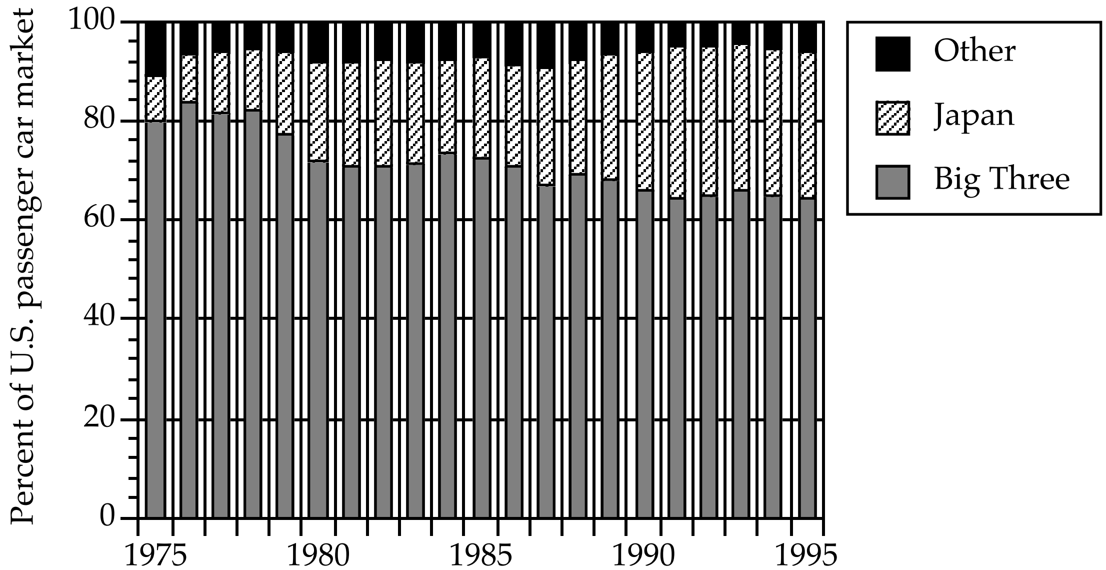

FIGURE 20-9. The Big Three (Chrysler, Ford and GM) have not been able to hold the very large market share that they had before the "energy crises" of the 1970s.
[Source: American Automobile Manufacturers Association.]

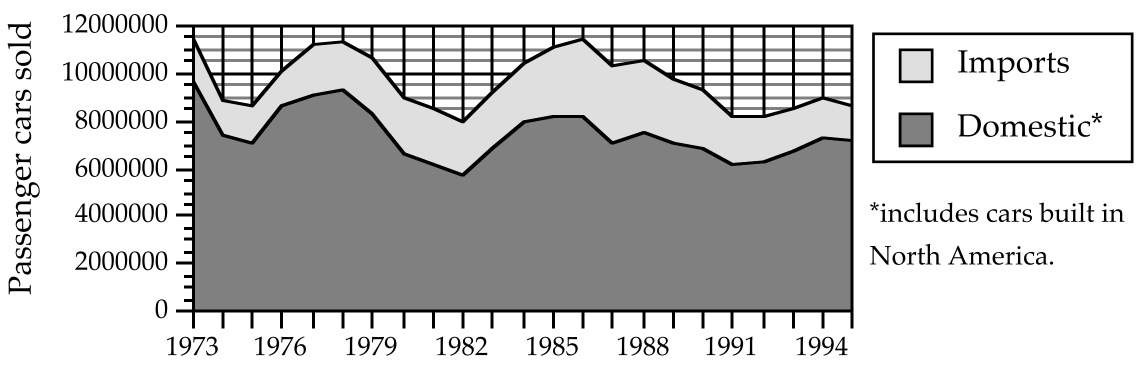

FIGURE 20-10. Domestic and foreign car purchases in the U.S. in the past 20 years.
[Source: American Automobile Manufacturers Association.]

Much has been said and written about the U.S. loss of the national market share in the process of switching toward more efficient engines. This is a well-documented fact, as illustrated in Figures 20-9 and 20-10 and Table 20-2. Domestic manufacturers will just have to try harder to beat the quality of the Toyotas and the Hondas in the high-efficiency end of the automobile market. It is interesting to note that after a 30-year dominance of Fords and Chevrolets, Honda and Toyota became among the best-selling car in late 1980s and early 1990s, even though the price of gasoline has not been particularly high in this period (see Chapter 21). Lately, some of these cars are built in North America and the contribution of imports has been decreasing (Figure 20-10).

Mileage: Vehicle Efficiency

In Chapter 19 we discussed energy conservation in the residential (and commercial) sector. We saw in Figure 20-1 that the transportation sector consumes almost as much energy as the residential and commercial sectors. Thus, there is plenty of opportunity for energy conservation here. As discussed in Chapter 19 (see Figure 19-2), one way to achieve this is to simply decrease the demand (that is, cut consumption). Another way is to increase the efficiency of the vehicle. These important facts are illustrated in Figure 20-11 and discussed below.

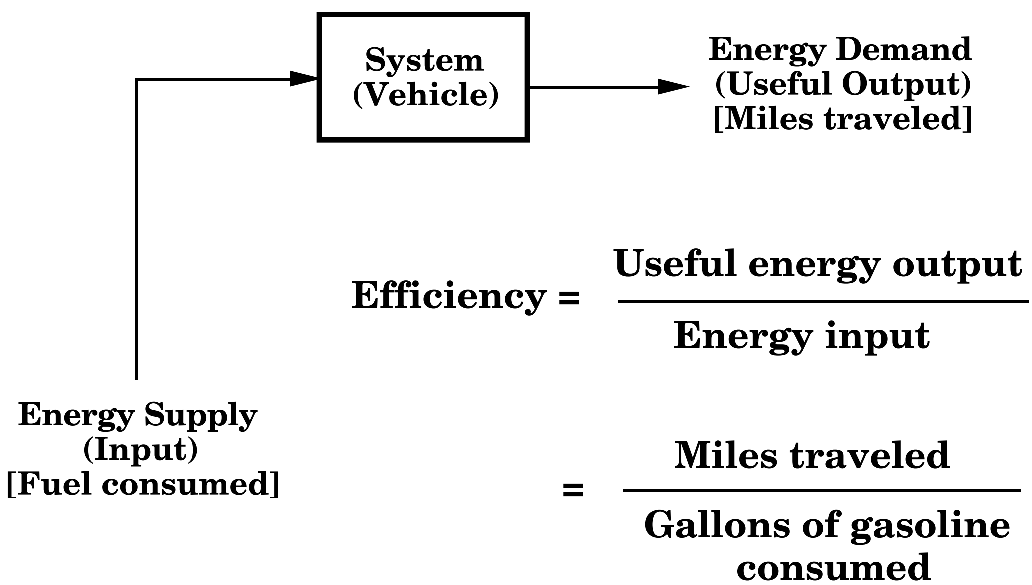

FIGURE 20-11
Thermodynamic analysis of a transportation vehicle: definition of ‘mileage’.

The term 'mileage', very familiar to all of us (and very popular in times of high oil and gasoline prices), is shown to be identical to the concept of vehicle efficiency. In Table 4-2 we showed the typical automobile engine to have an efficiency of 25%. The relationship between the efficiency expressed as miles per gallon (mpg) and as a percentage of the total energy input is shown below:

$$\text{Vehicle efficiency} = \frac{\text{Useful energy output}}{\text{Total energy input}} =$$

$$= \left[\frac{\text{Useful energy output}}{\text{Total energy input}}\right] \left[\frac{\text{Total energy input}}{\text{Gallons of gasoline consumed}}\right] \left[\frac{\text{Miles traveled}}{\text{Useful energy output}}\right] =$$

$$= \left[\frac{\text{Miles traveled}}{\text{Gallons of gasoline consumed}}\right] \;(= \text{mpg})$$

The ratio of energy input to gallons of gasoline consumed is a constant. We recognize it as the heating value of gasoline (see Chapter 8). The ratio of miles traveled to useful energy output is dependent both on automobile design (weight, 'aerodynamic' line, accessories such as air conditioning, etc.) and driving conditions (roughness of road surface, uphill or downhill, frequent acceleration, etc.). Its calculation is beyond the scope of our discussion. And we don't need it if we know the mileage of the automobile, as shown below.

Illustration 20-2. An automobile requires a useful energy output of 1100 BTU per mile traveled. Calculate its mileage if its efficiency is 20% and the heating value of gasoline is 125,000 BTU/gallon.

Solution.

$$\text{Mileage} = \left(0.20\,\frac{\text{BTU-useful}}{\text{BTU-total}}\right)\left(1.25\text{x}10^5\,\frac{\text{BTU-total}}{\text{gallon}}\right)\left(\frac{1\text{ mile traveled}}{1100\text{ BTU-useful}}\right) = 22.7\text{ mpg}$$

Driving less has turned out to be an elusive (and illusive?) means of decreasing our dependence on imported oil. This is documented in Figures 20-2, 20-4, 20-7 and 20-12. Despite the dramatic increases in the price of oil (and gasoline) in the last two decades, the total number of vehicle registrations has maintained its growth rate (Figure 20-7). The statistics on the number of new cars sold each year (Figure 20-10) and the annual average number of miles traveled per car (Figure 20-12) show a modest (especially the latter) and short-lived reaction to the oil and gasoline price increases in 1973/1974 and 1979/1980.

The main reason for this situation is the relatively low price of gasoline in the U.S., despite its large increases in the last two decades (that paralleled the oil price increases). There is simply not enough incentive to increase the use of relatively inconvenient and often inadequate mass transit at current gasoline prices. Increasing fuel efficiency has been less difficult to achieve than driving less. This is documented in Figures 20-13 and 20-14. Impressive mileage improvements were achieved in the 1980s. Current trends do not look as promising. There are two reasons for this: (a) the federal standards (see below) still linger at their pre-1990 levels (less than 30 mpg); and (b) gasoline is cheaper today –in inflation-adjusted dollars – than it ever was (see Figure 20-17).

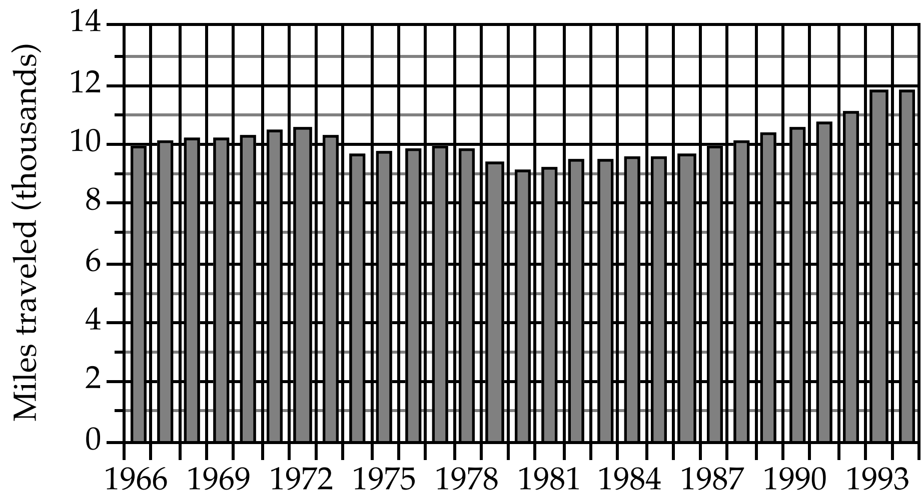

FIGURE 20-12. Average number of miles traveled per car in the U.S.
[Source: Energy Information Administration.]

Illustration 20-3. A car owner travels 15,000 miles every year. The current fuel efficiency is 13 miles per gallon. How many gallons of gasoline could he/she save if the efficiency were improved to 20 miles per gallon? How much money will be saved if a gallon of gasoline costs one dollar?

Solution.
The consumption of gasoline is obtained as follows:

$$\frac{\text{Gallons}}{\text{year}} = \left(\frac{\text{gallons}}{\text{mile}}\right)\left(\frac{\text{miles}}{\text{year}}\right) = \left(\frac{1\text{ gallon}}{13\text{ miles}}\right)\left(\frac{15000\text{ miles}}{\text{year}}\right) = 1{,}154 \qquad \text{(at 13 mpg)}$$

$$\frac{\text{Gallons}}{\text{year}} = \left(\frac{\text{gallons}}{\text{mile}}\right)\left(\frac{\text{miles}}{\text{year}}\right) = \left(\frac{1\text{ gallon}}{20\text{ miles}}\right)\left(\frac{15000\text{ miles}}{\text{year}}\right) = 750 \qquad \text{(at 20 mpg)}$$

So the gasoline savings amount to 404 gallons per year. Monetary savings are $404/year.

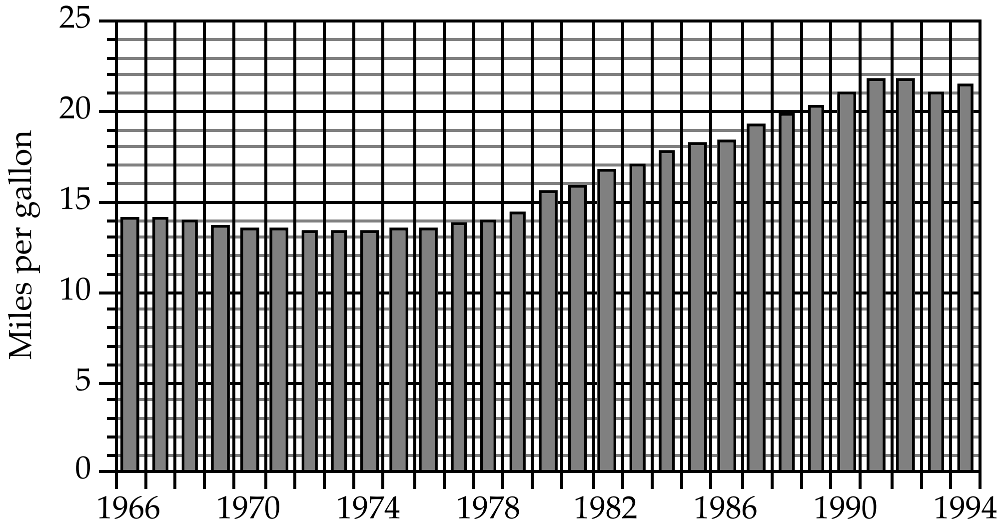

FIGURE 20-13. Yearly average mileage of passenger cars in the U.S.
[Source: Energy Information Administration.]

FIGURE 20-14
Efficiencies (in miles/gallon) of new car models sold in the period 1978-1990.
[Source: *The New York Times*, September 14, 1990, p. D1.]

The two arguments most often voiced against the government imposition of more stringent fuel economy standards (the so-called Corporate Average Fuel Economy program) are that smaller cars – the easiest response of the automobile industry – are more dangerous than the less efficient large cars, and that domestic car producers will further lose their share of the national market. The second argument is probably correct, as was mentioned above, unless small domestic cars become (or are perceived to be) as good as some of the imported ones. Whether the statistics support the first argument is debatable and very much debated these days. Automobile collisions are by far the principal cause of accidental deaths, but the trends in the last twenty years (see, for example, The World Almanac, 1991) do not seem to support this argument. On the other hand, simple laws of physics do support the argument that a person is more likely to survive a collision in a 4000-pound car than in a 2000-pound car. Even the influential political commentator George Will got into this debate some years ago, in one of his *Newsweek* editorials. He argued against more stringent standards by saying that 25% of the new cars made in 1978 weighed more than 4000 pounds; since 1984, only 1% weigh that much. The information in Table 20-1 supports this part of argument. But is there evidence for a clear correlation between automobile weight and fatalities? See Investigation 20-19.

The influence of weight (as well as other key performance characteristics) on automobile efficiency is complex and beyond the scope of our discussion. But Table 20-3 shows that beyond a certain weight and engine size, efficiency starts to suffer.

TABLE 20-3
Selected average characteristics of cars made in the U.S.

Property	1975	1988	1990
Weight, pounds	4,058	3,051	3,171
Acceleration (0-60 mph), seconds	14.2	12.8	12.1
Power, hp	136	116	129
Engine size, cubic inches	288	161	164
Mpg (combined city/highway)	15.8	28.6	27.8

[Source: Environmental Protection Agency, quoted by *The New York Times*.]

The current situation is best summarized by reproducing a not-so-recent article from *Time* magazine (October 8, 1990). The more things ‘change’, the more they seem to stay the same. This is another illustration of the fact that the options for our energy future have been the same for many years now; the only thing that changes, pretty much, is the politics surrounding them. This we shall explore in Chapter 21.

NEVER MIND THE BRAKES: EVEN AS OIL HITS $40, THE U.S. SHUNS A PLAN FOR FUEL EFFICIENCY

by S.C. Gwynne/Detroit.

'Every parent of a son or daughter in the Persian Gulf ought to ask his Congressman, "What's your plan to reduce our dependency on foreign oil?"' Richard Bryan, a Nevada Democrat, made that challenge last week after the Senate voted to block his bill, which would have imposed tough new fuel-economy laws on the auto industry. Unfortunately, most members of Congress would have to answer, "We don't have one."

In the two decades since the Arab oil embargo demonstrated America's vulnerability to the whims of foreign producers, the U.S. still has nothing resembling an energy policy. As oil prices reached $40 per bbl. last week, up from less than $20 before Iraq's invasion of Kuwait, the Bush administration sought solace in one of the few provisions the U.S. has made for an energy crisis: the Strategic Petroleum Reserve. Bush ordered 5 million bbl. of crude to be tapped from the 590 million-bbl. pool, which is stored in salt caverns in East Texas and Louisiana.

The reserve, established in 1975, holds the equivalent of 66 days' worth of oil imports. By releasing a symbolic trickle of 167,000 bbl. a day and demonstrating his willingness to open the spigot, Bush aims to curb the speculative frenzy in the oil markets. But oil traders, inflamed by the prospect of war in the Persian Gulf, have reacted with indifference. Scoffed Michel Halbouty, a Houston wildcatter: "It was like going to Galveston and pouring a glass of water into the Gulf of Mexico."

In Congress the failure of the Bryan bill pointed up how difficult it has been for legislators to come up with a plan to conserve gasoline. The original gas-guzzler law, passed in 1975, required automakers to achieve by 1978 an average fuel economy of 18 m.p.g. for all their models, up from an estimated 14 m.p.g. in 1974. The standard, called Corporate Average Fuel Economy (CAFE), was scheduled to reach 27.5 m.p.g. by 1985, but the Reagan Administration eased the level to 26 for 1986-88, which enabled automakers to indulge resurgent tastes for more powerful cars.

The Bryan bill would have required new-car fleets to reach a 34 m.p.g. average by 1996 and 40 m.p.g. by 2001. That would reduce U.S. oil consumption an estimated 2.8 million bbl. a day, or more than 15% of current usage. The proposal drew high-torque opposition from the automobile lobby, the United Auto Workers union, the insurance industry and the White House. They contended that the law would hurt the auto industry and hamper safety by forcing carmakers to build smaller vehicles. Many critics questioned the technological feasibility of achieving 40 m.p.g. in just a decade. "The best we could do, without having major shifts in car size, would be 35 m.p.g. by the year 2000," says John B. Heywood, director of the Sloan Automotive Laboratory at M.I.T.

The most effective solution, many experts say, would be a combination of market incentives and somewhat higher fuel efficiency standards. A stiff gasoline tax of $1 per gal. would encourage consumers to choose more economical autos. At the same time, *higher CAFE levels would require automakers to develop and produce efficient cars even during times of relatively cheap gasoline. But the current rise in oil prices may be too much of a slow-motion crisis to shatter the status quo. If the Bryan bill's fate is any indication, Washington is stuck in first gear on the road to a sensible energy policy.*

Illustration 20-4. Based on the information provided in Figures 20-4 and 20-14, show that, indeed, as stated in the *Time* article reproduced above, the Bryan bill would have reduced U.S. oil consumption by 2.8 million barrels per day, or by more than 15%.

Solution.
The U.S. gasoline consumption in 1989 was approximately 7.5×10^6 bbl/day (Figure 20-4), and the new car fuel efficiency was 28.5 mpg (Figure 20-14). An increase in fuel efficiency from 28.5 to 40 mpg represents a 40% increase. If the number of miles driven does not increase between 1989 and 2001, this would reduce gasoline consumption by 40%, to $7.5 \times 10^6/1.40 = 5.3 \times 10^6$ bbl/day. Gasoline savings would thus be 2.2 million barrels. This is less than 2.8 million, which makes sense because not all the oil can be converted to gasoline (see Chapter 8). If 75-80% of the oil is converted to gasoline, then the oil savings would be indeed 2.8 million barrels, which does represent more than 15% of the 1989 U.S. oil consumption (2.8/17.5=0.16; see Figure 8-3).

Another way to increase the efficiency of an automobile is to adjust the speed. The well documented tradeoff between speed and mileage is illustrated in Figure 20-15. This fact was the basis for imposing the 55-mile-per-hour limit in response to the oil shortages of the 1970s. (Time is money, of course, and we need to get to places within a reasonable period of time; that is why the optimum 45 mph was not selected.) There is no question that the effect was beneficial, even though we are sometimes envious of the German autobahn drivers who can easily travel 500 miles in 6 hours or so. Despite the fact that the number of cars on the road has continued to increase (Figure 20-7), both the CAFE standards and the speed limits have helped to maintain the consumption of gasoline relatively steady in the last fifteen years (Figure 20-4). It remains to be seen what the effect of the recent reversal of speed limits, from 55 to 65 mph on most highways, will be (see Investigation 20-17).

Finally, there are always the inherently more efficient compression-ignition or diesel engines for our cars and not only for trucks and buses. They have never been as popular in America as they are in Europe, ever since Mercedes introduced its D line in 1936. They are noisier because the fuel is supposed to ‘knock’ (see Chapter 8). They typically produce more soot than spark-ignition engines. Legislative action seems to be in the works to eradicate diesel-powered buses from metropolitan areas (see Investigation 20-4), so this does not seem to be a very promising alternative in pursuit of higher vehicle efficiency (see Investigation 20-4).

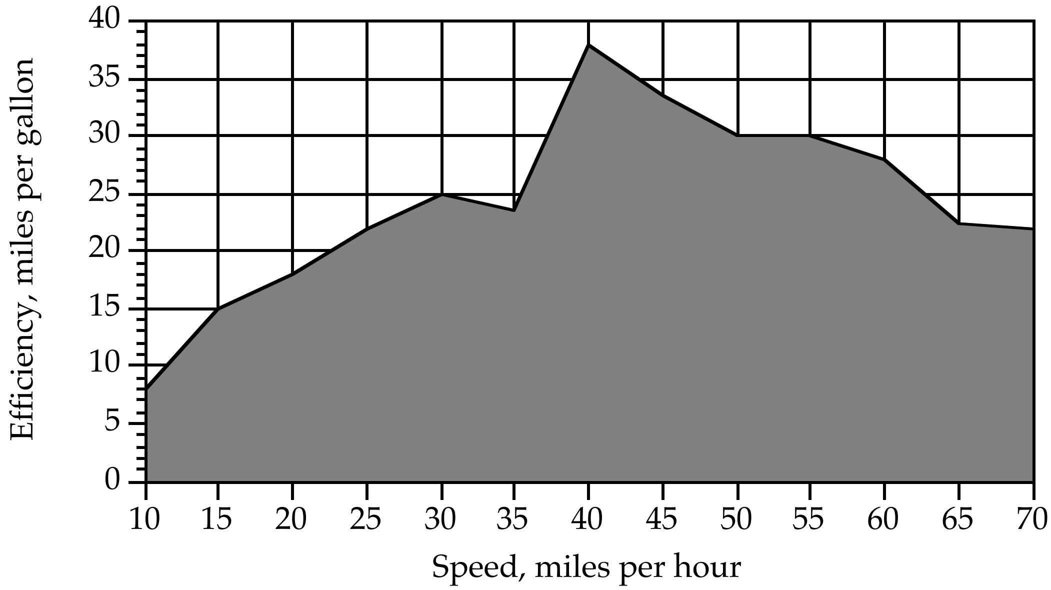

FIGURE 20-15. Vehicle efficiency (for a full-size 1989 model car) typically peaks at 40-45 miles per hour and decreases sharply at higher speeds.
[Source: Insurance Institute for Highway Safety, quoted by *The New York Times.*]

Alternative Transportation Fuels

With the adoption of the 1990 Amendments to the Clean Air Act (see Chapter 11), there has been much talk about alternative transportation fuels. One reason for having an 'alternative' to gasoline is that it is rarely good to have all the eggs in the same basket, as we have had in the case of spark-ignition engines. A more powerful reason today seems to be the search for a fuel that would not pollute the environment as much as gasoline. The leading candidates are methanol, ethanol, natural gas and 'reformulated' gasoline. Electric cars, or so-called zero-emissions vehicles, have recently become a more serious contender, although their cost is still prohibitive for most people. Figure 20-16 summarizes the estimated contributions to pollution by some of the alternative fuels. Pollution from electric vans is calculated based on emissions from power plants, which are mostly coal-fired, as shown in Figure 18-1. A more detailed comparison of the performance of alternative fuels in vehicles is provided in the table below:

PASSENGER CAR*	Range	Fuel cost	Vehicle cost	Advantages	Disadvantages
Unleaded gas	424	4.69	22.70	Readily available	Air pollution
Methanol	265	5.12	23.10	Excellent auto fuel	Vehicle range
Ethanol	331	7.98	25.70	Renewable	Fuel cost
Natural gas	106	3.16	23.80	Low air pollution	Vehicle range, cost
MINI-VAN**					
Unleaded gas	454	5.43	30.30	Readily available	Air pollution
Electric	120	1.63	28.70	Emissions control	Cost, performance

*Mid-size, 26.5 mpg; **comparable to gasoline-fueled mini-van (22.7 mpg).
Range given in miles traveled per tank of charge; fuel cost and vehicle cost given in 1988 dollars per 100 miles traveled in the year 2000 (the latter based on 20,000 miles per year). [Source: *Newsweek*, 5/21/90 (special advertising section).]

ELECTRIC CARS: WHAT GOES AROUND COMES AROUND

When GM unveiled its EV-1 electric car in the fall of 1996, there was much media hoopla. Probably as much attention was given to the first electric car almost a century ago. And who else but Thomas Edison had much to do with it? Together with Walter C. Baker, Edison wanted to put gasoline-engine vehicles out of business. The Baker Motor Vehicle Company, founded in 1898 in Cleveland, was perhaps the most successful electric car manufacturer in the United States, but this did not turn out to be one of Edison's successes. The main problem was the lack of a "more powerful and durable storage battery" (see *The Automobile Industry, 1896-1920*, FactsOnFile, New York). So what else is new? Before World War II, electric trams and trolleys were more successful than electric cars, but they were kicked out when cheap oil started pouring from the Middle East. Whether electric cars are here to stay this time around, for environmental reasons, remains to be seen (see Investigations 20-1, 20-3, 20-7 and 20-10).

Methanol can be produced from coal or natural gas, both of which - and especially the former - are more abundant than oil. A particularly interesting option seems to be the conversion of natural gas to methanol and its transportation as a liquid – at normal temperatures – instead of using the costly refrigerated tankers (see Chapter 9).

Ethanol was mentioned in Chapter 16; it is already making a modest contribution to the supply of transportation fuels.

Compressed natural gas is increasingly being used for fleet vehicles, as is electricity. These vehicles have a relatively short driving range and they can (and must) be refueled often.

Reformulated gasoline is the current response of some of the major oil companies to society's increased concerns about smog in large cities. It is advertised as a less-polluting gasoline and it is. It consists of a narrower petroleum fraction (see Chapter 8). Both the lighter, low-boiling-point hydrocarbons (such as butane, or in general those with a smaller number of carbon atoms in the chain) and the high-boiling-point hydrocarbons (olefins and aromatics) are removed in the refinery. This has the result that less gasoline evaporates into the atmosphere prior to burning. Less unburned hydrocarbons appear in the products of combustion as well. Both these effects reduce pollution significantly.

To some extent, the issue of alternative transportation fuels is not only an economic problem (since all of them are more expensive than gasoline). It is also a typical example of the ‘chicken-and-the-egg’ problem. The automobile industry is not ready to adapt its engines to new fuels until it is assured of adequate supply of these fuels. On the other hand, the potential suppliers of alternative fuels (such as methanol, in particular) cannot make a commitment to large-scale production until they see a large market for their product.

FIGURE 20-16. A comparison of pollutant emissions from different van vehicles. [Source: *The New York Times*, November 15, 1989, p. D1.]

Cost of Transportation

There is no doubt, of course, that the cost of transportation is directly linked to the price of crude oil, because the price of gasoline is dependent on the price of oil. This can be seen by comparing Figures 20-3 and 20-17. When adjustments for inflation are made, according to a recent report in *USA Today*, the results shown in Table 20-4 are obtained. Many assumptions go into calculations of this sort and it is difficult to compare ‘apples’ and ‘apples’ over such a long time period. But all the data point to one clear conclusion: both in nominal dollars (not adjusted for inflation) and in real dollars (of 1982 or 1990), gasoline is today quite inexpensive in the U.S. This is to be contrasted with the situation in practically all other industrialized nations, shown in Figure 20-18. The price of gasoline in the U.S. is considerably lower than that in Western Europe, Japan and indeed in much of the world. This is because most other countries impose heavy gasoline taxes, as seen in Figure 20-19.

FIGURE 20-17. Retail prices of gasoline in the U.S. (including taxes). [Source: Energy Information Administration.]

TABLE 20-4
The cost of gasoline in the last 50 years

Year	Nominal Cost ($)	Real Cost (1990 $)
1940	0.18	1.71
1950	0.27	1.45
1960	0.31	1.37
1970	0.36	1.20
1975	0.57	1.40
1980	1.25	1.97
1985	1.20	1.46
1990	1.31	1.31

[Source: *USA Today*, September 28, 1990.]

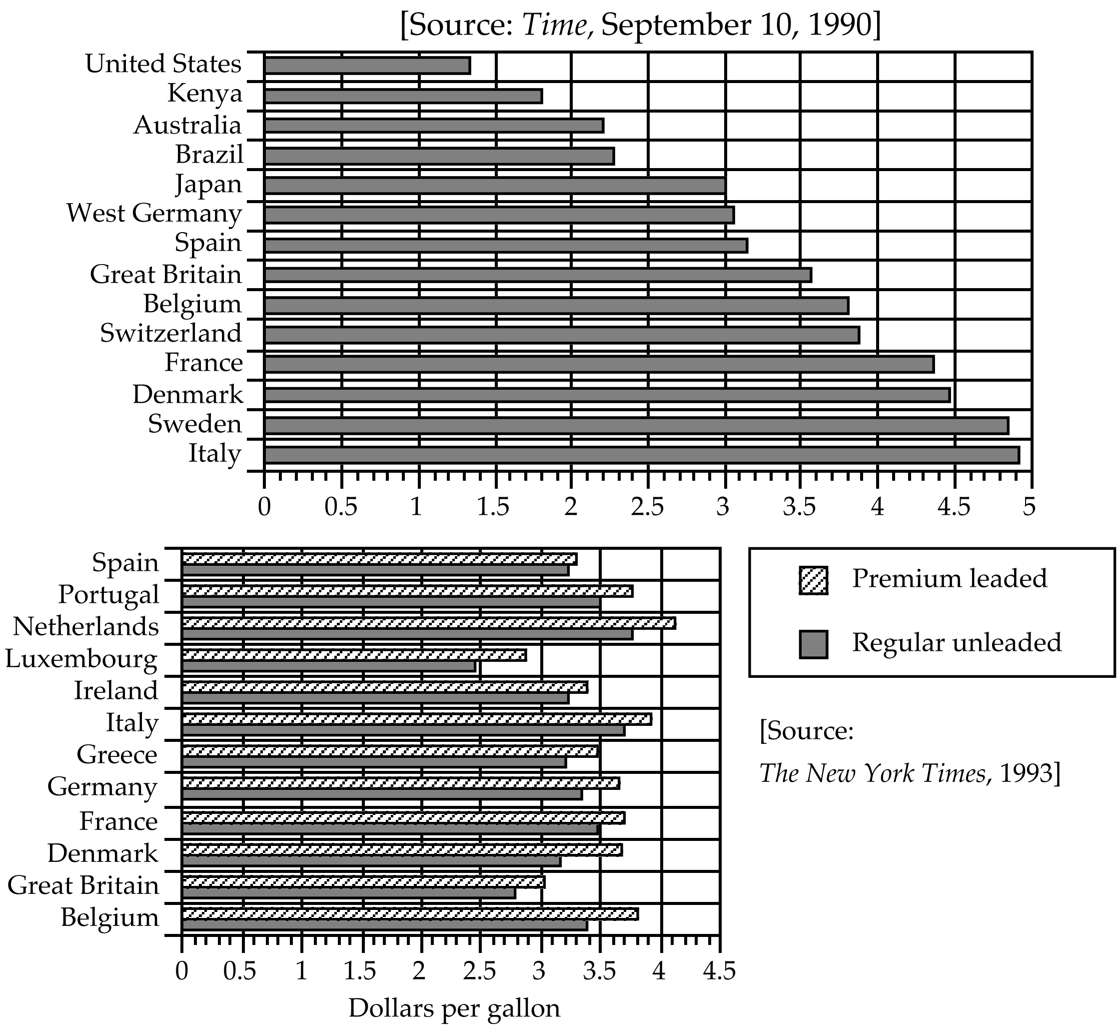

FIGURE 20-18. Retail price of gasoline in selected countries.

The issue of a gasoline tax in the U.S. receives periodic attention in the media. This is illustrated by the following editorial reproduced, in part, from *The New York Times*. A more detailed discussion is offered in Chapter 21.

FIGURE 20-19. Representative values of the tax on gasoline in selected countries (1st quarter 1990). [Source: *The New York Times.*]

THE SECOND-BEST WAY TO SAVE GAS

The New York Times, Editorial, September 20, 1990, p. A20.

There's a potent prescription that at a single stroke would slash America's dependence on foreign oil, trim the trade deficit, roll back smog and avert global warming. It's to mandate that auto manufacturers produce more fuel-efficient cars. The Senate is considering a bill by Senator Richard Bryan of Nevada to raise the fuel efficiency of new cars 20 percent by 1995 and 40 percent by the year 2001. That's not the best way of improving fuel efficiency, but it's a lot better than doing nothing.

The most efficient way of making the national auto fleet guzzle less fuel would be to slap a stiff tax on gasoline. Fuel efficiency standards mandated by Congress are in effect a hidden tax that bites by raising the price of cars. The standards are less effective than a gas tax would be because they hit only new-car owners. Owners of old cars will hang on to their gas guzzlers longer, as the efficient cars will cost more. And even new owners, if tempted to drive more, may use nearly as much fuel as before.

A gas tax would impinge on everyone equally; in addition, each cent per gallon would raise $1 billion in revenue. But half of Washington refuses to raise new taxes, and the other half lacks the courage to explain to voters why a gas tax is necessary. In this Sahara of leadership, the Bryan bill is a beckoning oasis.

[...]

The Bryan bill isn't the best way to make cars fuel-efficient. But it deserves the vote of every senator who dares not demand a higher tax on gasoline.

Illustration 20-5. (a) A car owner, driving 15,000 miles per year, averages 16 miles/gallon. By proper engine maintenance and careful driving, 20% of the fuel can be saved. If gasoline costs $1/gallon, determine the annual savings. (b) This car has an air conditioner (AC), which is estimated to reduce the car efficiency by 10%. The AC is used 25% of the time. Determine the annual cost of gasoline that can be attributed to the use of the AC. (c) Estimate the impact of fuel savings on the country's balance of payments if there are 40 million such cars that can turn off their air conditioners.

Solution.
(a) The amount of gasoline used per year is:

$$\frac{1.5\text{x}10^4 \ \frac{\text{miles}}{\text{year}}}{16 \ \frac{\text{miles}}{\text{gallon}}} = 937.5 \ \frac{\text{gallons}}{\text{year}}$$

Annual fuel savings are then:

$$(937.5 \ \frac{\text{gallons}}{\text{year}})\ (0.20) = 187.5 \ \frac{\text{gallons}}{\text{year}}$$

Annual dollar savings are thus:

$$(187.5 \ \frac{\text{gallons}}{\text{year}})\ (\frac{\$1}{\text{gallon}}) = \$187.5/\text{year}$$

(b) If the car is driven 15,000 miles at 16 miles/gallon, and the AC is used 25% of the time, the amount of gasoline consumed while the AC is used is:

$$\frac{(1.5\text{x}10^4 \ \frac{\text{miles-total}}{\text{year}})\ (0.25 \ \frac{\text{miles-with AC}}{\text{miles-total}})}{16 \ \frac{\text{miles-with AC}}{\text{gallon}}} = 234.37 \text{ gallons/year}$$

Ten percent of this quantity is attributed to AC use. Therefore, the gasoline consumed attributable to AC use is 23.4 gallons/year, or $23.4/year (at $1/gallon).

(c) The total amount of gasoline consumed that is attributable to AC use is:

$$(40\text{x}10^6 \text{ cars})\ (\frac{23.4 \text{ gallons}}{(\text{year})(\text{car})}) = 9.4\text{x}10^8 \ \frac{\text{gallons}}{\text{year}} \ (\frac{1 \text{ barrel}}{42 \text{ gallons}}) = 22.3\text{x}10^6 \text{ bbl/year}$$

This is equivalent to about three days of oil imports (see Figure 20-), assuming that 1 barrel of gasoline can be produced from 1 barrel of oil. (If not - see Chapter 8 - it will be equivalent to even more oil.) At $20 for a barrel of oil, this represents an annual sum of 446 million dollars.

The Bryan bill is still sitting somewhere in Congress, waiting to be rescued from (undeserved?) oblivion. Stay tuned to the future developments on this politically ‘hot’ issue (see Chapter 21). And in the meantime enjoy the low gasoline prices, while you can. Or, paraphrasing those famous lines from the inaugural speech of President Kennedy, do not wait for higher taxes (or prices) to make you conserve gasoline; you can start conserving now, to get used to it and be ready for the times when it will become necessary to do so.

Reading the Press: Gasoline Conservation Tips

How to get more miles per gallon has even become the subject of advertisements by major oil companies. Reproduced below is a typical article, with useful suggestions. All such articles “boil down” to the fact that we discussed in Chapter 4: the automobile engine – being a heat engine – is quite inefficient, and there is plenty that we, as well as the auto makers and oil refiners, can do to improve its performance.

FUEL TIPS FOR THOSE ENERGY-CONSCIOUS DAYS AHEAD
by Tom Incantalupo, Newsday (*The Altoona Mirror*, August 20, 1990)

You'll likely be hearing a lot in coming months about car-pooling and using mass transit to conserve gasoline, which has become more expensive and might soon be in short supply. You'll be urged to obey speed limits and avoid prolonged idling and jack rabbit starts, all good advice you've heard a hundred times before.

The American Automobile Association says gasoline has gone up by an average of 14.1 cents a gallon since Aug. 1 to $1.216. The U.S. Department of Energy says the average family living outside a city drives two cars a total of about 20,000 miles a year, using about 1,000 gallons of gasoline. So gas price increases so far will cost the average family an extra $141 a year.

It's not enough to break you, maybe, but here, from a variety of automotive experts, are some other things you can do to improve your car's gas mileage – suggestions that, hopefully, you haven't heard a hundred times before.

• Use a high-quality motor oil rated ‘SG’ and look for the phrase “energy conserving II” on the can, signifying an oil that can increase your fuel mileage by about 3 percent. If your car's manufacturer recommends 5W-30 rather than 10W-30 oil, use it: the 5W portion of that blend helps to reduce friction and improve mileage.

• Change your oil and filter regularly; dirty oil creates more friction and hurts fuel mileage.

• Try to keep your engine's fuel injectors clean by running a tank of premium fuel through them once every couple of months. In addition to the higher octane, which most cars don't need, the more expensive super grades usually have better detergents than the regular grade.

• Make sure your engine's air, gasoline and evaporative emissions filters and its PCV valve are clean.
• Make sure your front- and rear-wheel alignment is set correctly; if it's not, your tires' rolling resistance is increased.
• Be sure your spark plugs are clean and properly gapped.
• Check that your tire pressures equal what the car's manufacturer recommends; proper pressures should be in the owner's manual and are the same as the "maximum pressure" on the walls of the tires. If pressure is low, more of the tire is in contact with the pavement and rolling resistance is increased, hurting mileage.

Some experts recommend adding a few pounds to what the car's manufacturer recommends. But Jim Smith, a spokesman for Bridgestone-Firestone, Inc., says that can adversely affect handling and braking and increase wear at the center of the tire.

The Department of Energy estimates that as much as 100,000 barrels of oil a day could be saved if everyone in the United States maintained correct the pressures.
• Keep fuel economy in mind if you're buying new tires. Snow tires and off-road tires decrease mileage because of their high rolling resistance. Radials offer less resistance than bias-ply tires.
• On the highway, use your air conditioner rather than driving with the windows wide open. Yes, the AC is a drag on the engine that hurts mileage, but, with the windows open, the rear portion of the passenger compartment acts like a parachute, creating more drag than the AC. Around town, though, you'll get better mileage without the AC.
• Avoid add-on equipment such as bug shield, spoilers and car-top carriers, which hurt a car's ability to slip through the air.
• In driving, try to stay in the highest gear possible, whether your transmission is a manual or an automatic. Maintain a steady speed and avoid hard braking. The brakes don't burn gas, but you wasted gas to maintain the speed from which you now must brake sharply, rather than coasting slowly to a stop.

INTERNET INFO	Useful information on transportation issues can be found at the Web site of the American Automobile Manufacturers Association, www.aama.com.

REVIEW QUESTIONS

20-1. The *Economist* of 3/4/95 reports on the ingenious approach by the Unocal oil company to meet the provisions of the Clean Air Act (see Chapter 21). Unocal is buying and destroying 350 pre-1972 cars, which are 50-100 times more polluting than modern cars. By taking these cars off the road, Unocal hopes to eliminate annually 38,500 pounds of hydrocarbons, 10,500 pounds of nitrogen oxides and 210,000 pounds of carbon monoxide from the Los Angeles Basin. Show where these numbers come from and whether they are in the right "ball park."

20-2. Texaco, “the star of the American road,” has been selling petroleum products for the last 100 years (see D. Yergin's “The Prize,” Further Reading, p. 461) and sponsoring the Metropolitan Opera broadcasts for the last 50 years (see http://www.texaco.com). More recently it is advocating energy conservation! Under the title “Let's Put Our Energy Into Saving It,” it has taken out a whole-page advertisement/quiz, with the following multiple-choice, gasoline-saving tips, among others:

(1) If all Americans drove no higher than the posted speed limit, how many gallons of gasoline could be saved per day? What are the average annual savings per household? (a) 1.0 million ($5.50); (b) 2.0 million ($11.00); (c) 4.2 million ($22.50).

(2) How much fuel on average can be saved by having a regular tune-up? Annual household savings? (a) 1 mile per 13 gallons ($4.00); (b) 1 mile per 5 gallons ($10.50); (c) 1 mile per gallon ($53.00).

Check Texaco's math and check out Texaco's solutions in *Time* magazine of 11/26/90.

20-3. The *Economist* of 12/12/92 (p. 73) reports that the number of gallons (presumably of gasoline) per person per year consumed in the United States in 1988 was 500, compared to 200 and less in Germany, Britain, Italy and Japan. It also reports that the number of vehicle-miles traveled was about 2 trillion in the same year. Compare these numbers with the information provided in this chapter and estimate the average vehicle efficiency.

20-4. Briefly describe how a four-stroke spark-ignition engine works. How is a diesel engine different from this and what are its main advantages and disadvantages?

20-5. Indicate whether the following statements are true or false:

(a) Today's CAFE standards for new-car fleets is 35 miles per gallon.

(b) If the efficiency of automobile A is 45 mpg and the efficiency of automobile B is 17 mpg, and both A and B are driven 10,000 miles per year, the annual fuel saving for automobile A is 366 gallons per year.

(c) Figure 20-4 shows that the 1995 consumption of gasoline in the U.S. was greater than 2.5 billion barrels.

(d) Figure 20-5 shows that the percentage of OPEC oil imported into the U.S. was smaller in 1995 than in 1980.

INVESTIGATIONS

20-1. General Motors is aggresively pursuing its zero-emissions EV1 electric car, with an expected sticker price of about $35,000. Find out about the main performance characteristics of this vehicle. Where will it be sold first, when and why? See NYT of 3/10/96 (“What's the Buzz? G.M.'s Electric Car Is Headed to Showrooms”) and USNWR of 9/30/96 (“Look, mom, no gas”).

20-2. Much has been written recently about the comeback of “gas guzzlers” as a consequence of low gasoline prices. Analyze the relevant evidence. See NYT of 2/15/96 (“With Prices Low, Gasoline Guzzling Makes a Comeback”).

20-3. You can imagine that the Mobil Corporation is not thrilled about electric cars. Why not? Summarize Mobil's arguments against EVs. See the notorious Mobil ads, for example, in NYT of 5/10/95 (“Electric vehicles: a promise too far”), 5/24/95 (“Striking a Jurassic spark”), 11/9/95 (“The evidence keeps mounting”) and 4/4/96 (“Electric vehicles: charging ahead”). See also Mobil's web site (http://www.mobil.com).

20-4. Why are diesel-engine vehicles less popular in the U.S. than in Europe? What are their main virtues? What are their main problems? See NYT of 3/4/90 (“Bringing Diesel Up to Snuff Without Alternative Fuels”), 8/29/90 (“New York City in Violation on Diesel Soot”), 6/30/96 (“Americans Left Unmoved by the Diesel's Beat”), and 9/12/96 (“Diesel Buses to Be Replaced in Big Anti-Pollution Switch”).

20-5. The influx of Japanese cars into the U.S. is a closely monitored process. Summarize the most recent trends. See NYT of 1/6/95 (“Japan's Share of U.S. Car Market Rose in '94”) and 2/2/96 (“American Auto Companies Fear Weak Yen Gives Japan an Edge”); BW of 1/24/94 (“Trying to Rev Up: Can Japan's carmakers regain lost ground?”).

20-6. Valentin Technologies, Inc. recently paid a whole-page advertisement to make a case for its 120 mile-per-gallon engine design. Summarize its key claims. See NYT of 2/14/96.

20-7. Battery capacity, recharging and potential pollution are some of the important obstacles for the acceptance of electric cars. Review the recent media reports about these issues. See NYT of 4/2/95 (“Future Shock: Driving an Electric Prototype”), 5/9/95 (“Electric Cars Called Perilous to Environment”) and 2/4/96 (“Betamax Redux: Big 3 Brawl on Electric Cars”); BW of 9/23/96 (“Batteries not included”).

20-8. In its advertisement in NYT of 1/25/96 ("Car crazy: a hard habit to break"), Mobil makes an important point regarding pollution by gasoline-powered vehicles that are so dear to its heart. What is Mobil's main argument?

20-9. The *Economist* of 6/22/96 has some suggestions on "how to solve the problems caused by our 100-year love-affair with the car". What are they? How likely are they to be implemented?

20-10. In the NYT of 8/29/96 (p. D2) a case is being made against the conventional wisdom that electric cars = cleaner air. Summarize the arguments used to support this case. See also Letter to the Editor of 9/3/96 (“Electric Cars, Clean Air And the Latest Myth”).

20-11. Investigate the details of the gas-guzzling tax. See, for example, NYT of 7/30/95 (“Pricey, Gas-Guzzling Cars Face Double-Whammy on Taxes”).

20-12. Another one in the long series of high-visibility Mobil ads is a case against alternative automobile fuels (“Clearing the air #8: Assessing the alternatives"). Find this ad in an issue of *Time* magazine, in either 12/94 or 1/95. Summarize the arguments used by Mobil against liquefied petroleum gas, compressed natural gas, methanol and ethanol.

20-13. Mass transit in the U.S. is not used as often as in Europe or Japan. Discuss some of the trends and reasons for this. See NYT of 1/9/95 (“Riding the Bus”).

20-14. In the NYT of 10/17/93, under the title “After 20 Years, America's Foot is Still on the Gas,” Matthew Wald summarizes the changes in U.S. gasoline consumption in the period 1973-1992. Using his data, make graphs of inflation-adjusted gasoline prices and car efficiencies. Compare them with those provided in this chapter. Summarize the main conclusions of this article.

20-15. A ‘truckload’ of media reports exist either against or in favor of higher fuel efficiency standards. Summarize some of the most common and most important arguments. For example, the effects of car buying habits (Tables 20-1 and 20-2) on fuel efficiency trends are summarized in NYT of 11/28/95 (“In Energy Tug of War, U.S. Misses Its Goal on Emissions”) and 9/5/95 (“Trucks' Popularity Undermining Gains In U.S. Fuel Savings”). See also NYT of 4/6/95 (“Economic Scene: Were the Government's mileage standards for cars a mistake?”). For an earlier perspective, see NYT of 9/14/90 (“The Mileage Debate: Some say a tax increase is cheaper than putting cars on a stricter diet”).

20-16. The market share of U.S. car sales is one of the more closely monitored statistics. How is it related to the prospects for higher mileage standards? See *Time* of 11/9/92 (“What Went Wrong? Everything at once. How the world's largest corporation broke down, and why the human cost of repairs will be brutal.”). Have things changed for the better or for worse since late 1992? See www.aama.com.

20-17. The decision of the federal government to relax the 55 mph speed limits and give the states the authority to set the limits has been well received by most of us, impatient drivers. (I even had to retake the driver's exam a few years ago, with so many speeding tickets.) Yet it is not without controversy. Comment on the arguments against and in favor of this measure. See NYT of 11/29/95 (“President Signs Measure Repealing U.S. Speed Limits”), 11/19/95 (“Ending of Federal Speed Limit Wins Congressional Approval”), 10/29/95 (“In Reversal of 20-Year Trend, Traffic Deaths Increase in U.S.”), 7/31/95 (“Pulse: New Speed Limits”), 6/21/95 (“Senate Votes To Let States Set Car Speeds”); *Economist* of 12/2/95 (“Speed limits: Free as a bird”).

20-18. Mobil had something to say, of course, about the prices of gasoline. See the advertisement in NYT of 6/8/95 (“Gasoline: America's best bargain”). Summarize its contents and comment on them.

20-19. Explore the World Wide Web and other sources to find out whether statistical information is available regarding the relationship between automobile weight and auto accident fatalities.

20-20. Find out about some of the (easy?) ways to increase the fuel efficiency of automobiles. See NYT of 8/16/90 (“What It Will Take to Develop the Super-Car”).

20-21. The catalytic converter is a wonderful anti-pollution device but it is not very effective during car warm-up. Find out about some ways to resolve this problem. See NYT of 3/27/91 (“Researchers Act to Cut Auto Pollution Further”) and 7/28/91 (“When Clean-Air, Methanol-Powered Cars Hit the Road”).